

PUMP OR DROWN

THE WATER-LOGGED HISTORY OF HOLLAND

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Pre-print by A.A. Verveen.

The layout, hence, differs from that of the printed text.

The contents are, however, equal to those of the published paper and may not be
changed. One writing error was corrected (fig. 11 subscript: 1745 instead of 1974).

See my signature below.

Pump or drown

The waterlogged history of Holland

A.A. Verveen¹

The part of Netherlands that borders the North Sea also lies below sea level (figure 1a). During a long-duration north-westerly storm –the prevailing wind in winter– Great Britain and Scandinavia function as the barrel of a gun and funnel water from the Atlantic and the North Sea onto the Dutch coast (figure 2). A probable future is sketched in figure 1b with 50 percent of our country

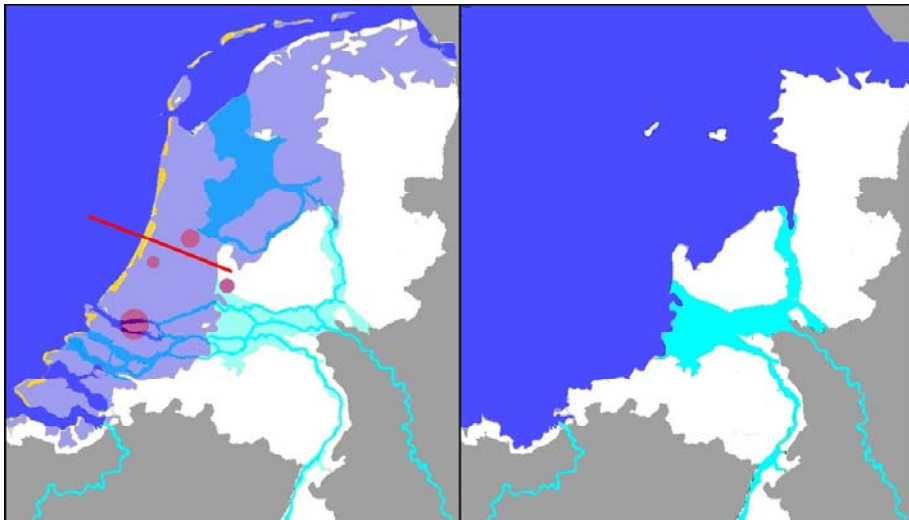


Figure 1a. A country at risk Figure 1b. The probable future
 Dark blue: North Sea, purple: land below sea level, lighter blue colours: fresh water lake and rivers, yellow: dunes, white: sand, grey: other countries
 Filled circles: the cities of Amsterdam (above), Leiden (left), Utrecht (right) and Rotterdam (below)
 Line: position of cross-section

permanently drowned by the sea. The sandy islands ringing the coast will be washed away by the strong sea current. Another 16 percent of the country may then be temporarily flooded when the dikes along the rivers fail after an exceptionally heavy rainfall of long duration in Western Europe.

Our perilous situation is unique in the world. Its daily consequences are relevant for every Dutchman, since there is no natural way for rain and seepage water to drain out of this large sink. Our water boards have to pump the excess water into the sea, day in day out. Most of us Dutchman take it for granted, however. Many not even know it, although each household pays the yearly tax levied by its district water board.

How did this risky situation come about and how do the Dutch cope?

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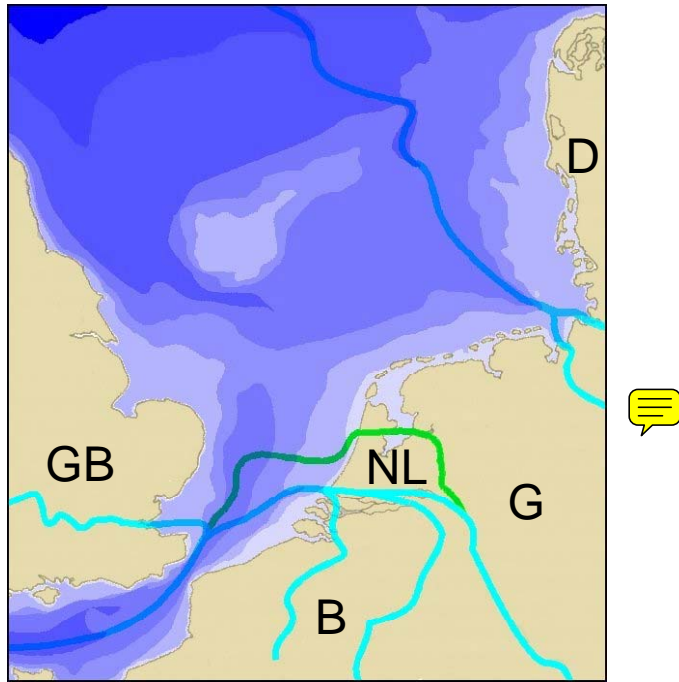


Figure 2. Formation of the North Sea
 B: Belgium, D: Denmark, G: Germany, GB: Great Britain and NL: the Netherlands. Green: an older branch of the Rhine River
 Contours sketched in part after Zagwijn, 1991

During the period of the Ice Ages (the Pleistocene) the Rhine River deposited a thick layer of sand on the Netherlands and its surroundings. This layer still extends far into the North Sea. Its surface slopes down towards the North and the West. After the last Ice Age the melting ice caps caused the sea to rise again.

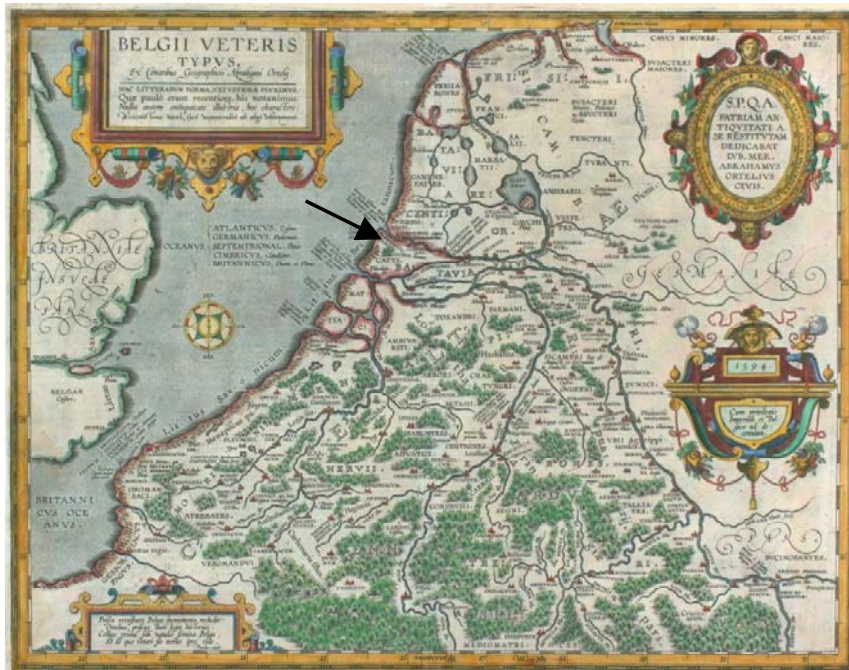


Figure 3. The Netherlands at the beginning of our era
 The arrow indicates the Roman fortification at Katwijk
 Coastal erosion left it on today's North Sea bottom
 Drawn by the author on a historical map by Ortelius from 1594

Between the year –10.000 and today the sea level increased by 55 m up to its present level (figure 2).

A strong tidal current runs in north-easterly direction along the sandy coast and erodes its eastern part. Some sand was blown onto the land, which created the coastal dunes. The remainder was and is carried forward to form “eastward walking” sandy islands, much like the whirls of smoke flowing out of a pipe. Between those islands and the coast many mudflats were (and are still) formed: the so-called Wads. At about the year zero the coast was nearly closed (figures 3 and 6a). Today the coastline has retracted several km due to erosion by the tidal current. To counteract the erosion we need to supply our coast each winter season with several million m³ of sand.

Behind the dunes and along the mudflats the rivers and the rain formed a swamp in which peat formation occurred. This wetland of peat bogs, mudflats and changing islands gradually became the home of the Friesians (figure 4), a Teutonic tribe which emigrated from Scandinavia several centuries before the beginning of the western calendar.

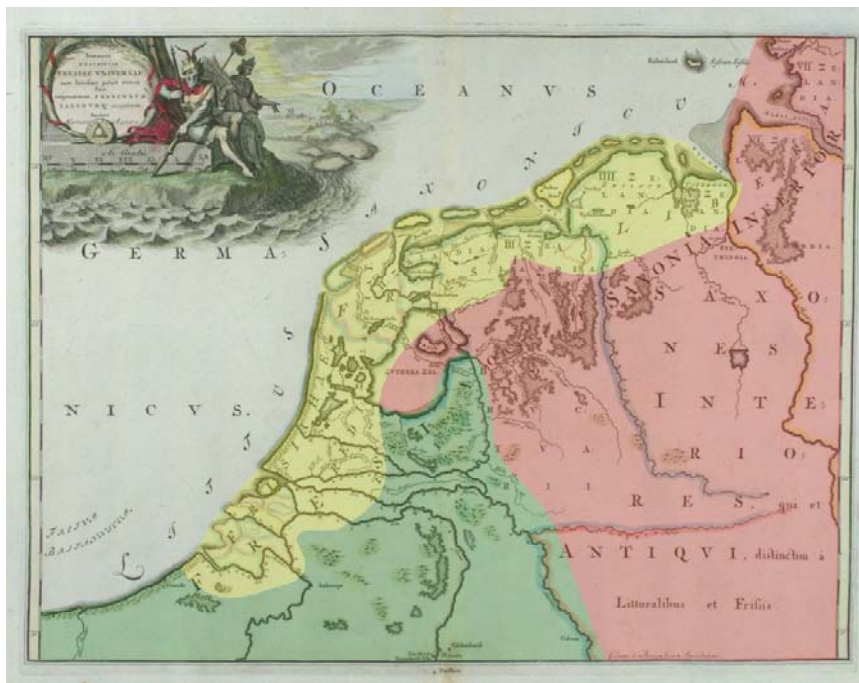


Figure 4. The Netherlands during the reign of Charlemagne
Distribution of the three tribes:

yellow: Friesians, green: Franks, red: Saxons

Coloured by the author on a historical map by Altling from ca. 1700

After the decline of the Roman Empire another Teutonic (i.e. German) tribe, the Franks (“Braves”), migrated into France. Their influence extended into the southern part of the Netherlands (figure 4). A third tribe, the Saxons (“Sword-carriers”) spread into present Germany and occupied the eastern part of the

Netherlands. The Frankish emperor Charlemagne (768-814) instituted the first feudal estates, many of which became future (mini-) states and are still present as provinces. The Friesians, however, always strove to maintain their independence, also among each other. Their kings were generals, chosen only when necessary and then for a limited period only on meetings called Dings or Things, a democratic structure, which survived in Iceland. Although the Friesian “farmer republics” became in later times restricted to the northern part of the Netherlands, the “federal peer democratic” nature remained the way of life within the coastal region. The Friesians were fisherman and traders. They dominated transit trade by ship in north-west Europe in the period between the decline of the Roman Empire until the raids by the Norman (Vikings), i.e. from about 450 to about 850 A.D. The Friesians exported leather and skins from cattle they raised on the mudflats in the north, and salt. In the south-west they mined salty peat which they burned to cook seawater in which they mixed the ashes. The sea replaced the mined flats as a result. Storm surges confounded this situation. This led to our first large-scale ecological disaster: the nearly complete loss to the sea of the present-day province of Zeeland (“Sea-land”, figure 7) between the years 0 and 1500 (cf. the lower left corners in figure 5a-c). Their total export of salt is estimated at 60 billion kg, an average of 40 million kg per year during a period of 1500 years!

Reclamation started at about 1100 A.D. Much land though not all was regained by the erection of “offensive” dikes around newly deposited mudflats in the region (figure 6c and d). Hence the national motto of the people of Zeeland: “Luctor et Emergo” i.e. “I struggle and emerge (out of the water)”.

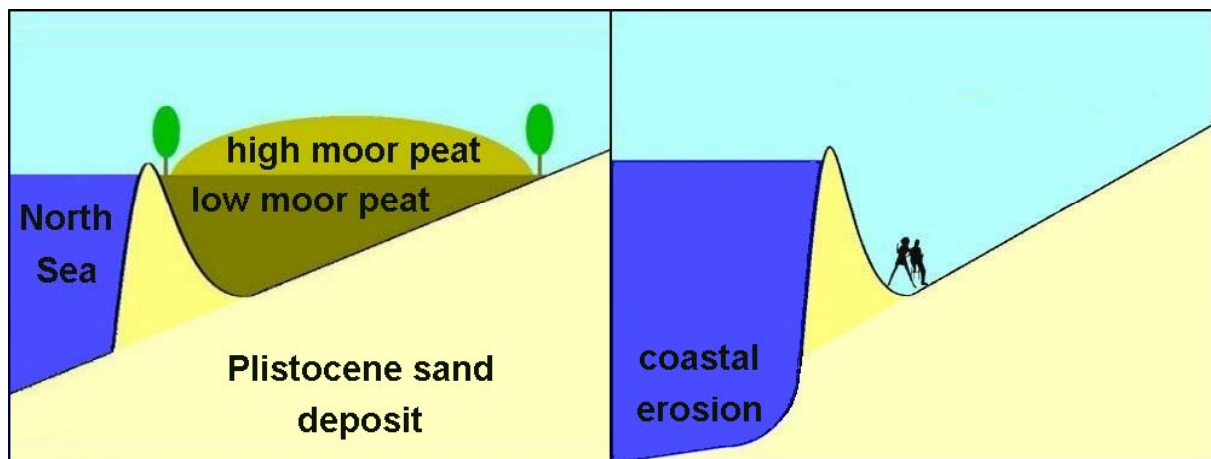


Figure 5. Simplified cross-section through Holland (see figure 1) at A.D. 0 (left) and today (right, with coastal erosion en new dune formation)
Dimensions: left to right (West to East) 100 km, vertical 20 m

Another ecological disaster was in the making when the coastal inhabitants developed the peat bogs (figure 5) for agriculture. Peat consists of a compressed layer of the remnants of plants that grew in the shallow lakes behind the dunes. Since the remnants are submerged in water that is oxygen depleted no further breakdown occurs and thick packets of dense “low moor” peat are the result.

When the packet rises above groundwater level only one single plant species - Sphagnum - is able to grow on it. This moss absorbs and grows on rainwater only. Its remnants also form peat, now drenched in oxygen depleted rainwater. As a result the top of the swamp may reach a height of several meters above the groundwater, hence sea-, level. This so-called high moor peat lacks nutrients and forms a prime-quality fuel with a quite low ash content.

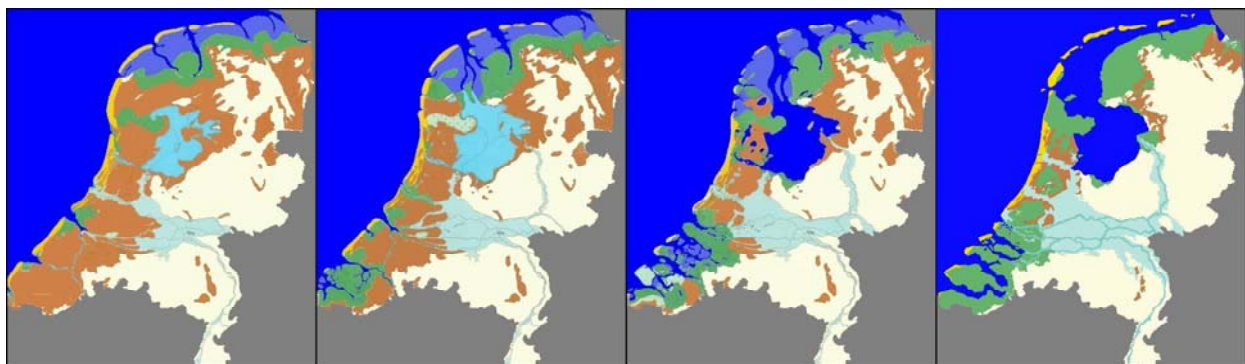
The peat was too wet for agriculture, so from about 800 A.D. on the farmers dug ditches to drain the land, as well as quays to prevent inflow of water from higher parts of the peat bog. This worked quite well, but generated serious side effects. Subsidence occurred because the water leaked away. The drainage also allowed the entrance of air into the peat soil. Since air contains oxygen the peat slowly decomposed into water and carbon dioxide and disappeared. Subsidence increased even more and the level of the soil gradually approached the new groundwater level. The ditches were, hence, dug out even more and the cycle repeated itself. The average level of the peat bogs ultimately came down to average sea level, which made natural drainage impossible, while storm surges started to cause the sea to occasionally flow over the land. From 1000 A.D. on so-called “defensive” dikes were built to stem the sea, for seawater poisons the soil. In our country it takes about ten years of rain to wash the salts away.

The gradual increase of sea level and the sinking of our part of the continental plate, though both are not noticeable within a single decade aggravate our situation. From 1100 A.D. on dams with self-regulating sluices that closed at high tide and opened at low tide were built in the natural outlets to the sea. Cities arose around these dams and were called after it. Amsterdam and Rotterdam, for instance, are contractions from the original (modern American usage-like) names [Amstel-Re-Dam and Rotte-Re-Dam, respectively, meaning Amstel- and Rotte-River-Dam.



Each area enclosed by dikes in which the water level was regulated became know as a “polder”. The participants, the farmers and when present, representatives of the city voted their delegates into the polder board. The size of the vote and the corresponding tax levied by the board depended upon size and value of the protected property. Conflicting interests between different polders necessitated co-operation on a larger scale. This led to the formation of larger water boards. The water boards regulated the water level in the widely branched reservoir into which the individual polders drained and kept the offensive dikes against the sea and along the large rivers in good condition. Members of a water board were voted and taxed by the much larger number of participants according to the same rules. Polder and water boards, still very much in action today, hence form our oldest democratic institutions.

A legendary (?) farmer lived at about 900 A.D. on a farm he called “Hol(t)land” situated north of today’s city of Leiden (cf. figure 1). He and his successors became the self-made Counts of Holland. They carved this state, Holland, out of the larger feudal estate of Utrecht (cf. figure 1). The name Holland means either woodland or hollow land, where “hollow” probably describes the uneven surface of the original moorland. These also literally borderline counts kept the welfare of the local population at heart, in contrast with the attitude of the “continental” nobility, who even murdered one of the Counts of Holland because of his attitude. In 1018 the Counts learned that the swamps were valuable in defence. The farmers of Count Dirk III of Holland won a pitched battle against Lorraine, for the heavily armoured knights got bogged down in the mud.



6a. 100 AD

6b. 600 AD

6c. 1200 AD

6d. 1900 AD

Figure 6. Simplified description of the development of the Netherlands
 Dark blue: sea and (lighter) wads, green: mudflats, brown: peat bogs, light blue: freshwater lake,
 greyish blue: river beds, white: sand

Drawn after Zagwiin, 1991 (a-c) and De Grote Bosatlas, 1995 (d)

Between 1162 and 1248 several heavy storm surges made the sea cut through the northern islands and wads and transformed the central Lake Almere (figures 6a and b) into a dangerous estuary, the Zuiderzee (“Southern Sea”, figure 6c and d). This extended the coastal area. Several inland states also became coastal

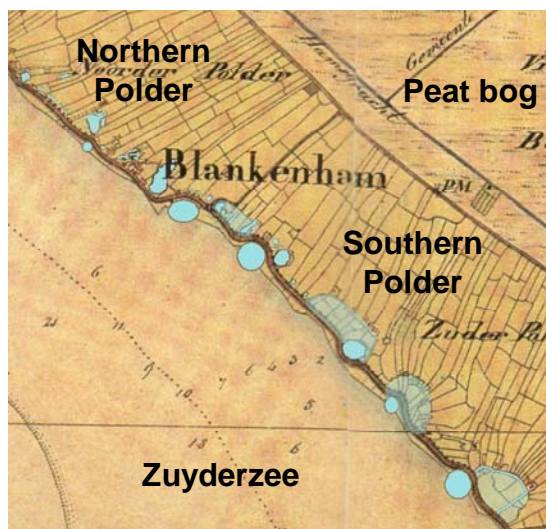


Figure 7

A 4.5 km long stretch of coastline along the western border of the Zuiderzee
 The flow through the dike bursts cut out pools coloured light blue by the author. They were deep so the new dike was laid along one side. Seaside pools (sketched) were quickly filled up with sand and disappeared. Those on the landside took much longer to be filled (transparent colour) and are still visible because of their ditch structure and their lower level. Recent pools are still present today.

Detail from the military map of 1852
 (Courtesy Wolters-Noordhoff bv, 1990)

ones (cf. figure 10). Since the Zuyderzee also acted as a second catching basin for the input of seawater during north-western storm surges, additional dike bursts and inundations became our fate (figures 7 and 13).

The whole western part of the Netherlands was broken into a series of islands (details not visible in figure 6), either bordered by the sea (West Friesland and Zeeland, figure 6) or by both sea and rivers (central part, the original state of Holland).

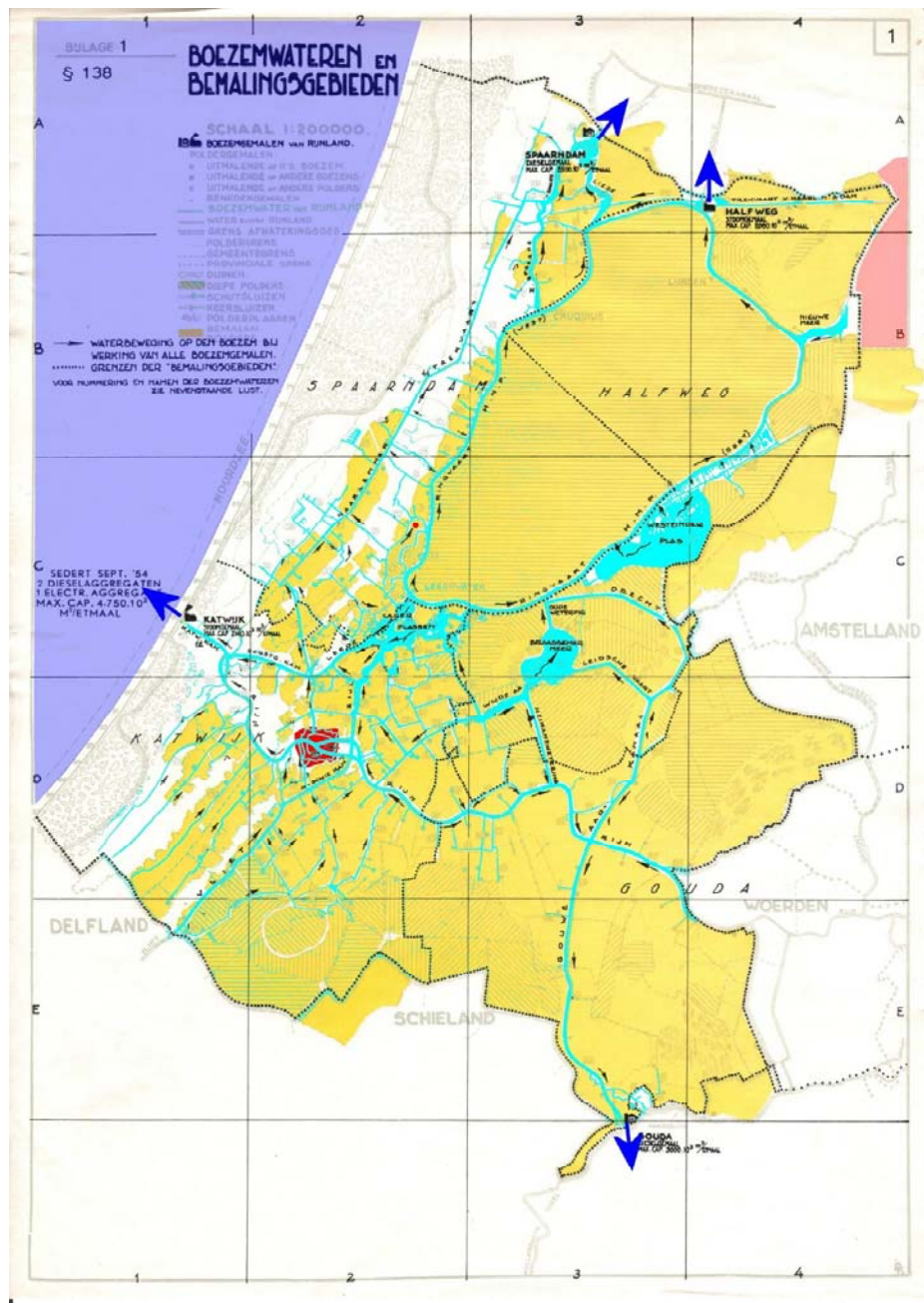


Figure 8. Water Board of Rijnland

Light blue: reservoir (note it's complex structure, surrounding the individual polders), arrows: pumping stations (upper arrows: into North Sea Canal, lower arrow: into and inlet from Rhine River)

Upper left: North Sea, light red: Amsterdam, dark red: Leiden
Modified 1884 map after Beekman 1932

One of the main interests of the Counts of Holland was the defence against the sea. They were instrumental in the promotion of the building of dikes and the formation of the water boards. Our oldest water board “Rijnland” (figure 8) owes its formal existence to a charter issued in 1255 by Count William II of Holland.

After the 12th and 13th century storm surges, transport by boat, already unavoidable, became a way of life and so was trade. The average subsidence of the soil already had about reached sea level. The fields became too wet for agriculture and fit for cattle only. The import of grain became of paramount importance to feed the growing population. The Counts of Holland again did not follow convention. They actively stimulated transit trade, especially Count William III (1304-1337). The stormy North Sea and the need to trade in bulk stimulated the development of sturdy ships with a large carrying volume. These boats turned out to be able to withstand the recoil of heavy cannon and were, hence, fitted with many. In several cities of Holland and Zeeland the local merchants formed trading corporations to equip armed cargo fleets. The cities hence engaged on their own account in wars at sea, for instance to break the blockade of the Baltic to reach the granary of Russia. The transit trade in bulk and the availability of peat as a cheap source of energy quickly made the (inhabitants of the) cities and countries very wealthy. They were not affected by

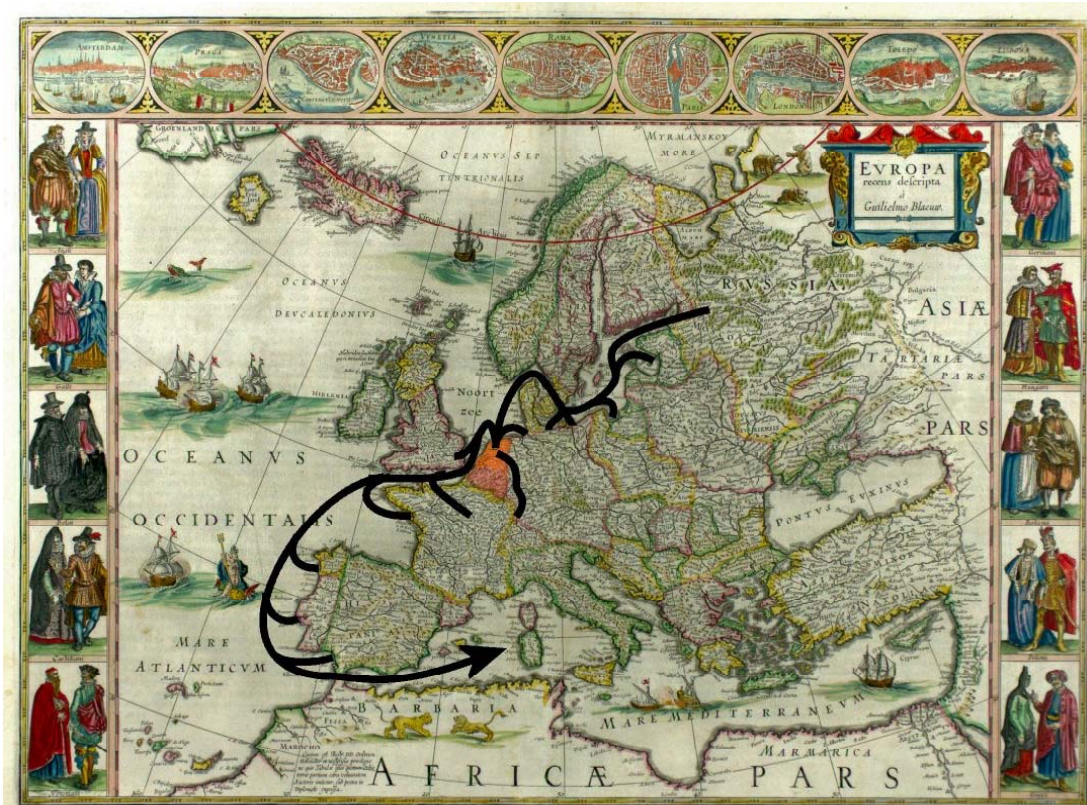


Figure 9. Dutch transit trade by sea

The arrow indicates the Mediterranean and the Levant trade
Drawing by the author on the map by Blaeuw from between 1631 and 1661

the economical recession of 14th century Europe, nor devastated by the Black Death (the pest) which had decimated Europe in the middle of the 14th century. The Dutch dominated West-European trade during the next four centuries (figure 9). From 1350 on the County of Holland was the great power at sea (figure 10) until Great Britain assumed this role in 1715.

The secretary of Count William III was the first of a long series of merchants who earned a fortune. He and his colleagues became wealthy enough to finance European kings and their wars. This financial support resulted in the relative independence of Holland after the last Count of Holland died in 1299 and the territories of the Low Countries formally succeeded to “continental” monarchs. The Counts had, in the mean time increased their territory with Zeeland (which kept its territorial integrity, however), and with West-Friesland (figure 10).



Figure 10. The County of Holland
Letters Z = Zeeland, H = Holland proper and
WF = West Friesland were drawn by the author on the
map by Maurik from 1610-1612

Participation of the territories in government, based on local traditions became official under Philips “The Good One” of Burgundy (1428-1467). He instituted advisory sessions on the state of each of the 17 territories of The Low Countries (The word “Low” means “Near” Brussels) approximated by the Benelux

(Belgium, the Netherlands and Luxembourg), the so-called State meetings (today: Provincial council). Hence the origin of the word “state” to denote a country and its government. In 1466 the first general meeting of the states of the Low Countries took place in Brussels, the “States General”, which is still the name of our parliament (“Staten-Generaal”).

After 1407 the windmill came into general use, both industrial (it functioned, for instance, in the large shipbuilding industry at the Zaan region north of Amsterdam) and as polder mills to pump water from the polder into the reservoir as well as from the reservoir into sea. Wet peat soils could, again, be used for agriculture, with the unavoidable activation of the vicious subsidence cycle. The average level of the peat soil crossed sea level at the end of the 15th century as a result.

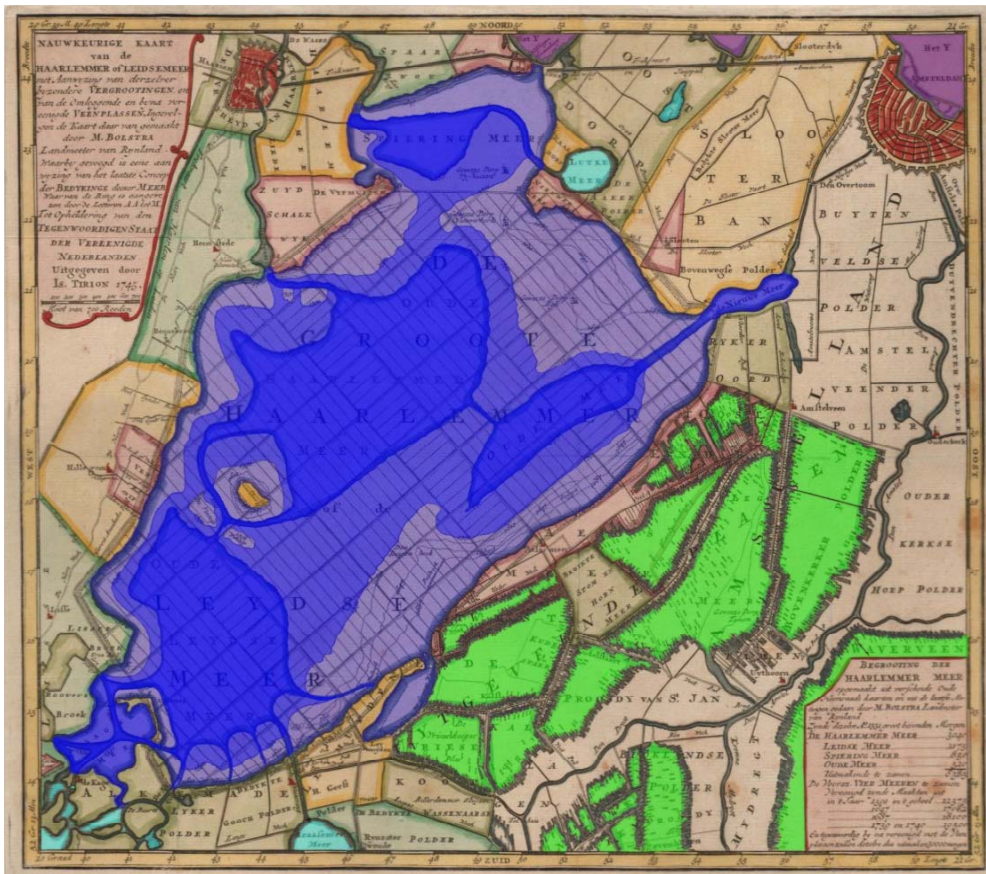


Figure 11. Increase in size of the Haarlemmermeer (“Haarlem Lake”). Situation in 1531 (dark blue), 1591 (lighter), 1610, 1647, 1687 (indicated by lines) and 1745 (still lighter). Other lakes are coloured light blue. The increase in size of the Haarlemmermeer not only endangered Amsterdam (upper right) and Leiden (just off the lower left corner) but also the lakes generated by peat mining (green) as well as the polders east of the lake. Pumping into the IJ-lagoon in the North (purple) drained the lake. Colouring by the author on the map by Tirion from 1745.

Wood had been used as a source of fuel and of building material for many centuries. The woods hence disappeared. Energy remained cheap, however, not only because the wind was extensively used but also because huge amounts of peat were locally available without heavy transport costs. Bricks made of high peat had already been in use since the 14th century. In the 16th century the mining of wet peat for the production of peat bricks was initiated on a large scale, especially in the southern part of Holland. The peat was mined away down to the sandy bottom. This activity not only resulted in the loss of arable soil, but also created many lakes (coloured green in figure 11). Storms washed their sides away, creating vast lakes out of the collections of smaller ones (different intensities of dark blue in figure 11). Laws issued to regulate peat mining could not prevent these processes, for both population and industry (such as metalworking for cannon, guns and other weapons) needed the bricks in quantity.

The Low Countries succeeded to Charles V of Habsburg, born in Gent (Flanders), who was appointed Lord of the Netherlands in 1515. He was also King of Spain and Emperor of the Holy Roman Empire (Germany). On 26 June 1548 Charles V decided that the 17 territories of the Netherlands formed a self-governing entity, the Low Countries (figure 12). He abdicated in 1555 in favour

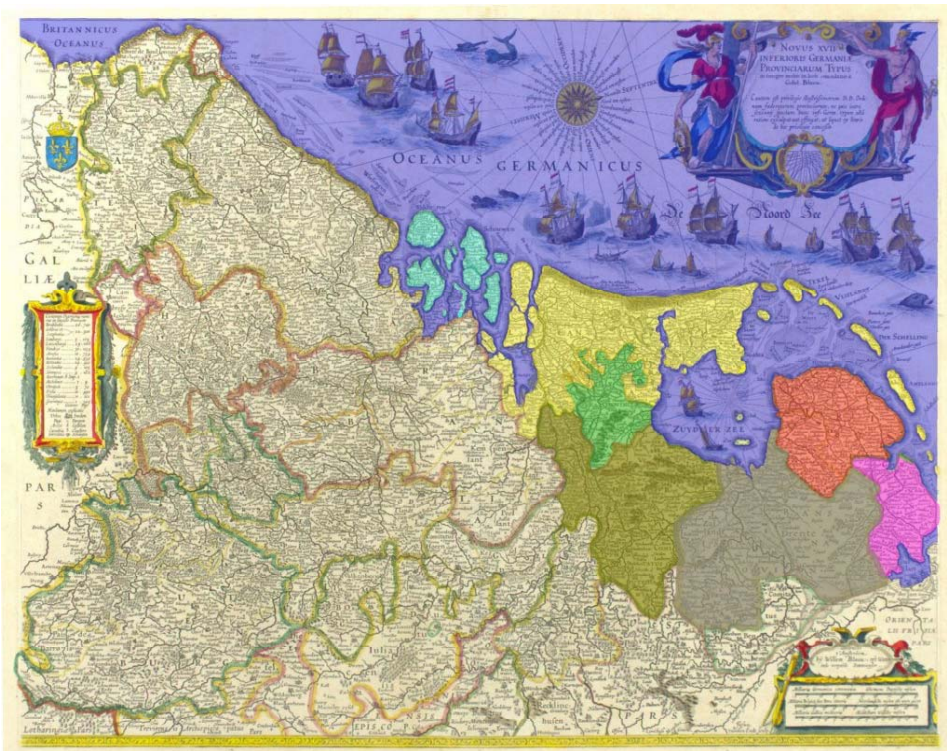


Figure 12. The seventeen territories of the Low Countries, including the seven states of the Federal Republic of the United Netherlands (1581-1795).

Clockwise from above left of centre: Zeeland, Holland, Friesland, Groningen, Overijssel, Gelderland (Gelre) and Utrecht.
Coloured by the author on a map by Blaeuw from between 1642 and 1662

of his Spanish son Philip II, who became King of Spain. Philip was an absolute monarch, who did not recognise the rights and privileges of his territories. He also wanted to eradicate the Protestants, who had obtained a firm foothold in the Netherlands. This resulted in the Eighty Years' War with Spain (1568-1648). Intermediary at first and, later, leader of the revolt was Prince William of Orange. The seven northern and coastal states formalised their defensive union at Utrecht in 1759. Since King Philips did not budge these states took a for monarchical Europe unheard of measure in 1581. They abjured monarchy and created the Federal Republic of the United Netherlands (figure 12), which from its very beginning was wealthy and powerful. It was a defensive union with autonomous territories and cities, each with its own council. The council of the union itself, the "Staten Generaal", also governed by common consent. The resulting "governmental chaos" proved to be quite effective, with tolerance as a spin-off. The Prince of Orange was appointed "Stadhouder" (from the French "lieu-tenant", "to keep the place (out of the hand of the enemy)") and functioned as General of the Army. He was in fact the States' highest civil servant. Like Switzerland and England, the Federation remained an anomaly in monarchical Europe till 1795.



The Dutch merchants were the European distributors of among other goods the spices imported by Portugal and Spain from the Far East, after their 16th century

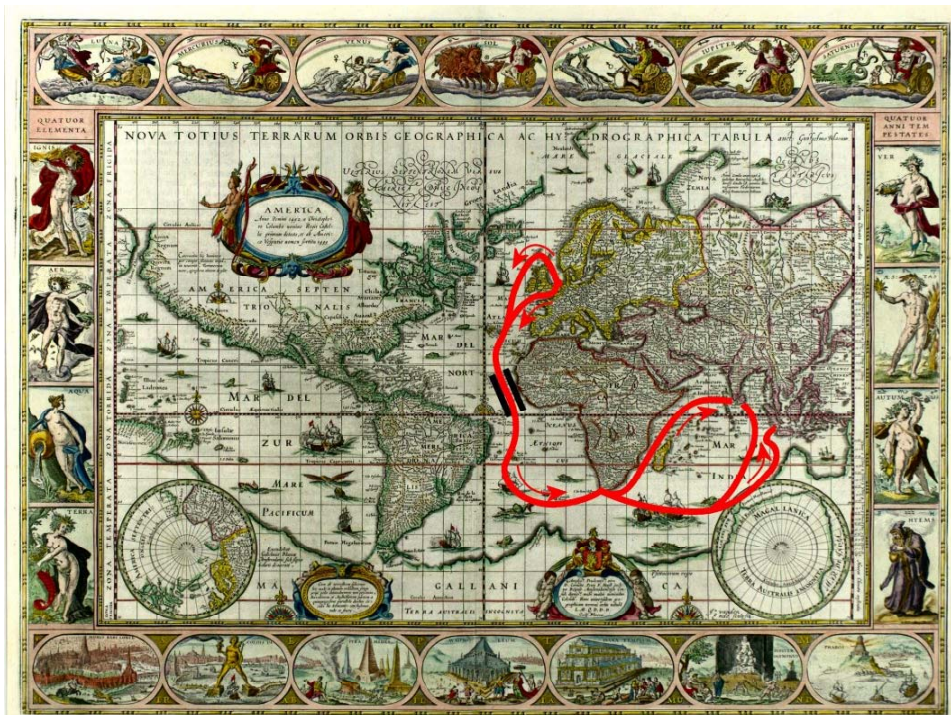


Figure 13. Sea-lanes of the VOC to the Far East

The ships had to sail between the two imaginary barriers (black) to prevent the arrival on the coasts of Africa or South America


After data from Gaastra drawn by the author on the map by Blaeuw from between 1631 and 1649

oceanic discoveries. Business went on as usual during the war with Spain. Dutch traders even kept selling weapons to their enemies (!). In 1585, however, Spain specifically blocked the spice trade with the Dutch. Ten years later, in 1595 merchants of the Dutch merchant cities formed groups (to spread the risks) to send their own armoured merchant fleets to the Far East (figure 13). Each city initially formed its own fleet, one per expedition. Each fleet was at first managed by a peer group of officers and merchants, just like a city. To facilitate decision making an admiral was, however, quickly added to the council.

In 1602 the seven merchant cities (situated in Holland and Zeeland) decided to co-operate and they formed the VOC, the Dutch East Indies Company, which on October 8, 1602, issued the first stock certificates, a world première. The company was ruled by an anonymous group of 17 representatives of the seven cities, the “Heren XVII” (“The Gentleman Seventeen”). At each session a representative of the hosting city functioned as temporary president. This company, active from 1602 to 1799 became extremely powerful (figure 14), though the British East India Company founded in 1600 became a serious competitor after 1650. A similar merchant company (the WIC or Dutch West Indies Company) was formed in 1621 to explore the west. One of their trading



Figure 14. Trading stations of the VOC in the Far East
After data by Gaastra drawn by the author on the map by C. Allard from
between 1691 and 1706

stations was New Amsterdam (1626), in 1673 called New York after an exchange with the British for Dutch ~~New Guinea~~ (Surinam). = 

The period from 1581 - 1715 became known as “The Golden Century”, despite the on-going war with Spain and the havoc created by the storm surges during the “Little Ice Age”(1400 – 1720) (figure 15). Trade with the use of cargo ships within Europe had already made the Federation the wealthiest nation of Europe. Amsterdam became its financial centre. Its exchange office created dependable money and transactions. Canals to generate dependable public transport by towing barges connected the cities. They were run on a tight time schedule. The night in the cities disappeared for the first time in history after Jan van der Heyden invented an effective oil lamp for streetlights. Industrial windmills powered saws and forges, among other businesses. The shipyards in the Zaan region were run like modern assembly lines and it took only four months to build one ship. They delivered 500 ships per year, of which at most only 25 were used by the VOC. The strategic inventions of the general Prince Maurits of Orange resulted in the ultimate defeat of Spain in 1648.

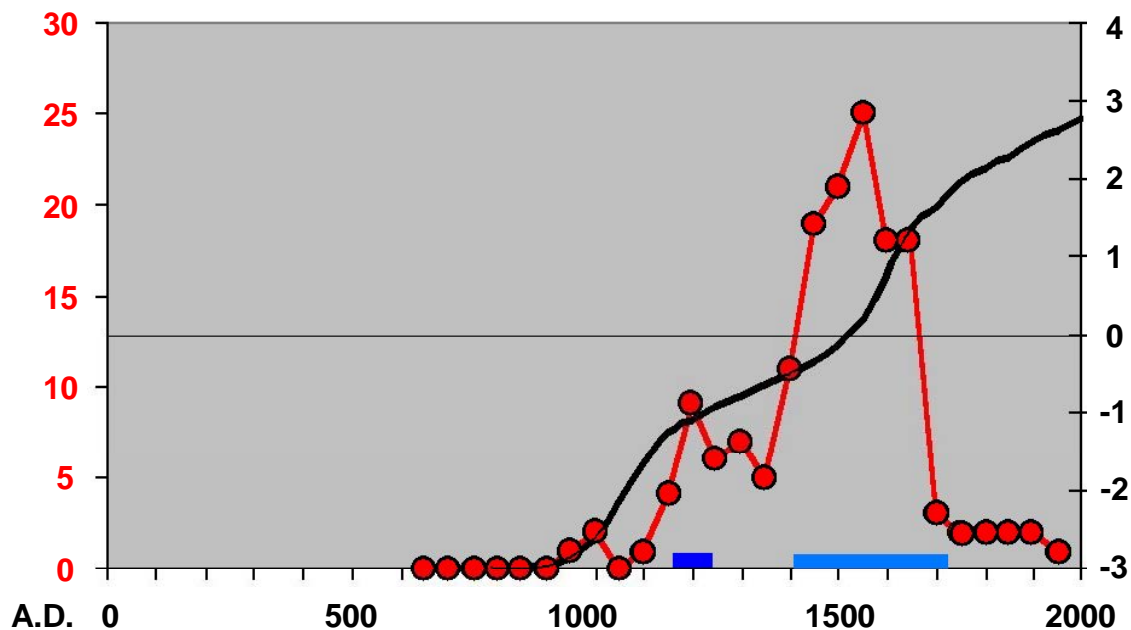


Figure 15. Growth of the ecological disaster by drainage as well as mining of peat
 Red: Number of inundations per half-century Black: relative sea level (m)
 Bars: Dark blue: Formation of the Zuiderzee Light blue: Little Ice Age
 Drawn after data by Gottschalk (1971-77) and Huisman et al (1998)

Able people such as scholars and craftsmen fled the religious persecutions in Flanders, Spain, Portugal, France, Poland and Germany. Their contributions stimulated many industries such as weaving of fine cloth and linen,

metalworking, and the diamond industry. Culture flourished with painters like Rembrandt, Vermeer, Frans Hals, philosophers (Descartes, Spinoza) and scientists (Huygens). The atmosphere of tolerance stimulated the production of many books and journals in many different languages. Cartography was stimulated in particular by the world-wide voyages of the VOC and the WIC. Many fine atlases were printed between 1608 (William Blaeuw) and 1726 (Gerard van Keulen). Shipworm, a mollusc, infected the wooden sides of the dikes. Dikes were fortified with stones imported from Scandinavia. Private merchant corporations reclaimed large lagoons and lakes in the north of Holland with the use of windmills as pumping stations. These reclamations are easily recognised on the maps by the carefully planned rectangular structure of their ditches. Together with the offensive reclamations of coastal mudflats in Zeeland, Friesland and Groningen these activities drastically altered the geographical shape of the Netherlands.

France as well as Germany liked to add the wealthy Republic to their prizes. During a war with France in 1672-78 their 1672/73 invasion was repelled by a system of inundations (coloured red in figure 16) in combination with natural

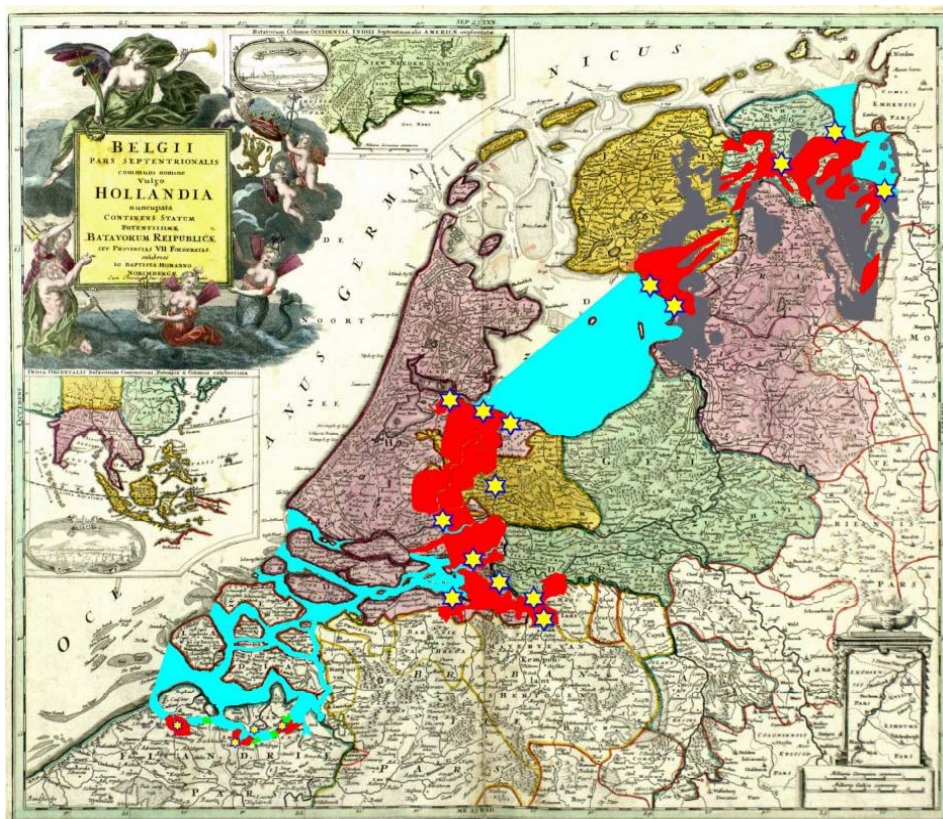


Figure 16. Inundations of 1672/73 against the French invasion
Coloured by the author after data by Gottschalk (inundations) and by
Zagwijn (peat bogs).

See text for explanation.

Drawn by the author on a map by Homanno from between 1707 and 1730

expanses of water (light blue) and swamps (dark grey). Note that the protected territory corresponds with the Friesian territory in the year zero A.D. (figure 4).

Inundations were a favoured means of defence and several elaborate water defence lines were developed during our history. Even during the Cold War an elaborate inundation system was built along the IJssel River. It was kept in function from 1951 through 1964.

Power and wealth harbour their own demise. After 1715 the governmental institutions fossilised in the hands of the wealthy burghers (regents). In the 18th century many of the lakes in the south of Holland generated peat mining were, nevertheless, also pumped dry. The French, however, tried again to obtain the riches of Holland. In 1795 a very cold winter disabled the water defence system and enabled the French to walk over the ice into the heart of the Netherlands. This ended the Republic. Under French occupation the economy decreased and much wealth was lost, though Amsterdam still remained Europe's financial centre. But there were also positive effects, such as the creation of laws, which formalised religious freedom as well as equality before the law and the gradual creation of a national system of water management.



Figure 17. The Kingdom of the Netherlands constructed in 1815
Map by Wild, 1815

After the defeat of France conservative Europe used this occasion to kill the Republic once and for all. They recreated the old 1581 Burgundian structure (figure 17, which covered the regions of today's Belgium, the Netherlands and Luxembourg) at the Congress of Vienna in 1815, and even installed absolute monarchy in the Low Countries. They did, however, keep the old feelings of the population in mind and installed an Orange as king. This structure was a misfit, however. Although King William I of Orange stimulated and financed transport (canals, railways), industry and commerce, the diversity between the different parts of the Low Countries was too large. Belgium seceded in 1830-39 and Luxembourg in 1890. In 1845 King William II was persuaded to install a

liberal constitution with voted members of the 2d House (States General), Provincial States and Municipal Councils. The ministers became responsible for governmental policies with the King as symbolic head of the nation, in fact the State's foremost civil servant as is the situation today. After 1860 the basically federal structure of the Netherlands gradually integrated to a national state. The voting rights were extended to all males in 1917 and to all females 1919.

In the 20th century industrialisation and the rise of new (originally) Dutch multinationals like Philips, Shell and Lever Brothers as well as of transit trade by water, road and air and a new local source of energy, natural gas, brought new wealth. The ministry of water management is responsible for the defence against sea and rivers.

After storm surge inundations of Amsterdam and its surroundings in 1916 a closure dike hemmed in the Zuyderzee in 1932. The dike transformed the estuary into the freshwater Lake IJssel, a much-needed extension of our overloaded water reservoir system. Much new land was gained by reclamation within this area. After a massive inundation by the sea in 1953 a very strong system of dikes and active storm surge barrier dams (the "Delta Works") was build along the coast and across all Zeeland estuaries but two. River dikes were strengthened after the near-inundations of the 1990's. Disasters caused by storm surge inundations by the sea and by river floods after exceptionally heavy rains mistakenly do not form the daily concern of the average Dutchman anymore. "Normal" rainfall gives us wet feet on occasion and cause protest by the citizens who expect to be free from nature's vagaries.

In the mean time the average level of the original peat soils decreased further to the present 3.5 m below sea level. This process goes on till all peat is gone and the basal layer of clay or sand has been reached. The already very low level of the agricultural peat polders and of the reclaimed peat-mined lake polders generated another problem, however. Of rain and seepage (750 and 400 mm per year per square meter, respectively) about 450 mm evaporates per year. The remainder cannot be drained away and threatens to raise the water level in the Dutch sink within five years to average sea level. So we pumped and pump: with windmills from 1408 to 1836, then with steam driven pumps and since about 1900 with the use of electricity. However, our fresh groundwater "bubble" floats on the brackish and salt groundwater "sea" extending throughout the Netherlands. We deplete it by pumping our polders dry, with upwelling of brackish water and salt-poisoned meadows as a result. ~~We, hence,~~ need even more rain and use river water in summer to compensate. This is a mixed blessing, however, since river water must be fresh and clean. Plans are under consideration to stop the pumps of our deepest polders to regenerate the lakes.

To regulate our water levels and, hence, pump 700 mm per square meter per year into the sea requires not only a well-kept infrastructure but also much energy. Over an area of half of the Netherlands, about 17.000 square kilometre, we have to pump per year 12 billion cubic meters of water into the sea. At a price of about €8 per 1000 cubic meters this costs us at present about €100 million per year.

The amount we pump into the sea is comparable with the yearly outflow of the river Meuse (8 billion cubic meters) or with a sizeable part of the Rhine (66 billion). One plan to cope with the future rise of the sea level consists, hence, of a large dike all around the Netherlands. Seven giant pumping-stations will take care of the work. One station for the water of the Scheldt river coming out of Belgium, three stations for the rivers Meuse and Rhine while the remaining three will be used for other outputs (Van der Ven, 1993). This presupposes the availability of cheap energy, however, while our sources of natural gas are finite. The Netherlands, hence, remain a country at risk (see figure 1).

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