Environment Agency

Regional Beach Management Plan 2017: Selsey Bill to Climping

Report – ENVIMSE100035/R-01

Final Report, August 2017

This series of regional Beach Management Plans for Southeast England are dedicated to the memory of Andy Bradbury.

The data that has been used to compile them is only available due to Andy's vision and drive for better coastal monitoring data to inform beach management.

Regional Beach Management Plan 2017

Selsey Bill to Climping

Main Report

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EXECUTIVE SUMMARY

This Beach Management Plan (BMP) has been prepared by **Canterbury City Council** on behalf of **Arun District Council, Chichester District Council and the Environment Agency**. The BMP sets out the data that can be used by operating authorities to implement approaches for intervention and monitoring to maintain the beach where it provides an integral part of the sea defences between Selsey Bill and Climping. The aim of the BMP is to inform, guide and assist these responsible authorities and organisations in managing the beach, and to ensure that the beach management continues to manage the risk of coastal flooding and erosion.

Beach Management Plans provide an accountable and transparent methodology for managing beaches as coastal defence assets based on risk information that derives from scheme design, monitoring and scientific/research input with the aim of managing the frontage in a sustainable way that enhances vegetated shingle habitats.

To this effect the BMP contains the evidence base that can lead to management options. To achieve this aim of accountability and transparency, all source data, documents and methods are appended to this report in the Appendices and in digital form in the enclosed DVD.

The BMP proposes the following activities:

- Continued monitoring as part of the Regional Coastal Monitoring Programme;
- Operating authorities use the calculated trigger levels (based on a standard of protection of 1:200 years) to inform beach management activities, ideally working across the sediment cell;
- Operating authorities use the overtopping results in Appendix G to calculate beach size necessary for different design conditions where necessary (allowable overtopping rate and chosen standard of protection).

1 INTRODUCTION

1-1 PRESENT SITUATION

1-1-1 SMP AND OTHER STRATEGY POLICY

The coastline between Selsey Bill and Littlehampton Harbour falls within the coastal frontage of the Beachy Head to Selsey Bill Shoreline Management Plan (2006) including policy units 4d20 (Littlehampton to Poole Place) to 4d27 (Selsey Bill), Table 1-1. The frontage is managed under the responsibility of the organisations shown in Figure 1-1 overleaf.

The Pagham to East Head Coastal Defence Strategy (2009) covers the West Sussex coastline between Pagham Beach and West Wittering; and the River Arun to Pagham Flood and Coastal Erosion Risk Management Strategy (2015) covers the coastline between Pagham and Climping. The Pagham to East Head strategy builds on earlier work and the relevant SMPs. The River Arun to Pagham Strategy follows from the uncompleted 2004 Coastal Defence Strategy, updated between 2008 and 2010 and reviewed following a legal challenge and judicial review.

TABLE 1-1 SMP POLICIES WITHIN BMP

POLICY UNIT	DESCRIPTION	SEDIMENT TYPE	SHORT TERM	MEDIUM TERM	LONG TERM
4D 20	LITTLEHAMPTON TO POOLE PLACE	SHINGLE	MR	MR	MR
4D 21	ELMER	SHINGLE	HTL	HTL	HTL
4D 22	MIDDLETON	SHINGLE	HTL	HTL	HTL
4D 23	FELPHAM TO ALDWICK	SHINGLE	HTL	HTL	HTL
4D 24	ALDWICK TO PAGHAM	SHINGLE	HTL	HTL	HTL
4D 25	PAGHAM HARBOUR TO CHURCH NORTON	SHINGLE	MR	MR	MR
4D 26	CHURCH NORTON TO SELSEY EAST BEACH	SHINGLE	MR	MR	MR
4D 27	SELSEY BILL	SHINGLE	HTL	HTL	HTL

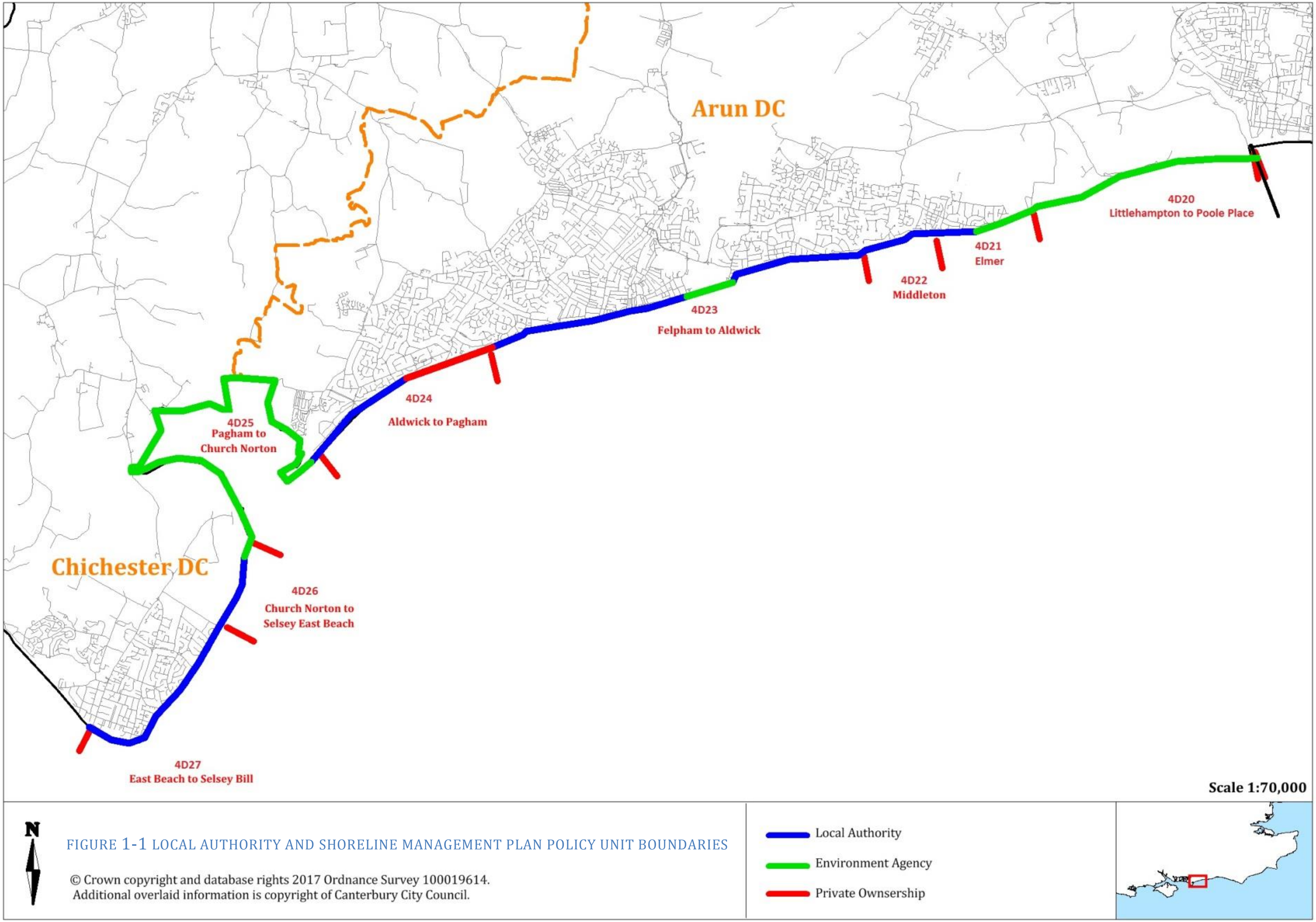

FIGURE 1-1 LOCAL AUTHORITY AND SHORELINE MANAGEMENT PLAN POLICY UNIT BOUNDARIES

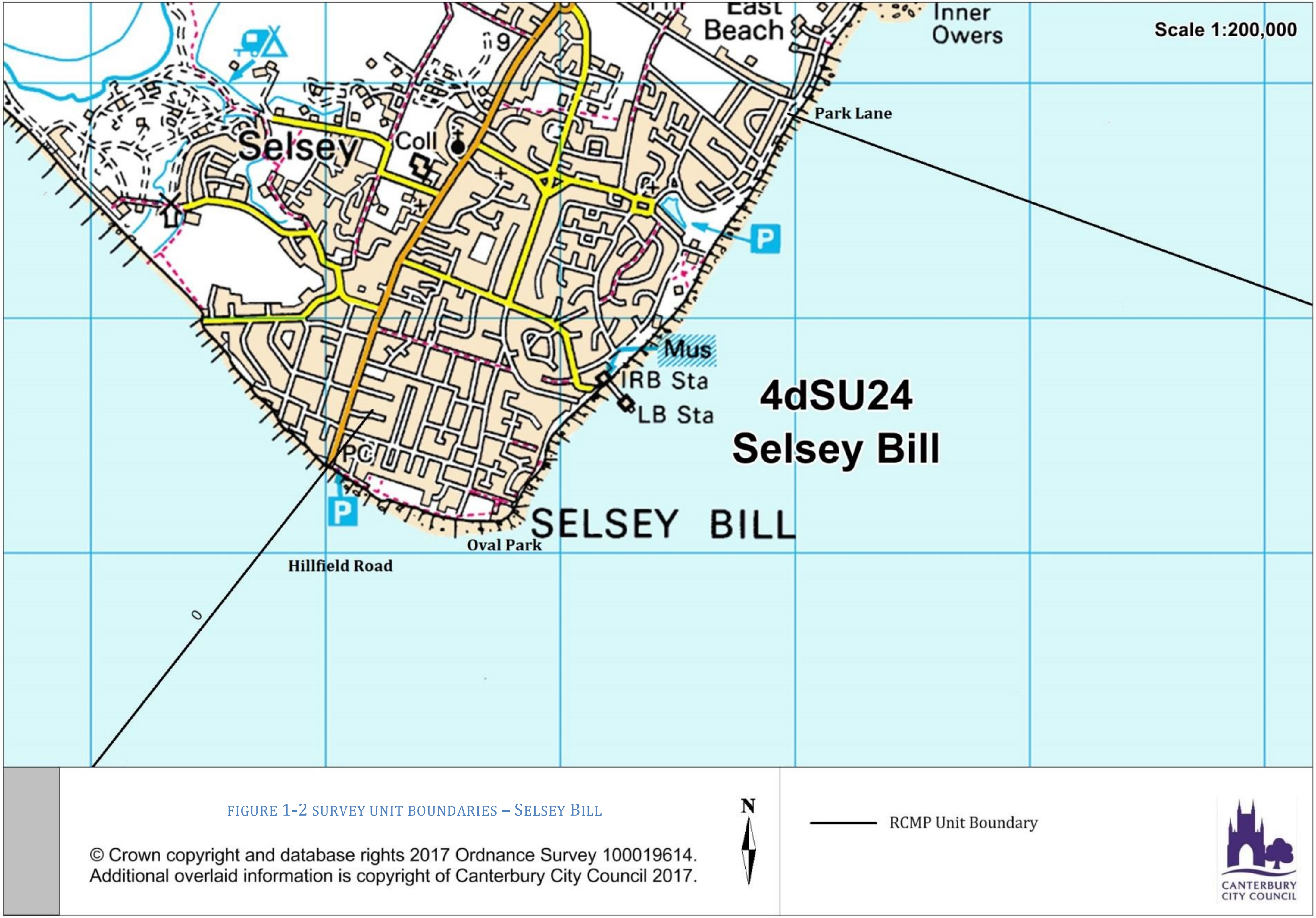

FIGURE 1-2 SURVEY UNIT BOUNDARIES – SELSEY BILL

CANTERBURY CITY COUNCIL

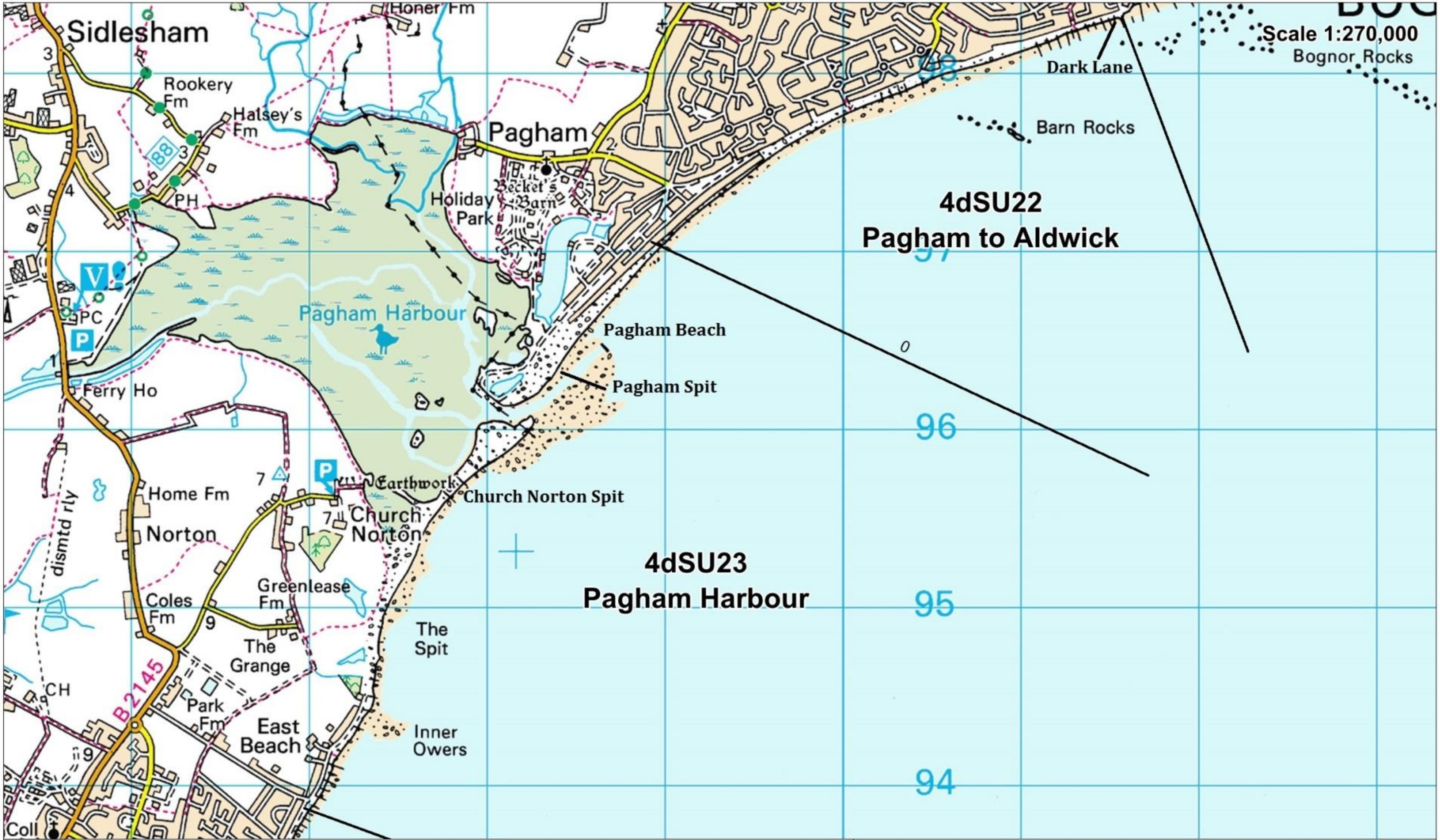

FIGURE 1-3 SURVEY UNIT BOUNDARIES – PAGHAM HABROUR AND PAGHAM TO ALDWICK

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RCMP Unit Boundary

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FIGURE 1-4 SURVEY UNIT BOUNDARIES – BOGNOR REGIS

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RCMP Unit Boundary

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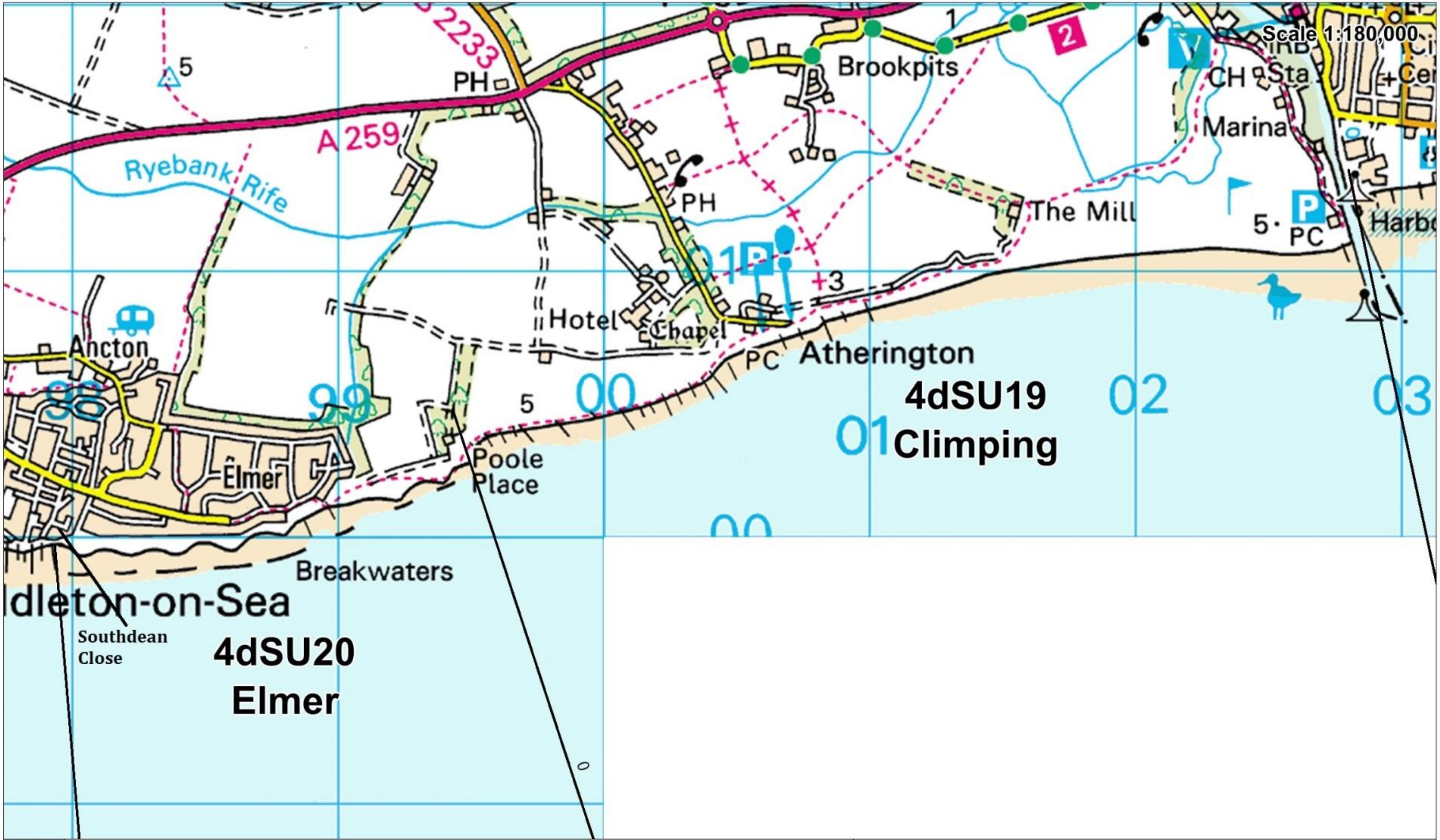

FIGURE 1-5 UNIT BOUNDARIES – ELMER AND CLIMPING

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RCMP Unit Boundary

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1-1-2 PHYSICAL CHARACTERISTICS AND COASTAL DEFENCES

The land between Church Norton and Littlehampton Harbour is low lying; flood basins are present at Pagham Harbour, Bognor Regis, Elmer and Climping. Selsey Bill, at the western extent of the study area, is a peak in an otherwise low lying landscape. The River Arun marks the most eastward boundary at Littlehampton. The beaches are mostly shingle and mixed shingle sand in places, with a sandy/shingle foreshore. Refer to Appendix A - Oblique Aerial Photography for place names and a frontage overview.

SELSEY BILL

The survey unit extends from Hillfield Road in the west to Park Lane in the east, extending 3.1km (Figure 1-2). Selsey Bill is characterised by a chalk headland, +10.0mOD at its highest point, that protrudes into the English Channel and marks the western most boundary of this study. The longshore drift direction throughout this study area is predominantly west to east, with the drift divergence on the western boundary of the study area. Shingle is transported around the peninsula in a north east direction, towards Pagham Harbour. The beach is mixed shingle sand composite and has a gradient to the foreshore that varies between 1:8 and 1:11.

The small beach between Hillfield Road and the Selsey Bill headland is locally known as Selsey beach where there are two small privately owned sections of sea wall with an elevation between +5.3m and +5.5mOD (Selsey and Wittering Beach Management Plan, 2012). A timber breastwork wall, 100m in length, follows the line of the old gabions between the Hillfield Road car park and the Oval Field. Moving west, between Selsey Bill headland and Park Lane is referred to as East beach and is defined by a concrete sea wall with an apron and promenade for the whole of its length. The rear wall has an elevation of +5.2mOD (Selsey and Wittering Beach Management Plan, 2012). During stormy weather in the winter period, the promenade is regularly overtopped and covered in shingle, restricting access.

PAGHAM HARBOUR

The survey unit Pagham Harbour extends from Park Lane in Selsey to Pagham village in the east, a 3.8km stretch (Figure 1-3).

The beach fronting East Beach Road and Park Copse is retained by 14 timber groynes. The spacing of the groynes becomes less frequent as the urban and farmland areas give way to the Pagham Harbour saltmarsh and tidal mudflats, where a wide shingle berm begins (Pagham Harbour Beach Management Plan Report, 2015). A 165m timber crib wall (+5.3mOD) is located just east of the house along Park Copse.

Pagham Harbour itself is a small tidal inlet on the Sussex coast with a low level freshwater discharge into the harbour from five small streams draining nearby fields (Pagham Coastal Defence Study Geomorphological Assessment, 2009). A large shingle spit known as the Church Norton spit runs across the length of the harbour mouth and comprises a series of sub-parallel (nearly parallel) shingle ridges and recurves, which mark different phases of extension and accretion (May, 1966). This spit extends eastwards from the village of Church Norton and at its longest extended up to Pagham beach to groyne 1295 (shown in Figure 1-6). There is a second spit that extends westward from Pagham, known as the Pagham Spit, which is held in its current position by the presence of a retaining (steel sheet piled) training wall at its southern end (PEHCDS Appendix A). In 2016 the Church Norton spit breached and since then a much shorter spit has remained.

The old spit head and much of the arm have transported eastwards to join Pagham beach, with the influx of material increasing the protection against erosion to the properties just south-west of the hybrid timber-rock groynes (shown in Figure 1-6). The properties within the groyne field are at continued risk of erosion.

The frontage has a relatively shallow lower foreshore due to the sheltering effects of an extensive offshore sand and shingle bank named 'Inner Owers'.

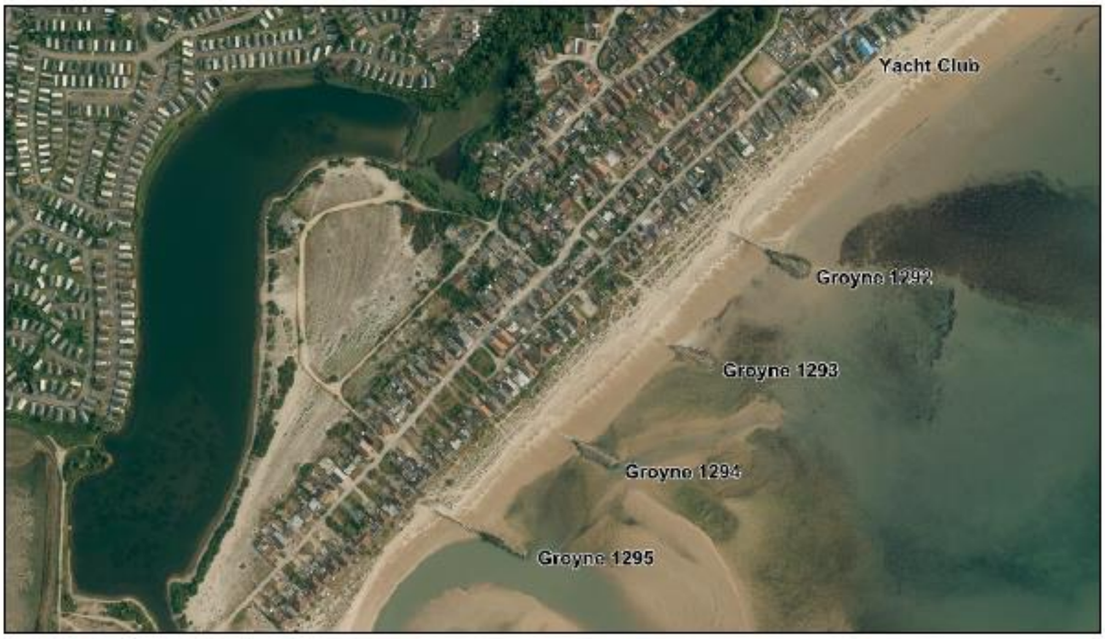


FIGURE 1-6 LOCATION OF GROYNES AT PAGHAM BEACH (PAGHAM HARBOUR BEACH MANAGEMENT PLAN REPORT, 2015)

PAGHAM TO ALDWICK

The Pagham to Aldwick beach extends 2.9km from Pagham village (Groyne 1292, Figure 1-6) to the rock toe protection at Dark Lane, Aldwick (Figure 1-3), fronting the settlement of Aldwick. The shingle beach sits naturally at a 1 in 8 slope down to the sand and shingle foreshore. The western extent is marked by a rock groyne, to the east of which there are two buried timber groynes close to the Yacht Club (Pagham Harbour Beach Management Plan Report, 2015). There are eight partially buried timber groynes at the eastern boundary at c.50m spacing but no hard rear defences within the frontage.

BOGNOR REGIS

Bognor Regis stretches for 6.6km from Dark Lane, Aldwick in the west, to Southdean Close, Middleton-on-Sea in the east, including the main town frontage of Bognor Regis and is inclusive of the villages of Middleton-on-Sea, Felpham and East Aldwick (Figure 1-4). The beach is shingle sand composite at a 1 in 9 slope with a sandy foreshore.

The houses between Dark Lane and Marine Drive West are fronted by a variety of different seawalls with elevations of +5.3mOD, with rear wall at +6.1mOD. To the east of these houses there is a long stretch of undefended promenade backed by the Marine Park Gardens (Arun to Pagham Strategy Appraisal Report, 2015). From the Marine Park to the Pier, there is a concrete sea wall with a rear wall ranging between +6.2m to +7.3mOD. East of the Pier to Sea Way (private estate) is defended by sea wall varying between +4.8m to +6.5mOD. Timber breastwork extends east of Sea Way to Sea Lane. A concrete sea wall starts again at Sea Lane and continues to the Bognor Regis and Elmer boundary and sits at +5.0 to +5.7mOD. A total of 92 timber groynes and 8 rock groynes are also present throughout this stretch with the majority of both rock and timber groynes graded as either good or excellent (Arun to Pagham Strategy Appraisal Report, 2015).

ELMER

Elmer is the shortest of all of the units, bounded by Southdean Close in Middleton-on-Sea to the west and the terminal rock groyne at Poole Place to the east (Figure 1-5). The 1.85km beach is mixed shingle and sand sediment, with a 1 in 10 gradient sloping to a sand foreshore.

The frontage is characterised by the presence of eight offshore breakwaters and salients which were constructed close to their current form following physical modelling; a rare example of this defence type in the UK. A terminal rock groyne at the eastern extent of the section aims to reduce the transfer of sediment into Climping thus maintaining the beach at Elmer.

Landward of the offshore rock breakwaters, the majority of the frontage has no further defences; however there is a short section of concrete sea wall (+5.5mOD). There is also a 200m rock revetment between two of the breakwaters. The rock revetment has a crest of +6.5mOD and a 1:3 slope (Arun to Pagham Strategy Appraisal Report, 2015). Approximately eight redundant and dilapidated groynes are half buried along the beach (Arun to Pagham Strategy Appraisal Report, 2015).

CLIMPING

The 3.7km beach at Climping extends from the Poole Place rock groyne at Elmer, in the west, to Littlehampton western Harbour Arm in the east and consists of mixed sand and shingle sediment t a 1:7.5 slope to the sand foreshore.

Climping is largely undefended although there are some sections of historic wartime concrete sea wall/blocks. Sand dunes span for just over a kilometre in the eastern extent.

There are 32 timber groynes which front Atherington and Climping which are spaced at 50m to 100m intervals. A single timber groyne is found at the eastern extent of the section (Arun to Pagham Strategy Appraisal Report, 2015).

1-1-3 GEOLOGY

TOPOGRAPHY

The study area is a relatively flat landscape ranging between +2.0 mOD to +13.0 mOD (Figure 1-7).

Four river outlets intersect the study area; the elevations here are much lower than the surrounding topography ranging between 0 and +2.0 mOD. The two larger rivers are Pagham Harbour and the River Arun and the two smaller outlets are the Aldingbourne Rife and Ryebank Rife.

A stony ridge, which forms the headland of Selsey Bill is elevated at +8 to 10mOD. A localised and transient high point is the windblown sand dune deposits at Climping which are between +9.0 mOD and 13mOD.

BEDROCK & SUPERFICIAL DEPOSITS

Four rock types are present within the study area, three of which are of soft, unconsolidated material and extend for the majority of the frontage from Selsey to approximately the Bognor Regis Pier.

The Bracklesham Group, which stretches from Selsey to Pagham, comprises of interbedded to interlaminated clays, silts and mostly fine sands. The Thames Group extends between Pagham Harbour and Bognor Regis, and is made up of fine material, including silts, clay and mudstone. A band of Lambeth Group Clay, approximately 700m wide, separates the Thames Group and the White Chalk Subgroup to the East. The remaining stretch of coastline is chalk.

Brickearths are the predominant superficial deposits throughout the study area, interspersed with alluvial material within low-lying flood plains. Vegetated sand dunes at West Beach, bordering the River Arun are gaining sediment through aeolian transport.

COASTAL EVOLUTION

The following paragraphs are excerpts from the website "Standing Conference on Problems Associated with the Coastline (SCOPAC)":

"The Selsey coastline is developed in Eocene (principally Bracklesham Group) sandstones and clays, overlain by Quaternary drift deposits. The former provide the substrate beneath the inter-tidal foreshore and are highly erodible; prior to the construction of comprehensive "hard" defences, coastline recession rates were up to 8ma-1 in places. Last Interglacial (Ipswichian stage)

Raised Beach deposits overlie earlier Quaternary deposits (Reid, 1892; West and Sparks, 1960; West, et al. 1984 and Bates, 1998 and 2000), but their formerly extensive exposure at the shoreline is now restricted to a few localities. Late Devensian or early Holocene loamy silt ('Brickearth') overlies the Raised Beach and provides the substrate to modern soil profiles. These deposits overlie the most recent of a sequence of marine erosional platforms that extend 25km inland. They have been interpreted as the product of successive Middle Pleistocene sea-level transgressions, punctuated by regressive stages and subsequently displaced by neotectonic movements (Bates, 1998, 2000; Hodgson, 1964; Bates, Parfitt and Roberts, 1997). Further detail is contained within the separate Section on the Quaternary History of the Solent.

Archaeological and sedimentological evidence supports the reconstruction of a continuous tidal creek linking Pagham Harbour with Bracklesham Bay (Heron-Allen, 1911; Millward and Robinson, 1973; Hinchcliffe, 1988; Wallace, 1990 and 1996; Castleden, 1998; Bone, 1996; Thomas, 1998). This may date back at least 2,000 years, perhaps resulting from a major breach of an earlier Bracklesham Bay barrier beach at Medmerry (Wallace, 1990). The Medmerry barrier is believed to have reformed and breached several times during subsequent centuries; at times isolating the Selsey peninsula as an island. Archaeological evidence demonstrates that the coastline was some 2 to 3km seawards of where it is now at about 5,000 years Before the Present (White, 1934; Wallace, 1967, 1968 and 1996; Goodburn, 1987; Thomas, 1998). Coastal erosion over this period must have occurred at a rate at least as fast as that recorded for the nineteenth and first half of the twentieth centuries (May, 1966). Documentary evidence for the medieval period (Bone, 1996) also indicates rapid coastline recession, especially during major storms. The latter probably caused the Medmerry barrier to repeatedly breach and break down, although there is reliable evidence that it was in place in the mid-sixteenth century. Stratigraphy from shallow boreholes into sediments infilling the former tidal creek isolating Selsey (Hinchcliffe, 1988; Wallace, 1990) clearly indicate oscillations between lagoon and brackish water conditions. A barrier spit may have connected Selsey Island with the mainland in the sixth century AD, but was permanently removed by a storm surge of exceptional magnitude in 1048.

Reclamation of some 120 hectares of saltmarsh occupying the tidal channel between Pagham Harbour and Medmerry was achieved when the Broad Rife sluice was built in 1884. This was undertaken in response to back barrier flooding resulting from a large pulse of gravel drift that blocked the Medmerry exit of this stream in 1880 (Bone, 1996). Further temporary blockages occurred in 1918, 1920 and 1924 before stabilisation of its present mouth in 1930.

The approximately triangular shape of the Selsey peninsula results from the protective presence of the Mixon reef some 2.5km seawards of Selsey Bill. This feature is composed of a relatively resistant

Eocene calcareous Alveolina limestone cap rock overlying Bracklesham sands and clays. Wallace (1967, 1968, 1990 and 1996) has described a well-defined valley, up to 25m in depth and scoured by tidal currents, to the immediate south of the Mixon. The Outer and Malt Owers and The Streets are smaller bedrock reefs, but other offshore banks within 3km of the modern coastline appear to be sediment accumulations. They may be relict parts of a multistage barrier structure that was progressively segmented and submerged between 2,500 and 800 years before the present (Wallace, 1990; 1996). A remnant area of lagoonal and colluvial sediment that accumulated behind this structure survives inland of East Beach. Very fast erosion of this weak material occurred in the 50 years prior to the completion of coastal defences in 1960.

Barrier breaching and shoreline recession associated with rising sea-level and storm events caused The Mixon to become an offshore bank, or shoal, probably at about 950-1050 AD (Wallace, 1990). It would have been emergent during mean low water, whilst the Inner Owers would, by this time, have been fully submerged. The Mixon therefore acquired its reef-like form and function from early medieval times onwards as sea-level rose further and both tide and wave-induced currents caused bedrock scour."

(SCOPAC, 2017).

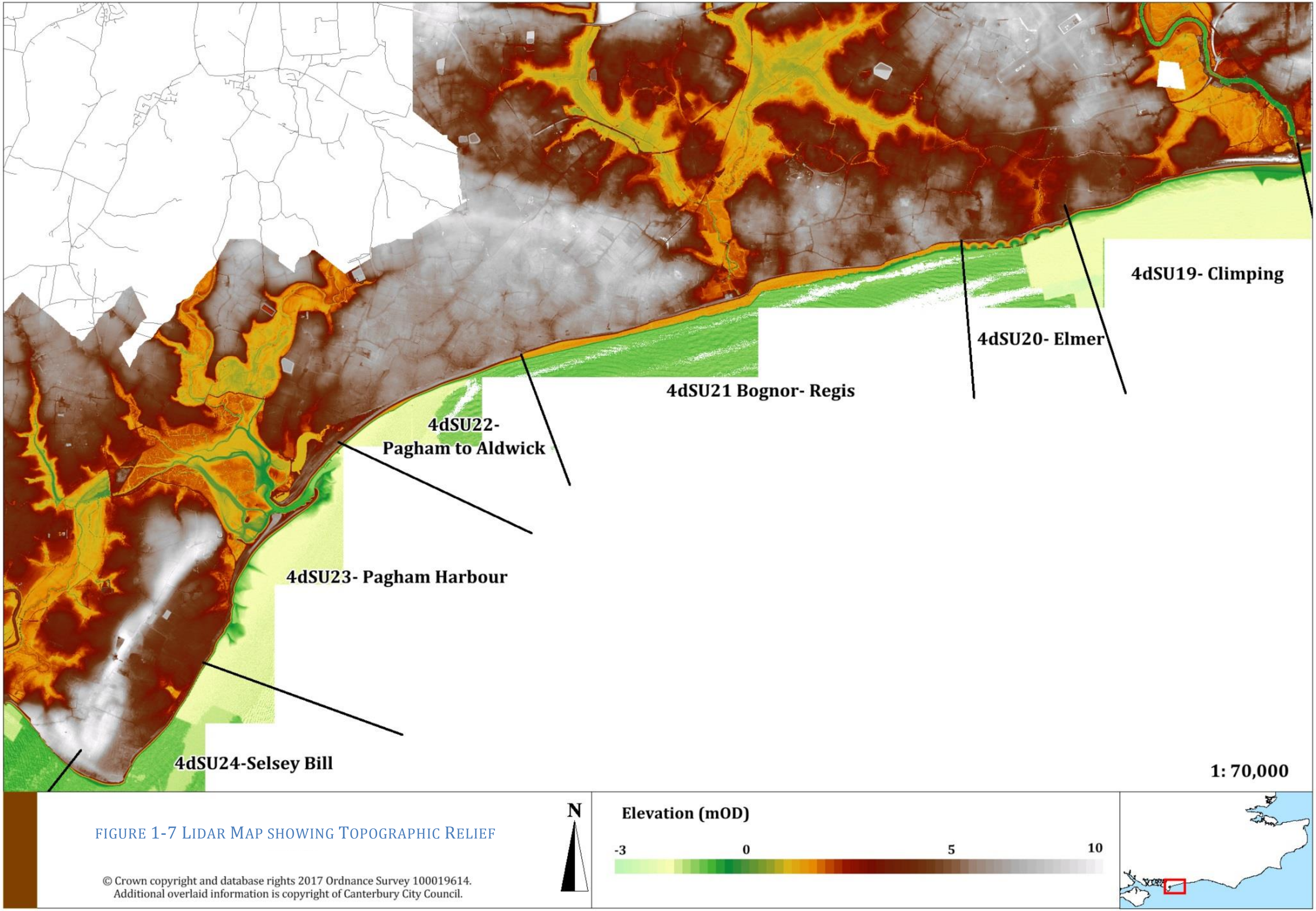


FIGURE 1-7 LIDAR MAP SHOWING TOPOGRAPHIC RELIEF

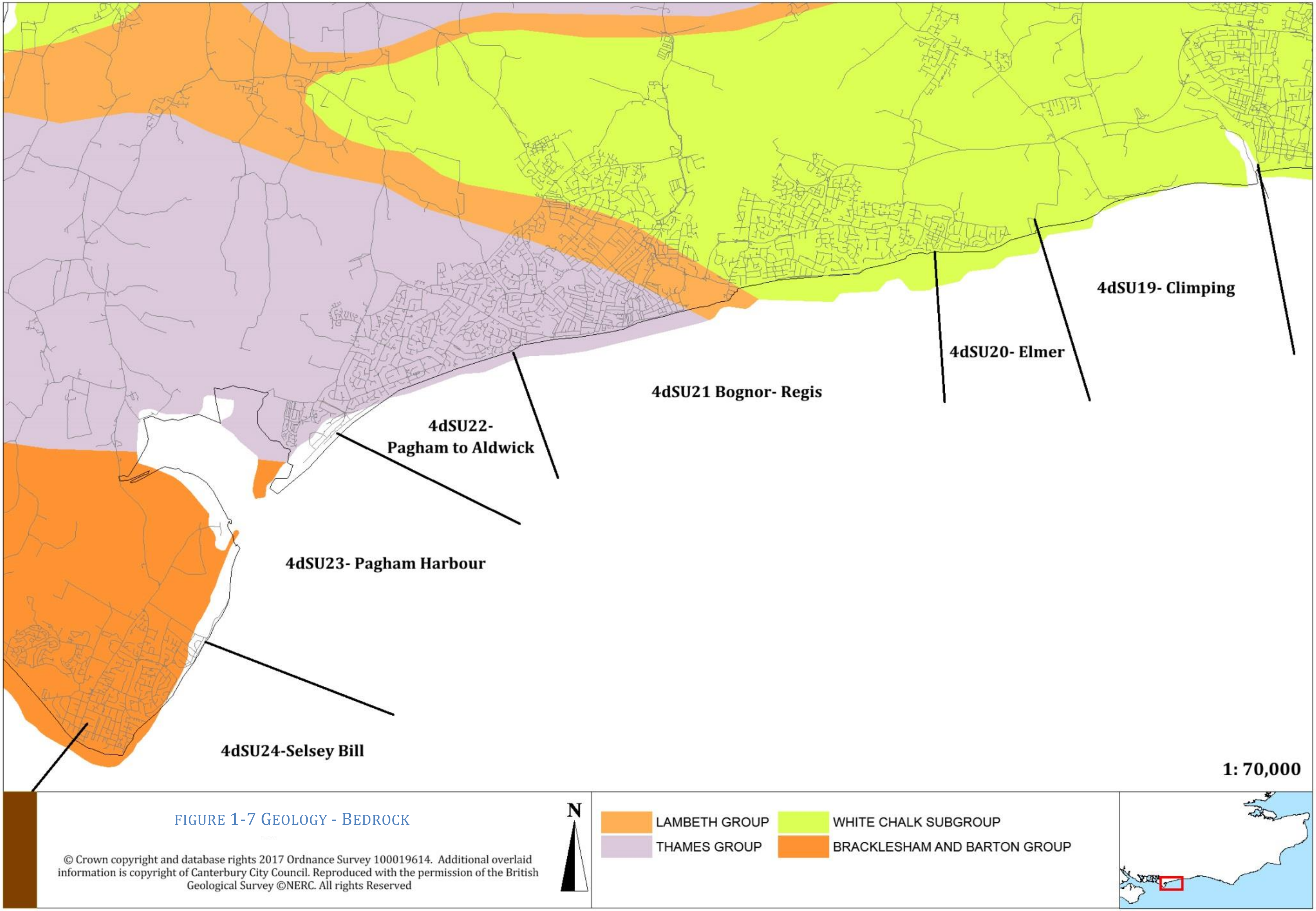


FIGURE 1-7 GEOLOGY - BEDROCK

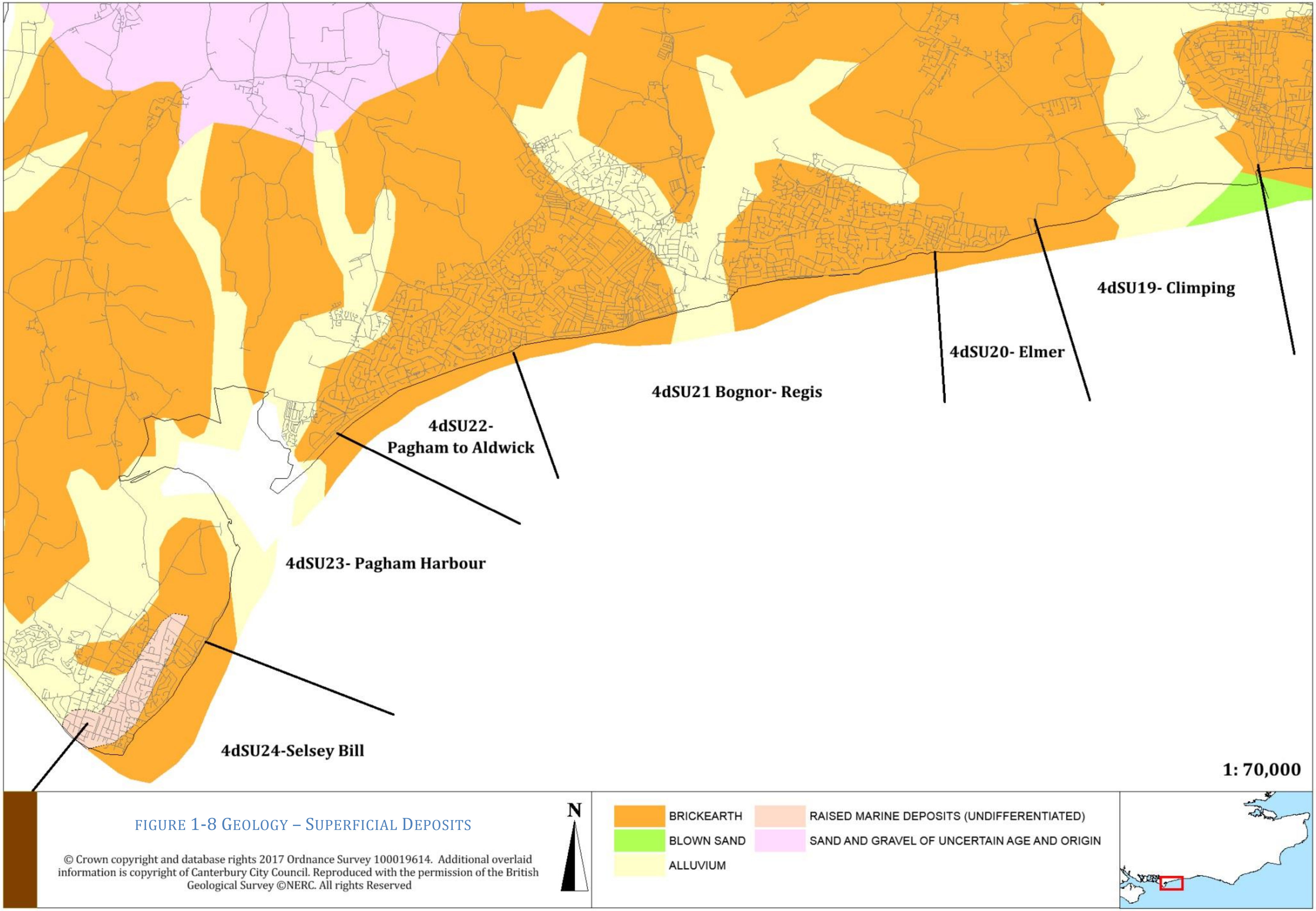


FIGURE 1-8 GEOLOGY – SUPERFICIAL DEPOSITS

1-2 HISTORY OF THE FRONTAGE

1-2-1 FLOODING INCIDENTS

Table 1-2 lists the flooding and storm events between Selsey Bill and Littlehampton. As these reports are typically in the mainstream press they frequently lack detail on the total number of properties affected and extent of damage. However this is sufficient to provide a threshold to aid validation of overtopping calculations.

TABLE 1-2 COASTAL FLOODING AND STORM INCIDENTS

DATE	LOCATION	DESCRIPTION	SOURCE
1875	ATHERINGTON	STORM DAMAGE TO TIMBER GROYNES	(BRITISH HISTORY ONLINE, 2017).
1933	PAGHAM	BREACH OF THE SHINGLE SPIT AND FLOODING OF PROPERTIES	(PAGHAM HARBOUR BEACH MANAGEMENT PLAN REPORT, 2015).
1980	BUTLIN'S, BOGNOR REGIS	WAVE OVERTOPPING CAUSED SIGNIFICANT DAMAGE TO SITE INFRASTRUCTURE.	(R. SPENCER, PERS. COMM., 25TH JANUARY 2017).
WINTER OF 1984/85	ELMER SANDS	MANY RESIDENTS ON MANOR WAY WERE FORCED TO LEAVE THEIR PROPERTIES DUE TO FLOOD WATER.	(ELMER SANDS LTD, 2017).
WINTER OF 1988/89	ELMER	BEACH LEVELS WERE REDUCED AND WAVES OVERTOPPED DEFENCE FLOODING 180 PROPERTIES IN ELMER.	(ELMER SANDS LTD, 2017).

1-2-2 EROSION INCIDENTS

The houses on the beach at Pagham were exposed to severe scour and erosion problems prior to the breach in 1910 of the Church Norton shingle spit. Since the breach the material which was severed from the spit has been transported eastwards and deposited in front of the houses at Pagham. Following a severe erosion event in 2013, a rock revetment was constructed in order to better protect the properties. No properties were lost from erosion at Pagham Beach. The Environment Agency and Natural England have also been involved in the management of the Pagham coastline (DEFRA, 2015).

1-2-3 HISTORY OF COASTAL MANAGEMENT

Figure 1-17, at the end of this section of text, shows a summary timeline of these activities.

SELSEY BILL

The first timber groynes at Selsey Bill were installed in 1956 along east beach. The concrete sea wall that runs for the whole length of east beach was also constructed in 1956.

In 2009/2010 25 timber groynes were renovated as part of a capital scheme (Selsey and Wittering Beach Management Plan, 2012).

PAGHAM HARBOUR

Pagham Beach has a long history of coastal change (DEFRA, 2015). The installation of a concrete and steel retaining wall was constructed in 1944 at the Church Norton end of the harbour in order to fix the harbour mouth in place. Further to this, the harbour entrance was stabilised a little further east by the installation of a steel sheet training wall. At a similar time, timber groynes were placed along the Church Norton spit.

Historically, the Church Norton spit has been artificially maintained, works between 1991 and 2004 involved recycling shingle from the ebb tidal delta was placed on the seaward face of the spit on an ad hoc basis.

More recently in 2013, a rock revetment was constructed in front of the houses to the west of the most westerly rock groyne (1295). In the following year rock was taken from the seaward ends of the existing rock groynes and used to improve Groyne 1295. Additionally, shingle geo-bags were placed along the beach fronting the houses until the arrival of larger rock, which was being delivered for the construction of another rock revetment east of the already existing revetment.

PAGHAM TO ALDWICK

The concrete defences to the west of Dark Lane were constructed during the 1960s. The remaining frontage from Pagham to Aldwick is largely undefended.

BOGNOR-REGIS

The frontage of Bognor Regis is almost entirely protected by concrete sea walls which occasionally have additional rear walls.

The coastline fronting Dark Lane and Aldwick Avenue saw the construction of concrete seawalls in the 1950's. Following this, the construction of a similar design concrete seawall in the gap between Dark Lane and Aldwick Avenue ensued in the 1960's. Marine Drive West saw a concrete seawall built in the 1980's. Central Bognor Regis to West Street is fronted by Victorian defences and from West Street to Bognor Regis Pier the defences were constructed in the 1980's (R. Spencer, Pers. Comm., 25th January 2017).

To the east of Bognor Regis Pier, there is approximately 500 metres of Victorian defence. In the 1980's this defence was refurbished with the replacement of the bullnose with a splash wall and the construction of new timber groynes (R. Spencer, Pers. Comm., 25th January 2017).

A large coastal defence scheme was designed and installed in front of the Butlin's Holiday Park in the 1960's. This scheme consisted of a round corner section of concrete seawall (extending approximately 1km) and a series of timber and rock groynes. Between 1997-1999, refurbishment was carried out to the bullnose seawall and failing groynes in front of Butlin's.

In the winter 2013/spring 2014 a series of storms caused significant damage to defences at Middleton-on-Sea. Three timber groynes, timber breastwork, concrete access steps and a top-mark were all damaged (R. Spencer, Pers. Comm., 25th January 2017).

ELMER

Records suggest that the first thoughts of the Elmer Sands Estate (established 1936) were to protect their land with sea defences. A splash wall was constructed for the full length of the estate, except for a 200m section whose construction was halted following the commencement of WWII (Elmer Sands Ltd, 2017).

A concrete sea wall extends for 150 metres which was built in the 1960's. After the 150 metre seawall ceases, an earth embankment protects the low-lying land up until the terminal rock groyne at Poole Place at the far east of the section.

Following the storms of 1989/90, 150m of earth embankment was reinforced with a rock revetment; at the same time as two emergency rock breakwaters were constructed and shortly after, the Poole Place groyne was completely reconstructed in rock. In 1993, following extensive 2D and 3D modelling, the main Elmer scheme, consisting of 8 rock breakwaters and imported shingle was undertaken. The pioneering scheme was proposed to try and retain beach material to protect the village from flooding and erosion. The scheme was a joint project between Arun District Council and the National Rivers Authority (now Environment Agency) at a cost of approximately £6m. Today Arun District Council manages the higher areas of defence whilst the Environment Agency manages the low lying areas (Elmer Sands Ltd, 2017). The breakwaters contain 100,000 tonnes of rock and there was 200,000m^3 of beach replenishment

CLIMPING

Historic coastal management at Climping included the installation of 12 timber groynes as early as 1770 as the sea was encroaching daily on farmland (British History Online, 2017). There were no hard defences at Climping until a wartime concrete sea wall was built to front Atherington and in turn try to stabilise the beach at that location due to its important amenity value (British History Online, 2017).

The beach is largely undefended between Poole Place and the village of Atherington; there are a few intermittent timber groynes and an old flint wall.

In 2009, the Environment Agency moved from the SMP policy of Managed Realignment to a policy of 'Withdraw Management' because the economic analysis identified that it would cost more to maintain the current defence of a concrete wall and timber groynes than the cost of the damage prevented. However, a new, more detailed analysis of the situation at Climping was undertaken in 2014 and it was concluded that the beach is more stable than first thought. This conclusion forced a change in the recommendation of 'Withdraw Management' to 'Do Minimum', which involves the current defence, the beach, being re-profiled and maintained as long as it is economically possible and it maintains the required SoP for at least 15 years (Climping Sea Defences, 2014).

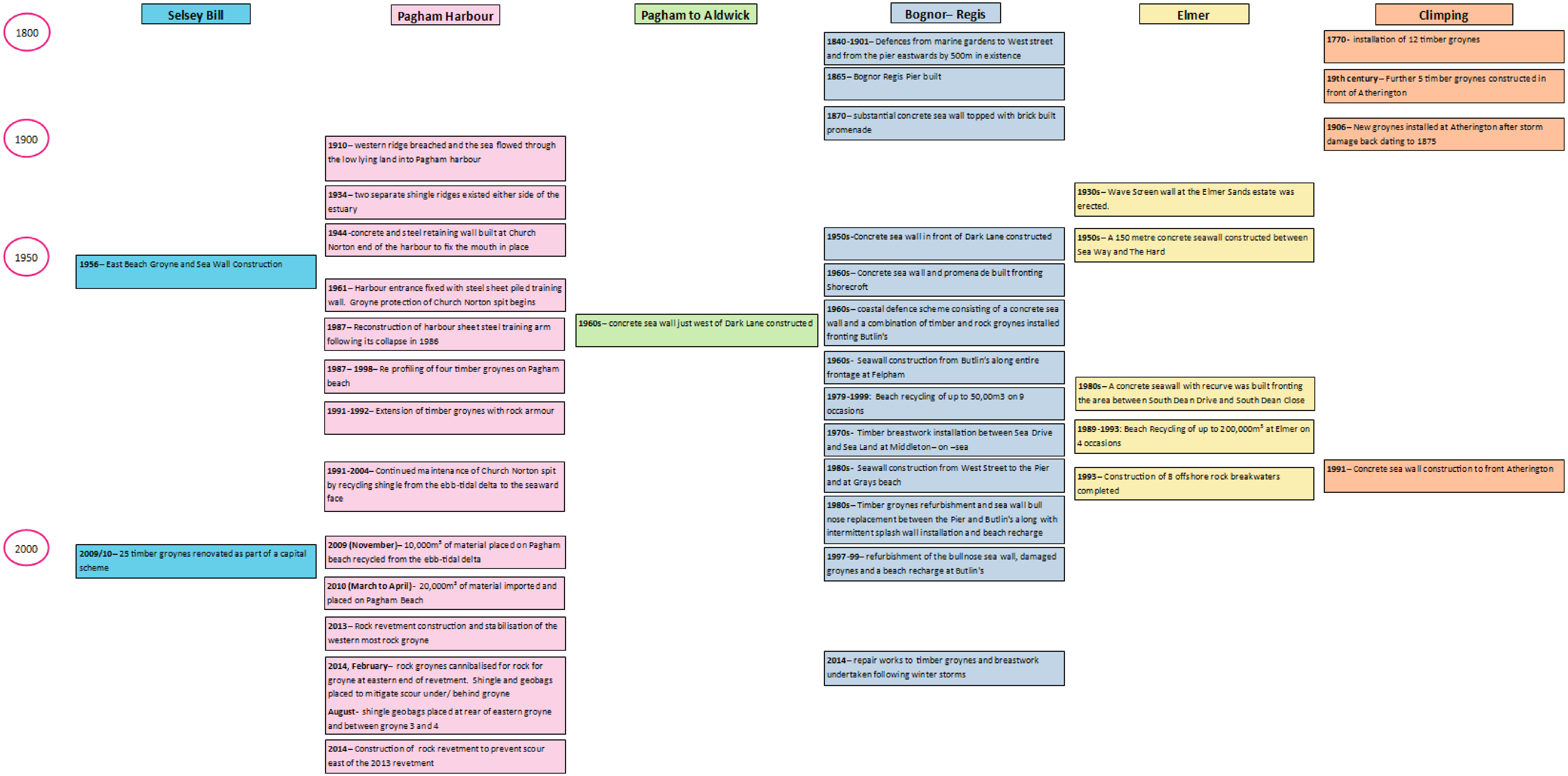


FIGURE 1-9- COASTAL DEFENCE TIMELINE

1-2-4 ENVIRONMENTAL OPPORTUNITIES AND CONSTRAINTS

The issues relating to the local environment are fully described in the Environmental Assessment in Appendix B of this report. The following section provides a brief overview of the key issues within the area, affecting coastal management, for protected sites, agriculture, infrastructure, tourism and recreation, culture and archaeology.

ENVIRONMENTAL RESTRICTIONS

There are two Marine Conservation Zones within the study area: The Selsey Bill and the Hounds MCZ in the west and Pagham Harbour MCZ. The presence of these sites means that the planning of beach management activities must take into account any downdrift impacts into these sensitive areas. Consultation with the MMO should take place for any coastal defence works, with the exception of beach recycling.

There are two reserves designated locally for their wildlife value. These are the Pagham Harbour Local Nature Reserve (LNR) and West Beach LNR. Any beach management activities will need to work around the priority habitats within these sites. For vegetated shingle this may involve fencing off areas to prevent trampling from trucks or scraping the top layer of shingle off, stockpiling it and resurfacing it after the works. These areas are outlined in Figure 1-10.

To ensure no damage is caused to the sites specific management requirements consultation with the land manager, i.e. Chichester District Council, should be undertaken.

ENVIRONMENTAL OPPORTUNITIES

Two Biodiversity Opportunity Areas exist within the study area. No statutory protection is afforded to these sites however it is in the best interest of sustainable development that these opportunities are considered and, potentially, integrated into any proposed scheme. Figure 1-11 outlines these areas.

More detail on environmental constraints and opportunities is given within Appendix B.

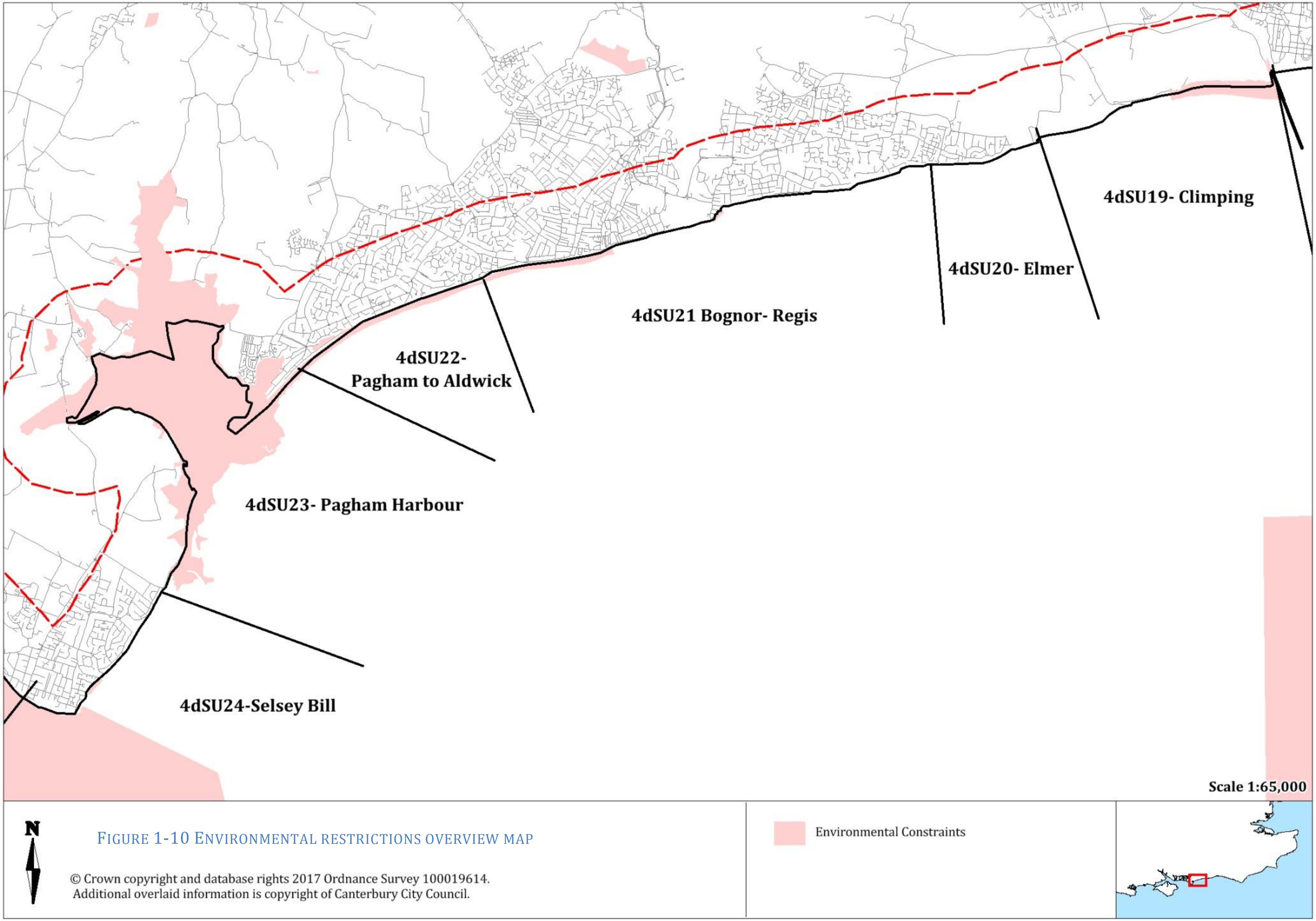


FIGURE 1-10 ENVIRONMENTAL RESTRICTIONS OVERVIEW MAP

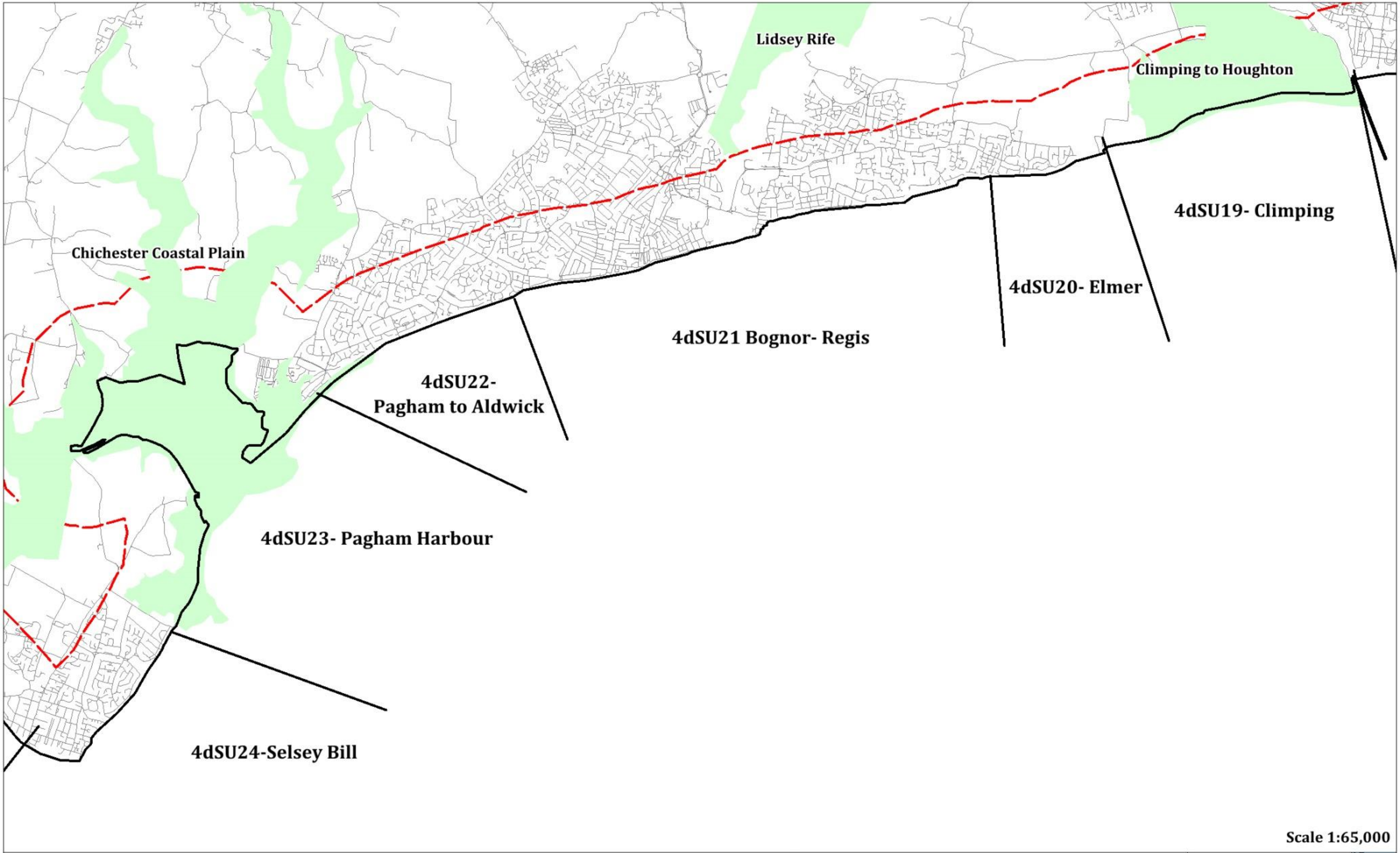


FIGURE 1-11 ENVIRONMENTAL OPPORTUNITIES OVERVIEW MAP

1-2-5 AGRICULTURE

The land surrounding the study area is largely urban. Arable land backs Bognor Regis and Atherington and there is another small area of agricultural land surrounding Selsey Bill.

1-2-6 INFRASTRUCTURE

A coastal road, the A259, extends between Climping and Bognor Regis. The only main road into Selsey is the B2145.

Train stations are present at Bognor Regis, Ford and Littlehampton and the line is a sub-branch of the West Coastway Line, which extends between Brighton and Southampton. The line itself is set back from the seafront, although it is within the 1 in 200 year extreme water level contour (Figure 2-3).

Littlehampton Harbour is the only commercial harbour berthing up to 120 motor boats. A small number of boats are moored offshore at Selsey. There are two RNLI lifeboat stations situated at Littlehampton Harbour and Selsey.

1-2-7 ARCHAEOLOGY & CULTURAL HERITAGE

When sites of high archaeological and cultural value have been identified, they are assessed and recommendations are put forward. In England, three statutes provide protection for archaeological sites and their settings:

- Ancient Monuments and Archaeological Areas Act (AMAA) 1979;
- Town and Country Planning (Listed Buildings and Conservation Areas) Act 1990;
- Protection of Wrecks Act 1973.

There are a number of Scheduled Monuments within close proximity (<1km) of the study area. The sites are: Ringwork south of St Wilfred's Chapel, Church Norton, Beckett's Barn, Pagham and adjoining earthworks, and a 19th century artillery fort known as Littlehampton Fort, behind the dunes on the west beach. There are also medieval earthworks at St Mary's Church, Climping, near to the River Arun and 1.7km inland from the open coast. None of these sites, with the possible exception of Littlehampton Fort are located directly on the coastline and therefore will not be directly be affected by any beach management works. Appendix B provides detailed mapping of all scheduled monuments and listed buildings in the area.

There are eight conservation areas within the study area: Selsey, Aldwick Bay, Craigwell House, Aldwick, in Bognor: Aldwick Bay, The Steyne, Bognor Regis Railway Station, Upper Bognor Road and Mead Lane, Felpham. There are approximately 165 listed properties within 1 kilometre of the coast. Approximately half of these properties are within the Bognor Regis Unit.

There are no protected wrecks within the study area.

2 CURRENT RISK

An essential part of this BMP is to go back to basics and consider the purpose of each beach to determine the standard of protection required. The purpose of the beach is graded against four categories; protection from still water flooding, and protection against overtopping, erosion and structure failure. The coastline has been assessed against the four hazards as summarised below. Appendix C provides detailed mapping of impacts under the following four classifications.

2-1 FLOODING

Coastal flooding can be highly destructive, damaging buildings and affecting the fertility of land. With regard to being a form of protection against flooding; the beach in reducing damage to property through flying shingle, over wash, ponding, partial breach and full breach are considered as the main impacts of flooding.

The disruption following coastal flooding can be extensive to the public, transport and agriculture. The salinity of the water can also cause issues by leading to farmers' land becoming infertile and upsetting natural freshwater habitats or saline intrusion to potable and agricultural abstraction points of the aquifer

Pagham Harbour, Bognor Regis, Elmer and Climping are at risk of coastal flooding for a 1 in 200 year event (Appendix C), with flood basins shown in Figures 2-2, 2-3 and 2-4 which are based on the undefended 1 in 200 year still water level. There is also a small locally important flood basin around the recreation ground at Selsey (Figure 2-2).

2-2 OVERTOPPING

Overtopping is classed as a danger to pedestrians on the beach, promenade and road and to vehicles on the road; the larger the beach the lower the overtopping. The coastline between Selsey Bill and Littlehampton is all at risk of overtopping due to the close nature of properties to the defences with the exception being the setback properties behind Pagham Harbour (since overtopping was calculated over the spit, which breaks waves, see Appendix C).

2-3 EROSION

Damage to slopes and cliffs, property on top of the slopes and cliffs and damage to property through loss of beach are all reduced by the presence of a shingle beach (Figure 2-1). Prior to the breach of the Church Norton spit, there was a risk of erosion at Pagham Harbour, there are also risks at Pagham to Aldwick, Elmer and Climping. There have been no properties lost to the sea in recent history (Appendix C).

FIGURE 2-1 EROSION OF THE BEACH WEST FRONT ROAD (2016)

2-4 DAMAGE TO STRUCTURES

With regards to reducing damage to structures, the beach; protects against undermining of the seawall which will lead to seawall failure and material washout from behind the wall, damage to the seawall face and crown, promenade, splash and retaining walls, revetments and lastly, damage to drainage outfalls, harbour arms and rock revetments, rock groynes and timber groynes. A network of concrete and timber defences protects Selsey Bill, Bognor Regis and Elmer; however the majority of the coastline at Pagham Harbour, Pagham to Aldwick and Climping is undefended (Appendix C).

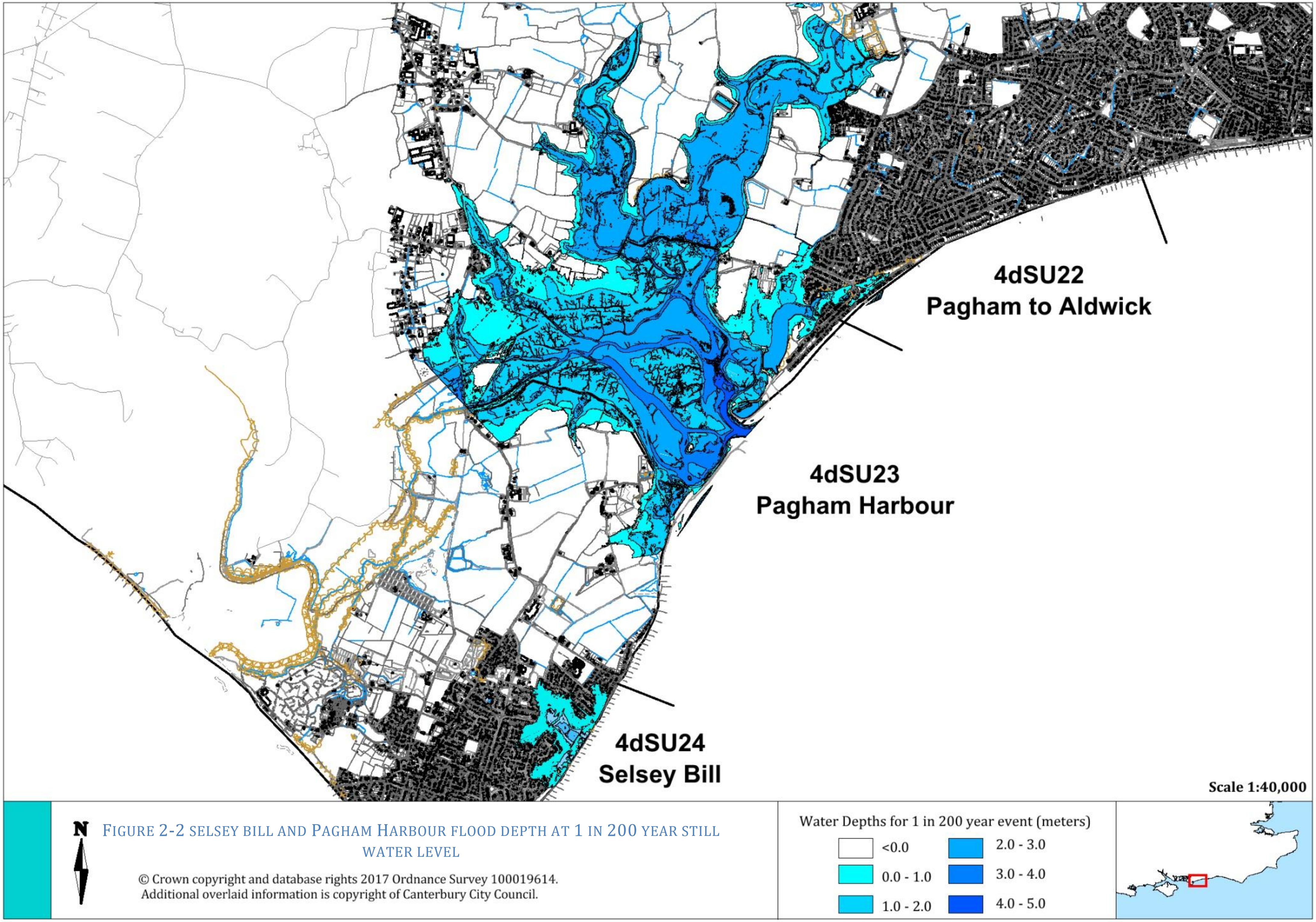


FIGURE 2-2 SELSEY BILL AND PAGHAM HARBOUR FLOOD DEPTH AT 1 IN 200 YEAR STILL WATER LEVEL

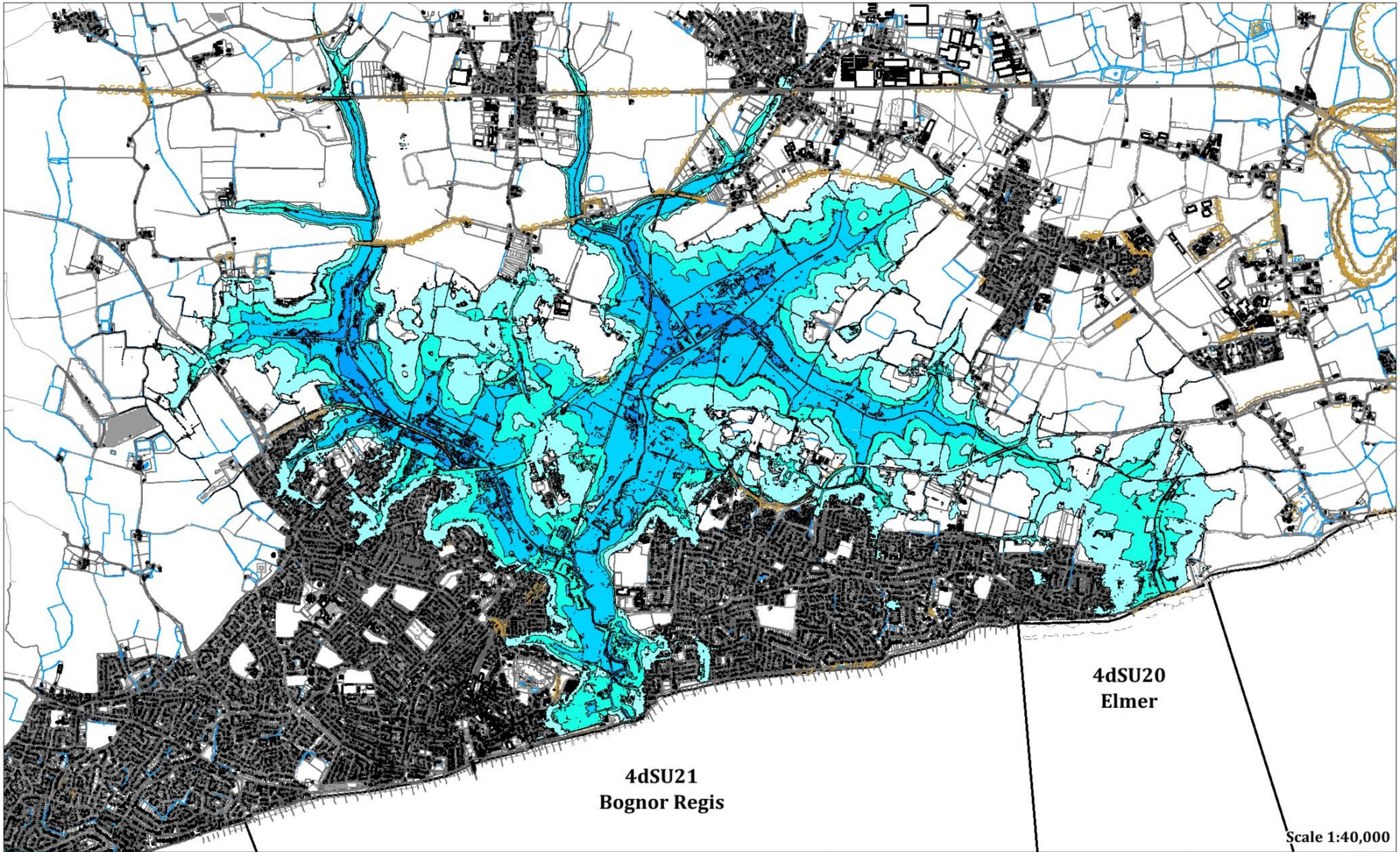
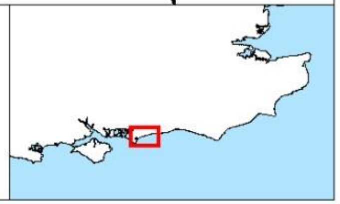


FIGURE 2-3 BOGNOR REGIS FLOOD DEPTH AT 1 IN 200 YEAR STILL WATER LEVEL

Water Depths for 1 in 200 year event (meters)

<0.0	3.0 - 4.0
0.0 - 1.0	4.0 - 5.0
1.0 - 2.0	5.0 - 6.0
2.0 - 3.0	



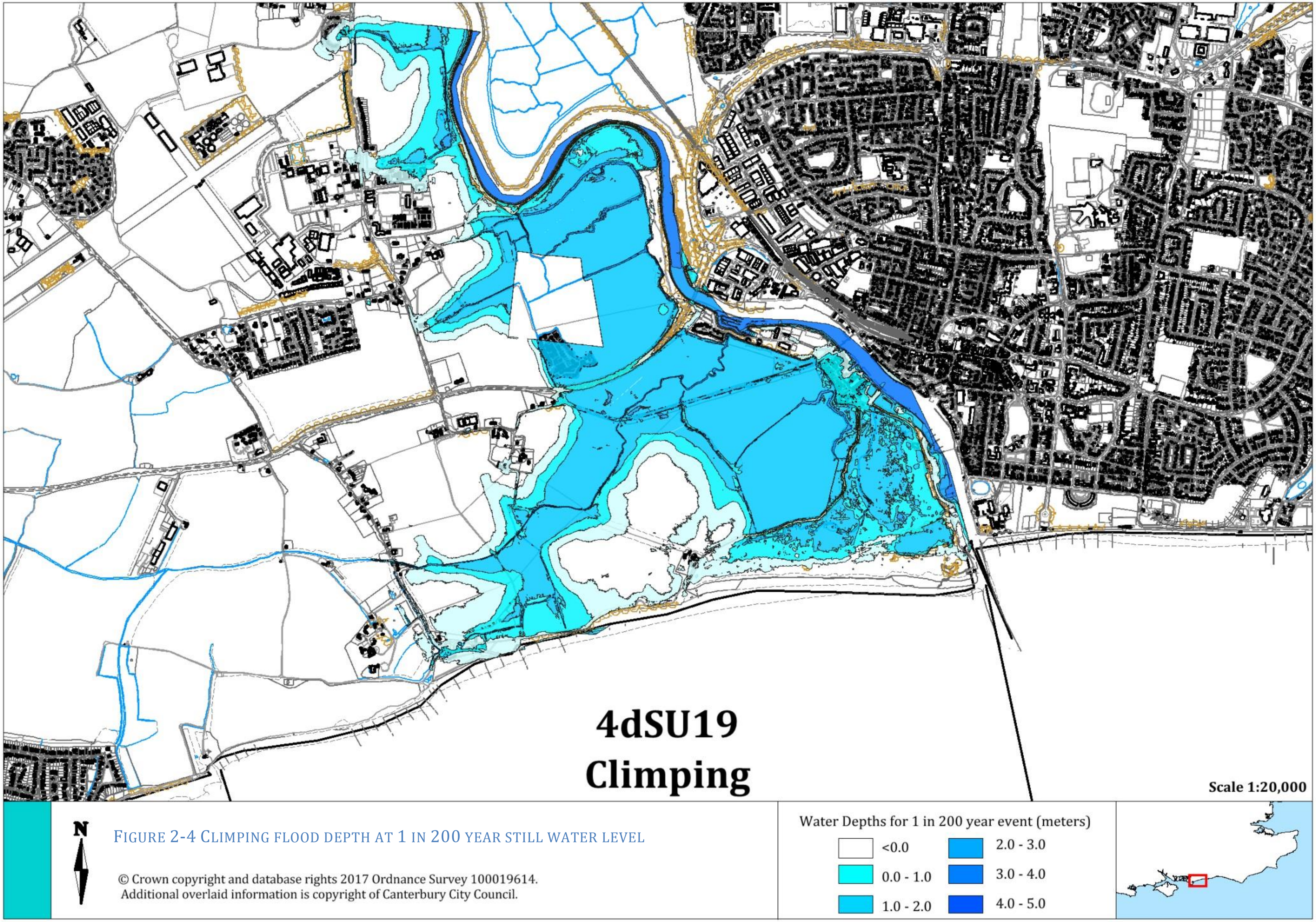


FIGURE 2-4 CLIMPING FLOOD DEPTH AT 1 IN 200 YEAR STILL WATER LEVEL

2-5 AMENITY

Amenity impacts include damage to the amenity which is not infrastructure, for example reduction in beach width. Each beach has been given a score out of 100 to determine the level of amenity at risk within a 1km buffer of the coastline. The Amenity criteria are listed in Table 2-1 and a summary of the results are in Table 2-2. The calculations are shown in Appendix C.

TABLE 2-1 CRITERIA FOR AMENITY SCALE

	POINTS	DESCRIPTION
	0-20	THE BEACH IS NOT EASILY ACCESSED, NO CAR PARKING, NO FACILITIES, LITTLE USAGE.
	21-40	THE BEACH IS ACCESSIBLE, NO CAR PARKING, MINIMAL FACILITIES, LITTLE USAGE.
	41-60	THE BEACH HAS EASY ACCESS, CAR PARKING, SOME FACILITIES AND REGULAR USAGE – MAINLY DOG WALKERS.
	61-80	THE BEACH HAS EASY ACCESS, AMPLE CAR PARKING, GOOD FACILITIES, WELL USED, GENERATES SOME INCOME TO THE AREA.
	81-100	THE BEACH HAS EASY ACCESS, AMPLE CAR PARKING, AND GOOD FACILITIES, IS A MAIN ATTRACTION FOR TOURISTS, HEAVILY USED, LIFEGUARDED AND RELIED ON FOR INCOME THOUGH HOTELS.

TABLE 2-2 AMENITY SCORES

LOCATION	SUB CELL	SCORE /100
SELSEY BILL	(WHOLE UNIT)	37.5
PAGHAM HARBOUR	(WHOLE UNIT)	7.5
PAGHAM TO ALDWICK	(WHOLE UNIT)	13.5
BOGNOR REGIS	DARK LANE TO THE PIER	33
BOGNOR REGIS	PIER TO WEDGEWOOD ROAD	65.5
BOGNOR REGIS	WEDGEWOOD ROAD TO ELMER BREAKWATERS	20.5
ELMER	(WHOLE UNIT)	4.5
CLIMPING	(WHOLE UNIT)	3.5

3 PHYSICAL INPUTS

3-1 WATER LEVELS

3-1-1 TIDAL WATER LEVELS

This frontage has a tidal range of 3.4m during a mean neap and 6.73m during a mean spring tide (Admiralty Tide Tables).

3-1-2 EXTREME WATER LEVELS

Extreme water levels were derived from the results of *Coastal flood boundary conditions for UK mainland and islands* (Environment Agency, 2011). Results from the coastal flood boundary conditions report for four locations along the study area, as depicted in Figure 3-1, are provided in Table 3.1. Extreme water levels increase from west to east along the frontage with a typical difference of at least 300mm between Selsey Bill and Littlehampton.

TABLE 3-1 EXTREME WATER LEVELS (+MOD) AND RETURN PERIODS

	SELSEY BILL	PAGHAM TO ALDWICK	BOGNOR REGIS	CLIMPING	UNCERTAINTY VALUES
1 IN 1	3.01	3.13	3.24	3.32	0.2
1 IN 5	3.18	3.3	3.41	3.49	0.2
1 IN 10	3.25	3.37	3.48	3.56	0.2
1 IN 25	3.35	3.47	3.58	3.66	0.2
1 IN 50	3.43	3.54	3.66	3.74	0.2
1 IN 100	3.5	3.62	3.74	3.81	0.3
1 IN 200	3.58	3.7	3.82	3.9	0.3

Values taken from Coastal flood boundary conditions for UK mainland and islands (Environment Agency, 2011)

The primary data sources within the study area are the Arun Platform tide gauge and the Rustington wave buoy. The closest primary port is at Newhaven. As a result the outputs are heavily reliant on the modelling and interpolation between nodes. Tidal predictions vary between software packages, namely POLTIPS (Proudman Oceanography Laboratory) and Admiralty TOTALTIDE (UK Hydrographic Office), and this may translate into uncertainty with regards the extreme sea levels.

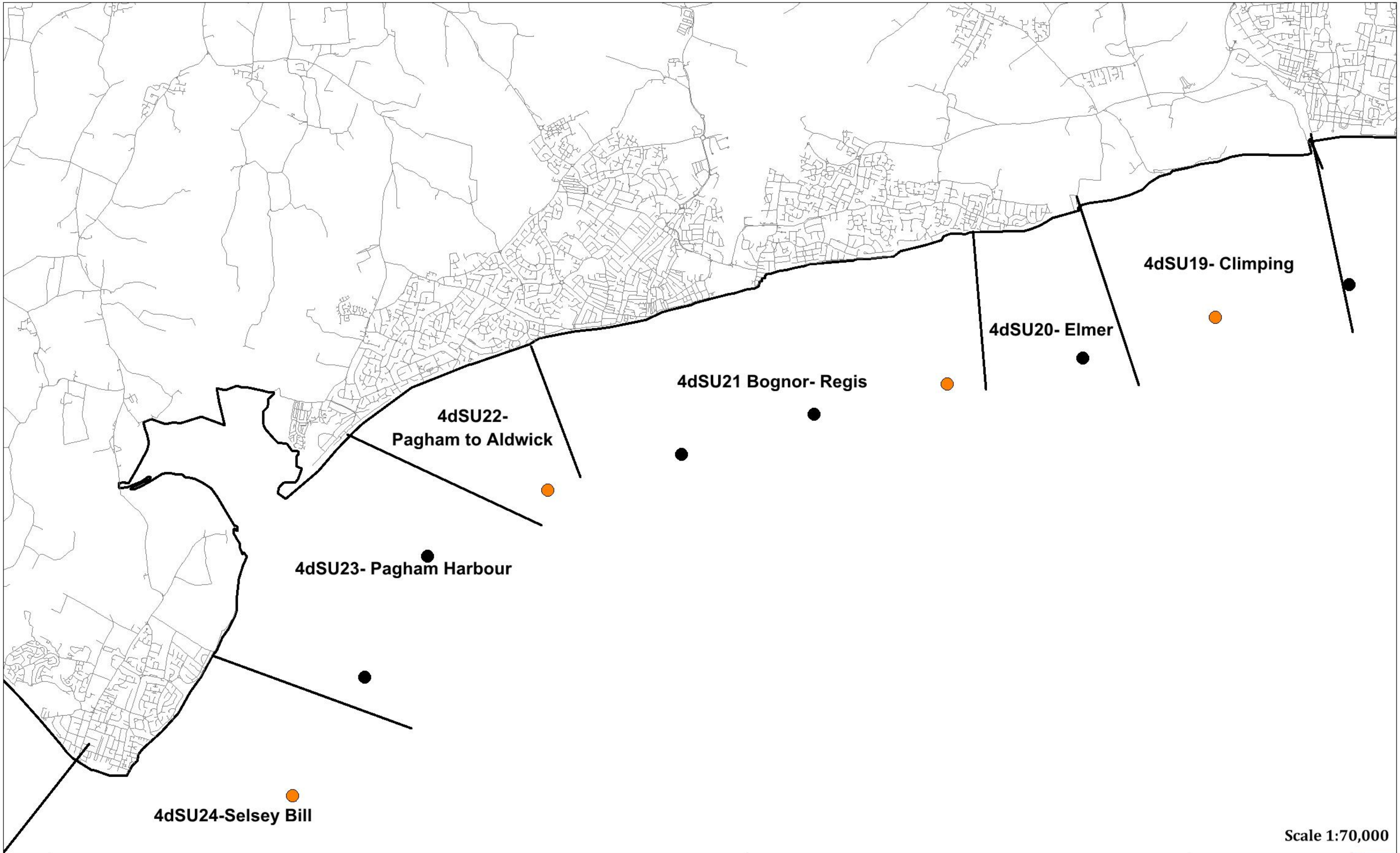
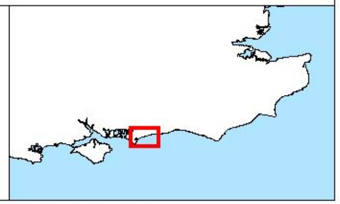


FIGURE 3-1 LOCATION OF EXTREME WATER LEVELS (EWL) AND EXAMPLE POINTS

Extreme Water Level Points

Example Extreme Water Level Points (see Table 3-1)



3-2 WAVES

The wave climate is dominated by waves from the south-west (Figure 3.3), resulting in a west to east drift of beach material along the whole frontage. Waves from the south-west are more frequent and typically larger in magnitude, but it should be recognised that periods of waves from the south-east can result in a temporary reversal in the sediment drift direction.

Two sources of data have been used for this study, measured data from the Rustington directional WaveRider buoys and Met Office hindcast data that models 33 years of predicted wave conditions.

3-2-1 WAVE RECORDER

As part of the Regional Coastal Monitoring Programme a network of wave buoys has been deployed around the coast since 2003.

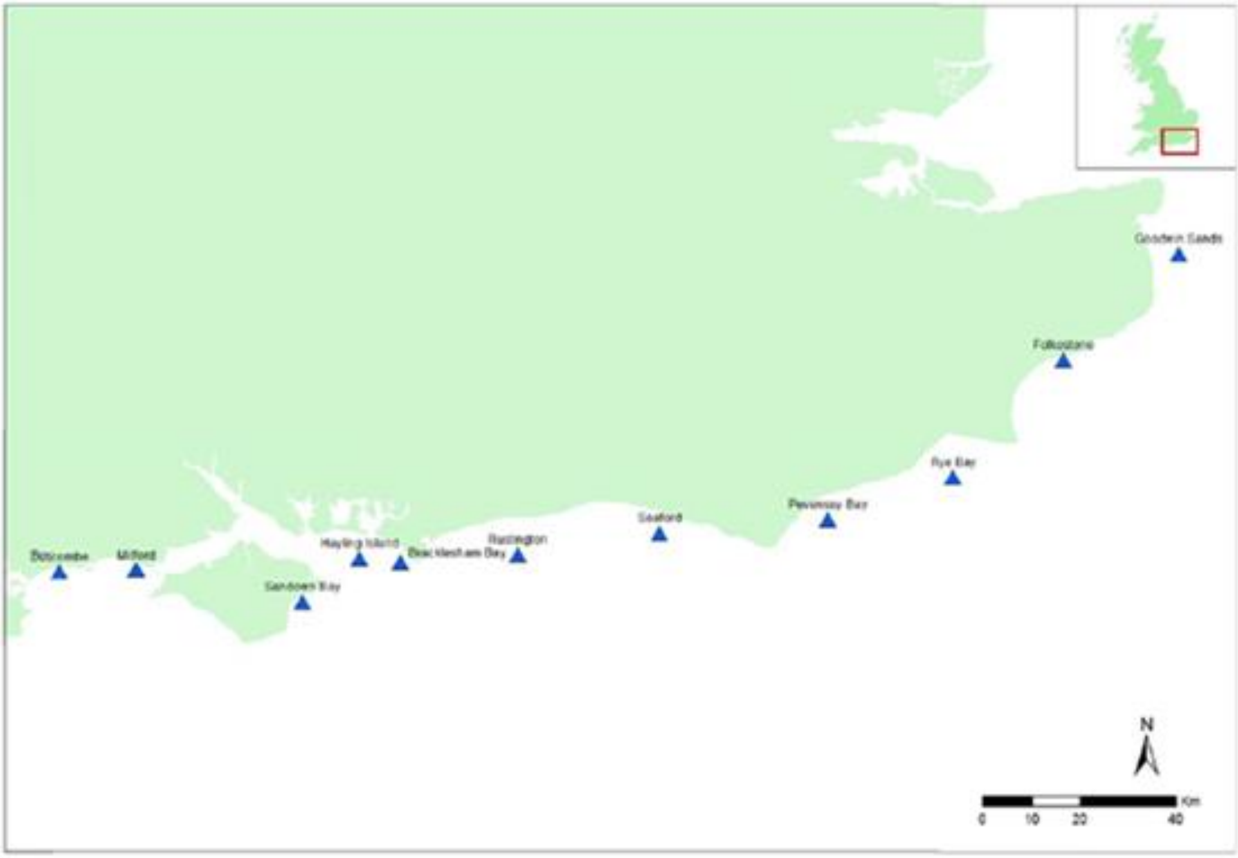


FIGURE 3-2 LOCATION OF WAVE BUOYS ON THE SOUTH EAST COAST

The only Directional WaveRider buoy applicable to this study is Rustington. Rustington has been operational since 15th July 2003 to the present day. The buoy is located along the 10m Chart Datum contour and a summary of collected data is presented in the following wave rose, Figure 3-3.

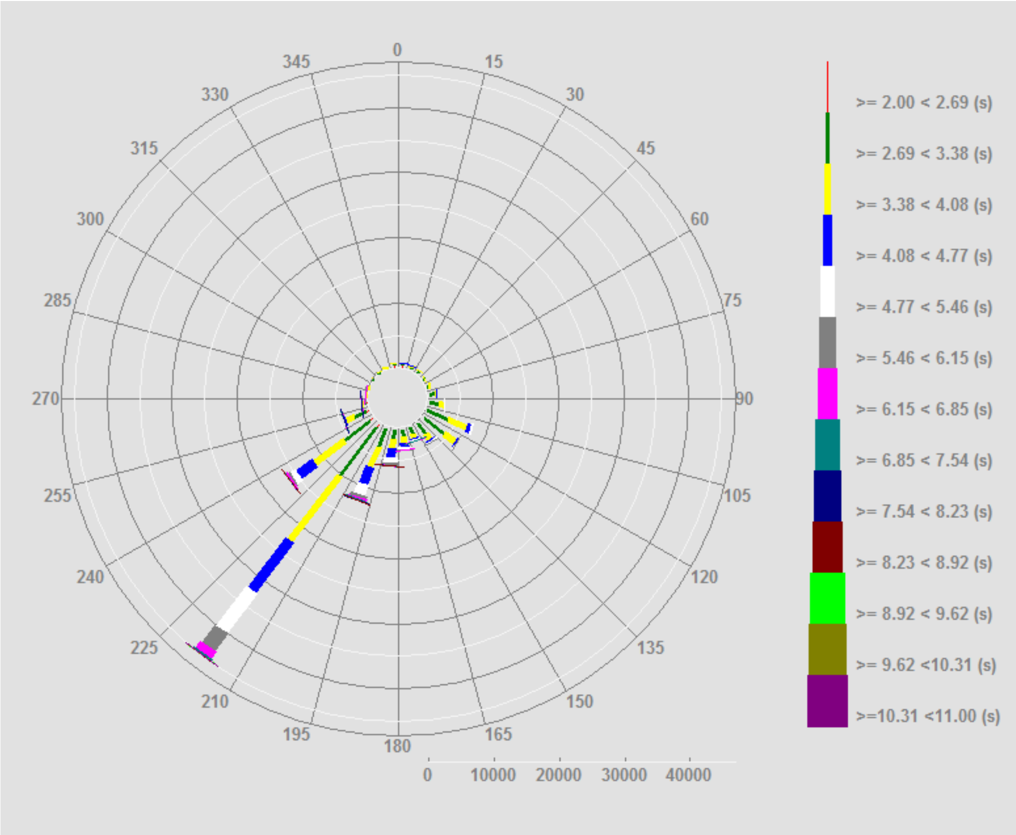


FIGURE 3-3 WAVE ROSE FROM RUSTINGTON DIRECTIONAL WAVERIDER BUOY SHOWING OFFSHORE WAVE HEIGHT (H_S) BETWEEN 01/05/2009 TO 31/12/2014

3-2-2 MET OFFICE HINDCAST

Using thirty-three years of Met Office Hindcast data for 52 nearshore locations at ~5km intervals (Figure 3.4) the Joint Return Probability for Beach Management study (Mason, 2014), calculated extreme return periods for each of these points.

FIGURE 3-4 LOCATION OF MET OFFICE HINDCAST POINTS

Significant wave height return periods for Met Office points M0433, M0430 and M0398 are included for reference in Table 3-2.

The methods employed to generate significant wave heights do not take into consideration water depth limitation. This is accounted for within the overtopping calculations.

Table 3-2 Significant Wave Height, Hs (m) return periods for four Met Office Hindcast points; values in parenthesis are the water depth at this point

Return Period (1 in x years)	MO398 (13m)	MO433 (12m)	MO430 (14m)
1 in 1	4.66	3.84	4.27
1 in 2	4.92	4.05	4.49
1 in 5	5.26	4.32	4.78
1 in 10	5.50	4.51	4.99
1 in 20	5.74	4.70	5.20
1 in 50	6.05	4.95	5.46
1 in 100	6.28	5.13	5.66
1 in 200	6.51	5.31	5.85

Contours of the annual 0.05% wave height exceedance are illustrated in Figure 3-5 and show the geographical variability within the study area suggesting very little variation in conditions between Selsey Bill and Newhaven.

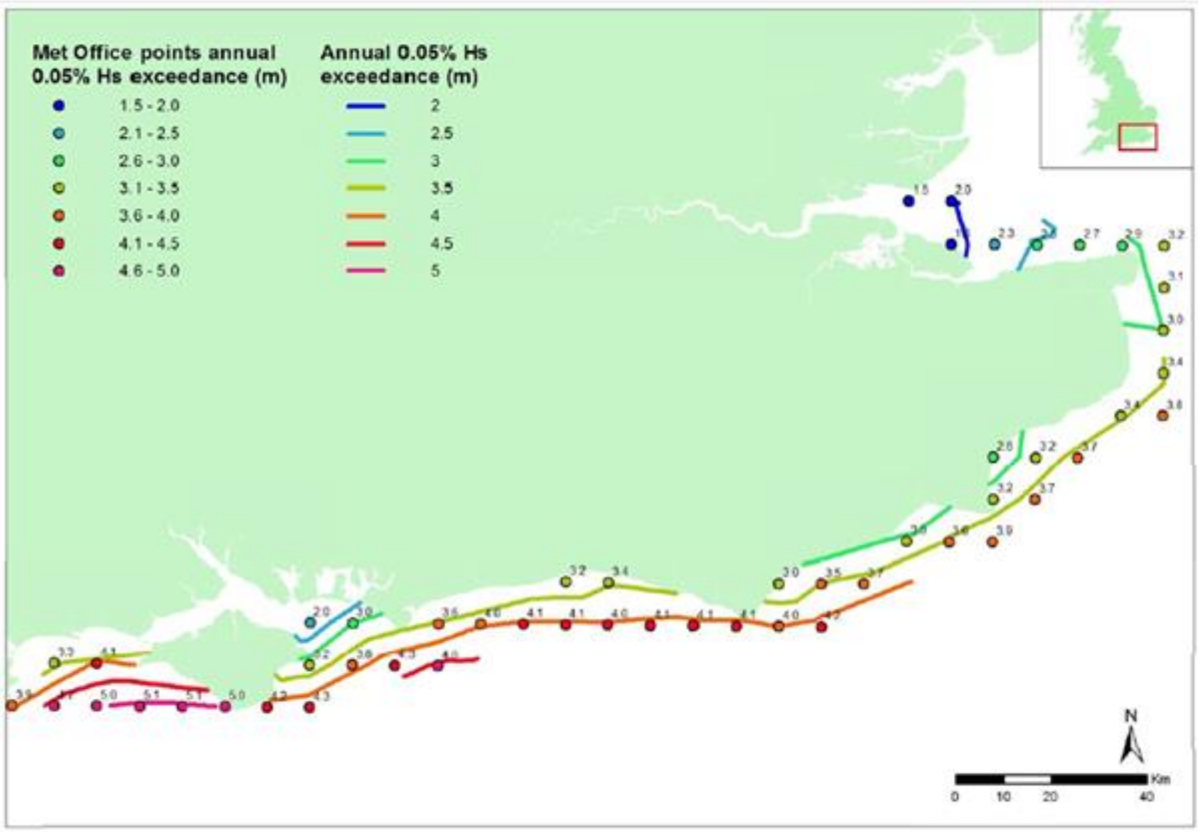


Figure 3-5 Annual Significant Wave Height (Hs [m]) 0.05% exceedance Joint Return Probability for Beach Management (Mason, 2014)

3-3 JOINT PROBABILITY ANALYSIS

Joint return periods were established using the 33 year Met Office Hindcast data and results from the EA water level boundary set as part of Mason (2014). These were calculated for 1, 2, 5, 10, 20, 50, 100 and 200 year return periods, using the HR Wallingford TR2 SR653 desk calculator, for each Met Office point.

Results for Met office points MO398, MO433 and MO430 are presented graphically below. Note that the potential depth limitation is broadly calculated and included on the charts, but this is calculated more accurately under specific conditions later in the report.

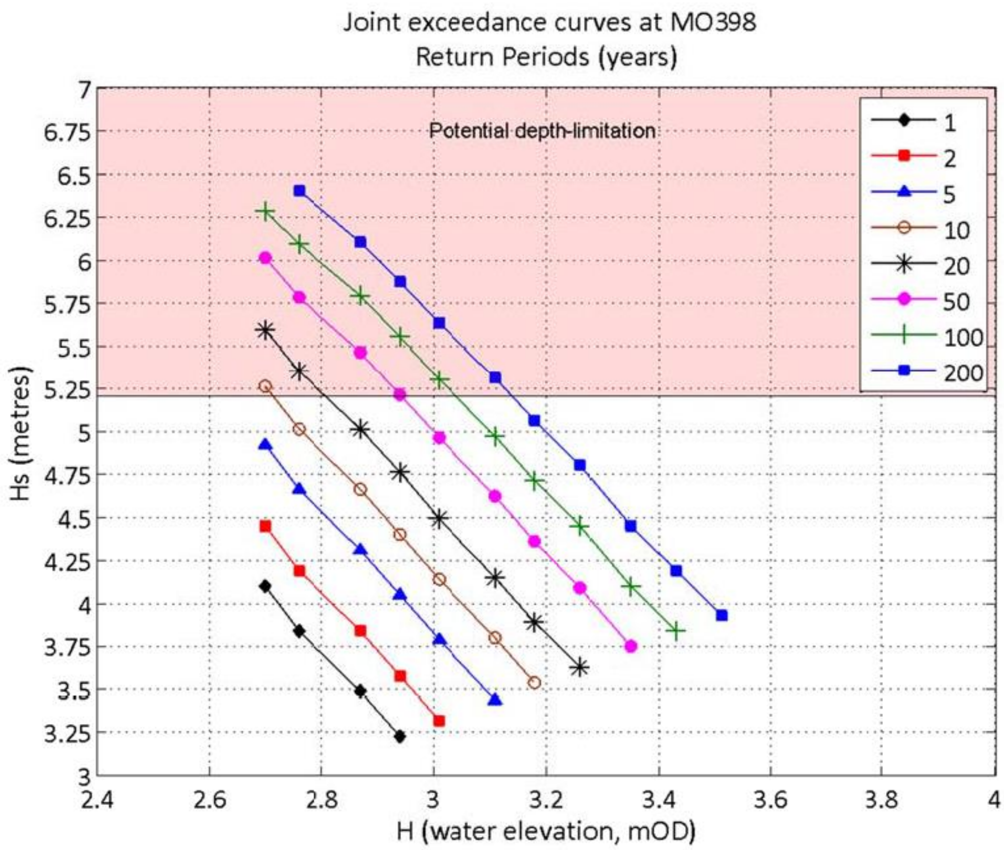
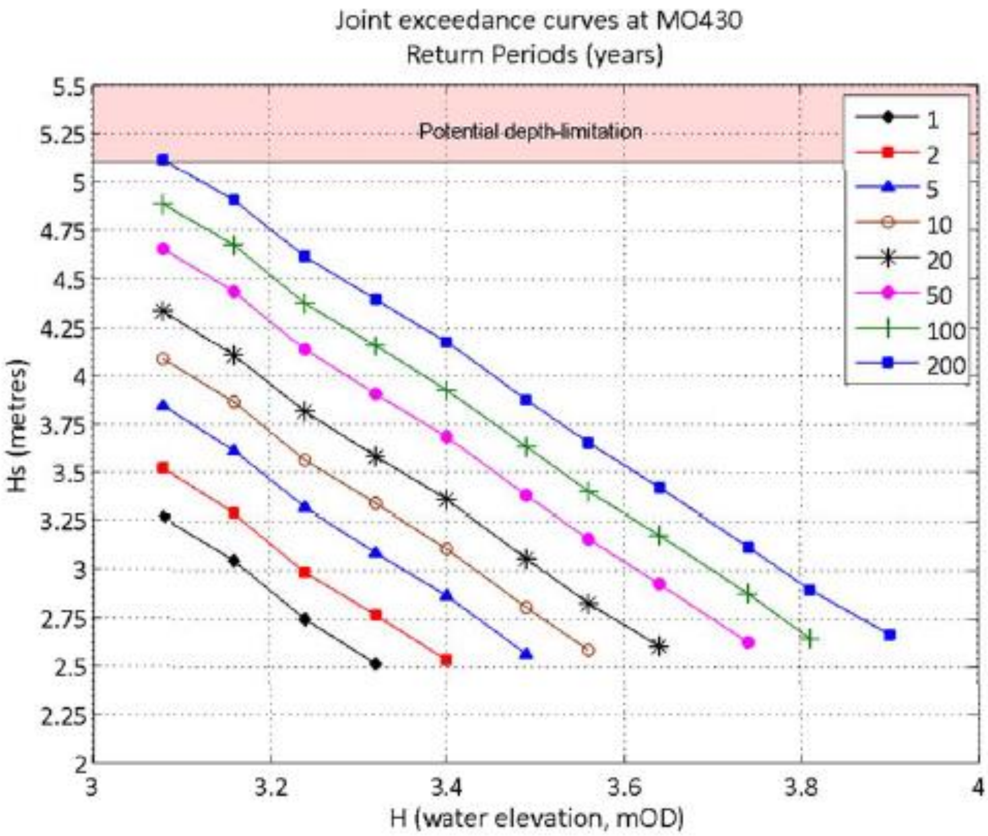


FIGURE 3-6 JOINT PROBABILITY EXCEEDANCE CURVES AT MO398, RETURN PERIOD (YEARS)



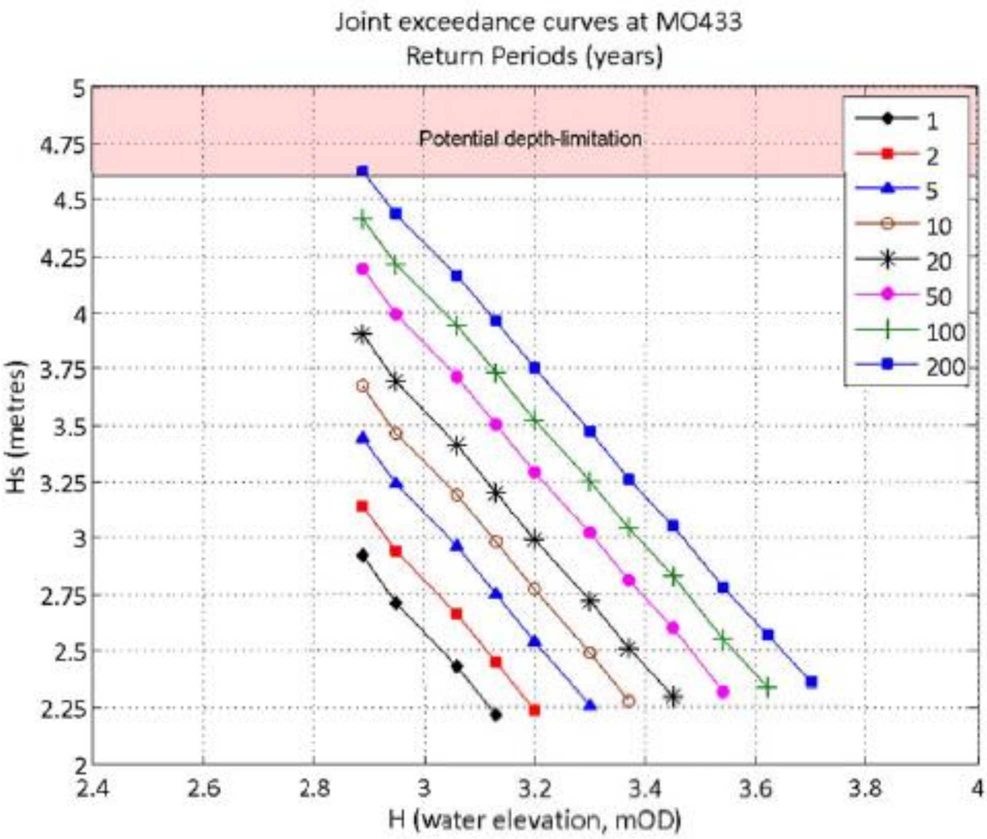


FIGURE 3-7 JOINT PROBABILITY EXCEEDANCE CURVES AT MO430 AND MO433, RETURN PERIOD (YEARS).

3-4 SEDIMENT CHARACTERISTICS

Beaches within the study area are typical of those found throughout the Southeast of England, comprising mixed sand and shingle sediment. Sediment grading curves are not readily available for this stretch of coastline, but visual observations would suggest the beaches are similar to other beaches within the southeast of England with a D_{50} of 10-14 mm. Chichester DC have historically imported shingle no less than 30mm+as an average $D_{50.}$

It is good practice to ensure that the characteristics grading envelope of the replenished material is as close to the natural beach material as possible. Therefore it is recommended that a grading envelope is used for all works and that the delivered material is monitored to ensure it meets the specification and avoids performance issues associated with sub-standard finer material.

3-5 BEACH GEOMETRY

The coastline between Selsey Bill and Pagham face south east and Aldwick to Climping faces more southerly.

Orientation is one of the factors which affect the rate of longshore transport as the dominant waves approaching from the south west tend to strike the coast at an acute angle promoting west to east drift. Conversely, waves from the east attack the coast in amore perpendicular fashion reducing the amount of material that is transported back in a westerly direction.

Figure 3-8, overleaf, identifies the orientation of the coastline in relation to due north.

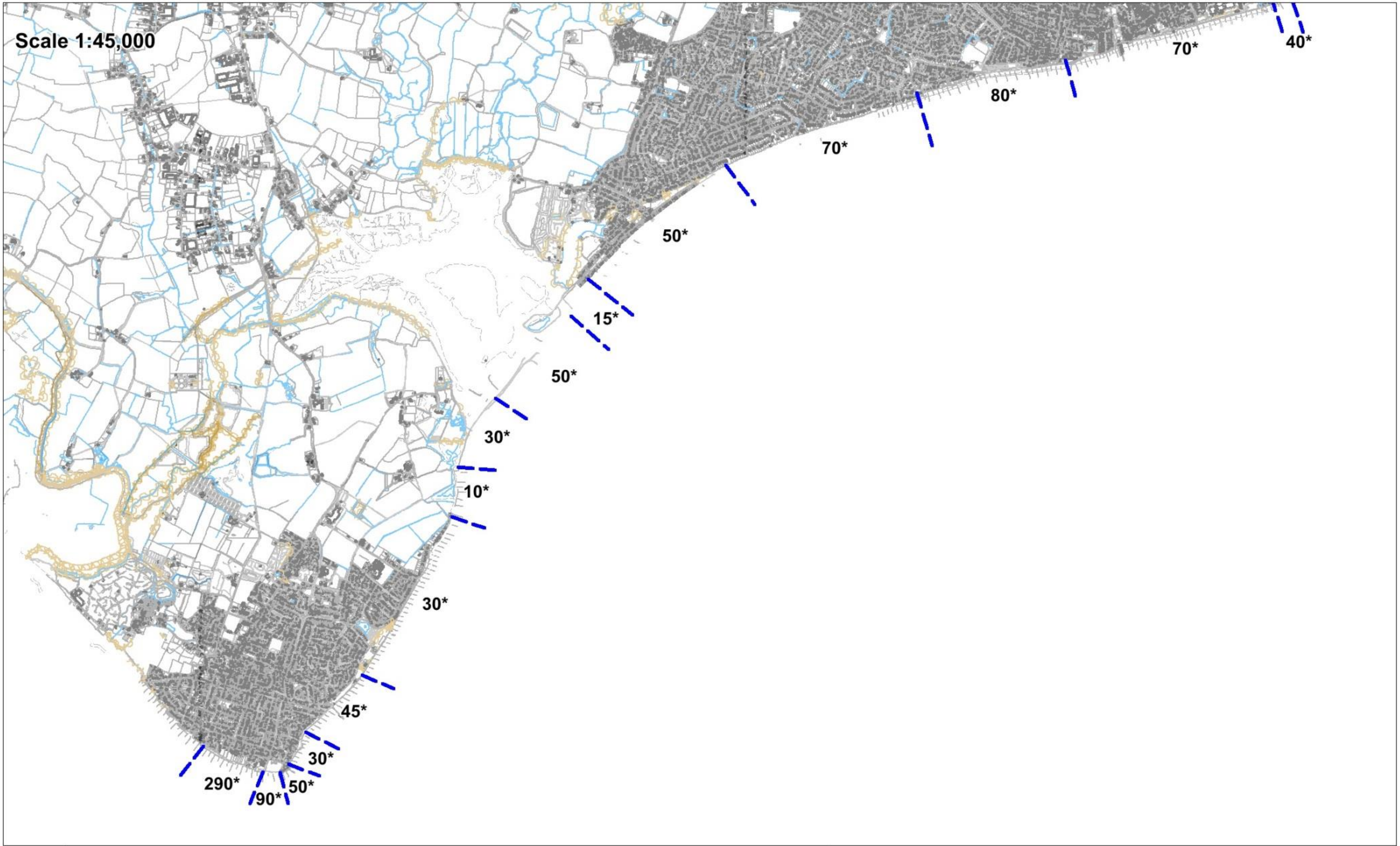


FIGURE 3-8 COASTAL ORIENTATION MAP – SELSEY TO BOGNOR REGIS

CANTERBURY CITY COUNCIL

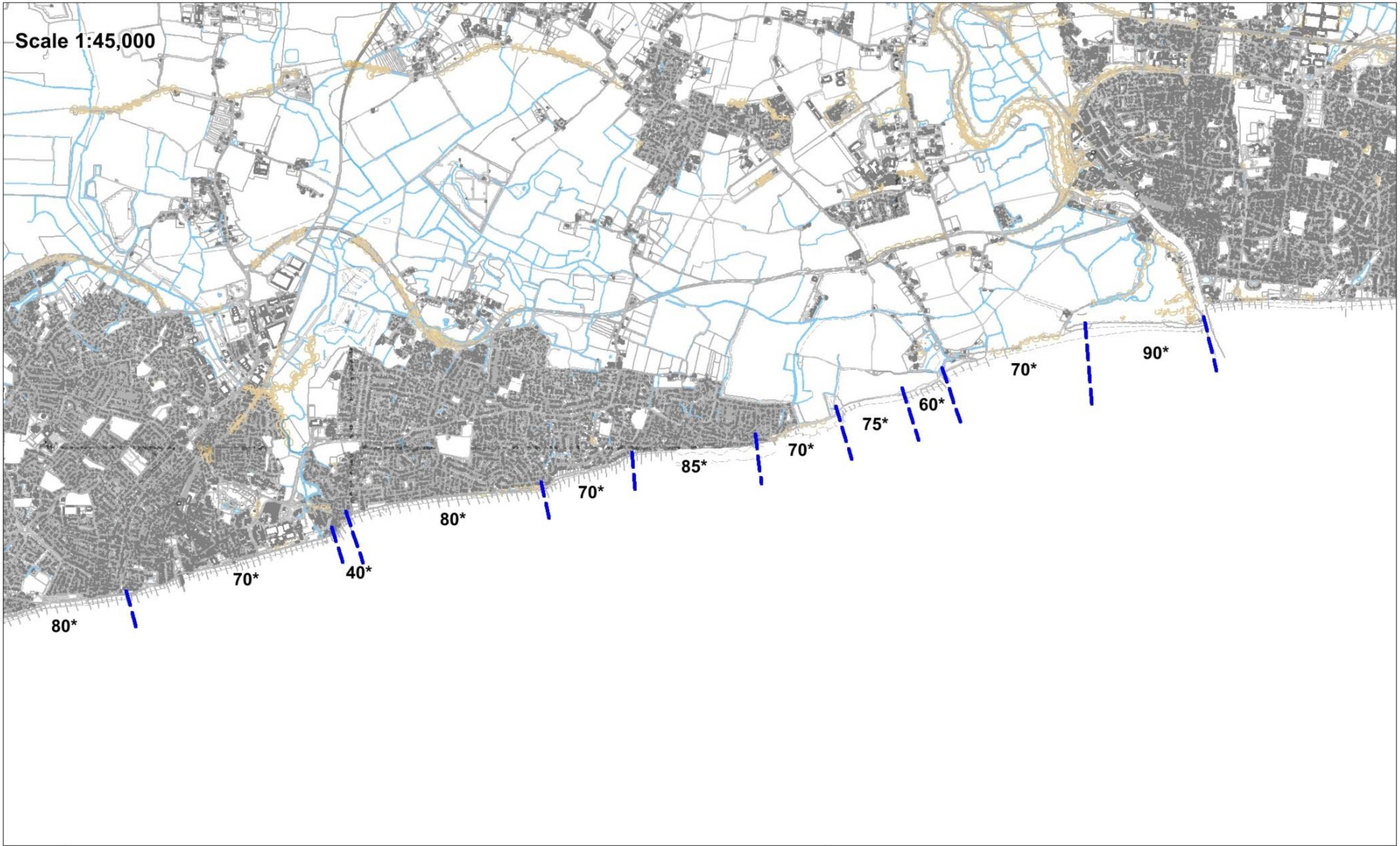


FIGURE 3-9 COASTAL ORIENTATION MAP - BOGNOR REGIS TO CLIMPING

CANTERBURY CITY COUNCIL

4 HISTORICAL MONITORING

4-1 CONTROL NETWORK

A control network was set up by Longdin and Browning for the Regional Coastal Monitoring Programme (RCMP) in 2003, covering the coastline between Littlehampton and Brighton Marina. It includes several E1 (surveyed for longer than 8 hours) and E2 pins (surveyed for 6 to 8 hours) which are both suitable for levelling and GPS surveys; their location is shown on the Location Map of Survey Pins overleaf. GPS equipment has an accuracy of +/- 15mm in the vertical and +/- 20mm in the horizontal.

The E1 stations at Chichester, Newhaven and Hastings are Trimble NetR5 or NetR9 Continually Operating Reference Stations that enable survey teams to connect to receive GPS corrections in real-time or if undertaking post processing or extending our control network, RINEX data can be downloaded directly from these stations or from channelcoast.org

http://www.channelcoast.org/data_management/real_time_data/charts/

4-2 TOPOGRAPHIC SURVEYS

Coastal monitoring is undertaken annually through the Regional Coastal Monitoring Programme; its primary aim is to provide a repeatable and cost effective method of monitoring the English coastline. The survey programme covers approximately 1,000km of open coastline and estuaries between the Isle of Grain and Portland Bill. Data are collected by Local Authority in-house teams and are freely available via the Channel Coastal Observatory, which is based at the National Oceanographic Centre (NOC) in Southampton. The same applies to the LIDAR data collected by the Environment Agency.

4-2-1 GPS

The elevations of the beaches between Selsey Bill and Climping have been surveyed using a number of techniques since the RCMP project began. ABMS Photogrammetry was used between 2001 and 2006 at a contact scale of 1:5,000 and 1:3,000, ATV GPS survey and profiles were undertaken between 2007 and 2011, and since 2012 ATV-mounted mobile laser scanning has point clouds of all the beaches. This data is then processed to provide a 3-D model of all the beaches and profile data are extracted.

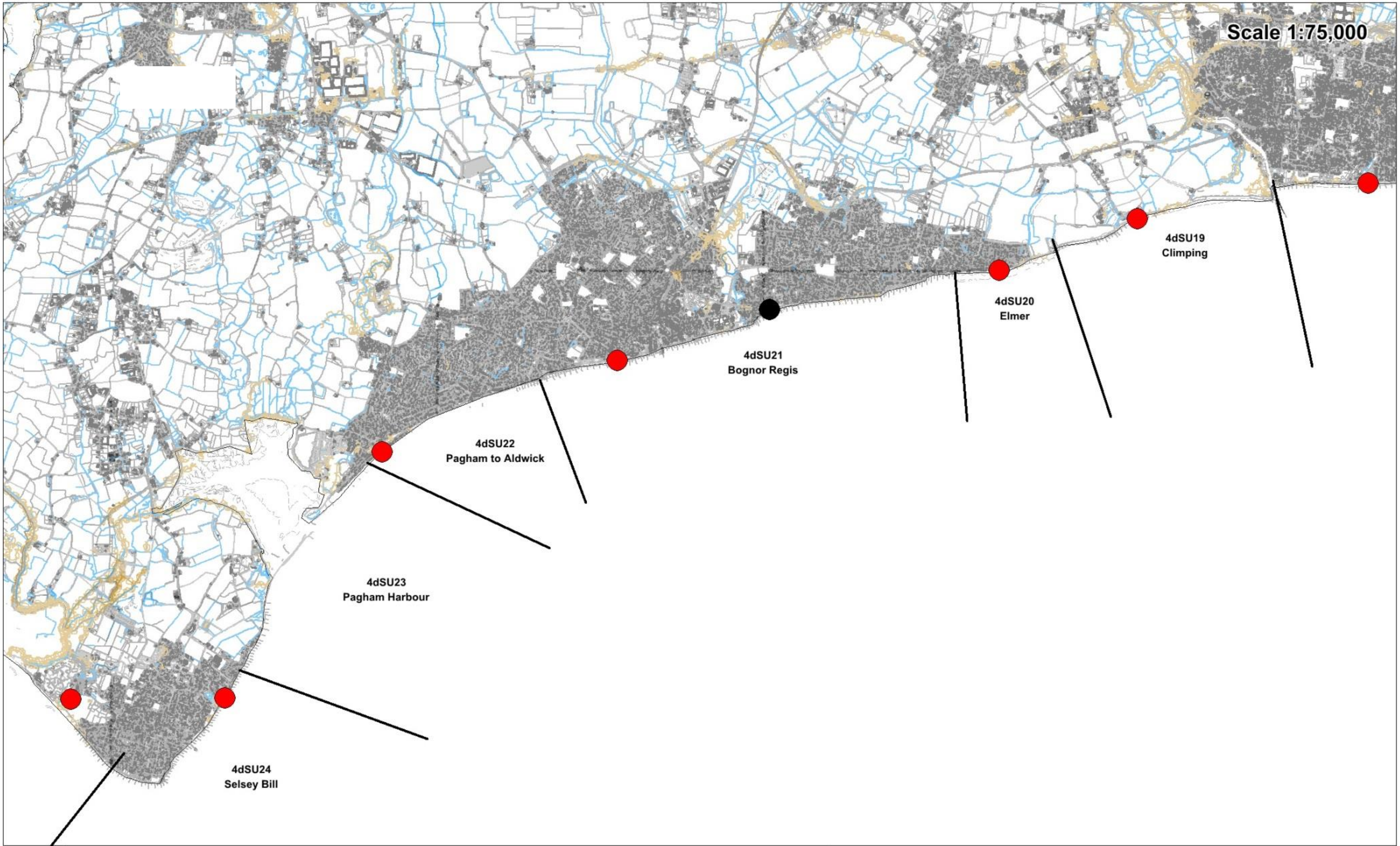


FIGURE 4-1 LOCATION MAP SURVEY CONTROL PINS

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SPRING & AUTUMN SURVEYS

Historically, designated profiles were surveyed during the spring and autumn, 2003 to 2012. Since 2012 ATV Laser Scan techniques has provided a full DTM survey for each spring and autumn. Profile data has been analysed to monitor beach response to wave conditions or replenishment schemes.

SUMMER SURVEYS

Prior to 2012 a full survey was conducted to provide a 3D model of the beaches once every five years, unless the survey unit is a Beach Management Plan Site where it would be surveyed annually. This survey included a full set of profiles and a continuous dataset of the beach and foreshore. Since 2012 ATV-mounted laser scanning provides full coverage, 3D datasets together with profiles along BMP sites; however this summer survey was removed from the programme in 2017.

POST STORM SURVEYS

Historically, following a series of storm waves which exceed the storm threshold as set by Channel Coastal Observatory, post storm surveys may be conducted as an additional set of data. The surveys have only been conducted if the Local Authority or Environment Agency managers deemed them necessary as the beach to showed significant damage i.e. large losses or severe drawdown of material which will not return over the course of the next few tidal cycles.

Since 2012 these post storms have been surveyed using the mobile laser scanner which is either concentrated in the specific areas of concern or the whole beach.

IN/OUT SURVEYS

Pre 2017, In and Out surveys refer to the pre and post work surveys respectively. The profiles and/or continuous is concentrated on those areas specified by the Local Authority or Environment Agency manager; usually the extraction and deposition sites.

4-2-2 HISTORIC

ABMS

Topographic profile lines have been derived from the photogrammetry recorded under the Annual Beach Monitoring Survey (ABMS) since 1973. This data covers 440km of South East coastline for the Environment Agency's coastline. This project has also contributed to the extensive photography of the coastline and provides a long term record of coastal evolution.

4-3 BATHYMETRY

The most recent bathymetry data is the 2013 multi-beam survey. Single beam surveys of the study site were undertaken in 2007 and 2004. EGS are currently (as of April 2016) undertaking a multi-beam bathymetric survey between Shoreham and Selsey.

4-4 BMP SITES

Survey unit 4dSU23 (Pagham Harbour) is a BMP site and receives three surveys per year. Spring and autumn survey windows are February to March and October to November respectively. Summer surveys are undertaken between June and September. Each survey unit must have a minimum of two months between each survey (Profile Location Maps are included in Appendix D).

Survey units 4dSU23 (Pagham Harbour) is a BMP site which historically received three surveys per year. Spring and autumn survey windows were February to April and September to November respectively. Summer surveys were undertaken between June and September. Each survey unit should have a minimum of two months between each survey (Profile Location Maps are included in Appendix D).

4-5 AERIAL SURVEYS

4-5-1 AERIAL PHOTOGRAPHY

As part of the RCMP ortho-rectified aerial photography is flown in the summer at varying intervals. The most recent available photography was flown in 2016 and prior to that in 2001, 2003, 2008 and 2013. This is available to download from the Channel Coastal Observatory website.

4-5-2 LIDAR

Lidar has been flown annually on behalf of the Environment Agency. Sites chosen for flight are highly dependent on budget and necessity and tend to be selected on a sliding scale; areas of few coastal defences would be a high priority and headlands or heavily managed beaches through defences or maintenance are low on the priority. All LIDAR data for this frontage is available to download from the Channel Coastal Observatory website.

4-6 STRUCTURES

4-6-1 GPS

The defence structures are surveyed every five years by the in-house coastal monitoring team as part of the baseline summer surveys. The most recent structure survey was undertaken in 2012, prior to that 2007 and 2003.

4-6-2 LOCAL AUTHORITIES

Local authorities have a requirement to regularly survey coastal assets.

4-7 HYDROLOGICAL MONITORING

4-7-1 WAVE RECORD

A wave buoy is situated offshore at Rustington. Real time data for the significant and maximum wave height are freely available via the Channel Coastal Observatory website. Wave parameters are recorded using a Datawell Directional WaveRider Mk III buoy.

4-7-2 TIDE GAUGE RECORDS

A tidal gauge is situated on the Arun Platform off of Rustington, which was installed in April 2008. Tide gauges are important for understanding the local tidal conditions. The real time data can be observed alongside the predicted data on the Channel Coastal Observatory website.

4-8 ECOLOGICAL MONITORING

4-8-1 HABITAT MAPPING

The beach vegetation within the south east of England was digitised in 2011 by the University of Southampton. The habitat mapping was based on the 2008 ortho-rectified aerial photography to provide an overview to the locations of vegetation along the coast. Results from Habitat mapping based on the 2013 aerial photography will become available during 2017.

4-8-2 ECOLOGICAL MONITORING

Wetland Bird Survey (WeBS) low tide counts are undertaken once a month over winter at Pagham Harbour. This survey monitors non-breeding waterbirds in the UK. The principal aims of WeBS are to identify population sizes, determine trends in numbers and distribution, and identify important sites for waterbirds. The monitoring scheme is part of a national data collation and analysis run by the British Trust for Ornithology.

The Sussex Wildlife Trust have undertaken several intertidal ecological surveys within the study area as part of the Shoresearch project. The key sites are: West Beach - Littlehampton (surveyed in 2011 - 2015), Selsey Bill west (surveyed in 2011 and 2016), Selsey Bill east (surveyed in 2012, 2013, 2014, 2016) and Bognor Regis – Aldwick (surveyed in 2011, 2013, 2014). The results from this survey feed into the national database 'Marine Recorder'. Habitat, species type, distribution and diversity are recorded. Additionally, if expertise is available on the day of the survey quantitative transect and quadrat surveys are undertaken alongside the usual recording. This enables a more accurate assessment of the relative richness of shores which provides a better measure of change over time. This data is freely available from the JNCC's Marine Recorder Application.

5 SEDIMENT BUDGET

5-1 METHODOLOGY

The sediment budget provides transparent and quantitative evidence of beach losses, gains and sediment pathways, in combination with both natural and artificial movements of beach grade material. This sediment budget predominately focuses on the shingle sediment movement, as this has the most relevance to beach management operations.

Data fed into the sediment budget is supplied through the Regional Coastal Monitoring Programme and uses the full dataset (2007 to 2017). To create the budget beach surfaces were combined to create continuous terrain models (gridded at 1m) across the whole frontage, Selsey Bill to Climping. With the compiled DTM's from all available survey years, it is possible create difference models from which volumetric change between two surveys can be calculated. Negative values represent erosion that has occurred between Year A and Year B, and positive values indicate accretion. Whilst these figures show an overall change in beach volume within each discrete section, it should be recognised that the data is based on the BMP survey, which is undertaken once each year and is a snapshot in time.

The sediment budget uses Equation 1 to calculate the sediment transport rate leaving the cell, and accounts for measured volume change, management activities and anticipated losses within a cell.

EQUATION 1 $$\boldsymbol{Qoutput = -(\Delta V - P + R - L) + Qinput}$$

Where ΔV is the as surveyed volume change, P is the combined recycling (deposition) and replenishment, R is the Recycling (Extraction), L is the combined Losses from attrition and those associated with recycling and replenishment activities. Qinput in the volume transported from the up-drift cell and Qoutput is the volume of material transported to the downdrift cell. A worked example is outlined in Figure 5-1.

The detailed methodology for the production of the sediment budget is outlined in detail within Appendix E. The outputs are available in spread sheets and graphical plates, an example of which is shown in Figure 5-2.

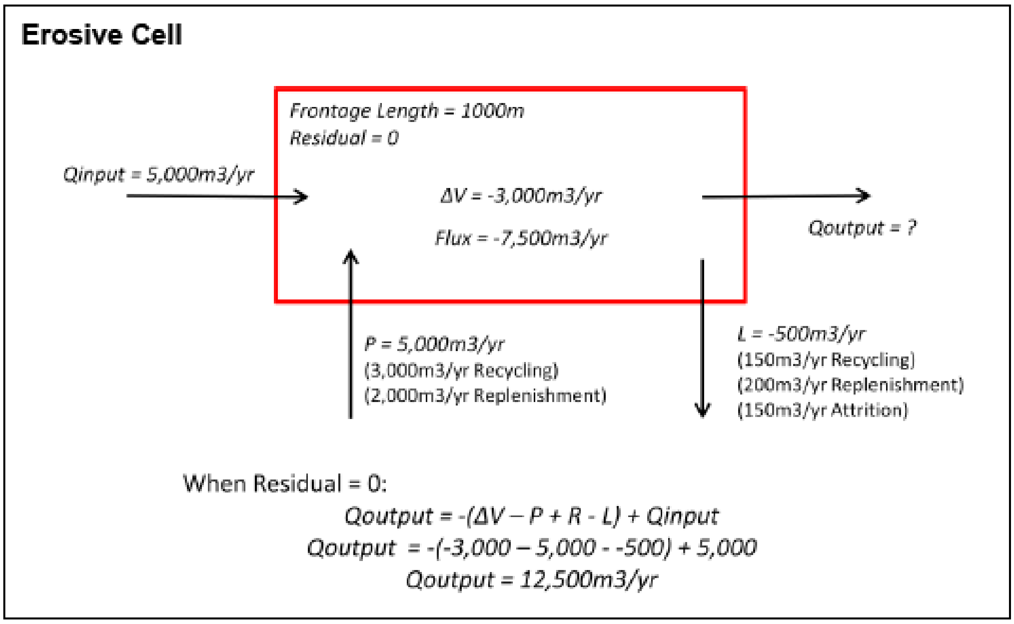


FIGURE 5-1 EXAMPLE OF AN EROSIVE CELL CALCULATED THROUGH THE SEDIMENT BUDGET

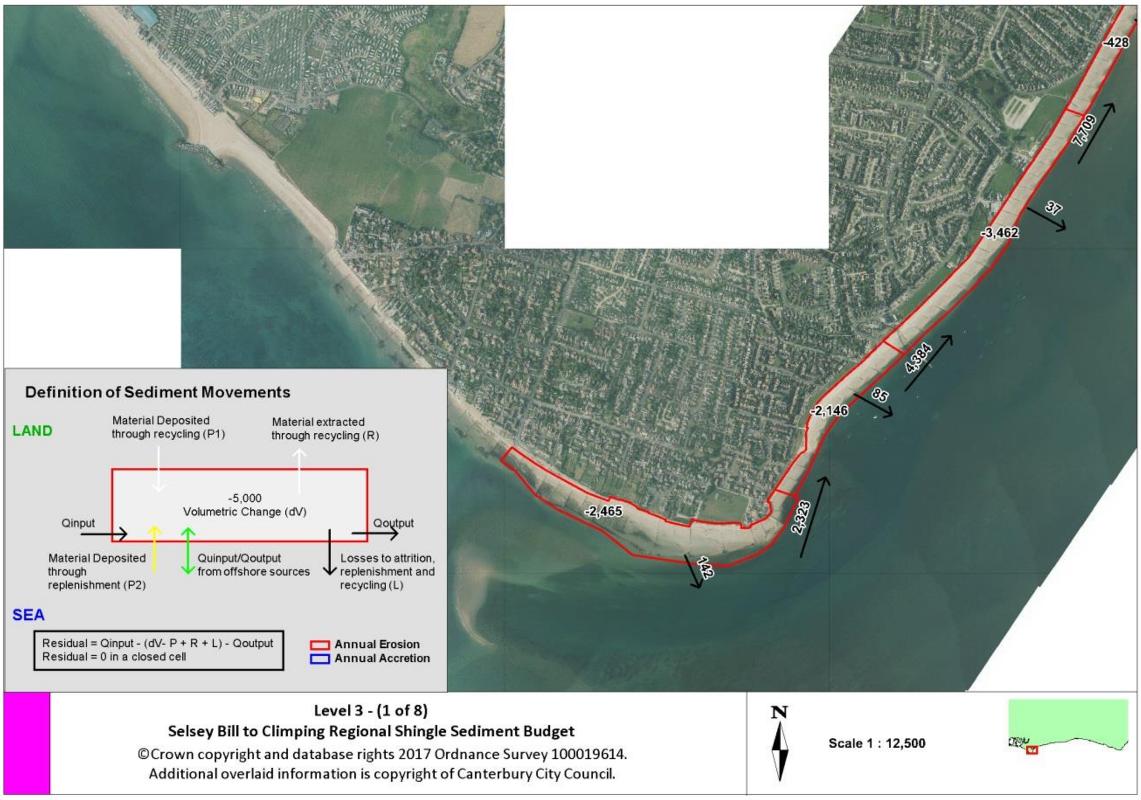


FIGURE 5-2 EXAMPLE OF DETAILED SEDIMENT BUDGET OUTPUTS (APPENDIX E)

5-2 BEACH MANAGEMENT ACTIVITIES

Within the last 10 years only Climping has undergone beach management, with material moved annually between 2007 and 2012 (with the exception of 2008-09). A summary of the total and average annual rates are listed in Table 5-1. Full details of annual quantities and the locations of the extraction and deposition sites can be found in Appendix E.

TABLE 5-1 SUMMARY OF BEACH MANAGEMENT ACTIVITY 2007 - 2017

LOCATION	TOTAL RECYCLING VOLUME (2007-2017)	AVERAGE ANNUAL RECYCLING VOLUME	TOTAL REPLENISHMENT VOLUME (2007-2017)	AVERAGE ANNUAL REPLENISHMENT VOLUME
CLIMPING WEST	100,740	10,074	0	0
CLIMPING EAST	-100,740	-10,074	0	0
NET	100,740	10,074	0	0

(Volumes provided by coastal management authorities)

5-3 SEDIMENT TRANSPORT RATES

From the budget it is possible to extract average annual sediment transport rates along the whole frontage based on the data collected from 2007-2017. These demonstrate high spatial and temporal variability throughout the frontage.

Sediment budget figures have been derived from the available datasets. Figures are correct to the best of our knowledge, subject to the assumptions detailed overleaf, and should be recalculated every few years.

Assumptions

The sediment budget shown in this report is one of several potential scenarios based on different assumptions and data. This sediment budget:

- assumes no sediment input from Kirk Arrow Spit which has a major impact on the longshore transport rates along Selsey East Beach
- predominantly only measures sediment on the upper beach, largely ignoring mobile sediment on the horizontal intertidal platform
- is restricted in the data used for comparison around the Pagham Harbour entrance due to the shifting nature of the location of the channel (no survey data below water) and the spit
- only uses data since 2007. Data going back to 2001 and possibly earlier, also including bathymetry data, annual aerial photography and ground photograph could be used to calculate a more accurate budget but this is far beyond the remit of this study.

Changes and rates shown on the plate are calculated based on 2007 and 2017 data and thus mask significant annual differences. The sediment budget presented should be used and interpreted with great care.

FIGURE 5-3 SEDIMENT TRANSPORT RATES – SELSEY BILL

FIGURE 5-4 SEDIMENT TRANSPORT RATES – PAGHAM HARBOUR

Estimated annual sediment transport in cubic meters.

Unit boundaries

N

0

1 - 2,500

2,501 - 5,000

5,001 - 10,000

10,001 - 15,000

15,001+

FIGURE 5-5 SEDIMENT TRANSPORT RATES – PAGHAM TO ALDWICK

Estimated annual sediment transport in cubic meters.

Unit boundaries

N

0 | 1 - 2,500 | 2,501 - 5,000 | 5,001 - 10,000 | 10,001 - 15,000 | 15,001+

FIGURE 5-6 SEDIMENT TRANSPORT RATES – BOGNOR REGIS

Estimated annual sediment transport in cubic meters.

Unit boundaries

N

FIGURE 5-7 SEDIMENT TRANSPORT RATES – ELMER

Estimated annual sediment transport in cubic meters.

Unit boundaries

FIGURE 5-8 SEDIMENT TRANSPORT RATES – CLIMPING

Estimated annual sediment transport in cubic meters.

Unit boundaries

5-4 EROSION/ACCRETION

With ten years of data it is possible to establish average annual erosion/accretion patterns with a reasonable degree of confidence. Standard difference models that illustrate the difference between pairs of individual surveys are misleading in this regard for the results are influenced by any beach management activities. Replenishment and shingle recycling deposition can mask erosive areas; conversely sites used as a source of recycling material can fail to highlight accretive areas.

Using the results from the sediment budget spread sheets it is possible to calculate the Net erosion/accretion rates, discounting the effects of beach management using Equation 2. Unfortunately due to the coarse nature of replenishment/recycling logs, which usually only define volumes to within the area of the works, this can only be achieved for coarse sediment cells. However, this is usually sufficient to gain an understanding of the erosive areas, the magnitude of the problem, and identify any future sources of shingle for recycling operations.

EQUATION 2: $$\textbf{Net Erosion/Accretion} = \Delta V - P + R$$

The following plates illustrate the average annual erosion/accretion across the study area discounting beach management works. Again, it should be stressed that these figures represent the average value you might expect based on 10 years of data. There can be considerable variation year on year and in some cases unusual conditions can result in a reversal e.g. an accretive area may erode due to a prolonged period of waves from a non-dominant direction.

This does however provide a basis for planning the likely necessity of beach management operations for future years based on actual recorded data.

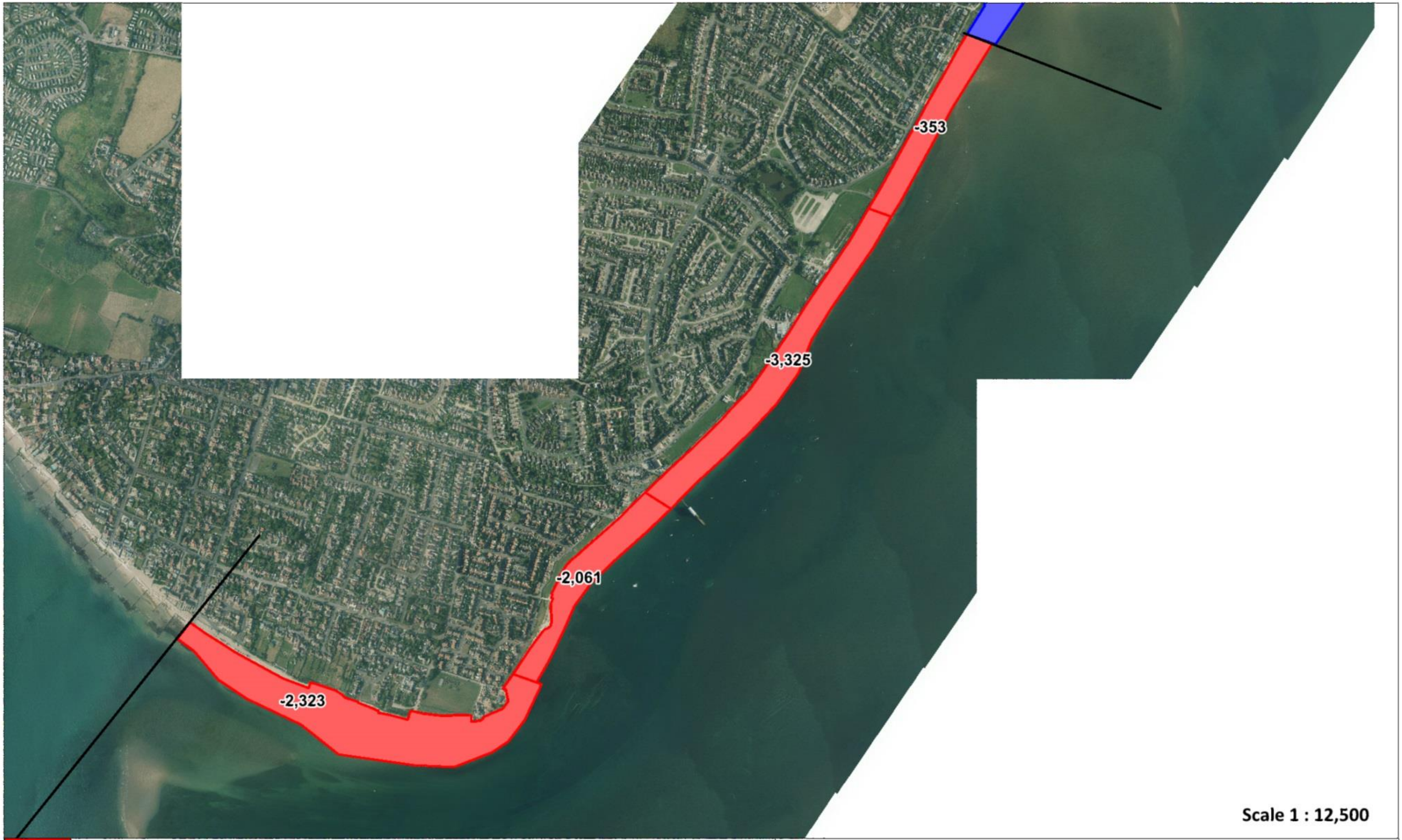


FIGURE 5-9 NET ANNUAL EROSION/ACCRETION – SELSEY BILL

The net accretion/erosion rate.
(Influence of beach recycling and replenishment discounted)

N

Erosive sub cell
Accretive sub cell
+/- 20 Volume change (m)
Sub cell boundaries

FIGURE 5-10 NET ANNUAL EROSION/ACCRETION – PAGHAM HARBOUR

The net accretion/erosion rate.
(Influence of beach recycling and replenishment discounted)

N

Erosive sub cell
Accretive sub cell
+/- 20 Volume change (m)
Sub cell boundaries

FIGURE 5-11 NET ANNUAL EROSION/ACCRETION – PAGHAM TO ALDWICK

The net accretion/erosion rate.
(Influence of beach recycling and replenishment discounted)

N

Erosive sub cell
Accretive sub cell
+/- 20 Volume change (m)
Sub cell boundaries

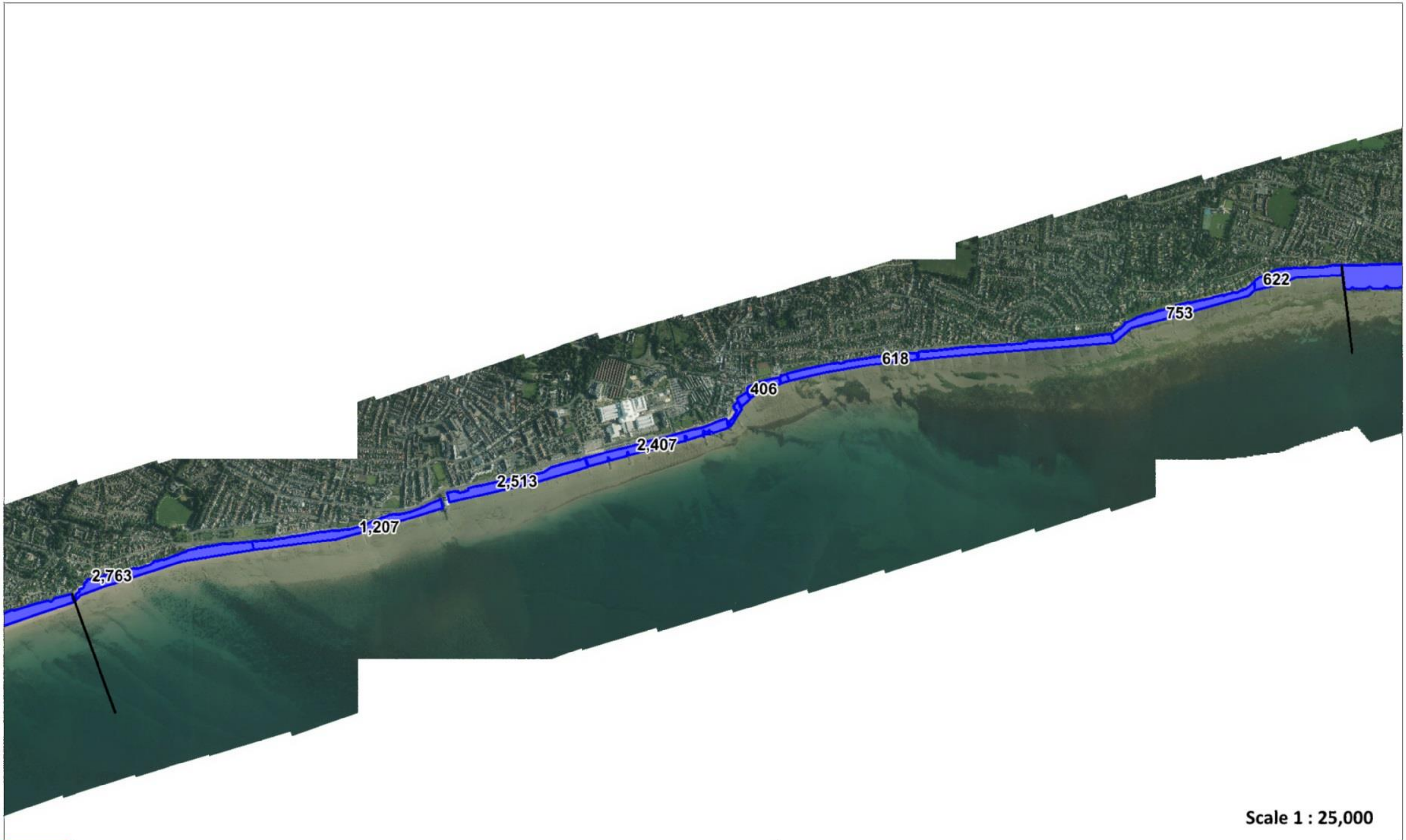


FIGURE 5-12 NET ANNUAL EROSION/ACCRETION – BOGNOR REGIS

The net accretion/erosion rate.
(Influence of beach recycling and replenishment discounted)

N

Erosive sub cell
Accretive sub cell
+/- 20 Volume change (m)
Sub cell boundaries

FIGURE 5-13 NET ANNUAL EROSION/ACCRETION – ELMER

The net accretion/erosion rate.
(Influence of beach recycling and replenishment discounted)

FIGURE 5-14 NET ANNUAL EROSION/ACCRETION – CLIMPING

The net accretion/erosion rate.
(Influence of beach recycling and replenishment discounted)

N

Erosive sub cell

Accretive sub cell

+/- 20 Volume change (m)

Sub cell boundaries

TABLE 5-2 AVERAGE, MINIMUM AND MAXIMUM ANNUAL VOLUME CHANGES

LOCATION	POLYGON (LABELLED FROM WEST TO EAST)	AVERAGE ANNUAL CHANGE (M3)	MINIMUM ANNUAL CHANGE (M3)	MAXIMUM ANNUAL CHANGE (M3)
SELSEY BILL	1	-2,465	-12,659	11,461
	2	-2,146	-4,788	3,258
	3	-3,462	-12,196	2,142
	4	-428	-5,971	8,247
PAGHAM HARBOUR	1	23	-11,546	8,030
	2	4,935	-3,552	49,347
	3	1,072	-12,867	14,954
	4	2,754	-39,541	73,556
	5	-7,364	-73,641	57,512
	6	296	-11,773	3,790
PAGHAM TO ALDWICK	1	584	-19,392	26,307
	2	506	-2,969	11,948
	3	333	-1,688	5,911
BOGNOR REGIS	1	2,624	469	10,071
	2	1,062	-3,021	6,614
	3	2,406	-10,550	13,843
	4	2,297	355	8,450
	5	348	-1,514	2,062
	6	372	-4,860	5,658
	7	638	-2,639	3,300
	8	555	-2,536	2,798
ELMER	1	280	-12,139	14,765
	2	-1,717	-14,543	3,825
CLIMPING	1	-13,739	-28,327	14,734

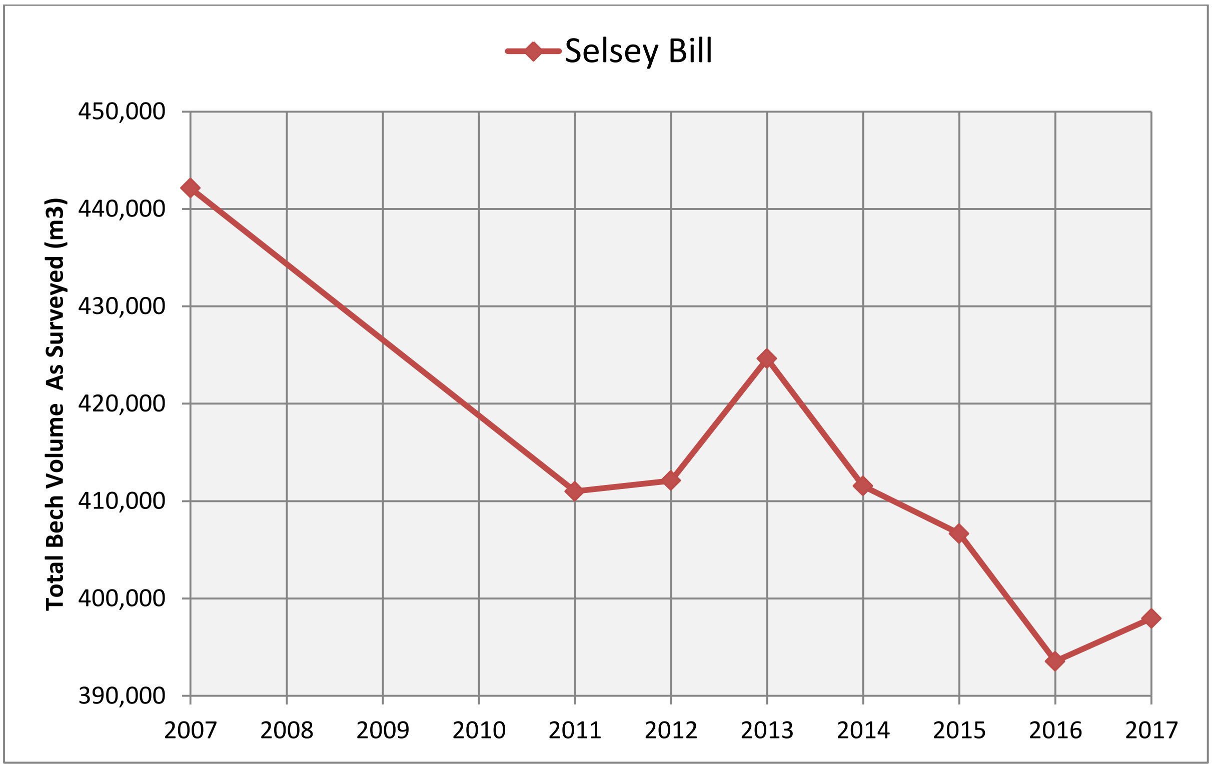
	2	-842	-12,352	2,663
	3	3,743	-4,215	29,220
	4	13,437	2,837	28,717

NOTE THAT VALUES DIFFER SLIGHTLY FROM THE PREVIOUS FIGURES AS ATTRITIONAL LOSSES ARE NOT INCLUDED IN THESE FIGURES.

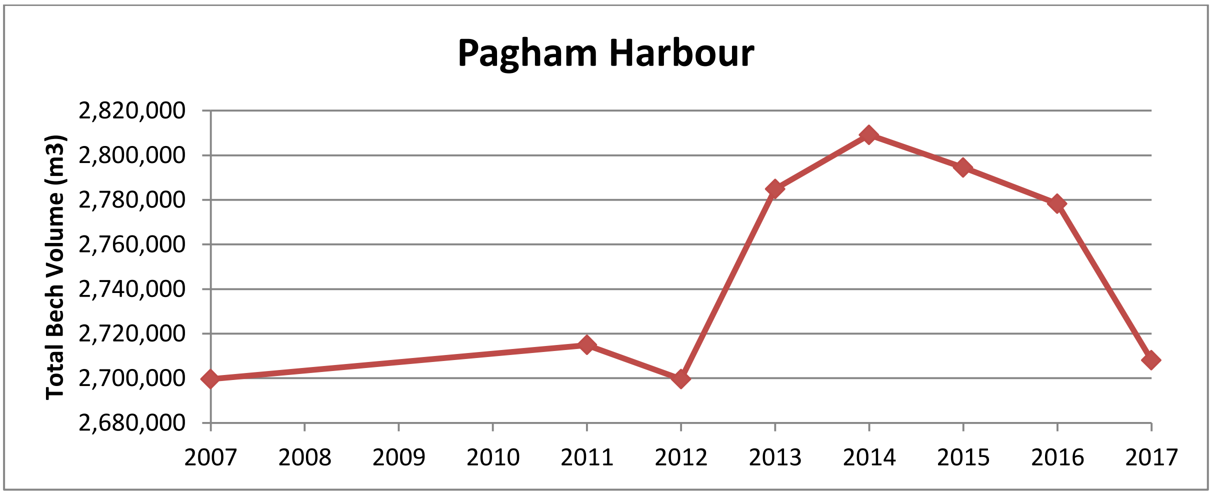
5-5 UNIT SUMMARY

The previous section discounted the effect of historic beach management operations, but in order to appraise those practices and consider the influence of natural processes it is important to look at the combined impact. This is considered broadly for each unit by calculating the changes in total beach volume.

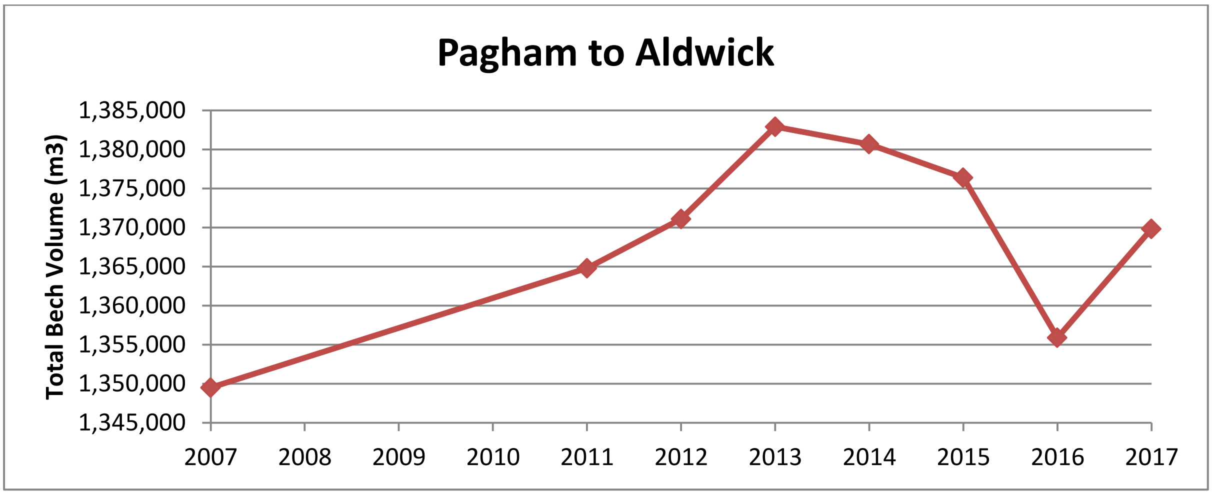
5-5-1 SELSEY BILL



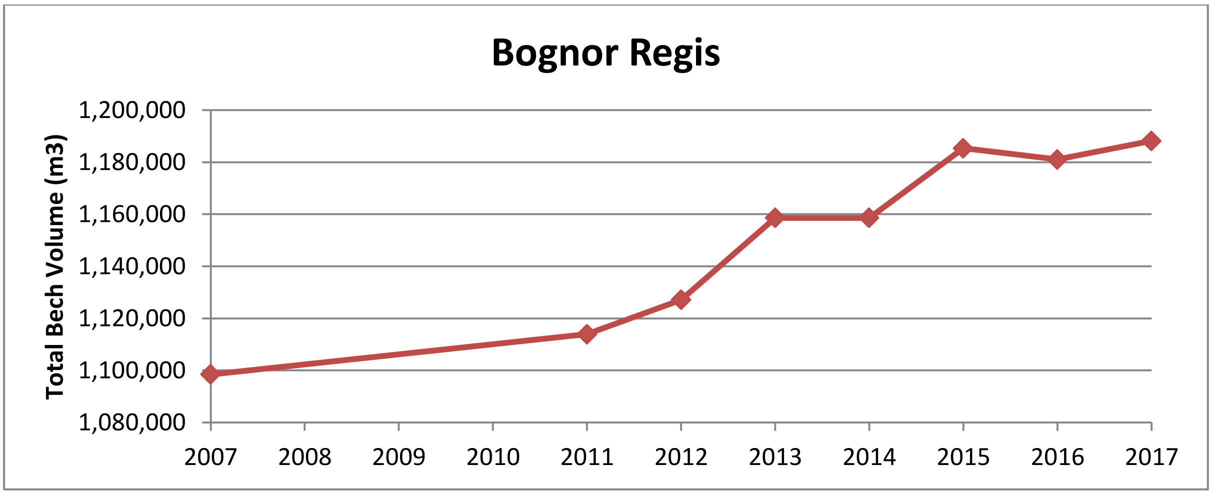
5-5-2 PAGHAM HARBOUR



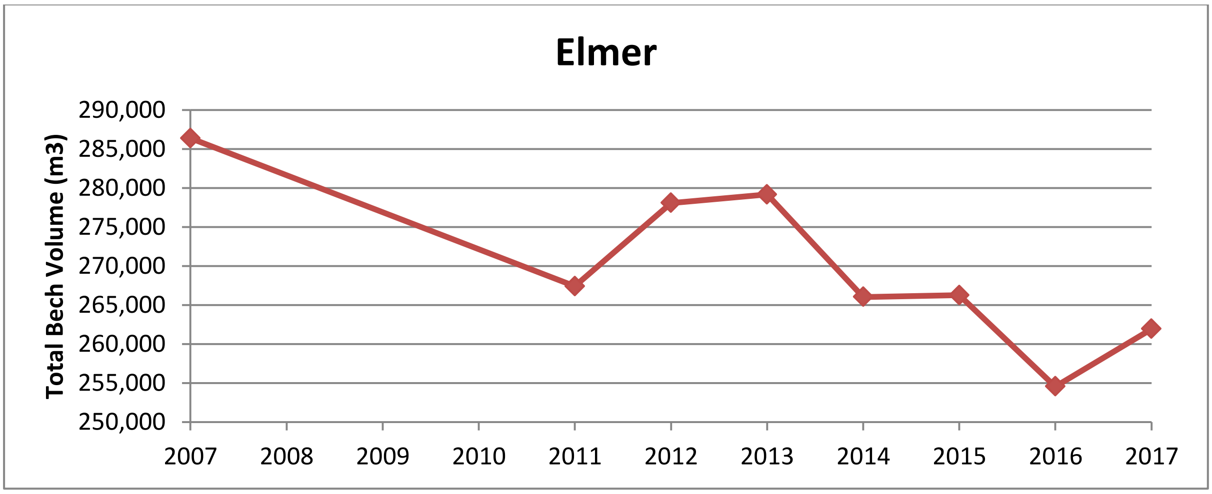
5-5-3 PAGHAM TO ALDWICK



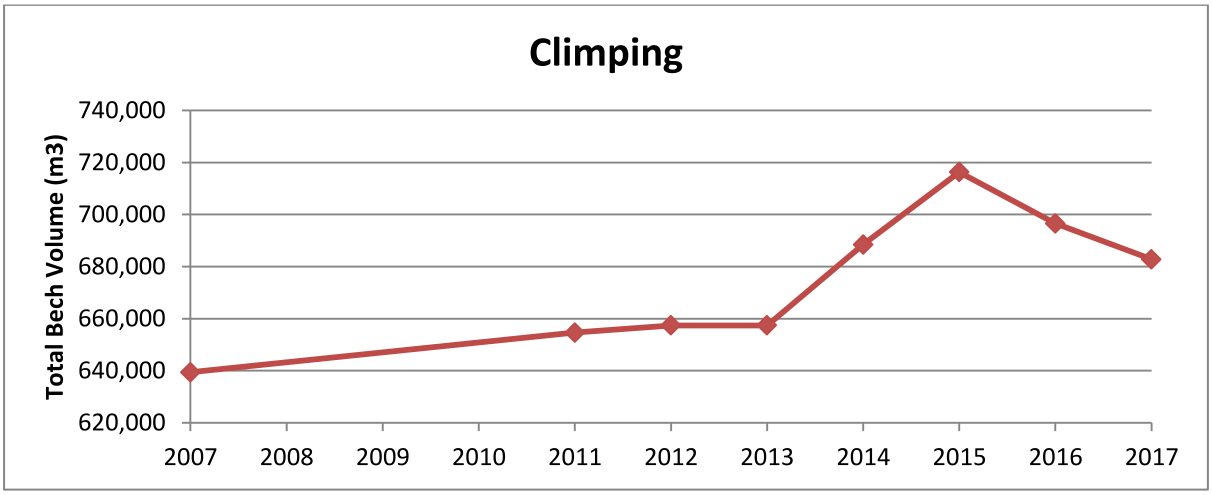
5-5-4 BOGNOR REGIS



5-5-5 ELMER



5-5-6 CLIMPING



6 RISK ANALYSIS

6-1 DEFENCE SECTIONS

In order to perform the risk analysis the coastline was split into representative defence sections based upon sea defence, beach and foreshore characteristics (Figure 6-1-1). Details on the defence type, elevation and geometry, foreshore levels and the calculations performed for each defence section is provided in Appendix G.

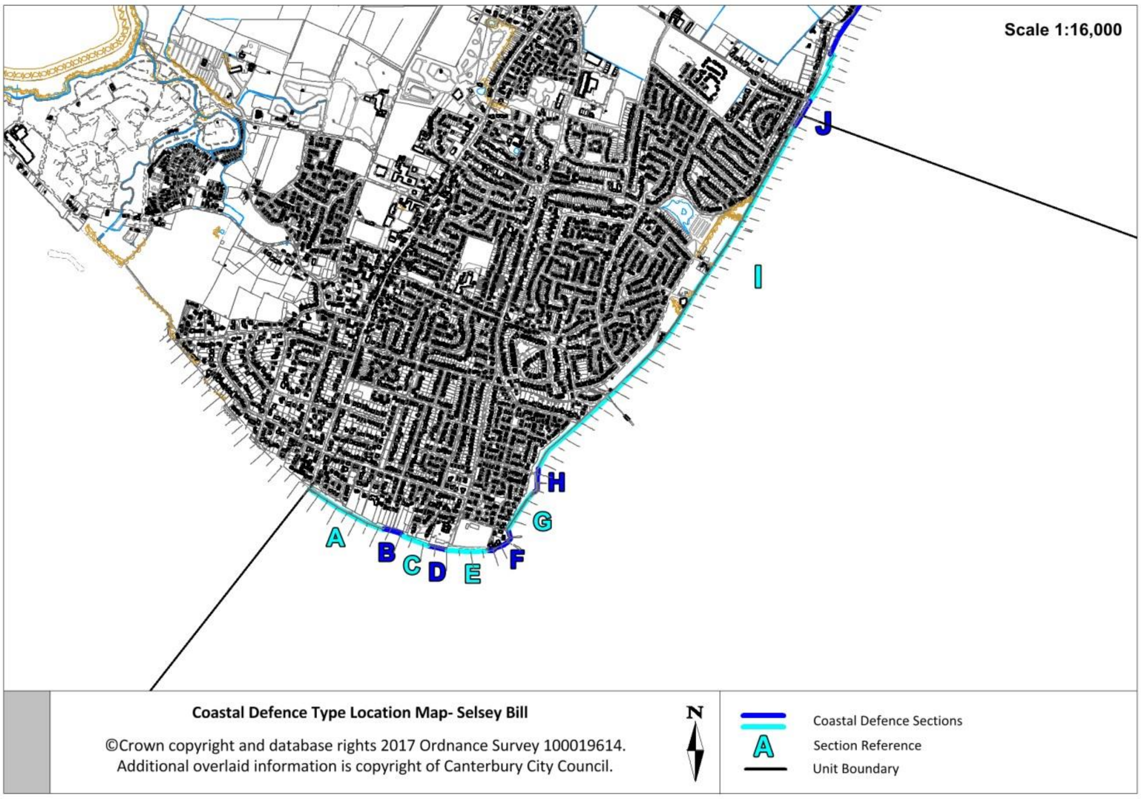


FIGURE 6-1-1 EXAMPLE OF DEFENCE SECTIONS FOR SELSEY BILL

6-2 METHODOLOGY

6-2-1 OVERTOPPING

The primary short-term threat considered in this report is excessive overtopping of the shingle beaches and structures, causing flooding and damage to property and infrastructure.

Overtopping can pose a risk to pedestrians, vehicles, trains and structures behind the defence through discharge flows and flying shingle. The EurOtop Manual (Pullen et al., 2007) defines the consequences of overtopping into four general categories;

a) *Direct hazard of injury or death to people immediately behind the defence.*
b) *Damage to property, operation and/or infrastructure in the area defended, including loss of economic, environmental or other resource, or disruption to an economic activity or process*
c) *Damage to defence structure(s), either short-term or longer-term, with the possibility of breaching and flooding.*
d) *Localised flooding from overtopping discharge*

Shingle beaches are very efficient at dissipating wave energy (Figure 6-2-1). To calculate overtopping rates under different scenarios a methodology was developed and applied consistently to the whole frontage. This is summarised in Figure 6-2-2 and described in the following text.

FIGURE 6-2-1 DISSIPATION OF WAVE ENERGY ON A SHINGLE BEACH (KINGSDOWN, 2009)

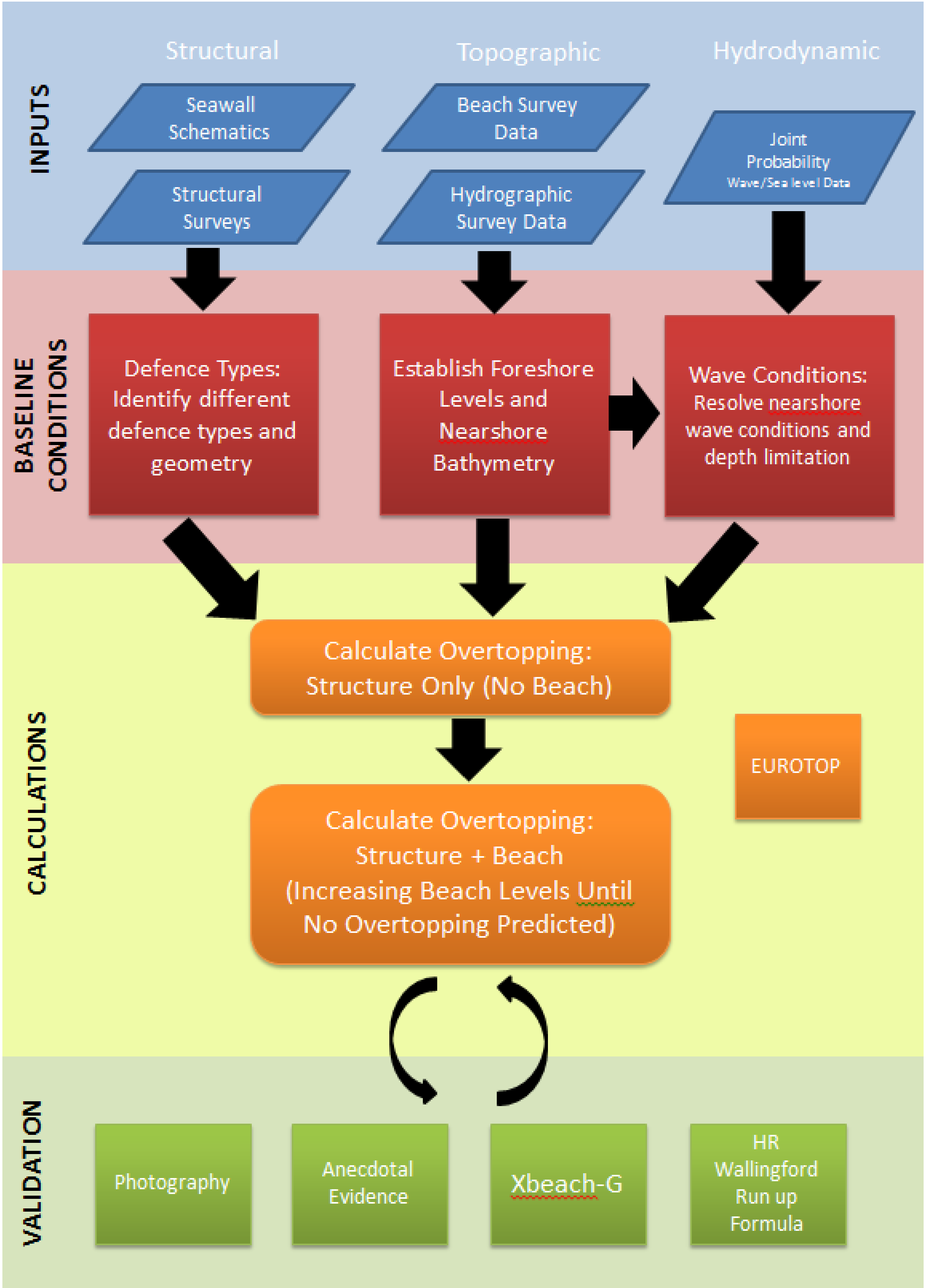


FIGURE 6-2-2 SUMMARY OF OVERTOPPING METHODOLOGY DEVELOPED FOR THIS REPORT

INPUTS

Structural geometry was obtained through seawall schematics/as built drawings where available. These not only provide the crest height of structures but also the hidden portion of the defence and toe levels obscured by current beach levels. In areas where this information was not available the analysis relied on structure surveys of the visible defence carried out as part of the Regional Coastal Monitoring Programme. When the latter provided insufficient detail it was supplemented with LiDAR data.

Beach survey data provided current beach levels and geometry in addition to historical variations dating back to 2003. Where this provided insufficient information on beach toe levels, foreshore heights and the approach to the beach it was supplemented with bathymetric survey data.

Hydrodynamic conditions were defined by the outputs of the joint probability study (Mason, 2014) and provided nearshore conditions for return probabilities from 1 to 200 years.

BASELINE CONDITIONS

Structural geometry and foreshore levels were used to break down each management unit into defence sections (see Section 6-1). These then formed the basis for each different set of overtopping calculations. In order to calculate the worst set of conditions for each set of joint probability values it was necessary to account for the effects of depth limitation and define wave conditions at the toe of the structure/beach (Figure 6-2-3).

All management units in the study area have depth limited waves under the higher return period events. To calculate the depth limited spectral significant wave height at the structure/beach toe the results from a simple 1D energy decay model (Van der Meer, 1990) are used, in which the influence of wave breaking is included. The model converts deep water wave steepness, local water depth and the slope of the foreshore into a breaker index (Pullen et al., 2007). The latter defines the reduction in significant wave height.

Results produce a wave height limited to between 50-60% of the water depth; precise figures for each defence section are included in the results spreadsheets in Appendix G.

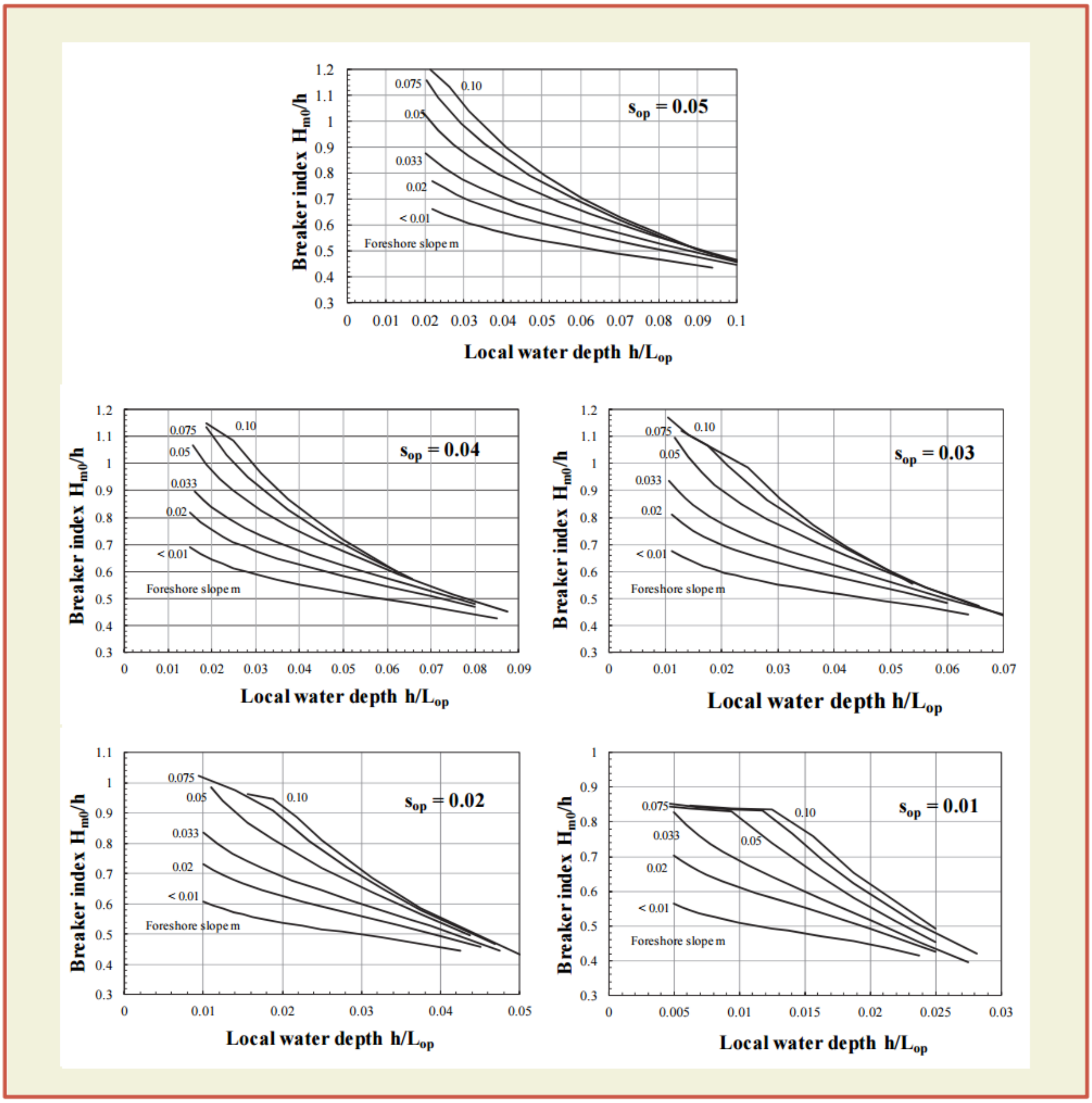


FIGURE 6-2-3 CALCULATION OF DEPTH LIMITATION USING THE BREAKER INDEX (PULLEN ET AL, 2007)

CALCULATIONS

For most calculations the EUROTOP research was used (Pullen et al., 2007), based on significant previous research and physical model testing it provides a tool for calculating overtopping at a variety of seawall and structure types.

Initial calculations were run for each defence type without a beach present (Figure 6-2-4); this provided a worst case scenario for each section. As there is more confidence in the overtopping results for standalone structures it also provided a baseline for further calculations.

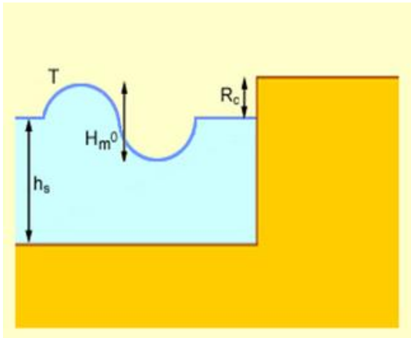


FIGURE 6-2-4 EUROTOP - CALCULATION OF OVERTOPPING AT A SIMPLE VERTICAL SEAWALL

The reason that there is more confidence in predicted results for standalone structures is that the geometry is simple and fixed. They are also well suited to Physical model testing with limited scaling effects; this also largely applies to more complex structures and rock revetments. Introducing a shingle beach to the defence geometry creates a higher level of uncertainty owing to the very limited number of laboratory or field tests.

When calculating wave run-up on shingle beaches there are a number of factors that will affect the result and are also subject to change in the short term. These include beach volume, beach shape and beach composition. The first two can be constrained by locally known variability from the coastal monitoring programme but beach composition, including grain size and grading, permeability and roughness factors can only be approximated, especially as they change both spatially (within a management unit) and temporally (over various time scales).

In order to improve on current methods of calculating beach run-up a sub-project to this report was commissioned, *Wave run-up on shingle beaches: a new method* (HRW, 2014). The report contains a comparison between a set of measured run-up data taken at Worthing beach and several established formula for predicting run-up. These include some of the methods available in EUROTOP, Figure 6-2-5 illustrates the results from one of the more simplistic approaches.

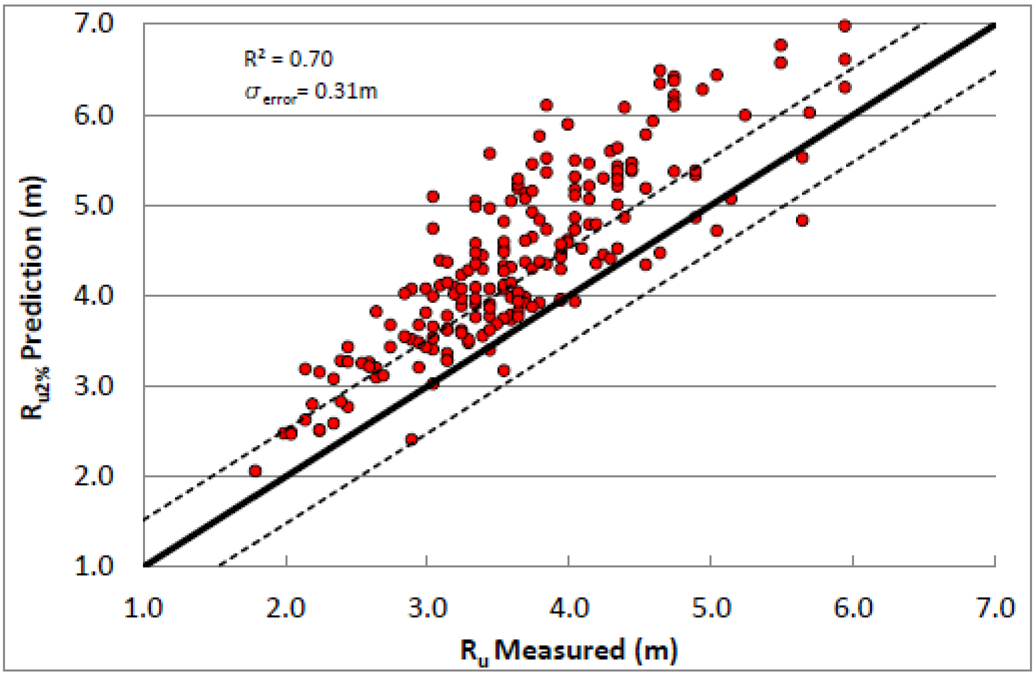


FIGURE 6-2-5 SIMPLISTIC EUROTOP METHOD VS ACTUAL MEASURED DATA AT WORTHING (HRW, 2014)

The main output of the report was an improved formula for calculating run-up on shingle beaches. The formula uses a representation of the spectral wave data, and in particular takes good account of the swell component, producing a much better fit to measured data at Worthing and smaller samples taken elsewhere on shingle beaches in the Southeast.

For this study the new formula was not used for the bulk of the calculations but was used as a validation tool to sense check the results from EurOtop, for example overtopping can only start once run-up has reached the beach crest level. There are two main reasons for this;

a) *The new formula uses spectral wave data and although recorded spectral data is available from the local wave buoys there is no way to predict the swell component of larger storms and their return periods.*

b) *There is no simple way to incorporate the new run-up formula into the EUROTOP calculation tools when assessing overtopping for a combined beach and structure.*

There are plans to update EUROTOP to include the formula, there is also on-going research at HR Wallingford to assess the effects of bi-modal seas and overtopping of shingle beaches and structures. When this is complete it may be possible to improve on the results of this study, but the results presented are produced using current EUROTOP methodology, however the improved formula is used to help validate results.

For each defence section the structure only results were used as a starting point, a small beach was then introduced to the geometry and overtopping rates calculated (Figure 6-2-6). The size of the beach was then steadily increased until the point was reached where no overtopping was predicted. In order to make the results more comparable with surveyed beach levels and design levels each beach size was converted to a representative cross sectional area (CSA).

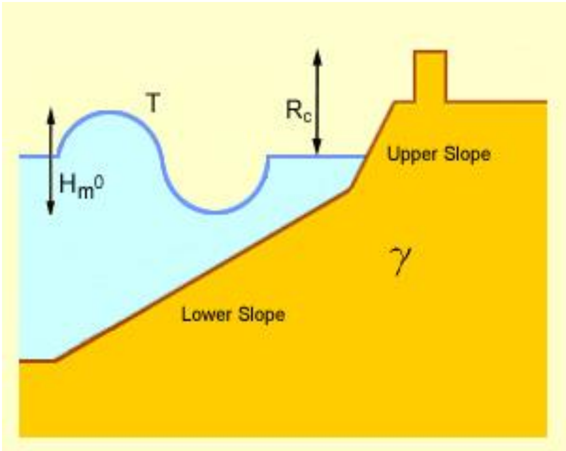


FIGURE 6-2-6 EUROTOP CALCULATION USING MORE COMPLEX STRUCTURES

In order to calculate the influence of wave return walls with beaches it was necessary to perform an adjustment outside of EurOtop. The general principle applied within EurOtop is that a wall with a large freeboard has the biggest reduction in wave overtopping as the wave has room to be channelled by the wave return. As water levels increase the effect of the wave return declines until it reaches a point where it has no effect at all in reducing overtopping. The same principle applies to shingle beaches, where crest levels towards the top of the wall diminish the effect. This is not accounted for in EUROTOP so the equations were adapted and applied as an adjustment to the overtopping figures. The full methodology is described in Appendix G.

While the authors concede that the EUROTOP methodology used for this study has a propensity to over predict run-up on shingle beaches, and therefore overtopping, it effectively calculates the maximum run-up/overtopping for a given set of input conditions. The variability introduced by not fully accounting for inputs such as swell conditions means that the actual values may be lower, but rarely higher. This is important when establishing critical defence levels, and also builds in a factor of safety to the final results; hence we have carried out the validation. For the sections fronting the breakwater at Elmer the overtopping methodology will not be directly applicable as the breakwater will cause attenuation. This limitation has been stated on the overtopping graphs in appendix G. For specific scheme design for this area it is recommended that additional computational modelling is undertaken.

VALIDATION

Given the potential uncertainty in overtopping results it was important to validate the results, this was done with four methods.

1. Photographic evidence of large overtopping events and retrospective comparison with predicted overtopping (e.g. Figure 6-2-7).

FIGURE 6-2-7 WAVE OVERTOPPING, SELSEY BILL (DECEMBER, 2012). PHOTO CREDIT CHICHESTER DISTRICT COUNCIL

2. Anecdotal evidence in the form of information that is not well documented or photographed. The prime example of this is shingle on the promenade, which is indicative of small scale overtopping (e.g. Figure 6-2-8). Where management authorities have to periodically clear this it is evident that the defence is subject to minor overtopping on a regular basis. Results can be queried to ensure these events are predicted.

FIGURE 6-2-8 EVIDENCE OF OVERTOPPING ON TO THE PROMENADE, SELSEY (2016)

3. XBeach-G is a software tool developed in collaboration between Plymouth University and Deltares (Masselink et al, 2014). It simulates storm impacts on gravel beaches and computes wave-by-wave flow and surface elevations over the duration of a storm. Sample data along the study area was run in XBeach-G to check the results were comparable (Figure 6-2-9).

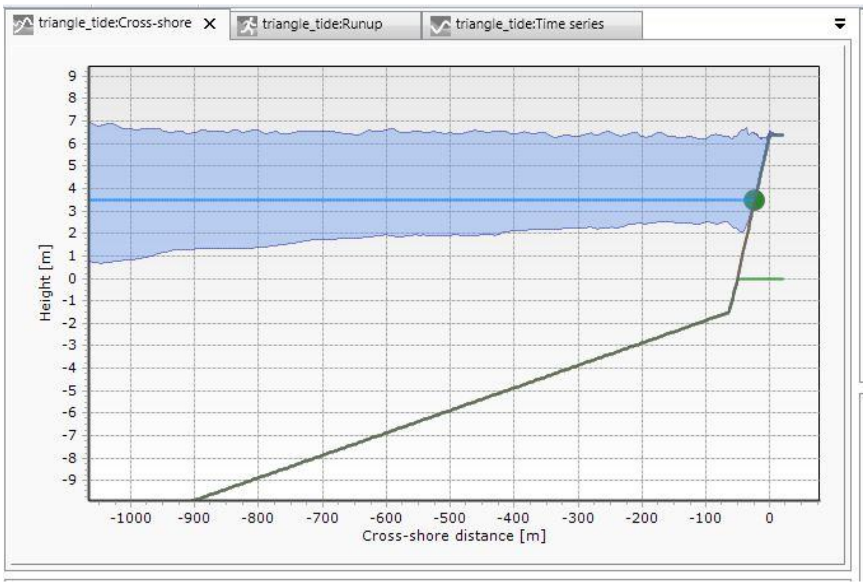


FIGURE 6-2-9 XBEACH-G SAMPLE SCREENSHOT

4. The improved formula presented in Wave run-up on shingle beaches: a new method (HRW, 2014, see Figure 6-2-10) was used in areas that were prone to green water overtopping (No structure and run-up exceeds crest). By running calculations for a number of swell components results could be verified as reasonable and ensure that an underestimate had not been made.

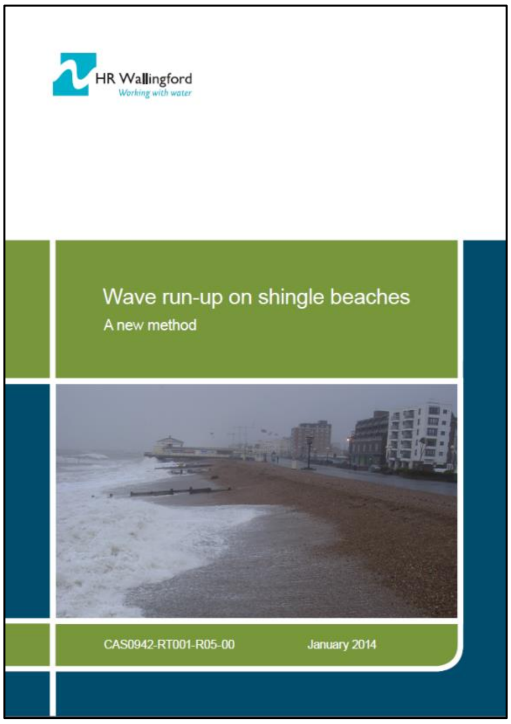


FIGURE 6-2-10 SUB-PROJECT RESEARCH AND DEVELOPMENT OF IMPROVED RUN-UP FORMULA

6-2-2 SEAWALL FAILURE

Coastal defences in the Southeast are most commonly comprised of a beach and structure combination. These work in unison with the beach absorbing wave energy, breaking waves and protecting the sea wall from direct wave attack. The wall acts to further reduce the risk of overtopping from waves that run up past the crest and present a significant barrier to overtopping and erosion should the beach levels drop to lower levels. Consequently these elements should not be considered in isolation, but as two parts of the same defence with each one playing a critical role.

As beach levels lower due to erosion, draw down in a storm, or failure of groynes that act as controlling structures the seawall becomes increasingly exposed to direct wave attack. In addition to a probable increase in overtopping rates, this significantly increases the risk of seawall failure.

FIGURE 6-2-11 DILAPIDATED GROYNES, LOW BEACH AND SEAWALL FAILURE AT SELSEY (2008)

As beach levels continue to drop there is an additional threat of undermining of the seawall foundations. This can cause the structure to collapse and/or a draining of the fill material from behind the seawall that reduces the structural integrity (Figures 6-2-11 and 6-2-12). A beach also provides a lot of support and weighting in front of the structure, without which toppling or sliding of seawall sections can occur (Figure 6-2-13).

Typically, before beach levels get low enough to pose a credible threat to the structure the standard of protection has already become sub-standard due to the increased likelihood and severity of overtopping. There are instances where the structure itself provides a sufficient barrier to overtopping, but often in these cases a beach is required to be maintained in order to protect the structure and prevent undermining.

FIGURE 6-2-12 EXAMPLES OF UNDERMINING AT TANKERTON (LEFT) AND RECULVER (RIGHT) (BOTH PHOTOS 1999)

Calculating failure probabilities for all stretches of structures along the study frontage is outside the scope of this report. Additionally, the conditions of seawalls are often unknown especially if covered by beach for many years. The report does however highlight areas where the loss of beach would result in the potential for undermining and/or increased exposure to wave attack that may result in a significantly increased risk of failure.

For coastal management authorities should undertake regular asset condition inspections in order to assess the need for any maintenance. Historically these may have been picked up by NFCDD inspections. It is anticipated that this will shortly be replaced by AIMS, but in the interim each coast protection authority should conduct their own regular coastal asset inspections.

FIGURE 6-2-13 FAILURE OF A SEAWALL AT ALL HALLOWS DUE TO SLIDING/TOPPLING OF DEFENCE SECTIONS (2015)

Two types of seawall failure are considered in this method; undermining and structural failure (breach or partial breach). For seawalls in good condition undermining is assumed to be the critical failure mechanism, and for seawalls in bad condition (where there is a risk that wave attack will cause failure) structural failure is assumed to be the critical failure mechanism. These calculations are dependent upon the type, construction and condition (where known) of the sea defences (all known defence schematics are provided in Appendix F).

For undermining calculations a beach level was calculated that prevents the defence foundations from being exposed, allowing for a 1:10 slope (due to draw down during a storm event) and a 50cm depth of scour (Figure 6-2-14). The full methodology is provided in Appendix G.

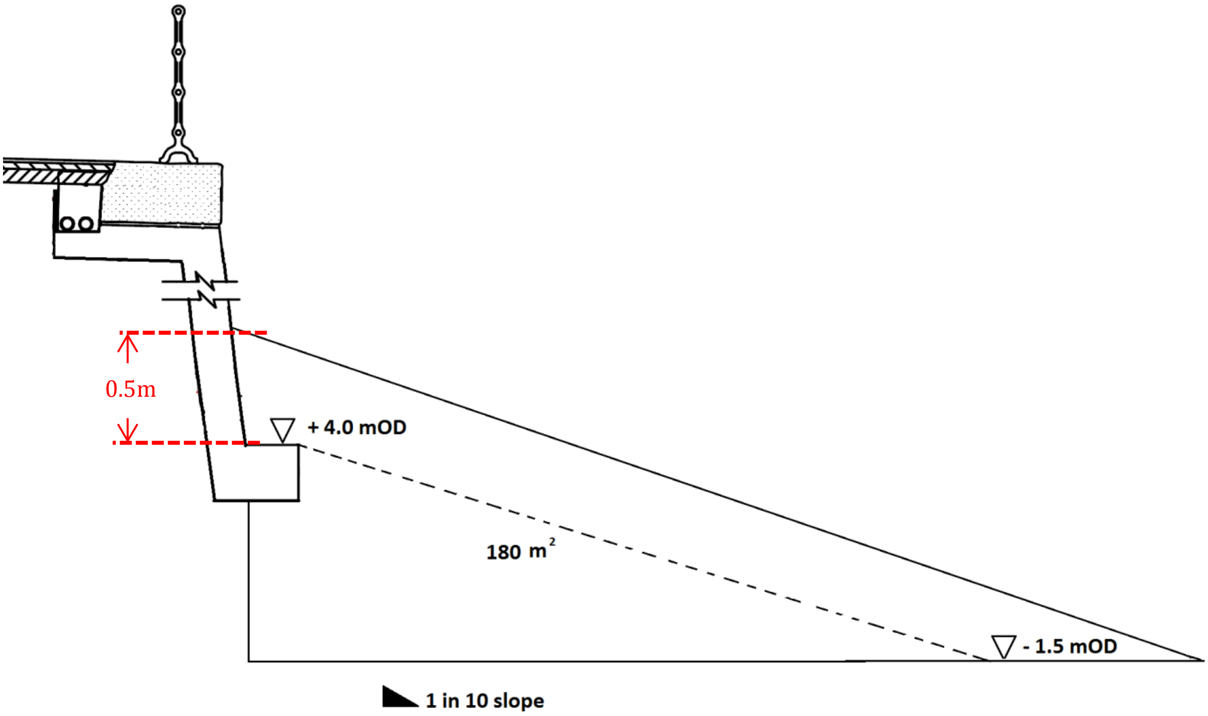


FIGURE 6-2-14 CRITICAL BEACH LEVEL TO PREVENT UNDERMINING OF THE DEFENCE FOUNDATIONS INCLUDING A 50CM ALLOWANCE FOR SCOUR

For structural failure a beach cross section is calculated that prevents critical overtopping (and wave attack) of the defence structure, using the Eurotop allowable overtopping limits (see Appendix C).

6-2-3 FLOODING & BREACHING

Flooding can occur through excessive overtopping, seawall failure or breaching of barrier beaches. All of these scenarios can result in flooding when the hinterland is below the extreme sea level or defence height.

In order to calculate the properties at risk from a 1:200 year event (4.5mOD) a planar still water level flood map was created using LiDAR data (most recent dataset, 2015) and combined with the Ordnance Survey's AddressBase property layer (Figure 6-2-15). There are three large flood plains within the study area: Pagham Harbour (c.740ha), Bognor Regis (c.1707ha) and the Adur River (c.378ha – Climping side of the river only), and a smaller basin at Selsey recreation ground (c.32ha).

FIGURE 6-2-15 EXAMPLE OF PROPERTIES (STARS) WITHIN THE 1:200 YEAR EXTREME WATER LEVEL PLANAR FLOODPLAIN (ELMER)

An average current house value per postcode was calculated using ZOOPLA, and from this the approximate value of properties at risk was calculated (Table 6-1).

TABLE 6-1 ESTIMATED PROPERTY DAMAGE COSTS

PLACE	PROPERTIES AT RISK	APPROX. VALUE (£K)
SELSEY BILL RECREATION GROUND	476	190,638
PAGHAM HARBOUR	440	176,220
BOGNOR REGIS/ELMER	5,034	1,552,158
CLIMPING	405	104,814
TOTAL	**5,879**	**2,023,830**

In total this equates to a theoretical value of over £2,000 million of property that is reliant on the sea defences not breaching on a large scale along this frontage. There are several important caveats; firstly that the planar still water level floodplain does not account for flood pathways, and secondly that above ground properties have not been removed from the total count. In reality, the most likely flooding events would result in only a partial inundation of the flood plain, however modelling numerous individual breach and overtopping scenarios is outside the scope of this report.

6-3 OVERTOPPING OUTPUT

In order to visualise the results for each defence section they are presented on a chart (Figure 6-3-1) which compares the predicted overtopping rate with the size of the beach cross sectional area (CSA). This shows the decrease in overtopping for each of the return period conditions (1 to 200 years) as the size of the beach increases. For sections where a rock revetment is present, a single overtopping calculation is performed for overtopping over the revetment.

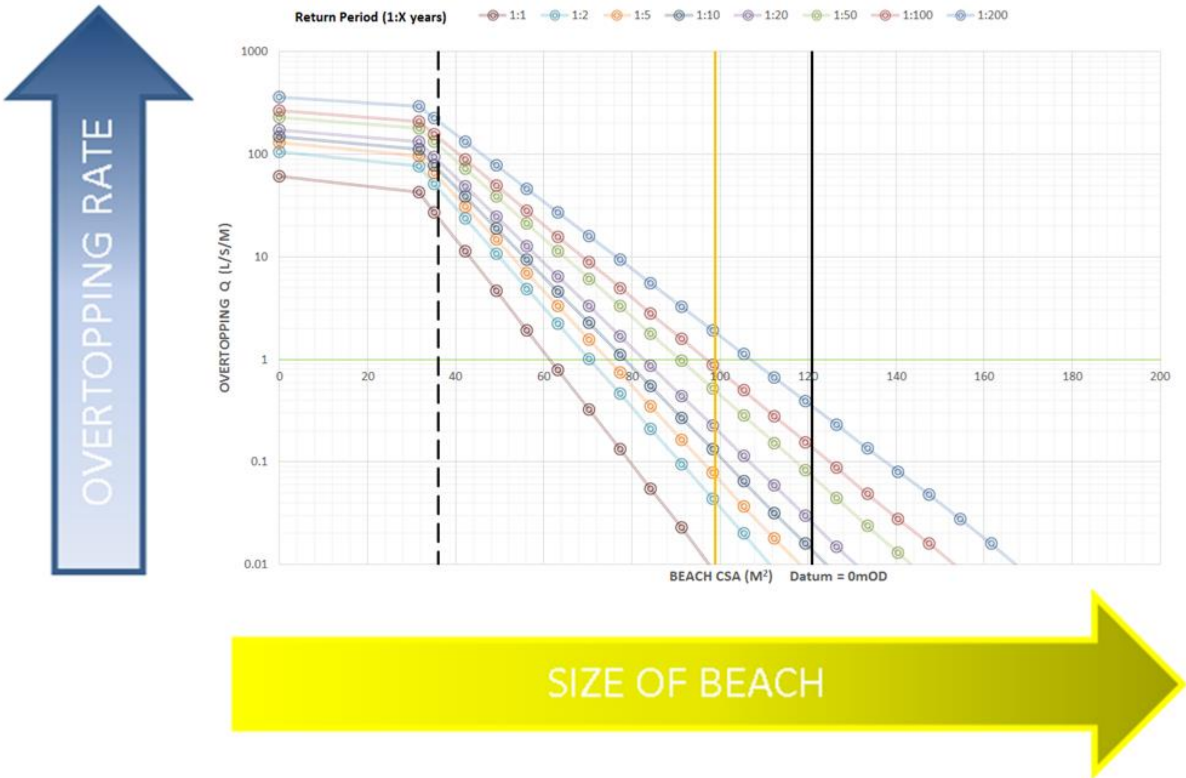


FIGURE 6-3-1 EXAMPLE OF OVERTOPPING RESULTS CHART

From the chart it is possible to read off a predicted overtopping rate for a particular beach size under different conditions. The jump from zero CSA to the next point reflects the fact that CSA is calculated above a datum (normally the beach toe level), but in reality some of that area is composed of foreshore and lower structure geometry, however to aid clarity calculations solely conducted on structures (no beach) are plotted at zero.

Three vertical lines are plotted on the chart to add context to the results.

Dashed black - the lowest CSA values recorded for the smallest beach profile (2003-2015)
Solid black – the highest CSA values recorded for the largest beach profile (2003 – 2015)
Amber line - the current (summer 2015) lowest CSA value recorded for any profile in that defence section.

All three of these lines could represent different profiles within the section. Details for each profile can be found in Chapter 7.

The majority of these frontages have a combination of beach and seawall and the overtopping calculations consider them both; presenting the results according to the actual structural configuration seen on site.

Where the beach is the only forward defence (i.e. no hard structure or rock armour) the calculations are based on the beach only and an additional line is plotted (red dashed), showing the minimum CSA at which the modelled crest height can be maintained at a 1:7 slope. The calculations for cross-sectional areas less than this threshold value are based upon a reduced crest height (Figure 6-3-2). This threshold CSA value is denoted by a dashed red line on the graphs.

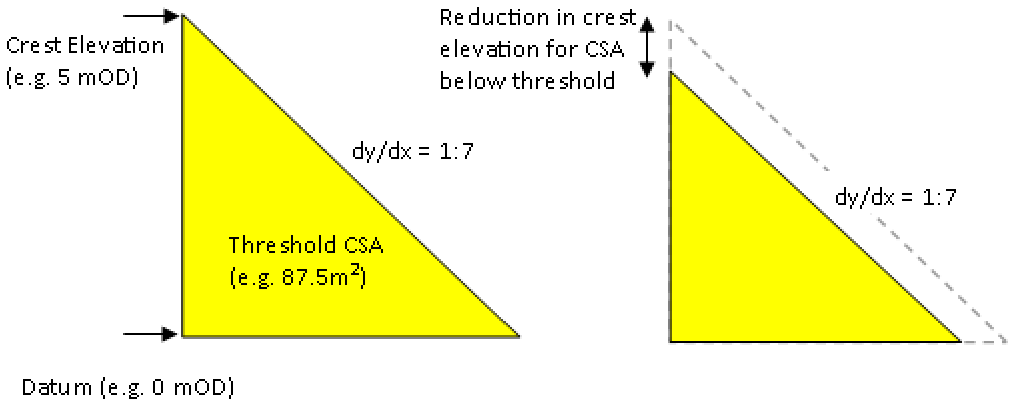


FIGURE 6-3-2 REDUCTION IN CREST HEIGHT FOR PROFILES BELOW A THRESHOLD CSA

Where defence structures have both a front wall and a rear wall results are presented for both components of the defence. The notation is a 2 after the section name for the rear wall, for example Bognor Regis G describes the results for the front wall, and Bognor Regis G2 describes the results for the rear wall. An example results graph is shown in Figure 6-3-3; full results and details of the input conditions are provided for each set of calculations within appendix G. The relationship to the defence standard of protection is shown in Chapter 7.

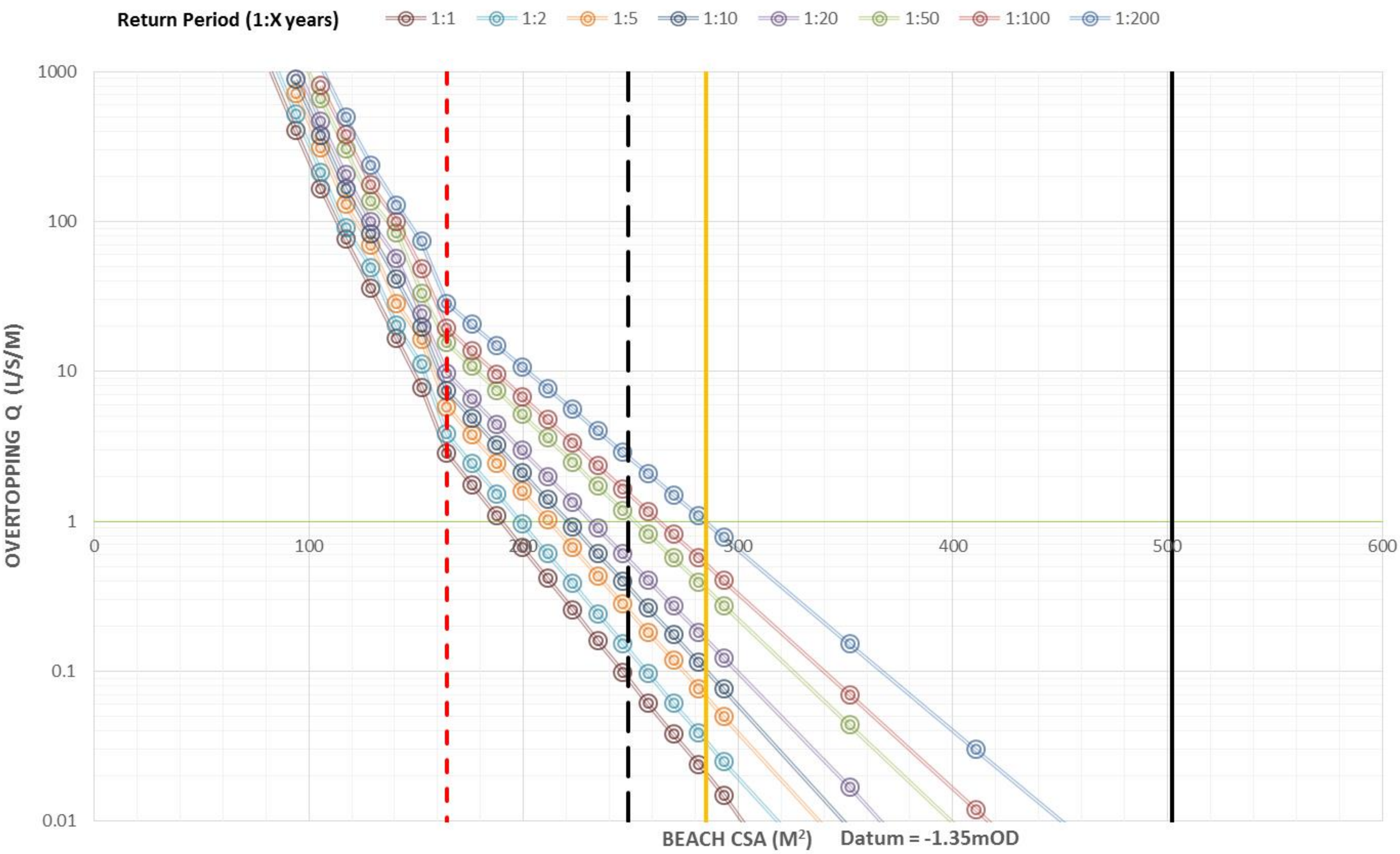


FIGURE 6-3-3 OVERTOPPING RATES EXAMPLE: CLIMPING – SECTION G (BIG BEACH)

Profile Range 4d01116 to 4d01112

Highest CSA of any profile in this section (2003-2015)

Lowest CSA of any profile in this section (2003-2015)

Lowest Current CSA of any profile in this section (Summer 2015)

CSA threshold at which crest width disappears under 1 in 7 slope

CANTERBURY CITY COUNCIL

7 STANDARD OF PROTECTION

7-1 BASELINE CRITERIA

This chapter provides technical analysis and advice on management of shingle beaches. A shingle beach performs two coastal protection functions by breaking waves and absorbing wave energy, in addition to providing a physical barrier;

1. ***Prevention of Flooding:*** Reducing wave overtopping and preventing inundation

2. ***Protection of Coastal Structures:*** Preventing structural undermining and reducing wave impact damage, whilst providing toe weighting and structural support

These two factors are considered in unison in order to calculate the current standard of protection (SoP) and recommended beach levels. Typically the primary failure mechanism is excessive overtopping, flooding and damage to structures close to the beach. In this respect the defence can be considered to have a sub-standard level of protection, in most cases there will have to be a further reduction in beach levels before a breach or seawall failure becomes a significant risk.

Minimum beach levels are calculated by defining a maximum allowable overtopping limit for each section based on the tolerable discharge limits and the overtopping results for a 1:200 year storm (see Appendix G). Maintaining a beach level above this threshold achieves a present day standard of protection of > 1 in 200 years. **A 1 in 200 year SoP has been used throughout this report and all sister reports, throughout the South East, in order to provide consistency in reporting.**

It is not possible to present standard of protection results for every return period, instead for SoPs other than the 1:200 year the required trigger levels can be calculated from the overtopping graphs, calculated for a range of return periods from 1:1 to 1:200 years and these are provided in Appendix G.

A full structural assessment of sea defence structures, and failure probabilities, is outside the scope of this report. It does however consider the risk of structural undermining, based on the structure toe levels of the sea defence schematics (Appendix F). The analysis takes into account beach draw down during a storm in addition to calculating the potential scour depth at the structure. This allows for the calculation of a minimum beach required to prevent undermining. In the event that this is larger than the threshold calculated for overtopping the undermining CSA is used in preference when establishing trigger levels.

It should be noted that although the overtopping limit is based on providing a 1 in 200 year standard of protection, structural damage and undermining can result from relatively minor storms once the beach level has dropped below the critical threshold.

7-2 TRIGGER LEVELS

The naming convention and definition of trigger levels varies significantly between previous beach management plans and other reports. For the purpose of this report three trigger levels are used and described below for clarity. These were designed to help aid interpretation of coastal monitoring data and to inform beach management works.

CRITICAL LEVEL – This is the minimum beach level required to prevent overtopping exceeding tolerable limits in a 1:200 year storm event and/or a significant risk of structural damage or undermining. A Sub-Critical level is also defined which is the equivalent level for a standard of protection of 1:10 (approximately equal to half the CSA of the 1:200 event).

The problem with a critical level from a beach management perspective is that any beach at or just above this level may drop below it during a single storm or in short time under exposure to average conditions. This would require regular intervention and beach works to increase the beach level throughout the year, and even then potentially leave the area with a sub-standard standard of protection during a storm. As such it is unlikely a beach would be maintained at the critical level, but it provides a good reference for when emergency works are required and the urgency.

MAINTENANCE LEVEL – This level is higher than the critical level. The difference in beach cross sectional area is defined by the largest observed annual drop in beach level (since monitoring began in 2003), or where greater the largest loss during a storm event.

If beach levels are maintained above this level then it is highly unlikely that the beach size will reduce to below the critical level within a year or during a storm event. In reality in most years the beach level will only reduce by a fraction of this amount. Having a beach this size gives the coast protection authority time to plan works and be more efficient with little risk of levels dropping below the critical level.

DESIGN LEVEL – This is higher than the maintenance level and takes into consideration the impact of the defence failing (though undermining or significant overtopping), and builds in an appropriate factor of safety. When carrying out works, where possible, the beach size should be increased to this level.

Due to the maintenance level only referencing actual changes in beach size since 2003, there is always the possibility of a larger storm, or series of storms, that would reduce the beach size by more than the maintenance level. The design level accounts for this by adding a factor of safety, this is not a consistent figure for all locations but based on the potential impact of the defence being significantly overtopped or failing. For example a heavily urbanised area with properties below MHW would have a larger safety factor than a defence section protecting farmland. It also follows that erosive beaches have a higher design threshold than stable or accreting sections. This also allows time for remedial action and beach works following a storm event.

However, a larger beach may also be prone to higher rates of longshore transport, in particular in un-groyned sections of the coast.

It is important to note that CSAs within the Design Range (Yellow) and Maintenance Range (Orange) are above the 1:200 standard of protection. These areas give a factor of safety to allow time for coastal managers to intervene before the beach conditions drops below the required level of protection (Figure 7-1).

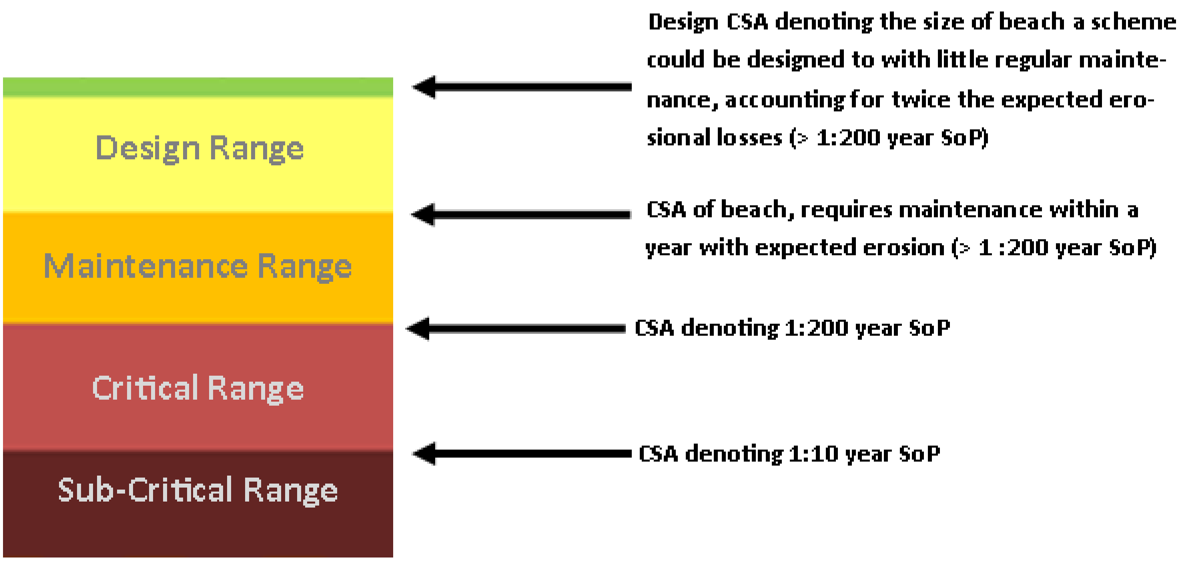


FIGURE 7-1 DESIGN, MAINTENANCE, CRITICAL AND SUB CRITICAL RANGES BASED ON TRIGGER LEVELS

7-3 CURRENT STANDARD OF PROTECTION

Having defined the trigger levels it is possible to ascertain not only the current standard of protection, but also to appraise how the beach has performed historically. Trigger levels are calculated as a beach cross sectional area (CSA) which are plotted for each profile location along the frontage and compared to the surveyed beach CSA through time. Profile locations overlain on aerial photography are provided in appendix D.

In order to condense this information so that the current standard of protection and historical performance can be viewed on a single graph for each management unit it is necessary to summarise the data for each profile as shown in Figure 7-2.

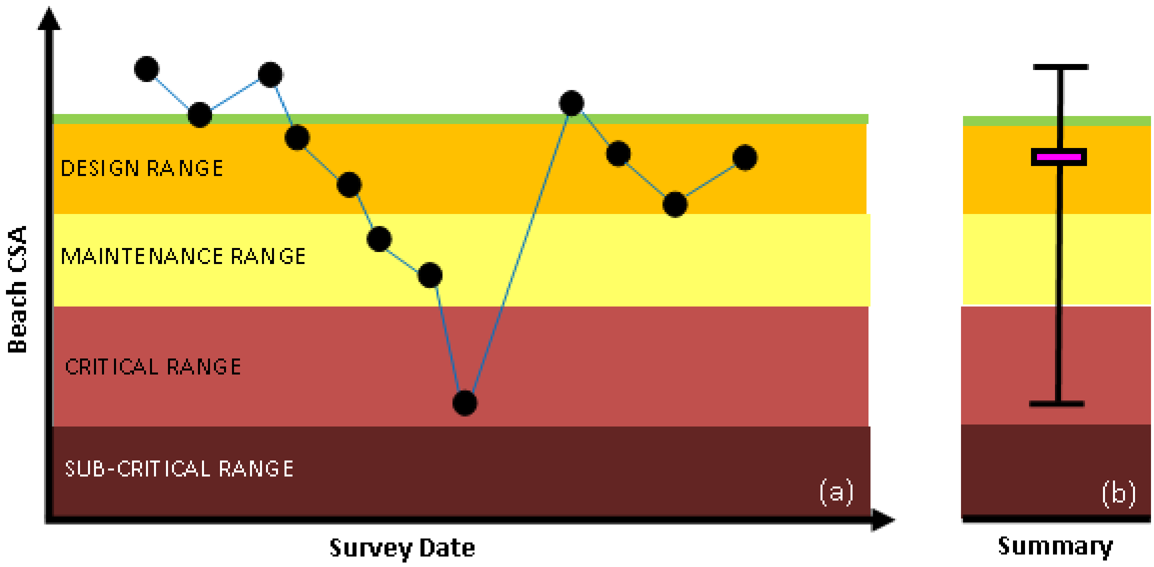


FIGURE 7-2 PRESENTATION OF STANDARD OF PROTECTION AND TRIGGER LEVELS

(a) historic variation of beach levels (csa)

(b) summary of data, pink bar – current beach level, black bars – historic high and low

The following pages provide a graphical summary of the SoP for each management unit alongside key parameters for each defence section including the primary risk, critical cross-sectional area and defence types.

IMPORTANT NOTE:

Standards of protection and trigger levels defined in this report are based on current information and historic data at the time of writing. This report focusses on the 1 in 200 year SoP for consistency but please note it may not be appropriate at all sites to provide this SoP as the required protection could be higher or lower. The chosen SoP should be economically viable and site-appropriate. Coastal managers should be aware that several factors can result in a change to the SoP and/or trigger levels. These include, but are not limited to the following;

- Deterioration of seawall condition leading to an increase in required beach
- Seawall raising or repair reducing beach requirements and trigger levels
- New development behind the sea defence may necessitate a higher standard of protection and larger trigger levels
- Groyne failure can result in higher trigger levels due to increased susceptibility to erosion.
- Introduction of new or larger controlling structures
- Reduction of input sediment to the system due to changes to management practices down drift
- A significant change to the grading characteristics of the beach material
- Drop in foreshore levels allowing larger waves to reach the beach
- Climate change
- A change to the management regime for example from ‘little and often’ to ‘large and infrequent’ or vice versa.

7-3-1 SELSEY BILL (4DSU24)

TABLE 7-3-1 SELSEY BILL INTERPRETATION TABLE: RISK MECHANISM AND CONSEQUENCES

DEFENCE SECTION	OPERATOR	PRIMARY DEFENCE	SECONDARY DEFENCE	KEY RISK MITIGATED BY BEACH	CRITICAL CROSS SECTIONAL AREA (M^2)	ALLOWABLE OT RATE (IF APPLICABLE) L $M^{-1}S^{-1}$	NO. OF PROPERTIES IN FLOOD PLAIN	HINTERLAND
A	CHICHESTER DISTRICT COUNCIL	CONCRETE WALL WITH RETURN	-	OVERTOPPING	68	10	-	HOUSES SETBACK 30-70M
B		BEACH	-	EROSION	142	10	-	HOUSES SETBACK 70M
C		TIMBER CRIB WALL	-	OVERTOPPING	72	10	-	HOUSES SETBACK 15-20M
D		SEAWALL	-	OVERTOPPING	75	10	-	HOUSES SETBACK 60M
E		BEACH	-	EROSION	115	50	-	GREEN SPACE
F		CONCRETE SEAWALL AND APRON WITH RETURN	-	OVERTOPPING	124	1	-	HOUSES BEHIND PROM
G		SEAWALL WITH RETURN	-	OVERTOPPING	90	25	-	HOUSES SETBACK ON LAND SLOPING UPWARDS
H		CONCRETE SEAWALL AND APRON	-	OVERTOPPING	45	25	-	HOUSES SETBACK ON LAND SLOPING UPWARDS
I		CONCRETE SEAWALL WITH RECURVE	CONCRETE REAR WALL WITH RECURVE	OVERTOPPING	59	10	476	HOUSES, SOME SETBACK AND SOME RIGHT BEHIND PROM
J		CONCRETE SEAWALL WITH RECURVE	TIMBER REAR WALL	OVERTOPPING	57	10	-	HOUSES, LAND SLOPES BACKWARDS

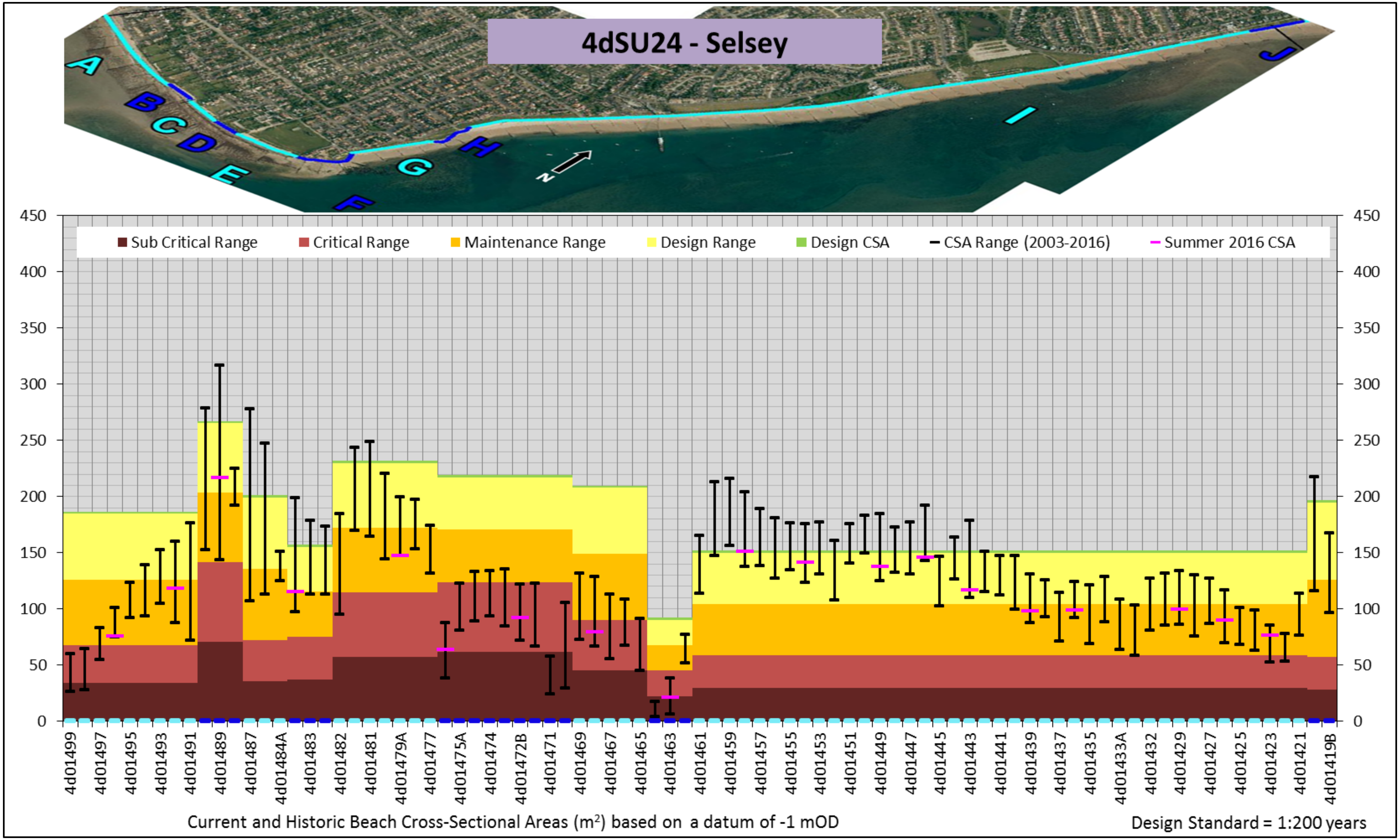


FIGURE 7-3-1 OBSERVED CSA CHANGES IN SELSEY BILL (4DSU24) WITHIN THE CONTEXT OF BEACH TRIGGER LEVELS

7-3-2 PAGHAM HARBOUR (4DSU23)

TABLE 7-3-2 PAGHAM HARBOUR INTERPRETATION TABLE: RISK MECHANISM AND CONSEQUENCES

DEFENCE SECTION	OPERATOR	PRIMARY DEFENCE	SECONDARY DEFENCE	KEY RISK MITIGATED BY BEACH	CRITICAL CROSS SECTIONAL AREA (M^2)	ALLOWABLE OT RATE (IF APPLICABLE) L $M^{-1}S^{-1}$	NO. OF PROPERTIES IN FLOOD PLAIN	HINTERLAND	NOTES
A	CHICHESTER DISTRICT COUNCIL	TIMBER WALL	-	OVERTOPPING	104	10	-	HOUSES SETBACK 20M, LAND SLOPING BACKWARDS	
B		BEACH	-	EROSION	185	10	-	HOUSES SETBACK 20M, LAND SLOPING BACKWARDS	
C		TIMBER WALL	-	OVERTOPPING	67	50	-	GREEN SPACE/SETBACK AGRICULTURAL LAND	
D	ENVIRONMENT AGENCY	BEACH	-	EROSION	135	50	440 (SHARED FLOODPLAIN WITH PAGHAM TO ALDWICK)	GREEN SPACE/AGRICULTURAL LAND/HARBOUR	PAGHAM HARBOUR SPIT

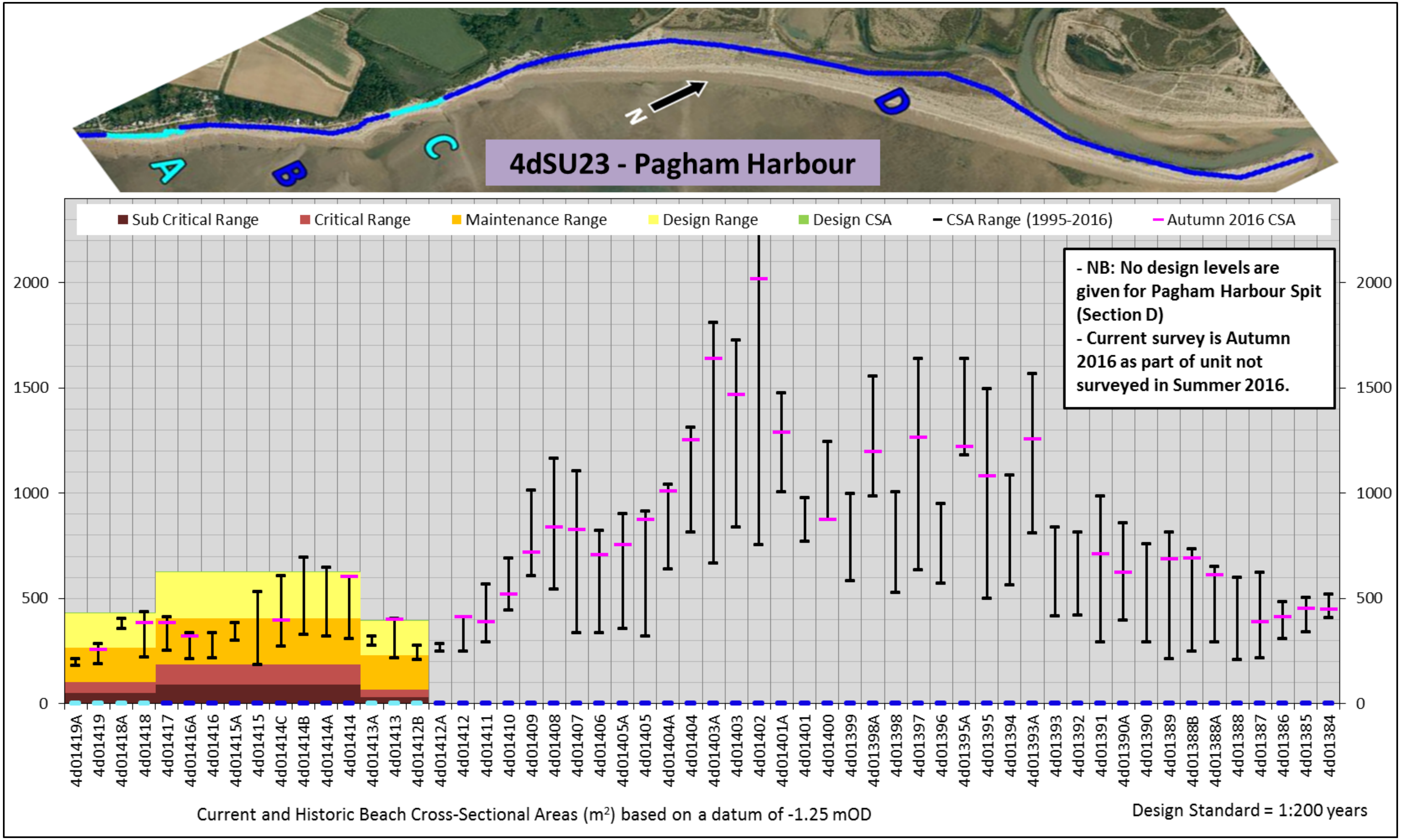


FIGURE 7-3-2 OBSERVED CSA CHANGES IN PAGHAM HARBOUR (4DSU23) WITHIN THE CONTEXT OF BEACH TRIGGER LEVELS

7-3-3 PAGHAM TO ALDWICK (4DSU22)

TABLE 7-3-3 PAGHAM TO ALWICK INTERPRETATION TABLE: RISK MECHANISM AND CONSEQUENCES

DEFENCE SECTION	OPERATOR	PRIMARY DEFENCE	SECONDARY DEFENCE	KEY RISK MITIGATED BY BEACH	CRITICAL CROSS SECTIONAL AREA (M^2)	ALLOWABLE OT RATE (IF APPLICABLE) L $M^{-1}S^{-1}$	NO. OF PROPERTIES IN FLOOD PLAIN	HINTERLAND	NOTES
A	ARUN DISTRICT COUNCIL/ PRIVATE	BEACH	-	EROSION	165	10	440 (SHARED FLOODPLAIN WITH PAGHAM HARBOUR)	HOUSES SETBACK 10-30M, FLAT LAND	
B	ARUN DISTRICT COUNCIL	SEAWALL WITH BRICK/STONE WALL ON TOP	-	OVERTOPPING	79	10	-	HOUSES SETBACK 20-30M, FLAT LAND	
C		CONCRETE SEA WALL	TIMBER CRIB WALL	OVERTOPPING	85	10	-	HOUSES SETBACK 20-30M, FLAT LAND	

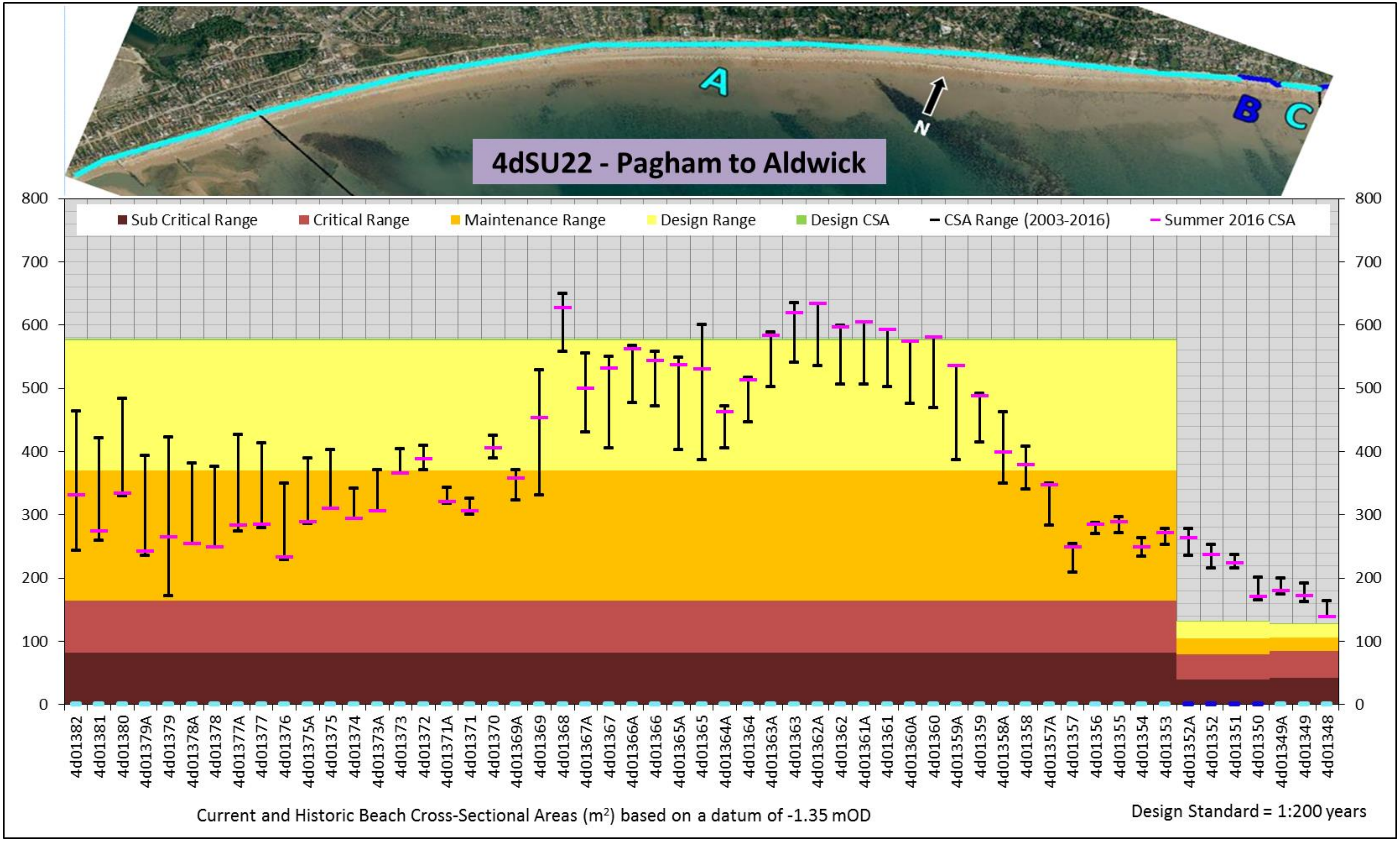


FIGURE 7-3-3 OBSERVED CSA CHANGES IN PAGHAM TO ALDWICK (4DSU22) WITHIN THE CONTEXT OF BEACH TRIGGER LEVELS

7-3-4 BOGNOR REGIS (4DSU21)

TABLE 7-3-4 BOGNOR- REGIS INTERPRETATION TABLE: RISK MECHANISM AND CONSEQUENCES

DEFENCE SECTION	OPERATOR	PRIMARY DEFENCE	SECONDARY DEFENCE	KEY RISK MITIGATED BY BEACH	CRITICAL CROSS SECTIONAL AREA (M^2)	ALLOWABLE OT RATE (IF APPLICABLE) $L\ M^{-1}S^{-1}$	NO. OF PROPERTIES IN FLOOD PLAIN	HINTERLAND
A	ARUN DISTRICT COUNCIL	SEAWALL WITH RECURVE	-	OVERTOPPING	152	1	-	PROPERTIES DIRECTLY BEHIND PROM
B		SEAWALL	-	OVERTOPPING	76	10	-	PROPERTIES SETBACK 30-50M
C		PROMENADE ON SEAWALL	-	EROSION	110	10	-	BEACH HUTS ON BEACH, PROMENADE THEN ROAD BEHIND
D		CONCRETE SEAWALL (MOSTLY BURIED)	-	OVERTOPPING	41	10	-	PROMENADE THEN ROAD
E		CONCRETE SEAWALL WITH RECURVE	-	OVERTOPPING	44	10	-	PROMENADE THEN ROAD
F		CONCRETE SEAWALL (MOSTLY BURIED)	-	OVERTOPPING	114	10	-	PROMENADE THEN ROAD
G		CONCRETE SEAWALL WITH RECURVE	-	OVERTOPPING	42	10	-	PROMENADE THEN ROAD. BUILDINGS ON PROM
H	ENVIRONMENT AGENCY	CONCRETE SEAWALL WITH RECURVE	-	OVERTOPPING	38	10	5,034 (SHARED WITH ELMER)	CARPARK THEN FLOOD BASIN/FLOOD BASIN BEHIND WALL
I	ARUN DISTRICT COUNCIL	CONCRETE SEAWALL	-	OVERTOPPING	69	10	-	SETBACK BEACH HUTS/AMENITY
J		CONCRETE SEAWALL WITH –RECURVE	-	OVERTOPPING	66	10	-	HOUSES BEHIND PROMENADE
J		CONCRETE SEAWALL WITH RECURVE	-	OVERTOPPING	69	10	-	HOUSES BEHIND PROMENADE
L		PARTIALLY BURIED SEAWALL	-	OVERTOPPING	127	10	-	HOUSES SETBACK FROM BEACH
M		BURIED TIMBER BREASTWORK	-	EROSION	180	10	-	HOUSES SETBACK 30-60M

		WALL/BEACH						
N		TIMBER WALL WITH SOME ROCK ARMOUR (BUT NOT A REVETMENT)	-	OVERTOPPING	117	10	-	HOUSES SETBACK 30-60M
O		CONCRETE SEAWALL WITH RECURVE	-	OVERTOPPING	116	10	-	HOUSES SETBACK 30-60M
P		CONCRETE SEAWALL WITH RECURVE	-	OVERTOPPING	90	10	-	HOUSES BEHIND BEACH, SETBACK 30M

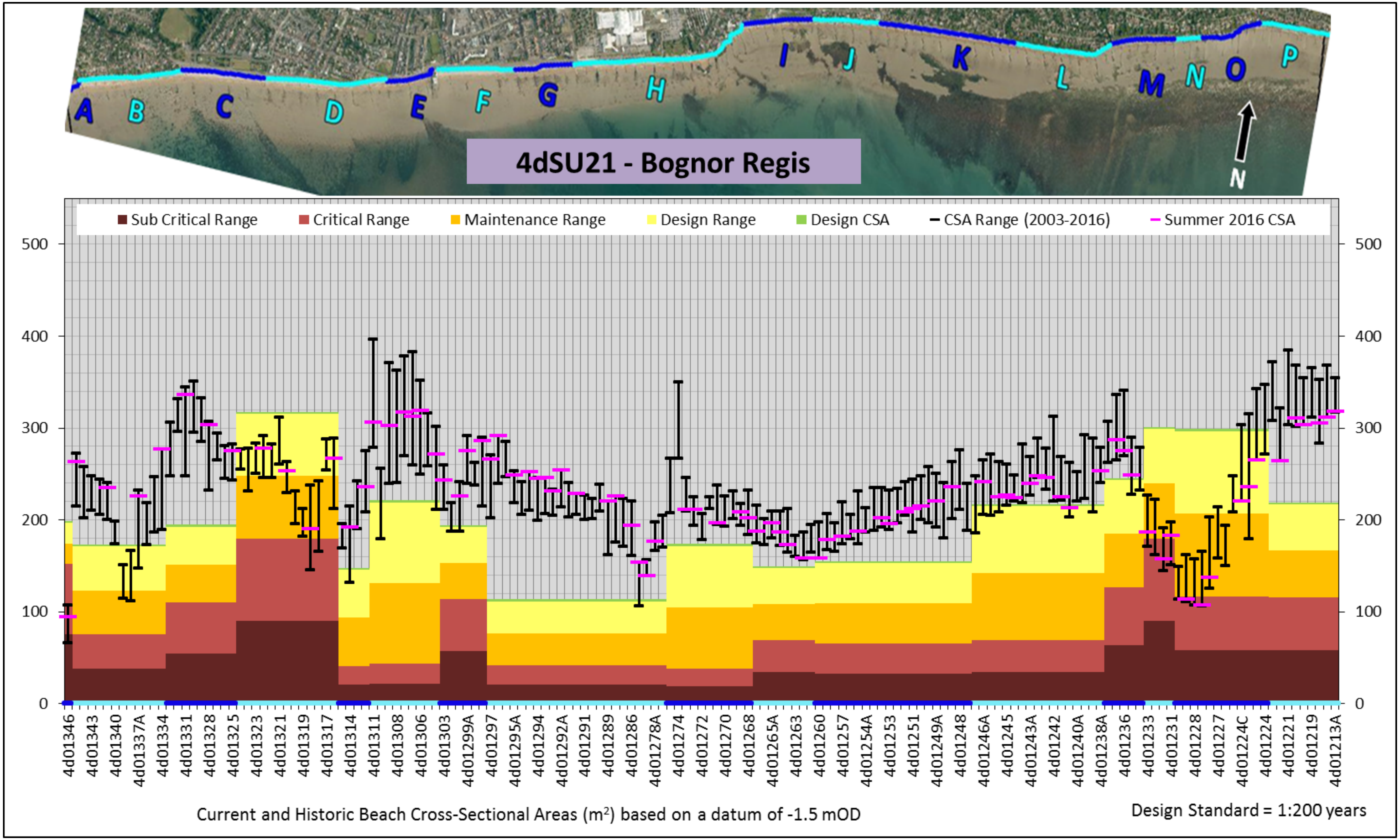


FIGURE 7-3-4 OBSERVED CSA CHANGES IN BOGNOR REGIS (4DSU21) WITHIN THE CONTEXT OF BEACH TRIGGER LEVELS

7-3-5 Elmer (4DSU20)

Table 7-3-5 Elmer Interpretation Table: Risk mechanism and consequences

Defence Section	Operator	Primary Defence	Secondary Defence	Key Risk Mitigated by Beach	Critical Cross Sectional Area (m^2)	Allowable OT Rate (if applicable) $l\ m^{-1}s^{-1}$	No. of Properties in Flood Plain	Hinterland	Notes
A	Arun District Council	Beach	-	Overtopping	240	10	-	Houses setback behind beach	Offshore breakwaters in unit so overtopping results and hence trigger levels considered very conservative
B	Environment Agency	Concrete seawall with R	-	Overtopping	113	10	(5,034 shared with Bognor Regis)	Houses setback behind beach	
C		Rock revetment	-	Structure Failure	Revetment sufficient for OT	10		Houses setback behind beach, floodplain	
D		Beach	-	Erosion	190	10		Green space and agriculture, floodplain	

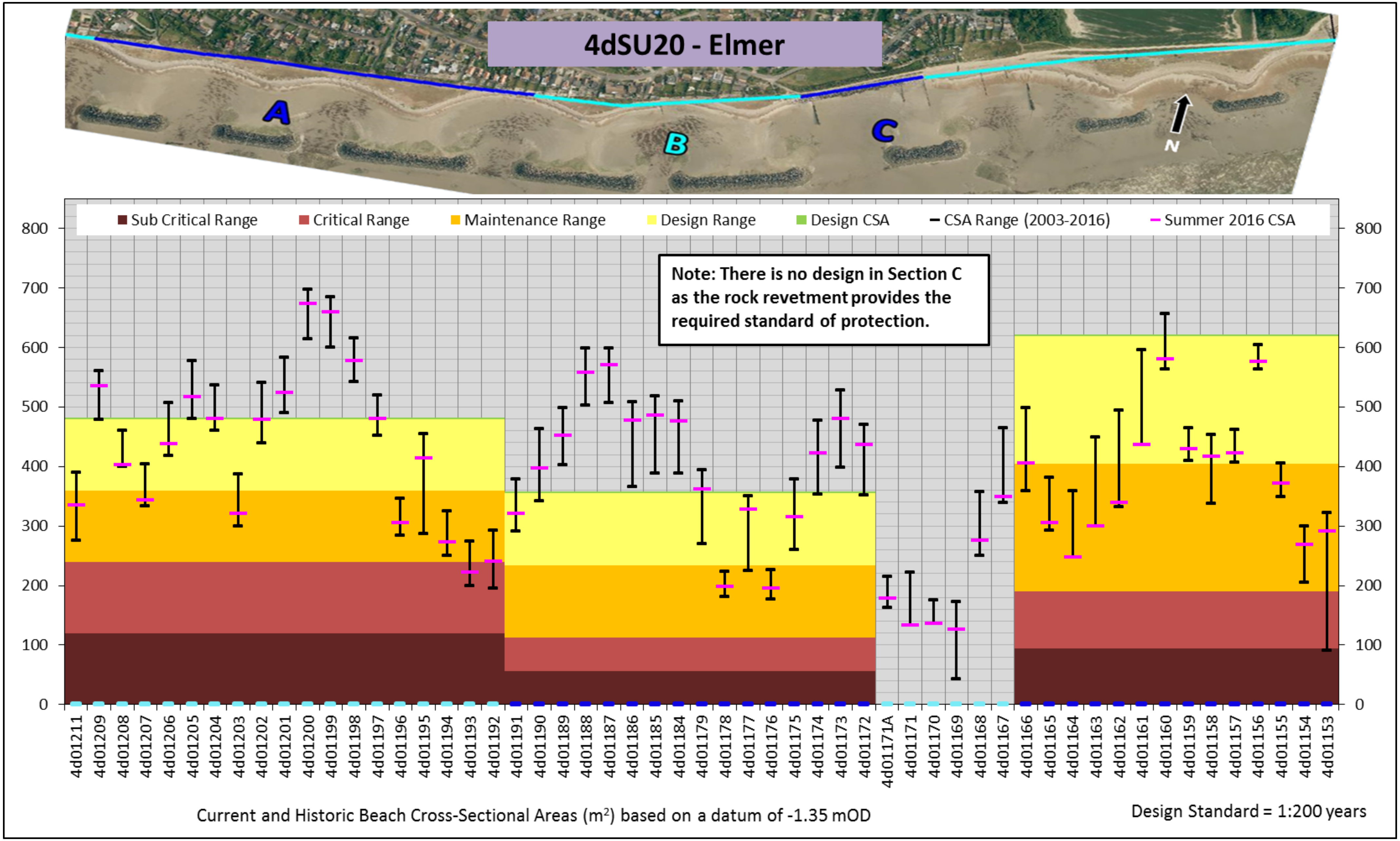


FIGURE 7-3-5 OBSERVED CSA CHANGES IN ELMER (4DSU20) WITHIN THE CONTEXT OF BEACH TRIGGER LEVELS

7-3-6 CLIMPING (4DSU19)

TABLE 7-3-6 CLIMPING INTERPRETATION TABLE: RISK MECHANISM AND CONSEQUENCES

DEFENCE SECTION	OPERATOR	PRIMARY DEFENCE	SECONDARY DEFENCE	KEY RISK MITIGATED BY BEACH	CRITICAL CROSS SECTIONAL AREA (M^2)	ALLOWABLE OT RATE (IF APPLICABLE) L $M^{-1}S^{-1}$	NO. OF PROPERTIES IN FLOOD PLAIN	HINTERLAND
A	ENVIRONMENT AGENCY	CONCRETE BLOCKS (POOR CONDITION)	-	OVERTOPPING	253	0.01	-	FARMLAND (LEGAL FRONTAGE)
B		BEACH	-	OVERTOPPING	445 (285 IF OT LIMIT IS 1)	0.01	-	FARMLAND (LEGAL FRONTAGE)
C		CONCRETE WALL (WITH GAPS)	-	EROSION	120	10	-	PARKLAND
D		CONCRETE WWII WALL AND TIMBER WALL	-	OVERTOPPING	111	10	405	PARKLAND/CARPARK
E		BEACH	-	EROSION	200	10		FARMLAND
F		FAILED SEAWALL	-	OVERTOPPING	185	10		FARMLAND
G		BEACH	-	EROSION	200	10		FARMLAND
H		CONCRETE WALL (UNKNOWN CONDITION)	-	OVERTOPPING	113	10		FARMLAND
I		BEACH	-	EROSION	200	25		SAND DUNES

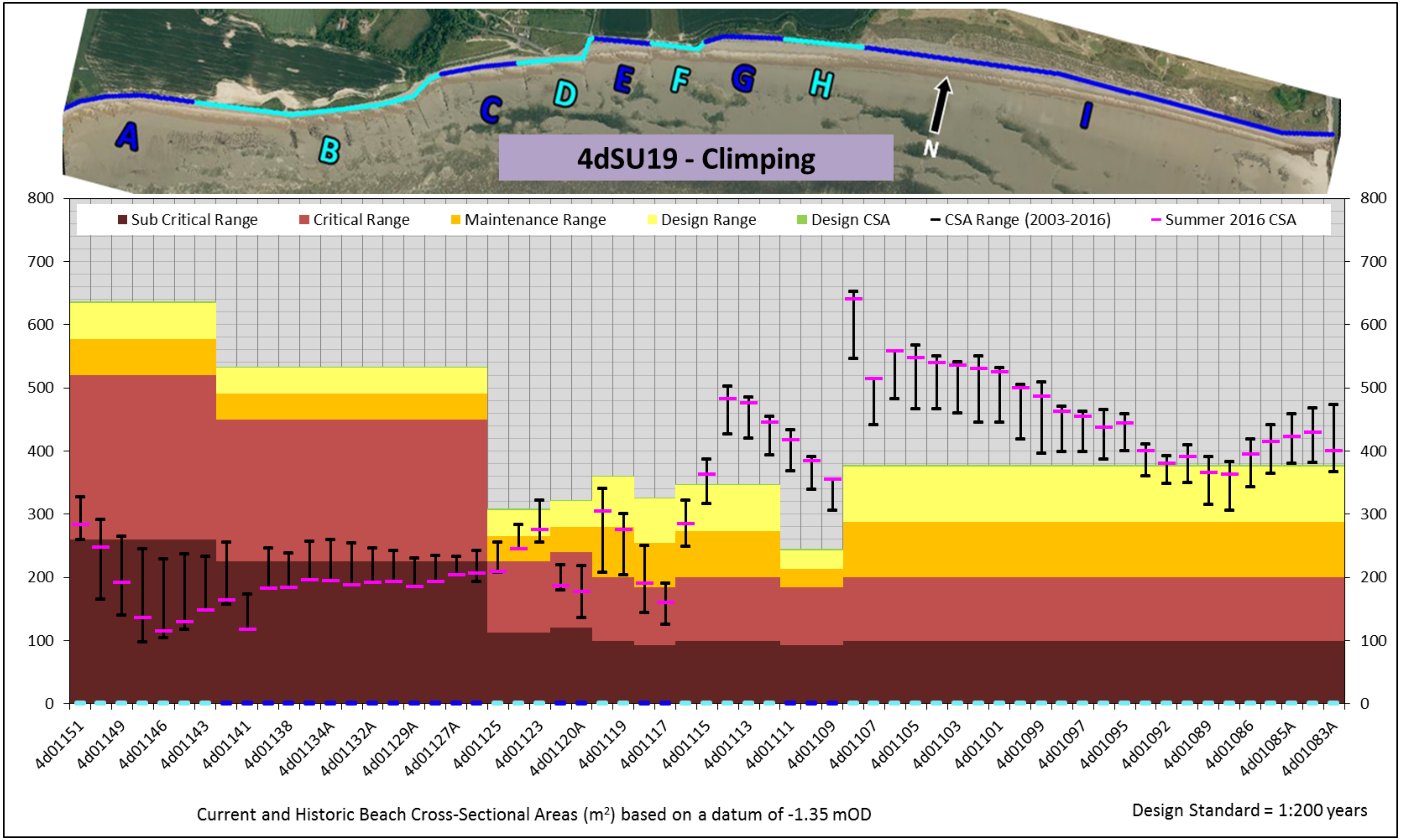


FIGURE 7-3-6 OBSERVED CSA CHANGES IN CLIMPING (4DSU19) WITHIN THE CONTEXT OF BEACH TRIGGER LEVELS

GLOSSARY

Accretion The addition of sediment vertically or horizontally due to the natural action of waves, currents and wind.

Accumulation Any addition of sediment, either natural (accretion) or man-made.

Alluvium A deposit resulting from the action and products of rivers or streams.

Apron A layer of stone, concrete or other material to protect the toe of the sea wall against scour.

Armour Resistant rocks or specially shaped concrete blocks of a specific size, geometry and weight which are placed as primary protection against wave action on the seaward side of other structures (see revetment).

Asset This refers to something of value and may be environmental, economic, social, recreational and so on.

Backshore A morphological term for the area of beach that lies between high water and the landward limit of marine (storm wave) activity.

Backwash The seaward return of the water following the up-rush (swash) of the waves. For any given tide stage the point of farthest return seaward of the backwash is known as the Limit of backwash. Depending on the permeability of the beach the water volume in the backwash is smaller than in the swash.

Bar An elongated deposit of sand, shingle or silt, occurring slightly offshore from the beach and submerged at high tide. The bar may be parallel to the beach or connected and at an angle.

Barrier Beach A sand or shingle bar above high tide with low lying land or a lagoon on the landward side.

Bathymetry Topography of the sea floor usually below low water.

Beach The zone of non-cohesive material (e.g. sand, gravel) that lies between the mean low water line and the place where there is a marked change in material or physiographic form, or to the line of permanent vegetation (the effective limit of storm waves and storm surge). The beach or shore can be divided into the foreshore and the backshore.

Beach crest width The horizontal distance of the crest measured from the seaward edge of the promenade (or other determined point, see beach) to the point where the beach slope angle drops down towards the sea. This usually assumes a uniform crest level but can also include a gentle slope. A better term is 'beach width at xmOD'.

Beach face Upper surface of the beach.

Beach Profile Cross-section (side view) of the beach perpendicular to the shoreline. The profile extends from a point landwards of the backshore to low water or beyond.

Beach recharge This is the management practice of adding new beach sediment (such as sand or gravel) to a beach using material from outside the sediment cell (for example offshore dredging sites or inland quarries). This is also known as beach replenishment or beach (re)nourishment.

Beach recycling The movement of sediment along a beach, typically from areas of accretion to areas of erosion.

Beach re-profiling The shaping of the beach profile to achieve a desired crest height, width or slope, typically using bulldozers or other plant.

Berm A constructive ridge located along the higher part of a beach, above high water as a result of cross shore transport moving sediment towards the swash limit. It is marked by a break of slope at the seaward edge. There are usually a sequence of berms present with storm berms located in the back beach area.

BMP Beach Management Plan. It provides a basis for the management of a beach for coastal defence purposes, taking into account coastal processes and the other uses of the beach.

Brackish water Freshwater mixed with seawater.

Breach Failure of a barrier beach or coastal protection structure allowing flooding through tidal water exchange for at least half of the tidal cycle, i.e. the level of the breach is at or below 0mOD.

Breaching Process of removing or lowering a beach or structure to form a breach.

Breaker zone Area in the sea where the waves break.

Breakwater A protective structure of stone or concrete used to break the force of waves, reducing wave energy and hence enhancing protection to the shore.

CCO Channel Coastal Observatory. Based at the National Oceanography Centre in Southampton, responsible for the distribution of data collected under the six Regional Coastal Monitoring Programmes.

CD Chart Datum – an arbitrary local datum or plane to which depths or heights are referred. (Also see OD).

Cliffing Cliffing on beaches refers to the development of seaward slopes in beach material that are at the angle of repose (Depending on the beach material properties [grain size composition, moisture, compaction, cementation] the angle of repose can vary between ~35 and 90 degrees.), usually with a sharp break of slope to the beach below developing near the wave run-up limit.

Climate Change Long term changes in climate. The impact of climate change along the coast is usually associated with changes in sea level and wave climate.

Coastal defence General term used to encompass both coast protection against erosion and sea defence against flooding.

Coastal processes Collective term covering the action of natural forces on the shoreline and nearshore seabed.

Coastline The generalised shape, outline, or boundary of a coast, which marks the area between the seaward limit of terrestrial influence and the landward limit of marine influence.

Consequence An outcome or impact such as economic, social or environmental impact. It may be expressed quantitatively (e.g. monetary value), categorically (e.g. high, medium, low) or descriptively.

Crest Highest part in cross section of a beach or structure (e.g. breakwater or sea wall)

Crest level The height of the crest (usually the highest point), generally in mOD.

Deep water Area where surface waves are not influenced by the sea-bed, i.e. where water depth exceeds half the wavelength.

Defence Manmade structure (e.g. sea wall, embankment, recharged beach) or natural feature (e.g. beach, dune) that prevents seawater from reaching the hinterland under varying conditions.

DEFRA Department for Environment, Food and Rural Affairs, formerly the Ministry of Agriculture, Fisheries and Food (MAFF).

Delta Sediment body, which is formed where a sediment-laden current enters an open body of water, and deposits its sediment load as a result of a reduction in velocity of the current.

Depth limited (waves) Situation in which wave propagation is limited by water depth.

Downdrift Direction of longshore movement of beach materials.

Dredging Excavation, digging, scraping, drag lining, suction dredging to remove sand, silt, rock or other underwater sea-bed material.

Drift reversal A switch of an indigenous direction of littoral transport.

Drift-aligned A coastline that is orientated obliquely to prevailing incident wave fronts. The coast is characterised by strong longshore transport.

Dune A landform produced by the action of wind on unconsolidated material, normally sand, to produce ridges or mounds of loose sediment.

Dynamic equilibrium A state of balance between environmental conditions acting on a landscape and the resisting earth material which themselves fluctuate around an average that is itself gradually changing.

Ebb tidal delta Material which has formed at the seaward mouth of tidal inlets as a result of interaction between tidal currents and waves.

Embankment A linear mound of earth that stretches some distance along the coast that protects the hinterland behind from flooding.

Environment Agency (EA) UK non-departmental government body responsible for delivering integrated environmental management including flood defence, water resources, water quality and pollution control. It has the strategic overview of all flood and coastal erosion risk management.

Environmental Impact Assessment (EIA) Environmental Impact Assessment. Detailed studies that predict the effects of a development project on the environment. They also provide plans for mitigation of any significant adverse impacts.

Erosion The removal of any material (clay, rock, soil, sand, gravel) by such agents as running water, waves, wind, moving ice and gravitational creep or falls from its original location. The landward retreat of a shoreline due to these processes.

Estuary Mouth of a river, where fresh river water mixes with the seawater.

Flint Micro-crystalline nodules or bands of silica found in the chalk. It is dark grey or black when recently released from the chalk or brownish in colour when it has been removed from the chalk for tens of thousands of years.

Flooding Refers to inundation by water of land whether this is caused by breaches, overtopping of banks or defences, or by inadequate or slow drainage of rainfall or underlying ground water levels due to tide locking of the coastal outfall structures.

Foreshore A morphological term for the lower shore zone/area on the beach that lies between mean low and high water.

Geographic Information System (GIS) Software which allows the spatial display and interrogation of geographic information such as ordnance survey mapping and aerial photography.

Groundwater The zone in a soil or rock that is saturated with water, mostly derived from surface sources.

Groyne A structure, which is generally built approximately perpendicular to the shoreline in order to control the movement of beach material and reduce longshore currents and/or to trap and retain beach material. Most groynes are made of timber, rock or concrete and extend from a sea wall or the backshore wall onto the foreshore and rarely even further offshore. They can also take the form of T-shaped groynes, fish-tail and terminal groynes. Other structures perpendicular to the coastline (e.g. outfalls, ramps) can function as a groyne.

Groyne bay The bay between two groynes.

Groyne field Series of groynes acting together to protect a section of beach.

Hazard A situation with the potential to result in harm. A hazard does not necessarily lead to harm.

Hinterland The land directly adjacent to and inland from a coast, extending landward from the upper limit of extreme wave and tidal energy.

Hold the Line (HTL) Shoreline Management Plan policy to hold the existing defence line by maintaining or changing the standard of protection. This policy should cover those situations where work or operations are carried out in front of the existing defences (such as beach recharge (see the glossary), rebuilding the toe of a structure, building offshore breakwaters and so on) to improve or maintain the standard of protection provided by the existing defence line.

H_s See significant wave height.

Hydrodynamic The process and science associated with the flow and motion in water.

Intertidal areas The area between mean high water level and mean low water level in a coastal region.

Inundation An overflow of water or an expanse of water submerging land.

Joint Probability The probability of two (or more) variables occurring together.

Joint Return Period Average period of time between occurrences of a given joint probability event.

Land Reclamation Process of creating new, dry land on the seabed.

Landslides The large-scale mass movement of sub-aerial material down-slope, or its vertical movement down a cliff face.

Longshore drift/ transport Transport of sediment along the shore by the combined effect of swash and backwash set up by wave driven currents. Currents produced in the surf zone are caused by waves breaking at an angle and the current running roughly parallel with the shore. (Also see drift-aligned, drift convergence, drift divergence, drift reversal).

Long term Refers to a time period of decades to centuries.

Managed Realignment (MR) Shoreline Management Plan policy to realign the shoreline by allowing the shoreline to move backwards or forwards, with management to control or limit movement (such as reducing erosion or building new defences on the landward side of the original defences).

Mean Low Water (MLW) The average of all low waters observed over a sufficiently long period.

Mean High Water (MHW) The average of all high waters observed over a sufficiently long period.

Mean Low Water Spring (MLWN) The lowest level to which neap tides retreat on average over a period of time (often 19 years).

Mean Low Water Spring (MLWS) The lowest level to which spring tides retreat on average over a period of time (often 19 years).

Mean Sea Level Average height of the sea surface.

(MSL)

Medium term Refers to a time period of decades.

Met Office UK Meteorological Office.

Metres Ordnance Datum (±mOD) Elevation in metres above or below Ordnance Datum.

Natural Processes Those processes over which people have no significant control (such as wind and waves).

Nearshore The zone, which extends from the swash zone to the position marking the start of the offshore zone, typically at water depths of the order of 20m.

No Active Intervention (NAI) Shoreline Management Plan policy where there is no investment in coastal defences or operations. This assumes that existing defences are no longer maintained and will fail over time or undefended frontages will be allowed to evolve naturally.

Offshore The zone beyond the nearshore zone where sediment motion induced by waves alone effectively ceases and where the influence of the seabed on wave action is small in comparison with the effect of wind.

Offshore Bank A large scale unconsolidated body of soft sediment, such as sand, gravel and mud which can form topographic highs on the seabed. They are located in the offshore zone and are permanently covered by shallow sea water, typically at depths of less than 20 m below chart datum.

Operating Authority A body with statutory powers to undertake flood defence or coast protection activities, usually the Environment Agency or maritime District Council.

Ordnance Datum (Newlyn) A universal zero point/datum used in the UK, equal to the mean sea level at Newlyn in Cornwall.

Overtopping Water carried over the top of a coastal defence due to wave run-up or still water level exceeding the crest height. See 'green water', 'white water' and 'overwashing'.

Overwashing Overtopping that leads to water and sediment transported landward which does not return back to the sea following the event.

Percolation The process by which water flows through the interstices of sediment. Specifically, the infiltration of water during swash into the unsaturated beach material which reduces wave run-up on the beach but which can also lead to water seepage at the landward side, potentially causing instability of the landward slope or a barrier.

Pile Long heavy section of timber, concrete or metal, driven into the ground or seabed as support for another structure. Especially around/or at the toe of a shore protection structure.

Recession Movement of the shoreline to landward.

Reef A ridge of rock or other material lying just beneath the surface of the sea.

Regression A fall in sea-level resulting in withdraw of the sea from the land.

Relict Geomorphological feature formed or sediment deposited under past processes and climatic regimes.

Return Period A statistical measure denoting the average probability of occurrence of a given event over time.

Revetment A sloping surface of armour used to protect an embankment, sea wall or natural shoreline against erosion.

Rock platform Gently seaward sloping, intertidal bench cut into the land mass by the action of waves and also known as a wave-cut platform.

Roll back The gradual net landward migration of the coastline, includes rollover of a subaerial sediment barrier, mainly shingle and gravel.

Saltmarsh An area of soft, wet land periodically flooded by saline water. Usually characterised by grasses and other low vegetation. Also known as a salting.

Scour Permanent or temporary erosion of underwater material by waves or currents, especially at the interface between sediment and a structure.

Sea wall A shoreline structure primarily designed to prevent flooding, erosion and other damage due to wave action. Structure types include solid, near vertical steel of concrete structures of different profiles. A stronger deviation from the vertical indicates a 'revetment'.

Sediment Particles of rock covering a size range from clay to boulders.

Sediment cell A length of coastline and its associated near shore area within which the movement of coarse sediment (sand and shingle) is largely self-contained. Interruptions to the movement of sand and shingle within one cell should not affect beaches in an adjacent sediment cell.

Sediment sub-cell A smaller part of a sediment cell within which the movement of coarse sediment (sand and shingle) is relatively self-contained.

Sediment supply The source of sediment.

Sediment transport The movement of a mass of sedimentary material by the forces of currents, waves or wind.

Setback Prescribed distance landward of a coastal feature (e.g. the line of existing defences).

Shingle Gravel-sized beach material, normally well rounded as a result of abrasion.

Shoreline A boundary line between land and water.

Shoreline Management Plan (SMP) A non-statutory plan, which provides a large-scale assessment of the risks associated with coastal processes and presents a policy framework to reduce these risks to people and the developed, historic and natural environment in a sustainable manner. The first SMP (SMP1) was completed for the Isle of Wight in 1997. The SMP is periodically reviewed. The second SMP (SMP2) is being competed in 2010.

Short term Refers to a time period of months to years.

Significant wave Height (Hs) The average height of the highest of one third of the waves in a given sea state.

Sink Area at which beach material is irretrievably lost from a coastal cell, such as an estuary, a deep channel in the seabed or dunes inland.

Spit An elongated accumulation of sand or gravel, which projects into the sea or across a tidal inlet. Longshore drift of material is usually responsible for the development of a spit.

Standard of Protection (SoP) The level of return period event which the defence is expected to withstand without experiencing significant failure.

Still Water Level (SWL) Average water surface elevation at any instant, excluding local variation due to waves and wave set-up, but including the effects of tides and surges.

Storm Surge A rise in water level in the open coast due to the action of wind stress as well as a change in atmospheric pressure on the sea surface. A surge typically has a duration of a few hours. See 'surge'

Subtidal Part of the coast that is permanently below water.

Surge Changes in water level as a result of meteorological forcing (wind, high or low barometric pressure) causing a difference between the recorded water level and that predicted using harmonic analysis, may be positive or negative.

Suspended Sediment A mode of sediment transport in which the particles are supported, and carried along by the fluid. See 'bedload transport'.

Swell Waves Remotely generated wind-waves (i.e. Waves that are generated away from the site). Swell characteristically exhibits a more regular and longer period and has longer crests than locally generated waves.

Tidal range Difference in height between high and low water levels at a point.

Tide Periodic rising and falling of large bodies of water resulting from the gravitational attraction of primarily the moon and sun acting on the rotating earth.

Toe level The level of the lowest part of a structure, generally forming the transition to the underlying ground.

Tombolo An accumulation of sediment from the shore to an offshore island, formed by the deposition of material when waves are refracted and diffracted around the island. In a tidal environment a tombolo may exists at all states of the tide or only during lower states leaving a 'salient' at high tide.

Topography Configuration of a surface including its relief and the position of its natural and man-made features.

Transgression The landward movement of the shoreline in response to a rise in relative sea level.

Trigger Levels A set of criteria that trigger an intervention. The intervention can range from increased monitoring to preparation of interventions to an intervention. There is a sequence of Trigger Levels with an increasing level of action and associated costs.

Undermining Erosion at the base, e.g. of a sea wall, so that the feature above becomes unstable and is vulnerable to collapse. Usually the consequence of 'scour'.

Updrift Direction opposite to the predominant movement of longshore transport.

Wave Climate The seasonable or annual distribution of wave height, period and direction measured over a longer period of time.

Wave Direction Direction from which a wave approaches.

Wave Height The vertical distance between the crest and the trough.

Wave Hindcast The retrospective forecasting of waves using measured wind information.

Wave Period The time it takes for two successive crests (or troughs) to pass a given point.

Wave Return Wall A sea wall whose seaward face is designed to reflect wave energy.

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