Old Castle Road, Weymouth

Landslide Inspection May 2020

07 July 2020

Dorset Council

Old Castle Road Landslide Inspection May 2020

Project No: B2363800
Document Title: Old Castle Road, Weymouth, Landslide Inspection May 2020
Revision: 1 incorporating client comments
Document Status: For Issue
Date: 07 July 2020
Client Name: Dorset Council
Client PO: 4500397933
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File Name: Old Castle Road, Weymouth Landslide Inspection May 2020 07072020

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Document history and status

Revision	Date	Description	Author	Checked	Reviewed	Approved
0	16 June 2020	Landslide Inspection Report for issue	OD and RF	RF	RM	RM
1	07 July 2020	Incorporating client comments	OD and RF	RF	RM	RM

Contents

1. Introduction

1.1 Project History

The northwest shore of Portland Harbour, Weymouth, Dorset, has a long history of coastal erosion, cliff instability and landsliding that threatens private property, services and infrastructure in various locations along a 2.5 km length of coastline between Bincleaves and Ferrybridge (Figure 1). Due to a significant landslide on this frontage at number 23 Old Castle Road, Dorset Council commissioned Jacobs to undertake a site inspection of the landslide and to report on future cliff recession scenarios and damage risk to the highways asset, Old Castle Road.

The Jacobs team, previously as Halcrow and CH2M, have significant local experience of the site having undertaken a preliminary study of the frontage in 2008 (Halcrow 2008) and a ground investigation in 2010, both of which informed the Cliff Management Strategy published in 2011 (Halcrow 2011). This Strategy identified Old Castle Road as one of the areas at most immediate risk of cliff instability and erosion and made recommendations for ongoing cliff management and monitoring.

Following this advice and the exceptionally wet winters of 2012/2013 and 2014/2015, Weymouth and Portland Borough Council (now Dorset Council) commissioned Jacobs to carry out cliff behaviour and condition assessment surveys (Halcrow, 2013 and 2015). The inspections revealed reactivation of deep-seated landslides had impacted the gardens of numbers 23, 25 and 27 Old Castle Road and that these had the potential to impact the road itself in the future.

Around the same time as these assessments, a proposal for a housing development at number 23 Old Castle Road was put forward. Because the site was known to be at risk of coastal erosion and instability, a key requirement for planning approval, which was granted in 2017, was for the development to include slope stabilisation and that this should provide support to the Old Castle Road itself. Since this time the development works have stalled and as a result Dorset Council has been required to start investigating management of its highway asset which is at risk to landsliding.

1.2 Terms of Reference

Dorset Council issued a Statement of Requirements for the site inspection and report on 22/04/2020.

Jacobs provided a proposal and commercial offer on 27/04/2020.

An instruction to proceed and Purchase Order (4500397933) were received on 22/05/2020.

1.3 Scope of Work

The scope of the site inspection and cliff assessment is as follows:

1. **Desk study -** synthesis of all available information and data, including previous site inspections, ground investigation boreholes and recent site works to help inform the ground model and understand the mechanisms and behaviour of the landslide.

2. **Desk mapping -** assess available remote sensing data (e.g. LiDAR and aerial photography) to update the chronology of historical headscarp retrogression and system development. This information feeds into defining future landslide hazard scenarios and timeframes.

3. **Site walkover inspection -** observations of the geology, geomorphology and general condition of the slope. Includes remapping of the site to document the location and nature of recent slope movements.

4. **Risk assessment -** brings together desk and site-based assessments to evaluate future cliff recession scenarios / timeframes and damage risk at Old Castle Road to enable informed management decisions.

5. **Recommendations -** identification of what will be required to monitor ground movement, manage risk and implement a solution to instability if one is required. Note Jacobs has not been instructed to considers landslide mitigation options at this stage.

1.4 Site Location

The site is located at Old Castle Road, Weymouth, Dorset, adjacent to house number 23 (see Figure 1).

Figure 1. Site location at Old Castle Road Weymouth.

1.5 Landslide Mechanisms and Causes.

This section provides background information on the types and causes of landslides which are described in this report. Figure 2 gives examples of landslide mechanisms and mass wasting processes in Britain and Table 1 a summary of internal and external causes of landslides.

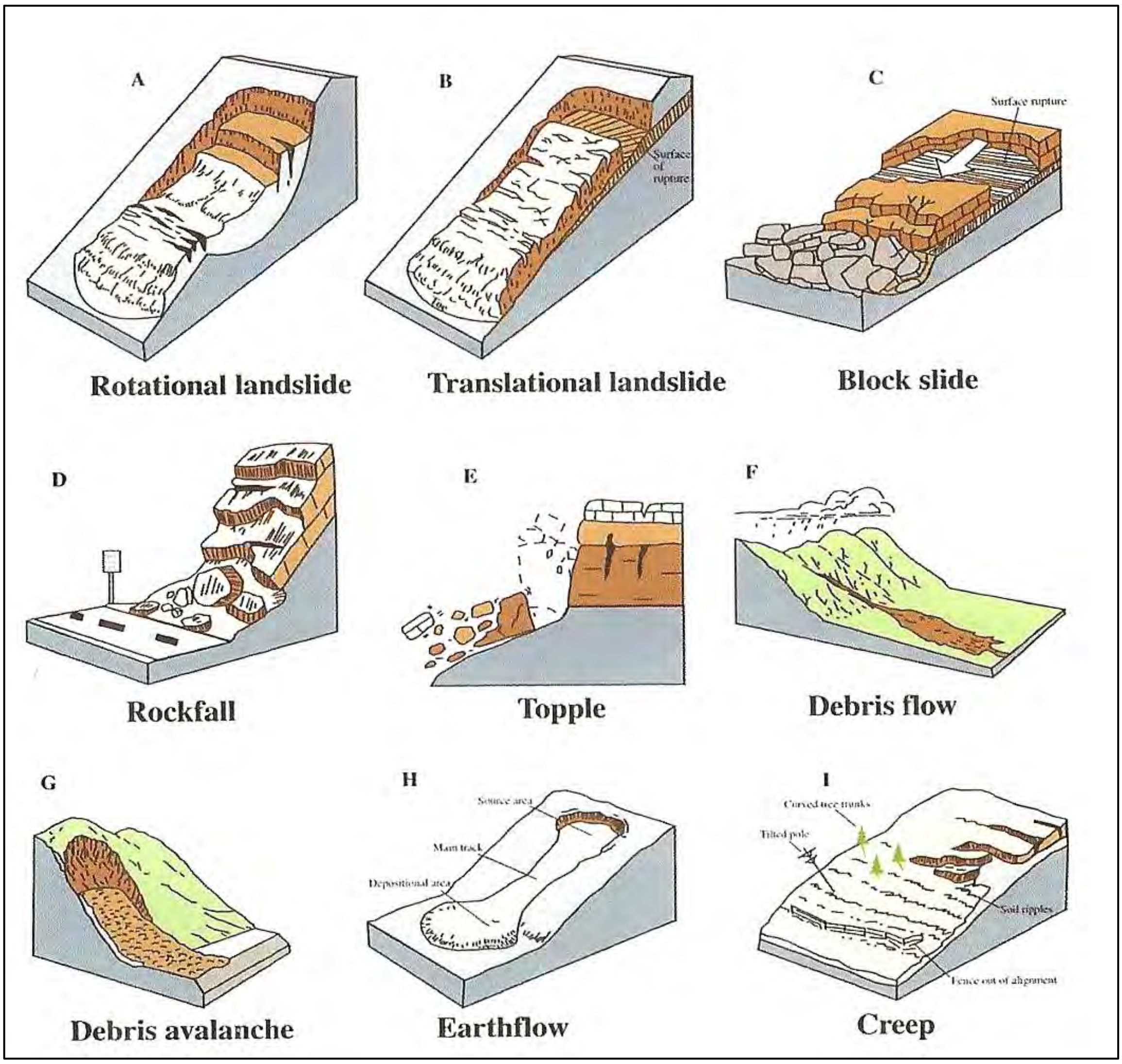


Figure 2. Examples of landslide mechanisms and mass wasting processes occurring in Britain (adapted from USGS, 2005).

Table 1. Internal and external causes of landslides

Internal Causes	External Causes
Materials: • Soils subject to strength loss on contact with water or as a result of stress relief (strain softening) • Cohesive soils which are subject to strength loss or gain due to weathering • Rocks with discontinuities characterised by low shear strength such as bedding planes, faults, joints etc.	**Removal of slope support**: • Undercutting by water (waves, stream incision) • Washout of soil (ground-water) • Man-made excavations
Weathering: • Physical and chemical weathering of soils causing loss of strength (cohesion and friction) • Slope ripening and soil development	**Increased loading**: • Natural accumulations of water, snow, talus (debris) • Man-made pressures (e.g. fill, tips, buildings) • Surcharging of ground water via man-made drainage, soakaways etc.
Pore-water pressure: • High pore-water pressures causing a reduction in effective shear strength. Such effects are most severe during wet periods or intense rainstorms.	**Transient Effects**: • Earthquakes and tremors • Shocks and vibrations

2. Desk Study

This section summarises information directly relevant to the study site at 23 Old Castle Road. Information on the wider Portland Harbour Northwest Shore is available in past Jacobs reports (Halcrow 2008; 2011; 2013; 2015).

The coastal cliffs at the site are formed in Corallian strata of Upper Jurassic age (see Table 2). They were formed through a combination of long-term coastal erosion caused by wave action and the effects of groundwater triggering mass movements in the cliffs. The BGS mapping shows the Upper Jurassic strata dipping gently to the southeast. This is consistent with the site's location on the southern limb of the E-W trending Weymouth Anticline and means that the slope is prone to bedding controlled translational landslides particularly when toe support is lost due to coastal erosion.

Since 1849 the Portland Harbour breakwaters have provided an element of protection against coastal erosion by reducing wave energy, yet previous inspections report widespread undermining of the frontage by marine processes. Furthermore, clay, which is susceptible to erosion, outcrops at beach level at the site. In contrast the cliff toe either side is relatively resilient to coastal erosion. To the south the frontage is protected by rock armour, following earlier landslides, and to the north resistant limestone outcrops at the base of the slope. Undercutting the slope reduces support to the weak clays above, promoting translational landslides and subsequent retrogression of the cliff at the top of the slope. Over time this difference in resilience against erosion has resulted in an embayment forming which is centred on the site. This embayment, which comprises low simple cliff formed in the Sandsfoot Formation, has trapped a small sandy beach at its toe and this possibly reduces erosion rates at the site.

Due to tree cover masking the slope toe it was not possible to accurately measure toe erosion using the LiDAR data. However, despite the possibility that coastal erosion rates might be relatively low at present, comparison of the current cliff top line with those visible in LiDAR surveys going back to 2008 show that the cliff is retreating by over 1 m/year (see past headscarp positions shown in Appendix 1). The ongoing retreat of the cliff top demonstrates the importance of water in driving instability at the site. Groundwater activity at the base of the Sandsfoot Grit Member and surface water entering the top of the slope from Old Castle Road and adjacent properties increase porewater pressures in the cliff and reduce stability.

In line with the shoreline management policy for the site to 'hold the line' for the next 100 years, the Cliff Management Strategy (Halcrow 2011) identified Old Castle Road as one of the areas at most immediate risk of cliff instability and erosion and made recommendations for ongoing cliff management and monitoring.

Table 2. Stratigraphy of the Old Castle Road site.

Stratigraphic unit	**Material description**
Upper Sandsfoot Grit	Hard orange brown slightly gravelly very fine CLAY/dense very clayey fine to medium SAND. Gravel is angular fine to medium with shell fragments. *This geology forms the headscarp of the landslide.*
Lower Sandsfoot Grit	Very stiff brownish grey, becoming grey occasionally mottled orange brown CLAY with small pockets of fine sand. *Landslides are known to form at the base of this geology.*
Sandsfoot Clay	Very stiff to hard fissured dark grey CLAY. *This geology outcrops at beach level over most of the site.*
Clavellata Beds	Strong bedded grey bioclastic LIMESTONE with occasional hard friable dark grey fine sandy clayey silt and occasional very weak siltstone. *This geology only outcrops at the base of the slope at the very far north of the site.*

Past assessments (Halcrow 2008; 2011; 2013; 2015) split Portland Harbour Northwest Shore up into a number of cliff behavioural units (CBUs) based on geology and the various associated cliff instability mechanisms. The landslide reported here is located in CBU C. Table 3 provides a summary of geomorphological characteristics and observations of change since the 2011 in CBU C.

Table 3. A summary of geomorphological characteristics and observations of change in the vicinity of the site.

CBU	Geomorphological characteristics	Observed change between 2011 and 2013	Observed change between 2013 and 2015	**Observed change between 2015 and May 2020** (full details in the Site Walkover Inspection section below)
C	Beach embayment with low simple cliffs, formed in the Sandsfoot Member. The cliffs are subject to undercutting and rockfall along the headland due to the presence of weak clays at the cliff toe. To the south, larger simple cliff landslides with steep arcuate headscarps are seated in the clay. The cliffs are fronted by sandy and boulder foreshore and are defended by a rock revetment along the shore	Large-scale reactivation of the pre-existing landslide complex, leading to retrogressive failure of the headscarp by up to 1 m at Old Castle Road. Headscarp 2 m from edge of veranda and garage at 27 Old Castle Road, fresh movement and tension cracking on cliffs, including lateral shears and bulging and heave in the compression zone	Viewed from the lower slopes, no observable change in the pre-existing landslide at Old Castle Road. Headscarp position and condition was not clearly observed at 27 and 29 Old Castle Road as access was not possible. Observation from the cliff toe indicated no change. Site clearance and shallow slope reprofiling was observed on the upper slopes at the western edge of CBU C in preparation for the construction of three properties. Two recently installed concrete piles at the crest of slope.	Deep-seated translational failure has spread northwards from 25 and 27 Old Castle Road into 23 Old Castle Road. The failure appears to be along a bedding-controlled shear surface in the soft clay at the base of the Sandsfoot Grit Up to 7 m retreat of the headscarp to within 2 m the road. Headscarp is up to 5 m high and unstable. There is evidence that the failure began in January 2020, peaked in early March following a prolonged period of heavy rainfall and is still moving.

3. Site Walkover Inspection

A geomorphological site walkover inspection was conducted on 27 May 2020 to take advantage of a favourably low tide in the early afternoon. Conditions were sunny and dry with moderate wind. The objectives of the survey were to:

- Identify and record evidence of recent or ongoing instability and ground movement at the site; and
- Assess any change in cliff behaviour and ground conditions since the previous inspection survey in 2015.

During the survey, records were made, and photographs were taken of features indicative of recent cliff instability and ground movement, such as tension cracking and heave, and updating field maps and GIS layers.

The key observations from the site visit are summarised as follows:

1. The site contains a deep-seated translational failure which outcrops approximately 5 m above beach level (see Photo 1). A translational failure (see Figure 2 for diagram) is a slide-type landslide where material has moved downslope along a distinct surface of weakness such as a bedding plane. The failure is described as deep-seated because the thickness of the failed material is greater than 5 metres i.e. it is not a thin layer of failed material as with a earthflow. In this instance and in comparable geological settings (i.e. relatively strong sandstone over relatively weaker clays) the failed clay in the lower slope leaves behind an unsupported sandstone cliff at the top of the slope. Failure of this type of cliff can occur because over-steep or can be triggered via additional movement of the clay below

2. The failure has retrogressed the headscarp of the slope to within 2 metres of Old Castle Road (see Photo 1 and geomorphological map in Appendix 1).

3. The failure appears to be along a bedding-controlled shear surface in the soft clay at the base of the Sandsfoot Grit (see cross section in Figure 3).

4. There is photo evidence that the failure began in January 2020, peaked in early March following a prolonged period of heavy rainfall and is still moving (see timeline Photos 8 to14).

5. The failure has transported heavily-vegetated debris, including trees, downslope and onto the rear of the beach. Fencing and a hut at the southern end of the site have also been displaced (see Photos 3 and 5).

6. Toe heave has occurred close to the base of the slope. This is backed by compression ridges of displaced material as evidenced by the exposure of yellowy brown sandy clay in Photo 4.

7. In response to the loss of basal support following movement of the lower slope, up to 7 m of the plateau at the cliff top has failed (see Appendix 1). To the north of the site the plateau loss tapers out.

8. The greatest proportion of this failed material is derived from the remnants of a spur which previously separated the south of the site from no. 25 Old Castle Road (see Appendix 1).

9. Material from the failed plateau has been displaced up to 5 m vertically and up to 10 m horizontally, leaving a 5 m high headscarp.

10. The new headscarp is an extension of the headscarp to the south which previously ended at no. 25 Old Castle Road. The new failure and the previous observations of cliff retreat to the south demonstrate that cliff instability is spreading northwards along the frontage.

11. Surface and ground water which elevate pore water pressures and reduce stability are likely to have triggered the landslide following the prolonged wet period over Winter 2019/20.

- Local topography directs rainwater from Old Castle Road and the buildings, hardstandings, soakaways and gardens (surface geology is low permeability clay) of local properties into the headscarp of the landslide. As the low permeability ground surface is opened up by landsliding, it is likely that surface water will become a larger problem in triggering instability as it will have easy access to the landslide shear surface though the headscarp and tension cracks.

- Groundwater, which is likely recharged several hundred metres inland of the site where porous sandstone outcrops, naturally drains downdip to the site through the permeable layer.

12. Although, over many years, toe erosion is an important preparatory driver of landsliding along the frontage there was no evidence of erosion or removal of the recently failed landslide debris by marine processes; material appears intact with no visible indications of scour or undercutting. This observation and the presence of a beach fronting the site suggest that toe erosion may only occur when spring high tides and storm surges combine. This hasn't happened since the recent failure but could remove landslide debris and cause instability in the future.

13. The new failure has the potential to spread upslope and laterally.

    - The headscarp is oversteep and unstable. There is evidence of ongoing small-scale cliff falls which could retreat the headscarp and breach Old Castle Road (see Photo 10).

    - The loss of the remnant spur (see Appendix 1) and large cliff fall in the south of the site (see Photo 10) may have reduced support to the adjacent cliff at number 25 Old Castle Road. This area may become unstable.

    - Photos 8 to 14 show that the main translational failure occurred over several months and that there is no clear evidence that residual movement has stopped so may continue for some time, even without fresh trigger.

    - Coastal erosion and prolonged rainfall have the potential to trigger additional significant failures at the site. This may include recession of the head scarp in a similar size bite (c. 7 m) and/ or spreading of the scarp northwards as per the trend in recent decades. Note that the northwards spread of the landslide may ultimately be slowed then limited by the Clavellata Formation (limestone), which outcrops at beach level and provides better resistance against toe erosion that the clay elsewhere in the site.

Photos 1 to 8 in the table below show a selection of the key photographs taken during the site inspection. Photos 8 to 14 show the development of the landslide through the first half of 2020. The location that each photo was taken is shown in Appendix 1.

	
Photo 1. Fresh headscarp of the recent translational failure. Debris from a subsequent cliff fall from the oversteep scarp is visible in the foreground.	Photo 2. Failed plateau material which has toppled into the space vacated by the translated block below.

Photo 3. Vegetated and compressed landslide debris in the mid to lower slope. Toe heave is evident close to the trees near the base of the slope.

Photo 4. Exposure of Lower Sandsfoot Grit in zone of toe heave close to the base of the slope.

Photo 5. Hut at the southern end of the site has been displaced seaward and twisted by the landslide debris.

Photo 6. Sandbags placed along the edge of Old Castle Road to prevent water from entering the landslide headscarp. Evidence that the road edge has been affected by subsidence.

Photo 7. Shallow cross-shore valley separating the debris of the recent landslide at No. 23 Old Castle Road and the existing landslide to the south.

Photo 8. View upslope to the headscarp across vegetated debris through the centre of the landslide from 3 m above beach level.

Photo 8. 19th January 2020. Scarp begins to open up at the southern end of the site in response to translational failure below.

Photo 9. 23rd February 2020. Scarp extending northwards and growing in height as translation failure below continues.

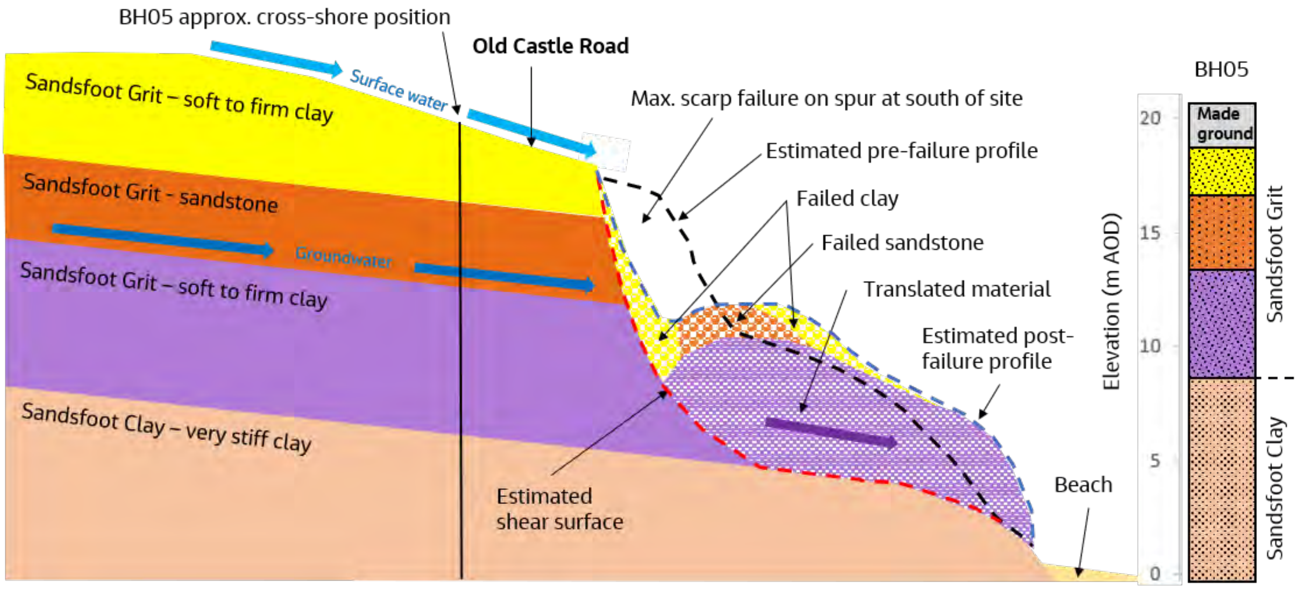
Photo 10. 5th March 2020. Further significant displacement of translational failure and growth of headscarp height. Cliff fall debris from the overstep scarp is visible in the foreground.

Photo 11. 22nd March 2020. Continued but slowing of translational failure and scarp development. Amount of cliff fall debris growing.

Photo 12. 3rd April 2020. Further continued slow translational failure and scarp development.

Photo 14. 19th May 2020. Changes to slope becoming disguised by vegetation growth.

Figure 3. Schematic cross-section showing the geology, landslide geometry and pre and post-landslide slope surface. Note that Borehole 5 is shown in the correct cross-shore position but is located 30 m to the south of the cross-section.



4. Risk Assessment

The inspection indicates that the site is affected by an active, deep-seated translational failure with a retrogressing headscarp within 2 metres of Old Castle Road. The points below summarise the potential future cliff recession scenarios / timeframes and damage risk to the highways asset:

- Observations show that there is ongoing residual translational displacement of the failed mass and cliff falls from the oversteep headscarp which could result in further retreat of the cliff top edge towards Old Castle Road. This process could impact the road within a year, even without additional triggers. Damage will likely manifest as curvi-linear tension cracks, progressive dis-levelment between cracks, and gross settlement/breaching of the road.
- Future toe erosion events due to storm surges with spring high tides and/or elevated groundwater pressures due to prolonged/heavy rainfall have the potential to cause further movement within the body of the landslide and ongoing episodic landward migration of the headscarp toward/onto the road. Based on the rate of historical cliff top erosion (which is episodic but averages at over 1 m/year with reference to past LiDAR scans) and the size of the recent plateau failure (3-7m), it is anticipated that the next significant movement of the main translational slide could result in loss of some or all of the road. Such an event is most likely during winter but is possible at any time in response to rainfall, storm and wave triggers.

Both of these processes place the road at significant risk of breaching by the landslide. The level of risk is such that short-term intervention to protect the road is needed to secure time to implement a more permanent solution.

5. Recommendations

Due to the level of landslide risk to Old Castle Road, the following actions are recommended in the short-term:

- Emergency installation (*i.e.* before the wet weather returns later in the year) of a high, continuous kerb stone replacing the sandbags currently situated along the roadside. Although the sandbags help direct water away from the landslide, a kerb stone will intercept and divert a greater proportion of surface water, preventing it from entering the landslide system. Care will need to be taken not to disturb the cliff edge when installing the kerb stone.

- Highway Authority to undertake weekly inspections of the road and the ground between the kerbside and cliff edge for signs of cliff retreat, subsidence, tension cracks and surface water flows.

- Act to prevent water entering the cliff from the road if signs of surface water flows are observed.

- Close the road if settlement or tension cracks, which are a sign of imminent collapse, are observed in the road.

- Consider a weight restriction of 7.5t on the road to reduce loading by vehicles which has the potential to trigger failure of the cliff and cause damage to vehicles and other property.
- Monthly monitoring of toe erosion. Ultimately any successful scheme to stabilise the road could have to include an element of toe protection for the slope to provide support and prevention of undercutting.

- Monthly inspection of the landslide to identify ongoing movement and risk.

- Ground investigation to define the elevation and behaviour of key geological units and groundwater within the system and the landslide ground model. Along with the slope monitoring in the point below, the results could provide the information required to design and install a soil nail and mesh system devised to stabilise the upper part of the cliff and protect the highways asset in the short-term.

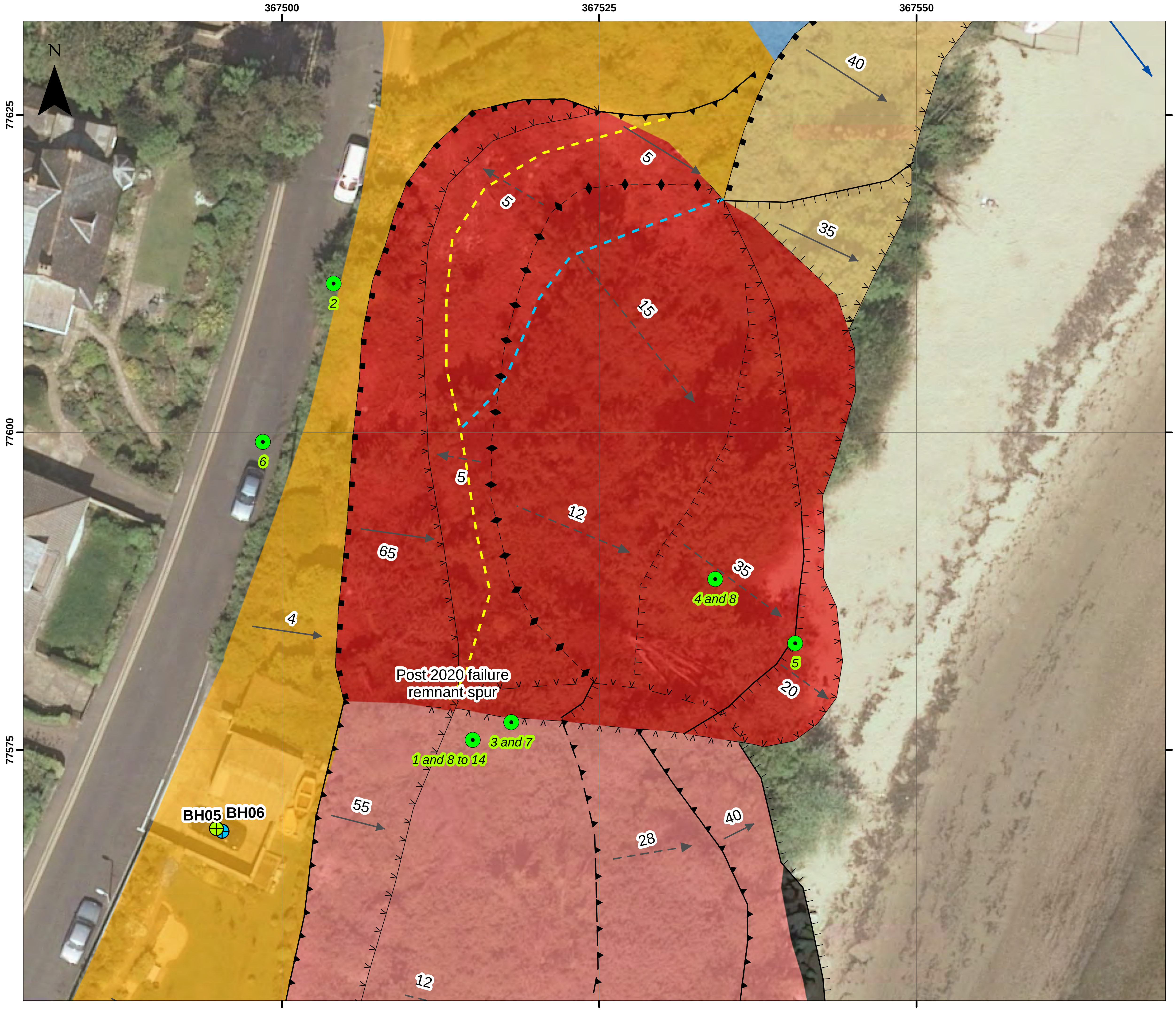
- Slope instrumentation (including inclinometers and piezometers) and laser scanning to detect and monitor groundwater occurrence and slope movement. Depending on the coverage and array of the instrumentation, this may also provide a suitable early warning system for conditions which may result in further slope movement.

These actions have been outlined as temporary measures to monitor and reduce the risk of further ground movement in the short-term. During this time, it is recommended that an options assessment be carried out, which may identify the funding and data necessary to carry out the resultant preferred scheme. It is anticipated that a preferred scheme could also include a means to isolate the road from the landslide, more formal toe protection in order to stabilise the base of the landslide, and targeted drainage to alleviate excess pore water pressures within the system.

6. References

- Halcrow. (2008). Portland Harbour North-Western Shore Strategic Study – Final Report. Weymouth and Portland Borough Council. Investigation (Supplementary) Factual Report & Interpretative Report.
- Halcrow. (2011). Portland Harbour North-Western Shore Study Coastal Instability Analysis and Cliff Management Strategy. Weymouth and Portland Borough Council. Investigation (Supplementary), Factual Report & Interpretative Report.
- Halcrow. (2013). 2013 Portland Harbour North Shore Cliff Behaviour and Condition Assessment. Weymouth and Portland Borough Council, Factual Report & Interpretative Report.
- Halcrow. (2015). 2015 Portland Harbour North Shore Cliff Behaviour and Condition Assessment. Weymouth and Portland Borough Council, Factual Report & Interpretative Report.

Appendix 1. Old Castle Road Landslide Mapping and Observations



Legend

- Site photos 2020
- Borehole Inclinometer
- Borehole Piezometer

Feature

- Sharp ridge
- Smooth ridge
- Sharp convex break of slope
- Cliff
- Sharp break of slope
- Smooth break of slope
- Smooth convex break of slope
- Sharp concave break of slope
- Smooth concave break of slope
- Flat ground
- Slope angle
- Slope angle (undulating ground)
- Stream
- Approx pre-failure headscarp
- 2008 headscarp position

Features in Sandsfoot Grit/Clay

- Cliff top in Clavellata Beds
- Cliff top in Sandsfoot Clay
- Cliff top in Sandsfoot Grit
- Cliff in Sandsfoot Grit/Clay
- Degraded coastal slope
- Marginally stable landslide
- Active landslide
- Valley side slope

Dorset Council

Appendix 1
May 2020 Landslide Mapping and Observations

Drawn by:	RF	Date:	June 2020
Checked by :	OD	Date:	June 2020
Approved by:	RM	Date:	June 2020

Background image is a 10cm resolution orthorectified aerial photograph taken in 2008. Courtesy of the Channel Coastal Observatory.

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