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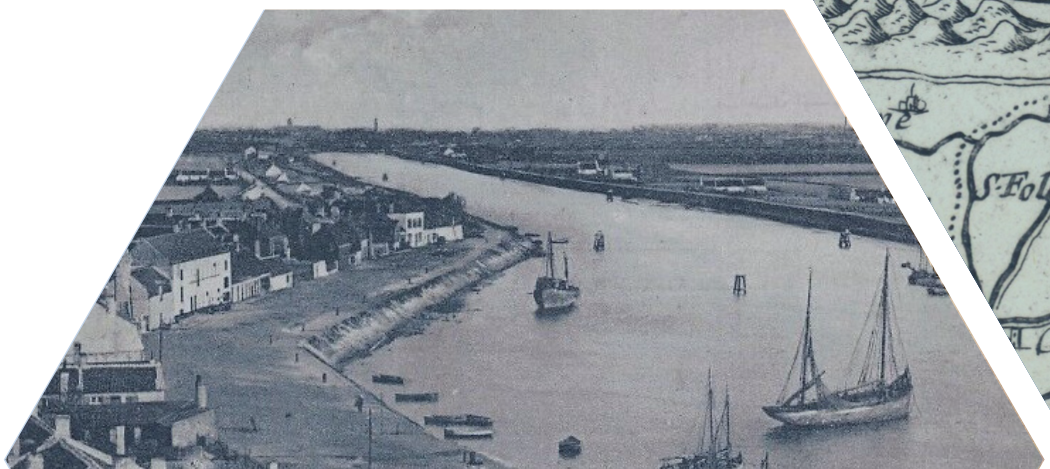
European Regional Development Fund

SARCC

Gravelines Pilot Study: Report in Support of the Maritime Atlas



Gravelines Pilot Study

Report in Support of the Maritime Atlas

Contents

1. Introduction

The Gravelines SARCC Pilot is one of seven pilot sites within the SARCC project that are developing Nature Based Solutions to coastal management in urban settings along the 2Seas coasts. Details of the Gravelines scheme will be provided on the SARCC Website: https://www.sarcc.eu/pilots. This report concentrates on presenting details in support of the Maritime Atlas which considers how data from archaeology, paleoenvironmental material, historical sources, art, charts, maps and photographs can provide vital information on long term coastal change. This, in combination with datasets on storms, flooding patterns and sea-level changes, ensures schemes incorporating Nature Based Solutions for coastal management have the full benefit of hindsight when planning for future changes.

Humans have interacted with the environment and landscape for thousands of years during which time the coastline has changed and evolved. The coast has been attractive for human use due to a wide range of social and economic reasons which include trade and defence, and in the last few centuries tourism and leisure activities. The resulting construction of settlements which have grown into urban centres and conurbations and their shoreside harbours, facilities and buildings have then required the establishment of coastal defences to prevent flooding and damage.

This report introduces the pilot area with Section 1 providing data on geomorphology, coastal processes and environmental impacts. The results of the results of the archaeological and palaeoenvironmental study are then presented (Section 2), followed by the maps and charts (Section 3) and then the pictorial resources – art and historic photographs (Section 4). The analysis of these results in combination as applied to a number of features along the Gravelines frontage then demonstrate the scale and rate of coastal change and are presented in Section 5.

1.1 Introduction to the Pilot Study Area

Gravelines is situated in the north of France at the entrance to the Aa canal and rests between the two great harbours of Calais and Dunkirk. The entrance to the canal, which reached St-Omar when it was originally constructed, has gradually silted up and can now only be accessed 2 hours either side of high water (also depending on size and draft of the vessel).

There is 1km of concrete breakwater protected channel through the beaches, then another 3km to the marina entrance. South of Gravelines the river is navigable to St-Omar, a distance of 27km. The ‘maritime waterway’ that was once managed by the Port of Gravelines is now closed since the authority was formally disbanded in 2017 and the tidal sluice gates and moveable bridges are now no longer in use.

The coastal beach area is separated from the main part of the town by heavy fortifications built to protect the inhabitants and commercial activities from the invading forces over the centuries.

Adjacent to the beach area on the eastern side of the canal is where the SARCC pilot project is being undertaken (Figure 1 & 2). A presentation provided by the Ville de Gravelines indicated how in an area around ‘Petit Fort Philippe’ an area of dunes is subject to break through and impacts from ongoing erosion. As part of the SARCC project three investments are being deployed in the area (Figure 3), these are:
Investment 1: Setting up 620m of dune ‘cordon’.
Investment 2: Redeveloping two points of access to the sea.
Investment 3: Elevation of access to the beach of the sand yacht.

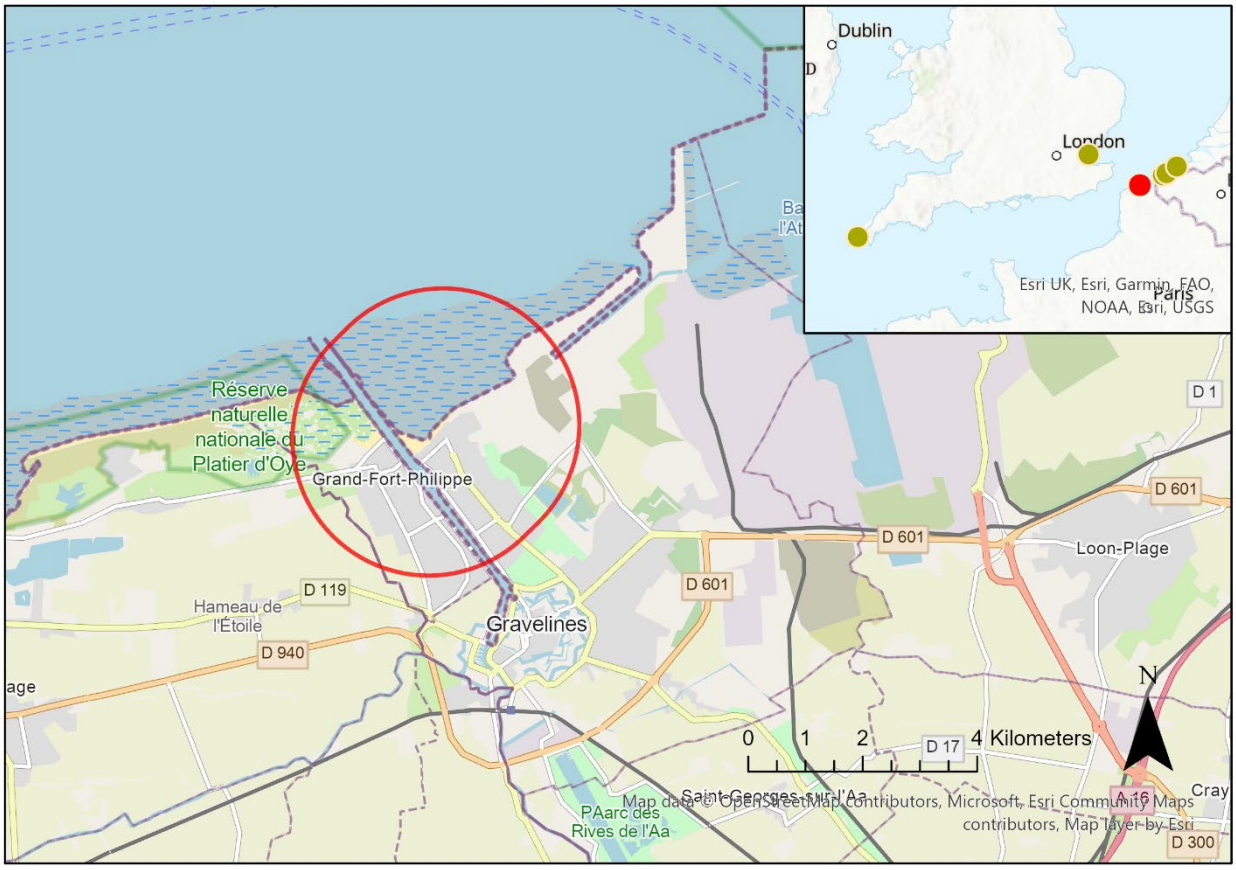


Figure 1: The location of the Gravelines Pilot Study area, inset map shows Gravelines (red) and the other SARCC Pilot Sites (green).

Figure 2: Photograph of the beach front area at Petit Fort Phillippe where the SARCC pilot is being undertaken.

Figure 3: Image produced by the Ville de Gravelines showing the three SARCC investments – red line = investment 1, blue arrows = investment 2, green arrow = investment 3.

1.2 Geology, Geomorphology and Topography of the Pilot Area

The predominant underlying geology of the region is chalk formed 66-100 million years ago in the Cretaceous period. It would have developed in warm shallow chalk seas with little sediment input from the land. The Dover strait is thought to have been formed by erosion of a land bridge that linked the Weald in Britain to the Boulonnais in Pas de Calais. This also created the White Cliffs of Dover in the UK, and the Cap Blanc Nez in France. Solid chalk had to be bored through in the construction of the Channel Tunnel.

In terms of the more recent quaternary formation the area has two many features – dune formations and bay sealing sediments (sand and mud), the coastline has no hard formation so is relatively unstable. The foreshore between Dunkirk and Gravelines is between 1 and 1.5 kilometers wide with the sand dunes reaching between 500m and 1km wide. The topography of the offshore sand banks imapacts the sedimentation and erosion mechanisms. Wide, gently sloping sandy barred beaches are a feature of the North Sea coast of France with sand banks particularly widespread in this area. They form parallel to the shore or slightly oblique around 10-30km long and 1-3km wide. From Gravelines to the Belgium border the shoreface and nearshore zones are characterised by the presence of several sand banks which belong to the Dunkirk's banks. They are 8 –32km long and 1.5 – 3km wide and up to 15-20m high with crests that may be exposed a low spring tide. Results from a study of bathymetry evolution in the area since the early 19th century by Latapy et al, 2019, found that nearshore sand banks mainly migrated onshore and gained sediment acting as temporary sediment sinks which can in turn serve as sand sources for providing sediment to the coast. The migration and elongation of sand banks alongshore can be related to tidal asymmetry mostly directed to the east-north-east in the region.

The construction of the harbour piers at Dunkirk has caused the beaches to the west to become enhanced, although the surface area of the dunes has shrunk and they have reduced in height. The sand banks systems have been a long-term feature of this coastline and they feature in a number of the maps and charts reviewed for this study, Figures 4 and 5, show the sand dunes in relation to the SARCC pilot study area. Further changes to the coastal frontage occurred from 1974 when the construction of the nuclear power station began. This advanced and changed the coastal profile between Gravelines and Dunkirk.

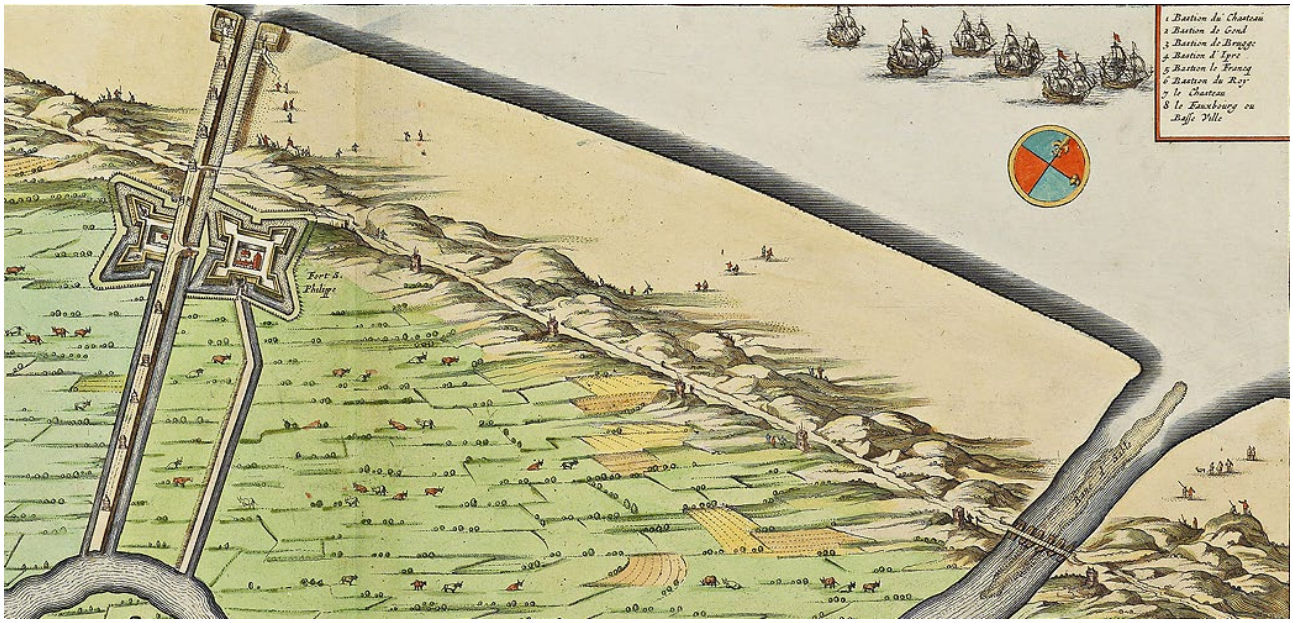


Figure 4: Close up of a map of 1698 (Atlas_de_Wit) showing detail of the coastal area and dune systems, at this time the River Aa was still the key route to Gravelines (Public domain, via WikiMedia Commons).

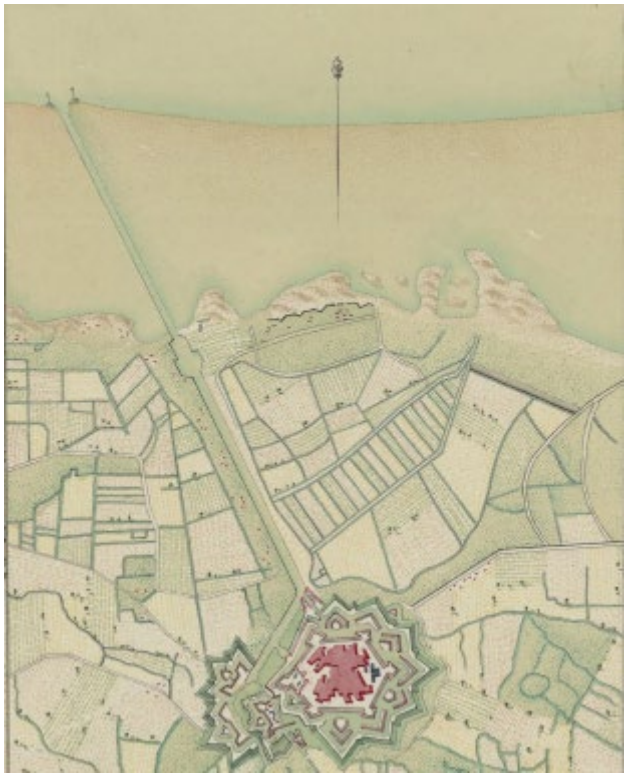


Figure 5: Plan of the Port of Gravelines from 1777 (Public domain, via WikiMedia commons), showing the canal established at the only route to the sea and no further trace of the River Aa's previous course is seen.

1.3 Storms and Flooding Patterns

As with the other channel coast SARCC pilot areas, Gravelines has a long history of impacts from flood and storm events. The presence of the nuclear power station between Gravelines and Dunkirk means that the stability of the coast here has been subject to high levels of study. Work undertaken by the Institute for Radiation Protection and Nuclear Safety and CNRS Chrono-Environment at the Universy of Besancon on the analysis of coastal risk in this area was published in 2018 (Hamdi et al, Journal Natural Hazards Earth System Science). This work included a review of past storm and flooding events impacting the area. Extracts of this work relevant for the SARCC pilot area have been summarised below.

"The Dunkirk region is believed to be vulnerable and subject to several climate. More severe coastal flooding events, such as the November 2007 North Sea and the March 2008 Atlantic storms, could have had much more severe consequences if they had occurred at high tide. The return periods of such events (especially in the current context of global climate change and projected sea-level rise) needs to be taken in to account in order to manage and reduce coastal hazards, implement risk prevention policies and enhance and strengthen coastal defence against coastal flooding.

The well documented storm of 31 January to 1 February 1953 caused the greatest surge and was the most damaging in the area. A surge was generated by this storm that, in conjunction with a high spring tide, resulted in particularly high sea levels. Around the southern parts of the North Sea the maximum surges exceeded 2.25 m, reaching 3.90 m at Harlingen, Netherlands. Large areas were flooded in Great Britain, northern parts of France, Belgium, the Netherlands and the German Bight. During this event, the water level exceeded the predicted water level at the eastern dyke of Dunkirk by more than 2.40 m.

On 1 March 1949 a violent storm had caused a storm surge that reached the coast of northern France and Belgium. The tide gauge of Antwerp in the Escaut estuary measured a water level higher than 7 m Tweede Algemene Waterpasing (TAW, a Belgian chart datum), classifying this event as an extraordinary storm surge. For the Dunkirk area there are two sources reporting water levels: the first saying that 7.3m was reached as a maximum water level at the eastern dyke in Dunkirk, exceeding the predicted high tide, i.e., 5.7m, by 1.6m. A second document relates that the maximum water level reached was about 7.55 m at Malo-les-Bains, which would mean a surge of 1.85 m.

In 1791 and 1808, there is sufficient evidence that extreme surge events took place (extreme water level on Walcheren Island) but the sources are not informative enough to estimate water levels reached in Dunkirk. A surge of 1.25 m is given for the storm of 1921.

In November 1897 an eastward-moving storm with gale-force winds over Great Britain, Denmark and Norway, caused interruption of telephone communications between the cities of Calais, Dunkirk and Lille and great damage to the coastal areas. At Malo-les-Bains, a small town close to Dunkirk, the highest water level reached 7.36 m, although the high tide was predicted at 5.5m, resulting in huge damage to the port infrastructures.

During the night from 14 to 15 January 1808, "a terrible storm, similar to a storm that hit the region less than a year before on February 18, 1807" hit the coasts of the most northern parts of France up to the Netherlands. This storm caused severe flooding in the Dunkirk area as well as in the Zeeland area in the southwestern parts of the Netherlands where the water rose up to 25 feet on the isle of Walcheren (i.e., 7.62 m). For the Dunkirk area, the last time the water levels rose as high as in January 1808 was 2 February 1791.

For events in 1778, 1791, 1808 and 1825, the sources clearly report that winds were blowing from northwesterly directions and that in Dunkirk the quays and docks of the harbour were overtopped as the highest water levels were reached. After the event of February 1825, at least 19 storm events occurred and there is good evidence to believe that some of them induced extreme surges".

There has clearly been considerable impacts to this area of the coast from historical flooding and storm events, which continue to impact today.

1.4 Current Environmental Impacts/ Threats & Management Approach

"France has no national coastal management strategy. Coastal management is the responsibility of municipalities. By law, local communities are allowed to carry out coastal defence works where this is deemed necessary to preserve common interests. Municipalities or communities bear the costs of local defence operations, with the possibility of additional funding by the Regional Council. Exceptions are the coasts adjacent to the three major ports of Marseilles, Le Havre and Dunkirk, which are managed by the port authority. An overall view of management practice has generally been lacking. As a result, the spread of beach erosion has commonly been aggravated by the individual communal efforts lacking a common view of the effects on downdrift sectors of engineering structures implanted in updrift sectors" (Climate Change Post, 2020).

The Ville de Gravelines is working to develop responses to threats from increased storms and associated flooding within its jurisdiction. Due to its position on the coast Gravelines is subject to increased sea levels related to climate change. Breaches through the dune system have been highlighted as a particular area of concern as they allow water ingress during storm conditions A study has been undertaken on the dune system of Gravelines to better understand these threats.

The key factors acting on the coast are:

- Winds - predominantly from the South West, which can induce waves and surges during storms, wind also reduces the sand on the beaches transporting it to 'feed' the dune systems.
- Water levels – in particular during storm surges when a build up of water mass towards the coast increases the height of the water level on shore. Interactions between the tidal cycle and the storm surges can further increase levels.
- Coastal currents – the speed of water movement varies depending on whether there are neap or spring tides.
- Sea state – the swells that reach the coast come from the English Channel and spread to the North Sea, they mostly come from the southwest. The waves are generally short, however, in storm conditions they can increase to up to 5m height and be associated with long swells. In northerly wind conditions waves can come from a NW to NE direction.

The SARCC pilot project has been designed to counter the environmental threats and associated impacts, they are working with nature to develop these defences.

2. Archaeology & Palaeoenvironmental Resources

This section provides initial background to the palaeoenvironmental, archaeological and historic development of the area surrounding the Pilot Project to put its development into longer term context. It then presents a range of sites, buildings and features within the pilot study area to identify those which provide potential for informing on the scale and pace of coastal change.

2.1 Archaeology and History of the Pilot Site Area

Evidence from prehistoric periods through to modern day includes a wide range of traces of the environmental changes through preserved deposits and land surfaces in addition to the many finds, traces of buildings and burials through to historic development of coastal hamlets then towns. This evidence provides the long-duree of human use and occupation at the shore, including how people have both influenced coastal change through structures and have themselves been impacted through storms and coastal changes.

Many such traces are still preserved below ground within sites and deposits, but are also very visible within the form and character of Gravelines today through buildings and structures. Some of these key features can be used to help determine coastal changes over time.

Pre-Roman Period
The Pas-de-Calais is a department in northern France named after the French designation of the Strait of Dover which it borders. The region has been inhabited since prehistoric times, a map depicting Bronze Age sites though France show a number in the area close to Gravelines. During the third century BC the earliest settlers to make their home in Pas-de-Calais were the Celtic tribe known as the Belgae.

Roman Period
The region was populated in turn by the Celtic Belgae, the Romans, the Germanic Franks and Alemanni. The Roman practice of co-opting Germanic tribes to provide military and defence services along the route from Boulogne-sur-Mer to Cologne in the Fourth and fifth centuries, created a Germanic-Romance linguistic border in the region.

Medieval Period (500AD – 1485AD)
Saxon colonisation in the region from the fifth to the eighth century extended the linguistic border south and west so most inhabitants north of the line between Bethune and Berck spoke a dialect of Middle Dutch while those to the south spoke Picard (a variety of Romance dialects) by the ninth century.

The story of Gravelines begins around 800. In the 12th century the Count of Flanders, Thierry d'Alsace, decided to surround a rampart of stones and stakes and to build a new estuary for the River Aa. Gravelines became the entry port of Saint-Omer: a port of fishing for herring, transit for salt, fruit and wine. St-Omar was an important port in western Flanders in the early 12th century until it was cut off from the North Sea when silting gradually blocked the channel. A new canal was constructed between St-Omar and the North Sea creating the new town of Gravelines at the coast which became heavily fortified as it now guarded the western boarders of what was then Spanish territory in Flanders. At this time the River Aa was used as the main route in from the North Sea. The contested nature of the area and need for strong defences was further highlighted by the Norwich Crusade of 1383 which saw Gravelines taken by Henry le Despenser's English forces and the town was destroyed on his orders (Allington-Smith, 2003).

Post Medieval (1485 – 1900)
Recent excavations within Gravelines town ahead of development have discovered traces of occupation from the 13th to the 17th century. This includes walls of buildings, a preserved well and a number of burials (Ville-Gravelines, 2021). This demonstrates the extent of remains within the town and on-going analysis of environmental material will help add to the understanding of the development of the town in relation to the canal and the coast.

Historical records indicate that there was a famous meeting at Gravelines in 1520, between the Holy Roman Emperor Charles V and Henry VIII of England. A land battle was fought nearby in 1558 resulting in a Spanish victory over the French with Gravelines becoming a Spanish stronghold in Flanders. Gravelines was also the setting for Sir Philip Sidney's failure to deliver the town from Spanish occupation in July 1586, which is described in the anonymous 'A Discourse of the enterprise of Gravelines'. The 'Battle of Gravelines' was a naval attack when England's Royal Navy attacked the Spanish Armada using fire ships in 1588 just off the port.

The war between Francis I and Charles V led the latter to rebuild the four bastions of the square which is when Gravelines gained it hexagonal form. The town was captured and recaptured several times by the French and Spanish between 1639 and 1658 (It was only in the 19th century did the population become entirely French-speaking). It was finally annexed to France in the Treaty of the Pyrenees of 1659. The city

retained its strategic importance and Louis XIV instructed the completion of the defences with a set of half-moons, counterscarps and locks.

The River Aa and the port of Gravelines were vital to commerce in Flanders from the mid-17th century, when Vauban drew up the first plans for the Canal de Neuffossé to link further inland with Lille. Map evidence shows the position of the canal from the defended area of the town to the shore and the position of Fort Philippe which was constructed at the canal mouth to help defend it. Under Louis XV, a channel project, designed by King Philip IV of Spain, was completed between 1736 and 1740. This helped the maintenance and development of Gravelines as an important maritime centre. The precise phases of cutting the canal to the sea, developing its size and defences and then construction of the breakwaters protecting the entrance are not specifically known, however, its form and size can be seen through its presence on historic maps.

In the early 19th century Gravelines became a focus for smugglers with the then exciled Napoleon allowing and encouraging English smugglers to use the port. “The smugglers enclosure at Gravelines became known as the ‘ville des Smoglers’, the French borrowing and modifying the English word. The mischief of the English smugglers was indeed great: they brought across gold guineas, escaped French prisoners, newspapers, and the occasional spy; and returned to England laden with gin, brandy, and silks” (Daly, 2007: 334).

The maritime importance of Gravelines lead to the construction of the light house between 1837 and 1843. It stands at 25.5m high and is visible for 26 miles out to sea. Originally painted white it acquired its black and white colours in 1924. The lighthouse is now listed as a historic monument.

Gravelines was an important centre for fishing. Between 1860 and 1870 much of the town was involved in this trade – particularly fishing for cod off Iceland which involved relatively small family run ships being away from port for up to 6 months.

The uncertainty of maritime ventures lead to the construction of the Chapel of the Sailors (The Petite Chapelle Notre-Dame des Flots) which was built on the dunes by the sea in 1829, it was destroyed by German bombing in 1942 and rebuilt in 1954.

Modern

From the 19th century until 1938, cod fishing was one of the main activities of seafarers from Gravelines. There was significant impact to the area with the Nord-Pas-de-Calais region being a strategic target during the First World War, with German forces holding much of the ‘French Flanders’ region.

During WWII the area held many weapons and bunkers, the remains of these survive close to the coastal frontage today (Axis History Forum, 2021). On May 24, 1940, during the Fall of France, German Field Marshal Gerd von Rundstedt, commanding Army Group A, ordered his armoured divisions to close up the "Canal Line" of Lens-Gravelines, and halt there (Wikipedia, 2021, Gravelines). Neighbouring Dunkirk was the last French town to be liberated from German occupation.

Following the economic crises caused by the wars, Gravelines had to change its economic policy by turning to industry and tourism. Port trade flourished until the 1960s. The nuclear power station started construction in 1974, and while not an historic building or feature it has had a significant impact on the coastal frontage in this area. Tourism continues to be an important industry for Gravelines today.

2.2 Results of Archaeology Scoring

This section outlines the results of the archaeological and historical scoring from the Gravelines study area, followed by a discussion of the results. The scoring methodology applied is detailed in *SARCC Maritime Atlas: Methodology Report* (MAT 2022). It should be noted that the scoring is not providing any measurement of historic or cultural significance of a site, only its potential to inform on coastal change.

Within the pilot area only a limited amount of data was obtained from available online sources. It is likely that more detailed information about local archaeological, historical and palaeoenvironmental remains exists in local sources and archive and could be added to this study in the future.

A number of sites were identified and scored, the highest combined scoring sites are shown in Figure 6 and listed in the table below, the total score has been normalised to give each site a score out of 100. It is possible for a site to score highly in one of the three scoring categories and still be important for informing on coastal change over time. The combined approach identifies those scoring highly across the scoring categories.

ID	Site Name	Site Type	Period	Score – sea level	Score – Environmental	Score – Temporal Continuity	Total Score	Coastal Context
6109	Phare de Petit-Fort-Philippe (lighthouse)	Building	19th century	High	High	High	100	Above high water
6111	Smuggler's Camp	Building	19th century	High	High	High	100	Above high water
6115	Breakwater	Marine installation	Early Modern	High	High	High	100	Inter tidal
6116	Breakwater	Marine installation	Early Modern	High	High	High	100	Inter tidal
6110	Collection of bunkers	Military installation	9th century	Medium	High	High	88	Above high water
6113	Petite-Fort Phillipe	Settlement	Early Modern	High	High	Medium	88	Above high water
6114	Grande Fort Phillipe	Military installation	Early Modern	High	High	Medium	88	Above high water
6112	Notre-Dame des Flots	Building	20th century	Medium	Medium	Medium	66	Above high water
3455	Wreck of Landing Barge	Wreck	Unknown	Low	Low	Low	33	Inter tidal
3459	Wreck Cargo ship	Wreck	Unknown	Low	Low	Low	33	Marine
3460	Wreck Portrieux	Wreck	WWII	Low	Low	Low	33	Inter tidal
3461	Wreck buried Unknown	Wreck	Unknown	Low	Low	Low	33	Marine
3462	Wreck unknown broken up	Wreck	20th century	Low	Low	Low	33	Marine
3463	Wreck of barge	Wreck	Unknown	Low	Low	Low	33	Marine
3464	Wreck Noroit	Wreck	20th century	Low	Low	Low	33	Marine
3465	Wreck Pavon	Wreck	WWII	Low	Low	Low	33	Marine
3466	Wreck Le Holland (previously Dansted)	Wreck	WWII	Low	Low	Low	33	Marine
6108	Bunker	Building	20th century	Low	Low	Low	33	Above high water

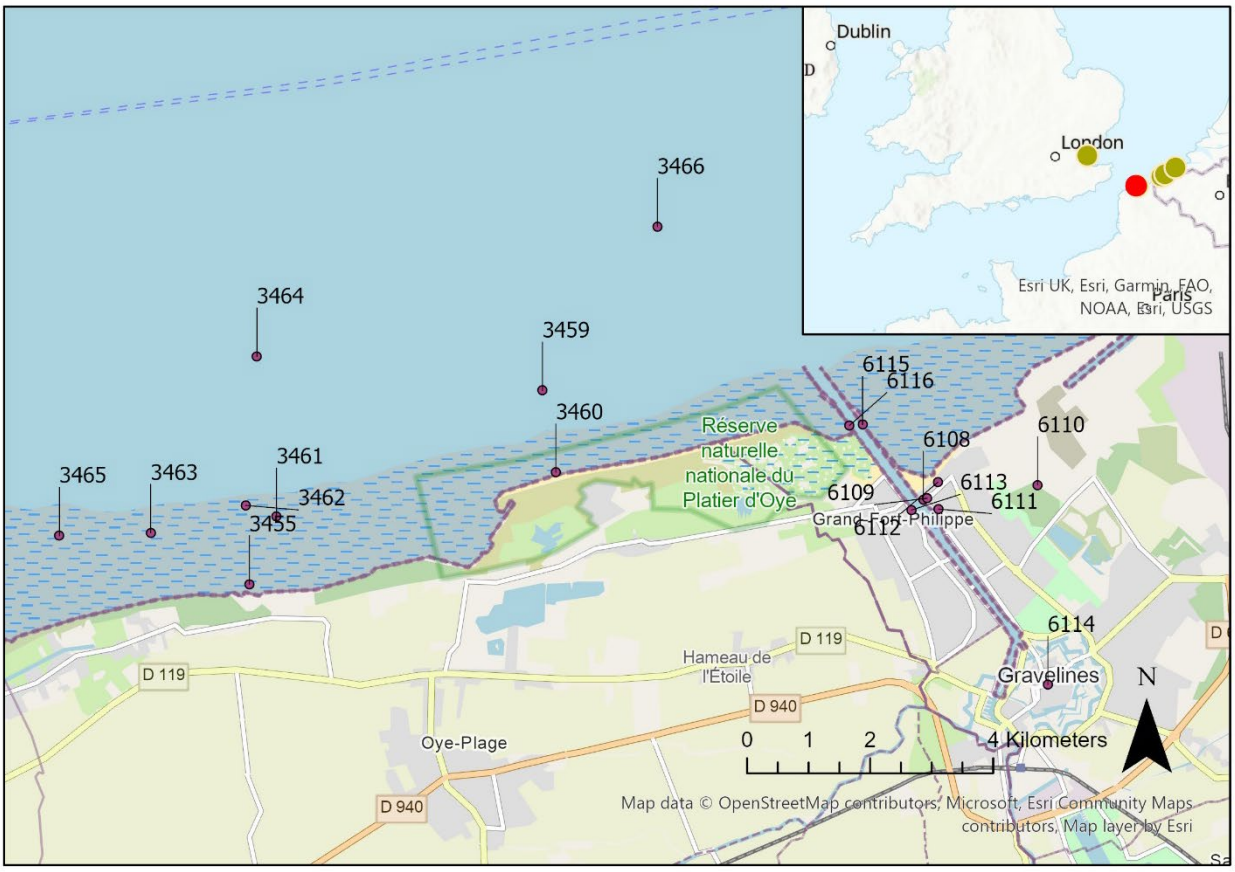


Figure 6: Distribution of high scoring archaeological and historic sites within the Gravelines Pilot Area.

2.3 Discussion of Scoring Results

Although the number of sites identified and scored was relatively low, they include some important examples for helping to demonstrate potential for understanding past coastal changes.

There are a range of structures linked to water levels and use of the coast – particularly the canal breakwaters (ID 6115 and 6116) which ensure safe passage into port. The position and size of these features are directly related to the sea level and processes of coastal sediment movements. Historic buildings related to the maritime use of the area also score highly including the lighthouse (ID 6109), the settlement of Petite Fort Phillipe (ID 6113), the 'Smugglers Camp' (ID 6111) and the Sailors Chapel (ID 6112).

World War II remains feature within the area and include a range of bunkers (ID 6110, ID 6108) which also have a direct relationship to the coast as they are needed to protect from marine based attacks. The position of a number of them close to or within the dune system mean that movements of sand can be measured against these hard concrete structures. A number of WWII wrecks also feature in the dataset (ID 3465, ID 3466), although these are not particularly high scoring, they represent securely dated wreck events and if there are physical remains of the wrecks still existing it is possible to monitor and measure the movement of seabed levels in relation to wreck remains.

2.4 Photography Survey of Heritage Features

Some of the sites and features that scored highly are in existence today and can be viewed/ visited. A site visit was undertaken to capture current day images of a number of the archaeological and historic features, a range of key examples are included below (Figures 7 – 9). These can now be used to directly compare with other available resources to demonstrate the extent to which there have been changes to the coastal frontage.

Figure 7: The breakwaters or canal 'arms' which protect access to the channel. Taken from the eastern break water, looking north.

Figure 8: The lighthouse (under repair at the time photograph was taken) in relation to the canal and foreshore.

Figure 9: The Chapel of the Sailor (circled red), in relation to the foreshore frontage.

3. Maps and Charts

This section provides a background to the development of maps and charts over time which have relevance for the area surrounding the Pilot Project. It then presents the results of the scoring of a range of maps and charts which cover the pilot study area with details that allow them to help demonstrate changes to the coastline over time.

3.1 Maps and Charts Background/ Map Progression

Prior to the Middle Ages, early maps were little more than a sketch of a small area, accompanied by a more detailed written report. In the fifteenth and sixteenth centuries, more traditional maps began to appear, but were usually drawn by artists and were of a pictorial nature. Focusing on the location of towns, castles and fortifications, rivers, lakes and woods, these large works were commissioned to be displayed in palaces and castles. It wasn't until the mid-sixteenth century when systems of survey and measurement were introduced, that the potential of maps as reliable tools for a variety of purposes was realised. Until the seventeenth century, Gravelines was part of Flanders. The oldest surviving property map of a piece of land in Flanders dates to 1307.

Gravelines can be seen on this early pictorial map by Pieter van der Beke dated 1538 (Figure 10). This map reflects the defiant independence of the Flemish cities against Spanish rule, containing heraldic shields, a genealogical log and the four bears representing the oldest families. The map was produced on four wooden sheets.

In 1540, Gerard Mercator, a Flemish pioneer of cartography was commissioned by the Merchants of Ghent to produce a map of the county of Flanders (Figure 11). The merchants hoped a more respectful portrayal of the county would replace the 1538 map and appease the Spanish Emperor Charles, following their rebellion. Mercator signed the map "Dedicated to Charles V most Holy Roman Emperor by the most devoted Gerardus Mercator of Rupelmonde". The accuracy of Mercator's map is attributed to triangulation already carried out by Jacob van Deventer. A coloured version of Mercator's map was included in the Theatrum Orbis Terrarum by Abraham Ortelius. Printed in 1570, considered to be the first true modern atlas.

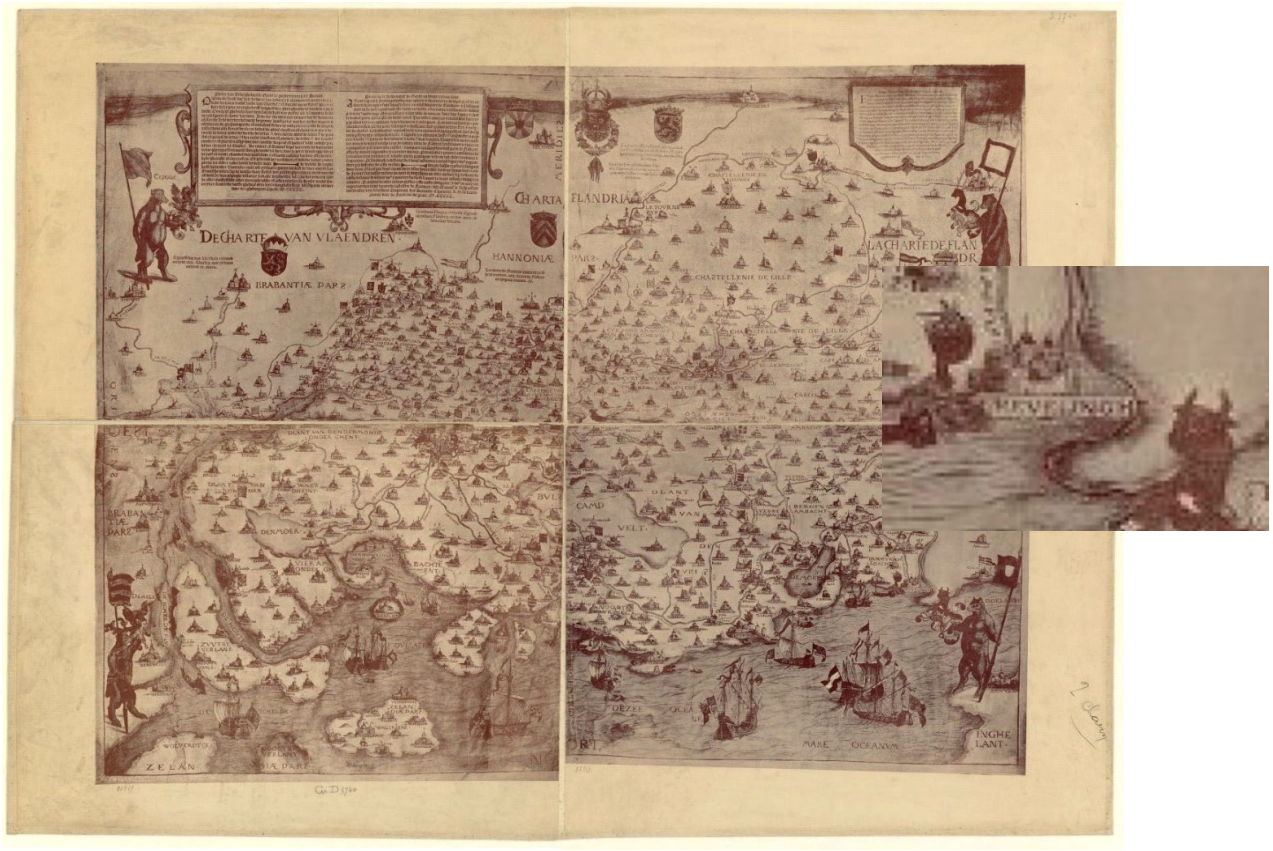


Figure 10: Charte van Vlaendren Pieter van der Beke 1538 (Source: Pieter van der Beke, Public domain, via Wikimedia Commons)

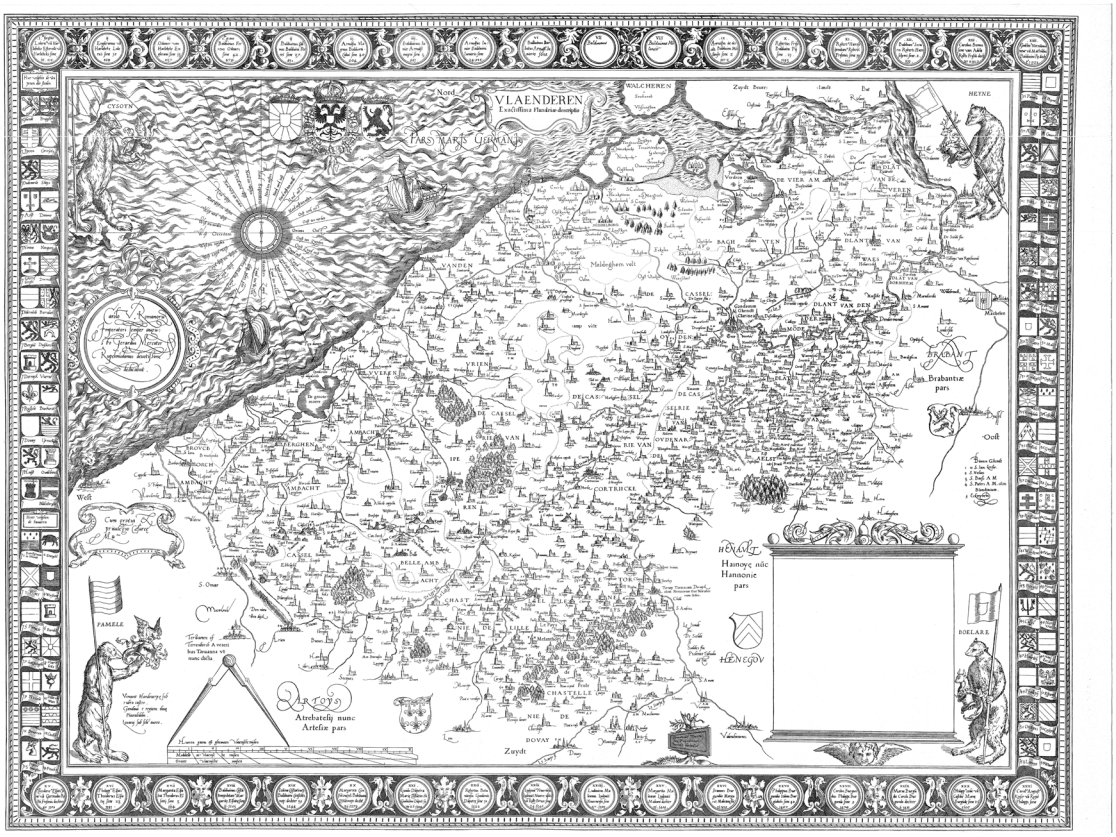


Figure 11: Flanders By Gerardus Mercator 1540 [ID 384], (Source: Gerardus Mercator, Public domain, via Wikimedia Commons)

Jacob van Deventer, a leading Dutch Renaissance Cartographer, was commissioned first by the Emperor Charles V and then in 1559 by King Philip II to create manuscript topographical plans for all of the cities of the low countries. This was to be his life's work. By the time of his death in 1575, he had created over 250 city maps. King Philip II required these maps to suppress the cities that revolted against him. Deventer pioneered triangulation to produce accurate scale maps. Drawn in plan, buildings were drawn side on for easy recognition by the soldiers. Important buildings, roads, rivers and fortifications were all mapped in water coloured detail. These plans were not published due to their secret military nature and were only rediscovered in the late nineteenth century. Gravelines was mapped by Deventer in 1545 (Figure 12).

Another excellent pictorial map with incredible detail from an oblique view was produced by an anonymous cartographer in 1558 to depict the Battle of Gravelines (Figure 13).

Meanwhile, topographical maps were produced at provincial levels, rising from the desire for self-representation. Printed province maps were produced in almost all the countries of Europe between 1575-1700, many of these maps clearly show Gravelines as a fortified town, such as this example by CJ Visscher, 1621 (Figure 14).

Figure 12: Jacob van Deventer map [ID358], (Source: Jacob van Deventer, Public domain, via Wikimedia Commons)

Figure 13: (left) 1558 Battle of Gravelines [ID 357], (right) close up of area of the town (Source: Rijksmuseum, CC0, via Wikimedia Commons Source: https://commons.wikimedia.org/wiki/File:Slag_bij_Grevelingen,_1558_Die_Schlacht_vor_Grevelingen Accessed 22/07/2021)

Figure 14: (left) CJ Visscher, Comitatus Flandria 1621, (right) close up of area of Gravelines. (Source: https://sanderusmaps.com/our-catalogue/antique-maps/europe/low-countries-belgium/antique-map-of-flanders-vlaanderen-by-c-j-visscher-22491 Copyright Unknown. Accessed 22/07/2021).

In 1638, Henricus Hondius in Amsterdam and Alexander Serhanders in Ghent, published a multi-sheet map of Flanders that superseded Mercator's map. This was the basis of Blaeu's six sheet wall map of Flanders published in 1643. Joan Blaeu also produced a map of the Seige of Gravelines (Figure 15) in 1649 with a key detailing important locations. Blaeu's panoramic image of the city 1649 (Figure 16) shows clear detail of the coastal area.

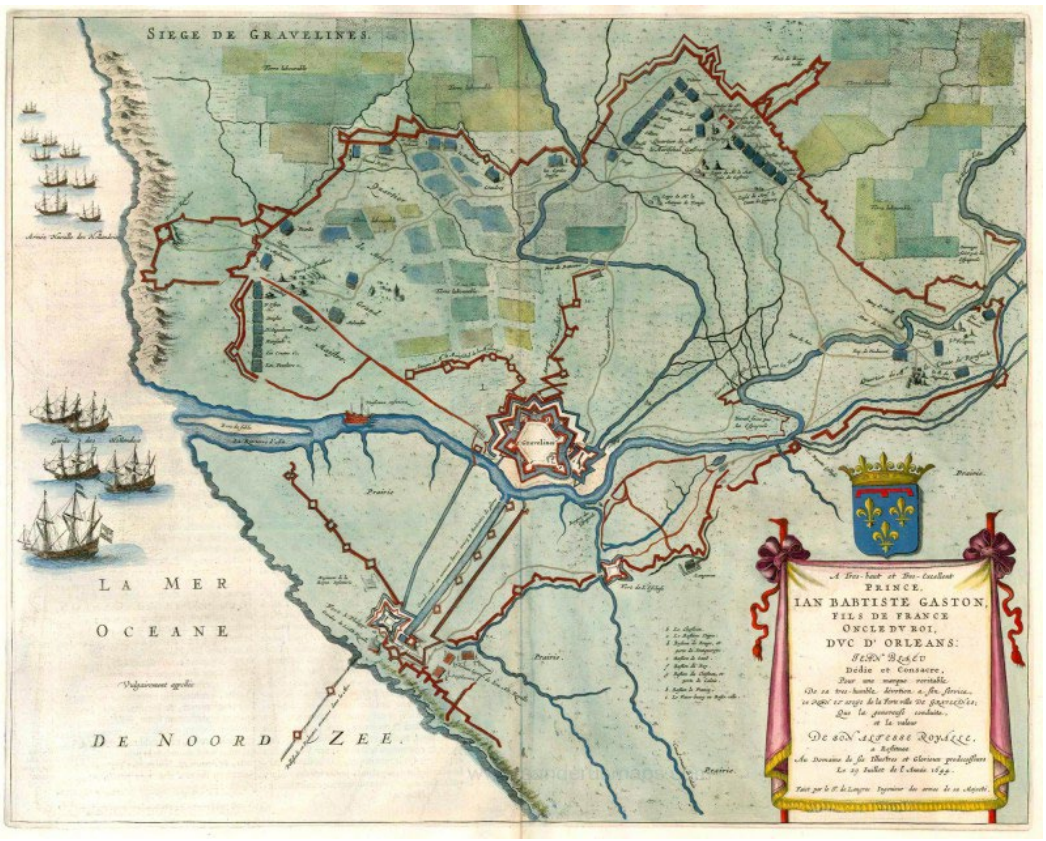


Figure 15: The Seige of Gravelines 1649 [ID361] J Blaeu Copper Engraving (Source: Michael Florent van Langren, Public domain, via Wikimedia Commons).

Figure 16: Gravelines by J Blaeu 1649[ID360] (Source: Rijksmuseum, CC0, via Wikimedia Commons)

Other topographical maps of Flanders were produced by: Seutter (1678, 1740, 1750), Jalliot (1695), Mortier (1700), Masse (1729), Visscher (1658, 1730), Bodenehr (1740), Frickx (1744) and Ferraris (1777). From the 1700's maps start to be produced on a smaller scale and contain much more detail. Good examples for Gravelines include Visscher 1658 (Figure 17), Beaulieu 1670 (Figure 18) and Fricx 1707 (Figure 19).

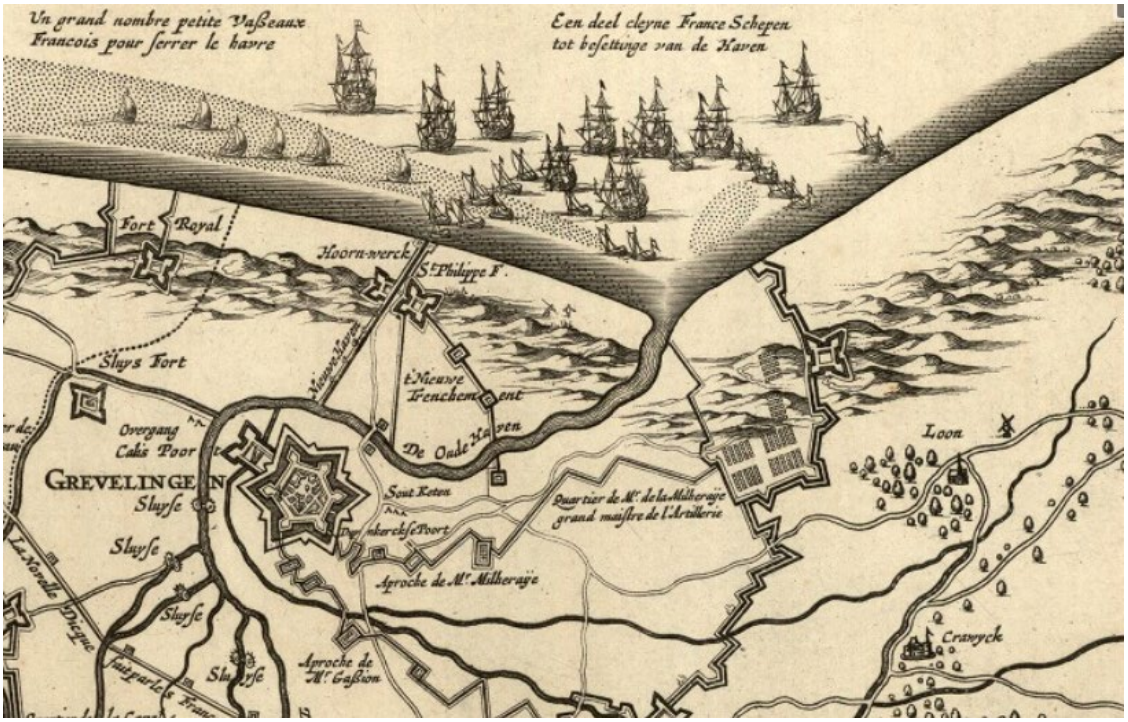


Figure 17: C.J. Visscher 1658 source: Attribution-Non Commercial 3.0 Unported (CC BY-NC 3.0) accessed 22/07/2021

Figure 18: Graveline ; Plan de la Ville de Graveline 1670 [ID 359] Beaulieu, Sébastian de Pontault, (Source http://digitalarchive.mcmaster.ca/islandora/object/macrepo%3A77637 Creative Commons Attribution-Non Commercial 2.5 License accessed 22/07/2021).

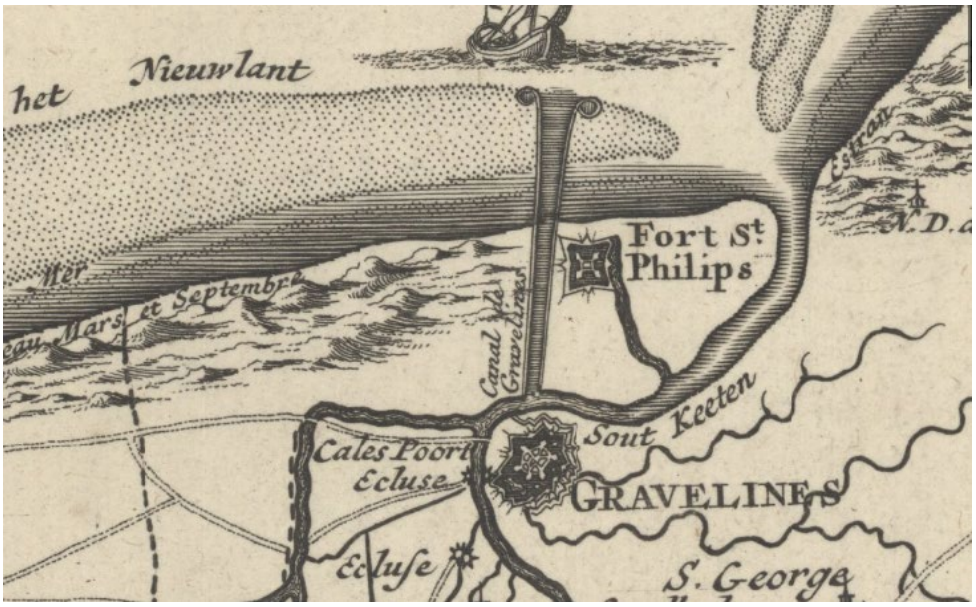


Figure 19: Carte particuliere des environs de Dunkerque, Bergues, Furnes, Gravelines, Calais, et autres [ID 363], Fricx 1707 Source http://digitalarchive.mcmaster.ca/islandora/object/macrepo%3A81581 Creative Commons Attribution-NonCommercial 2.5 License Accessed 22/07/2021

During the First and Second World Wars, the Ordnance Survey produced military maps. Accurate spatial positioning was essential for both defensive and offensive operations. These maps were produced using the British Trench Map Grid System, based on existing maps and aerial photography which was being pioneered at this time. The maps chart the changing front line and the location of enemy positions, detailing the position of communications trenches, gun emplacements, obstacles, observation posts. Between 1914-1918, the Ordnance Survey printed over 34 million maps. The originals are held in the National Archives and the Imperial War Museum. Scanned copies can be viewed online at the Royal Library of Scotland (https://maps.nls.uk/ww1/trenches/info1.html). Gravelines appears on a secret allied railway map dated June 1918 (Figure 20).

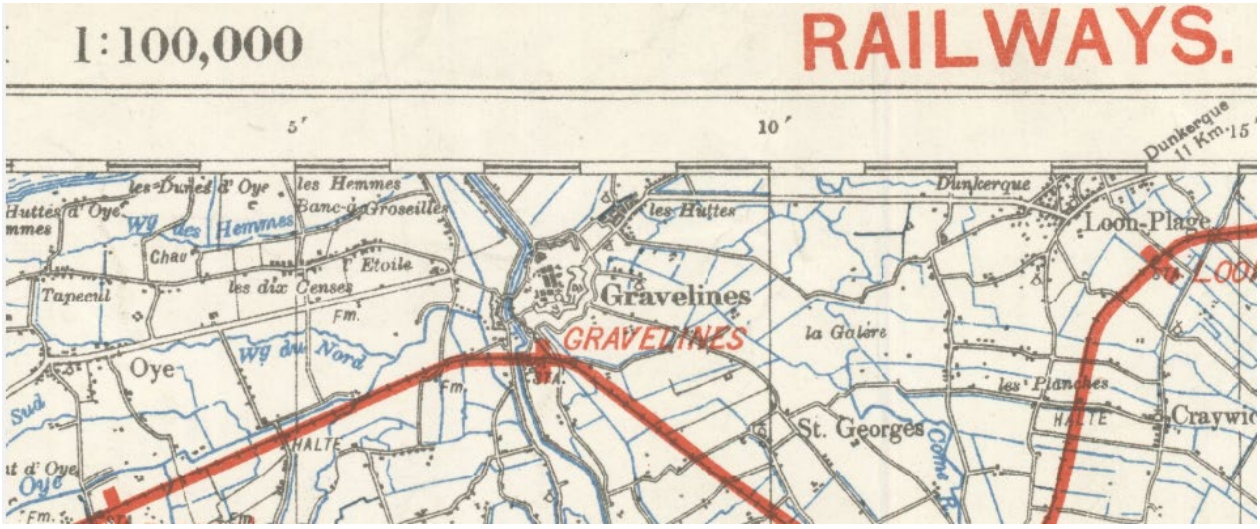


Figure 20: Secret allied railway map, June 1918 (Source: Creative Commons Attribution Non Commercial 2.5 License http://digitalarchive.mcmaster.ca/islandora/object/macrepo%3A73921 Accessed 22/07/2021).

3.2 Results of Scoring

The ranking system for maps and sea charts as set out in *SARCC Maritime Atlas: Methodology Report* (MAT, 2022) has been applied within the Gravelines pilot area. A range of historical maps and charts of the area were assessed as part of the project, with some dating back almost 500 years.

The study of maps and charts has utilised a range of online resources, it has been designed to show the potential of this type of resource for coastal change, but it is not an exhaustive study as other examples exist within archives, museums, libraries and galleries that is has not been possible to access due to Covid-19 restrictions. 24 maps and charts were analysed through the scoring system, the top 17 scoring examples are detailed below (Figure 21):

MAP _uid	Title	Year	Score Chronometric Accuracy	Score Topographic Accuracy	Score Detail in non-coastal area	Score Geometric Accuracy	Total Map Score
417	Siege of Grevelingen	1658	100	50.00	100	33.33	70.83
218	Cassini map 1700	1700	73.33	44.44	66.67	66.67	62.78
420	Belagerung der Statt Greueleingen	1644	100	44.44	66.67	33.33	61.11
339	Vlaamse-banken-1966	1966	100.00	41.67	33.33	66.67	60.42
215	WWll Admiralty Chart 1943	1943	73.33	33.33	66.67	66.67	60.00
198	Flandra Parte Occidentale	1697	100.00	38.89	66.67	33.33	59.72
359	Graveline ; Plan de la Ville de Graveline	1670	100.00	38.89	66.67	33.33	59.72
357	Battle of Gravelines 1558	1558	100.00	38.89	66.67	33.33	59.72
363	Carte particuliere des environs de Dunkerque, Bergues, Furnes, Gravelines, Calais, et autres	1745	100.00	38.89	66.67	33.33	59.72
422	Plans des ports de France, Gravelines	1777	100	33.33	66.67	33.33	58.33
384	Map of Flanders 1539. Gerardus Mercator.	1539	90.91	20.83	33.33	66.67	52.94
419	Atlas de Wit	1698	100	44.44	33.33	33.33	52.78
335	Vlaamse Banken (1866)	1866	100.00	38.89	33.33	33.33	51.39
361	Gravelines Seige 1644	1644	100.00	38.89	33.33	33.33	51.39
360	Gravelinga Gallis Gravelines dicta.	1649	100.00	38.89	33.33	33.33	51.39
330	Vlaamse Banken (1996)	1996	100.00	33.33	0.00	66.67	50.00
362	Dunkerque 1758	1758	100.00	33.33	33.33	33.33	50.00

Table: The highest scoring maps and charts from the Gravelines Pilot area.

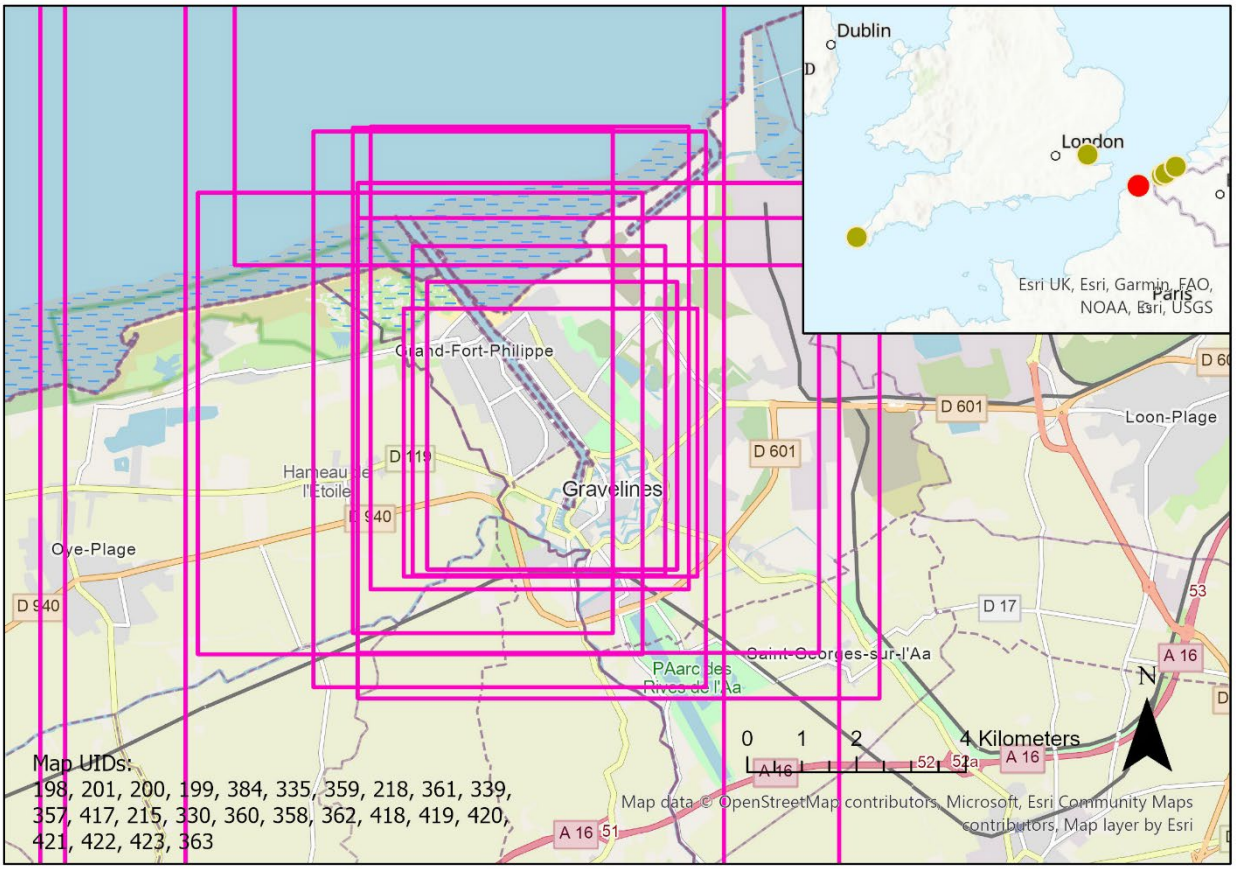


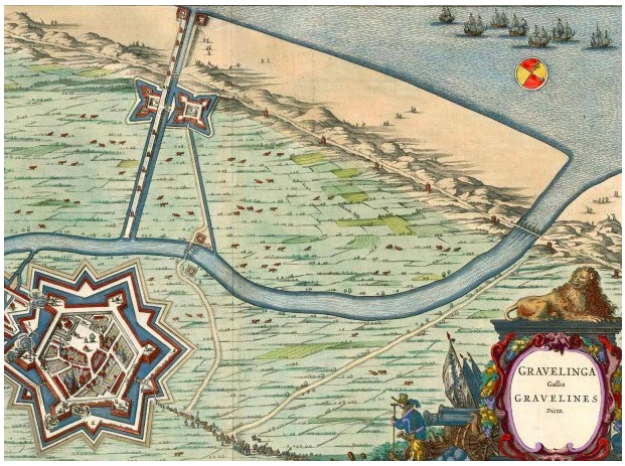
Figure 21: Area covered by the highest scoring maps and charts within the Gravelines Pilot Study Area

3.2 Discussion of Scoring Results

Gravelines is often included on maps and charts which cover 'Flanders' which frequently include Dunkirk with Gravelines appearing on the far west of the maps/ charts. A particularly early example is Gerard Mercator's 1540 map [ID 384] (see Figure 11 above).

Several of the high scoring maps have been produced due to the historical conflicts over the area, planning for invasions and planning for defence. These often produced very detailed depiction of both the coastline – which was important to understand for ships and shipping – and fortifications. The two examples by J Blaeu of 1644 (Siege of Gravelines [ID361]) and 1649 Birds-eye plan [ID360] (Figure 22)), provide highly detailed information. The 'Battle of Gravelines' military map of 1558 is the earliest map that has been scored.

The changes to the coastline and the impacts on ships and shipping can be seen through the maps. Initially the river access is shown, and later the 'new canal' is depicted. The Blaeu 1649 map clearly shows the river still flowing, along with the canal which has provided the direct access to the coast and has been fortified. The sand dunes and coastal road are also depicted in detail (Figure 22). The 1700 map by Cassini shows the river as a much smaller feature and the 'Port basin' is part of the canal system (Figure 23).



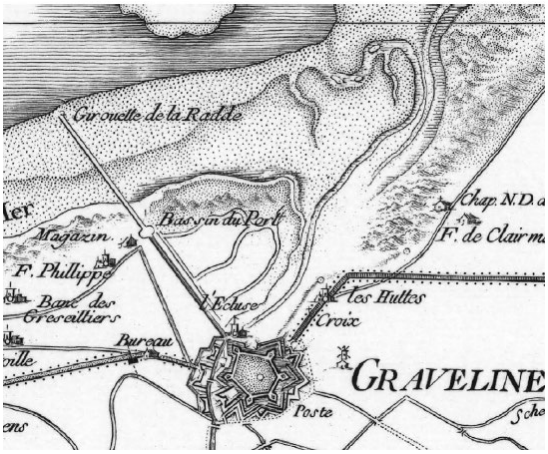
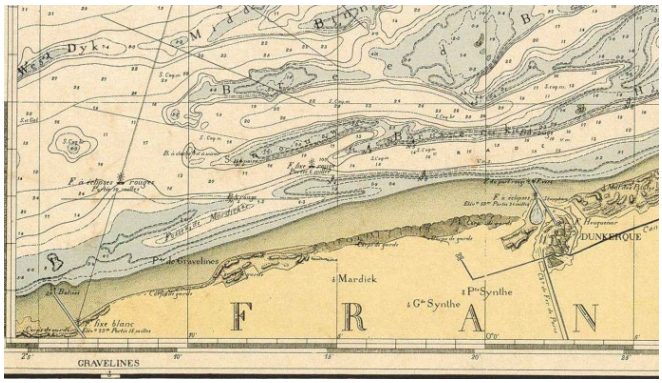


Figure 22 (left) extract from Blaeu map of 1649 [ID 360] (Rijksmuseum, CC0, via Wikimedia Commons).
Figure 23 (right) extract from Cassini map of 1700 [ID218].

There several more recent examples of Admiralty charts which appear in the high scores 1966 [ID339], 1943 [ID215], 1866 [ID335] (Figure 24) and 1996 [ID 330] (Figure 25), by these dates the practice of charting the coastline had developed significant accuracy and these can be relied upon for their depictions of the coastline and the near and offshore hydrography. They chart the offshore sand banks in great detail as these features had to be negotiated by ships. The two examples of charts below show the extent of changes along this stretch of the coast between Dunkirk and Gravelines, the construction of extensive harbour and port facilities have significantly reduced and changed the shape of the sandy foreshore and the form of the adjacent shallow water sand banks.



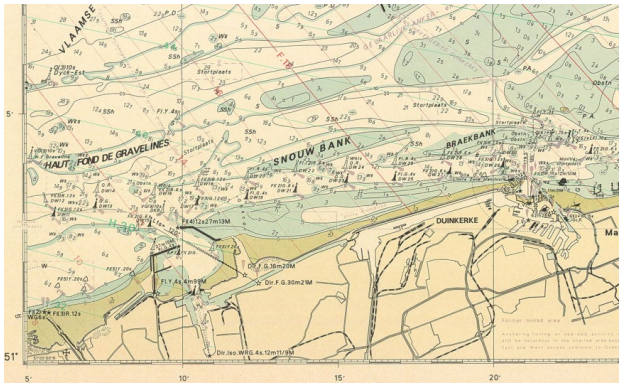


Figure 24 (left) 1866 chart of the coastline [ID 335] (Licenced under Creative Commons BY-NC-SA: 4.0)
Figure 25: (right) Chart of the coastline from 1996 [ID330] (Licenced under Creative Commons BY-NC-SA: 4.0)

4. Pictorial Resources Scoring

This section presents the results of the research, scoring and analysis of artistic images and historic photographs. The scoring approach for these resources has been developed to take account of the various styles, approaches and potential subjectivity (particularly of art images), and the potential of the resources to provide information on coastal change.

Artistic resources provide a similar time-depth to maps and charts in terms of the periods over which they have been produced, with photography being available for periods from the mid – late 19th century. Whereas maps and charts were designed to be as accurate as possible in producing 'plan views' which include the coast, art and photography provide a range of landscape and oblique views which give a different type of evidence of coastal change.

4.1 Artistic Images

The use of artistic images to help understand coastal processes, measure coastal change and inform approaches to coastal management has been developed over the past 20 years. Initial reports focused on the use of art resources to demonstrate coastal change in relation to issues for life and for economic assets (McInnes & Stubbings 2010, 2011; McInnes & Benstead, 2013, 2013, 2015). They demonstrated the potential for the resource to provide more data on other aspects of coastal management. The use of art images alongside archaeology and heritage data was further developed through the Arch-Manche project (https://archmanche.maritimearchaeologytrust.org/) which focused on long-term coastal change and included the assessment of artwork, cartography and photograph for more recent periods.

This section briefly outlines the art history relevant for the Gravelines Pilot Area before looking in detail at the high scoring art works, what these examples show us and how modern photos can be compared to the artistic views.

4.1.1 Art History/ Resource of the Area

The background to the development of artistic representations of the French coast was provided by Professor Robin McInnes for the Arch-Manche Project, which developed the approach to the scoring of art works that has been applied within the SARCC Pilot area. Professor McInnes introduction to French coastal art is provided here before more detailed consideration of those artists working at Gravelines.

“In France there is a long-standing tradition for capturing the landscape through art dating back to the Middle Ages. French artists such as Claude Lorrain played a highly influential role in the development of landscape art across Europe through paintings of the classical landscapes and pastoral scenes of Italy. A friend of Claude Lorrain, Nicholas Poussin, was also a leading figure in the promotion of eighteenth century European landscape art. Some of the first French landscapes were those by Jacques Callot (1592-1635), who was influenced by the Dutch and Flemish masters. The founding of the Paris Academy of Painting and Sculpture in 1648 also gave strong support for artists of the period. The paintings of Jean-Honore Fragonard (1732-1806), Hubert Robert (1733-1808) and Claude-Joseph Vernet (1714-1789) continued to promote the concept of the classical landscape in France through the eighteenth century.

It was in the early nineteenth century that landscape painting developed more expressively in France. Artists such as Eugène Delacroix (1798-1863) and Gustave Doré (1832-1883) encouraged by the establishment of the ‘Prix de Rome du Paysage Historique’ (Rome Prize for Historical Landscape) in 1817. As the Norwich School of Artists developed in East Anglia, in England, in the early nineteenth century another group of artists gathered in the village of Barbizon near Fountainbleau south of Paris for the purpose of drawing and painting in the open air. Key figures in this group of artists included Jean-Baptiste-Camille Corot (1796-1825), JeanFrançois Millet (1814-1875), Paul Huet (1803-1869), Charles-François Daubigny (1817-1878) and Théodore Rousseau (1812-1867). The Barbizon School established a tradition of fine French landscape paintings that would prove to become perhaps the most influential in Europe for over a hundred years, leading to the Impressionist and post-Impressionist schools exemplified by the artists Camille Pissarro (1830-1903), Edgar Degas (1834-1917), Claude Monet (1840-1926), Pierre-Auguste Renoir (1841-1919) and Alfred Sisley (1839-1899).

On the coast, artistic communities flourished in Normandy and Brittany. Jules Noël (1810-1881) painted extensively on the Normandy coastline. At Honfleur Eugène Boudin (1824-1898) taught Claude Monet to paint and Boudin produced numerous beach and coastal scenes whilst Alexandre Dubourg (1821-1891) painted the coastal scenery on the banks of the River Seine. In Brittany, Alfred Guillou (1844-1926), Emma Herland (1856-1947), and Henry Moret (1856-1913) painted genre scenes and the landscape whilst along the whole of the Channel coast English artists including J.M.W. Turner, Clarkson Stanfield (1793-1867), Richard Parkes Bonington (1802-1828) and many others travelled across the Channel to paint coastal scenes in watercolour and oils”. An image by Richard Bonington [ID390] features within the high scoring art works for Gravelines.

The Dunkirk and Gravelines landscapes were abundantly painted in the 18th century. There are oil paintings in the Romantic style, depicting picturesque dune and maritime landscapes showing an idealised vision of fishing and life on the coast.

During the 19th century period of impressionist art, Gravelines was a favoured scenery point for many of the great French artists of the day. They were attracted by the combination of the sea and the wide stretching beach lines blending with the bracing wind and crashing waves (Good Life France, 2021).

Several famous paintings of the canal at Gravelines come from George Seurat (1859-91) who was founder of the French school of Neo-Impressionim. His technique of using tiny brush strokes, become known as pointillism and can been seen in one of his works that appears within the high scoring art works section [ID402]. There are several paintings by Seurat of Gravelines: 'An evening at the Port of Gravelines', 'Beach at Gravelines', 'The channal of Gravelines'.

Several paintings in the high scoring table are by Thomas Bush Hardy (1842-1897), he was a marine painter and watercolourist who was born in Sheffield, but also travelled in Holland and Italy. His paintings feature coastal scenes in England, the Netherlands, French channel ports and Venice. He was a very popular marine artist of the 2nd half of the 19th century.

4.1.2 Results of Scoring Art

The development of the scoring system for works of art is described in SARCC Maritime Atlas: Methodology Report (MAT, forthcoming). Details of each artwork have been entered into the project database, including information on artwork type, medium, subject matter, time period and other parameters, the database was then able to calculate the scores for works of art from the pilot study site. 15 artworks were scored and analysed for the project, their scores were:

Art UID	Source Title	Artist	Date	Score medium	Score period	Score style	Score heritage	Score environ	Total Score
389	Gravelines in the pas de Calais	Thomas Bush Hardy	1891	Watercolour Pre-Raphaelite	1880 - 1920	Coastal - Pre Raphaelite	Suggests position of shore	General view beach	77
402	The channel of Gravelines Petit Fort Philippe	George Seuret (1859-1891)	1890	Litho/ fine pencil/ watercolour drawing	1880 - 1920	Beach/ coastal scene	Suggests position of shore	Detailed shoreline	77
400	Gravelines	Thomas Bush Hardy	1893	Watercolour	1880 - 1920	Beach/ coastal scene	Suggests position of shore	General view beach	77
401	Lighthouse	Thomas Bush Hardy	1892	Watercolour	1880 - 1920	Beach/ coastal scene	Suggests position of shore	General view beach	77
444	Armada off Gravelines	Sir Oswald W Brierley	1588	Etching	Before 1770	Marine/ Shipping subjects	Suggests position of shore	General coast view	77
424	The beach Gravelines	Thomas Bush Hardy	1890s ?	Watercolour	1840 - 1880	Beach/ coastal scene	Suggests position of shore	General view beach	74
388	View at Gravelines	Thomas bush Hardy	1891	Watercolour Pre-Raphaelite	1880 - 1920	Marine/ Shipping subjects	Supports understanding of change	General coast view	70
399	Seige of Gravelines (El Sitio de Gravelinas)	Peter Snayers (1592 -1667)	1652	Oil painting	Before 1770	Beach/ coastal scene	Suggests position of shore	General coast view	59

Art UID	Source Title	Artist	Date	Score medium	Score period	Score style	Score heritage	Score environ	Total Score
442	Dunkerque, Gravelines and Bourbourg	Braun & Hogenberg	1575	Copper plate engraving	Before 1770	Coastal - Pre Raphaelite	Suggests position of shore	General coast view	59
445	The channel at Gravelines	George Seuret	1890	Oil painting	1880 - 1920	Beach/ coastal scene	Suggests position of shore	General view beach	59
390	Entrance to Port	After Richard Parkes Bonington (1802-1822)	1823	Watercolour	1770-1840	Marine/ Shipping subjects	Suggests position of shore	General coast view	55
398	Calais, view taken from Gravelines coast	Auguste-Xavier (1799-1826) Leprince,Frederic Salathe, J F D Ostervals.	1820	Watercolour	1770-1840	Marine/ Shipping subjects	Suggests position of shore	General coast view	55
423	Gravelines - Entree du port	Andre Derain 1880 - 1954	?1920s?	Oil painting	1880 - 1920	Beach/ coastal scene	Suggests position of shore	General coast view	51
425	High tide at Gravelines	Theodor Weber 1836-1907	?1880s?	Oil painting	1840 - 1880	Marine/ Shipping subjects	Suggests position of shore	General coast view	44
443	Gravelines 1835 old antique vintage print picture	A Hugo	1835	Steel plate/ aquatint	1770-1840	Marine/ Shipping subjects	Suggests position of shore	General coast view	44

Table: The scores for artworks within the Gravelines Pilot Study Area

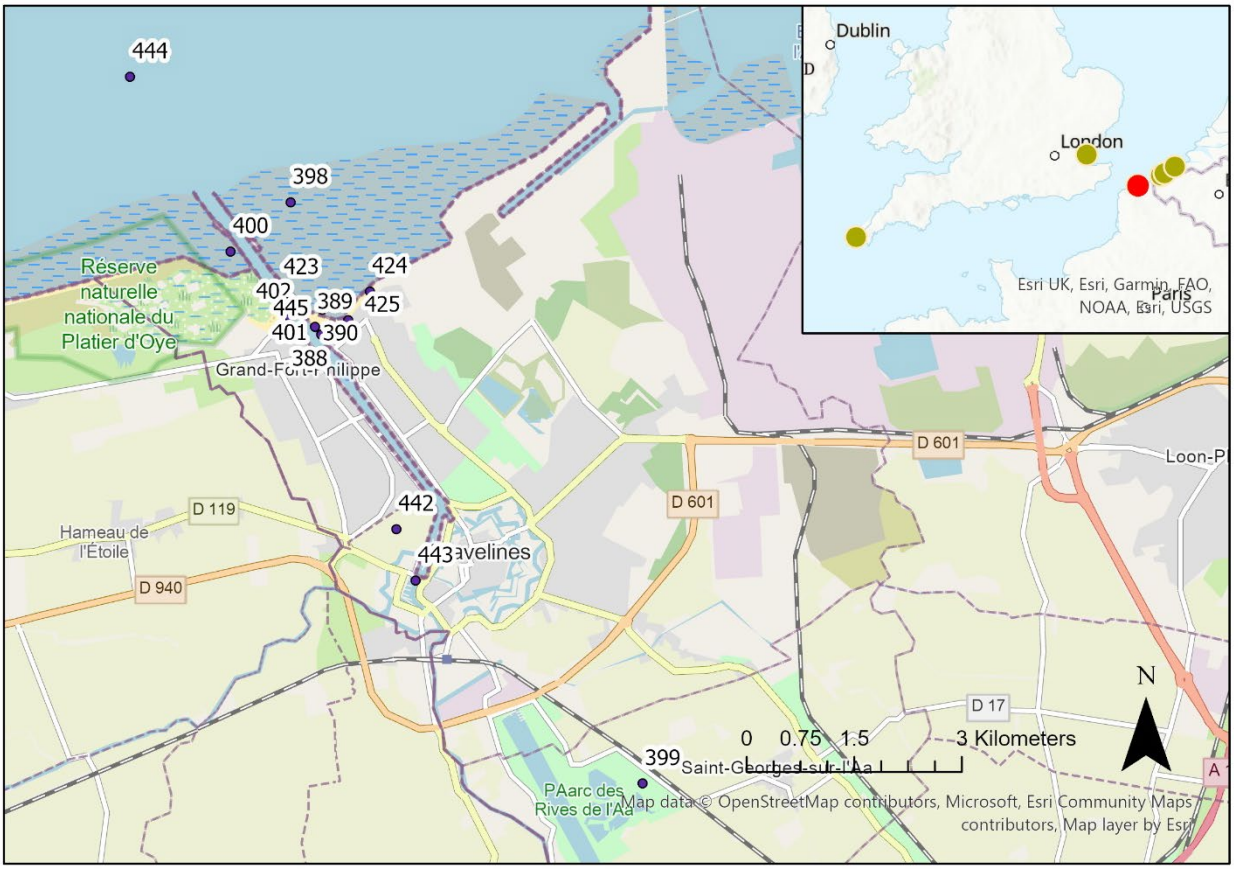


Figure 26: Distribution of the highest scoring art works from the Gravelines Study Area

4.1.3 Discussion of Scoring Results

Many of the highest scoring art works were watercolour paintings or watercolour drawings, with etchings and oil paintings also being featured. The medium of watercolour allows for fine representation of features and the paintings by Thomas Hardy Bush having particular detail of the coastal frontage and adjacent features that can be compared to the same view today.

The picturesque nature of the canal at Gravelines and the adjacent beaches mean they are and have been popular subjects for painters. Many of the top scoring images include the canal, often with ships and boats included with people working on them. The lighthouse has been a key feature here since 1843, so features in many paintings. Of interest is the painting by Richard Bonington from 1823 which shows the area prior to the construction of the lighthouse (Figure 27), giving detail of the edges of the canal which at this time are less formalised than the breakwaters seen today.

Several of the high scoring artworks are described further below in the comparative analysis of them with the modern day shoreline. The highlighting of these areas through the scoring system has allowed more detailed analysis of change over time, showing the impact of differing coastal conditions and processes as well as structures and construction along or out from the shoreline.

Figure 27: Entrance to Port 1823 After Richard Bonington (1801-1828) Watercolour World ©trustees of the British Museum (CC BY-NC-SA 4.0)

4.1.4 Field Survey of Art Locations

Following scoring of the artworks a number of examples have been the subject of more detailed analysis involving a site visit. Where it was practical to gain access and relevant to the study, present day photographs were taken in the field to try, as far as possible, to match the views painted by the nineteenth and early twentieth century artists. It also provided the opportunity to assess the conditions of the shore and canal side to note changes that may have taken place over time; inspection was timed to coincide with Low Water.

This ensured that thorough comparison could be made between the situation depicted in the artwork and the present-day situation.

Figure 28 shows the painting by George Seuret from 1890 [ID445], which uses the pointillism technique of small brush strokes, it appears to capture the canal in sunny conditions. This has produced a detailed view which looks from the western breakwater back towards Petit Fort Philippe and shows the lighthouse in its original white colour. The comparative view from modern day shows there has been little change to the form of the canal or the footprint of the buildings adjacent to the lighthouse.

Figure 29 is a painting by Thomas Hardy Bush from 1891 [ID389], this was the top scoring art work for the Gravelines study area. It looks out from the beach at Petit Fort Philippe along the eastern canal breakwater and shows boats drawn up on the foreshore as well as within the canal, there are also several groups of figures which appear to be walking along the breakwater in wintery or stormy conditions. Comparison with the modern day photograph of a similar view allows direct comparison of the beach levels in relation to the breakwater structure.

Figure 28: (left) The Channel at Gravelines Petit Fort Philippe 1890 George Seuret (1859-1891) [ID402] (Source: Indianapolis Museum of Art, Public domain, via Wikimedia Commons) and (right) the modern day view of the same scene.

Figure 29: (left) Thomas Hardy Bush 'Gravelines in the Pas de Calais' [ID389], (right) modern view of the same breakwaters along the beach.

4.2 Photographs/ Postcards

Photographs are an invaluable resource to support coastal change studies because they represent true depictions of the landscape; there is not the need to rank them in the same way as artworks (where views may be susceptible to interpretation and variation). For photographs to be used to assess how they can support studies of coastal change the two key issues are the content (in terms of what the image tells us) and

the quality of the image. Because of the dynamic nature of this coastline historic photographs can be a particularly valuable resource with many historic photos containing depictions of the shore and sea front with recognisable heritage features nearby, including buildings, quays and bridges. These can be compared to the modern situation and from this an accurate idea of the rate of erosion, or scale of change, since the date of the photograph can be gained.

A total of 30 historic photos were assessed as part of the project, images include those from locations within the pilot area where historic paintings and archaeological sites were also known. The photographs were collected and then scored using the methodology outlined in SARCC Maritime Atlas: Methodology Report (MAT, 2022). The study and scoring of historic photographs highlights the potential for historic photos to provide information on coastal change. Sources used were primarily online archives and resources, with some images identified during field visits. Due to Covid it has not been possible to visit archives in person, and there are likely to be further examples available that could aid future study.

4.2.1 Results of Scoring

This pilot area has a number of available historic photographs and postcards many of which depict the beach frontage and area where the canal crosses the foreshore to open water. 30 photographs were entered into the project database, those images which scored 55 or above have been included below within the 'high scoring' results. Figure 30 shows the distribution of the images and the table has the detail of their subjects and scores.

Image ID	Title	Year	Purpose	Score Heritage View	Physical Image State	Total Score
1417	Sepia Fort Philippe Postcard	1926	Unknown	Detailed view	Good	100
1418	Aerial view of Gravelines down to the channel	0	Unknown	Detailed view	Good	100
1432	Boats in the channel	1900	Unknown	Identifiable period	Good	77
1371	Gravelines with lighthouse		Unknown	Identifiable period	Good	77
1366	Gravelines Nord Chenal 1917	1917	Unknown	Identifiable period	Good	77
1369	Gravelines lighthouse		Unknown	Identifiable period	Good	77
1430	Edges of the Aa	1917	Unknown	Identifiable period	Good	77
1433	Ships from Iceland	1900	Unknown	Identifiable period	Good	77
1431	Women on the causeway		Unknown	Identifiable period	Good	77
1434	Channel Fort Philippe	1900	Unknown	Identifiable period	Good	77
1420	Gravelines Bassin		Unknown	Identifiable period	Good	77
1421	Petit Fort Philippe Boulevard de L Est	1910	Unknown	Identifiable period	Good	77
1426	Gravelines north, unloading schooners	1908	Unknown	Identifiable period	Good	77
1427	Channel and boats	1900	Unknown	Identifiable period	Good	77
1428	Mouth of the Aa	1905	Touristic	Identifiable period	Good	77
1437	Pont le Nouvelle voie du BassinÂ		Unknown	Identifiable period	Good	77

1368	Petit Fort Phillippe La Plage	1925	Unknown	Identifiable period	2	66
1370	Petit Fort Phillippe - The beach in the sunset		Unknown	Identifiable period	2	66
1435	Dock of the Batellerie	1904	Unknown	Identifiable period	2	66
1436	Gravelines-Pont-Jaune-et-Pont-du-Chemin-de-Fer	1906	Unknown	No chronological indication	Good	55
1367	Petit Fort Phillippe 1918	1918	Unknown	No chronological indication	Good	55
1429	Gravelines-Pont-Jaune-et-Pont-du-Chemin-de-Fer	1906	Touristic	No chronological indication	Good	55

Table: High scoring historic photographs from the Gravelines Pilot Area

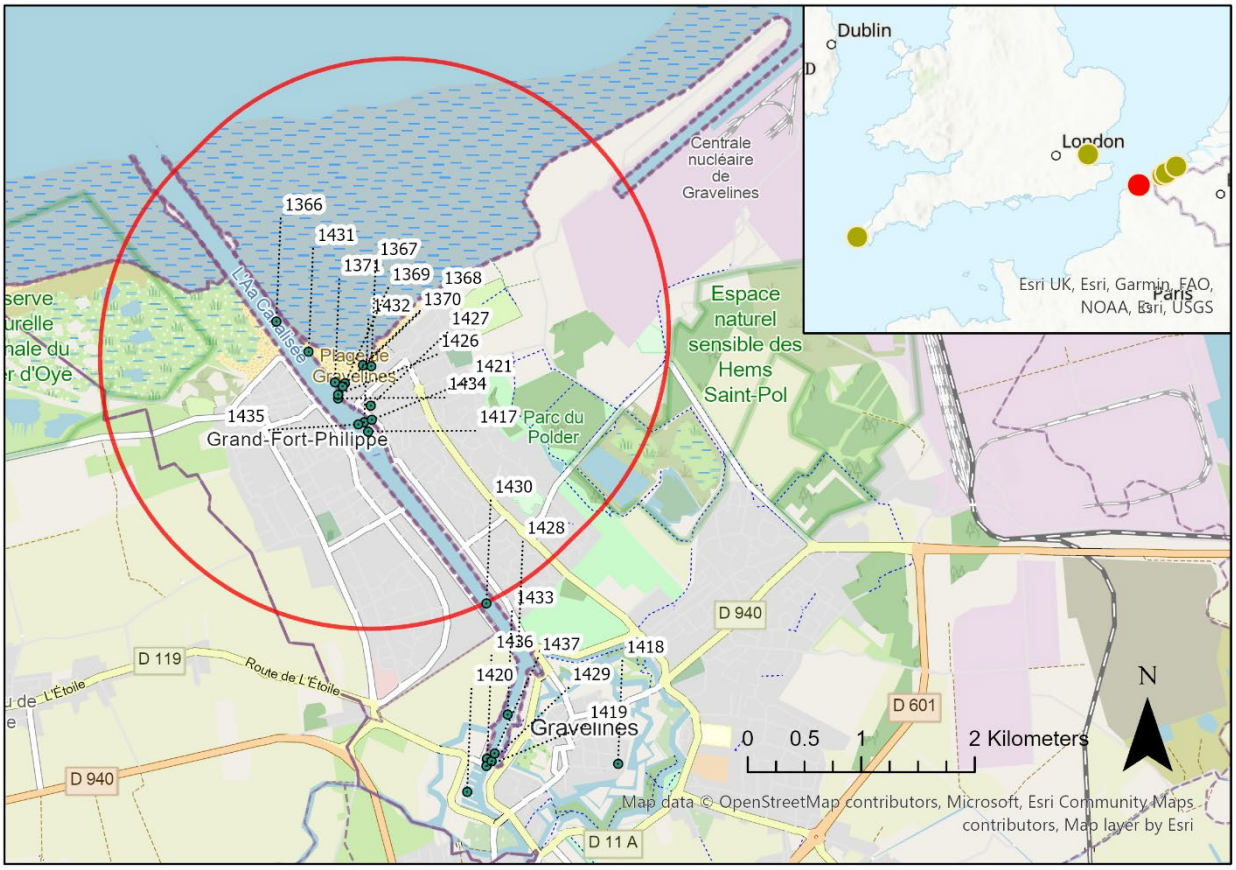


Figure 30: Distribution of historic photographs and postcards from the Gravelines study area

4.2.2 Discussion of Scoring Results

All of the high scoring photographs from the Pilot Study area were within the category of 'heritage view'. Most contained features or buildings that can be identified today, or were images across or along the coast showing changes. Some of the oldest photographs available date to around 1900, then there are increasing numbers of photographs available as you go through time.

A number of historic photographs are considered in this Section to demonstrate their potential for providing detailed information. More historic photographs are included in Section 5 to show how they can be utilised within combined analysis, with other examples also included within the demonstration of field results for gathering directly comparable data (Section 4.2.3).

Figure 31 provides an interesting view which captures the Study Area in around 1925, this shows the beach profile and adjacent buildings. The white octagonal building is visible here as is the Chape of the Sailors beyond, these two features often appear in historic photographs and act as reference points from which it is possible to gauge changes to the adjacent dunes and beach profile.

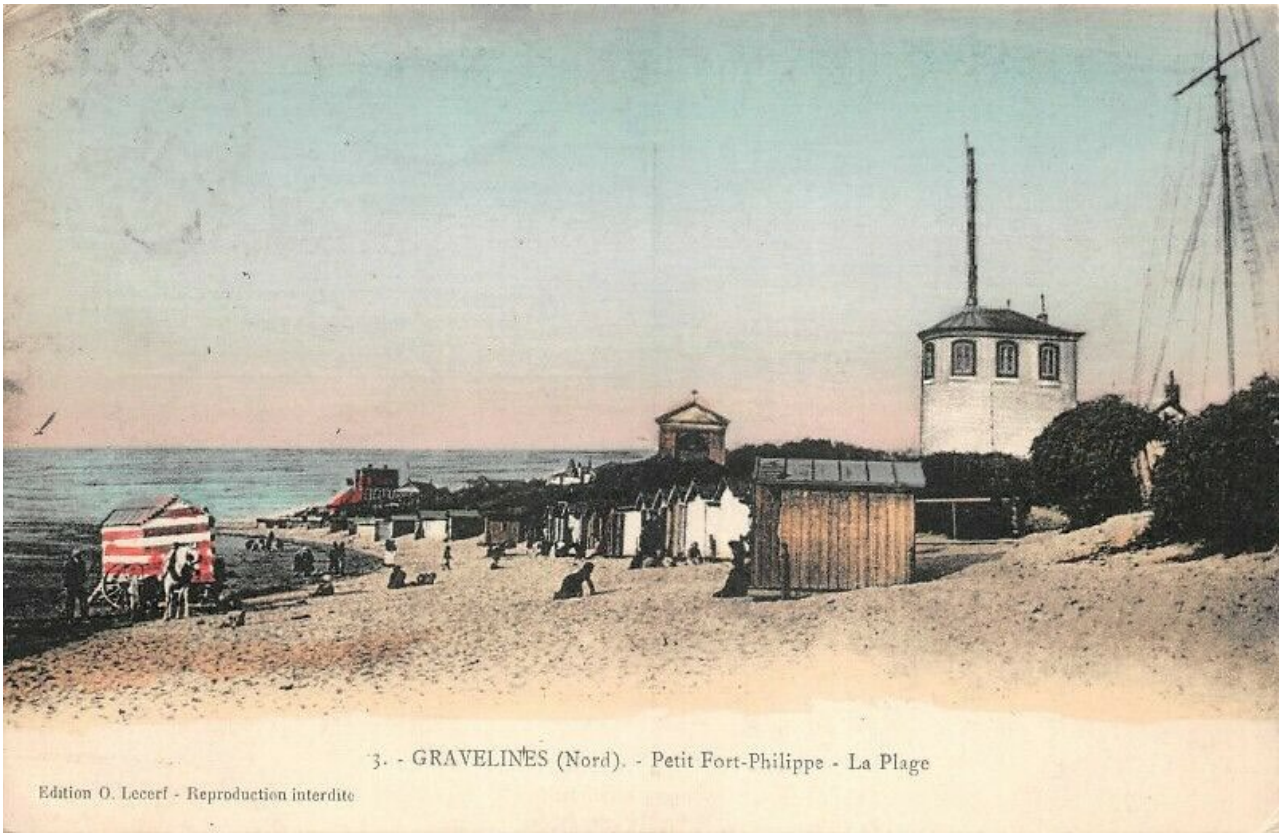


Figure 31: 1368 Petit Fort Phillippe La Plage, date 1925

4.2.3 Field Survey of Photograph Locations

Following scoring of the photographs a number were the subject of more detailed analysis involving a site visit. Where it was practical to gain access and relevant to the study, present day photographs were taken in the field to try, as far as possible, to match the views. It also provided the opportunity to assess the conditions of the shore and canal side to note changes that may have taken place over time; inspection was timed to coincide with Low Water. This ensured that thorough comparison could be made between features shown in photographs with the present-day situation.

Figure 32 shows a historic photograph featuring the lighthouse, nearby buildings and the dock side at the edge of the canal. Comparison with the modern view includes the lighthouse (covered in scaffolding) and it is possible to see what appear to be some of the same buildings, along with others that have been built on the same site as earlier examples. There appears to have been a change in the canal side here with the previous dock having been replaced with a slipway.

Figure 32: (left) Historic photograph 'Gravelines with lighthouse' [ID1371], with the comparative modern day image (right).

It is possible to see changes in the form of the canal breakwater in Figure 33 which shows and earlier survey with cobbles and a large rail along the eastern edge. The comparison modern photograph has the tide at a different position, but it is possible to see that it appears that sand has built up to a higher level on the seaward (east) side of the breakwater. There has also been resurfacing over the cobbles with tarmac.

The historic photo in Figure 34 is assumed to have been taken from the lighthouse. It shows the beach with the tide relatively high, the beach huts, dunes and adjacent buildings. Comparison with the modern day image shows a change in shape of the sand bar at the far end of the beach, there also appears to have been regression of the dunes which are relatively continuous in the historic photograph, but now have several areas which are stepped back progressively towards the lighthouse.

Figure 33: Women on the 'Causeway' [ID1431] which forms one of the 'arms' that form and protect the canal.

Figure 34: (left) 'Gravelines (Nord) – Vue du Petit Fort Philippe, and (right) modern day view showing the same area of foreshore and dunes.

5. Combined Application for Analysis of Coastal Change

The above sections have demonstrated the potential of each type of resource – archaeological, palaeoenvironmental, artistic, maps and charts and photographs – to be assessed and analysed to inform on the scale and pace of coastal change. When these resources are utilised together to look at particular areas or features this provides an exceptionally powerful set of data to be able to understand the long-durée of the coastline. In addition to the frontage that is directly adjacent to the Pilot Area there are a number of other features on the nearby areas which help show and understand how the local shoreline has changed. These are explored further here.

5.1 Petit Fort Philippe and Canal Development

Why selected for detailed study: Petit Fort Philippe, the location of the SARCC Pilot project owes its name to a fort that protected the entrance to the canal leading to Gravelines. Originally Gravelines was accessed by the River Aa, which ran to the east of the canal position and due to works to make the river navigable from as early as the 12th century it gave access to the town of St-Omer 27 kilometres further inland. Changes in the river and the cutting of a canal to the sea transformed this area of the shoreline. Petit Fort Philippe and the canal 'arms' or breakwaters which stretch for over a kilometre to protect the entrance to the port have a direct relationship with the SARCC Pilot area and the environmental forces impacting the frontage here.

Detail from scoring of available resources:

As significant physical features so closely linked to the development of the harbour and the canal Petit Fort Philippe and the breakwaters appear across the range of scored resources. Figure 35 includes a combination of these resources to show changes over time.

- Archaeology – the two 'arms' of the breakwater (ID 6115 and 6116) are high scoring features within the dataset. Their position in relation to the intertidal zone and ensuring coastal protection for safe passage to the harbour means they can inform on changes through using them to monitor associated sediment levels.
- Maps/ Charts – using the results of the scoring exercise it was possible to identify those maps and charts with most detail on the form of the river, canal and breakwaters over time. A sequence of high scoring maps seen in Figure 35 show some of the key features and changes over time. The Sanderus map of 1641, shows the situation when the River was the main navigable route to Gravelines and beyond, then by 1700 the Cassini map [ID 218, score 62.78] shows the canal as the main route to the sea, with the port basin and breakwaters. The map of 1777 by an unknown author details the fortifications, but also provide very detailed information on the layout of the can, size of the basin and the use of adjacent fields and the shape of the foreshore.
- Art – as the canal is a key local feature is appears in a number of high scoring art works. The art works provide a different dimension to the maps and charts with data on the vertical dimensions,

construction materials and the nature and form of the foreshore. Several works by Thomas Hardy Bush show a similar view of the break waters and the adjacent foreshore and frontage.

- Photographs – as with the art works, the canal breakwaters have been frequently captured within photographs. The photograph in Figure 35 [ID1431, score 77] provides an interesting view looking out along the breakwater with the profile of the foreshore on either side visible, it also shows the importance of the features for tourism and recreation with ladies enjoying a walk along the feature.

How the combined resources inform on coastal change:
The Sanderus map of 1641 shows the River Aa as the main access for navigation to Gravelines and beyond. At this time there is a 'canal' which links from the River to the shore defended by Forts on either side of the feature. It is slightly unclear when the 'canal' was cut through to the sea, with some maps of the 17th century showing a 'basin' or canal that only reached the Fort, while others show it as an open water way from the mid 17th Century.

It is clear that the channel underwent significant works under Louis XV, when a 'channel project', designed by King Philip IV of Spain, was completed between 1736 and 1740. This helped the maintenance and development of Gravelines as an important maritime centre.

Changes shown on the three maps examples within Figure 35 show the establishment of the canal as the main route to Gravelines and the gradual narrowing and siltation of the previous river route. In the detailed map of 1777 there was no longer even a small river channel to the sea and it is only the canal providing access. Channelling the river would have established a hydrographic regime that helped keep the channel clear and the construction of the breakwaters stretching across the foreshore to deeper water ensured safe access and passage for shipping. The maps show the sand dunes in this area persisted and would have changed form following the reduction in the river and increased flow through the canal.

These significant changes to the frontage at Petit Fort Philippe from the re-routing of the river and construction of hard engineering features of the breakwaters lead to the establishment of a new frontage from the canal heading east. The form of the frontage that established with the changed course of the River Aa can also be seen within the charts within Figure 37 (see Section 5.3).

The relationship of the beach/ foreshore frontage at Petit Fort Philippe and the canal breakwaters has then been captured within a range of art works and historic photographs over time which allows the changes in the beach frontage and profile to be viewed adding important data on the vertical dimension of long-term coastal changes. The historic photograph in Figure 35 of women on the 'causeway' is of unknown date, but likely to be late 19th century, or early 20th century, while the profile on the canal side looks relatively unchanged in comparison to the modern situation, it appears that there has been a build up of a sand on the foreshore side. The 'causeway' has also been slightly raised, or at least resurfaced.

Figure 35: Combined resources used to understand changes at Petit Fort Philippe, particularly the development of the canal.

5.2 Lighthouse

Why selected for detailed study:

The maritime importance of Gravelines, facilitated by the canal, lead to the construction of the light house, which was commissioned in 1843. This key maritime feature is very close to the SARCC pilot site and has a particular relationship with the sea and use of the port.

Detail from scoring of available resources:

The lighthouse is an important practical feature for ships and shipping using the port, and a dominant building at the foreshore at Petit Fort Philippe. It appears across the range of scored resources. Figure 36 shows a combination of these showing the lighthouse over time.

- Archaeology – The lighthouse is a listed as a historic monument, it is the highest scoring feature in the dataset (ID 6109).
- Maps/ Charts – the lighthouse appears marked on maps and charts dated to after 1843. There are relatively few charts from the more modern periods in the dataset, however, they can be used to show development around the lighthouse close to the foreshore.
- Art – The earliest representations of the lighthouse are within artistic resources. Again the paintings of Thomas Hardy Bush, who was a prolific artist working here show the lighthouse, with many of his paintings appearing in the high scoring list. Figure 36 shows his painting titled 'Lighthouse' from 1892 [ID401], which captures the lighthouse and the adjacent buildings with important detail of the coastal frontage here.
- Photographs – As the lighthouse was constructed prior to the invention of photography, it appears in many of the images available of the study area. Figure 36 includes one such high scoring early photograph, although of unknown date it predates 1914 due to the colour of the lighthouse.

How the combined resources inform on coastal change:

The lighthouse was built between 1837 and 1841 and was particularly needed by the fishermen of Gravelines, many of which took part in the fishing for cod off Iceland. It stands at 25.5m high and is visible for 26 miles out to sea. It was originally painted white, but as this was not always very visible out to sea it acquired its distinctive black and white colours in 1924.

The position of the lighthouse can be used to show changes to the adjacent foreshore and buildings and its location has been used to compare views from art works and historic photographs. The change in colouring of the lighthouse also helps date pictorial resources showing coastal changes. Figure 36 shows a painting by Thomas Hardy Bush alongside and early photograph, they are both showing a similar angle and buildings. It appears that between the painting in 1892 and the photograph which predates 1914 there has been some consolidation of the foreshore at this location with the edge of the causeway/ walkway of the breakwater visible in the photograph.

The comparison of the view of the lighthouse with the dock edge (lower Figure 36), which again predates 1924 as the lighthouse is white, with the modern vide of the same area shows some change to the edge of the dock facilities. It appears that some remains of the earlier dock still survive as they can been seen close to the water, however, behind the area of the old dock is now a modern slipway.

Lighthouse

Painting: Lighthouse, Thomas Hardy Bush, dated 1892 [ID401]

Photograph: Undated but prior to 1924 due to lighthouse colour.

Painting (left): Gravelines – Entrée du port – Andre Derain 1880-1954 (source, unknown) and (right) comparative modern day view (MAT 2021)

Historic photo (left) showing the dock side and lighthouse [ID1371, score 77], with the comparative modern day view on the right (MAT 2021)

Figure 36: Combined resources used to understand changes in relation to the lighthouse at Petit Fort Philippe.

5.3 Beach Frontage of Petit Fort Philippe

Why selected for detailed study:

This area is where the SARCC Pilot project is being implemented and is being directly impacted by the measures being put in place to work with nature to manage the coast. This frontage has undergone change over time and the use of archaeological, artistic, cartographic and photographic resources helps understand changes to its shape and the relationship of development to the nature of the foreshore.

Detail from scoring of available resources:

The beach frontage at Petit Fort Philippe appears across the range of scored resources.

- Archaeology – There are a number of historic buildings and features which have scored highly for informing on changes. These include the Chapel of the Sailors (The Petite Chapelle Notre-Dame des Flots at Petit-Fort St Philippe) built in 1829 (ID 6112), it was destroyed by German bombing in 1942 and rebuilt in 1954, and a number of Second World War Bunkers (ID 6110 (collection of bunkers) and ID 6108). These are relatively modern features, however, their position in relation to the frontage and dune systems can help measure changes.
- Maps/ Charts – Figure 37 includes a sequence of high scoring maps and charts which help to show the significant changes that have occurred to this area through changes from the original river system, the construction of the canal and the abandonment of the river.
- Art – A high scoring art work by Thomas Hardy Bush from the 1890s [ID424] provides an interesting perspective across the SARCC pilot area, this time looking west back towards the canal. The detail of the dune topography and limited edging fencing provides early evidence of their form.
- Photographs – the development of the area for tourism means there are many historic photographs and postcards which show the coastal frontage here. Figure 37 includes two historic photographs – one from leach level looking east with the distinctive white octagonal building which is to the right of the Chapel of the Sailors, and one which must have been taken from the lighthouse showing the same view from a higher vantage point.

How the combined resources inform on coastal change:

The beach frontage at Petit Fort Philippe has undergone some significant changes over time with the map and chart evidence providing detail from the situation in the late 16th century when the river was the main access route to Gravelines, through into the 17th century when a canal was cut to make a more direct route to the sea which was defended by structures. Over time the river access to Gravelines silted up due to reduced water flow and this changing situation is seen in the maps in Section 5.1. Concentrating on the specific areas of the frontage here more modern charts show that from the mid 19th century this area was relatively consistent in its form with a dune system and substantial foreshore area. The construction of significant port facilities at Dunkirk changed the nature of the foreshore, pushing out into the marine zone with hard engineering of harbour structures. Further local changes occurred with the building of the power station in the 1970s.

The construction of hard engineering has changed the movement of sediments on a local scale and these small scale changes can be seen through the use of art works and historic photographs which provide more detail of vertical change. Figure 37 shows the comparison of a historical photograph taken from the lighthouse with the modern day equivalent. This shows differences in the form of the sand bank area shown at the furthest point in the photograph, which is now much reduced in extent. The frontage has also undergone changes with elements of the vegetated dune frontage appearing to have regressed backwards in places as it is not as continuous as in the earlier photograph.

Understanding these micro-scale changes to the frontage can help monitor levels of historic changes which aides with planning for future management.

Beach Frontage of Petite Fort Phillipe

Maps and Charts top to bottom: 1588 Armada Plate (British Museum, Public domain, via Wikimedia commons); 1698 Map (Frederik de Wit, Public domain via Wikimedia commons); 1866 chart of the coastline [ID 335] (Creative Commons BY-NC-SA: 4.0); Chart of the coastline from 1996 [ID330] (Creative Commons BY-NC-SA: 4.0)

Painting and photographs from top to bottom: Thomas Hardy Bush, Gravelines The Beach [likely 1890s, ID424]; Postcard of Petit Fort Philippe beach in the sunset [ID1370]; Postcard Petit Fort Philippe, 1918 [ID1367]; Modern photo of beach frontage (MAT).

Figure 37: Combined resources used to understand changes at the beach frontage of Petit Fort Philippe.

6. Conclusions/ Recommendations

The variety of available sources for the Gravelines Pilot Study has demonstrated the potential of the SARCC scoring approach that has been applied to identify those resources of particular importance for understanding the long-durée of the coast.

Evidence from archaeological and historical sites provide evidence from early historic periods through to the Second World War. Combining the archaeological and historic data with artistic resources, including historic maps, charts, photographs and artworks allows us to understand change from prehistory up to the present day. Through a better understanding of how the Gravelines area developed, and in particular the frontage at Petit Fort Philippe became what it is today coastal managers will be better placed in planning for the future.

The combination of the various available sources of data have provided detail on the form and scale of change over time – particularly with the installation of the canal and changes to the adjacent coastal frontage. This information is of importance to the coastal scientist.

In many coastal locations detailed monitoring has taken place for less than twenty years. This pilot study helps explain the rate of change over past centuries as a result of sea level changes, human construction and the relationship of this with apparent periods of increased storm frequency. These data can supplement existing and future monitoring of trends and can support predictions for the future.

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