Flooding in river mouths: human caused or natural events? Five centuries of flooding events in the SW Netherlands, 1500-2000

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Abstract - This paper looks into flood events of the past 500 years in the SW Netherlands addressing the issue what kind of flooding events have occurred and which ones have mainly natural causes and which ones are predominantly human induced. The flood events are classified into two major categories: a) flood events that were caused during storm surges and b) flood events which happened during war fare. From both categories a selection of flood events has been made. Each flood event is discussed in terms time, location, extent of the flooded area and specific conditions. Among these conditions specific weather circumstances and how long they lasted, the highest water levels reached and dike maintenance are discussed as far as flood events caused during storm surges are concerned. Flood events during war fare as both offensive and defensive strategies are relevant; the paper demonstrates that although the strategic flood events obviously were man-made, the natural feature, being the use of fresh water or sea water, of these events also played a major role. Flood events caused during storm surge may have an obvious natural cause, but the extent of the flooding and damage it caused were largely determined by man.

1. Introduction

In this paper five centuries of flooding events in the SW Netherlands are analysed. This former delta area is dominated by the mouths of the rivers Meuse, Eastern and Western Scheldt (van de Spek, 1997). It is comprised of the Dutch province of Zeeland, the western section of North-Brabant and the region south of Rotterdam (Fig. 1). The area was an archipelago consisting of islands on which many small polders were interwoven with dikes into one big patchwork of defences. As the area borders the southern North Sea tidal water is funnelled into the delta daily, some of which could reach dangerously high levels during winter time. Since medieval times the area has been exploited, providing people with their livelihood, such as farming, peat cutting and fishing. At points in time the area was also a theatre of war during which a strategy of flooding was applied, which also adversely affected the landscape. Therefore the main research question of this paper is to investigate how much of the flooding events have natural causes and how many are a result of anthropogenic interference? As the list of flooding events in the area is too long, the focus will be on the major 16th century flooding events, in particular three cases from the 17th and 18th century and the two major flooding events of the mid-20th century.

2. Background

Since 1000 AD local communities – at that time still living on low dwelling mounds - began to build low dikes in the archipelago of the mouths of the rivers Meuse, Eastern and Western Scheldt. Gradually small islands were extended and some were joined into even bigger ones by dikes and dams. Many centuries later islands such as Schouwen and Duiveland, but also Goeree and Overflakkee became bigger islands. On every island settlements were founded and on the major islands towns rose. This coastal area was attractive for settlement because of its natural resources. The clay soil was very fertile and suitable for arable farming and where areas remained under the influence of the tides there was sheep farming (Verhulst, 1995, 64-76). As the process of land reclamation developed, local communities were joined by big investors such as feudal lords, monasteries and hospitals located in towns such as Ghent and Bruges. As the medieval period ended, land reclamation and dike building was predominantly undertaken by big investors (de Kraker, 2011a; de Kraker, 2011b). Their main task was to maintain the dikes in order to keep out the outside water and to maintain a network of ditches with a sluice in order to discharge the polders of fresh water on the inside. Long-term water discharge

of polders meant a gradual drop in surface level, because of the thick layer of peat in the subsoil that compacted at several locations.
Next to farming these thick peat layers were also a second major natural resource of the archipelago. Large peatbogs had formed since 5.000 BC in a fresh water environment protected from the North Sea by a system of coastal barriers on one hand, while on the other hand the ground water table slowly rose corresponding to a slowly rising sea level. The flow of water through the rivers Scheldt and Meuse contributed to the expansion of the peatbog area (Baeteman, 2013; Weerts, 2013). After the 3rd century AD peat growth was interrupted by large scale flooding. This affected the peat in two ways. At some places it was removed by clay deposits, in most places however, peat was penetrated by sea water and covered by a fresh clay layer. Peat could therefore be used for two purposes: fuel and salt extraction (de Kraker et al, 2008). At the end of the medieval period some twenty towns were active in making salt from peat, employing thousands of workers (de Kraker, 2007). It meant that in vast areas peat was cut and therefore the original surface level of the old polders dropped (Borger, 1992; van Dam, 2001). In spite of regulations forbidding entrepreneurs to cut peat in polders too close to dikes, the process of land subsidence continued unabated. The alternative was to cut peat at low tide in the saltmarsh or flooded areas.
On the one hand the sea had contributed much to building the landscape of the archipelago in terms of clay soils and salt in the peat layers, on the other hand it also had its downside. Contemporaries building dikes could determine how high and how broad its base had to be, but storm events towards gale force (8 – 9 Beaufort) or even storm force (10-11 Beaufort), could not be foreseen. As the wind turned to NW direction and coincided with New Moon or Full Moon, water levels could be pushed up to a level of more than 0.5 m above the highest dike levels causing flooding with dikes levels varying from 3.85 m – 4.95 m (Van de Ven, 1993; De Kraker, 2005). As the water of the North Sea was not only funnelled into the southern North Sea but further upstream into the mouths of the rivers Meuse, Eastern and Western and Scheldt, polders lying at the far end needed to have higher dikes than those located at the river mouths.
It was not until the mid-19th century that it became possible to foresee how the weather would turn and what the levels of daily high water levels, in particular spring tide levels, would be. From that period onwards hydraulic engineers regularly monitored and measured top levels of all the dikes in the area and made plans to improve them. Making plans is one thing, but implementing them on all the so called free polders, which were completely autonomous, was another. Generally the administration of such polders chose to govern their polder and maintain their dikes at the cheapest price, rather than spending 'spoilt' money on raising top levels of dikes mainly aimed at pleasing the tax paying landowners. This radically changed after the major flooding of 1953.

3. Materials and Methods

This paper builds on ongoing multi-disciplinary research into how the landscape of the study area has changed during the past five centuries. This consists of extensive research of documentary evidence which can be subdivided into the following categories. Documents that relate to landownership and land use, such as manorial accounts of which monasteries and nobility are most important. Accounts of the maintenance of sea defence such as dykes, dunes and sluices which were controlled by the many water boards in the area. If preserved each single polder had to keep an annual account of dyke maintenance. Correspondence of various stake holders in flooded areas and local administrations and provincial governments are of interest and historical maps made after flooding events. All of this documentary evidence provides information on flooding events and specific details about how, where and when flooding happened, what was the extent of the damage and how this could be repaired. For some flooding events (1715 and more recent ones) specific damage assessment reports were made. In conjuction with historical geographical research also archaeological information is used of specific locations, features and even settlements which disappeared shortly after a flooding event and were buried under new clay deposits. In this respect aerial survey proved to be a very useful tool where the focus was on crop marks. Finally geological maps (1 :50,000) were used along with the digital elevation model of the Netherlands (Actueel Hoogtebestand Nederland). In particular old soil maps

with cross-sections of subsoil layers of Holocene peat proved to be very useful clearly identifying locations where new tidal channels had removed peat or had not affected the old layer at all.
The general literature about flooding events in the Netherlands mainly focusses on the 1953 event and its aftermath as far as the SW Netherlands is concerned and the 1916 event as far as the Dutch provinces of Holland, Utrecht, Gelderland and Overijssel, surrounding the former Zuiderzee are concerned. The 1953 event became the onset of the many Delta Works carried out here and the 1916 event became the onset of the closure of the former Zuiderzee and large scale land reclamation in the area. Most of the studies focussed on hydraulic engineering aspects (an de Ven 1993), some on the human suffering and the initial causes of the event (Slager, 2003). The 1953 flooding was also the start of a broad scientific research programme of historic flooding events caused by storm surges and river flooding 7th century AD - 1700 (Gottschalk, 1971, 1975 and 1977). Many case studies of the history of small polder areas published by small water boards located in the coastal areas of Holland and Zeeland also provide detailed information on single flooding events (Kool-Blokland, 2003; de Kraker et al, 2000; van Tielhof et al 2006). Recently there is also a focus on flooding within the framework of climate change (all extreme weather events) both in coastal and river areas and the perception of flooding events by contemporaries from the past (Bosch 2010; van Dam, 2012; de Kraker, 2013).

4 Flood events, 1500 – 2000

4.1. General

The major flooding events in the research area referred to as storm surges are well known. Gottschalk (1971, 1975, 1977) has studied these events by using chronicles and related documents which enabled her to make a distinction between actual and erroneous events (Table 1, Graph 1). If we include the occasions on which parts of the area flooded at other points in time than during storm surges (anthropogenic caused floods – Table 2, Graph 2), the picture becomes more complete, except for those polders that flooded because their dikes collapsed, at places where the meander of a river moved closer to the foot of the dike. Such incidents could happen during very low tide in any given season caused by the strong ebb and flow of the water undermining the sandy layers underneath clay and peat; of such flooding events no inventory has yet been made.

4.2. Flood events 1509-1511

On 26 September 1509 (n.s. 6 October) a major storm surge hit the archipelago and many polders flooded. A chronicler at Antwerp wrote:
'On Saint Cosmas and Damian's night there was a big flood and tempest of wind causing many dikes to collapse and consequently flood. We also saw wagons floating over the Scheldt ferry outside the Croonenborch gate… There came word about the big flood from Holland and Zeeland from which it appeared that not all the land was flooded, but only some, such as Cats, Stavenisse, Hontenisse and in many more waters were already disappearing…' (S1)
In the Zwin area of Bruges, town authorities spoke of the event in terms of bad weather and high flood (S2). Although this event is counted among the big disasters of the 16th century (Essink, 2013) perhaps less than 10% of the areas actually flooded, which comes fairly close to the assessment of the Bruges' officials. As repairs were rapidly undertaken, most of the flooded land was in use again by 1510. In some places, however, landowners were unwilling to cooperate in undertaking out the repairs. Such areas were even more vulnerable when a second storm surge hit the area on 14 December 1511 (n.s. 24 December) (S3). Apart from the extreme weather event, most of the flooding could be attributed to the fact that either dikes breached in 1509 were still freshly made and therefore too brittle to withstand the big waves or some areas were left flooded in 1509 which two years later made it easier for the high flood to penetrate deep into the older polders with both dikes and a surface level which was too low. Areas in the province of Zeeland, north of the Westernscheldt basin were very badly hit during storm surges of the 16th century of which vast areas remained under water for a very long time (Fig. 2 areas E).

4.3. Flood events of 1584-1586

During the Eighty Year's War (1568-1648) the Spanish army campaigned in Northern Flanders to recapture the towns of Bruges, Ghent and Antwerp, which held the rebel side. The rebels resisted the policy and reforms made by Philip II, King of Spain and hereditary ruler of the Low Countries. After the suppression of the rebel uprising in 1566, the opposition was led by William of Orange, based at Middelburg (Zeeland) across the Western Scheldt, who encouraged the besieged towns to stand firm against the Spanish. Meanwhile the Spanish systematically subdued the countryside of all the polders in the areas closing in on the three towns on one hand and gaining control over the Western Scheldt on the other hand. It made it even harder for the rebel war ships to send relief to besieged towns. They therefore decided to remove the Spanish from the countryside and to keep them away from controlling the Western Scheldt which would make it easier for the rebel side to relieve the towns (Groenveld et al, 2008. 117-119).

This led to the adaptation of the strategy of deliberate and large scale flooding of the polders on the Flemish side of the Western Scheldt. Experts were summoned to Middelburg to explain where the dikes and sluices could be best destroyed in order to guarantee the largest possible area to be flooded (Fig. 2). In order to relieve Antwerp, the seawalls were destroyed at Saeftinghe in February 1584 (now: Verdronken Land van Saeftinghe, 51°21' E and 4°96' N, see Fig. 2 no 2, area A) (S4). At Campen the seawall was breached in May 1584 (now: west of the present hamlet of Kampen, 51°21' E and 3°57' N, Fig. 2 no 3, area B) and east of Terneuzen the sea wall was breached in the same month (now near the sluice of Othene in the town of Terneuzen, 51° 19' E and 3° 51' N, Fig. 2. no 4) and at Sluice-Aardenburg this also happened in the summer of 1584 (S5). In July1586 another inundation was caused near Axel (Fig. 2 no 5 area B), but this did not serve to relieve Ghent which was already dominated by the Spanish (de Kraker, 1997, 335-337). The carefully chosen places to make breaches in the seawall or to simply take out a wooden sluice had a devastating impact on the landscape, but this strategy completely missed its directly anticipated goals. Bruges, Ghent and Antwerp were subdued by the Spanish in the course of 1584 and 1585, leaving the rebel side empty handed. The impact of these flooding events on the landscape were without precedent, because even secondary dikes (dikes in second line) were also affected, finally flooding about 2/3 of the late medieval landscape. The flooded zone also isolated the area from its historical hinterland, from which money usually came and decisions were made for repairs. From the rebel side all possible money for repairs went to the military and was not spent on newly conquered areas of which control remained uncertain. As the area became a frontier between the two warring parties, there was no rush to undertake fast repairs. Besides, nobody could survive in the flooded area. In fact the vast flooded land, which separated the warring parties, was gradually considered to be a rather practical solution to avoid any kind of hostile engagement in the field.

If there was no eagerness to reclaim the flooded land, what happened to it? The military took even further control of the flooded polders by building earthen fortresses at strategic points. These were built both by the Spanish and the rebels leading to the development of a chain of fortresses or Spanish line of defence and a rebel chain of fortresses or Dutch line of defence. Over the next two centuries these defence lines, after 1648 taken over completely by the Dutch Republic, became the blue print for further land reclamation.

Another major impact on the landscape as a result of these strategic inundations was the start of a new process of erosion and deposition. At places where dike breaches were caused deep new channels were formed which slowly developed into new large creeks (the Otheense Kreek, Hellegat and Vlaamse Kreek). As the process of reclaiming these areas started very late, most of the minor creeks had already silted up again yielding new rich clays soils for arable land. Silting up also occurred in areas which had been overexploited during the late medieval period, which had caused large scale subsidence of surface level, leaving behind a new thick clay layer. At most places where the late medieval landscape had been overexploited a thick new clay layer covered all remnants of buildings, roads and ditches. Also medieval villages were abandoned and finally lost (Hontenisse, Aendijcke, Beoostenblije and Othene). Some of these villages have never been found, others are under the new deposits in recently reclaimed polders.

Closely related to the long duration of the strategic flooding events and the gradual reclamation of land afterwards is the deep impact on the population. As the original inhabitants had to abandon the flooded lands, gradually new inhabitants settled again, but this time mostly coming from the Dutch Republic, mainly being of protestant belief and speaking with a slightly different tongue.

It needs to be said that in the province of North Brabant the area of Bergen op Zoom and its vicinity and some adjacent polders further to the north east also experienced strategic flooding of which the first happened in 1584 east of the town. Polders and villages disappeared. It was not until about 1700 that most areas were gradually recovered again, this time without villages (Kluiving et al, 2006).

4.4. Flooding 1682-1715 compared

Another flooding event occurred on 26 January 1682 during which about half of the area of Dutch northern Flanders was submerged, while on the other islands of the archipelago and parts of North Brabant the area flooded ranged from 10% up to 25% (Fig. 3). The following extended quote summarizes what happened around Antwerp:

'On the 26 January 1682 there was a big tempest with a high flood and according to the word that came from Antwerp this was never seen nor heard of before. Because of the extreme violence caused by this flood water flowing into polders of Kallo where about all of the polders drowned as far as the fort Vlaamsche Hooft located on the left bank of the river Schelt. Only those polders having strong dikes such as the Beverenpolder, Verrebroek and around were spared. It was a real deluge because everywhere there were dead bodies of people and dead animals floating and a lot of grain, household goods, stables and even entire barns in such large numbers that it was hard to describe it all. Damage was estimated to run in the millions and thousands of people were ruined'.(S6)

Officials inspecting the broken dikes and going into the flooded lands saw and heard numerous people who had taken refuge on the rooftops of their houses, barns and stables. They could only get down safely if they were rounded up by rowing boats and barges. But most of them were too frightened because they feared the small boats would be shipwrecked as the storm that caused all of this lasted for several days. Therefore it was feared that most would not resist any longer such conditions and would eventually starve. The floodwaters also entered the town of Antwerp where it caused large scale damage to merchant and warehouses of which a lot would be bankrupted.

The floodwater also came into the main church of Antwerp. Here thomb stones were uplifted, and graves collapsed. In the cemetery of fortress called Vlaamse Hoofd dead bodies were lifted from their graves and floated towards the main gate of the fortress. Here the floodwaters washed a hole in the pavement of about sixty feet long making its way to the gate on the interior which was ruined. Then the water made it way towards the church of the fortress making the situation very dangerous.'

Also the fortified town of Hulst was badly flooded. Along the North Sea coast of Flanders several areas were flooded too (S7). Although reports of the event from several areas hit in Zeeland were sent to the provincial capital Middelburg, mostly begging for assistance, no general relief was given. Initially all areas had to rely on themselves to make their land dry again. Soon afterwards the provincial government advised some polder boards to raise the top levels of their dikes and the commander of Hulst took many measures to strengthen the town.

The next flooding occurring on 3 March 1715, which was not as devastating as that of 1682. Many people in 1715 still remembered the flood that happened 33 years ago (de Kraker, 2013). In general the same polders were hit again, but waters did not penetrate that deeply into the hinterland as they did in 1682. Also the town of Hulst remained dry, because of the measures it had taken. In terms of flooded area it hardly surpass 10% and in terms of casualties the 1715 flooding was hardly a serious one, except on the islands of Goeree and Overflakkee where some polders had to be abandoned for some years.

4.5. Strategic flooding events of the 17th and 18th centuries

In both the Dutch part of northern Flanders and the area north of Bergen-op-Zoom a long area consisting of creeks and salt marshes was not given out for reclamation. Some already reclaimed neighbouring areas could be given back to the sea through the opening of sluices or by making breaches in seawalls.

In 1672 when the French army marched into Flanders, also threatening the Dutch part, commanders of garrisons opened sluices at several locations (Table 2, Graph 2). One such event took place near Sas van Gent, where a large new polder (reclaimed in 1652) was given up and flooded (S8); also further to

the east polders were flooded. Some were drained as soon as hostilities were over, others flooded again in 1682 (see above).
In the course of the 18th century and after another threat from the French an ingenious network of sluices and channels was developed in order to generate flooding within a few days (S9). From Liefkenshoek (northwest of Antwerp) as far west as Sluice a long area could serve as a water barrier. Water had to reach 40 to 60 cm, which prevented guns being dragged nor the use of boats, while foot soldiers could easily be stopped.
At the start, strategic flooding events mainly used sea water, but by the end of the 18th century fresh water could also be used, by simply leaving sluices closed. This last case required the building of special parts in the big sluices that were built of stone and brick.

4.6. Strategic flooding in 1940-1944

During the Second World War both the German occupying army and in 1944 the liberating allied forces used inundation as part of their military strategy (Table 2, Graph 2). Flooding could be used for both defensive and offensive war fare.
As the allied threat of invading the Continent of Europe became greater and finally the allied armies marched from France north to liberate Belgium and the Netherlands, the Germans had already begun to make plans to flood parts of Zeeland. In April flooding near Axel started, which was a fresh water flooding. (van der Ham, 1990, 277-278). Around the same time the islands of Schouwen-Duiveland, Tholen and St. Annaland were flooded too. Flooding here was undertaken by opening sluices and allowing sea water to come into the polders.
The allied forces moved quickly northwards in mid-1944. In order to gain control over the mouth of the Western Scheldt and use Antwerp for providing the troops, on October 1st general Eisenhower gave the command to chase the Nazis off the main island of Walcheren by flooding the entire island. The Walcheren landscape resembled a basin which would fill with water within a day. The allied forces bombed the seawall at four locations, through which deep and broad gaps water flooded the island (van der Ham, 1990, 439-443). As a result the Nazis surrendered Walcheren and left it within days. The impact of the flooding was huge, not only on the four locations where much collateral damage to properties was caused, but also over 150 people perished during the blast. As the flooding occurred on 3 October 1944, much additional damage was caused during the bad weather over the following weeks.

4.7. 1953 Flooding event

The most recent and by far most devastating flood event occurred on February 1st 1953. A W to NW storm blew for two whole days pushing up the tides to extreme heights into the inlets of the rivers Meuse, Eastern and Western Scheldt on the Dutch side and the river Thames on the British side of the southern North Sea. Due to its long duration and extreme high water levels vast areas flooded. In particular where islands of Schouwen-Duiveland and Goeree-Overflakkee and neighbouring areas nearly completely flooded. Flooding reached as far north as Dordrecht and to the east even beyond Geertruidenberg (Fig. 4). The numerous reports and testimonies of the disaster, still revealing new facts after so many years are very similar to the description of the dramatic consequences of the 1682 flood event. However, damage can also be summarized in terms of facts and figures such as: 200,000 ha land flooded, 100,000 people evacuated, 1836 people died and overall damage Euro 700 million in 1953 (Slager, 2003, 7).

5. Discussion

Looking at the selection of flood events in the SW Netherlands of the last five centuries it is clearly demonstrated that no flooding event was alike, but generally two categories of flood events can be distinguished. The first one being the flooding events occurring during storm surges. The second category consists of flooding events during warfare or related to war. There is also a special category of flooding events which have to do with erosion in meanders of the mouths of the rivers Scheldt and Meuse. Because these are local and incidental they have not been considered in this paper.

5.1. Storm surges

Most flood events occur during storm surges usually unexpectedly, sometimes during the day time, sometimes at night, but always during the storm season (October-March) and in particular two days after New or Full Moon. The impact of the event depended on many circumstantial and additional conditions, which will briefly be discussed.

One of the conditions of large scale flooding during a storm surge was long duration combined with strong winds. During the 1953 storm surge, wind force hardly surpassed 9 Beaufort, but the surge lasted for more than two successive high tides (Hickey, 2001). After the first high tide which was already dangerously high, the following ebb tide also remained high, which consequently caused the second high tide to be higher than the first high tide. Also the flooding event of 1530 is known for its extreme high level. Some contemporaries spoke of two feet or even a beer barrel's height above the top level of some dikes, which meant that water level was more than half a metre higher than top levels of dikes at the time. Because each polder or water board maintained its own standards for top level height, it is hard to generalise flood level back in 1530. More likely big waves were pushed over the dikes during gusts of strong wind, which led water to affect the landside slope of dikes which were more brittle than the extra defended gentle slopes on the seaward side. If this went on for hours dikes could collapse from the landward side very easily, such collapses were widely observed in 1953 in the SW Netherlands again. Once such collapse started, the top level slid down (like a very local landslide) making a hole in the dike through which water could penetrate into polders making deep erosive gaps.

Flooding during a storm surge could also occur if two or more extreme weather events happened within a short time span. The 1421-1424 Elisabethan floods (Leenders, 2009), 1509-1511, the 1530-1532 and January-February 1552 storm surges all came in pairs. Areas hit during the first storm surge were either not given enough time for repairs to be undertaken or dikes that had already been repaired properly still proved to be too weak and therefore collapsed again as the second surge hit the area. At this point there is a great amount of resemblance between communities hit by two successive years of crop failure and communities hit by two successive flooding events (Campbell, 2010). In both cases resilience is put to the highest test, usually meaning that contemporaries could not cope well with such extremes reoccurring in fast succession.

The opposite is also true. This is the case of the 1682 flooding which seems to have come out of the blue, being the second extreme event of its kind in the area during the entire 17th century. As the first flooding occurred on Easter Monday 1606, nobody in 1682 had any recollection of that early flood which most likely had made water boards less vigilant leading to neglect of extra maintenance of dikes. The 1682 flood also hit major trade centres such as Antwerp and Flushing inflicting damage to stocks and other properties. For the region of Zeeuws-Vlaanderen it should be noted that the vastness of the flooded area must have partly contributed to the strategic flooding that occurred barely a decade ago. Not all of the flooded area had been properly recovered, while some flooded polders were left disputed, because landowners did not want to pay for all the drainage costs themselves. The 1715 flooding demonstrates that some extra measures taken after 1682 paid off, but not everywhere (de Kraker, 2013). It should be noted that the storm surges, such as 1715, happening during day time, did not came as such a surprise as the 1682 one. Compared to other 18th century storm events and storm surges the 1715 flood event must be considered as being the major flooding event of its century in the SW Netherlands (Baart et al, 2011; Demarée and Muir-Wood, 2008; Pfister et al, 2010).

The 1953 flooding event in the SW Netherlands, compared to the other flooding events is special in many ways. It is not only the extremely high water level reached on 1 February which generally is considered to be its main cause. It happened at a time most people could have still remembered the 1906 flood, which was a rather small scale event not having caused large scale flooding and not having caused a large human toll. There are more factors to be considered. One of them being the failure to raise top levels of dikes regularly up to a level of 6 metres as it was ordered by Rijkswaterstaat. So it was common knowledge that dikes were too low. At places where top levels had been raised this was undertaken by building concrete walls (Muralt walls) on top of the dike which were fastened into the topsoil. Because of the wave action and the sheer volume of water these concrete walls were simply pushed over the dikes during the storm surge. The extent of the flooding was also very much caused by the slow response of officials of local water boards. As the flooding happened on Sunday morning many people were attending church service or were still asleep. At the same time it clearly exposed the weakness of the water board organisation, consisting of about 300

water boards all having to decide which measures had to be taken to prevent that one dramatic flooding event. The large scale material damage and the high human toll were also largely caused by the weak buildings in the flooded area not withstanding the impact of the incoming tide. So many having taken refuge on rooftops (compare 1682) still did not make it because their houses collapsed. Most had to wait and endure the cold until relief came, which during the first days consisted of fishing boats and other vessels, while only two helicopters were available.

5.2. Strategic flooding

Looking at the second category of flooding events, caused by the military and occurring during warfare or prior to the threat of an enemy invasion, demonstrates that especially the flooding during the Eighty Year's War stands out as a set of major events. As the rebel side asked experts of the local water boards to advise on the locations where breaches should be made, this guaranteed the largest possible extent of such a flooding. The initial intention was having water in polder areas standing two feet high. This prevented the use of flat bottomed barges and made it impossible to drag heavy artillery through the area. As the flooding in some areas remained too limited it was soon ordered to also make breaches in secondary dikes lying more inland, so that water could penetrate as deeply as possible into the area. As there was no backup plan for repairs after hostilities, no dikes were repaired ('t Hart, 2014, 105-107). Moreover soon the flooded area became part of a strategic line of defence. From then onwards reclamation of flooded land could only be undertaken with a special permit from the government who first asked the advice of the military. The long duration of the war (1568-1648) and the incorporation of the flooded areas into further warfare had profound consequences for the landscape. Large and deep new tidal channels formed, such as Saeftingher Gat, Hellegat, Braakman and Havengat in Zeeuws-Vlaanderen, clearing old medieval settlements and other structures. Floodwaters used the old ditches and canals to finally fill the areas where large scale subsidence of surface level had taken place by cutting peat for fuel and salt making. On the other hand a thick new clay layer was deposited at most places. At places designated as strategic inundation areas the process of depositing would go on until the end of the 18th century. Here the level of the salt marshes had already become so high that the strategy of flooding had become inefficient and therefore completely outdated.

Another consequence of this kind of flooding on the landscape was that salt water had a devastating effect on crops during the first few years. Because strategic flooding events were undertaken in the common interest, therefore no compensation was paid to farmers. It was not until the end of the 18th century that the view on strategic flooding began to change. Instead of using sea water, fresh water could also be used. This led to the building of special sluices, inundation sluices, that were able to store the fresh water in the polder areas (Fig. 5). However, there was only one major problem. If an enemy army attacked by surprise, there was not enough time for a fresh water inundation to reach a level of two feet in polders. This took some weeks and was almost completely dependent on rainfall. Intensively spying on the enemy could provide information far in advance and as a result of this flooding could already be set in motion. In 1784/5 strategic flooding proved to be completely unnecessary because no enemy force came to the area. The outcome was a growing opposition against this weapon of war.

The strategic flooding events of the Second World War show two faces. The Nazi flooding of parts of Zeeland Flanders with fresh water and the islands of Schouwen-Duveland, Tholen and St. Philipsland with sea water were caused far in advance of a possible allied attack. This way there was time enough for the water to rise to the level aimed at. Moreover weak locations could be re-enforced properly. Being purely defensive these flooding events did not stop the allied forces from marching north and only slowed them down. The allied strategic flooding of the former island of Walcheren in 1944 was undertaken within a day, allowing sea water to flood 70% of the island. It proved to be very effective. The Nazis immediately surrendered the island to the allied forces and then repairs began; gaps were closed and dikes rebuilt and re-enforced. Meanwhile the flooding of the island was the main cause to undertake a major land re-allotment and land consolidation in the years after. This meant that by 1953 this area in the SW Netherlands had already been changed to meet the demands of modern times, including its sea walls, from which it benefitted very much during the storm surge that year when only a small strip in the east of the island was flooded.

436 5.3. Comparison and the wider scope
437 Comparing the two categories of flooding events (storm surges and warfare) it needs to be said that the
438 human factor plays a major role in both. Strategic flooding events are caused by man, but water as a
439 natural feature should finish the job by pushing into areas making them inaccessible. Flooding events
440 during storm surge do have an important natural component which as such could be very devastating,
441 but much depends on the vigilance and resilience of humans in preventing this from happening or to
442 limit damage as much as possible. Five centuries of flooding events in the SW Netherlands have made
443 it clear how vital the anthropogenic factor is to have an influence on the kind, extent and the duration
444 of flooding. Since1953 it has been the dominant factor in the prevention of further flooding events in
445 the area and still is.
446 A comparison between the coastal flooding events in the SW Netherlands and flooding in more
447 upstream river areas demonstrates both the similarities and the differences. Upstream river areas and
448 the lower river basins not being under tidal influence tend to flood at times of extreme rainfall, peak
449 discharge caused by sudden thaw, ice blocking or a combination of such events. None of these factors
450 plays a role of any significance in the tidal inlets of rivers. There have only been two events of ice
451 playing a role in coastal areas. In both cases a lengthy period of frost caused sluices to become
452 jammed. After having been defrosted, the sluice doors could function again. The large scale strategic
453 flooding events in the Dutch river between 1672 and 1795 were caused partly by piercing the river
454 dikes in place. Especially during the French War of 1672-1678 it caused large scale flooding in
455 Central Holland and Utrecht which rendered areas out of agrarian use for some years. At that time this
456 Old Dutch Water Line proved to be effective. It was to be extended further south and east in later
457 centuries (New Dutch Water line) with additional strategic flooding areas around the rivers Lower
458 Rhine and IJssel. None of these ever achieved their ultimate goals.
459 Looking at the flooding events in the SW Netherlands, 1500-2000 and putting them in a much wider
460 European scope of flooding events, it becomes clear that there is a much longer tradition of
461 researching flooding events in the Netherlands. This is especially due to the fact of the vulnerability of
462 the Dutch landscape to both coastal and river flooding. It is low lying with large parts below sea level
463 and three major rivers (Rhine, Meuse and Scheldt) form a kind of delta near the North Sea. Dyke
464 building along with other coastal defences and embedding of many water boards has been the response
465 to flooding in the past, it still is in the present and will be far into the future. Regarding this long
466 tradition and the very nature of the Dutch landscape, the use of flooding as part of a military strategy
467 sounds logical. Flooding events outside the Netherlands have begun to receive special attention as
468 climate has contributed to some major river flooding in various parts of Europe in the past few
469 decades (Glaser et al, 2004; Brázdil et al, 2012;. In terms of causes and consequences there are
470 differences with flooding events in the Netherlands. The most important cause of recent flooding
471 across Europe are extreme rainfall events, even in summer, while in Dutch coastal flooding, storm
472 surges and gale force storms play a major role. In river areas across Europe, such as Central Europe
473 (River Danube (Kiss et 2013; Rohr, 2013), River Rhine (Wetter et al, 2011) and River Elbe) most
474 damage is caused in river towns, while in the Netherlands mostly rural areas were hit. Finally the
475 response to flooding in the Netherlands is a large scale project which gives more room for rivers to run
476 through densely populated areas and to store large amounts of water of which some aspects go back to
477 the early 19th century. Across Europe such projects are just beginning to be developed. Studies on
478 flood events across Europe therefore began to focus on flooding events of the past, unravelling
479 patterns, how people responded to events and what measures they took. Having studied that, the
480 challenge is how to deal with present and future flooding in a generally highly urbanised environment,
481 which is completely different from the landscapes of the past.
482 A last aspect that needs to be mentioned is the present urge to again flood areas in the SW coastal area
483 of the Netherlands. This is not motivated anymore by strategic reasons or economic reasons. It has to
484 do with restoring lost tidal landscapes. Within the framework of Natura 2000 tidal wetlands are made
485 again, however without little knowledge of flood events of the past centuries.
486
487 **6. Conclusion**
488 This paper set out to explore how natural flood events of the last five centuries in the SW Netherlands
489 were. These flooding events have been classified into two groups: flooding events caused by storm
490 surges and flooding events occurring during warfare. The multiple century overview of the events has

demonstrated that the first category has an initial natural cause, being meteorological in terms of severe gale force Beaufort 8 – 11 coinciding with New and Full Moon and human intervention in terms of vigilance and resilience. As no flooding event caused during storm surge is alike, the extent of the flooding and the damage caused depended a great deal on the duration, wind force, time of day or night and the weather condition at that particular date. Moreover the human response to each flood event also differs a great deal, depending on how often such flooding events occurred during a life time, how fast a second flooding happened, the organization of the local water boards, the state and maintenance of dikes, while sometimes much depended on the individual measures people were willing to take. The second group of flooding events occurring during warfare are man-made, either caused by fresh water or – as was the case before 1800 in the SW Netherlands – by sea water. The strategic flooding during the Eighty Year's War failed to facilitate the rebel offensive to free the besieged towns of Ghent, Bruges and Antwerp. The strategic flooding of later centuries failed as a defensive strategy to stop the French armies from invading the area. Although the strategic flooding during the Second World War did not help the Nazis from stopping the allied march, it did help the allies in liberating parts of the SW Netherlands before the winter 1944/45 began.
The impact of flooding events caused during storm surges and those happening during warfare is different. In terms of extent of flooding and devastation, the strategic flooding events of 1584-1586 and 1621 had the biggest impact on the landscape, so did the 1953 flooding caused during a storm surge.

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641 **Fig. 1.** The former archipelago of the mouths of River Western Scheldt, Eastern Scheldt and River
642 Meuse. The study area in the box consists of the Dutch provinces of Zeeland, the western part of North
643 Brabant and the area south of Rotterdam.

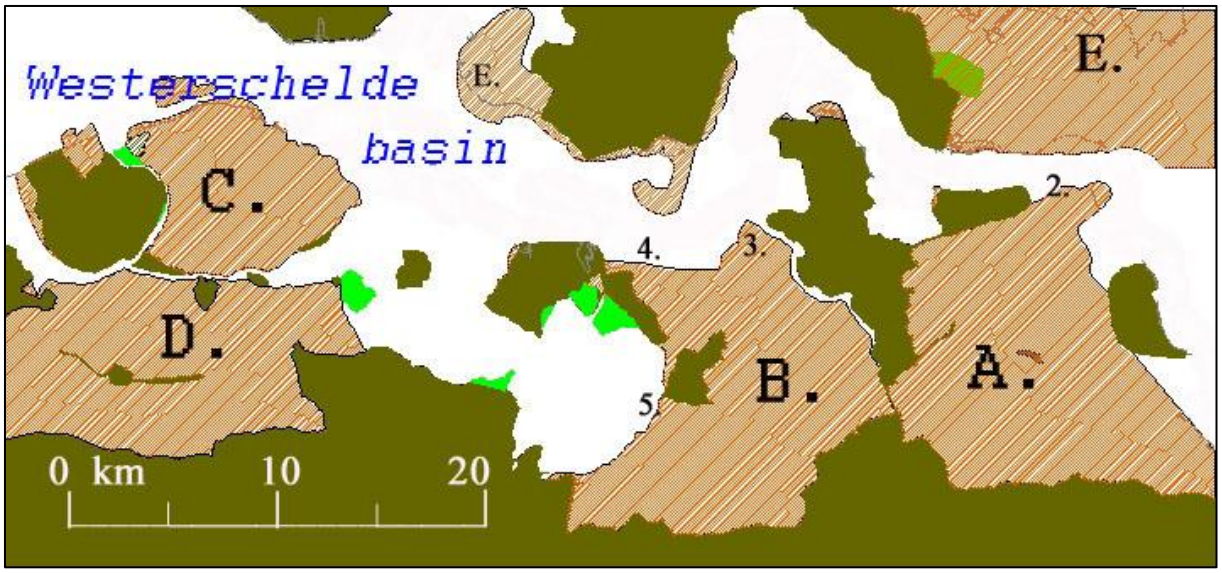

Fig. 2. Strategic flooding during the Eighty Year's War (1568-1648) in Zeeuws-Vlaanderen. A. Flooded in February 1584 at no 2., B. Area flooded in July 1584 and the southern area flooded in July 1586 at no 5. C. Area flooded in 1584. D. Area flooded in 1584, then reclaimed again and flooded again in 1621-1622. E. Areas flooded during storm surges, 1530, 1532 and 1570.

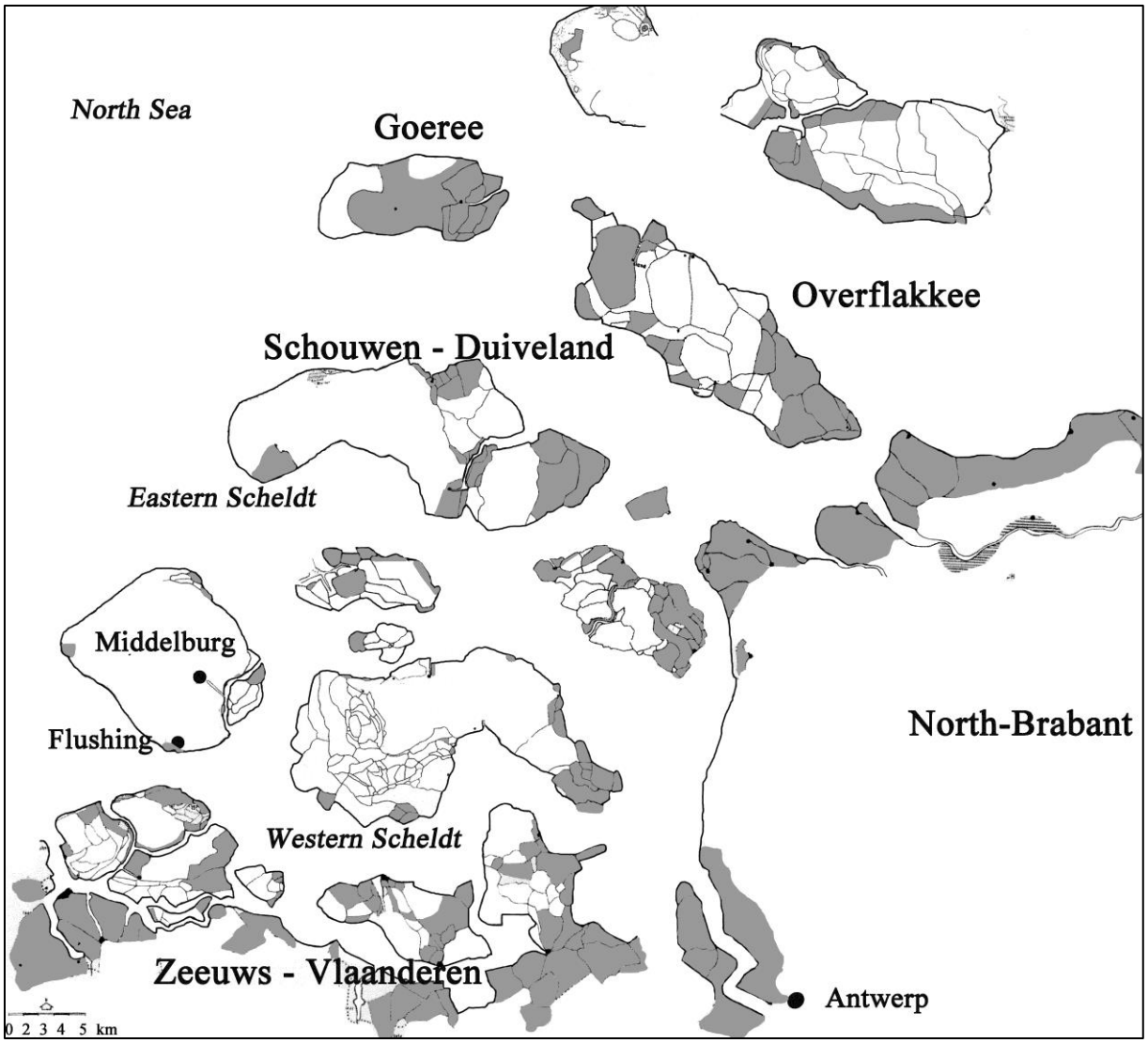

Fig. 3. Reconstruction of the flooded areas (shaded) on the main islands and in the western part of North-Brabant during the storm surge of 26 January 1682 (Gottschalk, 1977).

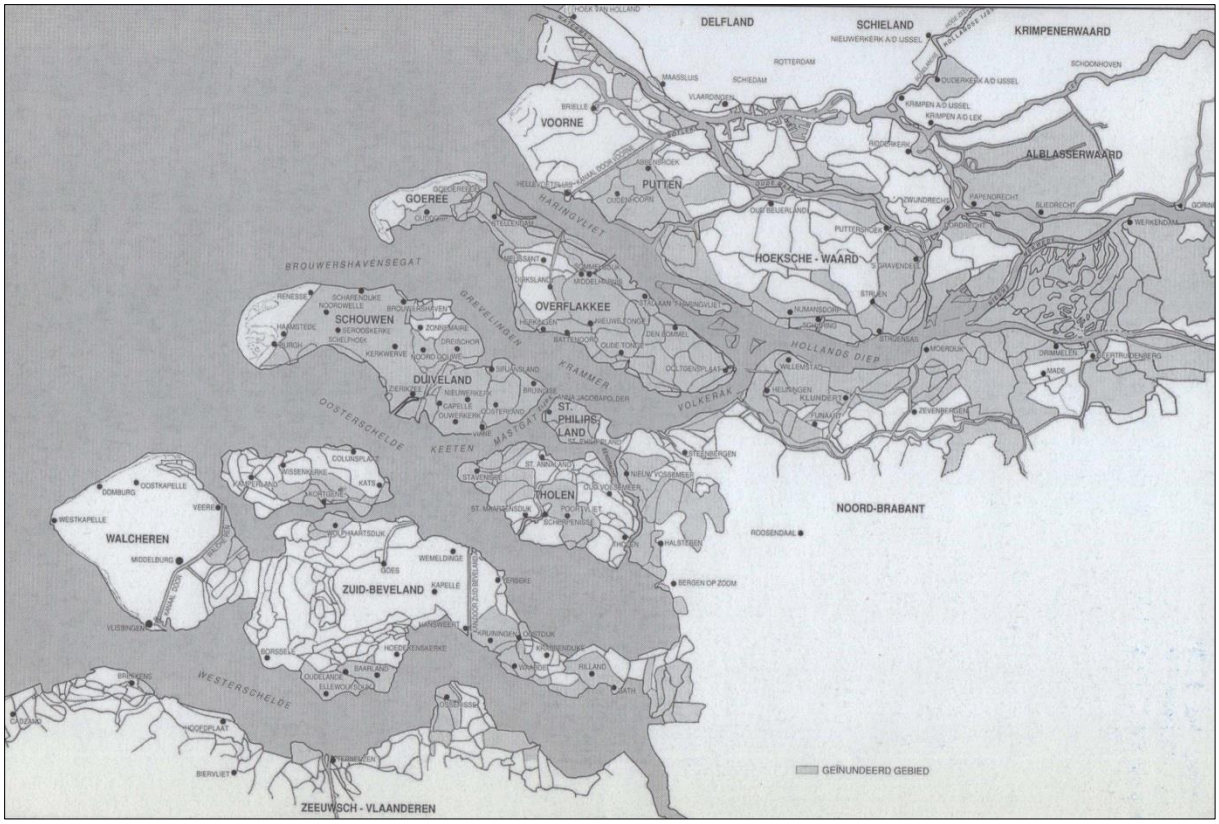

Fig. 4. Reconstruction of the flooded areas (shaded) in Zeeland, parts of the provinces of South Holland and North Brabant during the storm surge of February 1st 1953.

Fig. 5. Land side of an inundation sluice, built in 1789 by the Estates General of the Dutch Republic at Zwartenhoek (51°15' N and 3°51' E). Notice the double groove in the protruding parts in which beams could be installed. As the space in between the beams could be filled with earth, this construction was strong enough to prevent the fresh water from flowing seaward. After some weeks water in polders could reach a level of some decimeters. As soon as the threat of war disappeared, beams and earth were removed again (photo, Nellie de Kraker).

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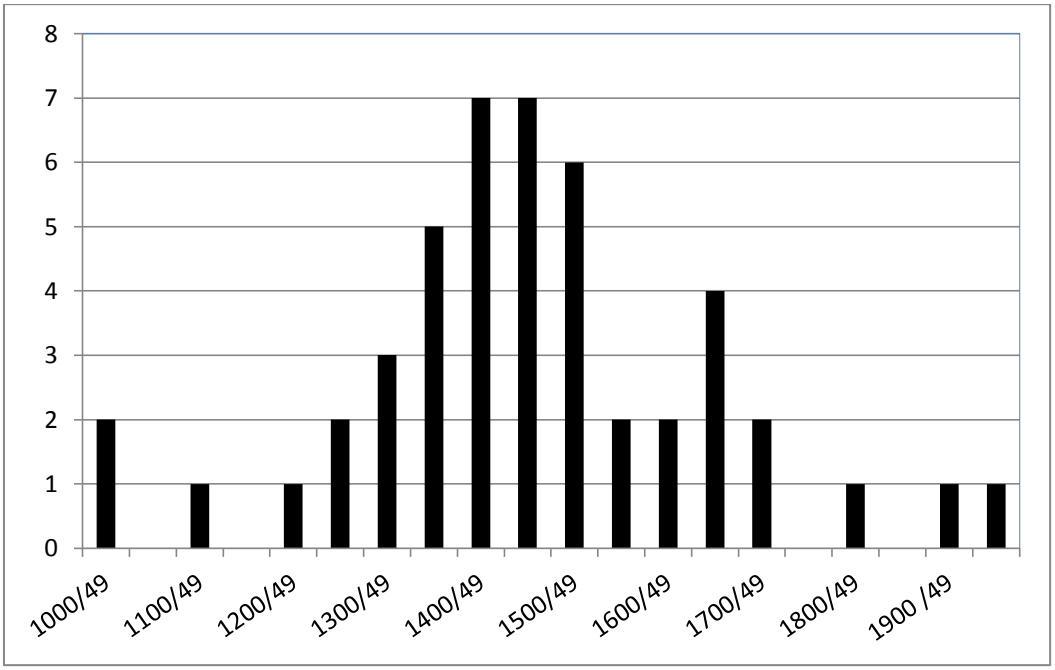
Table 1 Flooding caused by storm surges in Zeeland-Flanders and elsewhere in Zeeland, 1014-1953

Year	Old Style	New Style	Year	Old Style	New Style
1014	28 September	2 October	1488	25 December	3 January 1489
1042	2 November	6 November	1491	14 September	23 September
1134	2 October	7 October	1493	no exact date	
1248	28 December	3 January 1249	1497	no exact date	
1262	28 January	3 February	1502	16 October	26 October
1268	28 January	3 February	1509	26 September	5 October
1288	14-17 December	20-23 December	1511	14 December	24 December
1330	24 December	31 December	1516	26 December	5 January 1517
1334	23 November	30 November	1530	5 November	15 November
1341	no exact date		1532	2 November	12 November
1357	24 December	31 December	1552	13 January	23 January
1374	9 October	16 October	1552	15 February	25 February
1375	8-10 October	16-18 October	1570	2 November	12 November
1394	21 January	29 January	1606		27 March
1398	no exact date		1609		18 February
1404	19 November	28 November	1671		22 September
1409	10 February	19 February	1682		26 September
1421	19 November	28 November	1683		18 February
1424	19 November	28 November	1695		January
1436	31 Oct - 1 Nov.	9-10 November	1715		2 March
1446	10 April	19 April	1717		25 December
1449	22 March	31 March	1808		
1468	21 October	30 October	1809		
1472	5 October	14 October	1906		2 March
1477	27 September	6 October	1953		1 February

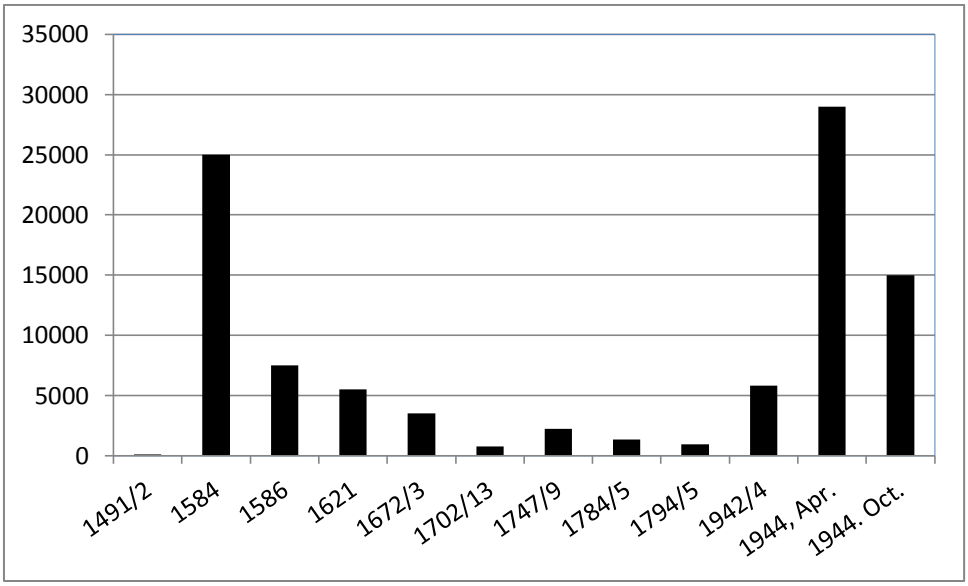
Table 2. Flooding caused during war fare in Zeeland-Flanders and elsewhere in Zeeland, 1491-1944

Year	Old Style	size flooded area	location
1491/2	no exact data	> 100 hectares	Bruges area
1584	February - July	± 25,000 hectares	Zeeland-Flanders
1586	July	± 7,500 hectares	Zeeland-Flanders
1621		± 5,500 hectares	Zeeland-Flanders
1672/3	no exact date	± 3,500 hectares	Zeeland-Flanders
1702/13		775 hectares	Zeeland-Flanders
1747/9		2,200 hectares	Zeeland-Flanders

1784/5		1,330 hectares	Zeeland-Flanders
1794/5		950 hectares	Zeeland-Flanders
1942/4		5,800 hectares	Zeeland-Flanders
1944	April	29,000 hectares	Island of Schouwen-Duiveland and the islands of Tholen, St. Philipsland
1944	October	70%	Island of Walcheren



Graph 1. Number of flood events caused by storm surges in the SW Netherlands, 1000-2000, per half a century. This number does not say anything about intensity, damage or scale, most of the events barely flooded 5% of the territory, others (16 Nov. 1530, 12 Nov. 1570) perhaps about one third.



Graph 2. Flood events caused during warfare in the SW Netherlands, 1491-1944. The intensity and damage is indicated in hectares.