Under the Sea. Predicting 16th to 18th century shipwrecks in the waterscape of Walcheren based on historical sea charts and geomorphology

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UNDER THE SEA

Predicting 16th to 18th century shipwrecks in the waterscape of Walcheren based on historical sea charts and geomorphology

Philipp Conrad

Cover Image: Ships at anchor at the roadstead of Fort Rammekens (left)

(Source: [adapted from] Zicht op de rede van Fort Rammekens bij Vlissingen [painting], by W. H. van Diest, 1657. CC0)

Under the Sea

Predicting 16th to 18th century shipwrecks in the waterscape of Walcheren based on historical sea charts and geomorphology

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Bachelor Thesis (1083VBTHEY)

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Preface

While writing this thesis, I received a lot of support from various people, whom I would like to thank here. Everyone mentioned below was immediately open towards me and everyone offered me help straight away.

First and foremost, I would like to thank my supervisor Joanne Mol for her patience, of which I am sure has been necessary to work with me. Without exception, she was always very quick to help and provided great and productive feedback. Along the way of writing this thesis, she also gave me a lot of advice for the future of my studies, for which I am grateful.

I would also like to thank my professors Martijn Manders, who gave me the idea for this thesis in the first place and followed my thesis with interest, and Milco Wansleben, who answered all my questions regarding the technical aspects of this research.

Further, I would also like to thank Menne Kosian of the Rijksdienst voor het Cultureel Erfgoed for giving up his time to explain and discus his work with historic maps in great detail through which I have learned quite a lot. I would also like to thank him for providing me with feedback and sources, which have been a great help.

I want to also express my gratitude to Jan van Duijvenbode of the Rijkswaterstaat for providing me with up-to-date bathymetric data and Dianne van de Zande of the Province of Zeeland for providing me with the necessary contacts. Additionally, I also want to thank all other people of the Rijkswaterstaat and Rijksdienst voor het Cultureel Erfgoed who answered my questions.

I also want to thank my family, especially my father who I have been discussing my research with and who has provided me with great feedback, but also my mother and brothers Pascal and Ernst, for supporting me through the writing of this thesis. I also want to express my sincerest gratitude towards them for supporting my choice of going from Germany to the Netherlands to study Archaeology, even though it can be hard at times to be at a distance from each other.

And I am very grateful for the friends I have made along the way, who have continued to show their support for me. Without you guys, Dion, Nienke and Raphaël, this Bachelor would have been very lonely and I am happy to call you my friends. Last, but not least, I want to really thank my girlfriend, Carien Papikinou, who with her unwavering support has been a large (ionic) pillar for me this whole time.

Chapter 1: Introduction

1.1 General Introduction of Research

Every ship has a story - regardless the material, its size or where it has been – from when it was built to the end of its journey. However, the journey of some ships is somewhat more special. For various reasons, it might happen that a ship never reaches its port of destination and instead sinks to the bottom of the sea. There, under the right circumstances, it can preserve for hundreds of years and become frozen in time. It is in the present in which such a ship might "resurface" and with the help of archaeologists continue its journey and tell the forgotten stories of times long past. This is why maritime archaeologists compare shipwrecks to time-capsules.

Shipwrecks are therefore an important part of the cultural heritage of any country that has a distinct seafaring history. One such country is the Netherlands. Today we know of around 500 shipwrecks in Dutch waters, however, we cannot be sure of the definite number, as there are probably still hundreds buried under the sand (Meelder, 2014, p. 7). Nevertheless 500 is a very large number for such a small country. But the small size of the Netherlands is deceiving. For a period of around 200 years, from 1602 AD to 1800 AD, it was home to the largest trading and seafaring company of its time: the Dutch East India Company or VOC (Jacobs, 1991, p. 95). In its time, the VOC commissioned thousands of sea journeys to East Asia where they built colonies, exploited local inhabitants and resources, fought off rivalling European seafaring companies and thus became a trade monopoly (Gaastra, 2002, pp. 37-39, 115, 171).

The VOC consisted of 6 headquarters, each one placed in the most important Dutch port cities where the activities of the VOC were carried out. These 6 departments were the so-called Chambers of the VOC, all being named after the city the headquarter was in. The most famous one is the Chamber of Amsterdam, as per decree it was accountable for 50 percent of all VOC activities and decisions: it built and equipped half of all VOC ships, made half of all journeys and was in charge of 50 percent of all VOC-trade. Therefore, it was also the richest VOC Chamber. Furthermore, half of the board of the VOC was nominated by them, which meant they held the power over half of the VOC. The Chambers of Delft, Rotterdam, Hoorn and Enkhuizen were each responsible for one eighth of all VOC activities and decisions. The chamber that sometimes gets overlooked is the chamber of Zeeland, which was the second most important chamber as it was responsible for a quarter of all the decisions and activities of the VOC (Gaastra, 2002, p. 20-21). What sets the Chamber of Zeeland apart is already hinted at in its name: it is named after a province, not just a city. This is because the VOC Chamber of Zeeland was made up of three cities: Middelburg, Vlissingen and Veere. With Middelburg being the most important one and contributing the most, the headquarters were placed there (Roos, 1987, pp. 33-35).

All of these three cities were located on Walcheren. Walcheren was an island at the time of the VOC (see Fig. 3) but is nowadays connected to the mainland through reclaimed land. It was this island of Walcheren, where all action of the VOC-chamber of Zeeland happened: the ships were built, started their journey to the east from Walcheren and foreign merchants came here to trade with the VOC of Zeeland (Roos, 1987, pp. 33-35).

Figure 1: Study Area of the waterscape of Walcheren. Adapted from Google Earth (https://earth.google.com/web/) (made by P. Conrad)

Walcheren had a very favorable position as it was located on the North Sea coast and it was therefore easy and relatively quick to reach for ships. In the north of it lay the Oosterschelde estuary and in the south of it the Westerschelde estuary. All three cities are roughly located on the eastern part of the island. Middelburg even had to dig a canal eastward as it was located more inland. Consequently, all ships wanting to reach the ports of Walcheren had to circumnavigate the island. There, on the eastward side of Walcheren lay the roadstead of Fort Rammekens (see Fig 1), “a place less enclosed than a harbour where ships may ride at anchor” (Merriam-Webster, n.d.). As it was the the main resting place for ships wanting to reach the ports of Walcheren, the roadstead of Fort Rammekens was very busy at the time (Roos, 1987, p. 96).

Due to it being an estuarine area, the tidal processes made Walcheren’s waterscape a very dynamic area (Meire et al., 2005, p. 1). Sandbanks moved constantly over time, making it harder to traverse, especially without proper knowledge of the area (Bos & Bosch, 2017, p. 96). Thus, because of high traffic from 1602 to 1800 and the dynamic nature of the area, through storms and war amongst other reasons, many sailing ships have wrecked in the waterscape of Walcheren (Roos, 1987, pp. 103-108).

As destructive as the waterscape of Walcheren was, it was also a blessing for the preservation of these shipwrecks. Shipwrecks were often quickly covered by sediment due to the tidal processes and thus they were preserved (Manders, 2017, p. 83). Unfortunately, this in turn comes with a catch. The ever-changing landscape causes shipwrecks to be exposed again as tidal channels shift and currents consequently erode the protective sand-layers away (Manders et al., 2017, p. 10). If there is no layer of sediment to protect a shipwreck, these very fragile time-capsules become prone to decomposition.

In order to prevent shipwrecks from eroding and keeping the time-capsule alive, multiple approaches to preserve shipwrecks have been developed. The first approach is excavating the shipwreck, but as this is very costly and requires many resources, especially with the quantity of shipwrecks, this is mostly uncommon and generally avoided. The nowadays preferred approach is preserving the shipwreck ‘in situ’, meaning protecting it from decomposition in the location where it has been found through reburying it for example. Because a shipwreck can 'turn up' at any place and any time, it is difficult to create proactive measures for their preservation and - like the aforementioned approaches - are mostly reactive (Manders, 2017, pp. 17-18).

In recent years however, archaeologists have started to work on proactive measures to preserve shipwrecks. One of these is the creation of prediction maps – maps that predict the expected likelihood of the presence of buried archaeology in any given area (Manders, 2017, p. 18). These prediction maps are already widely used in terrestrial archaeology, but are still rare and mostly vague in maritime archaeology (Verhagen et al., 2009, p. 19; Manders, 2017, p. 18; Manders et al., 2017, p. 7). What makes predicting shipwrecks especially difficult is the fact that ships could wreck almost everywhere where water was at the time of their sinking (Manders et al., 2017, p. 69).

However, in 2000 the Dutch Cultural Heritage Agency (RCE) made a first attempt to create a prediction map that next to terrestrial prediction, included underwater areas of the whole Netherlands. With the second version of their Indicative Map of Archaeological Value (IKAW), they split the Dutch waterscape into five maritime areas and divided them into three categories of expected archaeological values from high to low. Thus, the whole province of Zeeland was attributed the same level of expectation (Manders, 2017, pp. 42-43). In 2007, the third version of the IKAW was published which contained more detailed predictions for the maritime area (see Fig. 2). However, as the RCE stated in the instruction to use the IKAW 3, underwater areas are new to the IKAW and thus did not feel comfortable to give out advice based on their prediction map (Deeben et al., 2009, p. 9). These were the only two attempts of predicting the presence of archaeology in Zeeland's waterscape. As both of these maps were also made on a country-wide scale, they do not provide great detail.

Figure 2: Indicative Map of Archaeological Value (IKAW) 3. Created by the RCE. (https://www.cultureelerfgoed.nl/onderwerpen/bronnen-en-kaarten/documenten/publicaties/2018/01/01/bronbestanden-archeologische-kaart)

However, in 2014 Martijn Manders, Seger van den Brenk and Menne Kosian of the RCE created a new project, which was first intended to be IKAW's fourth version but turned out as Historic Geo-Morphological Map Set Waddenzee. This project was developed mainly as aid for the management and policy making of maritime cultural heritage. This project combined historical maps, reconstructions of the morphology of the Pleistocene and Holocene soils, modern bathymetric data, shipwreck location data and human disturbances of the seabed into a modular map set that predicts the presence of archaeological data from many periods in the western Waddenzee. In order to predict locations of shipwrecks, they developed an approach to visualise changes in the morphology of the seabed of the western Waddenzee from 1925 to 2008 (Manders et al., 2017, pp. 4, 35, 58-60).

For this thesis, that approach has been adapted and modified and, on its basis, combined with historical and geo-morphological information, this thesis has formed two hypotheses:

It is possible to predict areas in which ships could have wrecked.

It is possible to predict areas in which shipwrecks could have been preserved.

As there has not been any similar research regarding the creation of a prediction map of shipwrecks in the waterscape of Zeeland, this thesis aims to give Zeeland its well-deserved recognition in light of its seafaring past by creating a prediction map for shipwreck locations in Walcheren.

1.2 Specifications

For the purpose of this research the scope of the prediction map had to be limited and specified. The first specification is what type of watercraft this research focuses on. For this, I would like to make a distinction between boat and ship. The Cambridge Dictionary definition of a boat is a "small vehicle for travelling on water" (Cambridge Dictionary, n.d.-a) while a ship is "a large boat for travelling on water, especially across the sea" (Cambridge Dictionary, n.d.-b). This distinction is important because the larger size and depth of ships influences which waters are navigable and which are not, which is important for the prediction map. For this it does not matter which type of ship, whether it was a cargo ship, a war ship or else since I am concerned with the size, not the function of the ship. To summarize, this research focuses on any type of ship that was capable of travelling across the sea, no matter under what flag it was sailing or what it was doing, as long as it navigated the waters around Walcheren. For this, the ships of the VOC are used as a proxy to understand routes and anchoring patterns, which are important for creating the prediction map.

The second specification refers to the location. The choice of Walcheren as the location was primarily influenced by its seafaring history. As Walcheren was home to the second largest chamber of the VOC (Roos, 1987, p. 35), it attracted a lot of sea traffic. This meant that large numbers of ships were navigating Walcheren's waters, which results in a higher probability of shipwrecks for this area. This is also complemented by the dynamic nature of Zeeland's landscape. Thus, the research area was defined by Walcheren and the main seafaring routes to its ports (see Fig 1).

Furthermore, Walcheren and Zeeland in general have not received enough attention regarding the evolution of its landscape and its history of the VOC, in research and in the public eye. This became evident during my research which sometimes made it hard to find good sources. Hence, it is important that Zeeland receives the attention it deserves which also reinforced my choice of Walcheren.

The third specification refers to the time period this research will focus on. I chose to focus on the period of 1585 to 1800. Of course, ships did already exist before that time, but the existence of the VOC and its regional predecessors can be used as a proxy to provide evidence of seafaring activity around Walcheren. The VOC was founded in 1602 (Roos, 1987, p. 34) and officially fell on the 31st of December in 1799 (Roos, 1987, p. 171), making the period of 1602-1800 a good start. However, already before 1602 there were regional companies that undertook journeys to East Asia (Roos, 1987, pp. 16-17). The event that marked the beginning of Zeeland's uprising as an important destination for ships is the fall of Antwerp in 1585 (Roos, 1987, p. 16). Before 1585 Antwerp was the major port city in the area and Walcheren was only used as transit point for goods that were imported to and exported from Antwerp (Roos, 1987, p. 15). However, as the Spanish conquered Antwerp and the city fell, many merchants fled from Antwerp to Zeeland, especially Middelburg (Roos, 1987, p. 16). With Antwerp being powerless the possibilities for Zeeland opened up and it started to become an important place for maritime trade (Roos, 1987, p. 16). For these reasons the period of 1585 to 1800 was chosen.

1.3 Research Questions

Main Research Question:

> Can Walcheren's geomorphology and historical data be used for the prediction of 16th to 18th century shipwrecks in its waterscape?

Sub-questions:

> How did the waterscape of Walcheren change from 1585 to 2024?
>
> In which areas of Walcheren's waterscape were ships most likely to wreck between 1585 and 1800?
>
> In which areas of Walcheren's waterscape were ships most likely to be preserved between 1585 to 2024?
>
> In which areas of Walcheren's waterscape are ships most likely to be located and how does this compare to documented shipwreck locations?

1.4 Thesis Structure

In chapter 2 a brief description of the waterscape of Walcheren will be given. Then, a set of five historical maps will be described and their quality analyzed. Based on those maps, the changes in the waterscape of Walcheren will be interpreted. Chapter 3 will provide the foundation for the creation of the prediction maps. It will be argued based on what criteria the prediction maps will be created. Chapter 4 will present detailed methods used to create the methodology and subsequently present the results which will then be discussed. Finally, in chapter 5 a conclusion will be made and ideas for future research will be provided.

Chapter 2: The dynamic waterscape of Walcheren

2.1 General Description of Walcheren's Estuaries

The waters surrounding Walcheren are described as "highly dynamic and rapidly changing" as lies in the nature of estuaries (Meire et al., 2005, p. 1). Both the Oosterschelde and Westerschelde are relatively young estuaries, exhibiting full properties of an estuary since the 12th – 13th century (Coen, 1988, p. 157). But what is an estuary?

According to the United States Environmental Protection Agency "an estuary is a partially enclosed, coastal water body where freshwater from rivers and streams mixes with salt water from the ocean" (United States Environmental Protection Agency, 2024). As the ocean water can flow into the estuaries, they are also influenced by tides, meaning their water level rises with flood and lowers with ebb (Claessens, 1998, p. 163). These tidal currents are so strong that they erode bottom sediments from the estuaries and 'carve out' the so-called flood channels and ebb channels (tidal channels), which follow the direction of the water stream (Claessens, 1998, p. 169). These tidal channels will remain filled with water, even when the water level is at its lowest point (Vlaams-Nederlandse Scheldecommissie, n.d.-b) In between these tidal channels lay tidal flats, consisting mostly of sand and mud (Meire et al., 2005, p. 6). These flats can be intertidal, meaning they are submerged at high-tide and exposed at low-tide, or even be high enough to be supratidal, meaning they will even be exposed at high-tide (Vlaams-Nederlandse Scheldecommissie, n.d.-b). Twice every month there is a springtide, an exceptionally high tide which can also flood the supratidal flats (Vlaams-Nederlandse Scheldecommissie, n.d.-b). Additionally, the Schelde is a rainfed river which means that the river discharge changes per season, leading to a higher average in water level during the drier summer and autumn months and lower water lever during the winter and spring months (Bayens et al., 1998, p. 2).

2.2 Maps and Data

In order to understand how the dynamics of the Oosterschelde and Westerschelde changed Walcheren's waterscape since 1585, it is imperative to first examine the past waterscape by using historical maps.

For that purpose, this thesis made use of a set of historical reconstruction maps of Zeeland's bathymetry created by Menne Kosian of the Rijksdienst voor het Cultureel Erfgoed (RCE) in 2022 (Nationaal Georegister, 2022). This map set consists of four maps, each of which is a bathymetric reconstruction of the waterscape of Zeeland from 1600, 1700, 1800 and 1900 (see appendix Figs. A9, A10, A11, A12). These maps were each created by combining multiple historical maps from the same period. For this, the most detailed sections of each historical map were 'cut out' and then 'pieced together' to create four puzzle-like maps (Kosian, 2009, pp. 2-17). These reconstructions formed the foundation for describing and analyzing the changes in the waterscape.

To verify the accuracy of the reconstruction maps, I collected 31 historic maps that depict Walcheren and its surroundings for the period from 1585 to 1800 as a basic set of maps of which I selected five to be used for analysis. These were chosen based on regular time-intervals, the level of detail and the extent of change in the waterscape, so that all major changes during the whole period are represented. The following five maps have been used: the first one from 1585 by Lucas Janszoon Waghenaer (see Fig. 3), the second one from 1635 by Willem Janszoon Blaeu (see appendix Fig. A1), the third one from 1655 by Nicolaes Visscher (see appendix Fig. A2), the fourth one from 1744 by Isaak Tirion (see appendix Fig. A3) and the fifth one from 1810 by John Luffman (see appendix Fig. A4). I then used these five maps to describe and analyze the changes in the waterscape alongside the reconstructed maps, as they provide names of geographical features.

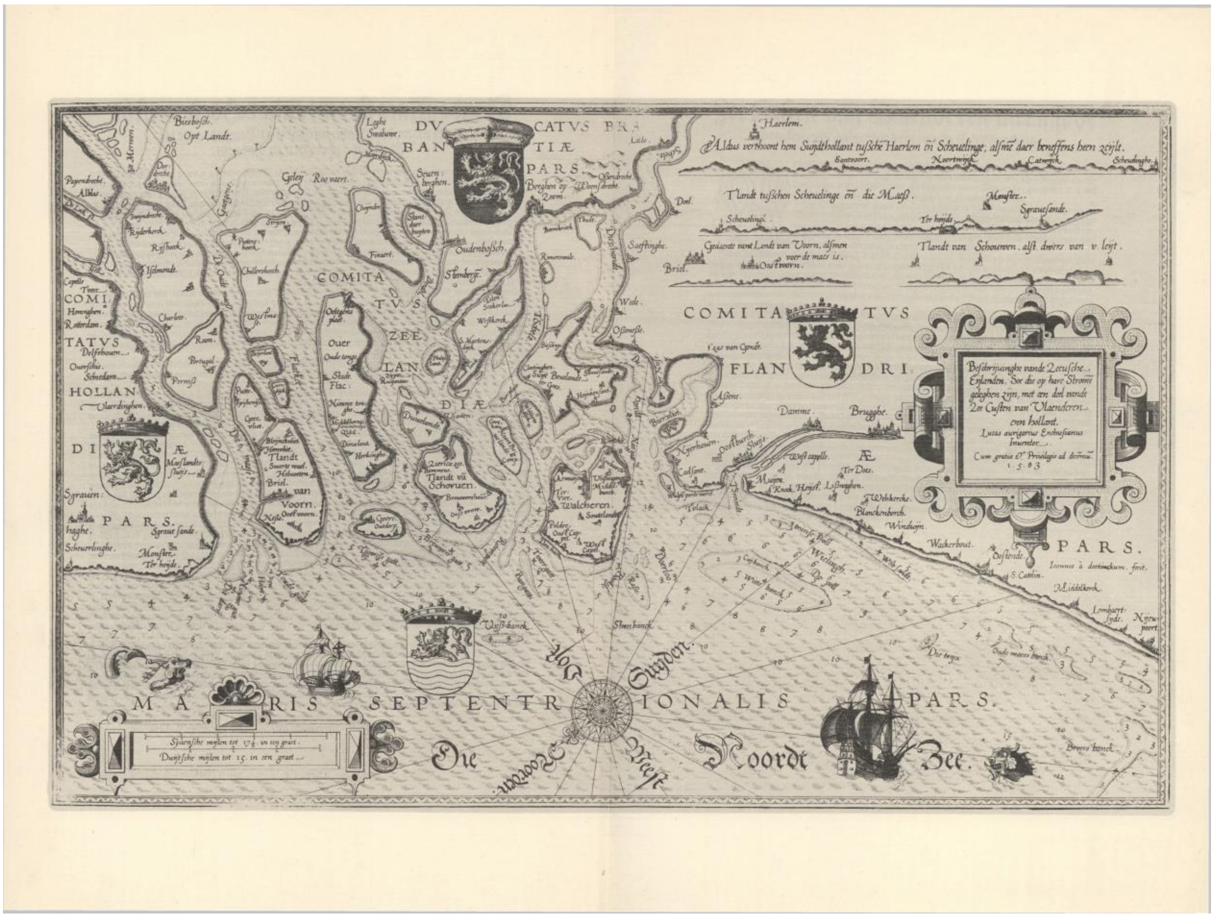


Figure 3: Map of Zeeland from 1585 by Lucas Janszoon Waghenaer. (Waghenaer, 1964, p. 59 https://www.vliz.be/imisdocs/publications/ocrd/225149.pdf)

Lastly, I used a current bathymetric map of the water depth of Zeeland to compare with the reconstructed water depth from 1600 to 1900. As this map is updated every week, this thesis worked with the map created on May 17th, 2024. This map was provided to me by the Ministry of Infrastructure and Water Management of the Netherlands (Rijkswaterstaat).

2.2.1 Data Quality

To be able to make conclusions about the quality and accuracy of both the historical maps as well as the reconstruction maps, it is necessary to understand how historic nautical charts were created and for what purpose.

Nautical charts from the 16th to the 19th century were mainly created for navigational purposes, even though they were often also sold as atlases to rich merchants (Kosian, 2009, p. 1). To create a nautical chart, mapmakers would choose two fixed points in the landscape of which they knew the distance (Kosian, 2009, p. 4-5). These points could be churches, towers or permanent buoys for example (Kosian, 2009, p. 17), as can be seen in many older maps (see Fig. 3). Mapmakers could then, standing at any location from which the other two points were visible, triangulate their distance to them with the help of navigational measurement tools like the Jacobs staff, the octant and the sextant (Reeves, 1916, p. 336). Then, the location of the third point could be drawn onto the first sketch of their map.

This principle of triangulation could be used for any three locations of which two were known, as long as there was a line of sight.

This principle of triangulation was also used by the seafarers using the nautical charts for navigation. With the navigational measurement tools, they could triangulate the position of their ship and know exactly where on the nautical chart they were. As a matter of fact, the historic nautical charts were extensively used and relied upon for navigating, especially along coastlines and to get into harbours through river mouths (Kosian, 2009, p. 1). This strongly suggests that these charts were in fact very reliable and accurate, at the very least for navigational purposes.

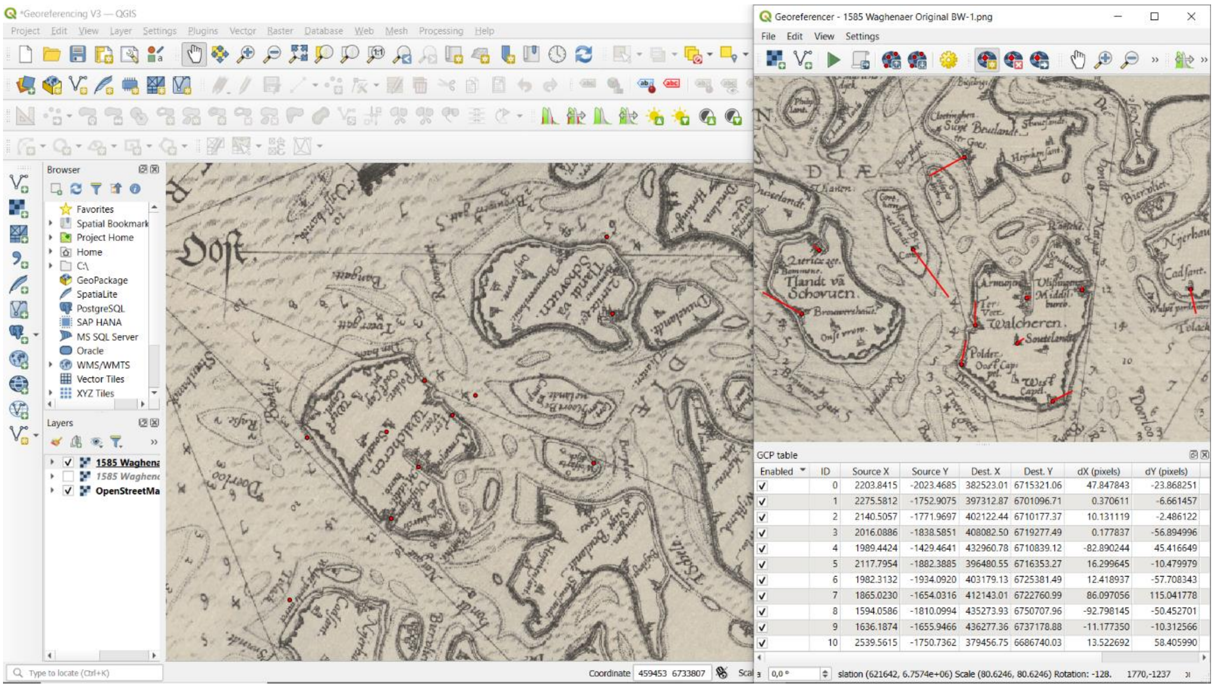
However, when examining the historic maps from 1585 to 1800 one thing becomes noticeable: the proportions of the maps, especially the older ones, and the locations of geographical features vary between the maps. To illustrate this, I overlaid the five historic maps with a modern map and then compared them. In order to overlay their actual location on the modern map, the historic maps had to be georeferenced.

Georeferencing means adding geographical information to a map, so that it can be placed over its actual location in the real world. This is done in a Geographical Information System (GIS) program, by assigning coordinates to points on the map from its respective real-world location. The software then calculates and places the map on top of its actual real-world location and saves the geographical information to the map (U.S Geology Survey, n.d.). Maps which are one hundred percent accurate only take two georeferencing points to be accurately georeferenced, although more points make it more reliable.

There are several transformations types that can be used on a map to georeference it. The three most basic transformations are positioning, scaling and rotation. These three transformations are executed by the "Helmert" transformation type. With the Helmert transformation type, reference points on the map are placed above their real-world counterparts and as some maps are not north oriented, they are rotated accordingly until all the reference points line up correctly (ESRI, n.d.). However, when a map has wrong proportions, it is not possible to line up every single reference point with its actual location. This means for example, that a city on a georeferenced map can still be on the wrong coordinates than it actually should be. Thus, maps that are disproportionate also need to be stretched or shrunk in various places to make up for this. The "Thin Plate Spline" transformation type does this by calculating distances between reference points through mathematical calculations and then stretches the map accordingly. This means that every reference point is lined up in the exact location of its real-world coordinates. The downside to this is, that the area between the georeferenced points is stretched or shrunk to fit, if the map is disproportionate. Thus, areas can be heavily deformed by the georeferencing (ArcGIS, n.d.). To prevent this, it is vital to create as many georeferencing points as possible. In any area of a map where this is not possible, and the to be georeferenced map is disproportionate, it is not possible to be one hundred percent certain of the georectification's accuracy of that area.

For the georectification of the five historic maps, that meant I had to locate points that have remained in exactly the same position since the creation of the maps – from 200 to 400 years ago. As the landscape has definitely changed and was most likely already not accurately represented in the historic maps, it could not be used for reference in this case. What did remain the same however, are churches, historic city centres and other historic buildings that have stood the test of time. This generally meant, that the landmasses containing multiple reference points were georeferenced relatively accurately, while the waterbodies remained distorted due to the absence of any permanent reference points.

For the georectification of the historic map from 1585 by Waghenaer I made two attempts: for the first attempt I used the Helmert transformation type and for the second attempt I used the Thin Plate Spline transformation type. For this, I created ten georeference points for the study area on permanent features on the historic map. Then I executed both transformation types.



Enabled	ID	Source X	Source Y	Dest. X	Dest. Y	dX (pixels)	dY (pixels)
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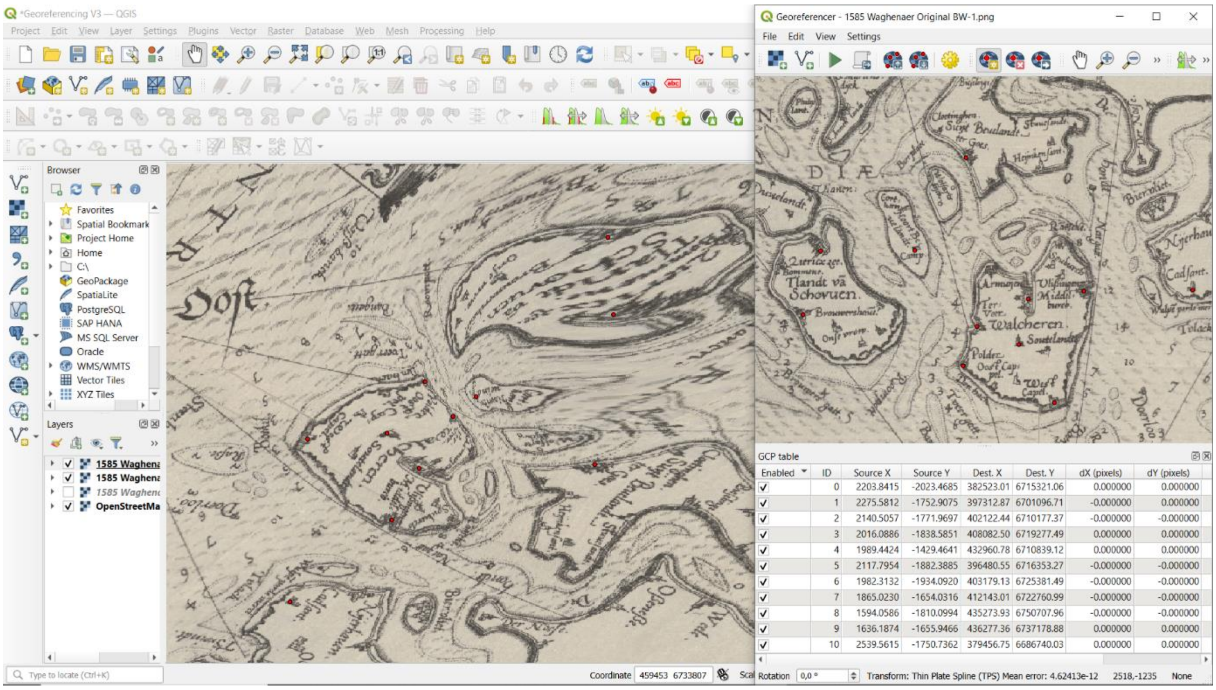
✓	1	2275.5812	-1752.9075	397312.87	6701096.71	0.370611	-6.661457
✓	2	2140.5057	-1771.9697	402122.44	6710177.37	10.131119	-2.486122
✓	3	2016.0886	-1838.5851	408082.50	6719277.49	0.177837	-56.894996
✓	4	1989.4424	-1429.4641	432960.78	6710839.12	-82.890244	45.416649
✓	5	2117.7954	-1882.3885	396480.55	6716353.27	16.299645	-10.479979
✓	6	1982.3132	-1934.0920	403179.13	6725381.49	12.418937	-57.708343
✓	7	1865.0230	-1654.0316	412143.01	6722760.99	86.097056	115.041778
✓	8	1594.0586	-1810.0994	435273.93	6750707.96	-92.798145	-50.452701
✓	9	1636.1874	-1655.9466	436277.36	6737178.88	-11.177350	-10.312566
✓	10	2539.5615	-1750.7362	379456.75	6686740.03	13.522692	58.405990

slation (621642, 6.7574e+06) Scale (80.6246, 80.6246) Rotation: -128. 1770,-1237

Figure 4: Screenshot of Helmert transformation in QGIS. The red lines show how much the individual points has to be corrected. (made in QGIS)



Enabled	ID	Source X	Source Y	Dest. X	Dest. Y	dX (pixels)	dY (pixels)
✓	0	2203.8415	-2023.4685	382523.01	6715321.06	0.000000	0.000000
✓	1	2275.5812	-1752.9075	397312.87	6701096.71	-0.000000	0.000000
✓	2	2140.5057	-1771.9697	402122.44	6710177.37	-0.000000	-0.000000
✓	3	2016.0886	-1838.5851	408082.50	6719277.49	0.000000	0.000000
✓	4	1989.4424	-1429.4641	432960.78	6710839.12	0.000000	0.000000
✓	5	2117.7954	-1882.3885	396480.55	6716353.27	-0.000000	-0.000000
✓	6	1982.3132	-1934.0920	403179.13	6725381.49	-0.000000	-0.000000
✓	7	1865.0230	-1654.0316	412143.01	6722760.99	-0.000000	-0.000000
✓	8	1594.0586	-1810.0994	435273.93	6750707.96	-0.000000	-0.000000
✓	9	1636.1874	-1655.9466	436277.36	6737178.88	0.000000	0.000000
✓	10	2539.5615	-1750.7362	379456.75	6686740.03	0.000000	0.000000

Rotation 0,0 ° Transform: Thin Plate Spline (TPS) Mean error: 4.62413e-12 2518,-1235 None

Figure 5: Screenshot of Thin Plate Spline transformation type. The image on the left shows the distortion created by the transformation. (made in QGIS)

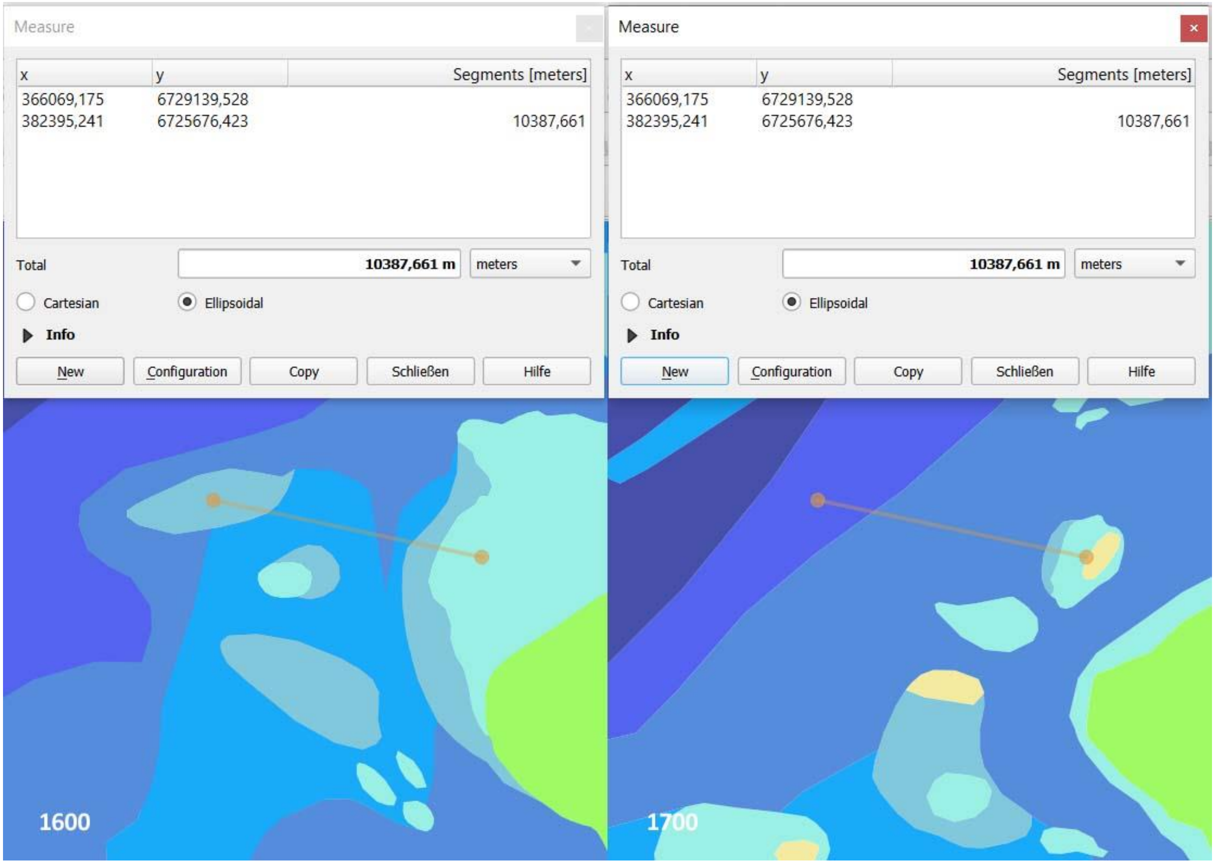
The resulting georeferenced map of the Helmert transformation type (see Fig. 4) has been positioned, scaled and rotated accurately. As expected however, the result is also disproportionate when comparing it to the modern map. The resulting georeferenced map of the Thin Plate Spline transformation type (see Fig. 5) has also been positioned, scaled and rotated accurately. However, the georeferenced map has been heavily deformed by the stretching and shrinking, because the original historic map was disproportionate. Additionally, the georeferenced map is still disproportionate, due to the lack of detail that could be used as georeference points.

Because of this, I georeferenced all the historic maps from 1585 by Waghenaer, 1635 by Blaeu, 1655 by Visscher and from 1744 by Tirion with the Helmert transformation type (see appendix Figs. A19, A20, A21, A22). This was done, as the maps were only needed for additional information and as reference, which did not require the maps to be proportionate and accurate. Even though the historic maps became more detailed with the passing of time, which would make georeferencing them with the Thin Plate Spline method more proportionate, the resulting georeferenced maps would always be disproportionate to some degree, as their original map was disproportionate to begin with.

The first historic map that I could accurately and proportionate georeference with the Thin Plate Spline transformation type was the map from 1810 by Luffman (see appendix Fig. A23). The resulting georeferenced map exhibits almost no distortion and only needed 11 reference points to be accurately georeferenced. This means, that mapmaking technologies had developed sufficiently around 1800 for nautical charts to be almost exact representations of the actual land- and waterscape, having almost precise proportions. This is also supported by a study done on the geographical history of the Thames estuary. In that research, the choice was made to only use cartography starting from 1800 to make bathymetric reconstructions of the Thames, as earlier nautical charts were not reliable enough (Burningham & French, 2011, p. 105). From this it can be concluded that the quality and accuracy of georeferenced historic maps succeeding 1800 are satisfactory and can therefore be relied upon for the description and analysis of Walcheren's waterscape in this thesis.

Basic georeferenced versions of historic maps before 1800 on the contrary, cannot be relied upon. It is for that reason, that Menne Kosian created bathymetric reconstruction maps of Zeeland's waterscape for 1600, 1700, 1800 and 1900 (Nationaal Georegister, 2022). As these reconstructions were created by combining multiple historic maps, one could presume that the reconstructions of 1600 and 1700 would be inaccurate and disproportionate. However, this is not the case. The reconstruction maps were created with the understanding in mind of how and for what purpose the original maps were created. And as already established, the historic maps were very accurate for what they were made for: nautical navigation. Thus, to make accurate reconstructions of the waterscape based on historic maps, the techniques used to create the original maps were simply used: "small part of coastline charted using triangulation and sightlines" (Kosian, 2009, p. 6-7).

This means, that each historic map was divided into small areas of coastline, which were then georeferenced. These smaller parts of the historical maps were then combined with other small parts of the same and other historic maps, based on the level of detail of the map, in order to create one large reconstruction existing of only the most detailed parts of historic maps from the same period (Kosian, 2009, p. 6-7). As the georectification of the small parts was very accurate and there could be no distortion of large areas due to the detailed and small-scale structure, the completed reconstruction maps are very accurate and have precise proportions.


Measure

x	y	Segments [meters]
366069,175	6729139,528	
382395,241	6725676,423	10387,661

Total 10387,661 m meters

○ Cartesian ● Ellipsoidal

Measure

x	y	Segments [meters]
366069,175	6729139,528	
382395,241	6725676,423	10387,661

Total 10387,661 m meters

○ Cartesian ● Ellipsoidal

Figure 6: Deviation of the location of the Rassen from 1600 to 1700. (made in QGIS).

However, there is still one concern regarding the accuracy of the historical maps and consequently also of the reconstruction maps: When comparing the location of the “Rassen” sandbank from 1600 and 1700, it is noticeable that their approximate location deviates by ten kilometres (see Fig. 6). This can already be observed between the maps from 1585 by Waghenaer and from 1635 by Blaeu (see Fig. 3 and appendix Fig. A1). It was concluded from this, that the reconstruction map of 1600 has to be treated with caution. Even though the approach used for the reconstruction of the waterscape created precise reconstructions, the reconstructions can only be as precise as the historic maps allow them to be. That means that if features on the historical map of Waghenaer for example were already charted in a wrong location, these features also appear in wrong locations on the reconstruction maps. However, since it is not yet technically possible to know what the exact formation of the waterscape looked like, historical maps are the best evidence for making such conclusions. Thus, even though the reconstruction map of 1600 might contain slight imperfections and does not provide exact locations, it still embodies a reasonably accurate representation of the waterscape of 1600. And given the fact that there are hardly any other such anomalies, the reconstruction map of 1600 can still be relied upon for analysis. It should just be acknowledged that the map might not be entirely accurate.

Nonetheless, the approach with which the historic waterscape was reconstructed, provides for bathymetric reconstruction maps of 1600 and 1700 that are proportionate and very accurate. Therefore, they can definitely be relied on for the description and analysis of the past waterscape of Walcheren. This can of course also be said for the reconstruction maps from 1800 and 1900, but seeing as the maps on which they were made were already highly accurate, there was never any doubt regarding their reliability. Lastly, the current bathymetric map of Zeeland is created with sonar and updated every week, making it also reliable (see appendix Fig. A14).

It is important to note that the water depth measurements of the historic maps, and therefore of the reconstruction maps, are less detailed as the historical maps get older. This is on the one hand due to the technique being used: a rope was cast into the water until it hit the ground to measure the depth (Reeves, 1916, p. 49). On the other hand, this was due to the frequency of the measurements: as can be seen in the map of Waghenaer (see Fig. 3) there are only few measurements, while the map of Luffman (see appendix Fig. A4) features considerably more measurements. Because of this, depth measurements of historic maps should be viewed and processed with slight caution.

Likewise, the time periods represented in the bathymetric reconstruction maps should be treated cautionary, as they were created of maps that were made roughly around that period. For example, the reconstruction map from 1600 makes use of the map from 1585 by Waghenaer (Nationaal Georegister, 2022). Thus, the reconstruction maps do not literally provide a reconstruction of the year they represent.

2.3 Description of Changes since 1600 AD

In the following, I will describe the changes in the water landscape and analyse them using the bathymetric reconstruction maps. As the reconstruction maps do not contain any names, the georeferenced historical maps were consulted to provide names for geographical features and thus created context, which made it possible to effectively describe the waterscape (see appendix Figs. A5, A6, A7, A8).

Two main trends can be derived from the reconstructions from 1600 to 1800: The first trend is that shallows and sandbanks as well as tidal channels move over time. The second trend is that many areas were reclaimed by diking off areas and then pumping the water out (Bos & Bosch, 2017, p. 19).

The two areas, where the shifting of tidal channels and shallows was probably most influential for seafarers, were the river mouth of the Oosterschelde in the north-east of Walcheren and the river mouth of the Westerschelde in the south-west of Walcheren, as any ship wanting to reach Walcheren's ports had to logically sail through either one of these. Unfortunately, as the historic maps from 1600 and 1700 were only of relatively low detail, and therefore the reconstruction maps are as well, it is not possible to indicate exact locations of main tidal channels and therefore of the main sailing routes. It is only possible to identify areas that are deep enough for ships to sail and areas that are too shallow for ships to sail. Only in the maps of 1800 and after is it possible to point out the exact locations of the tidal channels (see Fig. 3 and appendix Figs. A1, A2, A3, A4).

However, in the "Spieghel der Zeevaerdt", Waghenaer (1585, p. 58) meticulously describes all possible sailing routes to get to the ports of Walcheren and beyond. Waghenaer describes the following possible routes: ships coming from the north could sail through the mouth of the Oosterschelde, from there through the "Veergat", then through the "Sloe", where they could reach Middelburg or continue land inwards through the Westerschelde. Ships, coming from the south into the mouth of the Westerschelde had more options: they could either sail between Walcheren and the "Rassen", they could sail across the "Deurloo", across the "Spleet" or they could sail across the "Inner Wielingen". From there they could also either sail to Middelburg through the Sloe or continue land inwards on the Westerschelde (Waghenaer, 1585, p. 59).

All of the aforementioned channels were also navigable for ships in 1700 and 1800. This is on the one hand evident by the reconstructed depth maps for these periods, as the named tidal channels were still deep enough for the ships (see appendix Figs. A3, A4). Secondly, the channels were also still charted onto the maps from 1700 and 1800, meaning that they were still important and in use (see appendix Figs. A1, A2, A3, A4). The only channel that became impassable during this period, was the “Spleet”, which was not navigable after around 1700 as it became too shallow (see appendix Fig. A4). This is also confirmed by Roos, who states that the Spleet was already impassable after 1710 (Roos, 1987, p. 100). However, as he does not provide evidence or sources, the reconstruction maps from 1700 and 1800 are used for this observation. Furthermore, the river Sloe became continuously narrower from 1600 to 1800 because of land reclamations and silting (see appendix Figs. A9, A10, A11).

As the maps from 1800 onwards are much more detailed and accurate, it is possible to describe the changes in the waterscape more meticulously. The two general trends of reclamation and shifting of shallows and tidal channels are also represented in the reconstruction map of 1900 (see appendix Fig. A13) as well as the modern map (see appendix Fig, A13).

Because of this, many of the historic channels that were used by the seafarers have either changed or disappeared completely. Since 1900, the river Sloe as well as the “harbour channel of Middelburg” were silted up so much, that they were diked and the land was reclaimed. Consequently, the island of Walcheren was directly connected to the mainland and therefore ceased to be an island (Bos & Bosch, 2017, pp. 19, 95).

Yet, natural processes were not the only cause for the change in the waterscape of Walcheren: humans too had a strong influence on the waterscape. With the implementation of the Kreekrakdam in the 1860s the Oosterschelde was completely blocked off from the Schelde river and therefore also the inflow of fresh water. Because of the later implementation of the Deltawerken, a defense system against storm floods from the sea, the Oosterschelde was also cut off from all surrounding waters. Additionally, a flood barrier was built as part of the Deltawerken in the mouth of the Oosterschelde. Because the barrier is only closed when floods are imminent, the Oosterschelde still experiences the tides. With all these changes, the Oosterschelde is not considered an estuary anymore (Bos & Bosch, 2017, pp. 14, 23, 308). Apart from this, there has also been a significant change in the waterscape south-west of Walcheren, where the Outer Wielingen are presently the main tidal channel used for shipping. This was mainly due to the natural movement of the tidal currents and channels, but has also been dredged by humans to create a deeper and wider navigational channel (Devos et al., 2020, p. 32).

Chapter 3: Prediction Approaches

In order to determine specific areas where shipwrecks might be located, this thesis first investigates what constitutes a potential shipwreck location. To examine this, this thesis distinguishes between areas where ships might have wrecked in the past; and areas where shipwrecks might presently be preserved.

3.1 Risk Areas

Principally, a ship might wreck anywhere where there is water (Manders et al., 2017, p. 70). Therefore, it is not possible to determine, where ships have wrecked in the past. However, some underwater areas are so shallow that the risk for a ship to wreck in those areas is greater, than in areas that have a sufficient depth. Such areas, where ships were more likely to wreck, should they enter them, are referred to as “risk areas” in this research. Those areas are only considered a risk and not a cause for shipwrecks, as a ship does not necessarily have to wreck if it runs aground.

Based on the causality that ships run aground when sailing into waters that are shallower than the draft of the ships, this thesis hypothesizes that underwater areas shallower than the draft of the ships were more likely to have caused ships to wreck than areas that were deeper than the draft of the ships. This means, that shipwrecks were more likely to occur in those risk areas, than outside of them.

Risk areas are mainly defined by their depth. The depths that are considered to be risky are determined by the average draft of the ships, that is, how deep a ship is below the waterline. However, it is difficult to determine an average draft of all Dutch ships from 1585 to 1800 and there has not been any research investigating this. Thus, two VOC ships – the “Prins Willem” and the “Woestduin” – are used as precedent. The Prins Willem was built 1650 in Middelburg by the VOC chamber of Zeeland and with a length of 55,2 metres, it was the largest VOC ship in the 17th century (Roos, 1987, p. 89; MaSS, n.d.-a). Its draft of around 4 metres was therefore probably one of the deepest in terms of VOC ships from that time (MaSS, n.d.-a; VOCsite, n.d.). The Woestduin, which was built by in 1767 the VOC chamber of Amsterdam, was slightly shorter in length at 45,7 metres, but had a deeper draft than the Prins Willem at 4,3 metres (MaSS, n.d.-d). Both of these ships did also sail through Walcheren’s waterscape, as the Prins Willem was built in Zeeland and the Woestduin ran aground on the Rassen sand bank, while sailing across the Deurloo to Middelburg (Roos, 1987, pp. 89, 110).

For this research, these two ships are used representative of the approximate maximum draft of VOC ships which then lies over 4 metres. The complication with draft of ships is, that the draft naturally changes depending on the weight of its load. Thus, a definite average draft cannot be specified. However, as the reconstruction maps from 1600 to 1900 are categorized in areas of 0 to 2,5 metres; 2,5 to 5; 5 to 8 metres and so forth, it is only necessary to determine which of these categories are classified as risk areas. As a draft of over 4 metres comfortably falls into the 2,5 to 5 metre category, this category can be classified as risk area. Considering that this category also includes ships that have a draft of at least 2,5 metres – 1,5 metres less draft than the biggest ships – it is safe to assume that many slightly smaller ships also fall into this category. The fact is that there are no small ships, only ships that are smaller than the rest. Because naturally all depths shallower than 2,5 metres are risky for the ships as well, the category of 2,5 to 0 metres depth is also classified as risk area. Additionally, all intertidal areas as well as dry land areas which are bordering water are also considered risk areas.

What made the Ooster- and Westerschelde so dangerous, were not the risk areas themselves as they are inherently dangerous because they are to shallow for ships to sail, but the properties of the estuaries. Even currently, large ships are obligated to have a pilot on board for the crossing of the

Westerschelde (VNSC, n.d.-c) and nautical charts have to be update weekly to be accurate because of the rapidly changing waterscape (Vaarweginformatie, 2024). The obligation for ships to carry a pilot for Walcherens waterscape was already implemented by the VOC in 1600 (Roos, 1987, p. 97; Bos & Bosch, 2017, p. 96). Thus, it can be assumed, that the waterscape of Walcheren was already very dynamic in the times of the VOC. Therefore, the current properties of the Ooster- and Westerschelde are described and were used by this research to conclude the properties of the waterscape of the past.

What makes the estuaries so dangerous, are the rapid changing dynamics of the currents and sea floor (Meire et al., 2005, p. 1). The main influencing force are the tides wich change twice a day from ebb to flood (Coen, 1988, p. 160). With every tide a sediment layer of 2,5 centimetres is eroded from the seafbed and suspended into the waterflow, which then gets deposited somewhere else at the turn of the tide (Bayens et al., 1998, p. 6). Every two weeks even, there is a springtide which is stronger than regular ones and therefore has a greater impact on the morphology of the seabed (Claessens, 1988, p. 165). Additionally, as the Schelde is a rainfed river, the river discharge varies with the seasons. This means, that in drier months, there is less river discharge and thus a lower water level of the Ooster- and Westerschelde than in wetter months (Meire et al., 2005, p. 3). All of these factors contribute to the rapid change in the morphology of the seabed. It can therefore be perceived, that the form as well as the location of risk areas changed fast and constantly, making it more difficult to circumnavigate.

Despite the historical nautical charts being accurate and giving clear instructions on what areas to avoid, ships that entered the waterscape of Walcheren without a pilot were generally doomed. This was for example the case for the Woestduin, which ran aground the Rassen sandbank as no pilot was on board (Roos, 1987, p. 110). Pilots had a great knowledge of their area and were much more up to date about the locations of shallows, then seafarers returning from yearlong journeys.

The most important destination for ships in Walcheren was the roadstead of Fort Rammekens (Roos, 1987, p. 96). In the roadstead of Fort Rammekens the ships could anchor safely while waiting for winds coming from the east to start their journey. As the harbour channel of Middelburg was too shallow for most ships to enter, the ship’s cargo was unloaded onto smaller boats which then took it into the harbour and vice versa (Roos, 1987, p. 96).

But despite all this, despite the obligation of pilots, despite the accurate nautical charts and despite the existence of safe places like the roadstead of Fort Rammekens, ships still did manage to wreck as is evident by the many shipwrecks that have already been found (MaSS, n.d.-c). Unfortunately, there has not been much research regarding the leading causes of shipwrecks in Dutch waters in the 16th, 17th and 18th century. There has however, similar research been done regarding causes for shipwrecks from around 1600 to 1800 in the Gulf of Mexico (Garrison, 1998, pp. 303-316) and the Virgin Islands (Thomas, 2019, pp. 1-14).

The study by Garrison on the Gulf of Mexico analysed the spatial distribution of shipwrecks and their cause of sinking, to understand shipwrecking patterns (Garrison, 1998, p. 303). The study found, that many shipwrecks were caused by storms and hazards along seafaring routes. Garrison also found, that there were higher shipwreck concentrations in proximity of large ports and hazards (Garrison, 1998, p. 309). These findings also match the circumstances of Walcheren. Ships most probably would sail into the hazards through strong winds and storms, with the hazards in the case of Walcheren’s waterscape being the risk areas. This is also confirmed by the study of Thomas on the Virgin Islands in which data analysis of the most common shipwreck causes was performed (Thomas, 2019, p. 1). Thomas’ study found, that 40% of the shipwrecks were caused by hurricanes, 10% by storms and running aground and for 45% of the shipwrecks there was no documented cause (Thomas, 2019, p. 11). The only point where Thomas and Garrisons findings clash, is with the importance of hurricanes. Garrison found that hurricanes played only a small role in causing shipwrecks (Garrison, 1998, p. 309) while Thomas found that hurricanes were the main causes (Thomas, 2019, p. 11). This could be explained by the fact that the studies deal with two geographically different locations. Furthermore, as hurricanes do not occur in the Netherlands, I would argue to place hurricanes, storms and strong winds into the same category.

To sum up, storms and exceptionally strong winds and therefore natural elements were the main cause for shipwrecks, by “blowing” the ships into the risk areas where they would run aground and then wreck. This is also validated by the example of the ship the “Sandenburg” which on December 4th 1724 laid anchored at the roadstead of Fort Rammekens, when a storm blew the ship off its anchor into a sandbank, where it sprung a leak and consequently wrecked (MaSS, n.d.-b).

In order to test the hypothesis of whether or not risk areas correlate to actual documented shipwreck locations, I will create a map of the risk areas from 1585 to 1800 and compare it to a shipwreck location database (see chapter 4).

3.2 Areas of Erosion and Sedimentation

To be able to predict areas in which shipwrecks might presently be preserved, it is imperative to understand what conditions lead to preservation and what conditions lead to deterioration. There are numerous physical, chemical and biological as well as human factors and processes that influence the preservation of shipwrecks, most commonly in the form of erosion (Manders, 2017, p. 98; Wheeler, 2002, p. 1149). However, only two conditions are of interest for this research: Shipwrecks that are covered by sediments of the seabed and shipwrecks that are exposed to the seawater.

In general, it is understood that shipwrecks exposed to open seawater are eroded by physical force of currents and sediment movement as well as by biological deterioration through organisms like the shipworm. Shipwrecks that are buried beneath the seabed however, are protected from both currents and sediment movement. Biological decay still happens, but at a much slower rate. Thus, wood and therefore shipwrecks which are buried under the sand remain well preserved for very long periods as long as they stay buried (Manders, 2017, pp. 85, 91, 98; Gregory et al., 2012, pp. 139-140). This effectively turns them into time-capsules.

For the determination of areas in which a shipwreck might have been persevered, the following principle applies once again: a shipwreck can be located anywhere where water is (Manders et al., 2017, p. 70). However, based on stratigraphy and the changing seafloor of Walcheren’s waterscape, some areas can be identified that at present cannot contain shipwrecks of the period from 1585 to 1800. Consequently, areas can also be identified that have changed since that time in such a way, that the conditions of those areas enabled the possibility for a shipwreck to be preserved in it. Therefore, the likelihood of shipwrecks being preserved to the present day in those areas is higher.

To determine areas of high and low probability for the preservation of 16th to 18th century shipwrecks, this research makes use of the approach developed by Manders, van den Brenk and Kosian for their project to make prediction maps for maritime cultural heritage in the western Waddenzee. For that project, they combined multiple different datasets ranging from soil data to morphology of the seafloor, to create different maps indicating areas of archaeological and cultural heritage value. For this, they developed an approach to visualise changes in the morphology of the seabed of the western Waddenzee from 1925 to 2005 (Manders et al., 2017, pp. 4, 58-60).

The approach is based on comparing the documented water depths of a region from a point in time to the water depth of the same location in the subsequent years up to the present. It makes use of two basic maritime processes: erosion and sedimentation. If an area experiences sedimentation, i.e. when sediments are transported into the area by currents, the water depth of that area becomes shallower. If an area experiences erosion, i.e. when sediments are transported out of the area by currents, the water depth of that area becomes deeper.

In their approach, they compared the depth of the water from 1925 up to 2005, with several steps in between. From their findings, they concluded two possible outcomes that an area could have. The first conclusion they drew was that if an area had experienced erosion from 1925 to 2005, shipwrecks from before 1925 could either be located on top of the seabed or within it in 2005. Second, they found that if an area had experienced sedimentation from 1925 to 2005, there could not be any shipwrecks from before 1925 between the seabed depths of 1925 and 2005. This was also made evident by the fact that the vast majority of documented shipwrecks were located in the areas which they had found to have experienced erosion since 1925 (Manders et al., 2017, pp. 58-60).

For this research, that approach has been adapted to the waterscape of Walcheren from 1600 to 2024. On that basis, this thesis makes three conclusions regarding the influence of the changes in the morphology of Walcheren's waterscape on the preservation of shipwrecks:

If at any point in time the water depth – and thus the depth of the seafloor in which a shipwreck might be located – becomes deeper than the original water depth, the layer of sediments which either contains or protects possible shipwrecks is eroded. Consequently, any shipwreck that was buried in that layer would be exposed to erosion and decay.

On the contrary, if the water depth becomes shallower than the original water depth, the possible shipwrecks in that area will be covered by even more sediments. Those areas are very likely to contain shipwrecks that are still buried beneath the seafloor, as they are protected from erosion and decay by the sediment layers.

Furthermore, an area that was first experiencing sedimentation and is only at present experiencing erosion, has a high probability that the possible shipwrecks contained in it become uncovered and will therefore be exposed to erosion and decay (Manders et al., 2017, pp. 55-60).

Based on these conclusions and the approach developed by Manders, van den Brenk and Kosian I will create a prediction map which predicts areas where 16th to 18th century shipwrecks might presently be preserved (see chapter 4).

Chapter 4: Prediction Maps

4.1 Methods

This chapter presents the prediction maps and discusses the methods I used to create them. The maps have been created with QGIS as it is freely available and provides all necessary tools for the editing, analysis and creation of prediction maps. The reconstruction maps and the current bathymetric map were used as a basis.

To be able to run analyses on the maps, I had to convert the vector-based reconstruction maps into raster data displaying their height. The current bathymetric map was already converted into raster data with grid cells of 10 by 10 metres, and therefore I decided to use the same grid of 10 by 10 metres for the reconstruction maps, to make the analysis less complicated. The height values were already implemented into the reconstruction maps so I could convert the reconstruction maps into raster data based on their height, making them height maps.

However, there were some minor conversion errors which had to be modified. The reconstruction maps assigned a height value of 0 metres for the sublayer “marshes” and a height value of 0,5 metres for the sublayers “falling dry with ebb” and “flooded land”, which were interpreted by QGIS as non-existent data. Therefore, I assigned a height value of 1 metre to the “marshes” and a height value of -1 metre to the “falling dry with ebb” and “flooded land” sublayers. Additionally, as the bathymetric map from 2024 did not assign a height value to the dry land, I assigned it a height value of 1 metre.

4.1.1 Risk Areas

To create the risk area prediction map, I combined all risk areas of the reconstruction maps of 1600, 1700 and 1800 with water depths shallower than 5 metres in QGIS. For this, I selected the sublayers “2,5 – 5 m”, “0 – 2,5 m”, “land”, “falling dry with ebb”, “marshes” and “flooded land” separately from each reconstruction map and combined each type of sublayer with each other. I then copied all of them into one single layer called “risk areas”.

In order to test the hypothesis of there being a causal link between the location of risk areas and present shipwreck locations, I overlaid the risk area prediction map with the contemporarily documented shipwreck locations of the Archis Database. For this, I had to filter out all the relevant data from the database, as Archis contains 2273 results for the object type “Scheepvaart onbepaald”, referring to objects that are related to shipping. The results were filtered by location and date. They had to be located in either the province of Zeeland or the continental shelf zones S03, S05, S06, S08 and S10 dating to either the “Nieuwe Tijd Laat” or the “Nieuwe Tijd Midden” referring the early modern period. Then, I checked every result to eliminate all data that were not shipwrecks or were not dated to the correct period. This resulted in a total of 34 shipwreck locations. Then, I used the “Count Points in Polygon” tool in QGIS to count how many of the 34 shipwreck location points are exactly located within the risk areas of the prediction map.

Finally, I also overlaid the risk areas of each period separately with the documented shipwreck locations to count how many of the 34 shipwreck location points are exactly located in their expected risk areas. This was done to analyse the differences between risk areas of singular periods and of the total period from 1600 to 1800.

4.1.2 Preservation of shipwrecks

For the creation of the shipwreck preservation prediction map, I used the created raster versions of the bathymetric reconstruction maps of 1600, 1700, 1800 and 1900 as well as the bathymetric map from 2024. First, to make the changes of the seabed morphology visible, I compared every map with its preceding map. For that, I subtracted the height map of the younger maps from the older ones with the Raster Calculator tool in GQIS: 2008 minus 1900; 1900 minus 1800; 1800 minus 1700 and 1700 minus 1600 (see appendix Figs. A18, A17, A16, A15) The resulting height maps each compare the waterscape of the younger period to the older period and visualize the areas where the seabed was eroded and where it was sedimented.

From those height maps, I created the shipwreck preservation prediction map, which visualizes the changes in the morphology of the seabed from 1600 to 2024. This prediction map was created with the Raster Calculator in QGIS with the following calculation: 1700-1600 plus 1800-1700 plus 1900-1800 plus 2024-1900. I then overlaid this map with the documented shipwreck locations.

4.1.3 Comparison of risk areas and erosion/sedimentation

Lastly, I combined the risk area prediction map and the shipwreck preservation prediction map to create a map predicting to look for correlations. For this, I subtracted the risk area prediction map from the shipwreck preservation prediction map with the Raster Calculator in QGIS. This created a map of the risk areas with the erosion and sedimentation height data from the shipwreck preservation prediction map.

4.2 The Risk Area Prediction Map

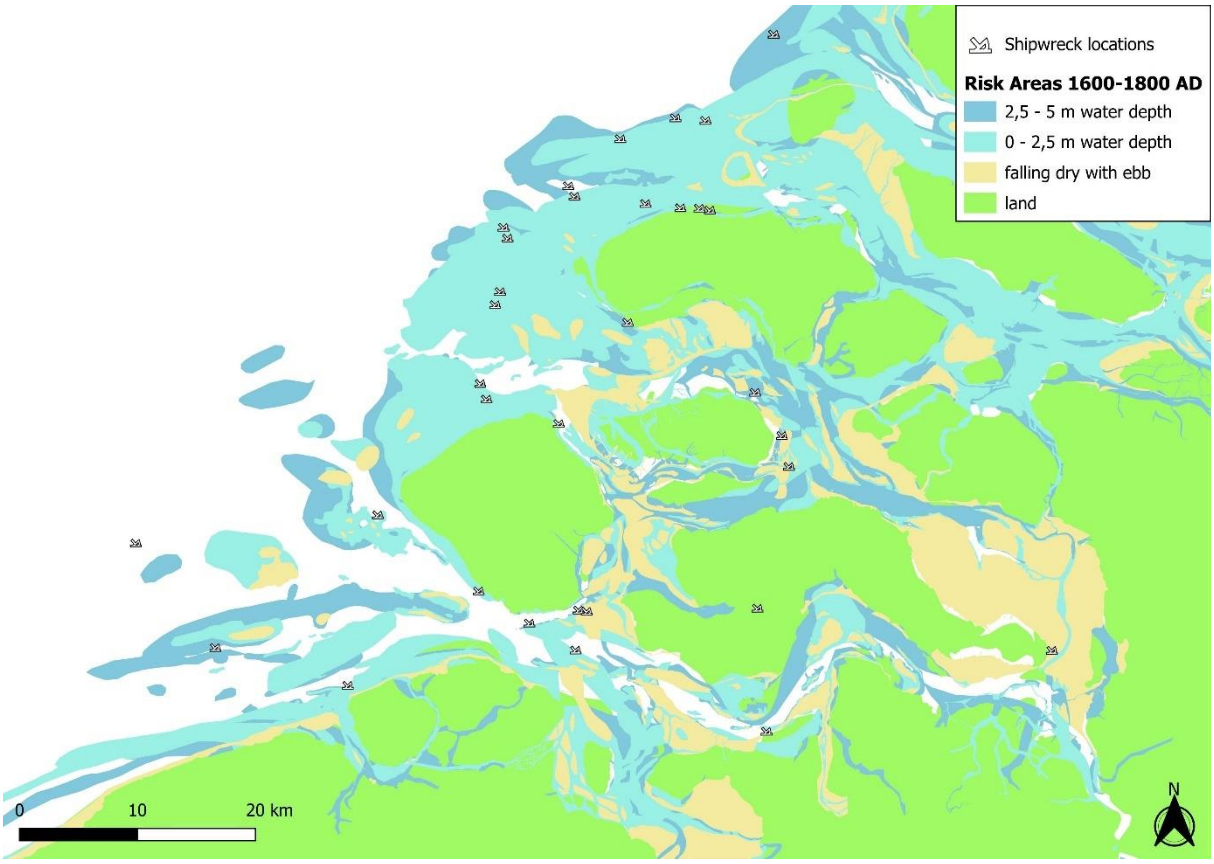


Figure 7: Risk Area Prediction Map for the Period from 1600 to 1800 AD. All shipwrecks from 1600-1800 are plotted on the map. (made in QGIS by P. Conrad)

In Figure 7 the Risk Area Prediction Map is displayed. The calculation of the documented shipwreck points resulted that 28 of the 34 points are located within the risk areas. Thus 82,35% of the contemporarily documented shipwrecks are located in the combined risk areas from 1600 to 1800 AD.

The next step is the compilation of a risk map for each period (See Figs. 8, 9, 10). Figure 8 displays the risk areas of 1600 and the documented shipwreck locations. The calculation of the shipwreck points showed that for the risk areas of 1600 AD, 19 out of the 34 documented shipwrecks are located within the risk areas which is 56%. Figure 9 shows similar results of 1700 AD. 17 out of the 34 documented shipwreck points were calculated to be within the risk areas of 1700. Therefore, 50% of the contemporarily documented shipwrecks are located in the risk areas. Figure 10 shows the risk areas of 1800 AD and the contemporarily documented shipwreck locations. It was calculated that 11 out of the 34 and thus 32% of the documented shipwrecks are located within the risk areas of 1800.

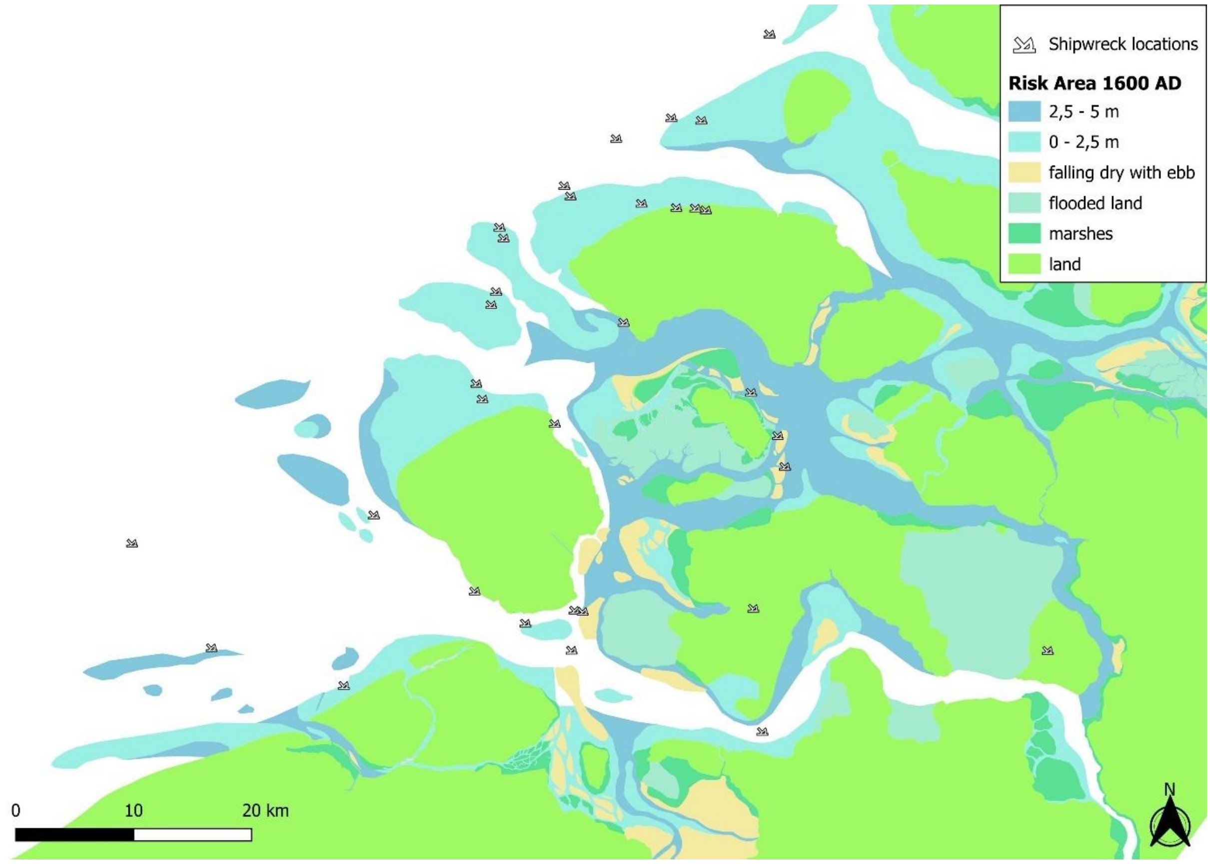


Figure 8: Risk Areas of 1600. With shipwreck locations from 1600-1800 plotted onto it. (made in QGIS by P. Conrad)

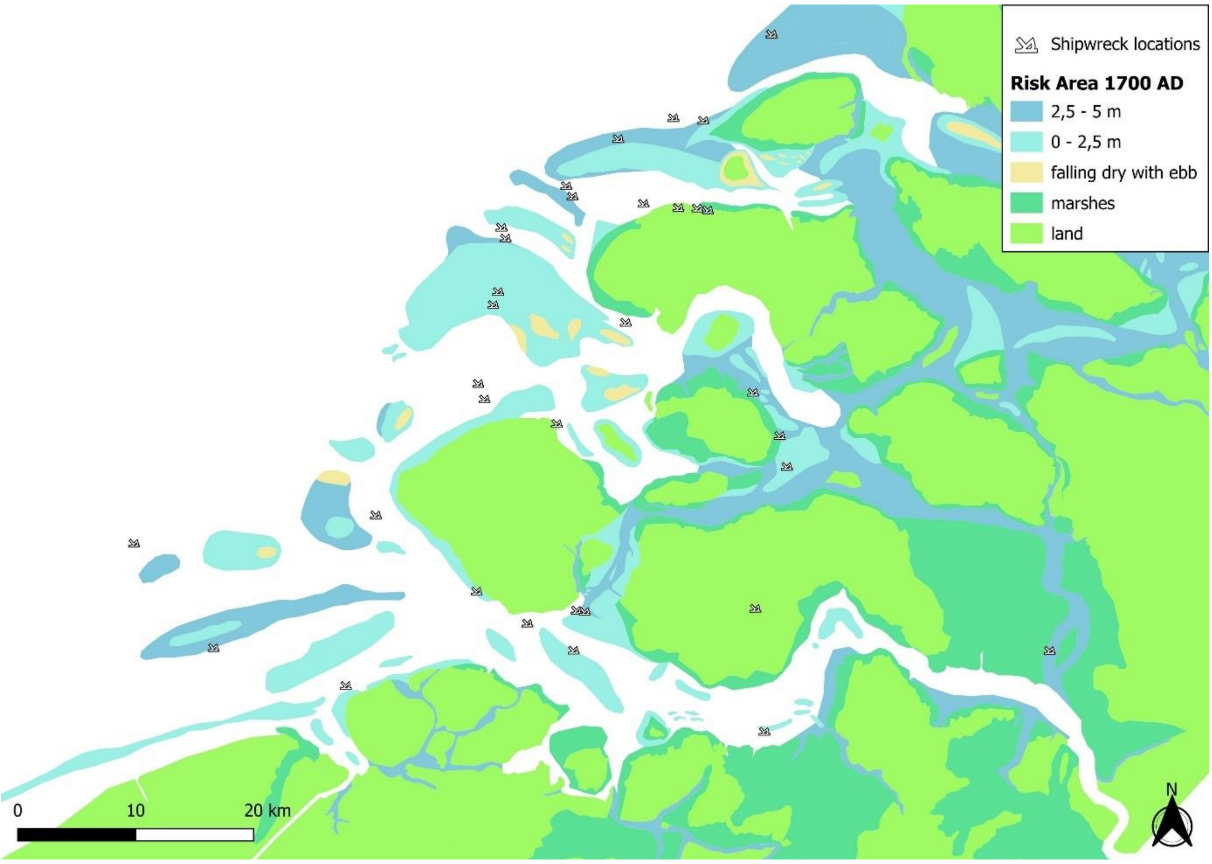


Figure 9: Risk Areas of 1700. With shipwreck locations from 1600-1800 plotted onto it. (made in QGIS by P. Conrad)

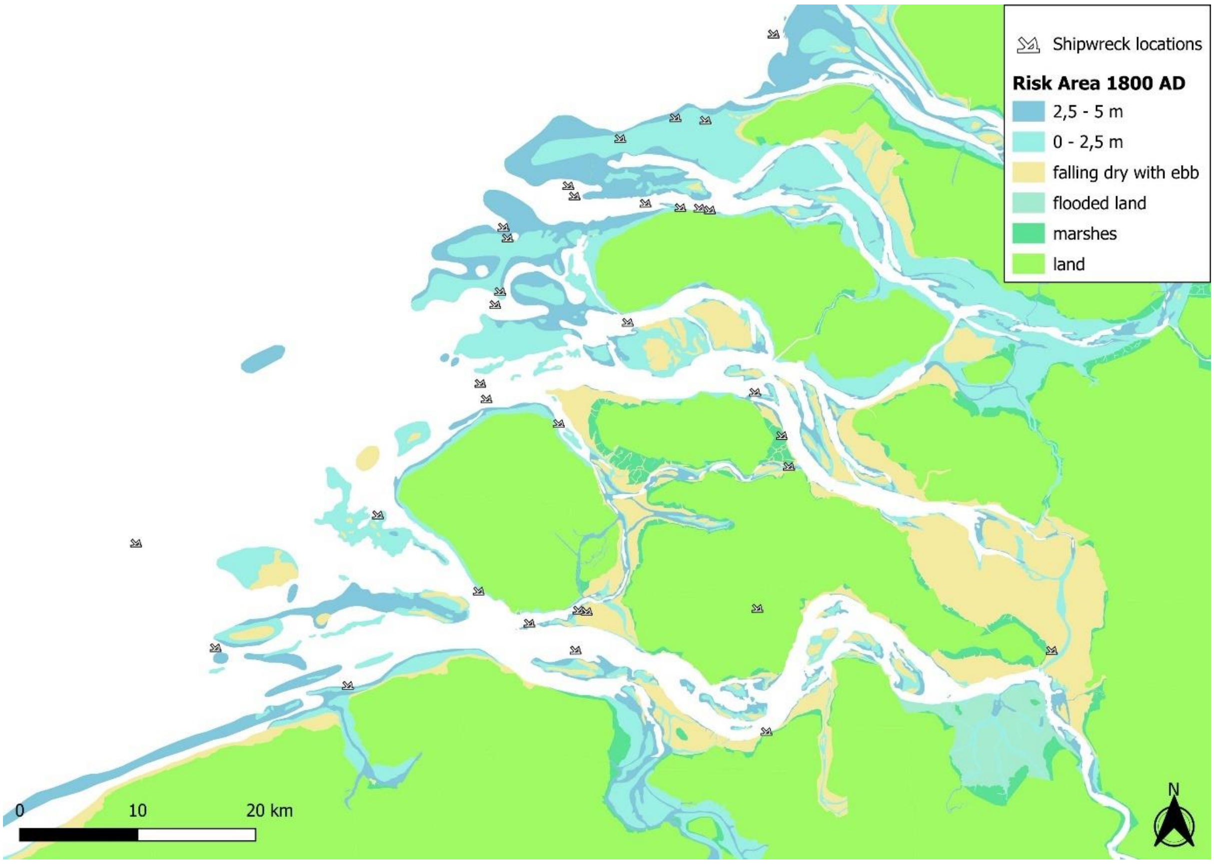


Figure 10: Risk Areas of 1800. With shipwreck locations from 1600-1800 plotted onto it. (made in QGIS by P. Conrad)

The overlap of 82,35% of shipwreck locations and risk areas in the risk area prediction map that combines all periods suggests, that there is indeed a causal relation between the risk areas from 1600 to 1800 and the current locations in which shipwrecks are found. However, as the risk area prediction map combines the risk areas of all three individual periods, it has a larger surface and thus a greater likelihood of documented shipwrecks being located within it. This might be an explanation for the higher percentages of this combination map.

Contrary to the high overlap percentage of the combined risk areas however, the overlap percentages of the individual risk areas get progressively lower from 1600 to 1800 AD. There are thus some shipwrecks, that are located in risk areas of only one or two periods. This could mean that shipwrecks of a certain period are only located within the risk area of that period and not within those of other periods. This would prove the accuracy of the risk area prediction map, but as there is not enough data regarding the age of the shipwrecks, this assumption remains hypothetical. Furthermore, the higher overlap of the older maps might also be caused by the accuracy of the historical maps. The contours of the waterscape features and the depth measurements of the reconstruction map of 1600 AD are more generalized and broader than those of the reconstruction map of 1800 AD. It is therefore logical that the risk areas of 1600 have more overlap with the shipwreck locations than the risk areas of 1800.

4.3 Shipwreck Preservation Prediction Map

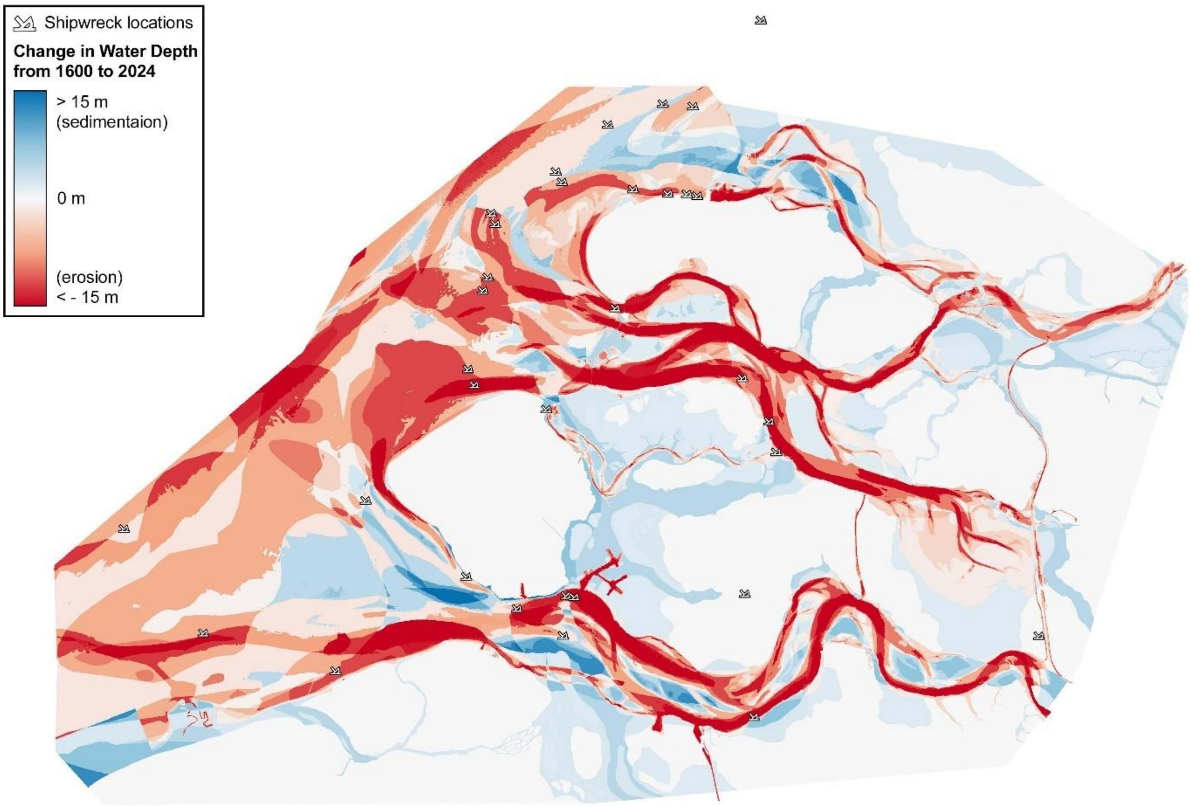


Figure 11: Shipwreck Preservation Prediction Map, with the location of all ship wrecks dating to 1600-1800 AD. Legend: red = water depth erosion since 1600, blue = water depth sedimentation since 1600. (created in QGIS by P. Conrad)

Figure 11 shows the Shipwreck Preservation Prediction Map, which indicates whether areas have experienced erosion or sedimentation from 1600 to 2024. The majority of shipwrecks is located in the red areas, that have experienced erosion. This is in line with the observation of Manders et al. (2017, p. 60) that most shipwrecks are currently found in areas which experienced erosion, as the wrecks are being uncovered from the seabed. However, the blue areas might contain shipwrecks underneath the seabed which were covered by the sediments. Two blue areas are especially promising, one in the south-west of Walcheren, as that was a place where most ships would have had to sail through if they wanted to make port at the VOC cities of Walcheren. The other one is in the east/south-east of Walcheren, where the roadstead of Fort Rammekens was located.

Based on the general trend of shipwrecks being located in the red areas I would suggest that the Shipwreck Preservation Prediction Map is accurate. It is important to note however, that as this prediction map is based on historical maps whose level of detail and accuracy might be of debate to some degree, the prediction can therefore not be a hundred percent reliable.

4.4 Risk Area Shipwreck Preservation Prediction Map

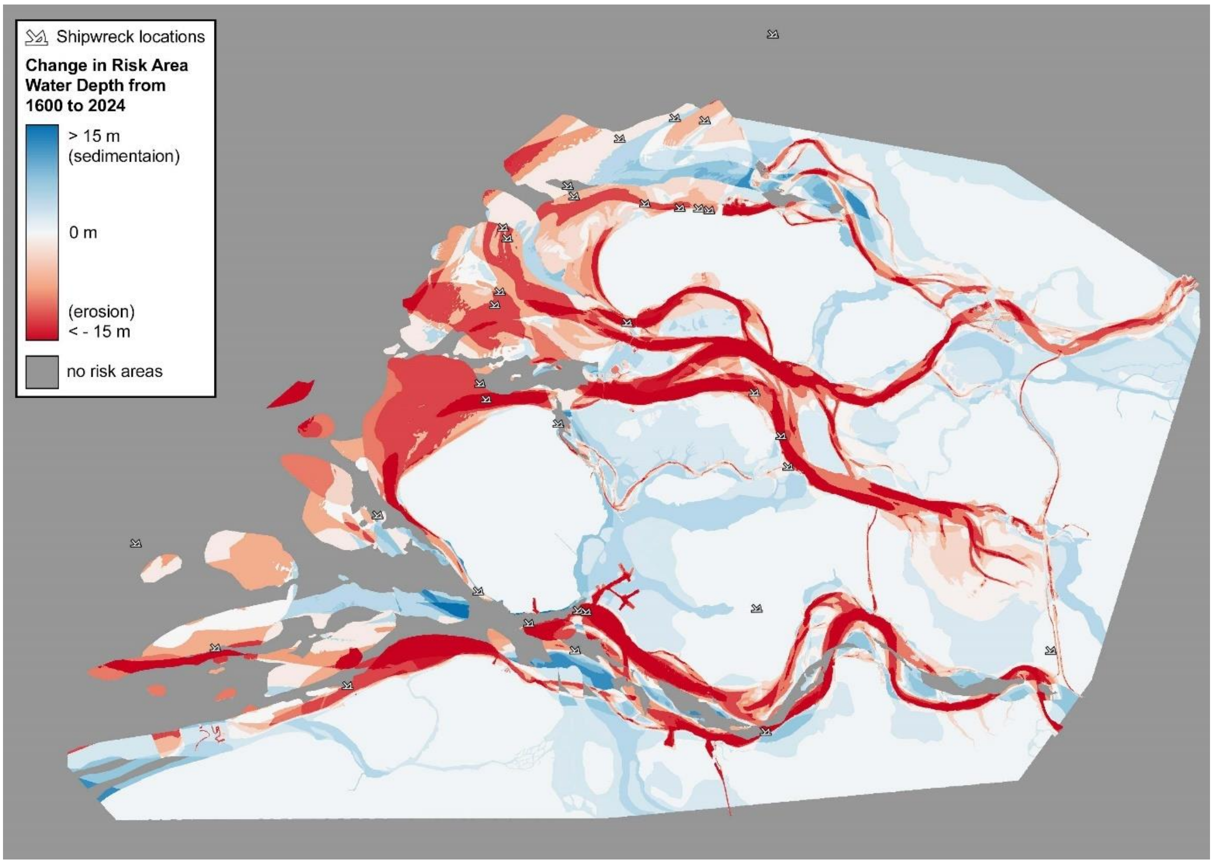


Figure 12: Risk Area Shipwreck Preservation Prediction Map, with the location of all ship wrecks dating to 1600-1800 AD. Legend: red = water depth erosion since 1600, blue = water depth sedimentation since 1600, grey = no expectation. (created in QGIS by P. Conrad)

Figure 12 shows the combination of all risk areas and areas experiencing erosion or sedimentation.

Since the prediction of both the Risk Area Prediction Map and the Shipwreck Preservation Prediction Map match the locations of documented shipwreck locations, the prediction of the Risk Area Shipwreck Preservation Prediction Map logically coincides as well. As this prediction map expects shipwreck to only be located in risk areas, it neglects all other areas. The presence of shipwrecks in the risk areas is again indicated by the colour of the area: blue sedimented areas might contain shipwrecks buried beneath the seabed, while shipwrecks might be on top of the seabed in red eroded areas. However, a ship might always appear outside of risk areas, a prediction map is not definite.

Chapter 5: Conclusion

The waterscape of Walcheren has been both dangerous and substantial for ships. From 1585 to 1800 AD, many ships found their temporary end in the everchanging depths and shallows of Walcheren. As they were quickly covered with sediments, many have been preserved to the present day. However today, these shipwrecks, being awakened from their centuries-long slumber by the erosional forces of the Ooster- and Westerschelde, they stand under great threat because of it. Biological, chemical, physical and human processes are taking their toll on the shipwrecks.

To be able to proactively protect them, it is necessary to quickly detect the shipwrecks. For this, the incorporation of prediction maps is imperative. Through the study of historical and geomorphological data I created a set of prediction maps predicting locations in which ships could have wrecked from 1585 to 1800 and locations in which they could be preserved. Through the comparison of those maps with actual current shipwreck locations, the accuracy of these maps was proven. It is important to keep in mind however, that these prediction maps are not definite evidence of shipwreck locations but rather provide general indications where shipwrecks might be located. However, I do believe that the prediction maps – especially the shipwreck preservation prediction map – produced by this research can be used both for archaeological research and as aid for the creation of policies in regard to the management of underwater cultural heritage around Walcheren.

In order to make these maps more accurate and reliable, future research efforts should focus on investigating shipwreck causes as well as mapping shipwreck locations. Most importantly, the Dutch province of Zeeland should be paid much more attention to, regarding its long and rich history, as this has not been done enough and in some ways was a limiting factor for this thesis.

Abstract

From 1585 to 1800, Walcheren was a major destination for international sailing ships in the Netherlands, as it was home to the headquarters of the VOC Chamber of Zeeland. In that time, many ships found their end around Walcheren. One of the many causes was the surrounding waterscape, which was and still is very dynamic and rapidly changing, because of which ships would run aground and eventually wreck. However, as they were also buried quickly by the sedimentation, a lot of shipwrecks has been preserved until today.

As the currents of the estuaries around Walcheren have moved over the past few centuries, the protective sediment layers on top of the shipwrecks is being eroded, uncovering the shipwrecks. On top of the seabed, the shipwrecks are exposed to decay and erosion, and thus archaeologists need to act quick. One of the approaches to proactively locate the shipwrecks before it is too late, is the creation of prediction maps.

This research has studied the changes in the morphology of the waterscape of Walcheren from 1585 to 1800, based on historical maps and bathymetrical reconstructions. These were combined with historical data of shipping routes and average drafts to create so-called risk areas that ships, if they were to sail into it, had a high a likelihood of running aground and consequently wrecking.

Based on the reconstructed and modern bathymetry, this research analysed the change in the waterscape from 1585 to the present. Based on this information, a prediction map was created, predicting areas in which shipwrecks are most likely to have been preserved. Both this preservation prediction map and the risk area prediction map were tested by overlaying them with contemporarily documented shipwreck locations. The results showed that the vast majority of documented shipwrecks was located in the predicted areas of both maps, proving their accuracy.

Figures

Figure 1: Study Area of the waterscape of Walcheren. Adapted from Google Earth (https://earth.google.com/web/) (made by P. Conrad)

Figure 2: Indicative Map of Archaeological Value (IKAW) 3. Created by the RCE. (https://www.cultureelerfgoed.nl/onderwerpen/bronnen-en-kaarten/documenten/publicaties/2018/01/01/bronbestanden-archeologische-kaart)

Figure 3: Map of Zeeland from 1585 by Lucas Janszoon Waghenaer. (Waghenaer, 1964, p. 59 https://www.vliz.be/imisdocs/publications/ocrd/225149.pdf)

Figure 4: Screenshot of Helmert transformation in QGIS. The red lines show how much the individual points has to be corrected. (made in QGIS)

Figure 5: Screenshot of Thin Plate Spline transformation type. The image on the left shows the distortion created by the transformation. (made in QGIS)

Figure 6: Deviation of the location of the Rassen from 1600 to 1700. (made in QGIS).

Figure 7: Risk Area Prediction Map for the Period from 1600 to 1800 AD. All shipwrecks from 1600-1800 are plotted on the map. (made in QGIS by P. Conrad)

Figure 8: Risk Areas of 1600. With shipwreck locations from 1600-1800 plotted onto it. (made in QGIS by P. Conrad)

Figure 9: Risk Areas of 1700. With shipwreck locations from 1600-1800 plotted onto it. (made in QGIS by P. Conrad)

Figure 10: Risk Areas of 1800. With shipwreck locations from 1600-1800 plotted onto it. (made in QGIS by P. Conrad)

Figure 11: Shipwreck Preservation Prediction Map, with the location of all ship wrecks dating to 1600-1800 AD. Legend: red = water depth erosion since 1600, blue = water depth sedimentation since 1600. (created in QGIS by P. Conrad)

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Figure A1: Map of Zeeland from 1635 by Willem Janszoon Blaeu. (Blaeu, 1635 https://hdl.handle.net/11245/3.772)

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Figure A3: Map of Zeeland from 1744 by Isaak Tirion. (Tirion, 1744. https://hdl.handle.net/21.12113/0B3EA9A294AD49A3A645999B4EA28E8A)

Figure A4: Map of Zeeland from 1810 by John Luffman. (Luffman, 1810. https://www.britishmuseum.org/collection/object/P_1875-0508-1582)

Figure A5: Reconstruction Map of Zeeland of 1600 with descriptions of places. (made in QGIS)

Figure A6: Reconstruction Map of Zeeland of 1700 with descriptions of places. (made in QGIS)

Figure A7: Reconstruction Map of Zeeland of 1800 with descriptions of places. (made in QGIS)

Figure A8: Reconstruction Map of Zeeland of 1900 with descriptions of places. (made in QGIS)

Figure A9: Reconstruction Map of Zeeland of 1600 AD. (screen shot from QGIS, data from Nationaal Georegister (2022))

Figure A10: Reconstruction Map of Zeeland of 1700 AD. (screen shot from QGIS, data from Nationaal Georegister (2022))

Figure A11: Reconstruction Map of Zeeland of 1800 AD. (screen shot from QGIS, data from Nationaal Georegister (2022))

Figure A12: Reconstruction Map of Zeeland of 1900 AD. (screen shot from QGIS, data from Nationaal Georegister (2022))

Figure A13: Modern Bathymetric Height Map of Zeeland of 2024. Created by P. Conrad in QGIS. Data provided by Rijkswaterstaat

Figure A14: Modern Bathymetric Data of May 17th 2024. Created by Rijkswaterstaat and adapted by P. Conrad.

Figure A15: Comparison of Water Depth of 1700 AD. minus Water Depth of 1600 AD. (created in QGIS by P. Conrad)

Figure A16: Comparison of Water Depth of 1800 AD. minus Water Depth of 1700 AD. (created in QGIS by P. Conrad)

Figure A17: Comparison of Water Depth of 1900 AD. minus Water Depth of 1800 AD. (created in QGIS by P. Conrad)

Figure A18: Comparison of Water Depth of 2024 AD. minus Water Depth of 1900 AD. (created in QGIS by P. Conrad)

Figure A19: Zoomed in screenshot of georeferenced Map of Zeeland adapted from map of 1585 by Lucas Janszoon Waghenaer. (Waghenaer, 1964, p. 59 https://www.vliz.be/imisdocs/publications/ocrd/225149.pdf). (created in QGIS by P. Conrad)

Figure A20: Zoomed in screenshot of georeferenced Map of Zeeland adapted from map of 1635 by Willem Janszoon Blaeu. (Blaeu, 1635 https://hdl.handle.net/11245/3.772) (created in QGIS by P. Conrad)

Figure A21: Zoomed in screenshot of georeferenced Map of Zeeland adapted from map of 1655 by Nicolaes Visscher. (Visscher, 1655. https://hdl.handle.net/21.12113/A886A8C177E54EECAC45D8FAED45A104) (created in QGIS by P. Conrad)

Figure A22: Zoomed in screenshot of georeferenced Map of Zeeland adapted from map of 1744 by Isaak Tirion. (Tirion, 1744. https://hdl.handle.net/21.12113/0B3EA9A294AD49A3A645999B4EA28E8A) (created in QGIS by P. Conrad)

Figure A23: Zoomed in screenshot of georeferenced Map of Zeeland adapted from map of 1810 by John Luffman. (Luffman, 1810. https://www.britishmuseum.org/collection/object/P_1875-0508-1582) (created in QGIS by P. Conrad)

Bibliography

ArcGIS. (n.d.) *How Spline works*. https://pro.arcgis.com/en/pro-app/latest/tool-reference/3d-analyst/how-spline-works.htm

Baeyens, W., van Eck, B., Lambert, C., Wollast, R., & Goeyens, L. (1998). General description of the Scheldt estuary. In Baeyens, W.F.J. (Ed.) *Trace metals in the Westerschelde Estuary: a case-study of a polluted, partially anoxic estuary. Developments in Hydrobiology 128* (pp. 1-14). https://dx.doi.org/10.1007/978-94-017-3573-5_1

Blaeu, W. J. (1635). *Zeelandia comitatus* [map of Zeeland]. Guiljelmus Blaeu & Willem Jansz Blaeu. https://hdl.handle.net/11245/3.772

Bos, K., & Bosch, J. W. (2017). *Landschapsatlas van de Oosterschelde : spiegel van verleden, venster op de toekomst* (J. Zwemer, Ed.). Bos & Böttcher.

Burningham, H., & French, J. (2011). Seabed dynamics in a lage coastal embayment: 180 years of morphological change in the outer Thames estuary. *Hydrobiologia*, 672(1), 105–119. https://doi.org/10.1007/s10750-011-0760-y

Cambridge Dictionary. (n.d.-a). Boat. In *Dictionary.Cambrigde.org.* Retrieved April 29, 2024, from https://dictionary.cambridge.org/de/worterbuch/englisch/boat

Cambridge Dictionary. (n.d.-b). Ship. In *Dictionary.Cambrigde.org.* Retrieved April 29, 2024, from https://dictionary.cambridge.org/de/worterbuch/englisch/ship

Claessens, J. (1998). Het hydraulisch regime van de Schelde. *Water: Tijdschrift over Waterproblematiek, 7*(43/1), 163-169. https://www.vliz.be/nl/imis?module=ref&refid=62567

Coen, I. (1988). Ontstaan en ontwikkeling van de Westerschelde. *Water: Tijdschrift over Waterproblematiek*, 7(43/1), 156-162. https://www.vliz.be/nl/imis?module=ref&refid=62589

Deeben, J. H. C., Derickx, W. J. B., Groenewoudt, B. J., Hallewas, D.P., Peters, J. H. M. & Rensink, E (2009). *Handleiding voor de Indicatieve Kaart van Archeologische Waaden 3e generatie & Toelichtingen op: De Globale Archeologische Kaart van het Continentale Plat De Kaart van Hoog Nederland met Afgedekte Pleistocene Sedimenten*. Rijksdienst voor het Cultureel Erfgoed. https://www.cultureelerfgoed.nl/binaries/cultureelerfgoed/documenten/publicaties/2019/01/01/bijlagen-bij-amk-en-ikaw/Handleiding+ikaw3+Noordzee+Pleistoceen+mei+2009.pdf

Devos, M., Desnerck, R., Fockedey, N., Termote, J., Termote, T., Tys, D., Van Cauwenberghe, C., Verheyde, F., Zwaenepoel, A. & Seys, J. (2020). Zeewoorden: Kombuis, het Scheur. *De Grote Rede: Nieuws over onze Kust en Zee*, 52, 29-32 https://www.vliz.be/nl/publications/zeewoorden-kombuis-het-scheur

ESRI. (n.d.). *Helmert transformation.* https://support.esri.com/en-us/gis-dictionary/helmert-transformation

Gaastra, F. S. (2002). *De geschiedenis van de VOC* (4th printed ed.). Walburg Pers.

Garrison, E. G. (1998). A Diachronic Study of Some Historical and Natural Factors Linked to Shipwreck Patterns in the Northern Gulf of Mexico. In Babits, L. E., Van Tilburg, H. (Eds.), *Maritime Archaeology* (pp. 303-316). The Springer Series in Underwater Archaeology. Springer. https://doi.org/10.1007/978-1-4899-0084-5_33

Gregory, D., Jensen, P., & Strætkvern, K. (2012). Conservation and in situ preservation of wooden shipwrecks from marine environments. *Journal of Cultural Heritage*, 13(3), S139–S148. https://doi.org/10.1016/j.culher.2012.03.005

Jacobs, E. M. (1991). *Varen om peper en thee : korte geschiedenis van de Verenigde Oostindische Compagnie*. Walburg Pers.

Kosian, M. (2009). GISing dead-reckoning; historic maritime maps in GIS. In W. Börner, S. Uhlirz & L. Dollhofer (Eds.), *Proceedings of the 13th Vienna Conference on Heritage and New Technology*.

Luffman, J. (1810). *Topographical Sketch of the Province of Zeeland From the latest surveys* [map of Zeeland]. James Ridgeway. https://www.britishmuseum.org/collection/object/P_1875-0508-1582

Manders, M. R. (2017a). *Preserving a layered history of the Western Wadden Sea: managing an underwater cultural heritage resource* [Unpublished doctoral dissertation]. Leiden University. https://hdl.handle.net/1887/58544

Manders, M. R., van den Brenk, S. & Kosian, M. (2017b). *De gelaagde geschiedenis van de Westelijke Waddenzee*. Rijksdienst voor het Cultureel Erfgoed. https://www.cultureelerfgoed.nl/binaries/cultureelerfgoed/documenten/publicaties/2014/01/01/de-gelaagde-geschiedenis-van-de-westelijke-waddenzee/De-geslaagde-geschiedenis-van-de-Westelijke-Waddenzee.pdf

MaSS. (n.d.-a). *Prins Willem*. Rijksdienst voor het Cultureel Erfgoed. Retrieved July 15, 2024, from https://mass.cultureelerfgoed.nl/prins-willem

MaSS. (n.d.-b). *Sandenburg*. Rijksdienst voor het Cultureel Erfgoed. Retrieved July 15, 2024, from https://mass.cultureelerfgoed.nl/sandenburg

MaSS. (n.d.-c). *stepping stones of maritime history*. Rijksdienst voor het Cultureel Erfgoed. https://mass.cultureelerfgoed.nl/

MaSS. (n.d.-d). *Woestduin*. Rijksdienst voor het Cultureel Erfgoed. Retrieved July 15, 2024, from https://mass.cultureelerfgoed.nl/woestduin

Meelder, D. (2014). *Scheepswrakken in de Nederlandse Noordzee: Een lange geschiedenis, maar onzekere toekomst?* Rijksdienst voor het Cultureel Erfgoed. https://www.cultureelerfgoed.nl/publicaties/publicaties/2014/01/01/scheepswrakken-in-de-nederlandse-noordzee

Meire, P., Ysebaert, T., Van Damme, S., Van den Bergh, E., Maris, T., & Struyf, E. (2005). The Scheldt estuary: A description of a changing ecosystem. *Hydrobiologia, 540*(1–3), 1–11. https://doi.org/10.1007/s10750-005-0896-8

Merriam-Webster. (n.d.). Roadstead. In *Merriam-Webster.com dictionary*. Retrieved July 15, 2024, from https://www.merriam-webster.com/dictionary/roadstead

Nationaal Georegister. (2022). *Historische bathymetrie Zeeland*. Rijksdienst voor het Cultureel Erfgoed. https://www.nationaalgeoregister.nl/geonetwork/srv/dut/catalog.search#/metadata/ade8aa87-7fa6-42e7-9750-a1d953aa680e

Reeves, E. A. (1916). The Mapping of the Earth, Past, Present, and Future. *The Geographical Journal*, 48(4), 331–346. https://doi.org/10.2307/1779762

Roos, D. (1987). *Zeeuwen en de VOC*. Stichting VOC Publicaties.

Thomas, O. L. (2019). *A Statistical Analysis of Colonial Shipwrecks in the Virgin Islands* [Unpublished term paper]. Texas A&M University

Tirion, I. (1744). *Kaart van Zeeland* [map of Zeeland]. Isaak Tirion. https://hdl.handle.net/21.12113/0B3EA9A294AD49A3A645999B4EA28E8A

U.S. Environmental Protection Agency. (2024, March 14). *Basic Information about Estuaries.* https://www.epa.gov/nep/basic-information-about-estuaries

U.S. Geological Survey. (n.d.). *What does "georeferenced" mean?*. U.S. Department of the Interior. https://www.usgs.gov/faqs/what-does-georeferenced-mean

Vaarweginformatie. (2024, July). *Elektronische Vaarkaarten*. Rijkswaterstaat. https://www.vaarweginformatie.nl/frp/main/#/page/infra_enc

Verhagen, P., Kamermans, H., & van Leusen, M. (2009). The future of archaeological predictive modelling. In H. Kamermans, M. van Leusen, & P. Verhagen (Eds.), *Archaeological Prediction and Risk Management.* (pp. 19-25). Leiden University Press. https://hdl.handle.net/1887/17627

Visscher, N. (1655). *Comitatus Zelandiae Novissima* [map of Zeeland]. C.J. Visscher excudit. https://hdl.handle.net/21.12113/A886A8C177E54EECAC45D8FAED45A104

Vlaams-Nederlandse Scheldecommissie. (n.d.-a). *Het Schelde-estuarium.* https://vnsc.eu/de-schelde/het-schelde-estuarium/

Vlaams-Nederlandse Scheldecommissie. (n.d.-b). *Slikken en Schorren.* https://vnsc.eu/themas/natuurlijkheid/slikken-en-schorren/

Vlaams-Nederlandse Scheldecommissie. (n.d.-c). *Veiligheid op het Water.* https://vnsc.eu/themas/veiligheid/veiligheid-op-het-water/

VOCsite. (n.d.). *Prins Willem (1650).* Retrieved July 15, 2024, from https://www.vocsite.nl/schepen/11191/

Waghenaer, L. J. (1585). *Teerste [-tweede] deel vande Spieghel der zeevaerdt, vande navigatie der Westersche Zee, innehoudende alle de custen van Vranckrijck, Spaignen ende 't principaelste deel van Engelandt, in diversche zee caerten begrepen* [Atlas]. Christoffel Plantijn. http://objects.library.uu.nl/reader/index.php?obj=1874-261573

Waghenaer, L. J. (1964). *Spieghel der Zeevaerdt* (R. A. Skelton, Ed.) [Atlas]. Theatrum Orbis Terrarum Series of Atlases in Facsimile. https://www.vliz.be/imisdocs/publications/ocrd/225149.pdf (Original work published 1585)

Wheeler, A. J. (2002). Environmental Controls on Shipwreck Preservation: The Irish Context. *Journal of Archaeological Science*, 29(10), 1149–1159. https://doi.org/10.1006/jasc.2001.0762

Appendix

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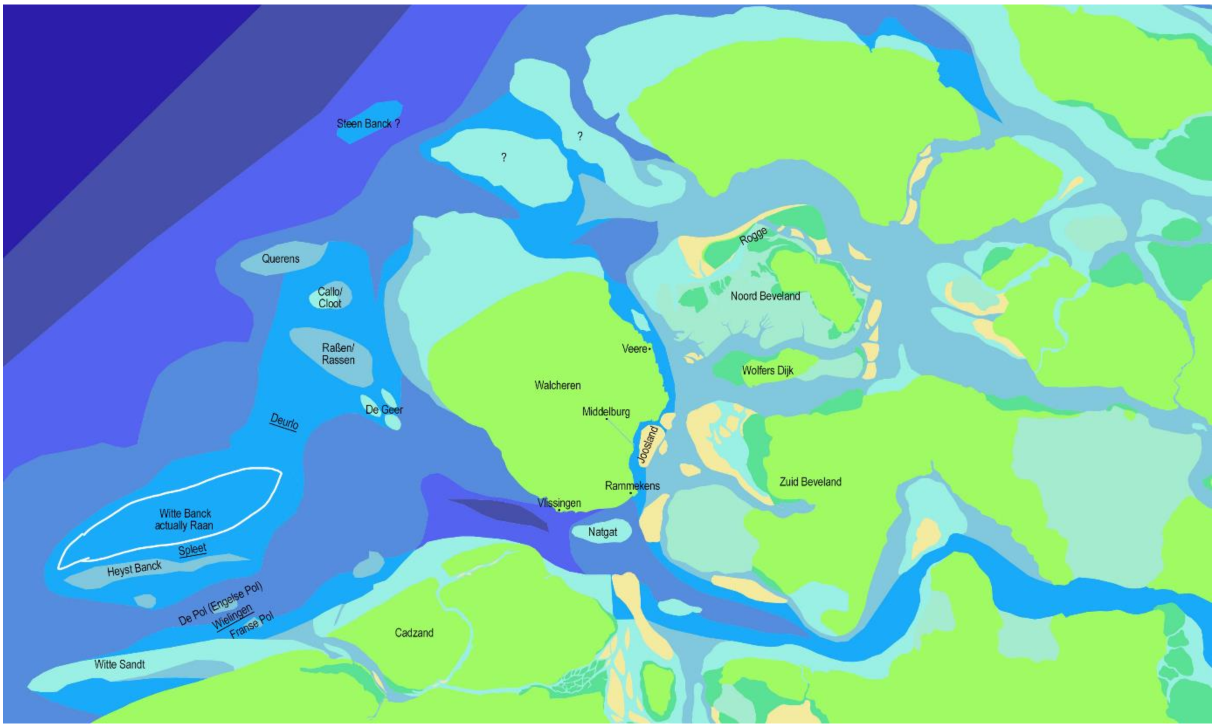

Figure A5: Reconstruction Map of Zeeland of 1600 with descriptions of places. (made in QGIS)

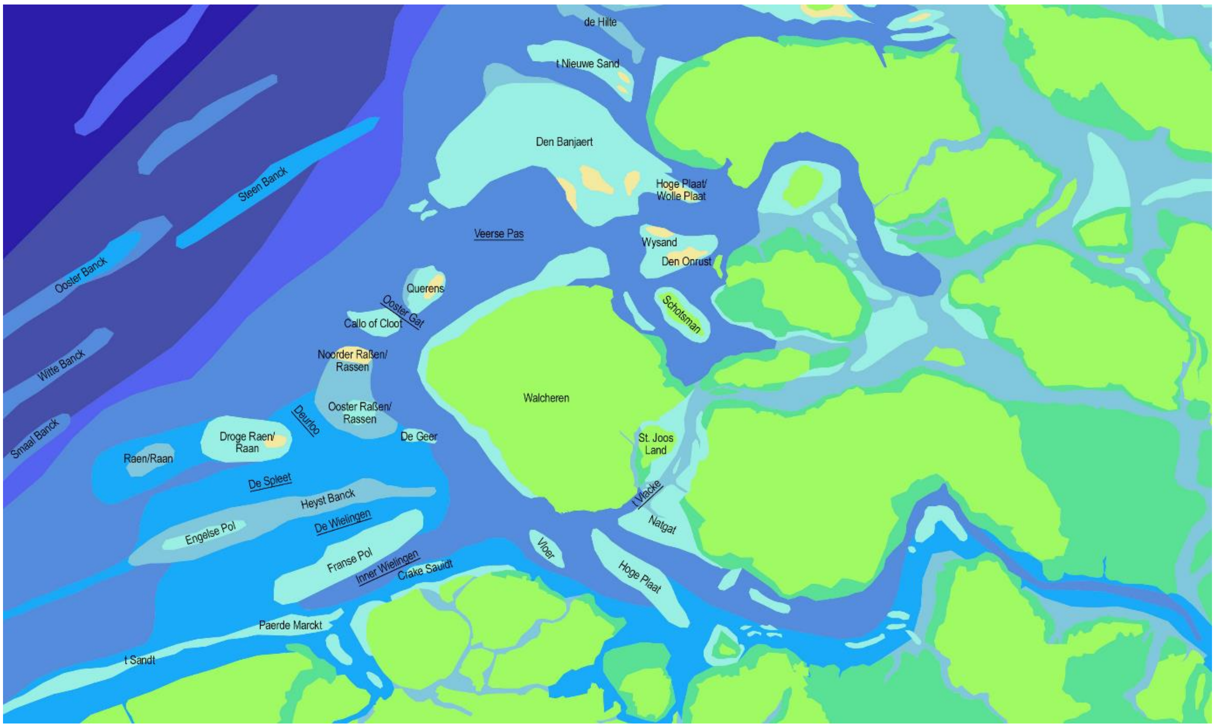

Figure A6: Reconstruction Map of Zeeland of 1700 with descriptions of places. (made in QGIS)

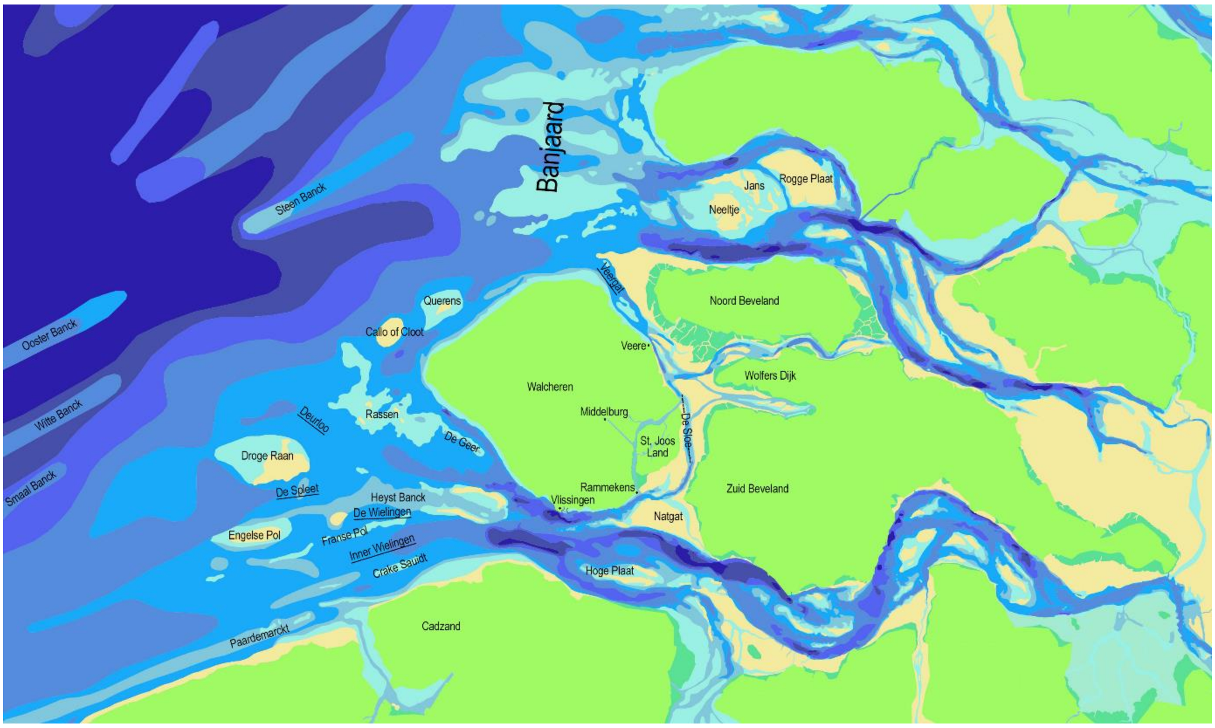

Figure A7: Reconstruction Map of Zeeland of 1800 with descriptions of places. (made in QGIS)

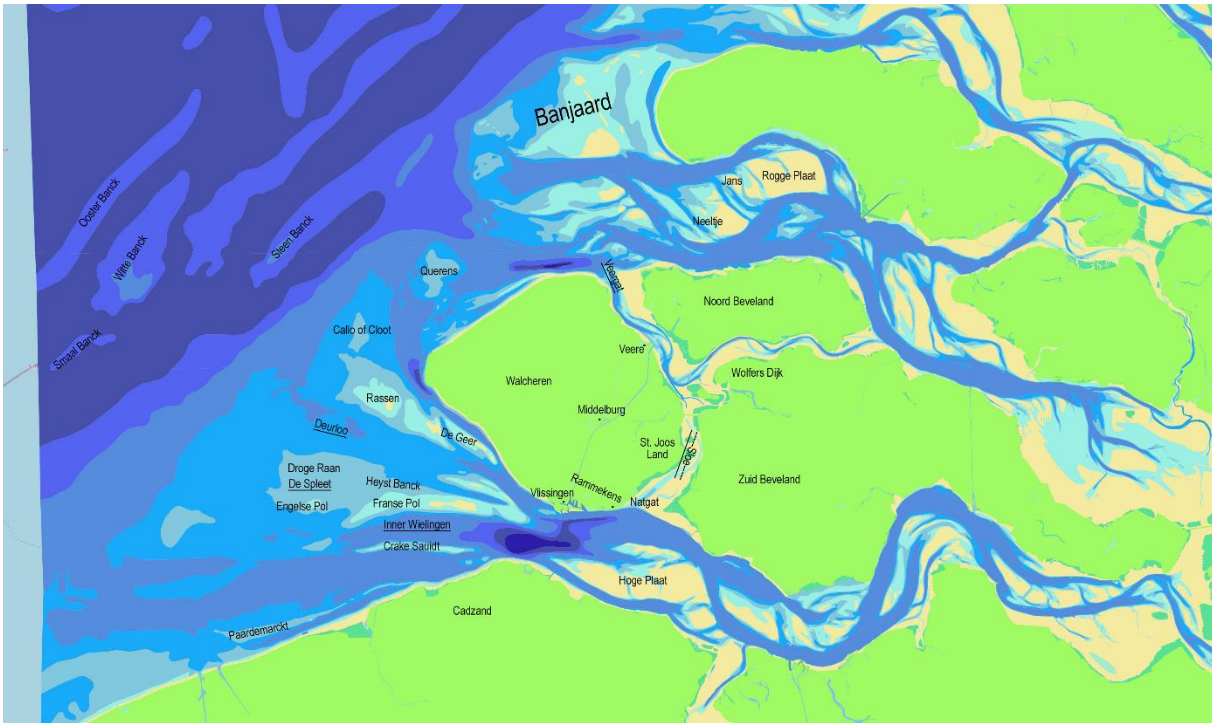

Figure A8: Reconstruction Map of Zeeland of 1900 with descriptions of places. (made in QGIS)

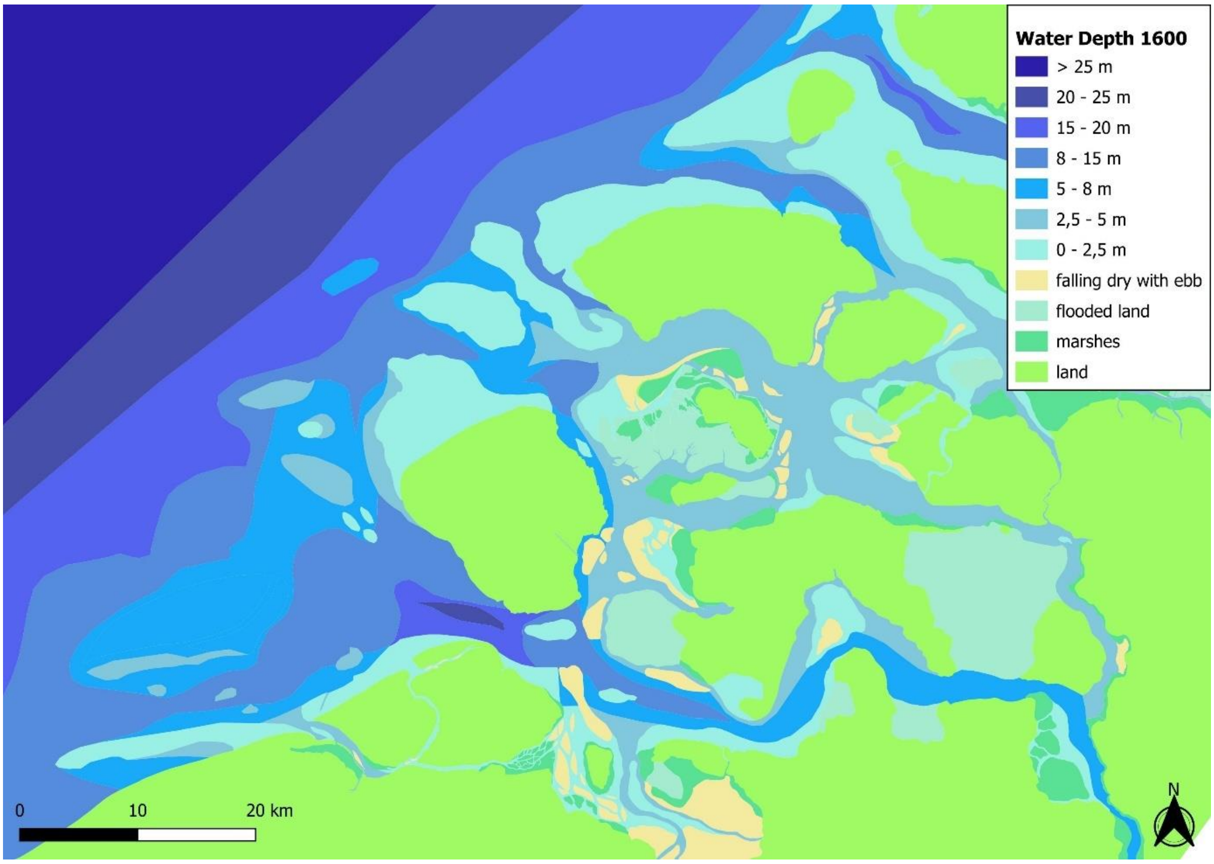

Figure A9: Reconstruction Map of Zeeland of 1600 AD. (screen shot from QGIS, data from Nationaal Georegister (2022))

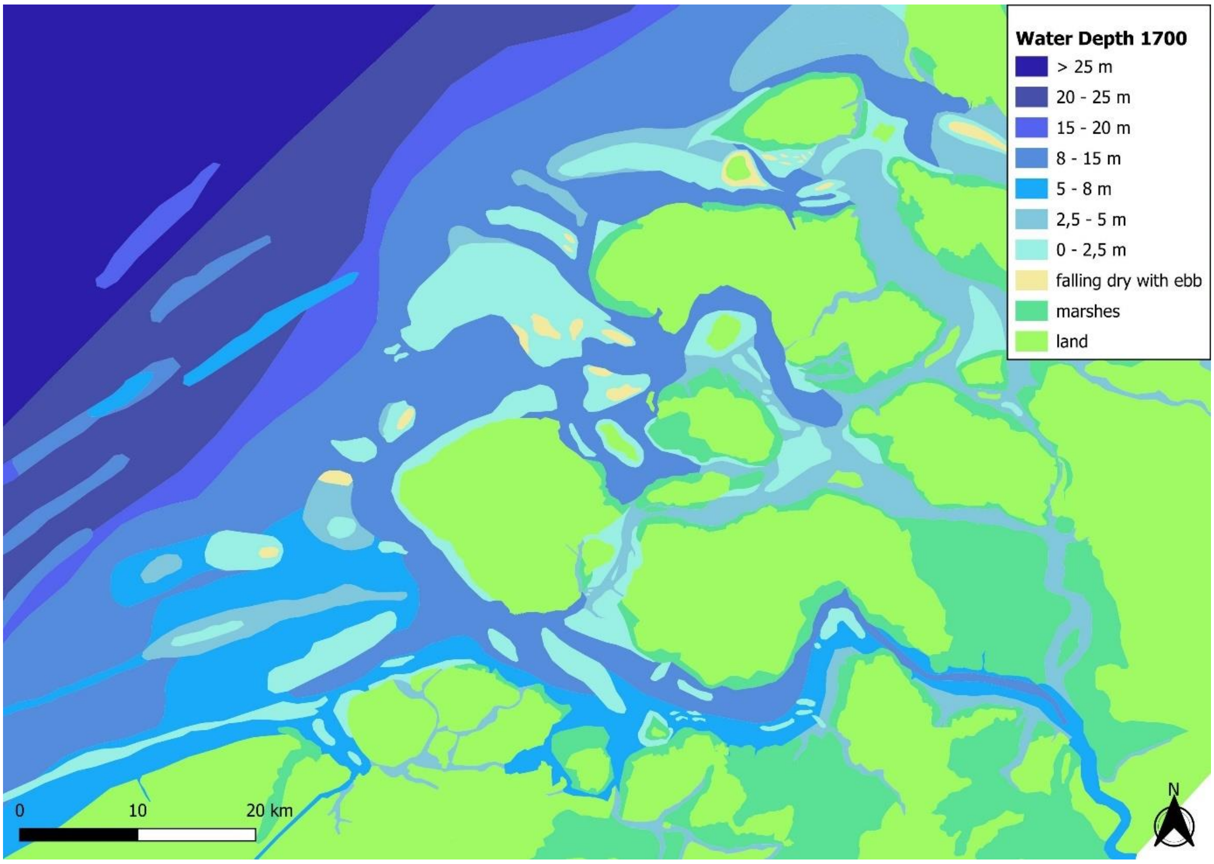

Figure A10: Reconstruction Map of Zeeland of 1700 AD. (screen shot from QGIS, data from Nationaal Georegister (2022))

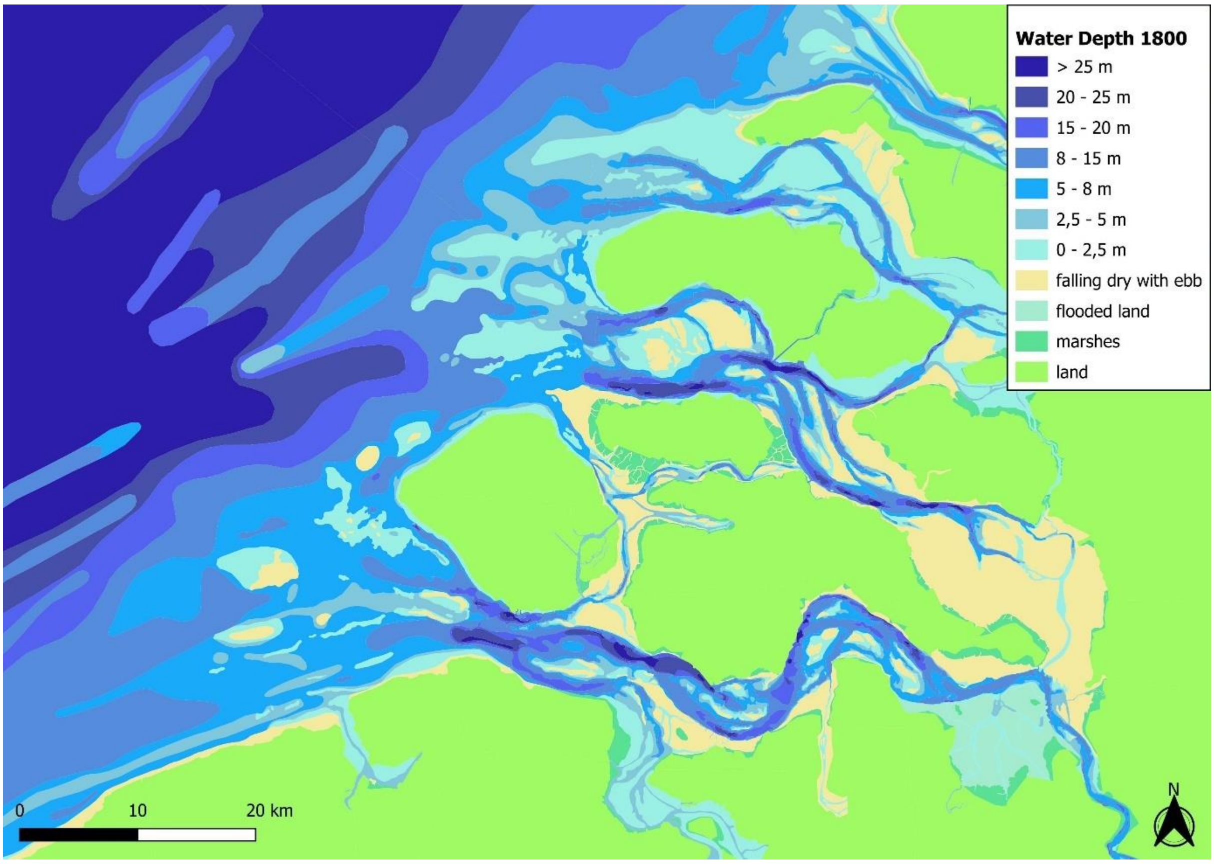

Figure A11: Reconstruction Map of Zeeland of 1800 AD. (screen shot from QGIS, data from Nationaal Georegister (2022))

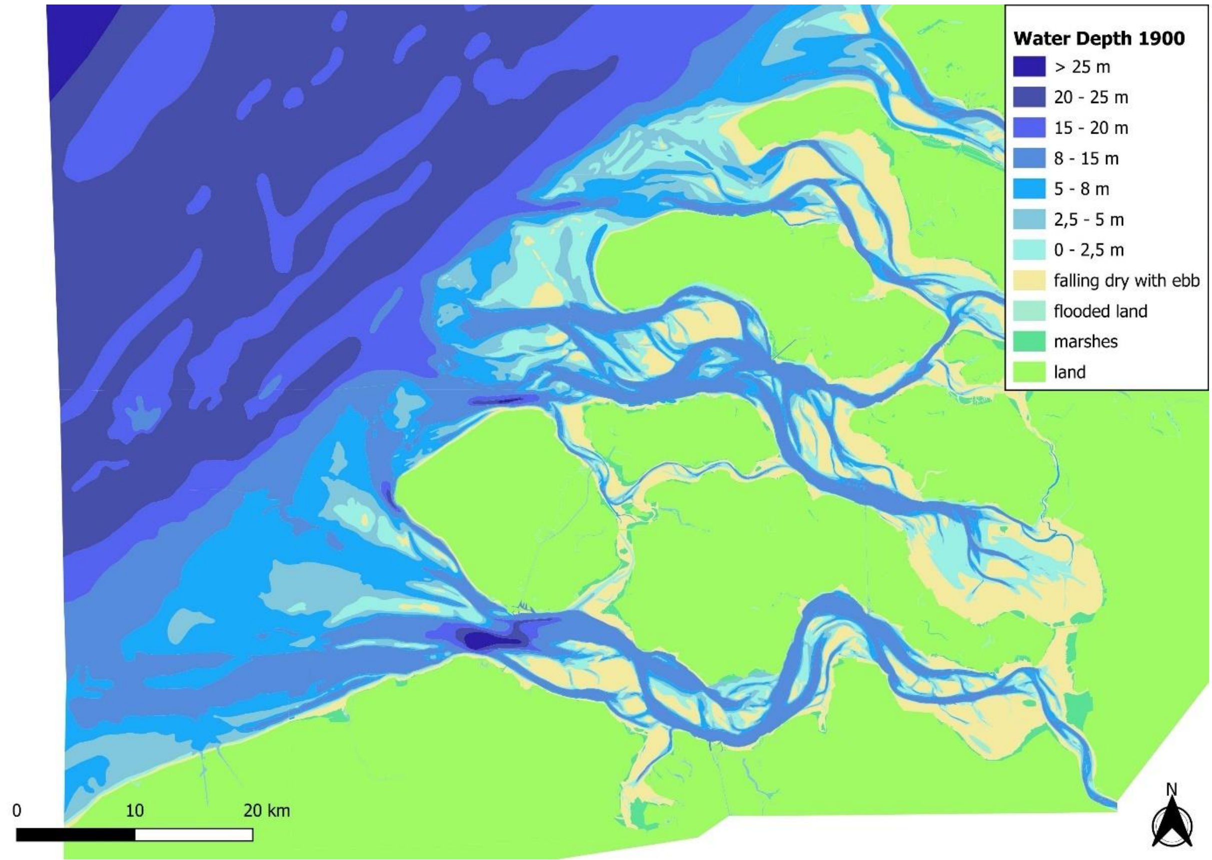

Figure A12: Reconstruction Map of Zeeland of 1900 AD. (screen shot from QGIS, data from Nationaal Georegister (2022))

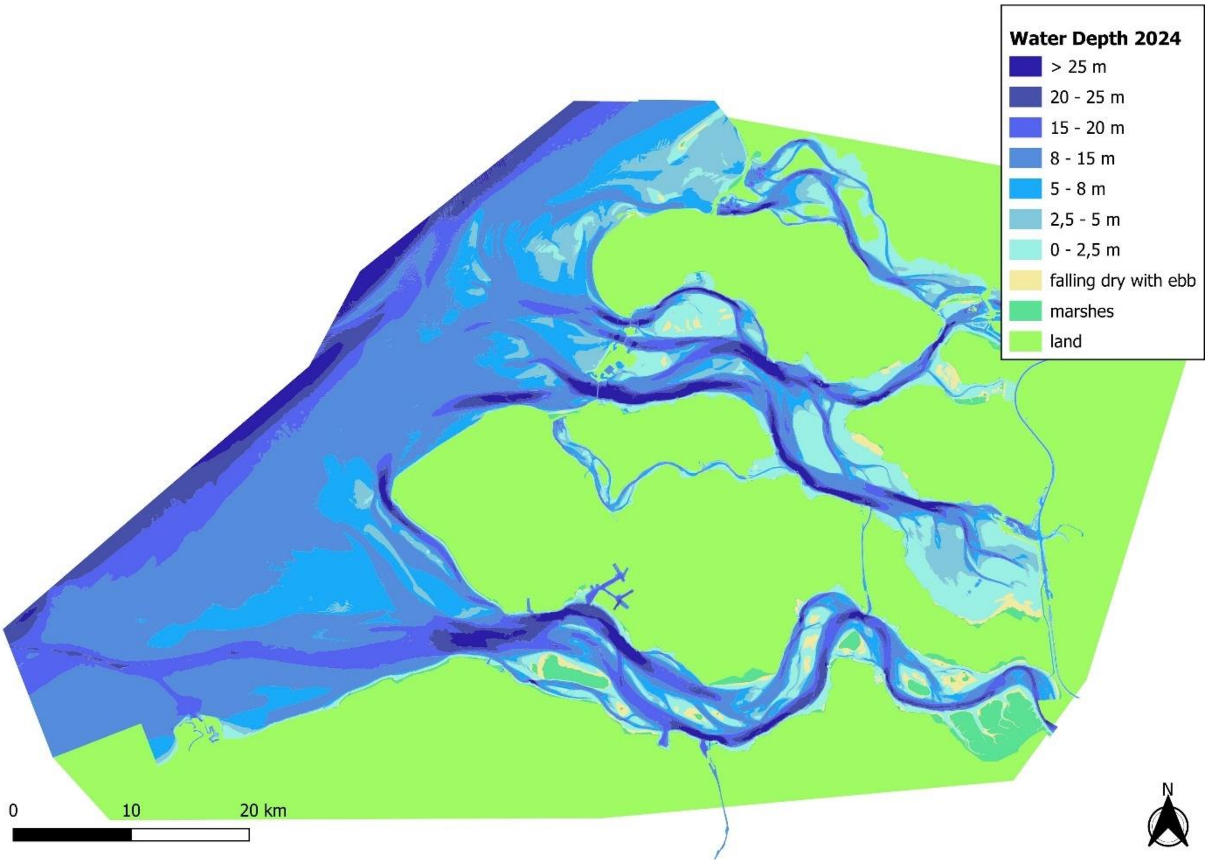

Figure A13: Modern Bathymetric Height Map of Zeeland of 2024. Created by P. Conrad in QGIS. Data provided by Rijkswaterstaat

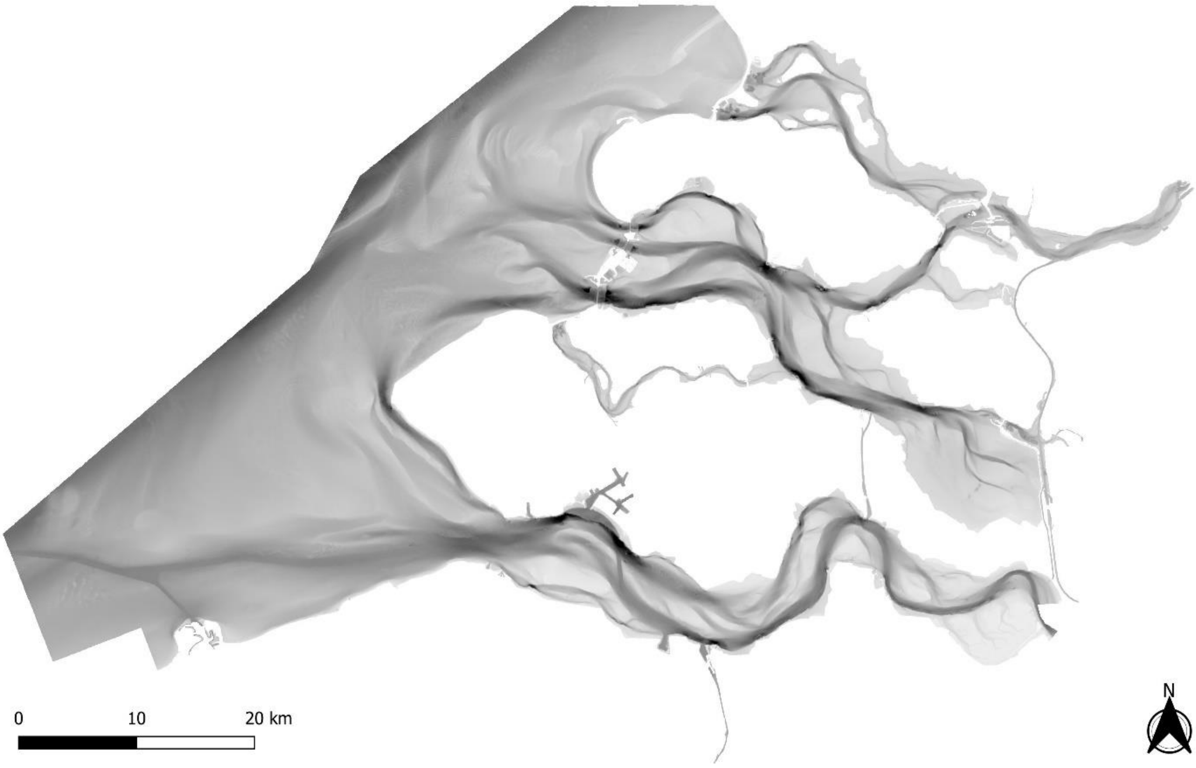

Figure A14: Modern Bathymetric Data of May 17th 2024. Created by Rijkswaterstaat and adapted by P. Conrad.

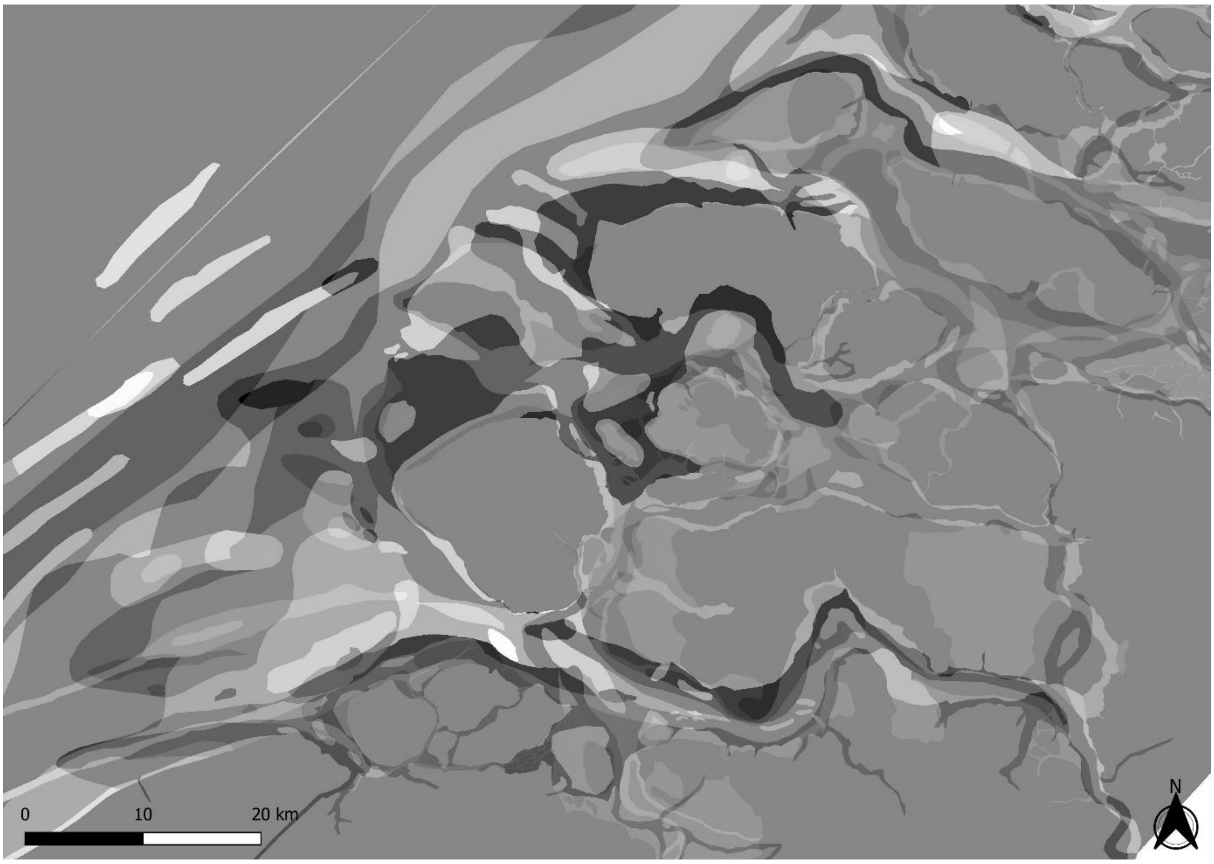

Figure A15: Comparison of Water Depth of 1700 AD. minus Water Depth of 1600 AD. (created in QGIS by P. Conrad)

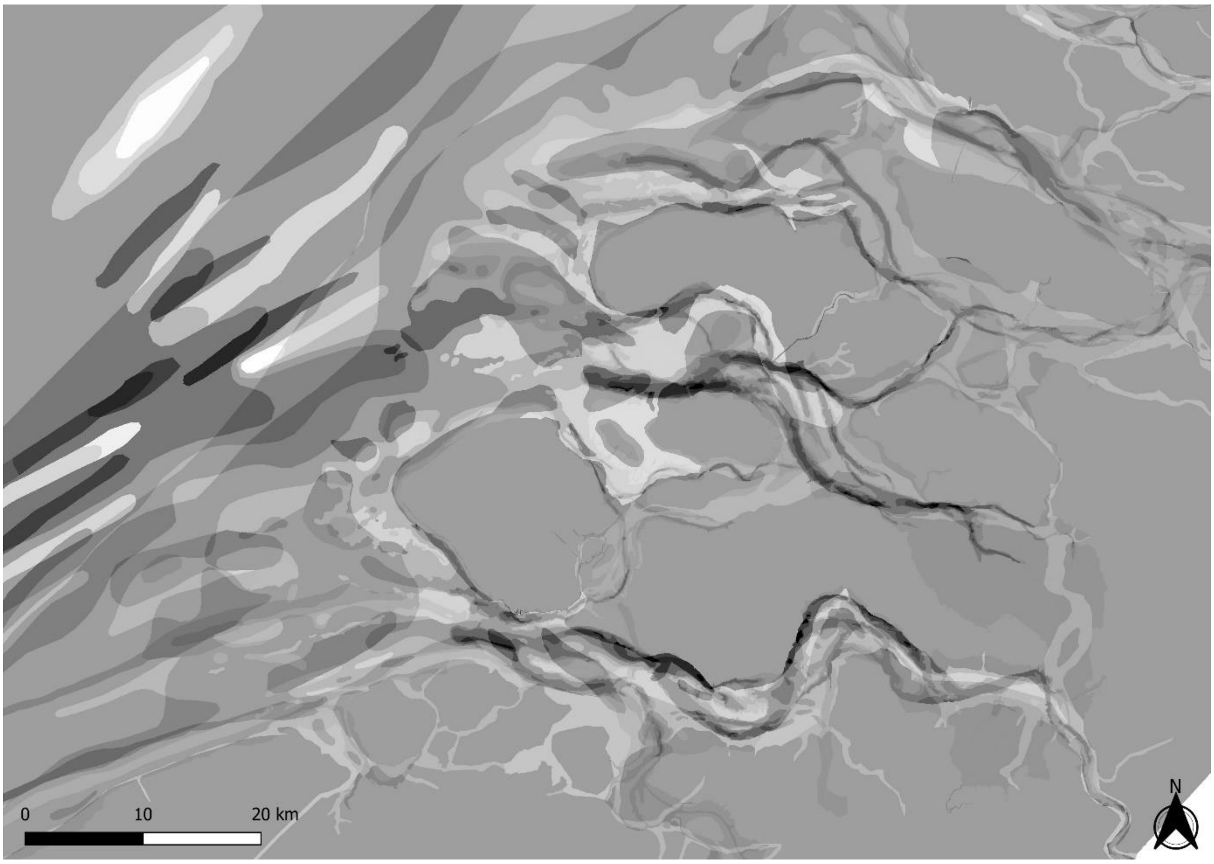

Figure A16: Comparison of Water Depth of 1800 AD. minus Water Depth of 1700 AD. (created in QGIS by P. Conrad)

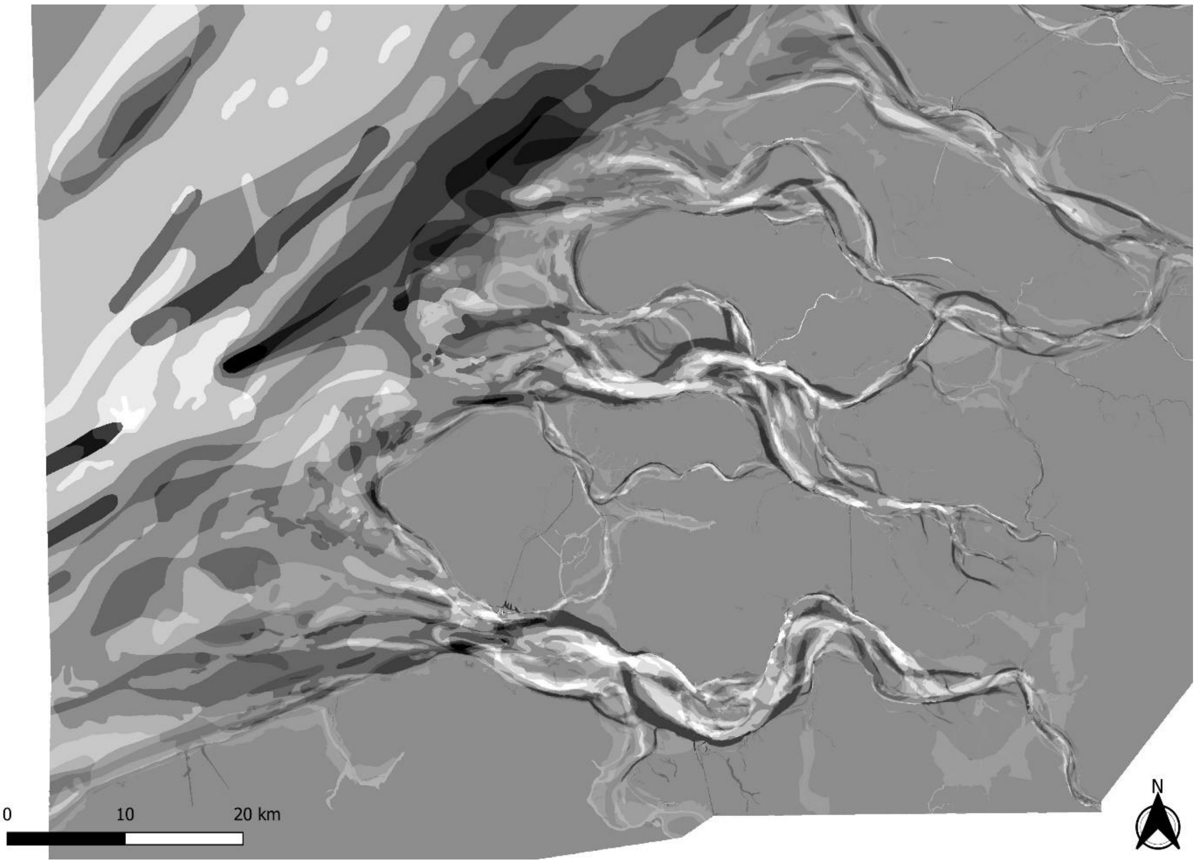

Figure A17: Comparison of Water Depth of 1900 AD. minus Water Depth of 1800 AD. (created in QGIS by P. Conrad)

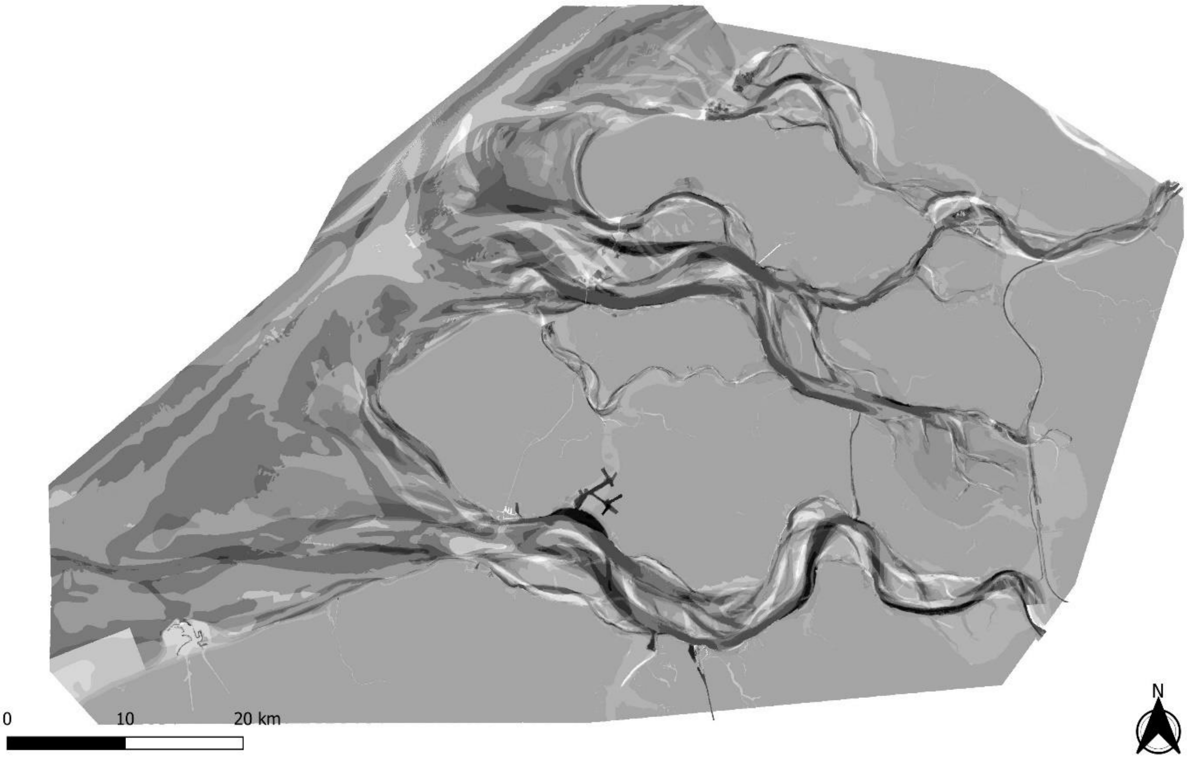

Figure A18: Comparison of Water Depth of 2024 AD. minus Water Depth of 1900 AD. (created in QGIS by P. Conrad)

Figure A19: Zoomed in screenshot of georeferenced Map of Zeeland adapted from map of 1585 by Lucas Janszoon Waghenaer. (Waghenaer, 1964, p. 59 https://www.vliz.be/imisdocs/publications/ocrd/225149.pdf). (created in QGIS by P. Conrad)

Figure A20: Zoomed in screenshot of georeferenced Map of Zeeland adapted from map of 1635 by Willem Janszoon Blaeu. (Blaeu, 1635 https://hdl.handle.net/11245/3.772) (created in QGIS by P. Conrad)

Figure A21: Zoomed in screenshot of georeferenced Map of Zeeland adapted from map of 1655 by Nicolaes Visscher. (Visscher, 1655. https://hdl.handle.net/21.12113/A886A8C177E54EECAC45D8FAED45A104) (created in QGIS by P. Conrad)

Figure A22: Zoomed in screenshot of georeferenced Map of Zeeland adapted from map of 1744 by Isaak Tirion. (Tirion, 1744. https://hdl.handle.net/21.12113/0B3EA9A294AD49A3A645999B4EA28E8A) (created in QGIS by P. Conrad)

Figure A23: Zoomed in screenshot of georeferenced Map of Zeeland adapted from map of 1810 by John Luffman. (Luffman, 1810. https://www.britishmuseum.org/collection/object/P_1875-0508-1582) (created in QGIS by P. Conrad)