Swanage North Beach Cliffs

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Site Inspection Report

Purbeck District Council

24 May 2013

A CH2M HILL COMPANY

Halcrow

Swanage North Beach Cliffs

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Document history

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Purbeck District Council

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1 Background and terms of reference

With the support of the Environment Agency, Purbeck District Council is seeking emergency funding to carry out minor works at North Beach, Swanage, to make good damage sustained during the extreme wet winter of 2012/13. The area affected is between Ocean Bay and Shep's Hollow by the most northerly groyne.

The works are needed to make repairs to coastal defences and clear cliff fall and landslip debris that has over-whelmed the promenade, splash wall and upper beach along a 120m length of shoreline; and to reinstate safe access along the promenade and beach where this has been cut off by slipped material, particularly at high tide. Several other locations along the North Beach cliffs have been adversely affected by cliff falls and landslides that pose a significant risk to privately owned beach huts located on the cliffs, and the public and promenade beneath.

The Council approached Halcrow on 17th April 2013 requesting advice on the scale of damage, recommended emergency works, and risk assessment of cliff falls and landslip. The aim is to inform the North Beach community where there are significant risks of future cliff falls and landslides. The scope of this report is as follows:

- Carry out a site inspection survey of the recent cliff instability damage and residual risk
- Identify emergency works to improve the short term stability /safety of the cliffs
- Identify emergency works to improve safe access along the promenade / beach
- Identify when it would be safe to undertake any emergency works

Halcrow issued a proposal to the Council on 21st April and received a Purchase Order (No: 18069) and instruction to proceed on 1st May 2013. The site inspection survey was carried out on 9th May 2013.

2 Site description

2.1 Location

Swanage is located on the picturesque Isle of Purbeck coast that stretches from Poole to Weymouth, and can be accessed via Wareham or Studland via a toll ferrybridge. The town provides the main tourist centre for exploring Purbeck and is a popular seaside resort. Swanage Bay has a wide sandy beach protected by natural headlands at Old Harry rocks to the north, and Peveril Point and Durlston Head to the south; these headlands protect the bay from predominant south-westerly winds and waves but the bay is directly exposed to extreme waves from easterly storms.

The area of interest for this report is North Beach, which extends from the slipway at Ocean Bay beach (where the seafront joins Ulwell Road) to Shep's Hollow.

2.2 Geology

The geology of Swanage Bay comprises relatively weak rocks of the Wealden Group. They comprise sediments that were deposited by rivers, in flood-plains and occasional freshwater lakes over 125-137 million years ago. The rocks are distinctive from their vibrant and variable colours including greys, purples, reds and greens. The sedimentary sequence comprises interbedded layered sequences of mudrocks, siltstones and sandstones which have been tilted and deformed to varying degrees due to subsequent land movements.

The area of interest is formed entirely within rocks of the Wealden Group; the inclination of the bedding steepens to the north at Punfield Cove where the Lower Greensand, Gault Clay, Upper Greensand and Chalk outcrop. To the south, Purbeck Limestone outcrops forming the headland at Peveril Point.

2.3 Geomorphology

The distinctive shape of Swanage Bay is the result of post-glacial sea-level incursion and differential erosion of the relatively weak rocks of the Wealden Group compared to the more resistant Chalk and limestone outcrops to the north and south, respectively. The broad shape of the bay seen today will have been formed about 3,000 years ago; ongoing erosion and undercutting of the cliffs will have continued to the present day in response to gradual sea-level rise and significant storm events.

In their natural state, the shoreline between Ocean Bay and Shep's Hollow comprises relatively low cliffs (up to 30m in height) fronted by a sandy beach. The Futurecoast cliffs database (Halcrow, 2002) categorised the site into a single cliff behaviour unit, S411, that spans the protected frontage of Swanage. The database summarises the following attributes: cliff type – simple cliff; geology – weak sandy strata; cliff failure mechanisms – toe erosion, rock fall, mudslides; status – marginally stable; sensitivity to climate – high; recession potential – 0.1m/yr toe erosion, 10-50m landslip every 10-100/yr.

The Shoreline Management Plan for Poole and Christchurch Bays includes erosion risk maps for Swanage (www.twobays.net). Projections of cliff retreat by 2025, 2055, 2105 are provide in Appendix C for units SW3 and 4 which cover North Beach. The erosion contours indicate potentially significant impact of cliff instability and recession on property over this period.

The National Coastal Erosion Risk Mapping programme (EA, 2012) provides projections of cliff retreat over the next 100 years and makes reference to the Shoreline Management Plan; predictions over this timescale are not presently available for Swanage.

Halcrow (2005) carried out an inspection and risk assessment of the cliffs at Swanage and North Beach as part of a major beach recharge scheme in 2005. This report has been consulted for comparison with the latest inspection presented herein.

2.4 Shoreline Management Plan

Timber groynes were first constructed at Swanage in 1930. The scheme was effective in retaining sand on the central section of the beach but had the effect of starving the beach further to the north. Consequently, a scheme to extend the sea wall and timber groynes to North Beach was carried out in about 1962. A major beach recharge scheme at Swanage was completed in 2005/6 that involved repair and upgrading of the timber groynes and import of sand to build up beach levels. The intervention of coastal defences provides protection to the cliffs from coastal erosion and toe undercutting, although they are still subject to instability, landslip and recession due to weathering, groundwater and development.

The Shoreline Management Policy for North Beach encompasses two management units M.1 (Handfast Point to Ballard Estate) and N.1 (New Swanage). The division between these units is located at Shep's Hollow, and coincides with the limit of development at Swanage:

M.1 - No Active intervention (0-100 years) – This stretch of coast has numerous environmental designations. It is towards the eastern end on the "Jurassic coast" although the rock exposures at this location are from the Cretaceous period. The important aim here is to preserve the natural processes which have given rise to this coast's exceptional landscape and geological value.

N.1 - Hold the Line (0-50 years) – The defences along this section of coast are to protect the coast against erosion rather than a defence against flooding. Over the existing beach area, this would typically be achieved by continued beach recharge together with groyne replacement and sea wall maintenance.

N.1 - Managed Realignment (50+ years) – In the longer term it is predicted that as the adjacent undefended cliff erodes, the northern end of the current defences will become untenable and there will be a need to create a transitional zone between the defended and undefended coast.

These policies are presently under review by the Coastal Strategy Study that is considering a "Sustain" policy for the developed frontage in the future, although no change is expected in the short term.

2.5 Development

The cliffs between Ocean Bay and the Pines Hotel (Burlington Road) have been substantially developed with beach huts and amenities, much of which is in private ownership. The nature and scale of development varies from site to site, from single rows of timber beach huts, to multiple rows of block wall and mass-concrete structures.

3 Site inspection

3.1 Introduction

A site inspection of the cliffs at North Beach was conducted on 9th May 2013 between 8.30am and 3pm. Weather conditions were unsettled, mostly warm with sunny spells, occasional strong winds and rain showers. The survey comprised a systematic visual inspection of the cliffs from the promenade and cliff top (where accessible), recording of observations on Ordnance Survey baseplans and in a field notebook, and photography of key features.

The inspection identified 12 site locations where recent cliff falls and landslip was evident. These are shown in Figures 1-3 and Plates 1-16 and described below.

3.2 Sites of instability

3.2.1 Site 1

A small failure of the upper cliff was evident at the boundary between Nos. 6 and 8 Ulwell Road (Figure 1). The scar measures 5m by 5m with an estimated volume $5m^3$. The rock fall debris has come to rest above a c.1m high retaining wall and row of beach huts of block-wall construction.

The slip occurred at the southern limit of a 20m length of bare sub-vertical cliff face in an otherwise subdued and well-vegetated section. Further cliff falls are likely from the bare section of cliff posing a risk to the beach huts beneath.

3.2.2 Site 2

A rock fall and debris slide has occurred beneath No. 9 Highcliffe Road (Figure 1). The failure measures 5m wide and 10m long with an estimated volume of $10m^3$. The slip appears to have run-out over a low makeshift retaining wall, impacting up to three adjacent timber beach huts, one of which had been dismantled.

The source of the failure extends 15m across and behind the adjacent three-tier beach hut development of block wall construction to the south (Plate 1); the retaining wall behind this development shielded the huts from the cliff fall and acted to divert the debris towards the adjacent property to the north impacting a single row of timber beach huts (Plates 1 & 2). Further cliffs falls and debris run-out are likely given the exposure of the bare sub-vertical cliff face and accumulated talus on the slope, posing a risk to the beach huts, and public and promenade beneath.

3.2.3 Site 3

A rock fall and debris cone was observed above a single row of timber beach huts (Figure 1; Plate 3). The rock fall source measures 5m by 8m with an estimated volume up to $10m^3$. The debris cone (talus) measures approximately 10m by 8m with an estimated volume of 40 m^3.

The cliff fall debris has accumulated above a makeshift retaining wall formed of steel scaffold poles and timber planks above a low block retaining wall of 0.5m height. The makeshift structure is unsuited to withstand significant earth pressures and appears close to failure in places.

A single row of 30 beach huts are located in front of the low block retaining wall. They are at risk of direct impact from falling rock from above and from failure of the makeshift wall and talus; the latter is most likely in the winter when groundwater levels are high and could result in significant run-out of debris onto the promenade and beach, destroying the beach huts in its path and posing a risk to the public.

3.2.4 Site 4

Site 4 is adjacent to Site 3 and comprises recent rock fall and debris run-out above a single row of timber beach huts (Figure 1; Plate 4). The rock fall source measures 5m by 5m with an estimated volume up to $5m^3$. The debris cone (talus) measures approximately 5m by 5m with an estimated volume up to $10m^3$.

As for Site 3, there is a significant risk of rock fall and landslip of the talus impacting the timber beach huts, and public and promenade beneath.

3.2.5 Site 5

A minor fall of debris occurred from beneath a private stair well and access to the promenade (Figure 1). The volume of debris was small (<1 m^3) and had been cleared by the time of inspection but staining of soil on the high retaining wall and promenade were still evident. It was noticed the crest of the retaining wall appears flush with the sloping ground above providing no protection (barrier) to surface run-off or landslip from cascading over the wall from above.

3.2.6 Site 6

A minor debris fall occurred on the steep cliff flanking the southern boundary to the Grand Hotel's frontage (Figure 1; Plate 5). The slip was reported at 16.00 on Friday 21 Dec 2012 by the Coastguard (BBC online news, 22 Dec 2012). The debris accumulation on the promenade was less than $1m^3$ (see Plate 5) and had been cleared by the time of the inspection. The debris fall occurred on a section of cliff that once had a protective block wall facing that has failed in the past and fallen into disrepair.

Further debris falls from this section are likely posing a risk to the public using the promenade.

3.2.7 Site 7

Damage to the block walls, paving and facilities on the lower cliff at the Grand Hotel appear to have been caused by landslip (Figure 1; Plate 6). Outward displacement of the upper course of block work and continuity of open cracks through walls and paving, is indicative of translational displacement of the lower cliff *en masse* and measures 20m across; the depth of landslip appears relatively shallow (1-2m) and rates of movement are likely to be extremely slow.

There is potential for ongoing and future movement of the lower cliff but given that rates of movement are extremely slow the risk to people is negligible. Ongoing landslip will have an adverse impact on structures, walls and paving and could render them dangerous without correction and repair. A development proposal of the lower cliffs at the Grand Hotel is presently be considered by the planning authority; a full stability report, ground investigation and design of cliff stabilisation measures will be required to support the proposals.

3.2.8 Site 8

A large cliff failure and landslip occurred at site 8 (Figure 2) which was captured on film and reported in the media 2012 (BBC online news, 22 Dec 2012). The slip measures approximately 15m by 17m with an estimated volume of $127m^3$. The landslip debris ran-out and came to rest upon a 3-tier and adjacent 2-tier block of beach huts and promenade (Plates 7-11). Although a significant mass of debris came to rest on the beach huts (of block-wall and concrete slab roof construction) they appear structurally intact. Some clearance of debris from the upper terrace and beach huts roof had been carried out at the time of the inspection.

There is potential for further movement and addition of cliff fall and landslip debris above the beach huts. Debris that has come to rest upon the beach huts roof will be applying load that could cause failure of the roof elements or indeed collapse of the multi-tier blocks of beach huts. The 3-tier block being of older construction appears particularly vulnerable to damage from loading of cliff fall and landslide debris.

3.2.9 Site 9

The cliffs fronting properties 30-32 Burlington Road (Figure 2; Plates 12-14) had been affected by small-scale landslip for several years (Halcrow 2005). Over the period late Dec 2012 and March 2013, large-scale failure of the cliffs occurred, forming two elongate mudslides with a distinctive source, track and debris lobe. The mudslides are up to 36m long from crest to toe, 10m wide, and between 0.5-1.5m deep, with an estimated total volume of displaced material up to 400 m^3.

Debris from the mudslides has had a major impact on the lower cliff destroying one beach hut of block wall or reinforced concrete construction and severely impacting another. Debris lobes up to 1.5m deep have run-out across the promenade and upper beach, comprising an assortment of rock and soil and large fragments of mass concrete, masonry and reinforced structural elements. The debris has cut-off access along the promenade to North Beach; at its most active the debris may best be described as viscous mud and there is a serious risk of people sinking and getting stuck in the mud.

At the time of the inspection, the stability of the cliffs had improved with the cessation of winter rainfall and decline in groundwater levels. This is likely to remain over the drier summer months until next winter when further mudslide activity can be expected. Localised falls and slides from the upper cliffs are likely through the summer months due to the effects of desiccation and rainfall events. There is a significant risk to the public who should be advised and/or prevented from accessing the site and walking across the mudslides.

3.2.10 Site 10

The cliffs fronting the Pines Hotel were affected by widespread instability between Dec 2012 and Mar 2013 (Figure 2; Plates 15-17). The cliffs may be sub-divided into 3 main sections, the cliff-top, mid-cliff and lower cliff. Failure of the mid-cliff section has resulted in run-out and deposition of debris on the promenade and upper beach; this in turn has resulted in collapse and recession of the cliff-top by up to 10m measuring 60m across (Plates 16-17). Two main areas of deposition are shown in Figure 3 measuring 15m by 25m and 40m by 12m, and between 0.5m to 1.5m deep; estimated total volume of displaced debris is 855 m^3. The primary cause of failure is attributed to the extreme rainfall and groundwater levels experienced over the autumn and winter period.

Debris run-out from the cliff instability has had a major impact on the lower cliff, causing burial of the promenade, groyne and upper beach. The debris lobes have cut-off access along the promenade to North Beach; at its most active the debris comprises viscous mud and there is a serious risk of people sinking and getting stuck in the mud if they venture onto the cliffs.

At the time of the inspection, the stability of the cliffs had improved with the cessation of winter rainfall and decline in groundwater levels. This is likely to remain over the drier summer months until next winter when further mudslide activity can be expected. Localised falls and slides from the upper cliffs are likely through the summer months due to the effects of desiccation and rainfall events. There is a significant risk to the public who should be advised and/or prevented from accessing the site and walking across the mudslides.

Planning approval has been granted for a cliff stabilisation scheme at the Pines Hotel. Following a tendering process a contractor has been engaged by the owners to start work in 2013. At the time of inspection, the programme was unclear but expected to commence in June 2013 to stabilise the cliff-top with works on the lower cliff planned for September 2013.

3.2.11 Site 11

The adjacent property to the north of the Pines Hotel (Figure 2) has been subject to major failure in the form of an elongate mudslide with a distinctive source, track and debris lobe. The mudslide is up to 50m long from crest to toe, 23m wide, and between 0.5-1.5m deep, with an estimated total volume of displaced material up to 525 m^3.

Debris run-out from the mudslide has had a major impact on the lower cliff, causing burial of the promenade, groyne and upper beach. The debris lobes have cut-off access along the promenade to North Beach; at its most active the debris comprises viscous mud and there is a serious risk of people sinking and getting stuck in the mud if they venture onto the cliffs.

At the time of the inspection, the stability of the cliffs had improved with the cessation of winter rainfall and decline in groundwater levels. This is likely to remain over the drier summer months until next winter when further mudslide activity can be expected. Localised falls and slides from the upper cliffs are likely through the summer months due to the effects of desiccation and rainfall events. There is a significant risk to the public who should be advised and/or prevented from accessing the site and walking across the mudslide.

3.2.12 Site 12

The section between Site 11 and Shep's Hollow is characterised by an active freely degrading cliff. The existing groynes and beach fronting this section provide a degree of protection but unlike the section to the south there is no promenade or coastal protection structure to prevent toe undercutting. The cliffs are undercut towards Shep's Hollow and degrade in the form of cliff falls and high-angle shallow debris slides. Towards the southern part of this section, adjacent to Site 11, there is evidence of larger-scale instability in the form of block failures and mudslides.

There is a risk to the public of rock fall and debris slides along this section and the public should be advised to keep off and a safe distance away from the cliffs.

4 Cliff instability and erosion potential

4.1 Cliff failure mechanisms

Failure of cliffs occurs through one or more landslide mechanisms or mass wasting processes. Those occurring in the UK are shown in Figure 4.

Rockfalls and topples are more common in steeper cliffs formed of harder rocks, where blocks of material detach from the cliff face along lines of weakness in the rock mass, whereas rotational failures, translational failures, mudflows/slides and debris flows are more likely to occur in cliffs formed of weaker materials such as softer rocks or superficial deposits.

Combinations of these failure types can also occur. For instance where a harder 'cap' rock overlies a weaker rock, rockfalls or topples may occur from the upper cliff and the weight of the overlying cap rock may drive rotational failure in the underlying weaker materials.

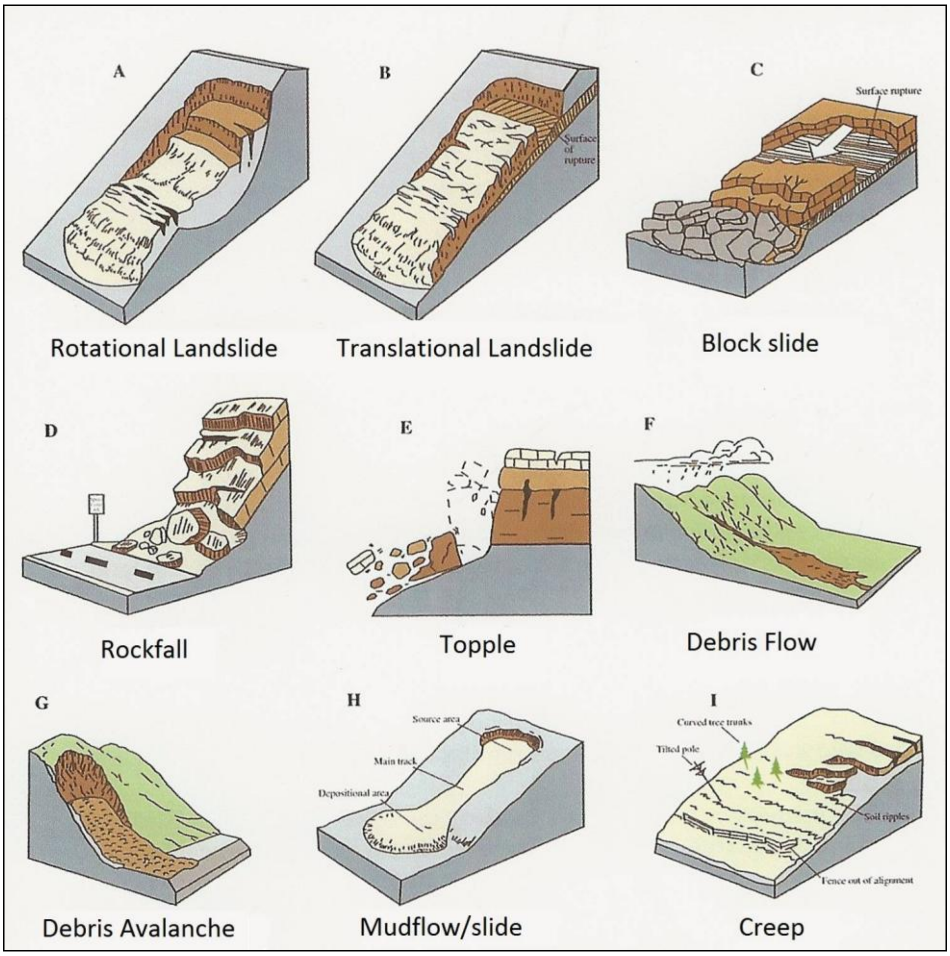

Figure 4: Examples of landslide mechanisms and mass wasting processes occurring in Great Britain (from Moore & McInnes, 2011).

4.2 Causes

Progressive weakening of cliff materials occurs through physical, chemical and biological weathering processes and is a preparatory factor in cliff failure. However, the principle *causes* of cliff failure at the coast in the UK are marine erosion, rainfall and development activities. Individually, these can all be causes of cliff instability, but in many cases, a combination of these factors will cause failure.

4.2.1 Marine erosion

One of the most common causes of cliff failure is the over-steepening of cliffs or removal of supporting material at the cliff toe by wave action (DoE, 1994). Once failure occurs, however, the newly failed material may provide temporary support to the cliff toe until wave action has once again removed the failed material.

Over shorter timescales, cliff failure caused in this way is likely to be episodic rather than continuous as erosion of debris and toe undercutting may take a long time in comparison to the duration of individual cliff failures. Furthermore, most removal of material at the cliff toe is likely to take place during high magnitude, low frequency storm events, especially those which combine with high tides and storm surges, when waves have higher energy and can erode material from higher elevations on the beach.

Rising sea levels ensure that, whilst cliff failure due to marine erosion is episodic at short timescales, unless inhibited by defensive structures, the overall effect of cliff failure at longer timescales is recession of the coastline.

4.2.2 Rainfall

Rainfall is another prevalent cause of cliff failure. As rainwater enters the ground it can have the effect of providing buoyancy to the cliff material, acting against the forces resisting failure (Selby, 1993). This is particularly the case where the pressure of the water within the ground (the pore-water pressure) increases because it is confined between impermeable layers of rock or soil, normally with a significant clay component.

Shallow, translational failures often occur soon after a rainfall event as rainwater directly enters the soil and increases pore-water pressures near the surface. However, the effect of rainfall is not always immediate and deeper failures may occur as a result of prolonged periods of rain that cause deeper groundwater levels to rise.

Figure 5 shows an example of the correlation between antecedent rainfall conditions and periods of ground movement at Ventnor, Isle of Wight. The upper graph shows that the most significant ground movements lag behind the first (September to December) peak in rainfall, responding to increases in pore water pressures (lower graph) which rise throughout the first rainfall peak and continue until porewater pressures begin to drop in April.

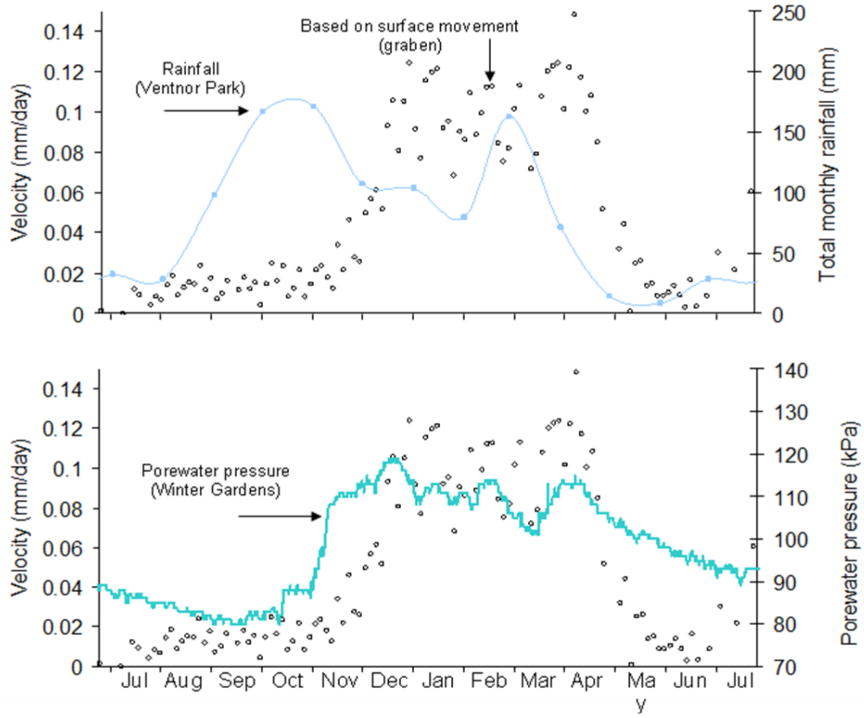

Figure 5: Relationship between rainfall, pore-water pressure and ground movement at Ventnor, Isle of Wight (Moore et al, 2010).

4.2.3 Development

Development of cliffs and areas adjacent to them are often, either directly or indirectly, a cause of cliff failure. Common actions that may cause cliff failure include excavations on and beneath cliffs, such as to make room for beach huts or coastal defences which has the effect of steepening the cliff or removing the restraining support that is inhibiting failure of the cliff.

Building on or near to cliffs can also be a relatively direct cause of failure, as the additional weight of the construction adds a 'surcharge' to the cliff. Cliffs made of cohesive material, such as clay, which are prone to rotational failure are more likely to be affected by the addition of surcharge. The position in the cliff at which the construction takes place will determine the impact it has. Building near the top of a slope is more likely to increase the forces driving failure, whereas additional weight at the toe of the slope is likely to increase the forces resisting failure (DOE, 1994).

Changes in the 'water regime' (DOE, 1994) are a third, relatively direct way in which development can cause cliff failure. The addition of water, and hence increases in pore water pressure, through actions such as the interruption of natural drainage pathways, leaking pipes and swimming pools and poorly planned soakaway drains can all lead to increases in slope instability and therefore cliff failure.

Less directly, changes in the coastal sediment regime may exacerbate cliff instability (DOE, 1996). For instance, the prevention of longshore sediment transport through the construction of harbour walls or the protection of eroding coastlines that supply sediment to the coastal system can deplete beaches leaving the cliffs behind them more vulnerable to undercutting from erosive wave action.

4.3 Rainfall history

Met Office data for Hurn, which is the longest available record in the area and around 20km north-east of Swanage, indicates average annual rainfall of around 830mm per year. Another relatively long term record (1973-2003) from Swanage Station Road, around 1km from the site, indicates average annual rainfall of 823mm per year. The Hurn record for the same period (1973-2003) shows that average annual rainfall was around 824mm, indicating that this is likely to be a useful proxy for rainfall in Swanage in the absence of more recent data.

Rainfall records are also available for Durlston Country Park, around 2.5km South of Swanage North Beach. However, these may not have been verified by the Met Office and indicate an average annual rainfall of 882mm for the period 2003-2012, relatively high compared to the Hurn record for the same period which indicates an average rainfall of 816mm. This discrepancy could be due to differences in measurement methods or the local topographic influences from Durlston Country Park's location on a promontory, whereas Swanage North Beach is in a more sheltered, east-facing location. As such, records from Hurn are used in this analysis.

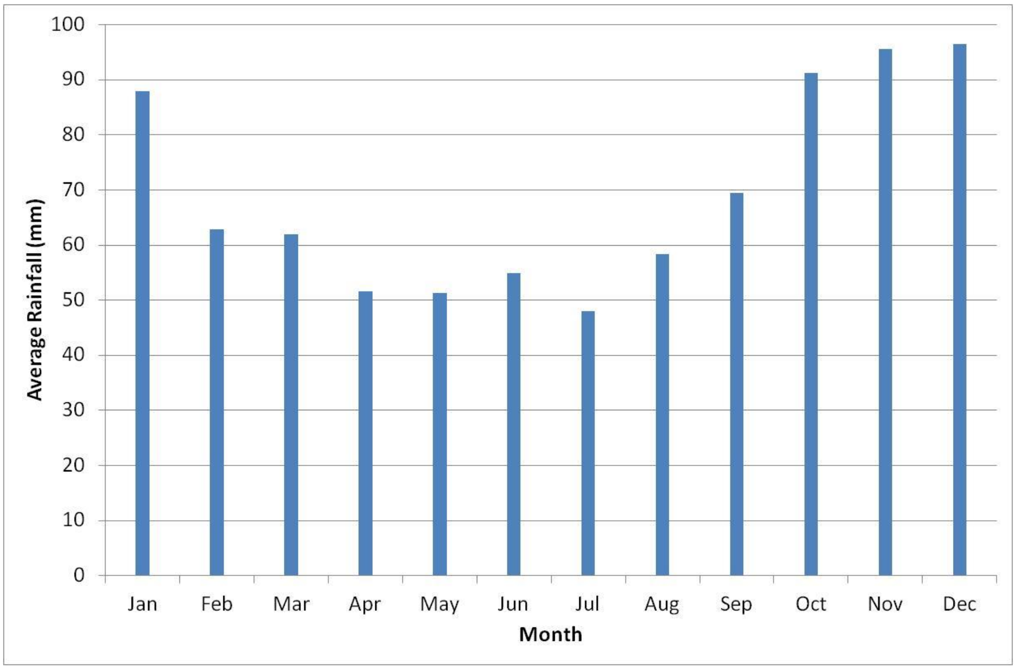

Figure 6: Average monthly rainfall, Hurn 1957-2012. (source: metoffice.gov.uk)

Figure 6 shows the average monthly rainfall at Hurn throughout the year, based on the full (1957-2012) record. The data indicate that October to January are the months with the most rainfall separated by a drier period from February through to September. Figure 7 shows the whole rainfall record, with average annual rainfall marked in red. 1960, 1993, 2000, 2002 and 2012 stand out as having significantly higher-than-average rainfall totals. The total annual rainfall for 2012 was the 3rd highest on record since 1957, and has a return period of 1 in 19 years.

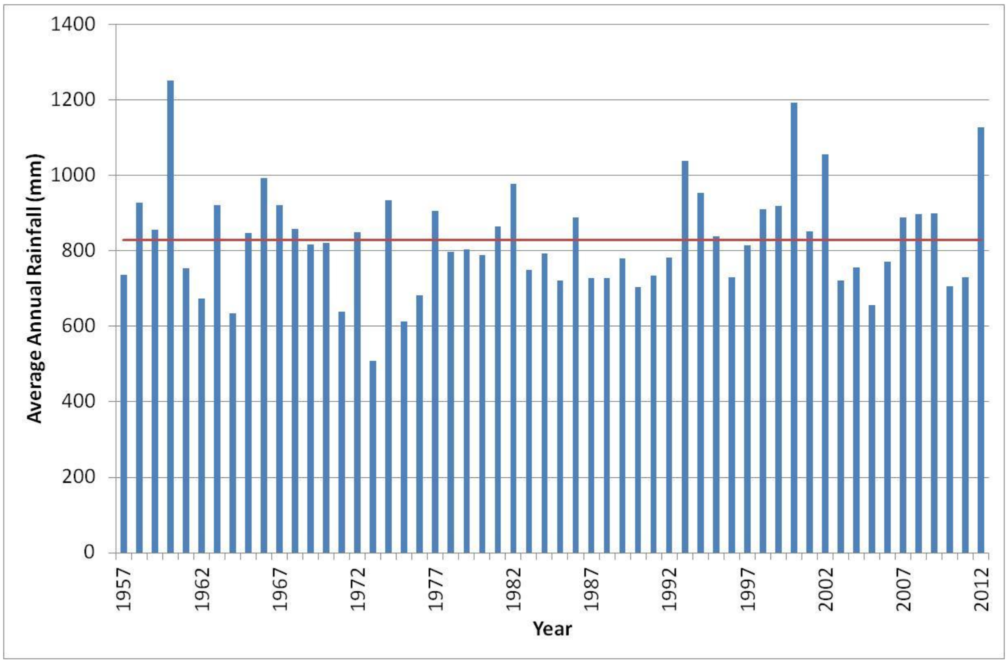

Figure 7: Long term annual rainfall record for Hurn, 1957-2012. Average annual rainfall during the period shown by red line. (source: metoffice.gov.uk)

Figure 8 shows the individual monthly rainfall records from January 2012 to April 2013 plotted against monthly average rainfalls. Exceptionally wet months are seen in April, June, July and December 2012 with, to a lesser degree, wetter than average months in September, October and November 2012 and January and March 2013.

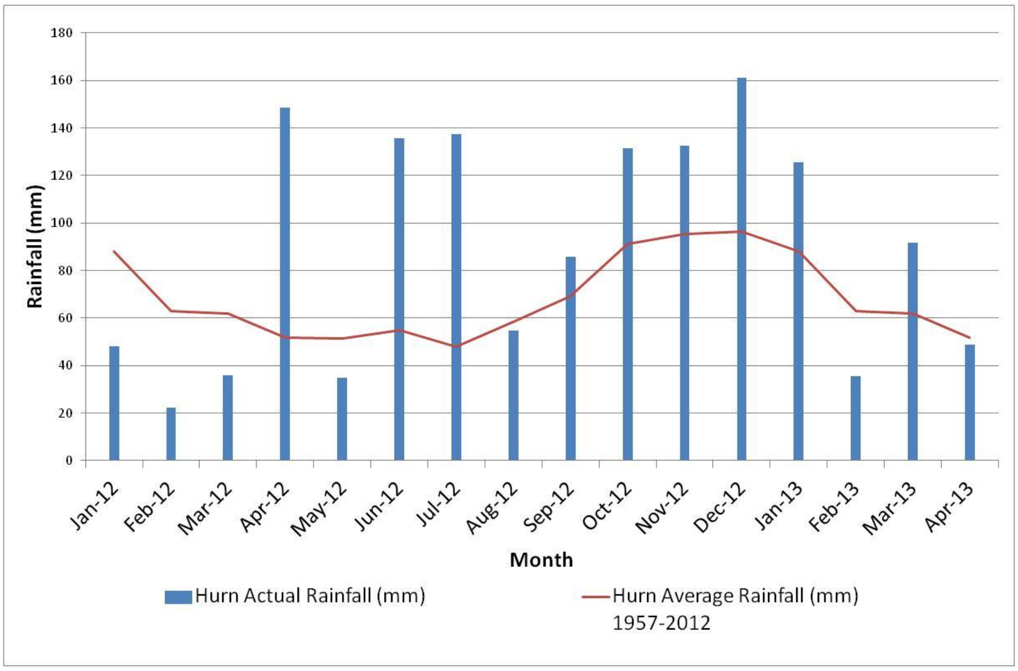

Figure 8: Monthly rainfalls January 2012 to April 2013 relative to average monthly rainfall, Hurn. (source: metoffice.gov.uk)

These periods of higher-than-average and exceptionally high rainfall, are likely to have counteracted the effects of the relatively dry months in early 2012 and contributed to excess groundwater and soil moisture levels by December 2012 and through January 2013, triggering the cliff falls and landslides that occurred during that period. Figure 9 shows the average 3-month (current month plus previous two months) antecedent rainfall totals overlain onto the actual monthly rainfall. This clearly shows a peak in the three month antecedent rainfall in December and January, when the cliff failures and instability were reported.

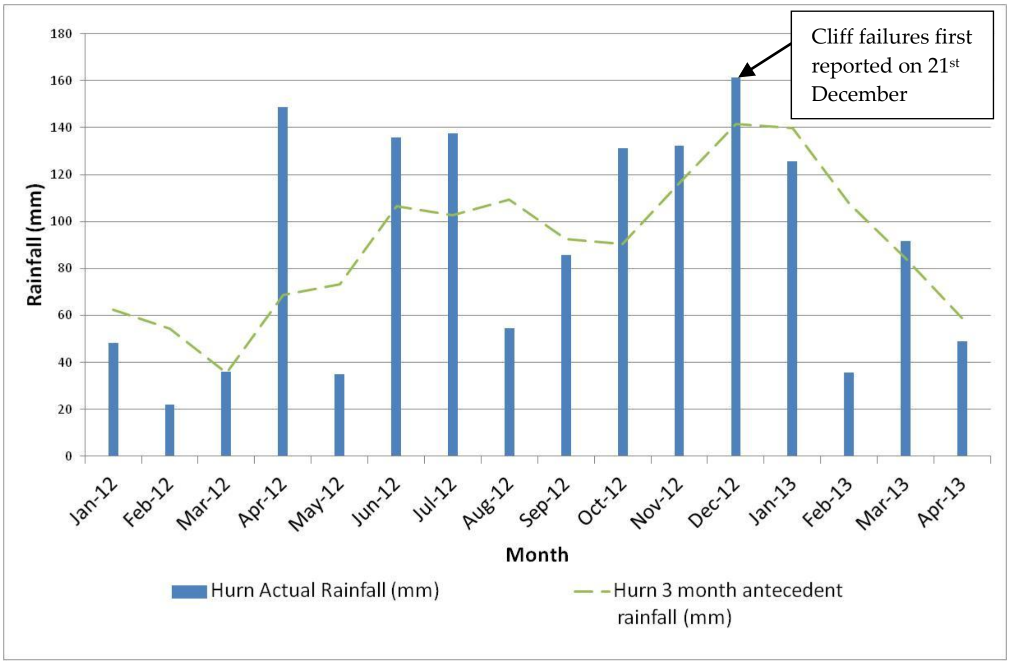

Figure 9: 3-month antecedent rainfall, Hurn. (source: metoffice.gov.uk)

4.4 Risk assessment

A risk assessment of the sites affected by cliff instability is provided in Table 1. The table outlines:

- the site number identified in Section 3,
- the nature of the hazard at the site,
- the likelihood of the hazard occurring,
- the impact should that hazard occur,
- the degree of risk, calculated from the likelihood and the severity of the impact and,
- actions that may be taken to mitigate the risk.

Table 1 shows that:

- Sites 8, 9, 10 and 11 carry an intolerable risk. These sites require the actions specified to be undertaken to reduce risk to a tolerable level.
- Sites 2, 3, 4 and 7 carry a substantial risk. It is recommended that the actions specified are undertaken at these sites to reduce risk.

Table 1: Risk assessment of sites of instability

Site No.	Hazard	Likelihood[a]	Impact[b]	Risk degree[c]	Actions
1	Small cliff fall	3	2	6	Prevent cliff fall and/or erect barrier to protect beach huts
2	Cliff fall & debris slide	3	4	12	Prevent cliff fall and erect barrier to protect beach huts & promenade
3	Cliff fall & debris slide	3	4	12	Prevent cliff fall and erect barrier to protect beach huts & promenade
4	Cliff fall & debris slide	3	4	12	Prevent cliff fall and erect barrier to protect beach huts & promenade
5	Small cliff fall	3	2	6	Prevent cliff fall onto promenade
6	Small cliff fall	3	2	6	Prevent cliff fall onto promenade
7	Shallow landslide	5	3	15	Investigate, design & construct landslide stabilisation measures
8	Cliff fall & debris slide	5	4	20	Clear debris from beach huts & promenade; prevent cliff fall
9	Cliff failure & mudslides	5	5	25	Clear debris from upper beach & promenade and install retaining wall to support excavation and protect promenade; design & construct landslide stabilisation measures for upper cliffs
10	Cliff failure & mudslides	5	5	25	Clear debris from upper beach & promenade and install retaining wall to support excavation and protect promenade; design & construct landslide stabilisation measures for upper cliffs
11	Cliff failure & mudslides	5	5	25	Clear debris from upper beach & promenade and install retaining wall to support excavation and protect promenade; place rock armour over 10m length to prevent toe erosion and outflanking; design and construct landslide stabilisation measures for upper cliffs
12	Cliff failure & mudslides	5	3	15	Advise public to keep clear of cliffs

[a] Likelihood scale: 1 - negligible; 2 - unlikely ; 3 - likely; 4 - probable ; 5 - certain
[b] Impact scale: 1 - negligible; 2 - low; 3 - moderate; 4 - high; 5 - extreme
[c] Risk degree: 1-5 insignificant; 6-10 significant; 11-15 substantial; >15 intolerable

- Sites 1, 5 and 6 carry a significant risk and consideration should be given to mitigating the risk at these sites.

Between and outside of these sites, within the area considered during the site inspection, the risk is of a lower level and no actions are recommended in this report.

5 Cliff instability and erosion management

The risk assessment highlights a serious issue regarding the management of cliff hazards on development and the public in the short- and long-term. In the short-term, engineering works may comprise the removal of rock fall and landslip debris and the design and construction of cliff protection/stabilisation measures. In the long-term, a cliff management strategy should be adopted by landowners and the coast protection and local planning authorities through their powers under the Coast Protection Act 1949 and the Town & Country Planning Act 1990.

5.1 Emergency engineering works

The following engineering works will be needed in response to the cliff falls and landslip that occurred between December 2012 and March 2013. Ball-park estimates of cost are provided for planning and budgeting purposes.

5.1.1 Debris clearance

Sites 9-11: removal of landslip debris from the promenade and upper beach over a 120m section; an estimated 1,000 m^3 of soil and inert debris will require excavation and breaking by machine, loading into dumpers and disposed, with the natural soil preferably disposed beneath the cliffs at Site 12, so that they will be eroded by the sea in time and contribute to Swanage Bay sediment cell.

Site 8: clearance of cliff fall and landslip debris from above the beach huts on the upper cliffs will need to be carried out by hand using rope access and temporary erection of debris chutes; an estimated 127 m^3 of debris needs removal. The debris will need to be loaded into dumpers and disposed, preferably beneath the cliffs at Site 12 so that the sediment contributes to Swanage Bay sediment cell.

A ball-park estimate for debris clearance is £101k excl VAT but inclusive of contractor mobilisation, insurance and consultants costs. The debris clearance should only proceed with the construction of a retaining wall (next item) to support the cut slope. The works would ideally be carried out after the summer holidays, in September 2013.

5.1.2 Retaining wall and rock armour termination

Sites 9-11: excavation of the landslide debris will leave an unsupported cut slope in debris on the lower cliffs which will lead to further cliff instability and debris run-out. It is recommended that a retaining wall, up to 1.5m high, is designed and constructed at the rear of the existing promenade to support the excavation, over a 110m length. The wall should allow free drainage of the cliffs and debris upslope and be designed to provide sufficient passive restraint to stabilise the cut slope in landslip debris on the lower cliffs.

Site 11: the mudslide at Site 11 straddles the termination of the promenade and groyne in this location. This will leave a 10m length of excavation cut into mudslide debris beyond the termination of the promenade where it is recommended rock armour is placed to prevent erosion of the cut face and protect against outflanking of the promenade.

A ball-park estimate for design and construction of the retaining wall and rock armour termination is £264k excl VAT but inclusive of contractor mobilisation, insurance and consultant's costs. The works would ideally be carried out after the summer holidays, in September 2013.

5.1.3 Rockfall netting and pinning

Site 8: following removal of debris (see above) the exposed cliffs above the beach huts should be protected with rock fall netting and pins, to prevent rock fall and small slides impacting the beach huts, public and promenade below. An area of 40m by 10m needs to be covered.

Site 6: an area 20m by 10m should be covered with rock fall netting and pinning to protect the public and promenade below.

Sites 2-5: rock fall netting and pinning should be installed across the entire section of exposed and unstable upper cliffs encompassing Sites 2-5. The area measures 90m by 7m and the netting will provide protection to the beach huts, public and promenade below.

Site 1: an area 20m by 5m should be covered by rock fall netting and pinning to protect a private beach hut development.

A ball-park estimate for installation of rockfall netting and pinning is £20k excl VAT but inclusive of contractor mobilisation, insurance and consultant's costs. There are economies of scale if the works for all sites were to be carried out by the same contractor in one mobilisation. The works would ideally be carried out as soon as possible before December 2013.

5.1.4 Rock fall catch fence

Sites 2-4: an engineering designed rock fall catch fence should be installed along this section to protect the timber beach huts, public and promenade from the impact of cliff fall and debris slide run-out. The catch fence would measure a minimum 55m across and up to 2m high subject to detailed design.

A ball-park estimate for installation of a rockfall catch fence is £46k excl VAT but inclusive of contractor mobilisation, insurance and consultant's costs. The works would ideally be carried out as soon as possible before December 2013.

5.2 Cliff stabilisation and engineering works

Sites 9-11: the lower and upper cliffs of these sites are privately owned. The cliffs are actively unstable and further instability and cliff top recession is certain in the future, and most likely during the wet winter months, without intervention. Stabilisation of the cliffs will require a combination of structural measures, drainage and re-profiling. Any scheme will require appropriate ground investigation and design, will need to take due account of shoreline management policy and environmental designations amongst other interests, and will be subject to planning consent. The Pines Hotel (Site 10) has been granted planning consent to construct a cliff stabilisation scheme which is to commence in June 2013 with completion expected by December 2013.

Site 7: Stabilisation of the shallow landslide at this site will require ground investigation and design of cliff stabilisation measures. A development proposal of the lower cliffs at the Grand Hotel is presently being considered by the planning authority.

5.3 Cliff management strategy

Management of cliff instability and erosion problems involves bringing together professional interests, including local authority coastal management, planning, building control alongside estate agents, construction industry representatives, the service industries and insurers, whom together can achieve an integrated approach to addressing cliff instability problems. Landowners and residents can also play a significant role by implementing good practice relating to property maintenance and land management. The role of climate change also presents significant challenges for those responsible for managing coastal erosion and landslides and it is necessary to provide information to residents, which explain potentially worsening scenarios.

Cliff management forms an effective means of helping to address the impacts of cliff instability and erosion. The cliff management approach avoids the shortcomings of the 'emergency response' and instead concentrates on pre-planning and preparation, allowing longer-term, more sustainable planning decisions to be made which are in line with the planning policy framework. With the support of a 'cliff management strategy' it is possible to address the different mitigation opportunities and to put policy into practice. The aims of such a strategy would include:

- Preventing unsuitable development through sound planning controls and building control measures
- Monitoring ground movements and weather conditions using a range of automatic and manual recording instruments
- Seeking to improve ground conditions through a range of cliff stabilisation measures aimed at controlling water in the ground as well as coast protection schemes which reduce erosion at the toe of the cliffs
- An awareness-raising programme for the benefit of both professionals and the general public living and working in the area.

As an example, the Jurassic Coast Pathfinder Project for the cliffs at North Beach was specifically selected because of the vulnerability to erosion. On completion of the project the Swanage Coastal Change Forum was set up to raise awareness about coastal change.

6 Summary and recommendations

Numerous instability events occurred at Swanage North Beach cliffs during the winter of 2012 and 2013. In the south (Sites 1-6), these instability events took the form of relatively small cliff falls, debris falls and debris slides which have either come to rest on beach huts, on the promenade or behind makeshift retaining walls.

In the central and northern areas (Sites 7-12), larger landslips and mudslides have developed which, in some instances, involve reactivation of pre-existing failures. The impact of these events has been to overwhelm the promenade and upper beach with up to 1.5m debris and to expose the upper cliffs which will be prone to further failure.

The trigger of the instability was the cumulative effect of a very wet summer and an above average wet winter in 2012/13 which raised ground water to exceptional levels causing excessive porewater pressures to develop in the cliffs. Other factors that will have contributed to the problems in the longer term include the effects of development activities and drainage on the cliffs, and coastal erosion in the undefended areas.

The following short-term and long-term actions are recommended:

- By virtue of their scale and impact on private development and shoreline infrastructure, the cliff falls, debris slides and mudslides affecting Sites 8-11 pose an intolerable (unacceptable) risk in the short- and long-term. Immediate action is needed to clear landslide debris from the upper beach and promenade and install structural support to the excavation and promenade to prevent further run-out of debris onto the beach. Stabilisation of the actively unstable cliffs will be a matter for individual landowners to implement.
- The cliff fall and landslide debris that inundated and presently loads the beach huts at Site 8 should be removed and cliff protection measures installed to protect the beach huts and occupants from repeat events.
- The shallow landslide at Site 7 (Grand Hotel) affects mostly private land but outward displacement of the block wall above the promenade poses a hazard to residents and the public, and the site should be stabilised and repaired.
- Small cliff falls occurred at Sites 5-6 which pose a significant risk to public. Cliff protection measures should be installed to prevent cliff fall impact on the promenade.
- Cliff fall and debris slide run-out at Sites 2-4 poses a substantial risk to a single row of 30 timber beach huts and the promenade. A makeshift barrier erected above the beach huts is close to failure, adding to the risk. Cliff protection measures and a rock catch fence should be installed to protect the beach huts and occupants, and the public using the promenade.
- A small cliff fall occurred at Site 1 impacting a private beach hut development. Cliff protection measures should be installed to protect the development from future events.
- A cliff management strategy should be developed and implemented with the agreement of all stakeholders in the long-term.

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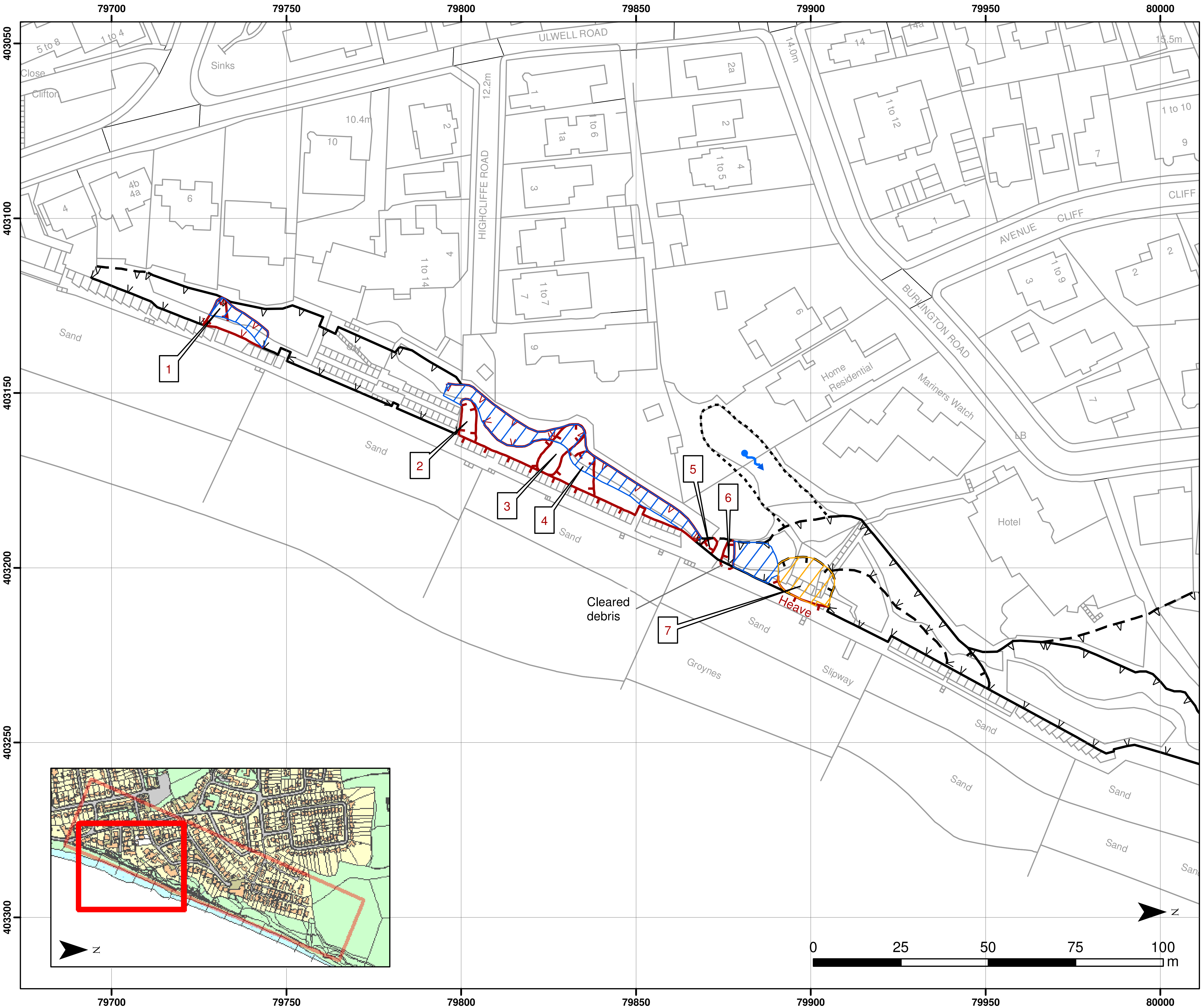

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Figure 1:

Swanage North Beach Cliffs Geomorphology and Recommended Works

South Section

Legend

Morphological Features

Currently stable areas

- Spring
- Gentle concave break of slope
- Small cliff
- Very small cliff
- Sharp concave break of slope
- Sharp convex break of slope
- Gentle convex break of slope
- Subdued morphological boundary

Areas of active instability

- Small cliff
- Sharp concave break of slope
- Sharp convex break of slope
- Morphological Boundary
- Cleared Debris Boundary

Existing Structures

- Wall (area of active instability)

Recommended works

- Netting and Pinning
- Debris Removal

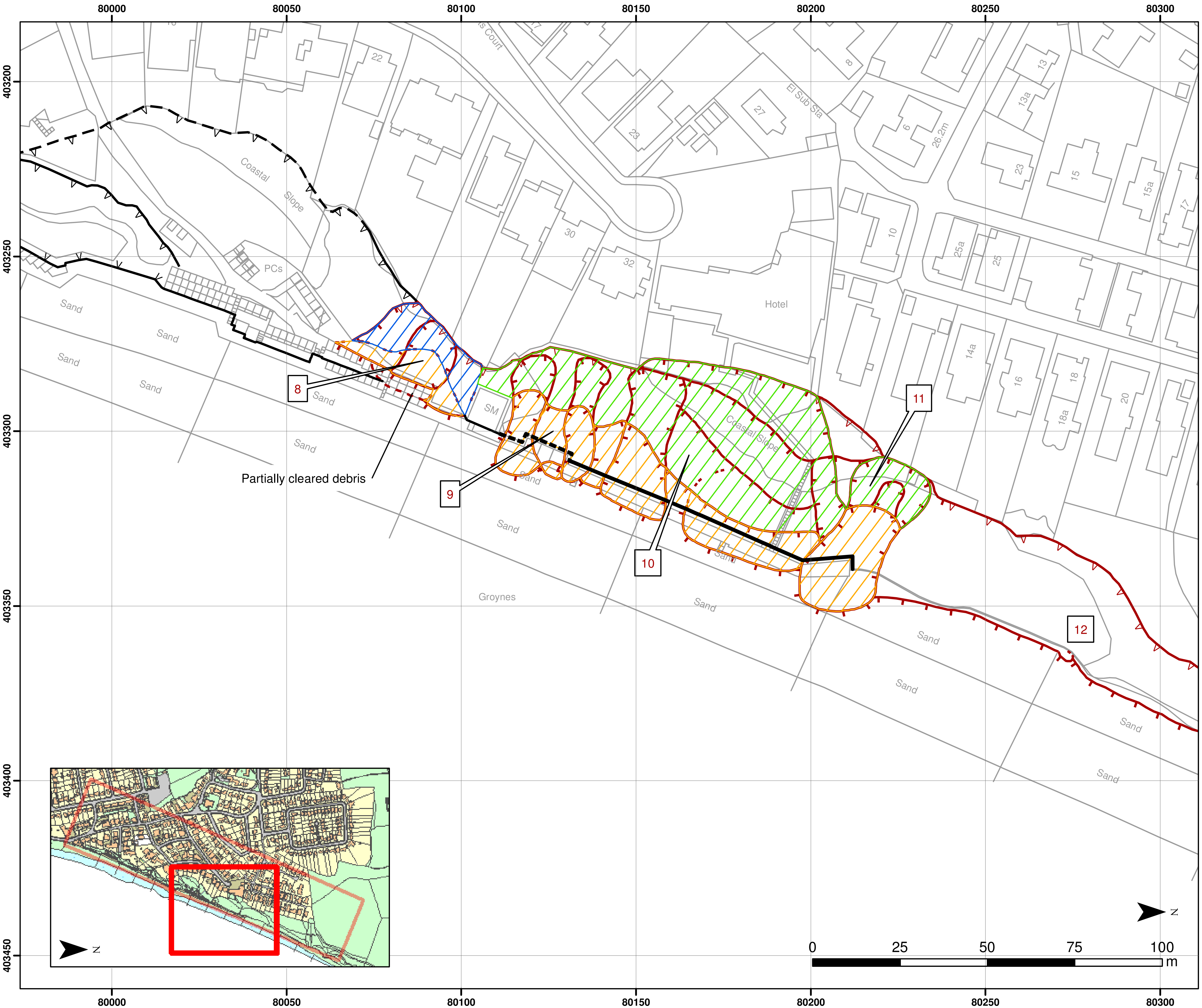

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Figure 2:

Swanage North Beach Cliffs Geomorphology and Recommended Works

Central Section

Legend

Morphological Features

Currently stable areas

- Sharp concave break of slope
- Sharp convex break of slope
- Gentle convex break of slope

Areas of active instability

- Small cliff
- Sharp convex break of slope
- Morphological Boundary
- Cleared Debris Boundary

Existing Structures

- Broken splash wall
- Splash wall
- Wall

Recommended works

- Cliff Stabilisation
- Netting and Pinning
- Debris Removal

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Figure 3:

Swanage North Beach Cliffs Geomorphology and Recommended Works

North Section

Legend

Morphological Features

Areas of active instability

- Small cliff
- Sharp convex break of slope
- Morphological Boundary

Existing Structures

- Broken splash wall
- Splash wall
- Wall

Recommended works

- Cliff Stabilisation
- Netting and Pinning
- Debris Removal

Plates

Plate 1 – Site 2 Cliff fall and debris run-out above 3-tier and single rows of beach huts

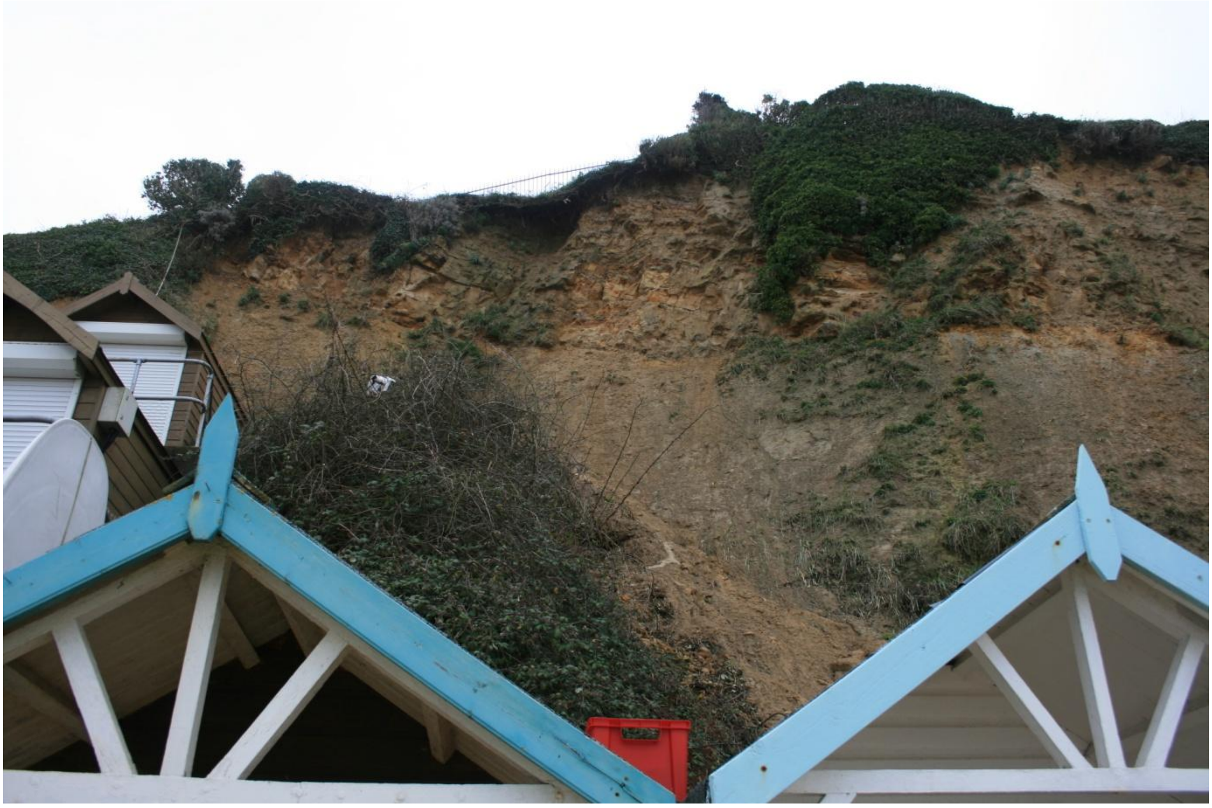

Plate 2 – Site 2 Cliff fall and debris run-out above single row of beach huts

Plate 3 – Site 3 cliff fall chute and debris accumulation

Plate 4 – Site 4 cliff fall debris and makeshift barrier

Plate 5 – Site 6 Minor cliff fall and debris

Plate 6 – Site 7 landslip damage to block walls on the lower cliff at the Grand Hotel

Plate 7 – Site 8 (mid-distance) cliff failure and debris run-out onto multi-tier beach huts

Plate 8 – Site 8 landslide and debris run-out onto multi-tier beach huts – looking north

Plate 9 – Site 8 landslide and debris run-out onto multi-tier beach huts – looking west

Plate 10 – Site 8 landslide debris run-out impact on multi-tier beach huts

Plate 11 – Site 8 landslide debris run-out onto promenade

Plate 12 – Site 9 landslide debris run-out over promenade and upper beach – looking west

Plate 13 – Site 9 landslide debris run-out over promenade and upper beach – looking southwest

Plate 14 – Site 9 close-up of landslip debris and structural elements

Plate 15 – Site 10 landslip and run-out of cliffs beneath the Pines Hotel

Plate 16 – Site 10 failure of cliff top at the Pines Hotel – looking southwest

Plate 17 – Site 10 failure of cliff top at the Pines Hotel – looking north

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