CASE STUDY

COASTAL EROSION RELATED TO A SEDIMENT DEFICIT IN THE NEARSHORE ZONE: THE CASE OF WISSANT BAY, NORTHERN FRANCE

LOCATION:
Wissant Bay, Northern France

TOPIC:
Beach morphology and evolution

KEYWORDS:
Beach erosion, sediment deficit

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Project part-funded by the European Union

EXECUTIVE SUMMARY

The coast of the Bay of Wissant, northern France, mainly consists of a wide macrotidal beach backed by coastal dunes located on either side of the small coastal resort of Wissant. A major part of the coast of the Bay of Wissant has been affected by very severe erosion since at least the middle of the 20th century, especially in the central part of the bay where coastal retreat rates reached up to 4 to 5 m/yr between 1949 and 2000. The analysis of bathymetry changes from 1911 to 2002 showed that coastline evolution is strongly related to nearshore morphological variations. There is actually a very strong correspondence between areas of significant nearshore erosion and sectors of coastline which experienced rapid retreat in the central and western parts of the Bay. Conversely, east of the resort of Wissant, where the shoreline advanced seaward several tens of meters, the seabed in the nearshore zone was either stable or characterized by sediment accumulation. Computation of sediment volume change showed that the net sediment budget in the Bay of Wissant was strongly negative during the 20th century, the sediment deficit being in excess of 100 000 m^3/yr on average.
This study shows that shoreline evolution in this area strongly depends on erosion and sedimentation processes that affect the whole littoral profile from the coastal dunes down to the shoreface several meters below sea level. Seabed erosion in the nearshore zone caused a lowering of the level of the intertidal beach, which favoured coastal retreat since lower beach levels result in higher frequencies of water levels that may reach and erode coastal dunes. This example of coastal evolution underlines the need to take into account the nearshore sediment budget prior to the implementation of protection measures.

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1 – GENERAL DESCRIPTION OF THE AREA

Wissant is a 5.5-km-long sandy beach located on the northern coast of France (Fig. 1) in a bay open to the northwest located between the cliff headlands of Cape Gris Nez and Cape Blanc Nez. The small town of Wissant is a coastal resort situated in the central part of the bay. The mean tidal range at Wissant is 5.84 m, with a maximum tidal range of 8.15 m at spring tide (SHOM, 2004). At low tide, the beach is 400-500 m wide and has a very gentle gradient (0.6 to 1 %).

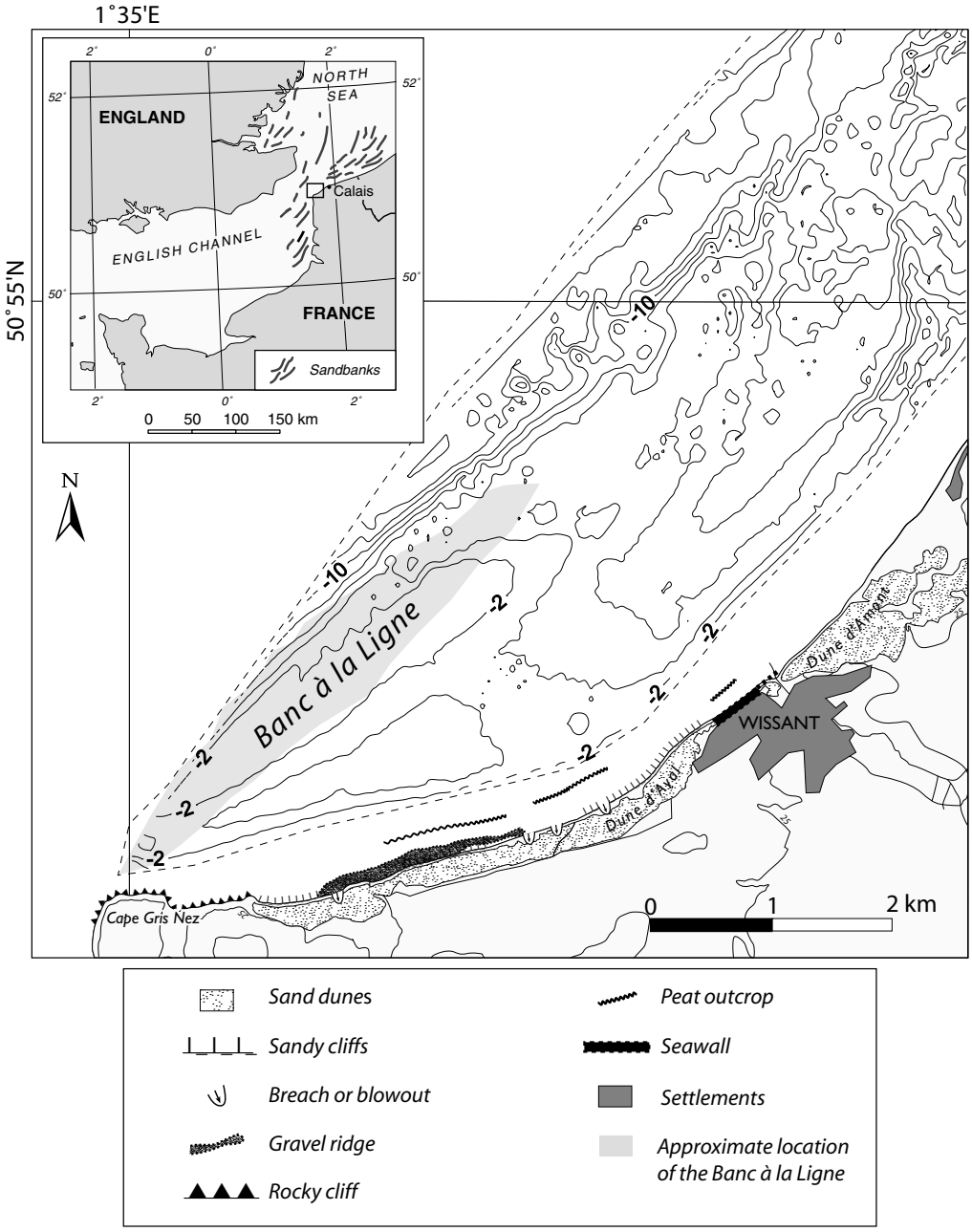

Figure 1. Location map (depht contours (m) correspond to the 2002 bathymetry)
Source: Aernouts and Héquette, 2006.

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The beach consists of fine homogeneous well-sorted sands (mean grain size 0.25 mm) and is characterised by irregular ridge and runnel morphology (Sipka and Anthony, 1999). The beach is backed by coastal dunes 100 m to 350 m wide and 3 m to 18 m high. The dune system consists of two dune masses located on either side of the coastal resort of Wissant. In the northeast, the coastal dunes are prograding, while west of Wissant resort they are affected by significant erosion.

Offshore, a prominent sand bank called the *Banc à la Ligne* is attached to Cape Gris Nez and extends eastward offshore to a distance of about 3 km, thus enclosing part of Wissant Bay (Fig. 1). Its seaward slope is composed of heterogeneous, sandy-pebbly sediments whereas its landward flank consists of medium sands (Clabaut et Chamley, 1986). Like the other sand banks in this area, it plays a fundamental role in the hydrodynamics and sediment dynamics of the coastal zone as it represents a potential source of sand for the beach-dune systems and partially dissipates storm wave energy (Anthony, 2002).

Due to the large tidal amplitude, tidal currents in the bay are strong, with maximum near-surface velocities that may exceed 2 m s^{-1} during spring tides. Although the velocity of tidal currents decreases shoreward, tides are responsible for alternating shore-parallel currents with velocities that reach about 0.5 m s^{-1} in the intertidal zone (Sedrati and Anthony, 2005). The Bay of Wissant is affected by waves originating from the English Channel, southwest of Cape Gris Nez, and by waves from the north-northeast that are generated in the North Sea. Most offshore significant wave heights are lower than 1.2 m, but wave heights of more than 5 m may be observed during high wind velocity events (Clique and Lepetit, 1986). Wave heights are much lower at the coast, however, due to significant refraction and shoaling over the sand banks of the northeastern English Channel.

2 - HISTORY OF COASTAL EROSION

Nowadays, the village of Wissant caters mainly for holiday makers, but in the Middle Ages it was a port engaged in cross Channel trade. The seaside resort of Wissant was inaugurated in 1903 and was established on 23 hectares of coastal dunes on which a luxury hotel, and numerous manors and cottages were built. A 302 m long, 16 m wide seafront embankment, designed as a promenade for tourists, was constructed in 1910. Later, it took on an additional coastal defence function, protecting seafront residences against storm damage. In the 1920s, a second embankment perpendicular to the first one was built in order to further protect residences from flooding. These works were further reinforced during the Second World War by the infamous 'Atlantic Wall' which included a moat, anti-tank devices and blockhouses.

Up to the 1960s, sand accretion in front of the seafront embankment was so significant that embryo dunes actively developed (Paxion and Cohen, 2002). In places, sand was so abundant that the embankment and residences behind were sometimes completely overwhelmed.

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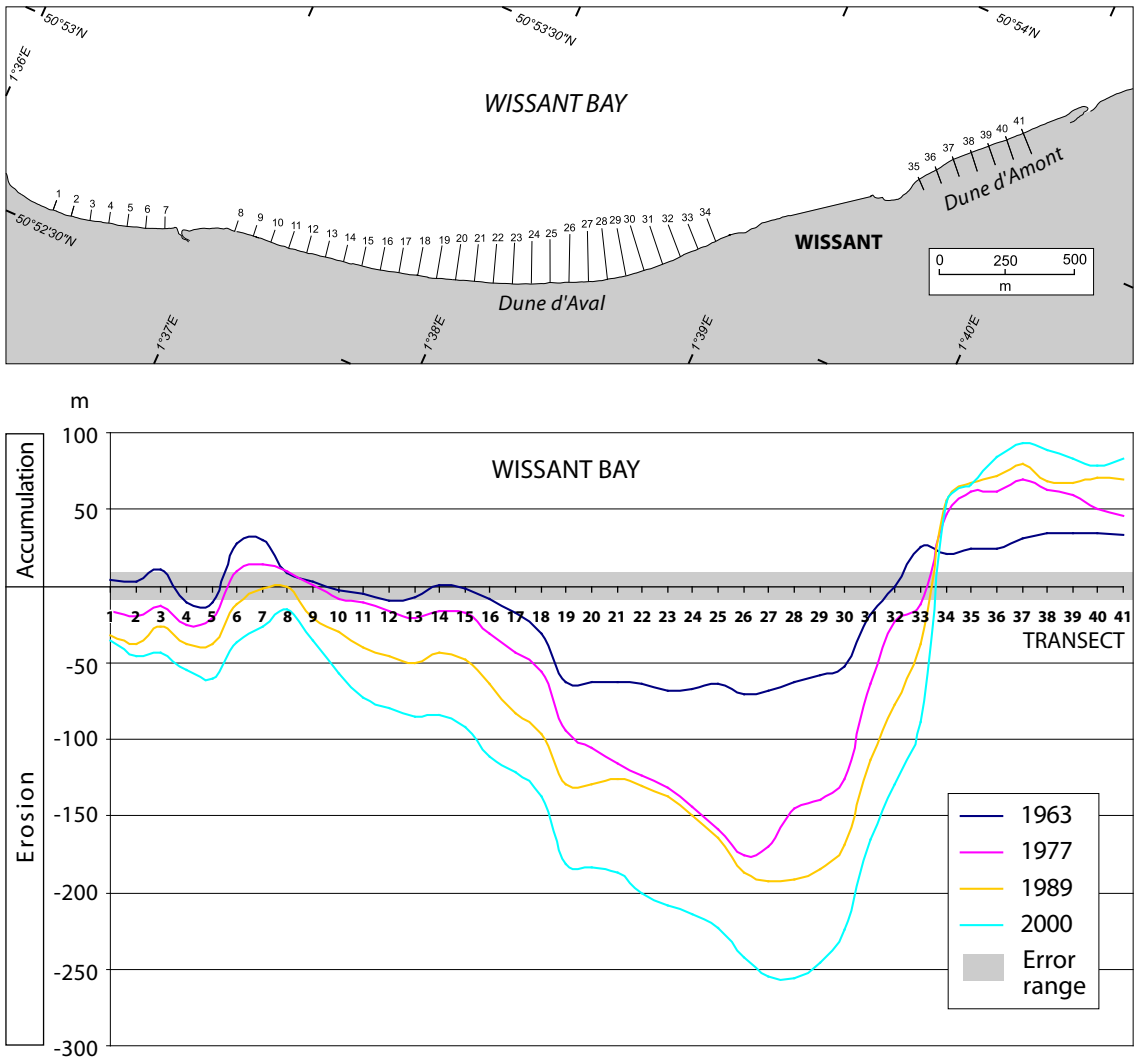

Figure 2. Shoreline evolution in Wissant Bay since 1949. Source: Aernouts, 2005

A study of shoreline evolution from 1949 to 2000 was carried out using vertical aerial photographs. Between 1949 and 2000 the western and central parts of Wissant Bay were affected by strong erosion, in particular in front of the *Dune d'Aval* (Fig. 2) where shoreline retreat generally exceeded 200 m, and even attained 250 m in places (Aernouts 2005). Annual retreat rates attained remarkable values of up to 4-5 m per year. Retreat rates tended to decrease westwards, although they were still higher than 1 m per year. In the central part of the bay, coastal retreat resulted in the complete loss of the foredunes. The inland dunes, now exposed at the shoreline, exhibit an erosional scarp 2-3 m high (Fig. 3). Back-dune vegetation (mainly *Hippophaë rhamnoïdes, Festuca sp., Ligustrum vulgare, Sambucus nigra*) is therefore now found in a seaward position (Ruz and Meur-Férec, 2004). Due to the rapid coastal retreat, an outcrop of organic-rich freshwater peat is exposed on the upper beach 15-20 m seaward of the dune toe. To encourage sand accumulation and prevent dune scarp erosion, sand fences were usually installed before summer (by the end of May) and retrieved at the beginning of autumn by the *Conservatoire du Littoral*, which owns 42 ha of coastal dune in Wissant Bay. As a

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result of coastal retreat, the embankment collapsed for the first time at its western end during the winter of 1994-1995. Embankment damage by storms since occurred in 1997, 1999, and in January and December 2000 (Fig. 3). Furthermore, the foreshore was lowered and the sand became thinner on the beach, seriously threatening the tourism activities.

Figure 3. Some effects of the erosion in Wissant Bay: coastal dune retreat west of Wissant (photo M-H. Ruz) and Embankment collapse in Wissant in 2000 (photo P. Overlau)

In contrast, sand accumulation occurred during the same period of time northeast of Wissant and coastal dune development resulted in shoreline advance of up to 90 m (Aernouts, 2005). The *Dune d'Amont* area (Fig. 1) underwent progradation at rates ranging from 1.3 to 1.8 m a year. It is likely that some of the sediments eroded in the western and central parts of the bay accumulate in this sector. However, there is a strong disproportion between the quantities of eroded sediments and those in the prograding sectors, thus suggesting an important net loss of sediment.

Our results also show that the retreat rates are variable through time. The period 1949 to 1977 was characterized by maximum retreat rates of more than 6 m/yr in the centre of the bay, while the coastline was relatively stable or slowly retreating in the western part of the bay during that period (Aernouts and Héquette, 2006). The analysis of shoreline positions indicates that coastal erosion was more extensive between 1977 and 2000, affecting almost the entire Bay of Wissant. The only exception was the eastern part of the bay, east of the hamlet of Wissant, where the shoreline conversely advanced seaward during both periods.

3- COASTAL EROSION LINKED TO A NET SEDIMENT DEFICIT IN THE NEARSHORE ZONE

An analysis of bathymetry changes, to a water depth of approximately 20 m, was also conducted, using 1911, 1977, and 2002 bathymetry surveys. The objective was to assess the morphological variations of the complete coastal profile including both nearshore and shoreface environments. The nearshore bathymetry showed important changes between 1911 and 2002 (Aernouts, 2005). The

analysis of bathymetry changes suggests that coastal evolution is strongly related to nearshore morphological variations.

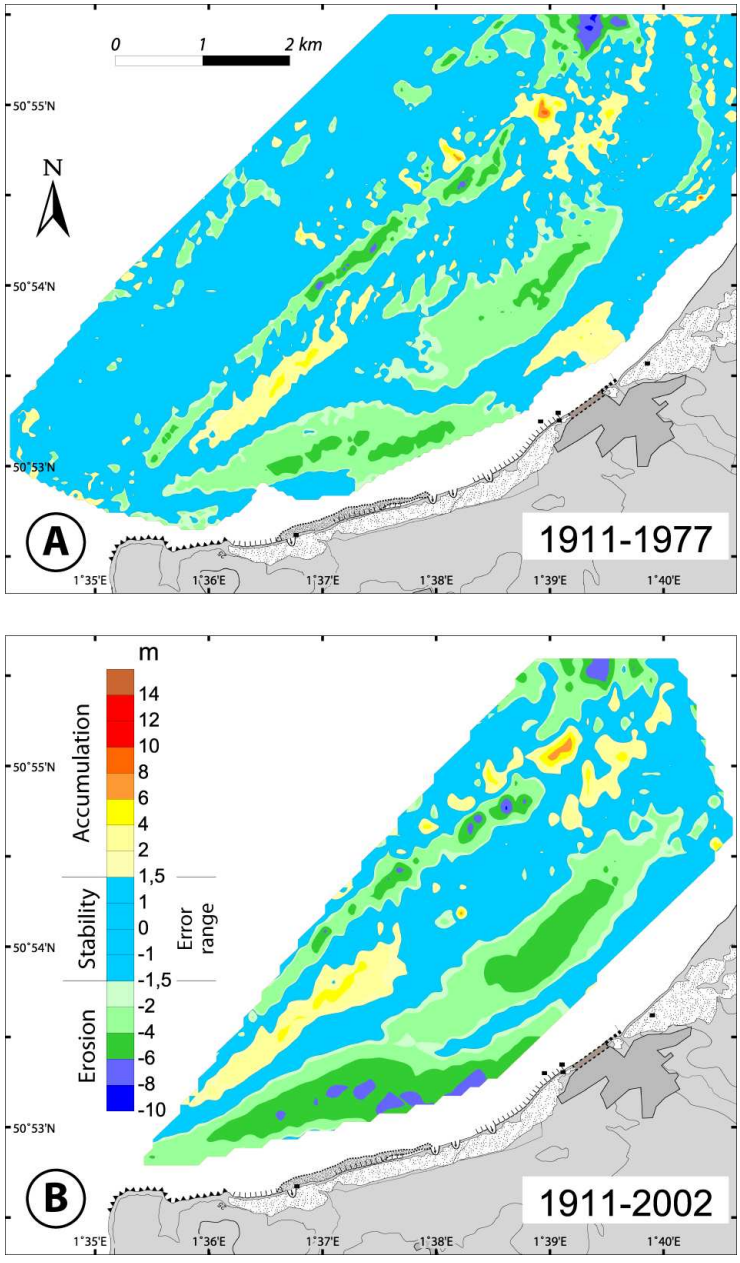

Figure 4. Maps of bathymetry changes in the Bay of Wissant. Source: Aernouts, 2005.

There is a very strong correspondence between areas of significant nearshore erosion and sectors of coastline which experienced rapid retreat in the central and western parts of the Bay (fig. 4). Conversely, east of the hamlet of Wissant, where the shoreline advanced seaward several tens of meters, the seabed in the nearshore zone was either stable or characterized by sediment accumulation. Computation of sediment volume changes showed that the net sediment budget in the

Bay of Wissant was strongly negative during the 20th century, the sediment deficit being in excess of 100 000 m^3/yr on average. Nearshore seabed erosion mostly occurred in a longshore trough located between the shore and the *Banc à la Ligne*. This bank also experienced a significant decrease in sediment volume. The decrease in the sediment volume of the bank, which represents a potential sediment source for the beach and coastal dune systems, may have contributed to a decrease in the littoral sand budget.

Bathymetric change analyses also indicate that nearshore erosion proceeded more rapidly during the 1977-2002 period compared to the preceding period, similar to observations of coastal erosion. Although the increase in coastal and shoreface erosion during the last decades of the 20th century may be partly explained by variations in storm frequency and intensity, anthropogenic factors should certainly be taken into account. Both the extraction of marine aggregates in the vicinity of the *Banc à la Ligne* and the extension in the early 1970's of a harbour jetty at Boulogne-sur-Mer, southwest of the Bay of Wissant, probably increased the sediment deficit in the bay.

CONCLUSION

This study shows that shoreline evolution in the Bay of Wissant strongly depends on erosion and sedimentation processes that affect the whole littoral profile from the coastal dunes down to the shoreface several metres below sea level. Seabed erosion in the nearshore zone caused a lowering of the level of the beach. This certainly favoured coastal retreat since lower beach levels result in higher frequencies of water levels that may reach and erode coastal dunes.

Exhaustive studies of the hydrodynamic, sedimentary and morphodynamic conditions prevailing in eroding sites are necessary prior to the implementation of protection measures. A prime consideration in this regard is the sediment budget of both the foreshore and the nearshore zone.

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