Rijkswaterstaat
Ministry of Infrastructure
and Water Management

Water management in the Netherlands

The Kreekraksluizen in Schelde-Rijnkanaal

Water: friend and foe!

Water management in the Netherlands

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The Netherlands is in a unique position on a delta, with nearly two-thirds of the land lying below mean sea level. The sea crashes against the sea walls from the west, while rivers bring water from the south and east, sometimes in large quantities. Without protective measures they would regularly break their banks. And yet, we live a carefree existence protected by our dykes, dunes and storm-surge barriers. We, the Dutch, have tamed the water to create land suitable for habitation.

But water is also our friend. We do, of course, need sufficient quantities of clean water every day, at the right moment and in the right place, for nature, shipping, agriculture, industry, drinking water supplies, power generation, recreation and fisheries.

It all sounds so obvious, but behind the scenes many water managers work continuously on the water supply, water drainage and water quality. At regional level, the Dutch water authorities have been doing that since 1255 and, since 1798, the Directorate General for Public Works and Water Management, Rijkswaterstaat, has coordinated the 'taps of the water system' at national level.

Our infrastructure and the 'rules of the game' for distribution of water resources still meet our needs, but climate change and changing water usage are posing new challenges for water managers. For this reason research findings, innovative strength and the capacity of water managers to work in partnership are more important than ever. And interest in water management in the Netherlands from abroad is on the increase. In our contacts at home and abroad, we need know-how about the creation and function of our freshwater systems. Knowledge about how roles are allocated and the rules that have been set are particularly valuable.

The Directorate General for Public Works and Water Management and the Association of the Dutch Water Authorities have combined that knowledge once more in this booklet. A useful reference work for anyone involved in water management and the water systems. But it is also a fascinating and informative document for water users and for educative purposes.
So what have you got to lose?

Michèle Blom
director-general of Rijkswaterstaat

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chair, Association of Dutch Water Authorities

Introduction

The IJsselmeer area looking towards the Houtribsluizen lock complex at Lelystad

The water system of the Netherlands is complex. Water managers have to deal with many areas of social interest, such as protection against flooding, nature, agriculture, shipping and recreation. This makes the distribution of water in the Netherlands anything but simple. Water policy needs to address many issues, and it is a subject that occupies many people. Climate change leads to rising sea levels, changes in river flows and a different rainfall pattern with more frequent, more intense showers coupled with longer dry periods. At that point it is helpful if everyone can rely on unambiguous know-how and use language that can be easily understood.

Many water managers and users only have professional dealings with a small part of the system. Under such circumstances it is difficult to get a grasp of how all aspects of water management interrelate. People sometimes have a misinformed perception of the options that are available for managing water. So there is good reason to illustrate how water is managed in water systems in the Netherlands. It is important to understand how water distribution is organised and to understand the aspects that are closely linked to it, such as surface runoff flooding and water safety, water shortages, drought and water salinisation, water quality and ecology. It is also important to understand what is at the heart of the matter and what sticking points to expect, should climate change continue to be a factor. By focusing attention on the waterways and how to ensure water safety, water quality and the distribution of water. Rijkswaterstaat and the various water authorities are tackling the issues that face environmental sustainability.

Hydrological map of the Netherlands

In the Netherlands, municipal authorities and provincial authorities have operational duties relating to water management. Municipal authorities bodies administer sewerage, collection of waste water, drainage of rainwater and urban groundwater. Provincial authorities manage waterways in the province in question and issue permits for large-scale abstraction of groundwater.

This booklet describes water management in the Netherlands. The first chapter summarises the geophysical natural history of the Netherlands and the methods used over the centuries to protect the country against flooding due to increased water discharge volumes in river systems, or storm surges. Aspects such as land reclamation and other hydrological engineering works, including digging channels to the sea and canalisation of rivers are also addressed.

Chapter 2 turns to the issue of water distribution, with the focus on the main system, regional systems and the interaction between them. Chapters 3 - 7 describe water distribution under normal circumstances, but also how water is distributed in times of surface runoff flooding or water shortages. They also discuss the relationship to water safety and water salinisation. Chapter 8 assesses the effect of climate change and socio-economic developments, while chapter 9 shows how policy and management can keep the water system in check. Lastly, chapter 10 addresses emergency response.

This booklet is intended for anyone who is involved in the organisation of water management and the water systems, such as water managers and policy officers at local-authority and provincial level, at water authorities and in government, but also for users of the water systems and for educational purposes. The aim is to provide basic information on the freshwater part of water management in the Netherlands, and water distribution.

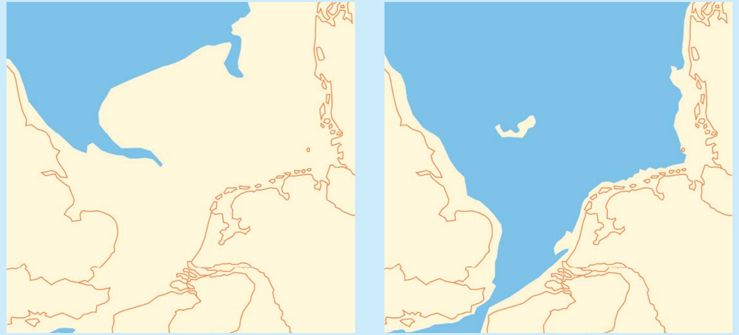
1 The development of water management in the Netherlands

De Biesbosch National Park

1.1 The formation of the Netherlands

Until the end of the last ice age, around 10,000 years ago, the North Sea was a vast plain. As it got warmer sea levels rose and, after a few millennia, the North Sea was lapping on the shores of the Netherlands. The river water stopped short of the barrier beaches that the sea had created. The silt sank and plants saw their chance to colonise the land in the warmer climate. This was the process by which a layer of peat was deposited on the existing sand ground.

For centuries this peat layer was allowed to grow, particularly in places where the barrier beaches formed a continuous line, such as the western seaboard of the Netherlands. But storm surges washed away the peat ground, which was replaced by marine depositions of clay. This was the case in the southwest of the Netherlands in particular. In central and eastern areas of the Netherlands the coarse and fine sandy depositions from the



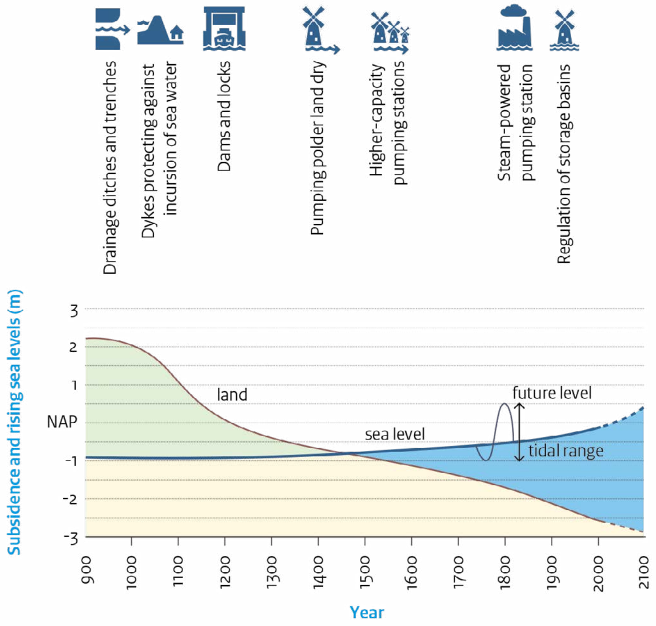
This is what the Netherlands looked like in 7000 BC and in 5500 BC.

various ice ages are visible at the surface. This area corresponds to the hilly areas of the Veluwe, the Utrechtse Heuvelrug, the Hondsrug and Salland, remnants of the ice age in the form of push moraines. The many streams that cut through this upland part of the Netherlands naturally irrigate and drain the land. Boulder clay can also be found in the north. Boulder clay is a mixture of boulders, gravel and loamy soil that was compressed to such an extent by the continental ice during the last ice age that it became impermeable. That has an impact on water management.

1.2 The history of water management in the Netherlands

Living on the dividing line between land and water has many benefits. That was why our forefathers settled here, despite the intrusive sea, trying to exist in a watery environment. Excavations towards the end of the 1990s in Vlaardingen revealed dams, retaining walls and culverts that showed beyond all reasonable doubt that thousands of years ago people were already trying to manage water flows. There is evidence that mounds were erected in the north of the country more than two thousand years ago. Then, in the Middle Ages, came the draining of the peat marshes. From the banks, ditches and trenches were dug to drain the swampy land. A side effect of this was that the peat oxidised and settled, because it was exposed to the air. This was a slow process. Over time, the ground level had fallen to such an extent that it was lower than the stream on the other side of the bank. Dykes and pumping mills were needed to drain the excess water from the land to the rivers. In the south-west of the country the peatland was not drained; rather it was excavated, initially for salt extraction and later for cutting fuel. This form of lowering the ground level gave the sea easy access. Large parts of the peatland were inundated, not least during St. Elizabeth's flood of 1421, which created the area known as the Biesbosch. Estuaries and other inlets were created, dotted with islands which were later connected to each other thanks to the building of dykes.

This had happened in the north a few centuries earlier. In 1170, the sea breached the barrier beaches there, wiping away the peatland of the hinterland. This was how the Zuiderzee was created. Shortly afterwards, in the 13th century, the inhabitants of the tidal marshes in the provinces of Groningen and Friesland decided to connect their mound settlements to each other. After the Middle Ages the sea level continued to rise, and the land continued to sink. There was a continuing need to raise the dykes. From 1684, this was done with reference to a fixed datum: mean sea level at Amsterdam. After 1875, these levels were revised and the reference datum became the *Normaal Amsterdams Peil* (NAP), mean sea level at Amsterdam under normal circumstances. But, at times, water management had to be strategic and offensive: lakes and pools that had been created by peat cutting were drained. A start was made on this process in the 17th century. The last part of this process involved the draining of the Haarlemmermeer, around 1850. That large body of water could finally be drained once sufficiently heavy-duty steam-powered pumping stations were available.

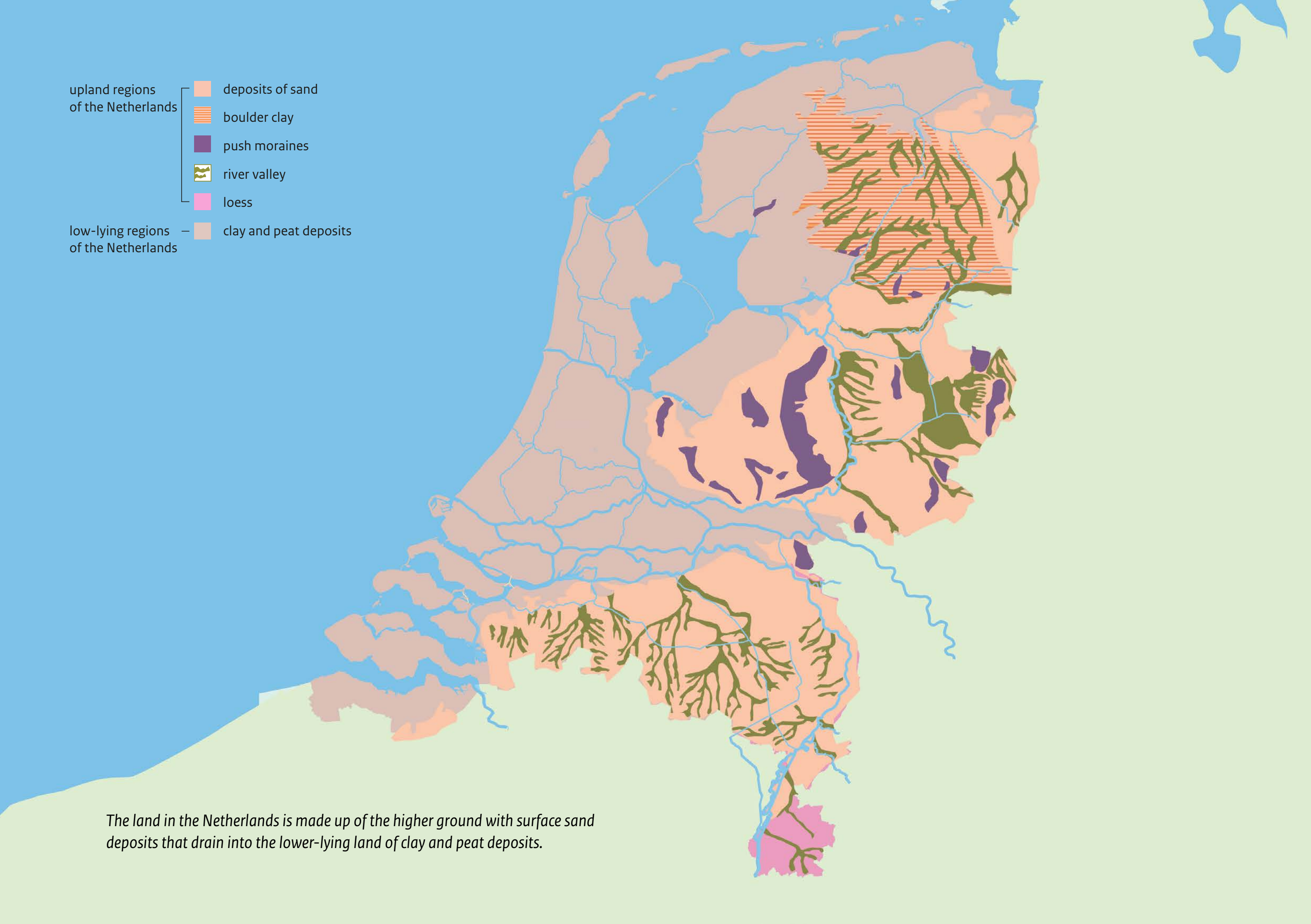


Successive, increasingly powerful water-management measures cause low-lying land in the Netherlands to sink over time. At the same time, the sea level continues to rise, at a rate that is accelerating.

NAP

All altitude measurements in the Netherlands relate to the reference datum of the *Normaal Amsterdams Peil* (NAP), mean sea level at Amsterdam under normal circumstances.
NAP elevation of 0 m is now approximately equal to the mean sea level of the North Sea. The NAP datum is essential to protection of the land against flooding with dykes and other flood defences. The height of flood defences is determined and reviewed in line with NAP. There are around 35,000 NAP elevation markers throughout the country. These NAP elevation markers show altitude in relation to NAP and are an integral part of houses, bridges and other such works. In addition there are 400 underground elevation markers to be able to correct the elevation markers in terms of subsidence.

The NAP datum is the normalised mean sea level at Amsterdam. This measurement, formerly known as AP, was the standardised mean sea level in Amsterdam that was established in 1684. It was the average high-water level registered in the river IJ between September 1683 and September 1684, and was thus the maximum extent of high water at that time. In 1818 a royal decree specified that AP, mean sea level at Amsterdam, should apply to the country as a whole. When more accurate measurement methods were available, the whole of the Netherlands was surveyed once more (between 1875 and 1885). In order to prevent confusion with the previous standard measurement, the new name *Normaal Amsterdams Peil* (NAP) was introduced. In 1879, Germany and Luxembourg started to use NAP as well. In 1973, they were joined by Sweden, Norway and Finland.

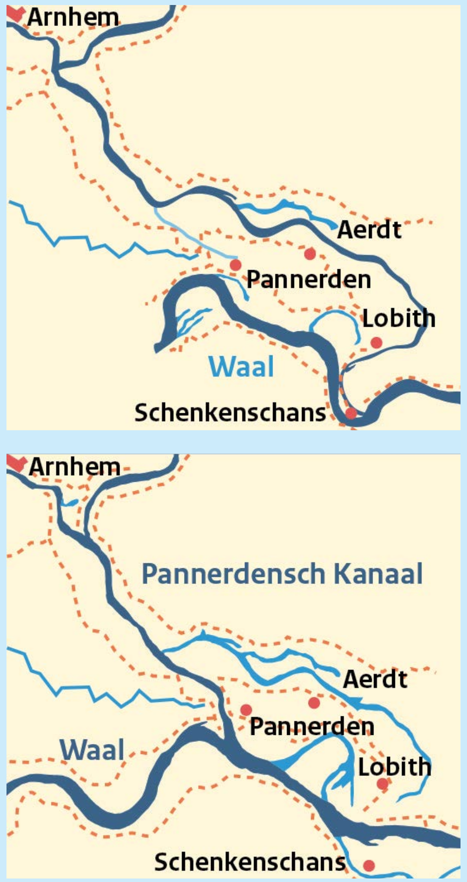


The land in the Netherlands is made up of the higher ground with surface sand deposits that drain into the lower-lying land of clay and peat deposits.

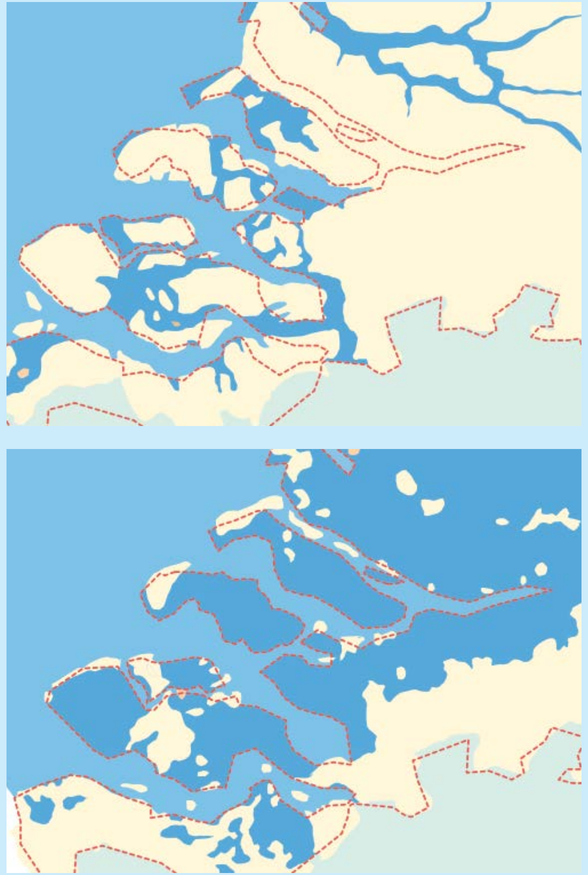
In the southwest and the north (the Dollard) parts of the land were reclaimed from the sea using dykes, although regular storm surges hampered such efforts. And in the Rivierengebied at the heart of the Netherlands there was also regular flooding. Ice barrages were often the cause of this. Ice floes would get caught on the banks of a river, stopping other floes flowing downstream until a blockade was formed, forcing the water to take an alternative course, or to burst through or over a barrage.

During the 17th century, the Waal became the most important branch of the Rhine system. Nearly 90 per cent of the water took this route to the sea, leading to a sharp drop in discharge volumes through the Rhine itself, and via the IJssel. In order to change this pattern and, not least, for strategic military and socio-economic reasons, the Pannerdensch Kanaal was dug in 1707.

In the 18th century, the rivers had difficulty discharging water to the sea. The mouth of the Meuse at Brielle silted up, while shoals formed upstream. It would be another century before measures could be taken to reverse this situation. In the 19th and the 20th centuries, there were even more drastic interventions, such as the digging of the Nieuwe Merwede, the Bergsche Maas, the Nieuwe Waterweg and the construction of barrages in the Lower Rhine that made a new distribution of the water in the Rhine system possible.



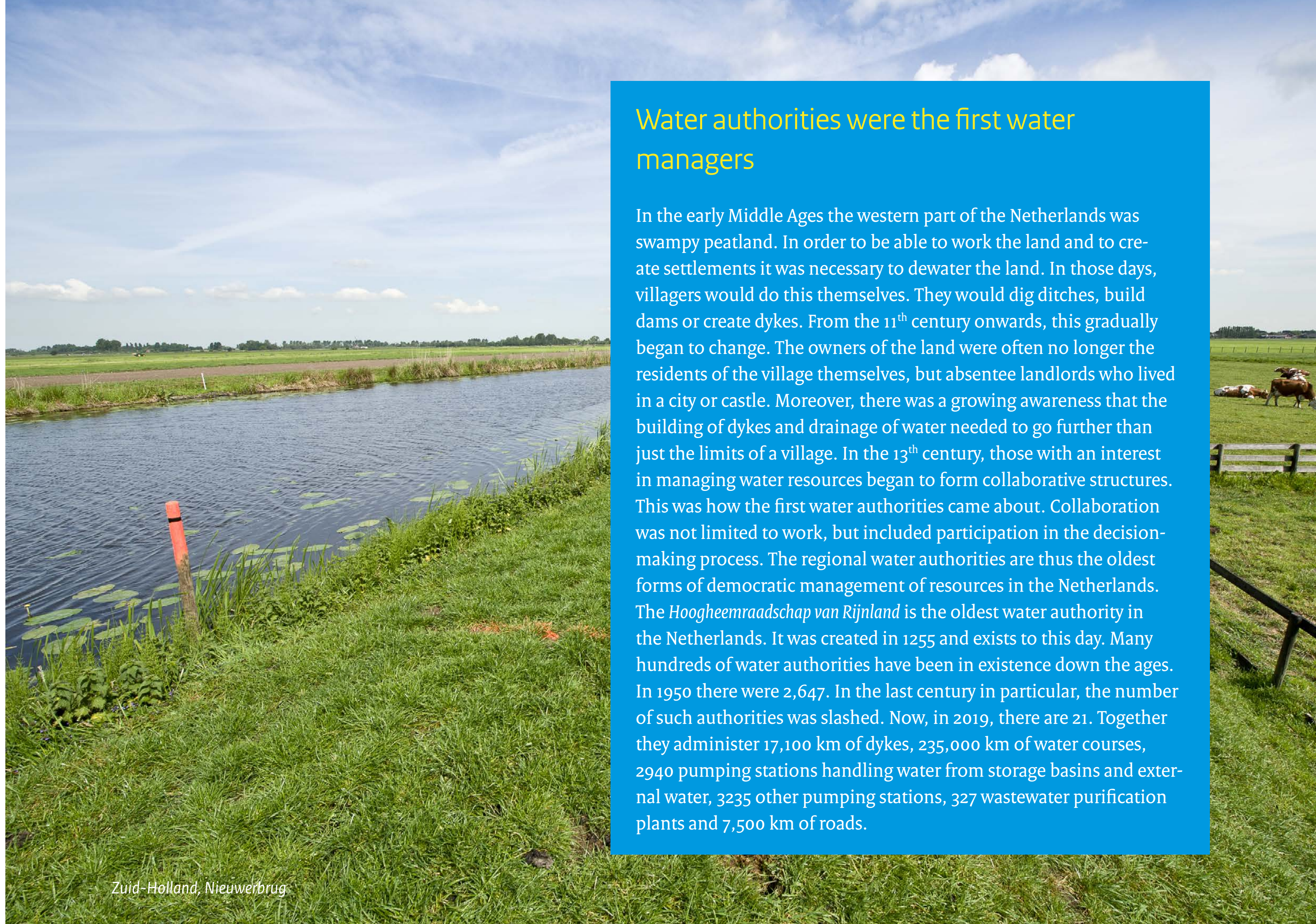
How the Pannerdensch Kanaal restored discharge patterns via the Lower Rhine and the IJssel.



The delta in the southwest of the Netherlands, showing land lying below sea level (dark blue). Above: situation during a storm surge. Below: situation during a storm surge had there been no water-management interventions.

The Netherlands became famous internationally for water management with the Zuiderzee works that began with the drainage of the Wieringermeer and construction of the Afsluitdijk causeway (1927-1932). This was followed by the drainage of the Noordoostpolder, Oostelijk- en Zuidelijk Flevoland and the Lauwerszee. Equally impressive are the Delta Works in response to the storm surge that engulfed the southwest of the Netherlands in 1953.
Many operations of this kind also have drawbacks, such as the ecological consequences of the Delta Works.

As a result the Oosterschelde dam, for instance, is only closed when there is a threat to public safety from flooding, while this also led to the policy of integrated water management, introduced in the 1980s. The effect of all this activity is that the coastline has stopped moving slowly eastwards. It is difficult to say where, precisely, the coastline would have been today without these interventions. The incessant battering from the sea would have faced 'opposition' from the rivers that would have continued creating their delta. But one thing is certain: the Netherlands would look different today, had humans not intervened.



Water authorities were the first water managers

In the early Middle Ages the western part of the Netherlands was swampy peatland. In order to be able to work the land and to create settlements it was necessary to dewater the land. In those days, villagers would do this themselves. They would dig ditches, build dams or create dykes. From the 11th century onwards, this gradually began to change. The owners of the land were often no longer the residents of the village themselves, but absentee landlords who lived in a city or castle. Moreover, there was a growing awareness that the building of dykes and drainage of water needed to go further than just the limits of a village. In the 13th century, those with an interest in managing water resources began to form collaborative structures. This was how the first water authorities came about. Collaboration was not limited to work, but included participation in the decision-making process. The regional water authorities are thus the oldest forms of democratic management of resources in the Netherlands. The *Hoogheemraadschap van Rijnland* is the oldest water authority in the Netherlands. It was created in 1255 and exists to this day. Many hundreds of water authorities have been in existence down the ages. In 1950 there were 2,647. In the last century in particular, the number of such authorities was slashed. Now, in 2019, there are 21. Together they administer 17,100 km of dykes, 235,000 km of water courses, 2940 pumping stations handling water from storage basins and external water, 3235 other pumping stations, 327 wastewater purification plants and 7,500 km of roads.

Zuid-Holland, Nieuwerbrug

Rijkswaterstaat

At the end of the 18th century, the government decided that there was a need for a powerful central authority to protect the country from the water. Naval shipworm was attacking the wooden sea walls and quaysides, natural harbours were silting up and ice barrages were causing flooding. Measures were taken to address these issues,but were often only a local 'sticking plaster', leading to new problems elsewhere. It was high time for a centralised water-management policy. This became reality on 27 March 1798. A '*Bureau voor den Waterstaat*' (Office of Water Management) was created, made up of a president, an assistant and a draughtsman. These days, Rijkswaterstaat is the executive organisation of the Ministry of Infrastructure and Water Management. The agency is responsible for the primary road network (3,072 km), the primary inland-navigation network (7,083 km) and the main water system (90,191 km²), plus the Dutch sections of the North Sea and the Caribbean.

Side channel in the Lek at Everdingen

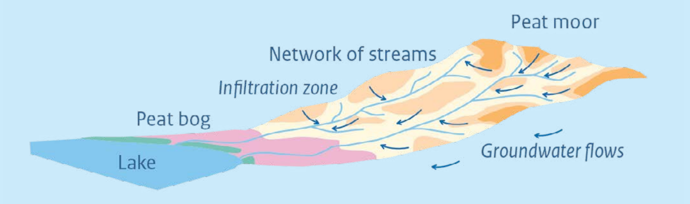
2

Water systems and their function

Spillway in the Lek at Hagestein

It could be said that the Netherlands is a gateway for water. Water from streams and rivers abroad flows through the country and on to the sea. And all precipitation that does not evaporate is infiltrated or flows with the surface water to the sea. In the east and south, the higher ground of the Netherlands, this process is assisted by topography and gravity. But in the low-lying, flat part of the Netherlands, below sea level, this needs help from other sources. Sources like pumping stations, locks, dams, dykes and barrages have been built to exercise a certain amount of control over the water. That has resulted in a mosaic of rivers, lakes and dammed inlets interwoven with drainage ditches, urban canals and long-distance canals. The management of these water systems is generally problem-free.

In the waters under their administration (the main water system), Rijkswaterstaat moves water in the Rhine and Meuse systems to where it is needed. For instance, in the IJsselmeer water is buffered for uses including drinking water and the irrigation of agricultural land, there is sufficient water in the canals, rivers and lakes for inland shipping, and the rivers supply sufficient water to combat salt-water intrusion from sources both internal (seepage) and external (the sea). Water management was previously focused primarily on removal of excess water. In the past few decades, water management has increasingly had to focus on preventing shortages.
What Rijkswaterstaat does for bodies of water at national level, the water authorities do for regional water systems: managing water resources in such a way that the best possible conditions for various social interests/functions are created. They also address problems caused by the muskrat and coypu, and the purification of waste water. Municipal authorities bodies administer sewerage, collection of waste water, drainage of surface runoff and urban groundwater. Provincial authorities manage waterways in the province in question and issue permits for large-scale abstraction of groundwater.



Water from higher ground flows towards the sea as surface water and, in addition, in groundwater flows.

2.1 An outline of the system

A water system is a geographically-delineated body of surface water, coupled with the system's groundwater, soil and river banks, including organic communities that exist in it, plus all associated physical, chemical and biological processes. The interplay with the atmosphere is also important. A water system is made up of a range of components that share a strong bond. They have an influence on each other, are dependent on each other and, moreover, are sensitive to problems relating to water quantity and quality being passed on to each other. In order to be able to understand the coherent nature of the system properly, we will first discuss the nature and character of the various components.

Higher ground

Rain that falls on high ground gradually passes into the soil through the process of infiltration. The rest of the water flows on the surface, towards lower-lying areas (not least through streams). Similarly, the infiltrated water flows underground and, at the foot of the higher ground areas of seepage develop. The area responds differently in summer and winter. In summer, the water table is low. As evaporation is low, the soil absorbs rainfall and flow rates drop. In the winter, the soil is saturated and rainfall runs off immediately. Human intervention, such as the digging of drainage ditches, trenches and canals, and lakes created by human activity may lead to other drainage flow patterns.

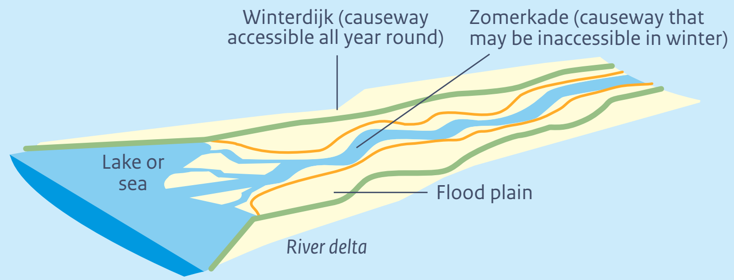
Rivers

Water in a river may be made up of melt water, rainfall and/or groundwater. In summer, there is little or no excess rainfall, little melt water and low groundwater levels. So rivers are low and 'narrow'. In periods of very high rainfall, much melt water and high groundwater levels, rivers can widen to cover the flood plains, the land adjacent to the river channel. As the flood plain is inundated, the water level in the river and the flow rate do not rise dramatically.

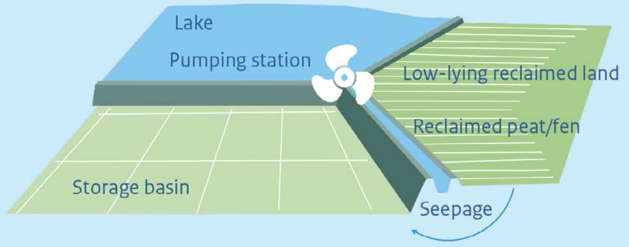
Reclaimed land and polders

Polder land is an area that is encircled by flood defences, where the water level is controlled artificially. A specific type of polder is land reclaimed from a body of water. This is land created by drainage (of a lake, or of shoals in an inlet/estuary). To do this a dyke is built to keep out the water (or part of it). Water is then pumped away from the encircled land. This means that polders are always lower than the adjacent land or the water level.

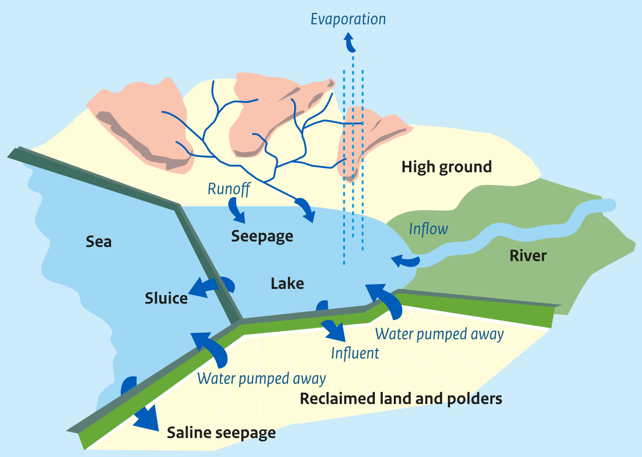
Any rainfall or seepage in a polder that is not necessary for use or strategic buffering can be pumped away from the land towards the storage basin. Polder land is often made up of discrete sections with modified channel bed and a different water level.



A river system



Schematic diagram of a polder and land reclaimed from a body of water.



How the elements in a water system interact

Kinderdijk

Flow of water between components

The various components (high ground, rivers and polders) cannot be seen in isolation from each other. Water is constantly exchanged between them. The river delivers water to the lake, the lake discharges water to the sea, the pumping station pumps water into the lake and (in summer) sometimes allows water in. The water level in the lake partly determines the seepage and groundwater flow rate. In short, the water level, rainfall, groundwater and seepage are all interrelated.

This sort of relationship is the basis for the management of both regional water systems and the main water system. Under normal circumstances it seems obvious that the water is at the desired level throughout the system, and that water flows to where it has to flow. But in periods of heavy rainfall in this country and in neighbouring countries upstream, or during extended periods of drought, water managers continuously need to 'tweak' the system so that they can still respect all interests. This is done by means of scenarios and agreements. The details of this will be discussed in the next section.

2.2 Management of the freshwater system

No matter how small the Netherlands is, it forms part of four international catchment areas; the Rhine, the Meuse, the Scheldt and the Eems.

All the water that flows through these river systems flows through the Netherlands to the Wadden Sea and the North Sea (see the map on page 10). This booklet focuses on the freshwater section of these catchment areas and the transitional zone of the southwest Delta. The Eems and Scheldt are brackish and have little interaction with the freshwater systems. The Eems is a 371-km long river that flows through the north-west of Germany, via the Dollard, and empties out into the Wadden Sea. It enters the Netherlands in the north-east border zone. The Scheldt is a river with a length of 350 km that rises in northern France. The river flows through Belgium and into the southwest of the Netherlands, ending at the North Sea.

The main water system

The larger rivers of the Netherlands have long been prevented from meandering. Dykes and other measures, such as the barrage at Driel, the locks at the Afsluitdijk, and the Haringvliet and Volkerak lock complexes determine the course of the flow and the distribution of water to the various arms of the system, hence which route the water takes to the sea. The main water system is thus sub-divided into various hydrologically interconnected sub-systems:

- The Meuse and the canals in central Limburg and Noord-Brabant
- The Rhine and the rivers that feed it
- The Amsterdam-Rhine Canal and the North Sea Canal
- The IJsselmeer area
- The southwest Delta

Maaswerken at Obbicht

Detailed representation of the sub-system formed by the Meuse and the mid-Limburg/ Noord-Brabant canals

The Meuse and the canals in central Limburg and Noord-Brabant

The Meuse is a truly rain-fed river, and thus often suffers from periods with low flow rates. In order to retain the water and keep inland shipping possible, seven barrages were built in the 20th century: those at Borgharen, Linne, Roermond, Belfeld, Sambeek, Grave and Lith. They are in operation almost continuously, and remain open only when flow rates are high. That is often the case in winter. At that time so much rain may fall that the river bed of the Meuse is unable to cope with the water coming into the system. This was the case, for instance, in 1993 and 1995. Almost immediately after the Meuse crosses the border into the Netherlands at Eijsden, it is divided over three watercourses: the Zuid-Willemsvaart, the Julianakanaal and the Gemeenschappelijke Meuse. For ecological reasons, agreement has been reached to keep up a flow rate of at least 10 m3/s through the Gemeenschappelijke Meuse, but this is not possible in dry periods. Another important point is that the Julianakanaal must remain navigable at all times. Lock operations to allow the passage of vessels from Born and Maasbracht, and abstraction of water for heavy industry require a flow rate of around 20 m3/s. During dry periods Rijkswaterstaat pumps the water that moves downstream due to lock operations back into the system.

The Meuse is the primary source of water for the provinces of Limburg and Noord-Brabant. The Meuse Discharge Agreement between Flanders and the Netherlands (1995) governs water distribution in low flows between the economic areas of both countries and nature in the Gemeenschappelijke Meuse, the border between the two territories. The assumptions made in the agreement relate to availability of equal amounts of water for economic uses in both the Netherlands and Belgium and joint responsibility for water flowing through the Gemeenschappelijke Meuse. Some of the water in the Meuse, for use in Flanders, is diverted even before the border, at Liege. The Flemish authorities use that to feed the Albertkanaal. The other portion of the water in the Meuse for use in Flanders under the terms of the agreement is taken from the river at Smeermaas and discharged via the Zuid-Willemsvaart. Some of this water is returned to the Netherlands at Lozen. The remainder is used to feed the canal system in Kempen, Flanders. That is possible because this body of water is subject to gravitational forces. Water management policy for the canal system in central Limburg and Noord-Brabant is set out in the water accord of the same name. The aim of this accord is to achieve an even distribution of the inflow and outflow of water in the adjoining water-management areas.

The Rhine and the rivers that feed it

The Rhine enters the Netherlands at Lobith. The first point at which the river splits is at the Pannerdense Kop, where the water is generally distributed at high water between the Waal (2/3) and the Pannerdensch Kanaal (1/3), which flows into the Lower Rhine. East of Arnhem, the IJssel leaves the Lower Rhine and Lek at the IJsselkop, diverting 1/3 of the total flow.

At low water the barrage at Driel, in the Lower Rhine, ensures that water from the Rhine system can flow as long as possible at a flow rate of 285 m^3/s via the IJssel to the IJsselmeer, with at least a flow rate of 30 m^3/s left over for the Lower Rhine. The rest flows into the Waal towards the sea, acting as a force against water intrusion from the sea. Moreover, this distribution of flow ensures that there is a reasonable draught available for navigation on the three rivers and, even in dry periods, there is usually sufficient water available for agriculture and other uses or functions. This situation can generally be maintained for nine months of the year. But, if the flow rate at Lobith is lower than 1300 m^3/s, there will be less than the usual 285 m^3/s available for the IJssel. Once the flow rate rises above 1300 m^3/s again, Rijkswaterstaat gradually opens the barrages at Driel, Amerongen and Hagestein, and the flow rate in the Lower Rhine increases, while at least 285 m^3/s continues to flow through the IJssel. If the Rhine system has to contend with a flow rate of more than 2400 m^3 of water per second, the barrages will be opened to their full extent, with no intervention of any kind on the distribution of the discharge. Discharge via the IJssel rises as well in a situation of this kind.

Water from the IJssel is exchanged with the canals in Twente via the lock and pump complexes at Eefde, Delden and Hengelo. At each complex water from the IJssel is pumped up to the following canal pound. This route means that water can be supplied to parts of southwest Overijssel, the Gelderland part of the Achterhoek, Twente and, ultimately, via the regional network, even Drenthe. In addition to the supply, drainage and transportation of water, the canals in Twente are also important to inland shipping.

Distribution of water through the branches of the Rhine

Twente Canals

As in many places in the Netherlands, there is a strong link between the main system (Twente Canal) and regional systems (Almelo - de Haandrik Canal, the Overijsselse Vecht and the Coevorden - Vecht Canal). Water from the IJssel is generally channelled during the summer period, when there is not enough water in parts of Overijssel, Gelderland and Drenthe to manage water levels, and to compensate for losses due to lock operation, leakage, evaporation and influent seepage due to insufficient water supply from the canal through the streams that feed it (the Dinkel, Regge, Berkel and Schipbeek). In addition, it is necessary to channel water via the Twente Canal, the Almelo - de Haandrik Canal, the Overijsselsche Vecht and the Coevorden - Vecht Canal for the standing demand for water treatment and industry, and seasonal water demand from the agricultural sector. Water is also needed for water quality and aquatic ecology. The average demand for water is 15 m^3/s.

Twente Canal

salinisation is a significant issue at the confluence of the Meuse and Rhine. Where the Nieuwe Waterweg empties into the sea, the undertow brings salt water into the system. As the shipping channel to Rotterdam was deepened, salt-water intrusion increased. As a result, in dry summers the water inlets to the Nieuwe Maas, the Oude Maas and the Hollandsche IJssel may become brackish, making the water unsuitable for agriculture and nature in general. In such situations, water may be abstracted from the Brielse Meer, in restricted quantities, while the Climate-resisting Water Sourcing (KWA) measures from the Amsterdam-Rhine Canal towards the province of Zuid-Holland take effect.

The Amsterdam-Rhine Canal and the North Sea Canal

The Amsterdam-Rhine Canal and the North Sea Canal form part of the major inland shipping connection between the IJmond, Amsterdam and Germany. So the water level to allow vessels to navigate this waterway is an important point for consideration. The canals form a single system and are of great importance to water management in the region as a whole. The area in green drains immediately, while the area in yellow can also drain indirectly via the North Sea Canal using the inlet at Schellingwoude (the Oranjesluizen lock complex) The system receives an average of fifty - sixty per cent of its water via the regional bodies of water managed by the water authorities (the area shown in green). The system discharges its water into the North Sea at IJmuiden. At low tide (at sea), this is done using sluice gates. The maximum sluice rate is 700 m³/s, but in order not to hinder shipping the sluice rate is usually kept to a maximum of 500 m³/s. If the water at sea is high the pumping station at IJmuiden, which has a maximum capacity of 260 m³/s, cuts in. In addition, the Amsterdam-Rhine Canal provides water for the drinking-water supply, and transports water to cool power stations in Utrecht and Amsterdam.

Basin of the Amsterdam-Rhine Canal and the North Sea Canal. The green area shows where the water is directly discharged, the yellow area shows indirect discharge.

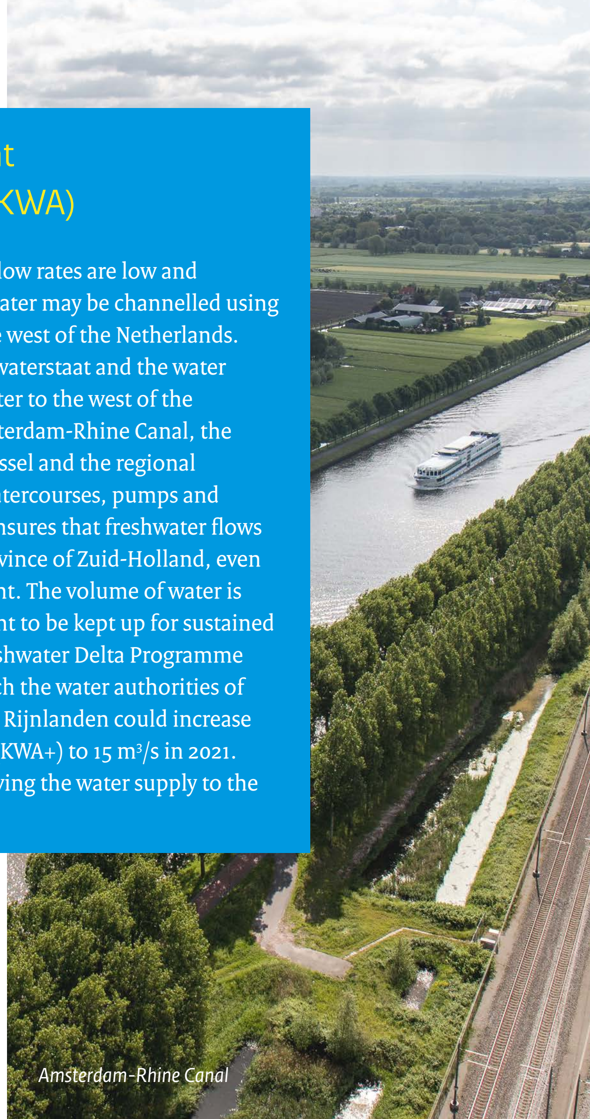
The Princess Irene lock complex at Wijk bij Duurstede and, to a lesser extent, the Princess Beatrix lock complex and the Koninginnen lock complex in Nieuwegein channel water from the Lek into the Amsterdam-Rhine Canal. The Oranje lock complex at Schellingwoude can channel water from the Markermeer into the North Sea Canal. Whether or not water is channelled from the Markermeer depends on sluicing policy and the water levels.

Many large vessels use the locks at IJmuiden. This allows saline water into the water system. For this reason there is a salinity gradient from IJmuiden as far as the start of the Amsterdam-Rhine Canal. From an ecological point of view, this salinity gradient gives the North Sea Canal a unique character. As there is a collection point for drinking water on the Amsterdam-Rhine Canal, the accretion of saline sediment must not stretch too far. The water accord for the Amsterdam-Rhine Canal specifies that the aim for the minimum rate at the confluence of the canal should be 10 m³/s. In addition, water channelled in from the Markermeer via Schellingwoude helps to keep down accretion of saline sediment. But that is not as effective.

During dry periods the Lower Rhine supplies insufficient water to feed the Amsterdam-Rhine Canal. When flow rates are low and the water level in the Waal at Tiel drops to around NAP +3 m, the Prince Bernard lock is opened; these gates can only redirect water towards the Waal.

Climate-resistant water sourcing (KWA)

In circumstances when flow rates are low and salinisation is an issue water may be channelled using the KWA measures to the west of the Netherlands. In such situations, Rijkswaterstaat and the water authorities feed freshwater to the west of the Netherlands via the Amsterdam-Rhine Canal, the canalised Hollandsche IJssel and the regional systems, a network of watercourses, pumps and pumping stations that ensures that freshwater flows to the polders of the province of Zuid-Holland, even in times of severe drought. The volume of water is limited, and not sufficient to be kept up for sustained periods. In 2014, the Freshwater Delta Programme set out terms under which the water authorities of Rijnland and De Stichtse Rijnlanden could increase the capacity of the KWA (KWA+) to 15 m³/s in 2021. Rijkswaterstaat is improving the water supply to the KWA.



Amsterdam-Rhine Canal

The water level between the barrages at Amerongen and Hagestein will then be the same as the water level in the Waal. The Waal is then, in effect, compensating for water abstraction at this reach. The amount of water channelled in at Wijk bij Duurstede during dry periods depends on the quantity of water available in the Waal, and the interests of inland shipping on the Waal, action against salinisation in the lower catchment area and the sluicing of the Amsterdam-Rhine Canal have to be weighed up. Where the water level in the Markermeer permits sluicing from the Vecht and water supply via Muiden, that route can also be used to bring water to the Amsterdam-Rhine Canal. In such circumstances, less water is required from the Waal and Lower Rhine.

When dry conditions persist, the water in the Amsterdam-Rhine Canal can also be used to sluice water to address salinisation in polders in Zuid-Holland. In this case, water in the Hollandsche IJssel is too saline for this, as saline accretion has built up too far along the Nieuwe Waterweg. The Freshwater Strategy Decision (2015) under the auspices of the Delta Programme (see chapter 9) envisages expanding capacity via the KWA+ to 15 m³/s before 2021.

The IJsselmeer area

The IJsselmeer area water system covers the IJsselmeer itself, the Markermeer and the Veluwe peripheral lakes. It is the largest freshwater basin in western Europe and functions as a buffer. It provides large areas of the north of the Netherlands with water. It is also a nature-conservancy area of national and international importance. Its primary function, however, is to discharge the water from the catchment areas of the IJssel, the Overijsselse Vecht and the Eem.

The IJssel is the most important supply line to the IJsselmeer and, in the summer months, for the Markermeer as well. From mid-2018 a new ordinance relating to the water level will give more latitude for a flexible water level in the IJsselmeer area. The general target for the level of the IJsselmeer and the Markermeer has been replaced by a 'bandwidth' of 20 cm, within which the water level may fluctuate, so that the water-level management can vary, depending on meteorological conditions and the demand for freshwater. A bandwidth has similarly been set for the winter period, focusing on the lower ranges of the bandwidth based on gravity drainage. Transitional periods have also been included at the start and end of the winter period. The IJsselmeer, Markermeer and Veluwe peripheral lakes now each have different periods with their own bandwidth for the water level:
In the winter, from November - February inclusive
a) IJsselmeer -0.40 to -0.05 m NAP
b) Markermeer -0.40 to -0.20 m NAP
c) Veluwe peripheral lakes -0.30 to -0.10 m NAP

Transition to the winter period: water level raised in March; drop in October
a) IJsselmeer -0.40 to -0.10 m NAP
b) Markermeer -0.40 to -0.10 m NAP
c) Veluwe peripheral lakes -0.30 to -0.05 m NAP

In the summer, from April - September inclusive
a) IJsselmeer -0.30 m to -0.10 m NAP
b) Markermeer -0.30 to -0.10 m NAP
c) Veluwe peripheral lakes -0.10 to -0.05 m NAP

In the event of persistent drought the summer water level may be raised, so as to build up a buffer for subsequent use. In the winter there is an excess, and water from the IJsselmeer flows under the force of gravity via the sluice gates at Den Oever and Kornwerderzand to the Wadden Sea. Where it is not possible to sluice water, water levels will rise. The winter average level for the IJsselmeer will remain at -0.25 m in relation to NAP until 2050; for the Markermeer this is -0.33 m in relation to NAP. In order to safeguard water safety and maintain average winter water levels over the years there is extra drainage capacity in the form of weepholes and pumps next to the sluice gates at Den Oever, so that it is possible to discharge sufficient quantities of water.

The assumptions and control criteria for water-level management are calculated in a so-called Water Management Protocol drawn up within one year of the new water-level ordinance coming into effect. It is expected that the water-level ordinance will be implemented in full from 2023 as part of operational water-management policy.

Volkerak-Zoommeer

Following the completion of the Eastern Scheldt Project, the Volkerak-Zoommeer was created in 1987 with the construction of the Oesterdam and Philipsdam. This is a non-tidal freshwater lake that provides freshwater for agriculture and collects water that runs down the natural gradient from west Noord-Brabant. Because of the excess nutrients in the water the Volkerak-Zoommeer faces issues each summer from algal bloom, which causes substantial problems for local residents and users. Studies have shown that a potential solution to the problems of algal bloom would be to increase the salinity of the lake and reintroduce a measure of tidal dynamics. This would have consequences for users. It would require measures to prevent salinisation in the surrounding area. And there would have to be an alternative source of freshwater for the areas that abstract their freshwater from the lake. Moreover, an effective barrier between freshwater and salt water must be created at the locks that form the boundary between the salt-water lake and the adjacent freshwater bodies, such as the Hollandsch Diep. The alternative freshwater supply forms part of the package of measures in the Delta Programme. For financial reasons, a salt-water Volkerak-Zoommeer is not on the agenda in the near future. However, in the longer term the idea remains on the table. The urgency appeared to have declined in recent years due to the improvement in the water quality, presumably as a result of the sharp increase in numbers of the quagga mussel, which has been recorded in the lake since 2008. However, in 2016 and 2017 there have once more been cases of algal bloom.

The Markermeer generally discharges any excess water in the winter half-year to the IJsselmeer. In summer, water supply from the IJsselmeer is often needed to keep the water level in the Markermeer at a certain level for the regional water supply, and to flush through the North Sea Canal. In the Veluwe peripheral lakes, the target water level from mid-March to the end of October is -0.05 m relative to NAP and, for the rest of the year, -0.30 m relative to NAP. The Veluwe streams and water from the adjacent polders primarily feed the Veluwe peripheral lakes. The Veluwe peripheral lakes drain into the Vossemeer (IJsselmeer) and Nijkerkernauw (Markermeer). The IJsselmeer supplies significant quantities of water to Friesland, Groningen and the northern tip of Noord-Holland, but also to large parts of Drenthe and the north-west of Overijssel. There is an entry point for water treatment at Andijk (intake of approximately 70m m^3/year). As for the Markermeer, the most significant entry points for the hoogheemraadschap Hollands Noorderkwartier Schermerboezem are at Lutje-Schardam, Schardam and Monnikendam. And water abstracted from the IJmeer can be fed in to the Vecht and the Amsterdam urban canal system respectively at Muiden and Zeeburg.

Southwest Delta

The Nieuwe Waterweg/Nieuwe Maas, the Biesbosch and the Scheldt estuary form the boundary of the southwest Delta. It is a complex system of interconnected large-scale freshwater and saline bodies of water that each have an influence on the system. Some bodies of water are stagnant, others are tidal. This is the confluence of the Rhine, Meuse and Scheldt. Hence this uppermost section of the southwest Delta, where the Rhine and Meuse meet, is also called the Rhine/Meuse estuary.
The Haringvliet lock complex generally distributes the water discharge over the Nieuwe Waterweg and the Haringvliet. The aim is to discharge 1500 m^3/s of water for as long as possible, via the Nieuwe Waterweg, to prevent salinisation of bodies of water such as the Hollandsche IJssel which, at Gouda, has the most significant entry point for the central area of the west of the Netherlands. Furthermore, the aim is to make sure that water levels in the Hollandsch Diep remain above NAP in view of the sea port at Moerdijk.

Southwest Delta

Where flow rates at Lobith fall below 1100 m^3/s, the Haringvliet lock complex is shut completely, with the exception of the saline outfall and fish pass. Where flow rates in the Rhine are between 1100 and 1700 m^3/s, a small flushing opening (25 m^3/s) is used where the level of the external waters is lower than that of the internal waters. In this way, the flushing rate in the western part of the Haringvliet is an average of approx. 50 m^3/s per tide.

For flow rates on the Rhine at Lobith from 1700 to 9500 m^3/s, the sluice opening opens progressively until, at flow rates above 9500 m^3/s, the Haringvliet lock complex is completely open. The Haringvliet lock complex's share in discharge of water from the Rhine/Meuse system increases from a few percentage points at low flow rates to 60-65 per cent. This distribution remains fairly constant where discharge via the Rhine increases. Starting in 2018 the Haringvliet lock complex no longer forms a hard boundary between the sea and the Haringvliet itself. The lock complex no longer shuts as the tide rises; rather, the gates remain ajar. This process creates a gradual transition from saline sea water to fresh river water. This means that migratory fish, such as salmon and trout, can pass through the complex and a more natural delta is created. A pre-condition for this is that the freshwater inlets do not salinate. This measure is entirely in keeping with the terms of the European Water Framework Directive and the Natura 2000 programme.

Lakes

In addition to the streams, ditches and canals, the Netherlands also has many lakes. These lakes were created in many different ways.

Natural source	A high water table and flooding formed natural pools. An example of this is the Naardermeer.
Peat cutting	The Nieuwkoopse, Loosdrechtse and Vinkeveense Plassen, the Weerribben, the Deelen and the Sneeker- Paterswoldsemeer are examples of pools that were created by peat cutting. Peat, dried out peat sods, used to be an important source of fuel. The bogland was cut on a large scale, from beneath the water table, which resulted in the formation of pools of water. Many such pools were later reclaimed to restrict the loss of land. Other pools are still in existence, and have been turned into recreational land or nature reserves.
Extraction of natural resources	More than 500 pools have been created by sand and gravel extraction. They were created when sand or gravel were excavated in areas with a relatively high water table (e.g. The Maasplassen).
Delta Project/ partial land reclamation	The IJsselmeer, Markermeer and the peripheral lakes are the result of the damming of sea inlets and reclamation of land. But the regional system also contains many lakes and pools. The Lauwersmeer (2400 ha), for instance, which was created by the damming of the Lauwerszee in 1969 and partial land reclamation.

Nieuwkoopse Plassen

The digging and subsequent deepening of the Nieuwe Waterweg, facilitating access to the Port of Rotterdam allowed the saline water to penetrate further inland, putting pressure on the water supply for the central area of the west of the Netherlands. To feed freshwater to Delfland, a pipe (with a capacity of 4 m^3/s) was laid from the Brielse Meer, underneath the Nieuwe Waterweg, through to Delfland. The water in the Brielse Meer is fed through the intake from the Spui at Bernisse. There are also opportunities for moving water through the Lopiker- en Krimpenerwaard at around 10 m^3/s. When conditions are dry, water can also be fed in from the Amsterdam-Rhine Canal via the KWA route.

Regional bodies of water

In addition to the main water system, the Netherlands also has a tightly-packed network of ditches, streams, canals and lakes that form part of regional water systems. The main water system and the regional systems are linked together in various places. On the one hand, the regional systems feed water to the main system, on the other hand, the main system may feed the regional water systems in dry periods.

In the higher ground of the Netherlands (large parts of Drenthe, Gelderland, Noord-Brabant and Limburg, plus a small part of the province of Utrecht), the water flows in a more or less natural way. 'More or less' in this context means that those areas also have plenty barrages, man-made streams and canals, and flood storage areas. Streams flow through the largely sandy ground. In these areas discharge flows are regulated, which has a knock-on effect on the levels of surface water and the water table. Water is retained in dry periods by setting up barrages. In some parts, water from elsewhere is primarily needed for irrigation purposes.

In low-lying parts of the Netherlands, no water flows in this way. This is where the polders are found, where people control water levels (water-level regulated area). Sometimes it is possible for polders to discharge their water under natural circumstances. But more often than not, a pumping station is needed to pump away excess water to bodies of water at higher elevation than the polder itself; the storage basins, which ultimately discharge their contents to the sea or to the main water system, either with or without the intervention of a pumping station. In the event of heavy rainfall or persistent drought it is not always possible to maintain the desired water levels in polders and storage basins.

And discharge of excess water is not the sole function of the storage-basin network. During dry periods it also feeds water in. In low-lying parts of the country, water intake has a range of functions. The most significant of these is to maintain water levels to prevent consolidation and subsidence in layers of peat. At least as important as this is to flush away natural sources of saline groundwater (seepage) in these low-lying areas, keeping the surface water sufficiently fresh, so that it can be used for irrigation purposes. And water is also needed for flushing in view of water quality and, for example, use in agriculture and market gardening. The use of the bodies of water and the adjacent land determines how the water is managed.

2.3 The limits of water management under extreme conditions

The water system in its current state is fit for purpose under normal circumstances. Under extreme conditions or when specific circumstances occur (or are combined), problems may arise:

Safety where high water levels pose a danger to life (human or otherwise) and/or result in substantial economic loss or material damage.

Localised flooding where excess water leads to damage to buildings (residential or otherwise), crops etc.

Water shortages where there is insufficient water for agriculture, drinking-water supplies, flushing, water cooling, water-level management and inland shipping.

Salinisation where the concentration of salt in the water rises, with adverse effects on agriculture, nature and drinking-water supplies.

Eutrophication where surface water is enriched with nutrients, creating water-quality issues in relation to a range of functions.

The fact that problems arise under extreme circumstances is hardly surprising: there is little leeway in terms of water distribution between and within elements of the system. Furthermore, the sole means of 'controlling' or otherwise managing the distribution of water discharge where flow rates in a river system are extremely low is restricted to lowering each of the barrages in the Lower Rhine, and closing the Haringvliet lock complex and the locks in the Afsluitdijk. At extremely high discharge rates, the only option is to open all barrages and sluice gates to the fullest extent.

Water managers in the Netherlands are continuously working together to distribute the available water in the best possible way. Climate change is making this task increasingly difficult, and water managers have to work in ever closer collaboration. Water managers are learning to put the opportunities presented by the water system as a whole to better use. Only then is it possible to prevent or defer inconvenience or damage due to drought or water runoff flooding. We call this Smart Water Management. Smart water management is where water managers combine all their data on water, knowledge and forecasts (including weather forecasts) with new or existing measurement and control technology, in order to distribute the water as smartly as possible with the existing infrastructure on the basis of real-time information, without the boundaries of water management forming a barrier.

Tap code	Name
H1	Weir at Driel
H2	Haringvliet lock complex
H3	Stevin lock complex, Den Oever
H4	Lorentz lock complex, Kornwerderzand
h1	Meuse 9
h2	Prins Bernard lock
h3	Volkerak lock complex
h4	Weir at Amerongen
h5	Prinses Irene lock complex
h6	Weir at Hagestein
h7	Oranje lock complex, Schellingwoude
h8	Sluice gates, IJmuiden
h9	Krabbersgat lock, Enkhuizen
h10	Houtrib lock complex, Lelystad
r1	Gat van de Kerksloot intake (drinking-water supply)
r2	Sluice/lock gate and Gat van de Ham
r3	Kromme Rijn intake gate
r4	Fan gates
r5	Pijnacker-Hordijk pumping station (Gouda storage basin pumping station)
r6	De Aanvoerder
r7	mouth of the Twente Canal
r8	Rogat lock
r9	Paradijs lock
r10	Teroelster gulley
r11	Tacozijl sluice
r12	J.L. Hooglandgemaal pumping station, Stavoren
r13	Drinking-water intake, Andijk
r14	Zeeburg pumping station
r15	Schardam
r16	Bernisse drinking-water abstraction point
r17	Haandrik lock
r18	Wortman pumping station
r19	De Blocq van Kuffeler pumping station
r20	Colijn pumping station
r21	Muiden sluiceway
r22	Vissering pumping station
r23	Linge intake
r24	Vallei & Eem intake

Overview of all 'taps' in the main water-management system

Flood plains alongside the Waal at Lent

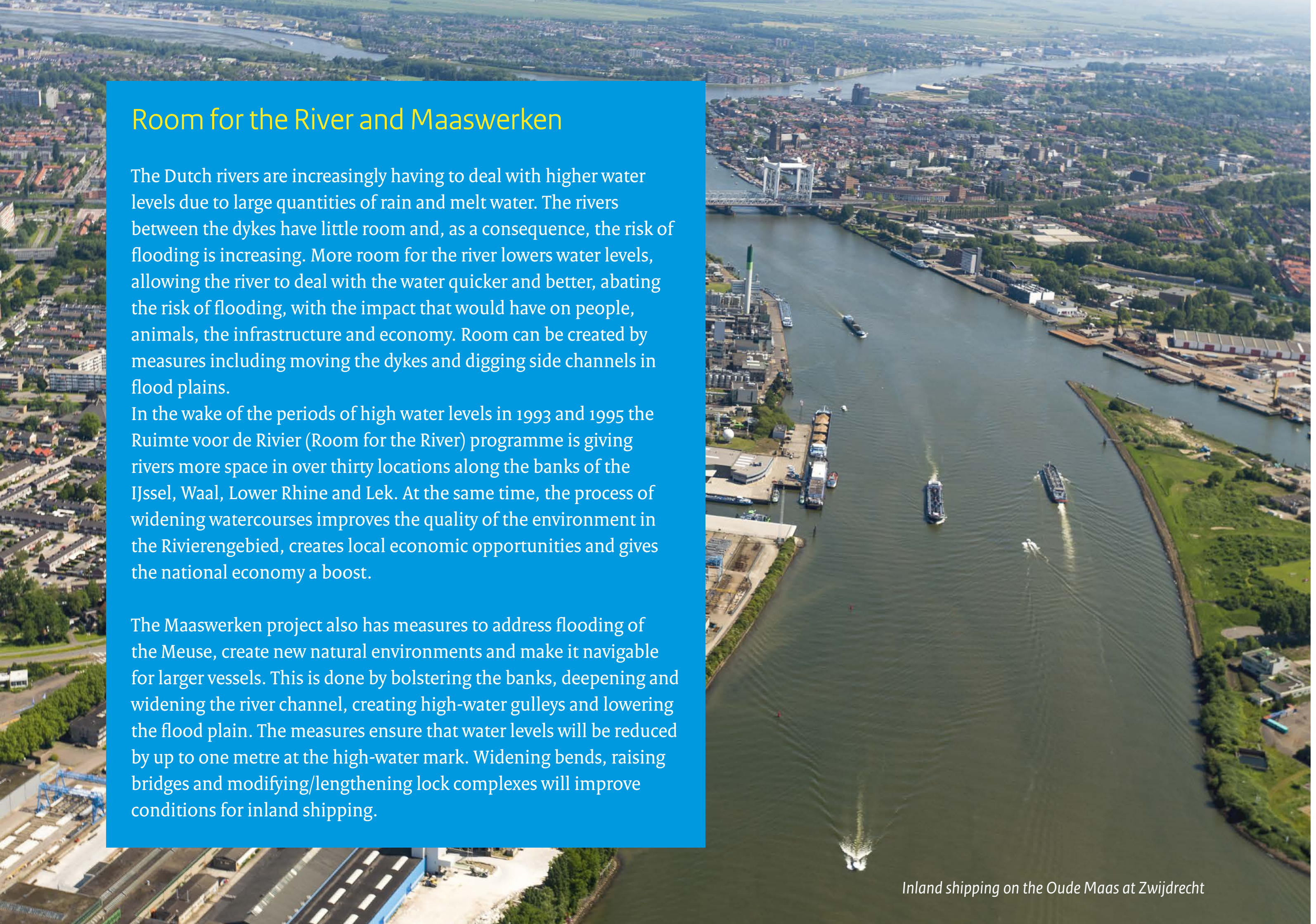
3.1 What is water safety?

The low-lying, largely flat location of the Netherlands at the mouth of several large rivers makes it particularly susceptible to flooding. Floods can claim many lives and cause destruction. So when we talk about water safety, we are referring to situations with the potential to take lives and/or cause substantial economic damage or loss.The threat presented by water may come from the sea or from the rivers. The map on page 46 shows that around 60% of the Netherlands would regularly be under water if there were no flood defences; this is either because the land in question is beneath NAP level or because it is an area that is susceptible to flooding. 40% of the land surface of the Netherlands is below NAP level, while 59% of the land surface is susceptible to flooding. 55% of this land is within the embanked land, and is protected by dunes, dykes, dams and other such man-made structures. The other 4% of this land is unembanked alluvial land, and is thus not protected by dunes, dykes, dams and other such man-made structures. How safe it actually is behind the primary flood defences depends on the place and the strength of the flood defence in question.

3.2 What are the parameters of water safety?

The safety of lakes, rivers, the delta and the sea is determined by different factors:

Lakes	water level, wind (action of the wind and wave run-up)
Rivers	drainage and, to a certain extent, the wind (action of the wind and wave run-up)
Delta	river flow rate, water levels at sea, wind (action of the wind and wave run-up)
Sea	tides, wind (action of the wind and wave run-up)



Room for the River and Maaswerken

The Dutch rivers are increasingly having to deal with higher water levels due to large quantities of rain and melt water. The rivers between the dykes have little room and, as a consequence, the risk of flooding is increasing. More room for the river lowers water levels, allowing the river to deal with the water quicker and better, abating the risk of flooding, with the impact that would have on people, animals, the infrastructure and economy. Room can be created by measures including moving the dykes and digging side channels in flood plains.
In the wake of the periods of high water levels in 1993 and 1995 the Ruimte voor de Rivier (Room for the River) programme is giving rivers more space in over thirty locations along the banks of the IJssel, Waal, Lower Rhine and Lek. At the same time, the process of widening watercourses improves the quality of the environment in the Rivierengebied, creates local economic opportunities and gives the national economy a boost.

The Maaswerken project also has measures to address flooding of the Meuse, create new natural environments and make it navigable for larger vessels. This is done by bolstering the banks, deepening and widening the river channel, creating high-water gulleys and lowering the flood plain. The measures ensure that water levels will be reduced by up to one metre at the high-water mark. Widening bends, raising bridges and modifying/lengthening lock complexes will improve conditions for inland shipping.

Inland shipping on the Oude Maas at Zwijndrecht

3.3 Water-safety policy

The basis for today's water-safety policy was laid by the Delta Committee that was founded in the wake of the 1953 North Sea Flood, which was particularly devastating in the Netherlands. Responding to recommendations put forward by the Delta Committee, the coastline was shortened by 700 km and safety standards were set for the storm-surge barriers and other flood defences. But things have moved on since then. Significant investments have been made and the population has grown considerably behind those barriers. Developments such as those will not stop any time soon. Furthermore, all the climate scenarios put forward by the KNMI predict rises in both the sea level and river flow rates. What that boils down to is that the threat and the potential consequences of a flood event are increasing. Large-scale flooding would cause devastating damage and loss, destabilising society in the Netherlands for a long time.

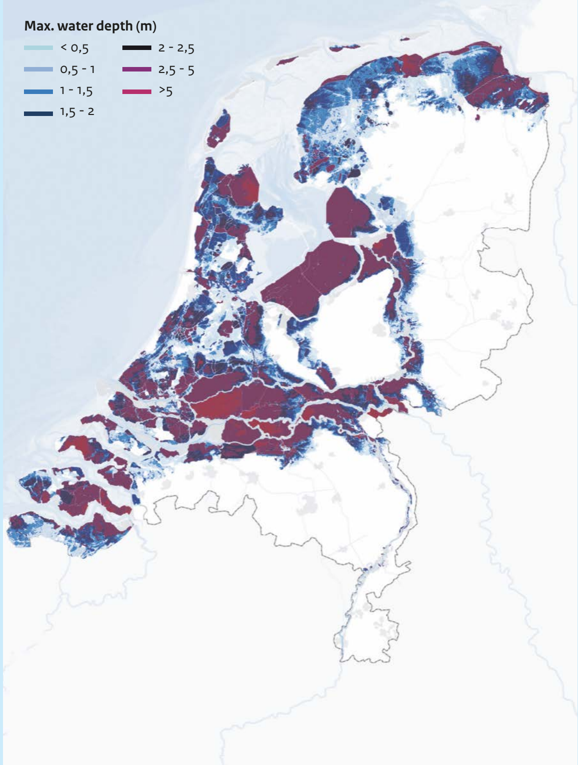
So in 2007, a new Delta Committee was set up (see chapter 9) to advise the government on its water-safety policy, and on protecting the Netherlands from the implications of climate change. In 2008, the Committee recommended setting new water-safety standards. This led to a new water-safety policy[1] that came into force on 1 January 2017.

[1] More information on the new safety standards can be read (in Dutch) at www.helpdeskwater.nl/wbi2017.

Under the new safety policy, the risk of deaths from flooding has been reduced to a maximum of once every 100,000 years. And in areas where large groups could have their lives and/or livelihoods threatened, the risk becomes even smaller. That also applies to areas with vulnerable infrastructure of national importance. This reduces the flood threat to a socially-acceptable level.

New standards for the primary flood defences have been determined based on these policy goals. The standards are expressed as the risk of flooding, and reflect the minimal risk of a flood event actually happening. This approach makes the differences in the threat facing the Netherlands as a whole smaller. As the implications of failure of a number of sections of a flood barrier in the same area can vary widely, ‘equalisation’ of the threat posed leads to a range of standards for those sections.

The water authorities and Rijkswaterstaat have until 2050 to bolster the dykes and dunes. Once that has been done, the Netherlands will be better protected against flooding.



60% of the land in the Netherlands is liable to flooding from the sea, lakes and the larger rivers, resulting in inundation rising to more than 5 m in places (source: Grondslagen voor hoogwaterbescherming, 2016)

In addition, as part of the new water-safety policy to maintain the Netherlands' preparedness for flooding in the next fifty - one hundred years, the government has opted for a sustainable water-safety policy based on the concept of 'multi-layered safety' in the National Water Plan and the Water Safety Decision as part of the Delta Programme.

3.4 Management of flood defences

The Netherlands has the world's safest river delta, but remains vulnerable. The country has to be defended permanently, both against the sea and against the water that flows into it via the river system. In terms of water safety, the Netherlands always has work to do.

Article 21 of the Constitution requires the government to ensure that the country remains habitable, and to protect and improve the living and working environment. Protection against flooding is a telling example of this. All sand dunes and the most important dykes, dams and storm-surge barriers form the primary flood defences. They protect the population against flooding from the sea, the larger rivers or lakes (such as the IJsselmeer, the Markermeer, the Volkerak-Zoommeer, the Grevelingenmeer and the tidal reach of the Hollandsche IJssel). The primary flood defences are the most important lines of defence. Rijkswaterstaat is charged with defending the coastline and administers the large-scale flood-defence works that close off the large sea inlets in the west of the country, such as the Oosterschelde storm-surge barrier, the Haringvliet lock complex, the Maeslant storm-surge barrier, the Ramspol inflatable dam, the Hartel storm-surge barrier, the Afsluitdijk and the Houtribdijk dam. The water authorities administer over 3,600 km of primary flood defences.

In addition to those there are secondary flood defences, or regional flood defences. These include storage-basin embankments and dykes along canals and smaller rivers, generally intended to prevent localised flooding from regional bodies of water. These flood defences are allocated and standardised on the basis of provincial-level regulations. The water authorities administer almost all the other flood defences (dykes, dunes and storage-basin embankments) in the Netherlands, a total of 13,500 km.

Management of the flood defences is the responsibility of the state and the water authorities. This responsibility implies that the manager of any given flood defence (water authority or Rijkswaterstaat) has a legal obligation to make sure that the safety requirements are met, and that the required preventative management and maintenance are carried out. Together with the cycle of standardisation, testing and bolstering, management and maintenance ensure that the flood defences are fit for purpose, that is to say to protect the country.

Multi-layered safety

The concept of multi-layered safety applies to protection of the land behind the dykes against flooding (and its consequences) from investment made in three layers.

Layer 1 prevention: preventing flooding
Layer 2 robust land-use planning
Layer 3 proper emergency-response management

The first layer (prevention) is, and remains, the most important pillar of the water-safety policy. However, flooding can never be ruled out. So the second and third layers focus on controlling the consequences of a flood event.

Taken together, the measures reduce the flood risk.
In extraordinary circumstances, measures from layers 2 and 3 may be used in place of the preventative measures. These are 'smart combinations'. Suppose for instance, that the bolstering of the flood defences is particularly expensive or has a radical effect on the landscape. That would require an additional change to the Water Act, as in such cases a lesser requirement would apply to the flood defence in question. In addition, measures in layers 2 and 3 may be used in tandem with the preventative measures. The ultimate choice of measures for a particular location depends on weighing up cost and effect. Land-use planning that tackles water issues may be a solution to spatial developments, such as building higher or creating escape routes.

4.1 What is surface runoff flooding?

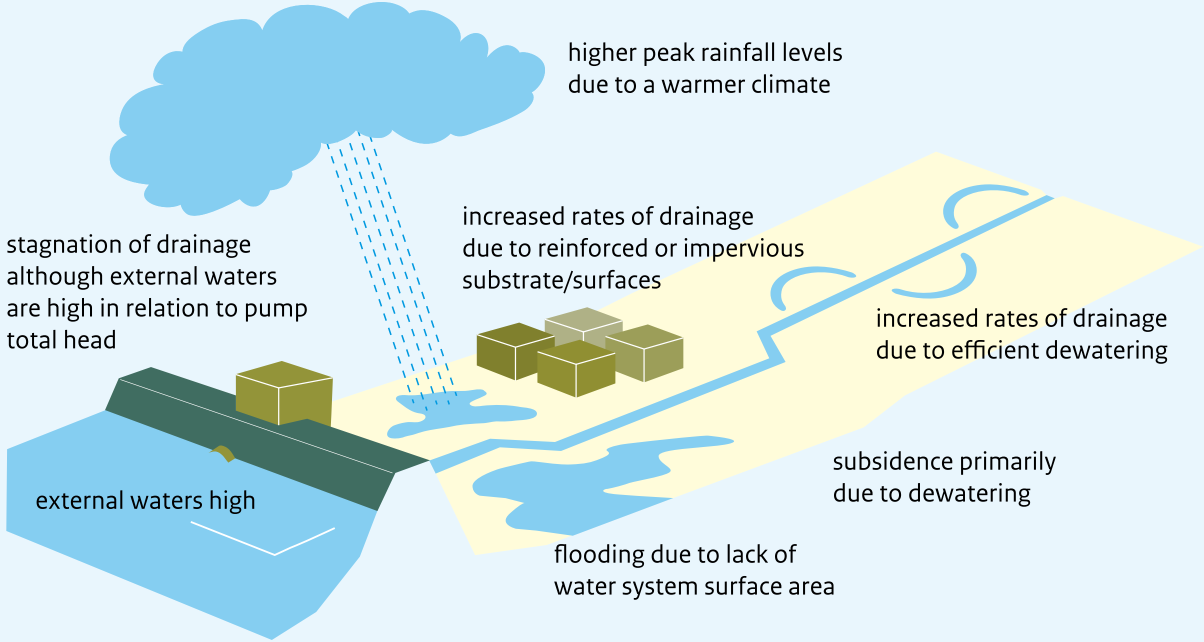
A basement full of water can be a hassle. And standing water in the road is bothersome. But the safety of the population at large is not at stake in either situation. Surface runoff flooding is a 'catch-all' term for situations in which problems caused by excessive amounts of water arise, without this threatening life. The water involved may come from above (precipitation) or from below (groundwater). The problems caused are usually transient, for instance in the wake of heavy rainfall. And this type of flooding is often local in nature.

Surface runoff flooding due to rain

Heavy, persistent precipitation usually falls between the months of September and March. That is also the time of year that the rivers are at their fullest. Problems caused by water from a combination of heavy rainfall and high water levels is felt most in low-lying areas. After all, that is the destination of the water, while the high levels make it difficult to pump the water away. That also applies to polders. In groundwater discharge areas the problem is amplified as in such places the water also seeps up from below ground. Even in summer extreme levels of rain can fall in a short period, leading to surface runoff flooding.

Surface runoff flooding due to groundwater levels

In areas with a high water table, surface runoff flooding can occur if there is insufficient drainage and water gets into crawl spaces or cellars and basements. A frequent problem is that seepage can occur spontaneously under houses. That is a problem that is difficult to solve except with drainage and, where possible, with pumps.



Comprehensive overview of the causes of surface runoff flooding.

4.2 What causes surface runoff flooding?

In regional bodies of water, surface runoff flooding occurs when the water systems have insufficient buffer capacity and/or discharge flow capacity, and watercourses burst their banks. In the main water system, surface runoff flooding occurs when national waters are insufficiently able to buffer or distribute the regional water discharge. National waters are often the last link in the discharge chain. They may not hinder water discharge from the regional systems that lie upstream. On the other hand, regional water managers should not pass on discharge problems to national waters. The agencies have confirmed agreements on this in water accords. National waters may cause surface runoff flooding in two ways. Directly, where the water overflows onto the wharf or quayside, and indirectly, where a high water level on national waters hinders discharge from regional waters. The causes of surface runoff flooding in polders, uplands, urban areas and unembanked alluvial land often differ greatly.

Polders

Surface runoff flooding can arise in polders due to:

- too little capacity in the water system. lack of buffer capacity for all the water.
- too small a pumping capacity to pump water to the storage basin. This causes problems where a lot of water has to be discharged and/or where the receiving body of water has a high water level, and the head of water increases.
- too rapid a discharge to the storage basin, so that the storage basin overflows.
- a high water level behind the dyke can cause extra seepage, leading to surface runoff flooding.

High ground

On higher ground surface runoff flooding can arise due to:

- backlog in the flow due to high downstream water levels or in receiving bodies of water.
- excessively rapid discharge, so that water levels in discharge flows arise. This rise in water levels is temporary, as the water then flows to lower-lying areas.

Urban areas

Surface runoff flooding due to rainfall arises primarily in towns or cities, or close to impervious surfaces. Nearly all the rainwater disappears down surface water drains there. That will generally be a 'mixed' drain (for both waste water and rainwater), although segregated sewerage systems that separate rainwater are gaining ground. In the event of heavy rainfall, the sewerage system may not be able to cope with the quantity of water, in which case it will overflow. In extreme situations, this leads to a layer of surface water on roads, or to basements and cellars being flooded. Mixed sewerage systems that overflow, moreover, present a threat to public health. Green or other, smart configuration of the surface of the built environment in urban areas can retain rainwater, or buffer it to lessen the strain on the sewerage system.

Measures such as these form part of the ‘urban planning adaptation’, with which the Netherlands aims to become more ‘climate proof'.

Unembanked alluvial land
Unembanked alluvial land is susceptible to surface runoff flooding when water levels rise. Surface runoff flooding in these areas is sometimes just a fact of life. If the main water system is unable to function without 'turning off the tap of the regional drainage system', surface runoff flooding may be the result. That may well prevent a less easily manageable flooding situation occurring in other places. Co-ordination and close co-operation between water managers is of great importance to this.

Increasing surface runoff flooding
Surface runoff flooding may increase due to:
- More frequent and more intense extreme precipitation as a result of climate change, which regional drainage systems are not designed to cope with.
- Higher water levels in external waters (river, sea), meaning that water from the hinterland cannot be drained quickly enough, or causes backflow.
- Changes to land use, meaning that space reserved for buffering water decreases, or discharge accelerates. Due to more intensive land use, increase of reinforced (non-permeable) surfaces and a smaller storage-basin capacity, leading to insufficient capacity to hold rain-water. Housing is sometimes built in areas that once served as a storage basin. In such conditions, even rewetting can result in damage.
- Subsidence. The ground level falls due to shrinkage, soil settling or oxidation of peatland, leading to groundwater rising more quickly to the surface, or to increased levels of seepage.

4.3 Surface runoff flooding policy

After heavy rainfall in 1998 in Delfland, the Noordoostpolder, Groningen and Drenthe, among other places, which caused more than € 400m worth of damage, the Commissie Waterbeheer 21e eeuw (Water Management in the 21st century committee) made recommendations aimed at better responding to situations of that kind. The Committee's motto was ‘retain, buffer, drain'. In consultation with the Association of Dutch Water Authorities and the Association of the Provinces of the Netherlands, the state initially drafted performance standards for the threat of surface runoff flooding. Based on these performance standards the National Administrative Agreement on Water (NBW; 2003) defined the parameters for realigning water management. The agreements reached were necessary to give a signal on the extent to which government could provide protection against surface runoff flooding. The standards for surface runoff flooding, introduced in the NBW, have been adopted, with the Water Act (2009), in the provincial water or environmental regulations. The Administrative Agreement on Water (2011) states that individual provinces must define the framework for preventing surface runoff flooding at regional level. The water authorities implement the measures, thereby adhering to the standards.

The Planning Adaptation Decision as part of the Delta Programme (see chapter 9) will, from 2020, encourage authorities, business and civil-society organisations to operate in a way that is climate-neutral and resilient in terms of water management. This is why the *Handreiking Ruimtelijke Adaptatie* (Planning Adaptation Guidelines), including the 'Ambition, Understanding, Working’ strategy was published in 2018. ‘Stress-testing' is part of the Understanding section of this strategy. Before 2023, local authorities and water authorities must implement a standardised stress test to assess preparedness to address surface runoff flooding. This will give the authorities, businesses and individuals a good understanding of the susceptibility of their environment to surface runoff flooding due to extreme rainfall.

5 Water shortages and drought

5.1 What is drought?

Even the Netherlands can succumb to a water shortage. Of freshwater, of course. Examples of this are the bone-dry summers of 1976, 2003, 2018, and the dry spring of 2006. Crops wilted in the fields, goods loaded onto vessels on inland waterways reduced the draught of the vessels making river transportation problematic, power stations could only take in limited amounts of cooling water and the natural environment dried up.

Drought is when there is a persistent shortage of water in a particular system, with all processes that depend on the water cycle suffering as a result. Drought can be seen in a lack of moisture in the root zone of the soil, low water levels in the rivers, insufficient water availability for cooling/intake and even dry river beds. In addition drought - due to a shortage of water to flush through a water system - may also lead to damage to agriculture as a result of salinisation. This will be addressed in the next chapter.

5.2 What causes a water shortage?

A shortage may be the result of a precipitation deficit, extensive evaporation and/or low volumes of water in river systems. But it can also be down to an absence of infrastructure to replenish the shortfall in precipitation. In isolated cases the cause can even be due to the available water not being distributed properly. And, finally, the water may be of poor quality: too saline (for irrigation), too hot (not suitable for cooling water) or have excessively-high concentrations of pollutants. But even when drought is not an issue, it is possible for a water shortage to arise. Simply because demand outstrips supply.

5.3 Who is affected by water shortages?

There are three categories of water shortage. The most frequent of these is a soil water deficit. In that case too little water is available for plants, so they grow less well. Also, a shortage of surface water may arise. The first action water managers take in such cases is to limit the use of water for irrigation and sluicing.
Where water levels drop, this may have an adverse effect on the stability of dykes, man-made structures and foundations. And it can cause peatland to oxidise. So maintaining water levels remains a priority. Thirdly, the quality of the available water may be insufficient. If not enough water at the right temperature and quality is available, power stations may not be able to take in cooling water, drinking-water companies may have to close their collection points and farmers and gardeners will not be able to irrigate their crops.

Water shortages can sometimes be very localised.
For instance, differences in water shortages in the earth can often be put down to meteorological conditions, the type of soil, the soil use, the management of surface-water levels and seepage. A shortage of surface water is usually caused by limited drainage from rivers or streams, large-scale evaporation and the limited opportunities for receiving freshwater. In the estuary region there is a direct link to external salinisation. A shortage of water can arise in almost any sector.

Agriculture

Water shortages lead to reduced productivity. The yield may turn out to be 5-10 per cent lower in an average year. But that does not necessarily imply that a loss will be made. In fact, scarcity can drive up prices. A substantial part of the reduced harvest due to water shortage is the result of the choice to prevent damage or loss due to surface runoff flooding. By opting for dewatering, farmers and market gardeners implicitly accept that they will occasionally lose some of their crop as a result of water shortages.

Inland shipping

When water levels are low, vessels can carry less cargo. These limitations come into play when the flow rate in the Rhine at Lobith falls below 1250 m^3/s. Vessels on the Meuse are faced with longer waiting times, and water is recycled after lock operations in order to maintain the water level.

Energy

In the summer months, generation of electricity is restricted from time to time as there is too little cooling water available. Of course, that is often more the result of the high temperature of the river water (making it unsuitable for use as cooling water) than low flow rates.

The dry regions and the characteristic problems they face

A schematic representation of priority sequencing

Nature

Choices made in terms of planning, and adjustments made to water management as a result, may lead to artificial situations that make the ecosystem susceptible to drought. And small-scale nature reserves and other areas, already suffering from the dry conditions, have even more to contend with as they have hardly any reserves on which they can call.

Drinking water

Even in dry periods the processing of drinking water is generally not endangered, as such water is generally stored in reservoirs. However, the drinking-water companies do ask their customers to be economical in their use of drinking water in dry periods.

5.4 Policy in periods of drought and water shortage

Sometimes a period of dry weather lasts so long that many functions are more or less affected. A choice will have to be made: who or what has priority in terms of the distribution of the scarce river water? Choices of this kind on the hierarchy of water distribution over the functions are governed by 'priority sequencing' (see figure on page 58). The priority sequencing hierarchy - enshrined in the Water Act - was drafted as a response to the exceptionally dry summer of 1976 and was updated after the summer of 2003, which was almost as dry. But regional considerations remain necessary.

In times of water scarcity, the flushing out of specific bodies of water is usually the first casualty. Then the target water levels for rivers, canals and inland ports fall (category 4). Should the volume of water fall further, then there will be no water for farmers and market gardeners growing capital-intensive crops and factories that need process water (category 3). Under such circumstances, the only water available is that for water treatment, power generation (category 2) and for all interested parties from the first category. Ultimately, only front-line interests remain: water safety and the prevention of irreversible damage to nature, such as the consolidation of soil or the disappearance of particular plants or animals.

5.5 Water quantity management

Management of water quantity by water managers focuses on reaching and maintaining, to the greatest extent possible, one or more water levels that are in line with the functions of the bodies of water in question (flood prevention, agriculture, inland shipping, nature). Proper flow and drainage of surface water prevents excess quantities and shortages.

Water quantity management in relation to bodies of water that are important at regional and local level is the responsibility of the water authorities. They configure the water system and ensure by carrying out regular maintenance, that flow rates are maintained, so that excess water can be discharged.

Haringvliet locks

6.1 What is salinisation?

salinisation occurs in two ways:

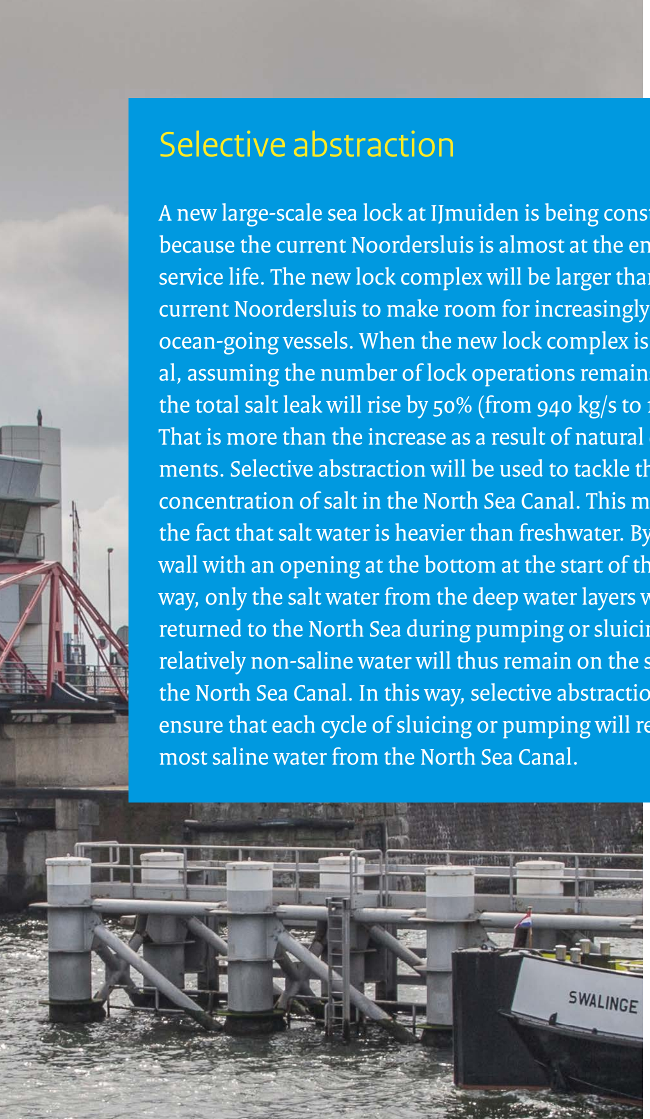
1. Salt, generally from the sea, penetrates into the system via the surface water - external salinisation.
2. As a result of groundwater flows caused by the difference in levels between the sea and lower-lying polders, salt rises as saline seepage - internal salinisation.

6.2 What causes salinisation?

'External' salinisation

There is one place in the Netherlands where salt and fresh water are still in communication with each other: at Hook of Holland. The extent to which sea water can penetrate the river system via the Nieuwe Waterweg depends on the relationship between river discharge and tidal levels Where there is average discharge from the Rhine, coupled with average tidal conditions at sea, saline accretion will reach the Willemsbrug in Rotterdam. However, if the water at sea is high and, at the same time, the Rhine is low, discharging lower levels of water than usual, the salt will penetrate further into the Rivierengebied.

The Haringvliet lock complex has an important role to play in tackling external salinisation via the Nieuwe Waterweg. By keeping the lock gates closed when flow rates in the Rhine system are low, even at low tide, all the water from the river system flows to the Nieuwe Waterweg. As long as water at a rate of at least 1500 m^3/s flows to the sea past Hook of Holland, the mouth of the Hollandsche IJssel will not salinate.



Selective abstraction

A new large-scale sea lock at IJmuiden is being constructed because the current Noordersluis is almost at the end of its service life. The new lock complex will be larger than the current Noordersluis to make room for increasingly large ocean-going vessels. When the new lock complex is operational, assuming the number of lock operations remains the same, the total salt leak will rise by 50% (from 940 kg/s to 1410 kg/s). That is more than the increase as a result of natural developments. Selective abstraction will be used to tackle the extra concentration of salt in the North Sea Canal. This makes use of the fact that salt water is heavier than freshwater. By erecting a wall with an opening at the bottom at the start of the sluiceway, only the salt water from the deep water layers will be returned to the North Sea during pumping or sluicing. The relatively non-saline water will thus remain on the surface in the North Sea Canal. In this way, selective abstraction will ensure that each cycle of sluicing or pumping will remove the most saline water from the North Sea Canal.

But it is not always possible to guarantee that minimum flow rate. Under certain circumstances external salinisation can even arise in the Haringvliet and the Hollandsch Diep, even when the Haringvliet lock complex gates are closed. Under those circumstances, salt penetrates 'through the back door': via the Nieuwe Waterweg, and then via the Spui and Dordtsche Kil. Reverse salinisation of this kind occurred in autumn/winter 2003 and 2006 when, at a time of low river system flow rates, the sea water was whipped up by a storm.

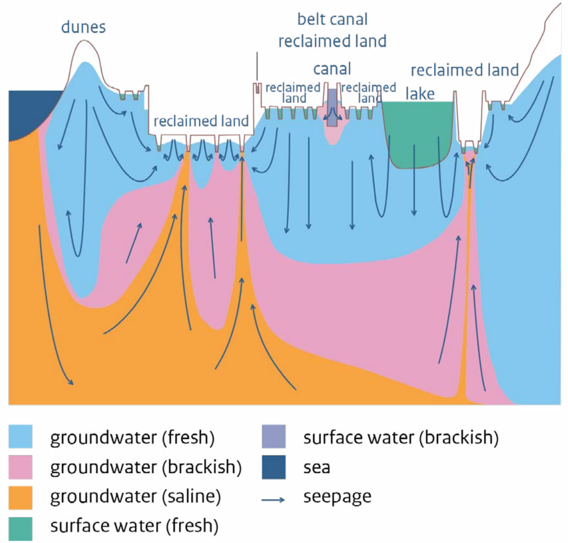
Reverse salinisation during the drought of 2003 (RWS-DZH, 2004).

External salinisation also arises in other parts of the water system, such as in the North Sea Canal and behind the Afsluitdijk. These are places where large quantities of salt water enter the system during sea lock operations.

'Internal' salinisation

In the larger part of the Netherlands deep groundwater contains brackish or saline water. Except for the coastline, this is water from the sea that remained in the substrate after the sea was forced back. This marine groundwater was originally relatively immobile, but land reclamation of various types caused it to start moving. Imbalanced layers of groundwater lead to strong inflows of saline groundwater. This form of salinisation is a process that can rarely be reversed. Even where sea levels do not rise, this process will continue for centuries. Rising sea levels and subsidence only accelerate the process. This phenomenon is at its most apparent in the west and north of the Netherlands. Further inland, the influence of rises in sea level has a less noticeable impact. For instance, internal salinisation can be seen in the Groot-Mijdrecht polder, in the province of Utrecht, without sea levels having an impact on the water system.

In lower-lying parts of the polders and other reclaimed land salt water can roil up and enter drainage ditches as seepage, as in the Haarlemmermeerpolder (see the figure opposite). Fresh water intake can be used to combat this sort of internal salinisation in polders. On the one hand, the water intake offers resistance to the saline seepage; on the other, it flushes out the watercourses. In this way the water in regional systems maintains a low saline content (chloride concentration). That does demand sufficient quantities of high-quality water in the main water system. During dry periods, however, flow rates in the rivers drop, leading to an increase in external salinisation and water that is not suitable for flushing out the system. Under such circumstances it is more difficult to manage internal salinisation.



The west of the Netherlands in cross-section. Sea water and deep brackish groundwater from the low-lying polders enter the surface water.

6.3 Who is affected by salinisation?

salinisation is only a problem if users are inconvenienced, or sustain damage or loss as a result of the chloride content of the water being above a specific concentration. salinisation in the mouth of the Hollandsche IJssel at Gouda, for instance, means that no more freshwater can be let in, so the west of the Netherlands would be at risk of damage or loss from drought and salt.

Agriculture
Salinisation is often a threat to agriculture in general. 'Traditional' agriculture generally benefits from water with a low chloride content. What a farmer or market gardener accepts depends on the crop grown. Fruit, for instance, is more sensitive to higher chloride contents than sugar beet or grain. Obviously, crops that grow in salty environments are very tolerant, but this is still a niche market. Within this sector there are opportunities for using brackish water, for instance for the production of protein-rich crops as an alternative for imported cattle fodder. In areas where salinisation is a problem, people are seeking alternative sources of freshwater and aiming to combat further salinisation.

Drinking water companies
Drinking water companies need water with a low chloride content to recuperate good-quality drinking water. Proper management of water resources and the best possible control of the water can prevent closure of water intake points due to salinisation. The number of intake points for surface water is restricted. If, during a period of dry weather, one or two have to be closed due to salinisation and an emergency situation arises, this can lead to problems for the drinking-water supply.

Electricity companies and industry
Power generators and other heavy industry are reliant on the availability of sufficient quantities of cooling water. Whether or not this needs to be fresh water depends on the choice of materials used. The design of systems and equipment usually assumes intake of freshwater. salinisation increases the cost of using process water, as extra measures are required.


Wieringermeer

7 Water quality

7.1 What is 'good-quality water'?

In general, freshwater can be said to be of better quality the fewer nutrients, toxins or salts it contains, so that it has no adverse effect on water-borne organisms or aquatic plants. It is also important for the water to be translucent, and a high oxygen content is also a good sign. The composition of water depends on where it comes from and the land use, soil type and groundwater flow (seepage/influent seepage) in the area from which the water originates. In addition, there is a close relationship between water quality and water quantity: pollution is less apparent if it is highly diluted.

7.2 What causes degradation of water quality?

Emissions and pollution from various sources are the most significant causes of poor water quality. The most pollutant substances are oxygen absorbents, heavy metals, nutrients and organic micro-pollutants such as solvents, pesticides, pharmaceutical products etc. Emissions directly into the surface water may come from businesses, households or urban areas. Indirect emissions are those made to a sewer system that is usually connected to a waste-water purification plant operated by one of the water authorities. In addition, a river may carry substances or nutrients, and pollutants may enter the surface water via rainfall and/or via flushing/rinsing from adjacent areas.

Bodies of standing water such as lakes, canals and drainage ditches are generally more sensitive to eutrophication than the flowing water of rivers and streams. In bodies of standing water it is primarily external forces, such as atmospheric precipitation, water from streams, pumping stations, rivers and waste-water discharge that determine the nutrient concentration. In rivers, although also in dammed inlets such as the IJsselmeer and Haringvliet, water from sources such as the larger rivers generally determines the concentration. The most significant source of emissions in streams in the sandy uplands is rinsing/flushing from agricultural land. As the flushing/rinsing depends on the water table and the extent to which the soil is saturated with water, the rainfall pattern also has an influence. And the season in which such emissions take place is also significant, along with the extent of drainage. Intensive drainage results in substances getting into the surface water more quickly.

7.3 Who is affected by degraded water quality?

Drinking-water companies, market gardeners, recreational users, the fishing fleet and the natural environment all thrive when there is a supply of good-quality water.
Each function to which water is put makes its own demands on the quality of water. The quality aspect almost always plays a role in the distribution of water.

The supply of freshwater is required to flush out nutrient-rich seepage from low-lying polders, and to address water depletion. But in nature areas - even where they are too dry - the only water that is acceptable is that which most closely approximates 'native' water. When water is drained from polders, nutrients and, more often than not, other chemical substances are carried by the water to the main system. That gives rise to extra quality-related problems for (primarily) bodies of standing water in the main system (IJsselmeer/Markermeer, Krammer/Volkerak and a number of canals). In low-lying parts of the Netherlands, too, complications can mount up due to the changing demand for water intake and water drainage where seepage pressure increases.
Pollution of the surface water threatens organisms. Humans, plants and animals suffer when water quality drops.

Eutrophication

Eutrophication, the enrichment of water with nutrients, may lead to algal bloom, water turbidity, large variations in oxygen content and fewer aquatic plants. In addition, it may create an unpleasant odour or colour, or cause an outbreak of botulism. This has an impact on nature, serious implications for recreational areas and bathing water, and demands investments and extra costs for collection of clean drinking water for human consumption.
Eutrophication occurs primarily in areas that are faced with a manure surplus. But eutrophication can also occur outside these areas. For instance due to flushing with water from a different, nutrient-rich area. Or where water is 'fed through' to replenish the buffer downstream. And the coastal zone as a whole is faced with eutrophication due to nutrients that flow through the river system. Eutrophication is a natural process, but excessive eutrophication is a problem.

Toxicity

Chemical substances may have any number of effects on water-borne organisms and aquatic plants in the surface water: restricted growth, endocrine-disrupting effects or the extinction of species. Birds and mammals face risks when eating aquatic organisms contaminated with such chemical substances. Such effects are not only caused by the presence of chemical substances. Hydromorphological factors may also have a role to play. Specific problems arise during times of peak load during emergency situations.

7.4 Water-quality policy and management of water quality

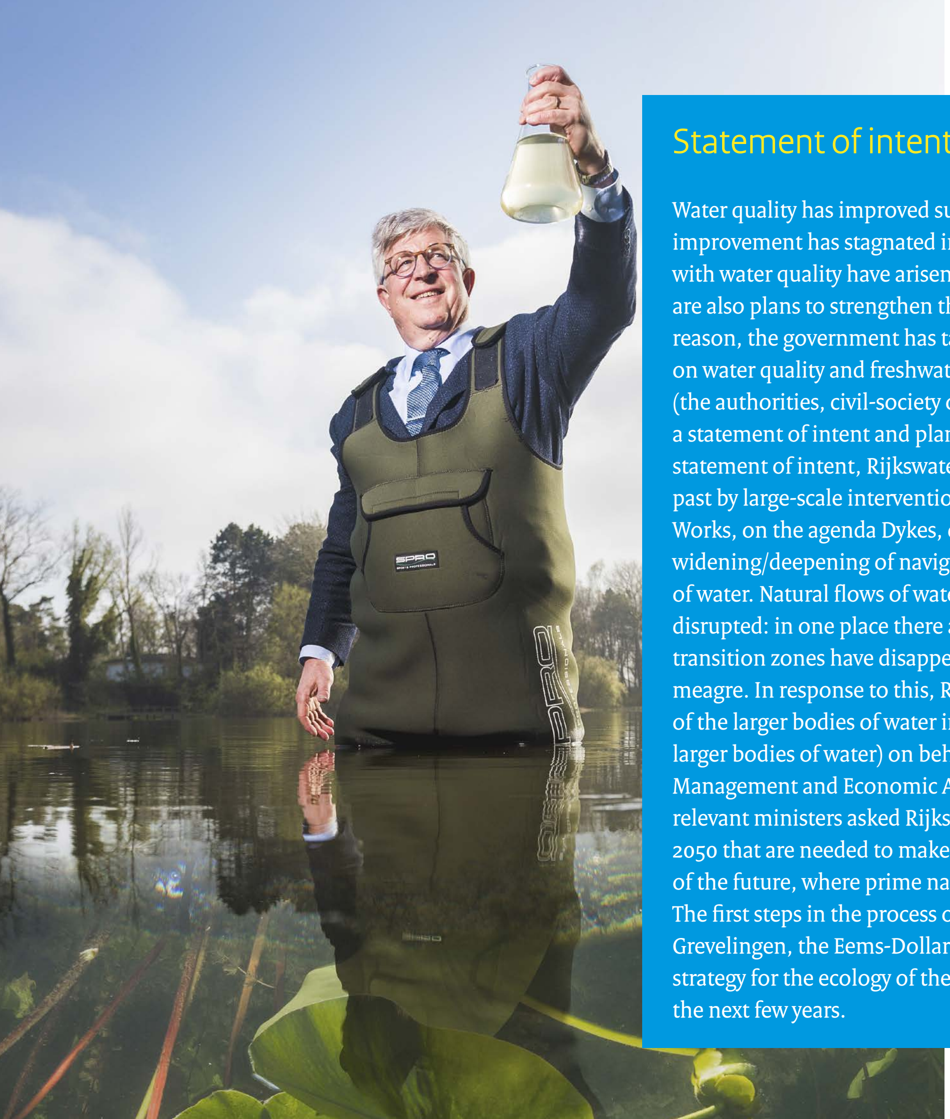
Within the European Union, the member states have committed to improving water quality under the terms of the Water Framework Directive (2000). An important target is achieving the ecological and chemical WFD objectives by 2027 at the latest. Extra efforts are needed to tackle new substances that affect water quality in terms of chemicals, such as drug residues and microplastics. The '*Delta-aanpak waterkwaliteit en zoetwater*' statement of intent on water quality and freshwater is aimed at driving authorities, businesses and civil-society organisations in the Netherlands to improve water quality. In this endeavour the priority of all concerned is on reducing the level of emissions of fertilizers, pesticides and medicines into water.

Eutrophication

At the end of 2017, the 6th Nitrates Directive Action Programme was set out. The effects of previous action programmes on nutrient content in groundwater and surface water are visible, but need time to work through the system in its entirety. The European Commission has accepted the Action Programme and has extended the permission granted to the Netherlands to allow higher amounts of fertilizer in specific areas.

Pesticide reduction plan

In the '*Gezonde Groei, Duurzame Oogst*' ('Healthy Growth, Sustainable Harvest', 2nd Memorandum on pesticides), the Dutch government included an implementation plan of measures for the period from 2013 - 2023 to substantially reduce emissions of pesticides. The overshoot in relation to the environmental quality standards for pesticides in surface water will have to be reduced by 50 per cent by 2018, and by 90 per cent by 2023. Comparable targets have been formulated for the overshoot in relation to the standard for surface water for water treatment (50% reduction by 2018 and 90% reduction by 2023).



Statement of intent on water quality and freshwater

Water quality has improved substantially over the past few decades, but this improvement has stagnated in the past few years. Furthermore, new problems with water quality have arisen, such as drug residues and microplastics. There are also plans to strengthen the link with the supply of freshwater. For that reason, the government has taken the initiative for the statement of intent on water quality and freshwater. At the end of 2016 all parties concerned (the authorities, civil-society organisations and research institutes) signed a statement of intent and plan of action to this end. In the context of the statement of intent, Rijkswaterstaat also put the economic issues caused in the past by large-scale interventions in the system, such as the Delta and Zuiderzee Works, on the agenda Dykes, dams, land reclamation schemes, weirs and widening/deepening of navigable waters have destabilised the larger bodies of water. Natural flows of water, sand, silt, salt and nutrients have been disrupted: in one place there are too many, while in another too few. Subtle transition zones have disappeared; the rich nature of the delta has become meagre. In response to this, Rijkswaterstaat has 'audited' the nature and ecology of the larger bodies of water in the Verkenning Grote Wateren (Survey of the larger bodies of water) on behalf of the Ministries of Infrastructure and Water Management and Economic Affairs. On that basis, at the start of 2018, the relevant ministers asked Rijkswaterstaat to take various steps between now and 2050 that are needed to make the larger bodies of water fit to face the challenges of the future, where prime natural sites are in step with a powerful economy. The first steps in the process of making this ambition reality will be taken in the Grevelingen, the Eems-Dollard, the Wadden Sea and the Markermeer. The strategy for the ecology of the larger bodies of water will be further shaped over the next few years.

Manufacturers of pesticides have drafted plans to reduce emissions for situations where there is a credible link between overshooting standards and use of a substance. From 2018, market gardeners have an obligation to purify discharge water.

Drug residue reduction approach

Drug residues in surface water have adverse effects on aquatic ecosystems. The Dutch government has opted to reduce the concentration of drug residues with a supply-chain-wide approach. The core assumption is stimulating a source-based approach at the start of the chain, with additional measures at the end of the chain (purification). Health-care institutions, which form a substantial source of drug residues, are currently engaged in making their operations more sustainable. Despite the focus on measures at source, further measures may also be required at water-purification plants. Research is needed to show the measures that will have the most effect, and how they can be funded. Together with the water authorities and the drinking-water companies, the government has reached agreement on the national chain-wide approach. One aspect of this approach is the acknowledgement of the urgency needed by all parties in the pharmaceutical products chain, and the charting of tasks and possible solutions in each phase (at source, when prescribing/use and waste stage). The national approach led to an implementation programme in 2018.

Waste water management

In total the water authorities manage around 360 wastewater purification plants with a capacity of 23m pollution units. On an annual basis they purify 2bn m³ of wastewater from households and businesses. The purification output is running at 93% for oxygen absorbents, 85% for nitrogen and 84% for phosphate. This is more than sufficient to meet the standards set out in the European Urban Waste Water Treatment Directive. The total bill for wastewater management amounts to around € 1.3bn. per year The producers of wastewater (households and businesses) pay that via the water-treatment levy.

The Energy Accord, to which the state and the water authorities are parties, enshrines a promise to continue the sustainability drive in wastewater management. By 2020, they want to be able to generate 40% of the energy they consume themselves. And they have the ambition of making the industry energy-neutral by 2025. That is why increasing numbers of wastewater purification plants are being converted into 'energy factories'. With nearly 100m m³ per year, the water authorities are already the largest producer of biogas in the Netherlands. The water authorities are reclaiming increasing quantities of valuable substances at wastewater purification plants, such as phosphates, cellulose and alginate from wastewater.

8 Future developments

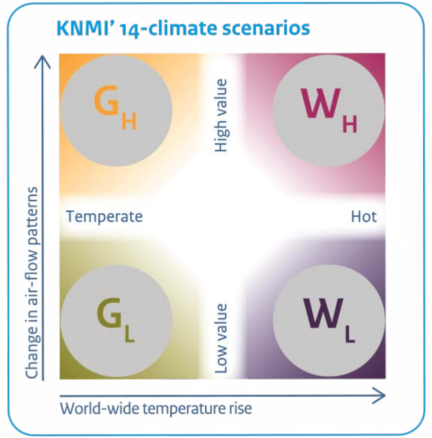
The Netherlands is becoming wetter and dryer, and salinity is on the increase. Sea levels are rising. Rainfall is sometimes on the increase, while often absent for long periods. And the land continues to sink, both due to geological influences and due to the actions of humans. Land use is also changing, the sectors in the economy are in a state of flux and society is making greater demands on water. This means that something will have to change in terms of water management and the use of water.

8.1 Physical and social changes

Climate

Since the start of the 20th century, average temperatures have risen by about 1°C. Humans are contributing to this rise. Burning fossil fuels, deforestation and certain industrial and agricultural processes have each contributed to a rise in the concentration of greenhouse gases in the atmosphere. Climate-modelling calculations indicate that the temperature might rise by 1.5°C - 4.5°C between 1990 and 2100. A rise of more than 2°C would probably result in large-scale changes, as sea levels would rise calamitously, there would be more frequent periods of drought and heatwaves, coupled with occasional periods of torrential rainfall.
There are many world-wide and regional models that attempt to predict these changes and chart them. The KNMI (Dutch meteorological office) then uses the results of these studies for the world-wide climate from the IPCC Report 2013 to determine what the effect will be for the Netherlands. The KNMI '14 climate scenarios for the Netherlands are based on perceived changes in the climate, recent calculations made with worldwide climate models for the IPCC and calculations with the climate model for Europe by the KNMI. The scenarios are emphatically neither predictions nor targets;

rather, they form what we might call the corners of the playing field of possible future developments in the Netherlands. The general picture presented by each of the four scenarios is that temperatures will continue to rise. The temperature continues to rise, while mild winters and hot summers are more frequent. Rainfall in winter will rise. Extremely intense rainfall all year round is set to increase in each of the scenarios, i.e. in summer as well as in winter. Even in scenarios in which summer precipitation falls.And as far as wind is concerned, it will continue to be as unpredictable as it is now. Sea levels will continue to rise, and the rate at which they rise will also increase. The rate of sea-level rise depends on the scenario.



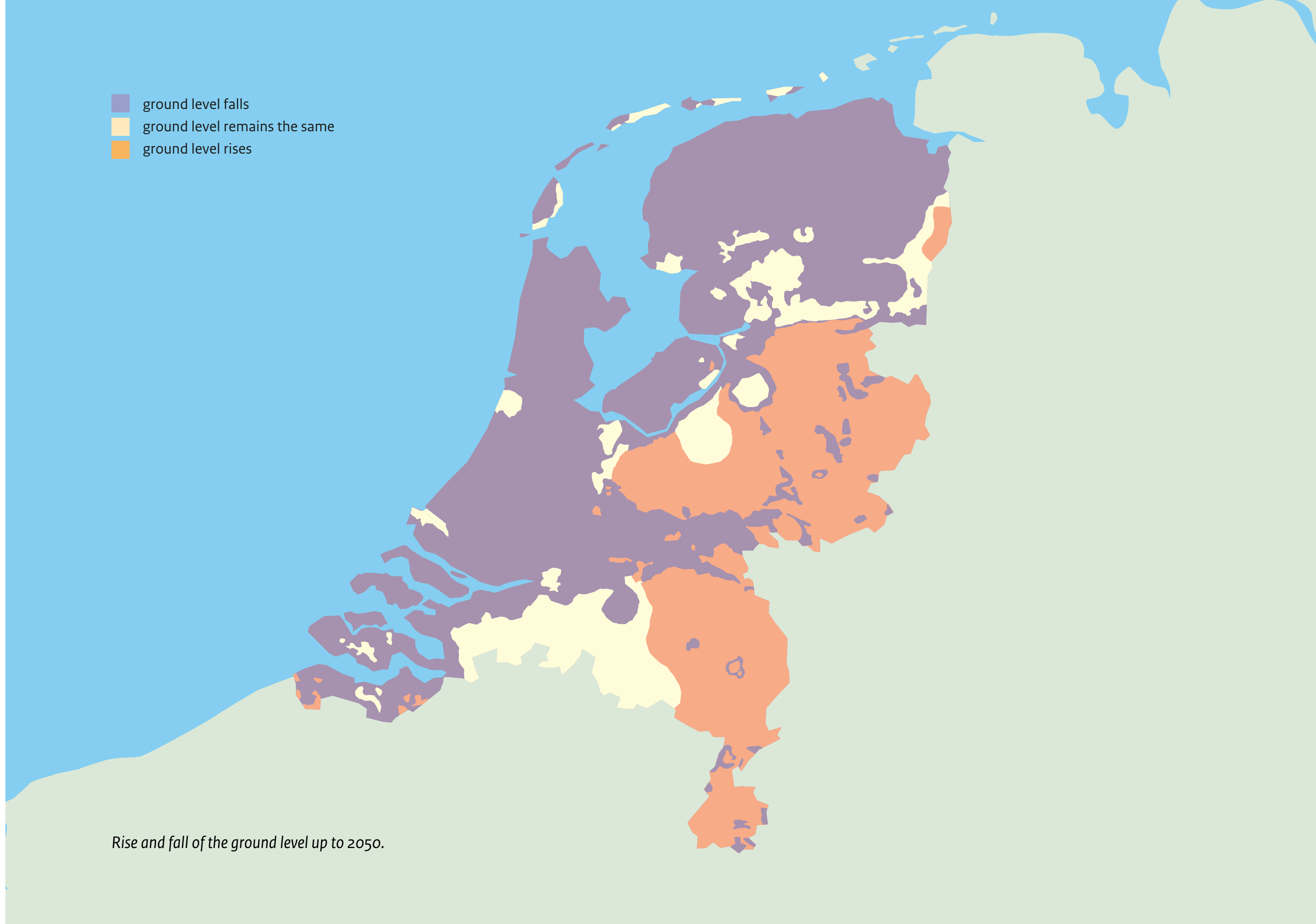
KNMI '14-climate scenarios

Subsidence and salt concentration

A large part of the low-lying parts of Netherlands is susceptible to subsidence as a result of subsidence, soil settling and oxidation of peatland. The greatest subsidence incidents are in the provinces of Groningen (due to extraction of natural gas) and Flevoland (soil settling). In contrast the south-east is rising slightly as a result of tectonic subduction. Salinity in the substrate of low-lying parts of the Netherlands is increasing. Three causes have been identified: a knock-on effect of earlier land reclamation, subsidence and the rise in sea levels. As a result of this, the rate of seepage of more saline water is rising. Expectations are that a significant increase will mainly be seen in the coastal areas of Zeeland, Friesland and Groningen, while some polders in Noord-Holland, Zuid-Holland and Flevoland will also face this phenomenon. In some smaller places, the salt concentration will decrease, as the larger rainfall excess counteracts the knock-on effect.

Economic and planning developments

In 2015 the Netherlands Bureau for Economic Policy Analysis (CPB) published new scenarios for Prosperity and the Living and Working Environment. These sketched the developments in the physical living and working environment for 2050, for the issues of regional development and urbanisation, mobility/transport, climate and energy, and agriculture. Two growth scenarios for this have been developed: High, with high population and economic growth, and Low, with a lower level of population growth and modest economic growth.



Rise and fall of the ground level up to 2050.

The scenarios sketch a population growth of over two million in the High scenario, with an ageing population. Growth of this kind is primarily in the Randstad area, and comes at the expense of areas suffering from depopulation, which generally have an ageing population. Economic growth is between 1% and 2%. The scenario is based on international climate targets. The agricultural sector remains the most significant, and largest land user in the Netherlands. There is a slight drop in surface area for land use of that type due to the spread of urban areas, plus more multi-functional land use, including space for nature. As with policy at national, provincial and sometimes even local level, European environmental regulations restrict the pressure on the environment. In both scenarios, emissions of ammonia, nitrous oxide, particulate matter and nitrogen oxides will fall in relation to 2013. However, the drop in the ‘High’ scenario is more significant than in the 'Low’ scenario. As far as phosphate and nitrate are concerned, however, their concentrations in areas with intensive agriculture will hardly fall at all. In the High scenario, consumers will more frequently be prepared to pay for other methods of production. This will lead to a slightly larger share for extensive farming. At local level this could have a positive effect on ecosystem services and water quality.

8.2 Consequences of climate change for management of water resources

Higher temperatures, wetter winters, more intense showers and dryer summers have implications for rising sea levels, river flow rates, the soil water deficit and salinisation.

Water flow in river systems

Each of the KNMI ‘14 scenarios assumes an increase in drainage from the Rhine system (15 - 30%) in winter and a decrease in summer (by up to 15%) by the year 2050. Peak discharge rates in winter will also rise, in the High scenario by around 5%. For the Meuse, the mean discharge in winter will also rise, between 10 and 25%. Peak discharge rates will also rise, in the High scenario by around 5 - 10%.
And as the Meuse has a much more variable discharge pattern with very low discharge in summer and autumn, most scenarios also assume lower discharge rates of up to more than 30% in the driest scenario. More water will have to be discharged in winter, while less water will be available in summer.

Soil water deficit and drought

Unless the air-flow patterns above Western Europe change substantially, the summer will see an average of a little more (3 - 8%) precipitation. However, if the east wind gains the upper hand rainfall could drop by 10 - 20% without any warning. Regardless of this, the likelihood of extreme drought increases because, as temperatures rise, more water will evaporate than will probably be replenished by extra precipitation. The impact of this on water management may thus change considerably: more rainfall in summer may lead to fewer water shortages, but higher temperatures may increase the likelihood of a water shortage.

Salinisation

The combination of the rise in sea levels and lower river flow rates in summer will lead to increased salinisation. Saline accretion will penetrate further inland, and the number of days on which freshwater inlets will be unusable will increase. Measures for inland shipping, such as deepening the channel in the Nieuwe Waterweg, increases in lock operations and new sea locks at IJmuiden will amplify this effect. At the same time, the quantity of water available to fight internal salinisation in the regional water system will fall.

Surface runoff flooding

The Netherlands will be confronted with extreme precipitation more frequently, long-lasting rainfall in the winter and short, sharp showers in summer. Extreme rainfall may lead to localised flooding. In contrast to drought, surface runoff flooding is often localised or confined to a single region, as rainfall can differ considerably from place to place.

Water safety

Climate change increases the threat posed by water, both from the sea and from the rivers. What all the scenarios show is that sea levels will continue to rise, while river flow rates increase. The only question is how quickly this happens. The KNMI climate scenarios assume a maximum sea-level rise of around 1 metre by the end of this century. But this appears to be a very cautious estimate. Rising sea levels and increasing discharge from rivers pose a greater challenge in respect of water safety. Doubly so for the areas where higher sea levels and greater river discharge coincide: the confluence of the Rhine and the Meuse in the southwest of the country and the confluence of the IJssel and the Vecht.

9

Towards a water management policy that can address climate change

Noord Brabant, Het Wild

In view of the changes we are faced with, we are unable to say whether the water system will still be fit for purpose in the future. As a result of climate change as outlined, together with socio-economic developments, protection against high water levels in densely-populated areas of the Netherlands is an issue that demands greater attention. The availability and quality of freshwater is also in decline, while there is increasing demand for water from population growth, increasing demands on the transport infrastructure and a range of water functions (agriculture, industry, drinking water, inland shipping, nature, recreation, water-level management and urban water). Increasing scarcity demands that choices relating to water distribution across the functions will have to be made time and again.

9.1 The Delta Programme

In September 2008 the Commissie Veerman (new Delta Committee) published the 'Samen werken met water' (Working together with water) report. This made twelve recommendations that were intended to tackle the threat posed by excess sea and river water, and to safeguard supplies of freshwater in the future. The most important recommendation was to draft a Delta Act. The Delta Act states that a new Delta Programme must be drawn up each year, that there must be a Delta Commissioner to co-ordinate the drafting and implementation of the Delta Programme, and that there should be a Delta Fund to help fund the Delta Programme. In 2015, the Delta Programme led to the five Delta Decisions adopted by parliament at the end of 2015.

Water Safety Decision

The Water Safety Decision addresses new standards for water safety. These new standards were drafted using the risk methodology: the standards relate not only to the risk of a flood event, but also to the consequences of a flood event. The magnitude of the consequences thus defines the parameters of the standard.
The new standards give everyone living in areas sheltered by dykes or dunes a basic level of protection of 1:100,000. That means that the risk of anyone dying as the result of flooding may not be more than once per 100,000 years. Where large groups are vulnerable to these risks or widespread damage could be caused by flooding, there is a higher level of protection. The presence of highly important 'vital' functions may be a reason for a higher level of protection. Flood defences that currently provide the required level of protection must be properly maintained. Where the flood defences need to be able to provide a greater level of protection dykes must be reinforced or rivers given more space to flow. For this purpose preferential strategies were devised and accompanying measures taken to achieve this for now and in the longer term. The preferential strategies form the basis for the new Water Safety Delta Plan implementation programme.

Freshwater Strategy Decision

Even now, there can be pinch-points in the supply of freshwater during dry periods. This will be a more frequent occurrence in future as the demand for freshwater increases and the climate changes. Increasing scarcity demands that choices relating to water distribution across the functions will have to be made time and again. In order to be able to justify these choices and the decisions for investment it is important for managers and other stakeholders to know where they stand. Part of the Freshwater Strategy Decision is thus that authorities and stakeholders can establish water availability in consultation, for 'normal' conditions and extreme drought conditions. Modifications to the main water system (the larger rivers, lakes and delta waters) and the regional water system (smaller rivers, canals and storage basins) are required in order to keep current water availability at a good level. Users of freshwater, too, will have to make a contribution, for instance by being more careful in their use of the available water. The measures are covered in the Freshwater Delta Plan.

IJsselmeer Area Decision

The IJsselmeer Area Decision deals with three strategic options: drainage to the Wadden Sea, the water level in the IJsselmeer, Markermeer and the peripheral lakes, and the supply of freshwater.
An important part of this decision is that the average winter water level in the IJsselmeer remains the same until 2050. The water is drained into the Wadden Sea. Where the sea level and weather permit, this is done by means of sluicing. Where sluicing is not an option, pumps may be used to guarantee sufficient drainage. In order to make this possible pumps will be built on the Afsluitdijk. After 2050, there will still be an option to raise the winter water level slightly, in line with sea levels (max. 10 - 30 cm), but only where to do so is necessary and cost-effective.
The IJsselmeer Area Decision also provides for more flexible management of the target levels. In that way it is possible for water managers to adapt to the expected weather conditions and create a larger supply of freshwater in summer. If the climate or the economy changes, the water availability and water use can change as well. It is important to keep supply and demand in a state of equilibrium. Flexible water-level management makes it possible to increase the freshwater buffer in the IJsselmeer area step by step and, at the same time, to economise on demand.

The first step to flexible water-level management means that the buffer of 20 cm in the IJsselmeer and Markermeer can be used in summer. Where the demand for freshwater increases, the buffer can be extended further, by 40 - 50 cm. In order to make flexible water-level management possible, alluvial areas will be given a flexible layout. After 2050, it may be desirable to allow more water to flow into the IJsselmeer via the IJssel in dry periods. Whether or not that is necessary depends on climate change.

Rhine-Meuse Decision

The Rhine-Meuse delta is the area where the rivers meet the sea: the area with the larger rivers, Rijnmond-Drechtsteden and the Southwest Delta. The foundations of water safety in the Rhine-Meuse delta are made up of the sandy seaboard, dykes, storm-surge barriers and sufficient space for rivers to flow. These foundations appear to be sound for the long term. Ingenious customised land use planning and adaptive delta management mean that the tasks can be tackled satisfactorily and in good time. In terms of water safety in this area how the water in the Rhine is distributed between the Waal, the Lower Rhine/Lek and the IJssel is highly significant. One aspect of the Rhine-Meuse Decision is thus that the existing agreements on the distribution of water discharge up to 2050 remain in place. Over the next few years a decision will be made on whether or not to keep the option to change the distribution of water discharge on the table for the period following 2050. This decision also covers the issue of there being no buffering of river water in the Grevelingen lake.
The decision proposes neither shutting off the Nieuwe Waterweg, nor building new flood defences at the confluence of the rivers. There is a proposal to build another closable 'open' storm-surge barrier after 2070, when the Maeslant barrier is scheduled to be replaced. The Ministry of Infrastructure and Water Management is looking into how the Maeslant barrier can make an even better contribution to safety in general up to 2070.

Planning Adaptation Decision

The Planning Adaptation Decision includes proposals to make land-use in the Netherlands as climate-neutral and resilient as possible in 2050. All authorities and parties in the marketplace have a joint responsibility for this.

To this end, the authorities have made the *Handreiking Ruimtelijke Adaptatie* (Planning Adaptation Guidelines) and a programme of incentives available. The state ensures that functions that are of great national importance or those that are very vulnerable will be more resistant to flooding by 2050 at the latest. This relates in particular to the power supply, telecoms and IT, wastewater processing, drinking water supplies, healthcare, pumping stations and sluices, road transport, and chemical companies and laboratories that use pathogens. Local authorities and water authorities carry out stress testing to get an understanding of susceptibility to surface runoff flooding, drought, heatwaves and widespread flooding. Moreover, it is becoming clearer how climate-related damage caused by the aspects referred to above can be prevented or, where this cannot be averted, kept to a minimum.

Sand Strategic Decision

The sand along the Dutch coastline is a natural form of protection against the sea. The Sand decision assumes that the sand balance on the coastline will be maintained, and that the coastal foundations will remain in a state of equilibrium with the rising sea levels. Where necessary, rainbowing can be used to bolster the sand. But rainbowing should not just be a means of maintaining the integrity of the coastline: where possible it should also boost local and regional targets for an economically viable and attractive coast.

There is a need for more knowledge on utilising the rainbowing process more effectively and cost-efficiently. This is why learning ‘on the job’ is an important part of the Sand Strategic Decision. That is done by implementing pilot projects, monitoring and investigating their progress and using the results to formulate new decisions.

9.2 The National Water Plan

The National Water Plan is the government-level plan for water policy and forms the framework for the regional water plans and management plans. A key assumption is 'sustainable water management'. That means ‘adapting to natural processes where possible, offering resistance where necessary and making use of opportunities for prosperity and well-being'. In order to achieve this, water must be more of a guiding factor in land-use developments. The National Water Plan 2016 - 2021 takes the policy set out in previous water plans and memoranda further. The outlines of the national water policy, the desired developments, the function and protection of water systems in the Netherlands, the measures and developments required, and the management plans for the catchment areas and areas susceptible to flooding cover these issues. In respect of land-use aspects, the National Water Plan is also a structural concept on the basis of the Dutch Planning Act. The Marine Strategy and North Sea Policy Memorandum also form part of the National Water Plan.

The Wadden Sea

9.3 Water-management plans

The way in which the water authorities and Rijkswaterstaat carry out their duties is primarily covered in the Water Act of 2009. That act specifies a number of obligations for them, such as drawing up a management plan and a land register. A management plan should include the programme of measures required for the development, function and protection of the water systems. In addition, the legislation provides them with a number of essential instruments, as far as water management is concerned, such as a permit system and general rules and regulations for all sorts of activities in and around water, obligations and authorisations in exceptional circumstances such as flooding or drought.

The Water Act will be incorporated into the Environment Act in 2021, along with 25 other acts. This does not alter the duties for which water managers are responsible, and the water authorities and the State remain responsible for water management and the granting of permits as appropriate. But the instruments that the Water Act uses will change. The regulations governing the water authorities (*Keur van de Waterschappen*), for instance, will become the *Waterschapsverordening* (regulations), and water-safety and water-quality standards will be transformed into 'environmental targets'. Furthermore, the Environmental Planning Act will create conditions for better collaboration in terms of topics such as climate change, housing construction and water-related issues that touch on these areas.

Management and Development Plan for National Waters 2016-2021 (BPRW)

The BPRW is a detailed interpretation of the National Water Plan. The BPRW describes how Rijkswaterstaat is going to administer the national waters between 2016 and 2021. A key starting point is the integral approach to the water system. The measures that are necessary for the targets in the Water Framework Directive, *Waterbeheer 21e eeuw* (Water Management in the 21st century), Natura 2000 and the development of the Water Safety and Freshwater Strategy Decisions under the Delta Programme were combined to achieve this. The BPRW was created by the Ministry of Infrastructure and Water Management.

Management Plan for the water authorities

The management plans for the water authorities constitute in-depth development of the regional water plans (of the individual provinces). The management plans set out the conditions and measures with which the objectives of the water plans can actually be achieved.
The water management plan for the water authorities is set out by the administrative body of the water authority in question.

9.4 Innovation

Innovative solutions are vital throughout the world if we are to be able to adapt to more complex challenges in a world of limited resources. Water is part of the fabric of global social issues, such as water safety, water quality, sanitation, food and power generation. With these issues, we have a continuous duty to seek smart, cost-effective solutions. This can be done with new technologies and insights, and with new forms of collaboration, in which authorities work with the market and research institutions at home and abroad. Joining forces like this in terms of knowledge and innovation makes the Netherlands as a whole stronger. The national Water and Climate knowledge and innovation programme, for example, envisages co-ordination and collaboration in fundamental research into practical applications, with the direct involvement of knowledge seekers and end users. The pooling of finances makes it easier to raise funds from institutions such as the EU, for instance. New methods of bolstering dykes and embankments, 'inland shores', the Nereda Technique of wastewater processing, capturing energy from tides, the collection and combination of data from multiple sources and the use of 3D technology to simulate flood situations are all examples of innovation. And the use of underwater drains also appears to be an innovative solution. In order to slow subsidence in peatland meadows, drains can be installed in agricultural land at approx. 10 - 20 cm below the water level of the drainage ditch. In that way, water from the drainage ditches is able to infiltrate the land via the drains in dry periods. Hence the water table will remain at the level of the water in the drainage ditch, and the soil will remain moist and anoxic. This slows the degradation of peatland. One condition for this is that water levels in the drainage ditches remain sufficiently high (which demands extra water), and that the drainage water can infiltrate into the peat soil.
Innovation is not an aim in and of itself, but a means to make water management better, smarter, more sustainable and keep it affordable. In urban areas in particular, where many challenges meet and many parties are involved, innovative solutions offer new opportunities for getting the water system working properly and utilising synergy.
Innovation is essential for putting the management tasks into practice in as sustainable and cost-effective a way as possible.

Ramspol inflatable dam

Emergencies and disasters come in all shapes and sizes. The most drastic emergencies are to do with water safety. But water shortages and water quality can also lead to emergencies with unpleasant consequences.
Where there are situations that could, potentially, present the threat of too little or too much water, the National Water-Distribution Co-ordination Committee (LCW) or the National Flooding Co-ordination Committee (LCO), as appropriate, takes action. In the event of large-scale water pollution due to discharge or spillage, the National Environmental Co-ordination Committee (LCM) takes action.
The National Co-ordination Committees can be found at the Netherlands Water Management Centre (WMCN) in Lelystad. This is the most important knowledge and information centre for water systems in the Netherlands. All water managers in the Netherlands work under the umbrella of the WMCN.

10.1 Flooding

Water managers oversee water safety by continuously monitoring water levels, waves, raising of water levels by the action of the wind and the strength of the dykes, and predicting trends in these factors. Where specific limits are exceeded, they raise the alarm. Where there is the potential for a crisis situation, the LCO drafts a national water policy based on information from water managers, the KNMI, the Waterkamer agency and the departmental crisis co-ordination team of the Ministry of Infrastructure and Water Management. The nationwide water picture/situation report is sent to the water managers and other interested parties. Furthermore, Rijkswaterstaat's chief engineer/director of Traffic and Water Management, in the capacity of national network manager, and the director general of Rijkswaterstaat are sent advice and recommendations.

Appropriately early alerting means that steps can be taken to avert surface runoff or widespread flooding, or to mitigate the damage. When alerting the population at large colour-coded warnings, such as those used by the KNMI, can clarify the threat posed by high water.
From the point of a 'yellow alert' the WMCN warns the water authorities, local authorities, Rijkswaterstaat and other interested parties. They then take steps, such as closing any openings in dykes, safety lock gates and some flood barriers, and the removal of cattle and vehicles from unembanked alluvial areas. At the level of a yellow alert there is not yet any imminent danger of flooding, but unembanked alluvial areas may experience consequences such as flooded wharves or quays, or flood plains. The WMCN sends advance warning to certain areas even before a yellow alert takes effect (e.g. Hollandsche IJssel flood barrier, the Oosterschelde flood barrier, the Ramspol inflatable dam).
From the point at which the alert level moves to orange, the steps taken become more intensive.
At that point the dykes are placed under surveillance (so that any potential weak spots can be rapidly repaired), the Maeslant flood barrier may have to close and, in more susceptible areas such as Kampereiland (near Kampen), preparatory protective measures for the flood barriers, such as sand bags, are put in place. Should the alert level rise to red, this means that there is imminent danger of flooding and the role of the 'security regions' (regionally co-ordinated emergency-response teams) becomes more prominent. If the situation is serious enough, they may make the decision to evacuate the local population.
A yellow alert may, depending on the area, be an annual event and an orange alert once every five years; a red alert, however, is a rare occurrence. These are situations such as 1953 in the southwest of the Netherlands, or 1993 and 1995 along the course of the Meuse and Rhine. The flood barriers have been strengthened to the extent that the risk of this sort of situation leading to flooding is very low.
Although the risk of a flood event is very low, the policy of the Ministry of Infrastructure and Water Management focuses on increasing the awareness of the public at large to the potential threat. The decision to evacuate an area depends not least on how the local population responds.
If the local population is well-prepared and aware of the potential threat, there is a greater chance of success. In the event of 'vertical evacuation' (seeking higher ground without leaving the area) people will, ideally, have emergency kits ready and waiting. In the event of 'horizontal evacuation' (leaving the area) the escape route should be known in advance and people should have an idea of the duration of the evacuation.

10.2 Water shortages

As with high water situations, it is advisable to take appropriate measures in good time in the event of water shortages. However, people have more time to prepare for a water shortage as water shortages tend to take time to develop. Where there is the threat of water shortages water managers first need to take minor measures such as water-saving during lock operations (as many vessels as possible per gate opening), recycling lock water and providing extra water from the larger rivers through pumping stations. The measures are governed by 'priority sequencing' (see the figure on page 58).
The WMCN oversees the drought situation in summer.
Forecasts of water levels, drainage and precipitation are important in this respect. Where there is a potential risk of water shortages, the LCW takes action. Where a dry period or period of low river flow rates persists and demand for water exceeds supply, the WMCN administers the 'drought monitor'. This describes the situation, the forecasts and steps taken.

10.3 Pollutants

The LCM gives advice and recommendations on what to do in the event of pollutants being released into the surface water for the Netherlands, the North Sea and the Dutch Caribbean islands. To this end, experts are available round the clock to provide advice on environmental chemistry, ecotoxicology, and nuclear/radiation issues. Where necessary they deploy extra experts to assist lab technicians to test samples. Models can be made to show and predict the spread of substances hazardous to the environment, such as oil, in surface water, to make it possible to calculate the duration of waves of pollution.

Administrative Accord on Water
An accord reached by the Dutch government, the provincial authorities, the IPO, the *Vereniging van Nederlandse Gemeenten* (Association of Dutch Local Authorities) and the Association of Dutch Water Authorities with the aim of getting the water systems up to par in 2015 (and keeping them at that level) in advance of changing conditions, such as expected climate change, a rise in sea levels, soil subsidence and an increase in paved surfaces.

Catchment area
An area from which all the water that runs over the surface flows to the sea through an interconnected network of streams, rivers and, possibly, lakes through a single river outlet, estuary or delta.

Closing a sluice gate
Closing a sluice gate to such extent that it stops the water from flowing downstream.

Dewatering
The removal of water over and through the ground, and through the network of watercourses.

Downstream
Downriver.

Eutrophication
Regular growth and bloom of certain species (of algae) as a result of the supply of nutrients to the water.

Evaporation
The part of the water cycle in which water in liquid or solid form is transformed into water vapour.

External waters
Water from a body of surface water where the water level is directly impacted by a storm surge, under excessively high flow rates in one of the larger river systems, at high tide in the IJsselmeer or Markermeer, or a combination of the above.

KNMI'14
The KNMI '14 climate scenarios for the Netherlands are based on perceived changes in the climate, calculations made with worldwide climate models (IPCC) and calculations with the climate model for Europe used by the KNMI (Dutch meteorological office), with baseline date 2014.

KWA
Climate-resistant water sourcing (formerly Small-scale Water Distribution measures), a mechanism in which freshwater is diverted to the west of the Netherlands due to excessively dry conditions in the Rhine basin.

Maaswerken
Implementation programme for the 'undyked' section of the Meuse carried out by the Ministry of Infrastructure and Water Management, aimed at flood protection in 2015, nature development, improvement of the shipping channel and mineral extraction.

Main water system
The main water system covers all bodies of water (salt water and freshwater, i.e. rivers, lakes, canals, the Wadden Sea and North Sea) managed by Rijkswaterstaat.

Management of water resources
The way in which water in a specific area moves, is absorbed, used or consumed and discharged. In the vast majority of cases human intervention has an impact on this.

Management plan
The plan outlining the various activities and measures administered by the manager of a flood defence or a water system.

NAP
Mean sea level at Amsterdam under normal circumstances. The reference datum or baseline relating to the water level in the Netherlands.

Natura 2000
The umbrella term for the network of European nature areas, referred to in the context of the Habitats Directive.

Nereda Technique
A waste water-treatment technology that uses bacteria to aerobically form granules that quickly form a sediment.

Net precipitation
The difference between precipitation and measured evaporation.

Primary flood defence system
A flood defence that offers protection against flooding from external waters.

Regional flood defence system
A flood defence that offers protection against regional bodies of water. These are found within a dyked area and prevent the water from spreading after flooding within the dyked area. There are also a few regional defences that are positioned ahead of a dyked area and protect unembanked alluvial areas.

Regulations
Regulations governing how water authorities operate when protecting flood defences, watercourses and associated civil-engineering works.

Reverse salinisation
Where high water levels at sea coincide with low water flow in river systems there is a danger of saline sediment accretion from the Nieuwe Waterweg right through to the Haringvliet and Hollandsch Diep. This is known as reverse salinisation.

Room for the River
Ministry of Infrastructure and Water Management implementation programme with the aim of creating space for the larger rivers, so that water flow can be guaranteed even when river-system flow rates are particularly high.

Saline sediment accretion
A stretched substrate of saline water in a watercourse.

Salinisation
An increase in the salinity of surface water or in the salinity of soil.

Salinity gradient
The difference in salinity measured across a specific distance.

Seepage
The escape of groundwater (under the influence of substantial infiltration outside the area under review).

Sluicing
Removal of poor-quality water by means of a controlled extra discharge in a watercourse.

Sluicing under the influence of gravity
The water is discharged under the influence of gravitational force.

Storage basin
The system of watercourses and lakes in open contact with each other where water from lower-lying polders is released. The storage basin may also be used for temporary storage of water to be discharged to external waters.

Subsidence
Sinking of the surface due to compaction, shrinkage, building of structures or construction of an embankment.

Water Accord
A voluntary instrument in which parties to the instrument confirm agreements on water outside the remit of individual management areas. The emphasis here is specifically on the quantity of water, but the issues on which agreement is reached may also cover water quality and ecology, the protection of areas against flooding and the protection of areas against surface runoff flooding or drought.

Water depletion (dehydrated areas)
All adverse effects in designated nature areas that are the result of poor water resources development, such as a drop in the water level (water table), soil water deficit, mineralisation, change in the impact of seepage and the intake of water from outside the system.

Water Framework Directive
European directive with the aim of improving the ecological and chemical quality of water.

Water management
A complex of research, planning, civil-engineering works and administrative measures aimed at creating as effective an integral management plan as possible in relation to the groundwater and surface water in question.

Water system
A water system is a geographically delineated body of surface water, including the groundwater with which it is connected, the ground and the banks or shore. This also includes the communities that live in the water system and all associated physical, chemical and biological processes, plus the interaction with the atmosphere.

Waterbeheer 21e eeuw
At the end of the 1990s, the *Commissie Waterbeheer 21e eeuw* (Water Management in the 21st century committee) ascertained that the system of water management was not able to respond to future developments. In the Anders omgaan met water policy memorandum (2000), the government suggested that a transition was needed, in which water was given more room rather than less. The new strategy was one of retaining, storing and discharging water. This policy was given shape as the Maaswerken and Room for the River projects.

Weir
Fixed or moving structure that serves to increase or regulate water levels upstream of the structure.

Paterswoldesemeer

Colofon

‘Water Management in the Netherlands’ is published by Rijkswaterstaat and the Association of Dutch Water Authorities.

This booklet is an update of the 2009 edition.

The Digital version can be obtained from Helpdesk Water
www.helpdeskwater.nl/watermanagement

For questions or further information, please contact Helpdesk Water, helpdeskwater@rws.nl.

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