Hutt City Council
30 Laings Road
Private Bag 31912
Lower Hutt 5040
New Zealand

www.huttcity.govt.nz

T 04 570 6666
F 04 569 4290

29 March 2023

Mark Crofskey
s 7(2)(a) [redacted]

Tēnā koe Mark

Request for Information pursuant to the Local Government Official Information and Meetings Act 1987 (LGOIMA)

Thank you for your official information request of 1 March 2023, addressed to Jo Miller and Derek Kerite. Jo and Derek have forwarded your request to me so that I can prepare the response.

You have requested the following official information:

> *"In your update you refer to access arrangements having been entered into with relation to non-council owned property - can you provide these to me - with personal details redacted of course.*
>
> *Could you please provide me with copies of reports you have on hand relating to the stability of the slope located above Eastern Hutt Road and below Holborn Drive (in particular relating to the area below the land at 58 and 60 Holborn Drive).*
>
> *I am also interested in any reports that you may have received relating to the slope below Easter Hutt Road in that area.*
>
> *I would be interested to see reports from well-respected firms such as Tonkin and Taylor, AECOM New Zealand Limited, IRBA Geological Engineering Consultants, OPUS/WPS, GNS Science, ENGEO, - but you may have received others.*
>
> *I am also interested in seeing reports (or indeed ANY information) relating to ANY council owned structures on or which traverse the properties located on 58 and 60 Holborn Drive, including, but not limited to, three waters infrastructure and any maintenance schedules or testing records on such structures.*
>
> *I would like to see any policies the council has in relation to the maintenance of council-owned infrastructure on private property.*
>
> *I would also like to see whatever policies or worksheets the Hutt City Council has in place to guide the CEO and staff on their duties and obligations to landowners upon the receipt of reports whose conclusions or recommendations might have an impact on land not owned by the Hutt City Council (for example which might indicate a risk of landslides).*

With respect to reports that indicate a risk of landslides (or other impacts) - in each case what dates were affected landowners made aware of such reports (or the relevant conclusions, summaries or recommendations)."

On 9 March 2023 you clarified that, for each of the above points, you also wanted information for 46 Holborn Drive.

On 9 March 2023 Brad Cato emailed you a link to a previous LGOIMA response that is published on Hutt City Council's website. The material attached to that response will address your information request in part. Where the information you requested is not provided in that published response, it is addressed below for each of your points.

In your update you refer to access arrangements having been entered into with relation to non-council owned property - can you provide these to me …

Access agreements are attached.

Could you please provide me with copies of reports you have on hand relating to the stability of the slope located above Eastern Hutt Road and below Holborn Drive (in particular relating to the area below the land at 58 and 60 Holborn Drive (also 46 Holborn Drive)

I am also interested in any reports that you may have received relating to the slope below Easter Hutt Road in that area

I would be interested to see reports from well-respected firms such as Tonkin and Taylor, AECOM New Zealand Limited, IRBA Geological Enginering Consultants, OPUS/WPS, GNS Science, ENGEO, - but you may have received others

Reports requested in the above 3 paragraphs are attached.

I am also interested in seeing reports (or indeed ANY information) relating to ANY council owned structures on or which traverse the properties located on 58 and 60 Holborn Drive, including, but not limited to, three waters infrastructure and any maintenance schedules or testing records on such structures (1 March 2023)

This information is currently being retrieved and will be provided to you in due course.
Attached to proactively released response

Please note that some material has been withheld from the attached documents under the following sections of the LGOIMA:

- Section 7(2)(a), to protect the privacy of the individuals concerned
- Section 7(2)(b)(ii), to protect the commercial position of the person who supplied, or is the subject of, the information

You have also asked for the information bulleted below:

- ***I would like to see any policies the council has in relation to the maintenance of council-owned infrastructure on private property***

- ***I would also like to see whatever policies or worksheets the Hutt City Council has in place to guide the CEO and staff on their duties and obligations to landowners upon the receipt of reports whose conclusions or recommendations might have an impact on land not owned by the Hutt City Council (for example which might indicate a risk of landslides)***

- ***With respect to reports that indicate a risk of landslides (or other impacts) - in each case what dates were affected landowners made aware of such reports (or the relevant conclusions, summaries or recommendations)***

No information is held by the Hutt City Council for the above 3 information sets. Accordingly your request for this information is refused to you under section 17(g)(i) of the LGOIMA.

You have the right to seek an investigation and review by the Ombudsman of this response. Information about how to make a complaint is available at www.ombudsman.parliament.nz or freephone 0800 802 602.

Please note that this letter may be published on the Council's website.

Nāku noa, nā

Susan Sales
Senior Advisor, Official Information and Privacy

HUTT CITY
TE AWA KAIRANGI

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T 04 570 6666

1 February 2023

[redacted]

58 Holborn Drive
Stoke Valley

LOWER HUTT

Jon Kingsbury
Transport
Jon.Kingsbury@huttcity.govt.nz

Dear [redacted]

RE: Access agreement to repair landslip

Dear [redacted]

This letter confirms your permission for Hutt City Council ("Council") and its contractors to access your property at 58 Holborn Dr for the purpose of remediating the landslip below. We will give you notice of work beginning so you know when we will need access.

As you know, on 22 July 2022, a major landslip occurred below Holborn Drive. There was a subsequent slip later in August below 58 Holborn Dr. The remedial work requires access from above through your property.

Council and its contractors will require access to your property and may need to store equipment on your property.

We will aim to cause as little inconvenience as possible, however there will be construction works and noise associated with this from time to time.

If you have any questions, please do not hesitate to ask.

Ngā manākitanga

Hutt City Council
Jon Kingsbury
Head of Transport

[redacted] give Hutt City Council and its contractors permission to access my property for the purpose of Eastern Hutt Rd slip assessment and remediation.

Signed [redacted]

Date 15-2-2023

WARRANT UNDER S129 OF THE BUILDING ACT 2004

I, Johanna Miller, Chief Executive, **Hutt City Council** (**Council**), determine that in my judgement there is, arising from the state of the dangerous building identified below, an immediate danger to the safety of people in terms of sections 121 and 129 of the Building Act 2004 and that the measures outlined below are necessary to remove that danger:

Dangerous building	**46 Holborn Drive, Stokes Valley, Lower Hutt 5019** Computer Freehold Register WN6D/371 legally described as Lot 9 DP 16216 and Lot 35 DP 24219 being 1643 square metres more or less. **(Building)**
Measures to be taken	Take any necessary action to remove the whole of the Building, and subsequently stabilise and/or reprofile the slip slope below. The works are broadly described below, and must include all necessary and related health and safety measures, traffic management, disconnection of services and removal of material offsite.
Overview of demolition and remedial works:	Demolition of the Building is to occur. A proposed demolition plan/methodology is to be prepared prior to commencement of work. That plan is to include:

1. When demolition is to commence.
2. When demolition is proposed to be completed.
3. Removal of demolition material from the site.
4. Any other specifications for demolition related to safety of Eastern Hutt Road below.
5. Technical specifications for what is required in terms of stabilising the slope.

I base my view on the need for demolition of the Building on:

1. Advice that I have received from Council building officers.
2. The content of the Aecom independent engineering report dated 18 January 2023.
3. Confirmation that Council received from two contractors on 14 February 2023 that the slope remediation cannot occur until the Building is removed.
4. An assessment from Council's building managers on 14 February 2023 confirming that it is unlikely that a building consent could be issued for re-piling/foundation strengthening of the Building in its current position. I have therefore accepted the advice that the option of installing an anchored shotcrete wall on the slip face at the same time as retrofitting the Building foundations is not appropriate for a range of reasons, including the time and uncertainty of outcome involved in that process.

Based on all of the information received and reviewed, I am satisfied that as a result of damage caused by the slip which occurred on 24 July 2022, the Building now poses an immediate and imminent risk of injury to people entering it or in its immediate vicinity and needs to be removed.

I have had due regard to the matters in section 129 of the Building Act 2004 and I am satisfied that the above measures constitute the most appropriate course of action in the circumstances.

In accordance with section 129 of the Building Act 2004, I issue this warrant authorising Council building officers to cause the measures above to be taken.

I understand that if required Hutt City Council will apply to the Hutt Valley District Court for confirmation of any action taken under this warrant, unless s130(3) of the Building Act 2004 applies.

Dated this 14th day of February 2023

s7(2)(a) [redacted]

Johanna Miller
Chief Executive
Hutt City Council

ACCESS AND COST SHARING AGREEMENT – 60 HOLBORN DRIVE, STOKES VALLEY, SLIP REMEDIATION

HUTT CITY COUNCIL

s7(2)(a) [redacted]

22 FEBRUARY 2023

PARTIES

Hutt City Council (**Council**)

s7(2)(a) [redacted] **(the Landowner)**

BACKGROUND

A On 21 July 2022, a significant rain event resulted in several slips along the Eastern Hutt Road. The top portion of one of these slips is on 60 Holborn Drive, Stokes Valley (being WN26A/407, Lot 42 Deposited Plan 24219) ("the Private Land"). The bottom portion of the slip is on land owned by Hutt City Council, with a legal road at the bottom of the slope ("the HCC land"). The slip affects both the Private Land and the HCC Land (collectively "the Land").

B A Dangerous Building Notice ("the Notice") was issued and remains in place for the dwelling on 60 Holborn Drive. While the dwelling has been assessed as structurally sound, the engineering advice to Council concludes that the dwelling would only be safe to occupy following remediation of the slope where the slip occurred. This is due to the potential effect of a further slip undermining the dwelling.

C Based on the engineering advice received, Council considers it has two viable options to remediate the slip on the Land:

i) The first is a catch fence below the slip. This will protect road users, however it will not remediate the slope. It would require the Dangerous Building Notice for the dwelling to remain in place indefinitely.

ii) Design and construct an anchored shotcrete wall to remediate the slip face as a whole, which necessarily involves work on both the Council's land and the Landowner's land. This is Council's preferred option. It is considered to be the better long-term solution, and once complete would enable the Dangerous Building Notice to be lifted.

D The purpose of this agreement is to set out the access and cost sharing arrangement in order for the anchored shotcrete option to proceed.

OPERATIVE PROVISIONS

1 DEFINITIONS AND INTERPRETATION

Definitions

1.1 In this agreement the following definitions apply:

Contractor means the Council's contractor/s undertaking the Project Works.

Practical Completion means when the Project Works for the Project have achieved practical completion (or equivalent status) under the construction contract for those works.

Project Works means the works necessary to remediate the slope, being an anchored shotcrete wall of the type described at paragraph 5.2.1. of the Aecom report of 22 November 2022, and all things necessary to achieve this. This does not include any works on the dwelling or garage. For the interest of clarity the works include all necessary work to remediate the Land.

2 COST SHARING AGREEMENT

The Project Works

2.1 The parties agree the following in respect of undertaking the Project Works:

2.1.1 Council will undertake the Project Works via the Contractor:

(a) on industry standard terms and conditions and in a good and workmanlike manner;

(b) in accordance with the terms and conditions of all consents and approvals, the requirements of any relevant authority and all laws applicable to the Project Works;

(c) with due care and respect for the Private Land;

(d) with advance notice being provided of start and finish dates, and any variations to them;

2.1.2 Council will ensure that the Project Works are adequately insured under industry standard contract works and public liability insurance policies.

2.1.3 The Council and Contractor will ensure that the finished Project Works and site, including the Private land will be left in a reasonable condition.

Cost sharing principles

2.2 The parties agree the following in respect of the costs associated with the Project Works:

2.2.1 Council will pay:

(a) all consultancy and consenting fees;

(b) the Preliminary and General Costs of Construction; and

(c) all costs associated with the Project Works.

2.2.2 The Landowner will pay:

(a) any costs associated with fencing and landscaping on the Landowner's property, that the Landowner will separately commission if required by law or a resource or building consent or may separately commission if not required by law or a resource or building consent ; and

(b) any variations or additions to the scope of the Project Works required by the Landowner and agreed to by Council. Council will pass along the costs directly from their contractors and not markup or apply any fees such as administration.

Payment

2.3 Following Practical Completion, Council will issue an invoice to the Landowner in respect of any costs outlined in clause 2.2.2 above.

2.4 The Landowner agrees to pay Council all amounts due and payable by the Landowner within 20 working days of receipt of an invoice from Council, or as otherwise agreed by the parties at that time.

Maintenance and Responsibility

2.5 Following completion of the Project Works, Council will be responsible for ongoing maintenance of the Shotcrete Wall located on both the Private Land and Council property. The parties agree that Council may register an instrument on the property title for the Private Land which enables it to have access for this purpose.

2.6 For the avoidance of doubt, Council does not assume any other legal responsibility for the Shotcrete Wall or any other works on the Private Land and improvements remain in the ownership of the Landowner. This does not extend to any Council owned drainage already present on the Private Land.

2.7 The Landowner will not do anything on their land that may affect the Project Works.

Health and safety and access for Project Works

2.8 Council and the Contractor will be responsible for day-to-day management of the site for the Project Works. The Landowner agrees that Council and the Contractor will have access to the site for the purposes of carrying out this agreement and the Project Works.

2.9 Council and the Landowner will comply with reasonable health and safety requirements. Council will procure the Contractor to comply with reasonable health and safety requirements.

MISCELLANEOUS

Assignments and transfers

2.10 A party must not assign or transfer any of its rights or obligations under this agreement without the prior written consent of each of the other parties.

GST payable

2.11 Unless otherwise stated, all amounts and values referred to in this agreement are exclusive of GST.

Contracts (Privity) Act 1982

2.12 Unless this agreement expressly provides otherwise, this agreement is not intended to confer a benefit on any person or class of persons who is not a party to it.

Costs

2.13 Except as otherwise set out in this agreement, each party must pay its own costs and expenses for preparing, negotiating, executing and completing this agreement and any document related to this agreement.

Entire agreement

2.14 This agreement contains everything the parties have agreed in relation to the subject matter it deals with. No party can rely on an earlier written document or anything said or done by or on behalf of another party before this agreement was executed.

Execution of separate documents

2.15 This agreement is properly executed if each party executes either this document or an identical document. In the latter case, this agreement takes effect when the separately executed documents are exchanged between the parties.

Further acts

2.16 Each party must at its own expense promptly execute all documents and do or use reasonable endeavours to cause a third party to do all things that another party from time to time may reasonably request in order to give effect to, perfect or complete this agreement and all transactions incidental to it.

Governing law and jurisdiction

2.17 This agreement is governed by the law of New Zealand. The parties submit to the non-exclusive jurisdiction of its courts and courts of appeal from them. The parties will not object to the exercise of jurisdiction by those courts on any basis.

Severability

2.18 Each provision of this agreement is individually severable. If any provision is or becomes illegal, unenforceable or invalid in any jurisdiction it is to be treated as being severed from this agreement in the relevant jurisdiction, but the rest of this agreement will not be affected. The legality, validity and enforceability of the provision in any other jurisdiction will not be affected.

Variation

2.19 No variation of this agreement will be of any force or effect unless it is in writing and signed by each party to this agreement.

Waivers

2.20 A waiver of any right, power or remedy under this agreement must be in writing signed by the party granting it. A waiver only affects the particular obligation or breach for which it is given. It is not an implied waiver of any other obligation or breach or an implied waiver of that obligation or breach on any other occasion.

2.21 The fact that a party fails to do, or delays in doing, something the party is entitled to do under this agreement does not amount to a waiver.

Key Hutt City Council Contacts

2.22 Caryn Ellis and Casey Truman at the Council will be the appropriate Council officer contact points once the Project Works commence.

EXECUTION AND DATE

Executed as an agreement.

Hutt City Council by:

s7(2)(a) [redacted] ....

Signature of authorised person

Jo Miller
Name of authorised person (print)

Chief Executive
Office held

The Landowner by:

s7(2)(a) [redacted] ....

....

Date: 22 February 2023

Tonkin+Taylor

Job No: 1503000.0036
30 November 2022

[redacted]
By Email

Claim for Natural Disaster (Landslip) Damage

[redacted] 46 Holborn Drive, Stokes Valley, Lower Hutt, Wellington, 5019

EQC/Insurer Claim Number [redacted]

1 Introduction

As requested, Tonkin & Taylor Ltd (T+T) inspected the subject property on 26 July 2022 (UAV survey), 11 August 2022 (internal inspection), 23 August 2022 (UAV survey), 15 September 2022 (UAV survey following temporary scaling works of the landslip face) to assess the claim for natural disaster damage. In particular the visit was undertaken to determine whether physical loss or damage to property is imminent as a direct result of the natural disaster that has occurred.

This claim relates to rainfall triggered landslips that occurred on the property in July 2022.

[redacted] for a landslip triggered by a rainfall event that occurred in [redacted] Further heavy and prolonged rainfall throughout July and August 2022 has resulted in the [redacted] landslip extending further to the south and the debris associated with it to remobilise. This has resulted in new damage occurring to the land and dwelling as a result of extraordinary weather conditions through July and August 2022.

[redacted] engaged [redacted] to review, and further assist with the geotechnical site conditions, evaluation and assessment of the area affected by landslip with a view to undertaking engineering remedial works for the December 2021 landslip. This information was summarised in a letter report 'Geotechnical Investigation and Assessment of the area affected by the Landslip and proposed remedial options' prepared by [redacted] dated 16 June 2022 (Project Number: [redacted]

This report has been updated and supersedes our previous report dated 11 November 2022.

Tonkin & Taylor Ltd | Harbour Tower, Level 4, 2 Hunter Street, Wellington 6011, New Zealand
PO Box 2083, Wellington 6140 P +64-4-381 8560 F +64-9-307 0265 E wlg@tonkintaylor.co.nz

2 Site description

The property is located on the northern side of Holborn Drive, upslope of Eastern Hutt Road. This property is legally described as Lot 9 DP 16216, where the site is located on the cut platform of a moderately steep (50 to 60 degrees) slope dropping away in a north and northeast direction. The paved accessway to the dwelling is cut into a slope of approximately 10 to 25 degrees, creating a steep slope between 0 m to 2 m high along the west side of the accessway. A rotary clothesline is located just west of the accessway at the top of the cut slope about 7 m south from the dwelling.

A single-storey dwelling is located at the middle of the property. There is a steel beam and timber deck constructed around the north, east and south side of the dwelling. The eastern and southern sides of the deck are supported on timber piles, the northern side is supported by a cantilevered steel beam which extends under the dwelling. A narrow unpaved access path exists next to the southeast side of the timber deck, with one end adjoining the northern end of the driveway and the other end being directly under the north-eastern corner of the timber deck. Looking from east to west at the north end of the access path, the underside structure of the timber deck and the corner of the dwelling could be observed. It was seen that the cantilevered deck appears to be built over an old concrete footpath that is now broken up. The timber deck was consented and constructed in 2002. Under the timber deck is a line of stormwater pipe, which runs along the eastern and northern side of the deck.

A property file search was carried out. The dwelling was constructed in the late 1950s. Original dwelling construction drawings are unclear however from site observations it is assumed the dwelling has precast concrete pile foundations, with an unknown founding depth. Typical construction of the time was for piles to be founded in the order of 300 mm deep or to solid bearing. Consent approved drawings of the 2002 deck construction, indicate the cantilevered steel beams (310UB46 – total length 7.5 m) extend approximately 4.5 m under the northern side of the dwelling. They are founded on 600 x 600 x 900 mm deep reinforced concrete foundations that are located at the northern perimeter of the dwelling and towards the centre of the dwelling. They do not appear to be connected to the dwelling piles however the drawings indicate the steel beams are connected to the external timber bearers at the perimeter of the dwelling, via coach screw connections.

Three landslips have occurred on the property as a result of the July 2022 heavy and prolonged rainfall events.

A large landslip (landslip 1) that occurred on the north facing slope (the escarpment) below the dwelling and cantilevered deck in December 2021, resulted in evacuation of land within 8m of the dwelling and no resultant dwelling damage. Further evacuation of land has now widened to the northeast and continued towards the southwest as a result of extraordinary weather conditions with continued prolonged rainfall throughout July and August 2022. The headscarp area of the original landslip does not appear to have regressed further back upslope, although some relaxation of land behind the headscarp is expected to have occurred, as the slope debris supporting the headscarp area has remobilised fully as a result of the recent July/ August prolonged rainfall. The evacuation of land continues down the entire escarpment slope across the property boundary into Hutt City Council (HCC) land and onto Eastern Hutt Road below. Debris has accumulated on land beyond the property boundary, which extends to the base of the slope. A series of shipping containers have been placed by HCC at the base of the slope within the road carriageway to reduce further slope debris material from depositing onto the road.

It is understood HCC has trimmed the slope of the large landslip 1 face of loose material and vegetation as reported by the property owner in early September 2022. A follow up inspection of the site was undertaken to determine the extent of debris clearing and trimming the council has undertaken.

Two small landslips have occurred on the west facing slope along the accessway. Landslip 2 is located within 8 m of the rotary clothesline resulting in evacuation and inundation of insured land. Landslip 3 is located upslope of the main accessway and is within 60 m of the dwelling resulting in inundation of insured land. There has been some movement of land and vegetation hanging on the slope around Landslip 3.

The published geology of the area[1] indicates that the site is underlain by Rakaia Terrane formation comprised of alternating sandstone/argillite (greywacke). Based on site observations, the slope appears to comprise a thin layer of colluvium over in-situ greywacke rock, as some rock outcrops were present in the adjacent slopes. Groundwater seepage was observed on the escarpment slope within the landslip 1 surface.

The locations of the landslips and the extent of the damage are shown on the attached sketches and photographs. The conclusions and recommendations in this report are based on a visual assessment of the site only. It must be appreciated that subsurface conditions may vary from those inferred in this report.

An unmanned aerial vehicle (UAV) survey was conducted as a part of the inspections to create an ortho-mosaic aerial image and digital elevation model (DEM) for use in this report. This data has not been georeferenced to cadastral survey and should not be used for design purposes.

Property boundaries are based on Land Information New Zealand (LINZ) information overlain on aerial imagery.

3 Property damage

Landslip 1: The damage to the property consists of an approximately 10-15 m wide landslip adjacent to the north side of the dwelling which has resulted in:

- Evacuation of insured land; and
- Internal cosmetic stress cracking damage to the dwelling walls and ceiling within the lounge as a result of relaxation (vertical support) of the land behind the headscarp due to loss of lateral land support.

The landslip scarp extends beyond the extent of insured land on the property and the area where debris has accumulated is beyond the property boundary. The landslip measured approximately 7-8m wide following the July 2022 rainfall and extended up to 15m wide following the heavy and prolonged rainfall throughout July and August 2022.

The northeastern corner of the lounge windowsill measured 0.5 degrees out of level however the property owner indicated this was historic and it had not changed as a result of the landslip.

Landslip 2: The damage to the property consists of a 2.6 m wide landslip located 4.8 m from an appurtenant structure (rotary clothesline) which has resulted in:

- Evacuation of insured land; and
- Inundation of insured land.

Landslip 3: The damage to the property consists of a 6 m wide landslip on the west facing cut slope, upslope of the accessway within 60m of the dwelling which has resulted in:

- Inundation of insured land.

1. Begg, J.G., Johnston, M.R. (compilers) 2000: Geology of the Wellington area. Institute of Geological & Nuclear Sciences 1:250,000 geological map 10. 1 sheet + 64 p. Lower Hutt, New Zealand. Institute of Geological & Nuclear Sciences Limited.

4 EQC considerations

We consider the damage bullet pointed above to be natural disaster (landslip) damage as defined by the Earthquake Commission Act 1993 (EQC Act).

It is considered some of the imminent risk has been realised from the July 2022 landslip as a result of the extension of the landslip towards the south in August as no remedial works could have reasonably been undertaken in that short timeframe.

5 Imminent risk

Within the following 12 months (under normal annual rainfall conditions) and as a direct result of the landslips that have occurred there is an imminent risk of regression/ relaxation of the landslip headscarps and sidescarps resulting in:

Landslip 1: within 8 m of the dwelling

- Evacuation of additional insured land; and
- Undermining and loss of lateral support of reinforced concrete foundations (No.4) supporting the cantilevered steel beams on northern side of deck
  - leading to potential deformation of 42 m^2 of deck structure.
- Undermining and loss of lateral support of concrete pile dwelling foundations (assumed No.12) on northern side of dwelling
  - leading to potential deformation / settlement of approx. 47 m^2 of dwelling including roof/ gutter, wall and ceiling framing and internal/ external cladding damage
  - Further internal cosmetic stress cracking damage to the gib walls and ceiling is likely to occur through to the southern extents of the dwelling.
- Services – stormwater pipe attached to the deck.

The dwelling has been damaged and is considered to be at imminent risk as a direct result of the natural disaster (landslip) that has occurred.

Landslip 2: within 8 m of appurtenant structure (rotary clothesline)

- Evacuation of additional insured land; and
- Re-inundation of insured land.

Landslip 3: On the accessway within 60 m of the dwelling

- Re-inundation of insured land; and
- New inundation of insured land.

6 Conceptual remedial works

The information in the following section is provided solely to [redacted] for EQC claim settlement purposes. The conceptual remedial works are for [redacted]ost estimation only, to enable [redacted] to assess the likely costs of repairing the damaged insured property and/or, the cost of preventing damage to insured property that is considered imminent as a direct result of the natural disaster that has occurred. The conceptual remedial works, and drawings, are NOT FOR CONSTRUCTION.

Landslip 1: There may be an alternative remedial works solution (e.g., relocate the dwelling within the property away from the risk of new land movement and the steep escarpment slope) which may be more cost effective or appropriate for the insured and wider property (beyond EQC insured land). It may also be possible to implement an alternative solution to work in collaboration with Hutt City Council regarding the entire affected escarpment slope.

The conceptual remedial solution is developed within the constraints of working solely within the property boundary. Consideration and collaboration with HCC would be required for working above the Eastern Hutt Road corridor. Access to undertake the conceptual remedial works is very difficult and works will need to be undertaken within the dwelling footprint, that will require equipment and construction inside the dwelling. Partial removal of the deck may be required depending on Contractor requirements for access.

A conceptual remedial works solution that removes imminent risk to insured property, could comprise the following:

- Remove loose material and vegetation from the slope and dispose off-site (~15 m^3);
- Prepare the working area, including scaffolding for anchor installation. It is expected that equipment will need to be carried by hand to the area, and abseiling required for construction on a steep slope; including construction of temporary catch fence at bottom of slope and establishing anchor points for abseil.
- Install vertical micropiles to underpin the northern edge of the dwelling and the steel cantilevered deck beams, with the following properties:
  - 8 No., along the northern edge of the dwelling, 100 mm diameter, 3 m total length, fully grouted with RB32 reinforcing. Micropiles to be installed each side of each deck beam footing, and attached to the footing via an in situ concrete pile cap and drilled and epoxied starter bars.
  - 2 No., along the eastern edge of the dwelling, 100 mm dia, 3 m total length, fully grouted with RB32 reinforcing. Micropiles to be installed each side of the existing timber dwelling bearer, connected by a steel beam that supports the dwelling bearer.
- Construct an anchored reinforced sprayed concrete retaining wall having the following dimension/characteristics/properties:
  - Up to 15 m long wall, 16 m maximum retained vertical height (19 m high slope length).
  - Install 78 No. RB32 galvanised steel bars in 100 mm diameter grout filled hole.
  - Rock anchors at maximum of 1.75 m horizontal and vertical centres, inclined at 15°. Minimum 5.5m long.
  - Colbond drains at 0.5 m horizontal centres pinned diagonally to slope
  - Minimum 150 mm thick, steel reinforced, 30 MPa sprayed shotcrete, Dramix fibre RC65/35 BN minimum dosage 38.5 kg/m^3 with two layers of 665 mesh around anchor heads. 150 mm localised thickening of sprayed concrete around anchor heads (~285 m^2 face area).

  - Galvanised anchor plates and lock nuts wrapped in densotape.
- Jack and pack the dwelling piles and deck as required.
- Reinstate damage to dwelling and deck.

A drawing of this conceptual remedial works solution is shown in Sketches 3 and 4.

Additional information for cost estimation:

Construction Issues	Easy	Moderate	Hard	N/A
Construction Access			☒	
Earthworks required			☒	
Constructability/Reinstatement			☒	

Construction methodology and sequencing of the remedial works will be required to ensure the slope, dwelling and deck are secured to safely undertake any proposed works along with consideration of working above Eastern Hutt Road.

A building and/or Resource consent, is likely to be required and this should be confirmed with the Local Authority prior to any remedial works being undertaken.

Subsurface investigation, engineering design and subsequent sign off by a chartered professional engineer is likely to be required as part of the building consent application. Regular inspections by a Chartered Engineer may also be necessary during the works to enable sign - off in accordance with the 2004 Building Act and the conditions of the building consent. Failure to obtain the required consents could mean that the building works have to be removed.

All remedial solutions should consider safety in design. Any construction works should be undertaken in a safe and appropriate manner, including the allowance for all necessary protection and temporary stabilisation works as required to ensure the safety of all persons working or present on site during construction.

We estimate the cost (excluding GST) to design and consent the proposed solution for Landslip 1 will be as follows:

Geotechnical engineering investigation, design and drawings	[redacted]	
Structural engineering design and drawings	[redacted]	
Survey	[redacted]	
Building/Resource consents	[redacted]	
Construction observations and Producer Statements	[redacted]	
Project Management	[redacted]	
TOTAL (Excluding GST)	[redacted]	

*The construction cost estimate for the proposed solution will be provided by the cost estimator.

There may be an alternative remedial works solution which is more cost effective or appropriate for the property owner and wider property (beyond EQC insured land). It may be possible to implement an alternative solution.

Landslip 2: A conceptual remedial works solution that reinstates the land damage to a similar condition and/or removes imminent risk to insured property, would comprise the following:

- Trim the slope and headscarp to a maximum of 60 degrees (estimate 2 m^3) and dispose spoil off-site
- Install timber crib retaining wall having the following dimension / characteristics / properties:
  - 3 m long wall
  - 1.8 m maximum retained height

A drawing of this conceptual remedial works solution is shown in Sketch 7.

Additional information for cost estimation:

Construction Issues	**Easy**	**Moderate**	**Hard**	**N/A**
Construction access	☒	☐	☐	☐
Earthworks required	☒	☐	☐	☐
Constructability/Reinstatement	☒	☐	☐	☐

We estimate the cost (excluding GST) to design and consent the proposed solution for Landslip 2 will be as follows:

Geotechnical engineering investigation, design and drawings	[redacted]
Survey	
Building/Resource consents	
Construction observations and Producer Statements	
Project Management	
TOTAL (Excluding GST)	

***The construction cost estimate for the proposed solution will be provided by the cost estimator.**

Landslip 3: A conceptual remedial works solution that removes imminent risk to insured property, would comprise the following:

- Remove debris (estimate 0.5 m^3) and dispose off-site.
- Install a timber pole catch barrier along the side of the accessway with the following dimension / characteristics / properties:
  - 6 m long wall, 1.2 m high
  - 200 mm SED (H5) poles at 1.0 m centres, embedded minimum 1.5 m
  - 50 mm rails (H4) spanning poles
  - Backfill with free draining material at base of wall to create catch pit to absorb energy of re-mobilised debris.

A drawing of this conceptual remedial works solution is shown in Sketch 10.

Additional information for cost estimation:

Construction Issues	Easy	Moderate	Hard	N/A
Construction access	☒	☐	☐	☐
Earthworks required	☒	☐	☐	☐
Constructability/Reinstatement	☒	☐	☐	☐

We estimate the cost (excluding GST) to design and consent the proposed solution for Landslip 3 will be as follows:

Geotechnical engineering investigation, design and drawings	[redacted]	
Survey (proximity to boundary)		
Building/Resource consents		
Construction observations and Producer Statements		
Project Management		
TOTAL (Excluding GST)		

*The construction cost estimate for the proposed solution will be provided by the cost estimator.

7 Summary of Information

	[redacted]	July 2022 [redacted]	Aug 2022
Is this natural disaster damage?	*Landslip*	**Landslip 1**	**Landslip 1**
Land within 8 m of dwelling or appurtenant structures	***Yes***	**Yes**	**Yes**
Area of insured land **damaged:** **Evacuated:** Note: **Total 55 m² new** area damage since Dec 2021	 *30 m²*	 50 m² (20 m² new area)	 35 m² (Imminent risk from July 2022 realised)
Inundated:	*3 m²*	Nil	Nil
Area of insured land **at imminent risk** **Evacuation: Total 65m²** (30m² newly identified land at imminent risk following August 2022 + 35m² of imminent risk from Jul 2022 not realised in Aug 2022)	 *19 m²*	 70 m²	 65 m²
New inundation:	*12 m²*	Nil	Nil
Re-inundation:	*Nil*	Nil	Nil
Main access way within 60 m of dwelling	***N/A***	**N/A**	**N/A**
Retaining walls supporting or protecting insured buildings and/or land located within 60 m of dwelling (or an appurtenant structure)	***N/A***	**N/A**	**N/A**
Dwelling and appurtenant structure(s)			
Has the dwelling or appurtenant structure been damaged as a result of the natural disaster? • *Internal cosmetic stress cracking damage to the dwelling walls and ceiling within the lounge as a result of relaxation (vertical support) of the land behind the headscarp due to loss of lateral land support.*	*No*	*Not assessed at time of site inspection*	Yes

	[redacted]	July 2022 [redacted]	Aug 2022
Is this natural disaster damage?	*Landslip*	**Landslip 1**	**Landslip 1**
Dwelling and appurtenant structure(s)			
Cost to repair damage	*N/A*	N/A	TBA*
Is damage to the dwelling (or appurtenant structure) imminent as the direct result of a natural disaster? • *Undermining and loss of lateral support of reinforced concrete foundations (No.4) supporting the cantilevered steel beams on northern side of deck* – *leading to potential deformation of 42 m^2 of north deck structure.* • *Undermining and loss of lateral support of concrete pile dwelling foundations (assumed No.12) on northern side of dwelling* – *leading to potential deformation / settlement of approx. 47 m^2 of dwelling including roof/ gutter, wall and ceiling framing and internal/ external cladding damage* – *Further internal cosmetic stress cracking damage to the gib walls and ceiling is likely to occur through to the southern extents of the dwelling.*	*Yes* *(See previous T+T reporting)*	*Not assessed at time of site inspection*	Yes
Cost to remove imminent loss threat to dwelling (or appurtenant structure)	*TBA**	TBA*	TBA*
Value of imminent risk damage to dwelling (or appurtenant structures)	*TBA**	TBA*	TBA*
Services within 60 m of dwelling			
Services damaged	*N/A*	No	No
Services where damage is considered to be imminent • *Stormwater pipe attached to the deck (~10 m)*	*N/A*	*Not assessed at time of site inspection*	Yes
Bridges or culverts situated on insured land	*N/A*	N/A	N/A
Conceptual remedial works type:			
To remove the imminent risk to insured land - remove loose materials from the landslip surface and dispose off-site and construct anchored sprayed concrete wall. To repair and remove imminent risk to the deck and dwelling - install micro-piles for underpinning the foundation and jack and pack to relevel. Plaster and paint walls.	*(See previous T+T reporting)*		[redacted] construction costs* (excluding GST)

*To be assessed by the cost estimator

In addition to the large landslip (Landslip 1) on the northern side of the dwelling two smaller landslips have occurred to the south of the dwelling as a result of the July 2022 rainfall event.

Is this natural disaster damage?	Yes **Landslip 2** [redacted]	Yes **Landslip 3**
Land within 8 m of dwelling or appurtenant structures	**Yes**	**N/A**
Area of insured land **damaged:** Evacuated: within 8m of rotary clothesline Inundated:	 2 m^2 1 m^2 (~1m^3)	 N/A N/A
Area of insured land **at imminent risk** Evacuation: New inundation: Re-inundation:	 1 m^2 Nil 0.5 m^2 (~0.5 m^3)	 N/A N/A N/A
Main access way within 60 m of dwelling	**N/A**	**Yes**
Area of insured land **damaged** on or supporting main access way: Evacuated: Inundated: within 36m of dwelling	 N/A N/A	 N/A 1 m^2 (~0.5 m^3)
Area of insured land at **imminent risk** on or supporting main access way: Evacuation: New Inundation: Re-inundation:	 N/A N/A N/A	 N/A 2 m^2 (~1.5 m^3) 1 m^2 (~0.5 m^3)
Retaining walls supporting or protecting insured buildings and/or land located within 60 m of dwelling (or an appurtenant structure)	**N/A**	**N/A**
Dwelling and appurtenant structure(s)		
Has the dwelling or appurtenant structure been damaged as a result of the natural disaster?	No	No
Is damage to the dwelling (or appurtenant structure) imminent as the direct result of a natural disaster?	No	No
Services within 60 m of dwelling on insured land	**N/A**	**N/A**
Bridges or culverts situated on insured land	**N/A**	**N/A**
Conceptual remedial works:		
Landslip 2: Remove debris, trim slope and construct timber crib retaining wall. **Landslip 3:** Remove debris and construct timber pole catch barrier to remove imminent risk of inundation.	[redacted] construction costs* (excluding GST)	[redacted] construction costs* (excluding GST)

*To be assessed by the cost estimator

8 Applicability

This report was produced for [redacted] for the sole purpose of assisting [redacted] to determine whether EQC has any liabilities under the Earthquake Commission Act 1993 and it may not be relied upon in other contexts or for any other purpose, or by any person other than [redacted] without our prior written agreement.

Yours sincerely

For Tonkin & Taylor Ltd

[redacted]

Principal Consultant

[redacted]

Engineering Geologist

Reviewed by [redacted] and authorised for T+T by [redacted] (Project Director)

Attached: Photographs (1 – 22)
Annotated aerial photograph overview of property – Figure 1
Landslip 1 - Sketches 1 to 4
Landslip 2 - Sketches 5 to 7
Landslip 3 - Sketches 8 to 10

30-Nov-22
t:\auckland\projects\1503000\1503000.0036\issueddocuments\july 2022 event\final report (combined)\t+t_[redacted] final report.v3.docx

Photographs 1 to 22: – 46 Holborn Drive, Stokes Valley, Lower Hutt, Wellington, 5019, NZL .

Photograph 1: Dwelling and landslip 1 from Eastern Hutt Road (Photo taken 10 January 2022).

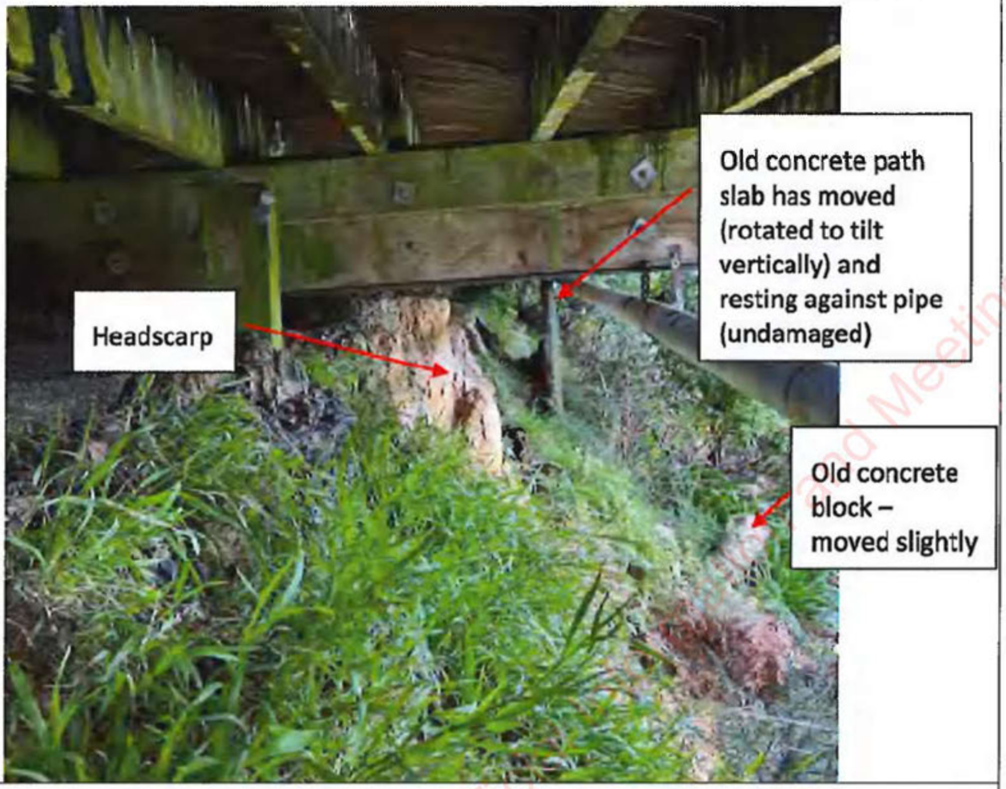
Photograph 2: Dwelling and landslip 1 from Eastern Hutt Road (Comparison photo taken 26 July 2022).

Photograph 3: View of landslip 1 from above – taken from deck (Photo taken 10 January 2022).

Photograph 4: View of landslip 1 from above – taken from deck (Comparison photo taken 26 July 2022).

Photograph 5: View of landslip 1 from above – taken from deck (Comparison photo taken 23 August 2022).

Photograph 6: View at top of landslip 1 from below deck (looking from east to west) (Photo taken 10 January 2022).



Photograph 7: View at top of landslip 1 from below deck (looking from east to west) (Comparison photo taken 26 July 2022).

Photograph 8: View at top of landslip 1 from below deck (looking from east to west) (Comparison photo taken 23 August 2022).

Photograph 9: View under deck (looking north) of landslip 1 (Photo taken 26 July 2022). Old concrete path slab has moved (rotated and tilted vertically) and resting against pipe (undamaged).

Photograph 10: View under deck (looking north) of landslip 1 (Photo taken 23 August 2022). Old concrete path slab has moved downslope as a result of further land movement.

Photograph 11: View under undamaged deck (looking north) down the landslip 1 (Photo taken 26 July 2022). Note old timber pile is not attached to the deck (undamaged).

Photograph 12: View under deck (looking north) down the landslip 1 (Photo taken 23 August 2022). Note timber pile is not attached (assumed to be old deck pile).

Photograph 13: Access to landslip 1. View from below eastern side of deck looking north-west (Photo taken 10 January 2022). This section of deck is supported by timber poles and timber beam.

Photograph 14: Access to landslip 1. View from below eastern side of deck looking north-west (Comparison photo taken 26 July 2022). This section of deck is supported by timber poles and timber beam (undamaged).

Photograph 15: Internal cosmetic cracking damage to internal walls in approximate centre of dwelling as a result of relaxation of land from behind the headscarp of landslip 1 (Photo taken 11 August 2022).

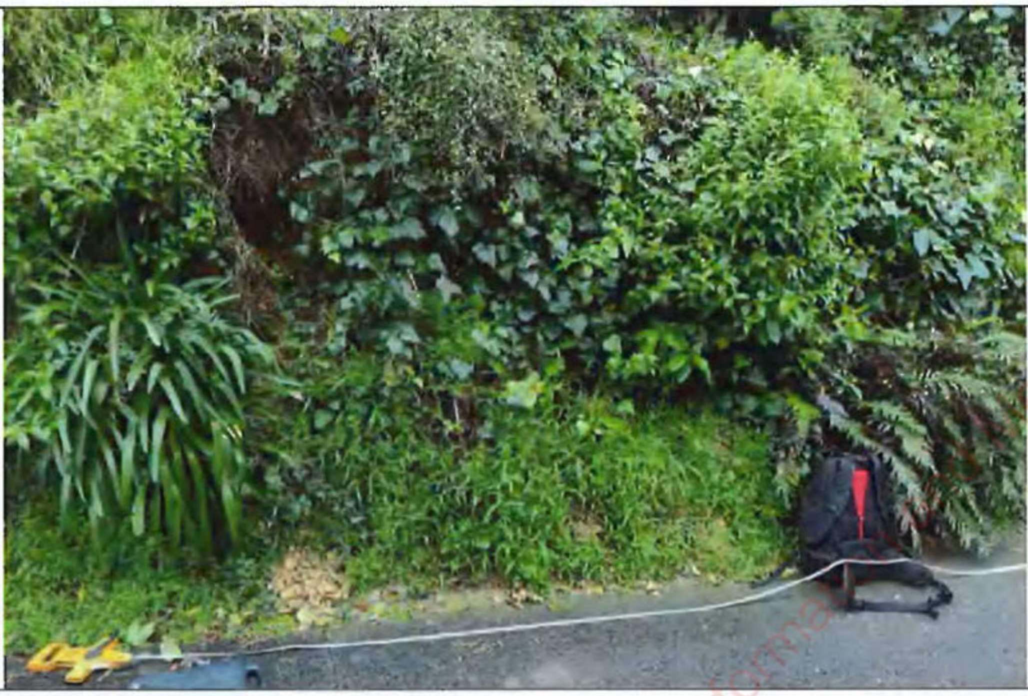
Photograph 16: View through internal floorboards of dwelling looking at concrete pile dwelling foundations and separate steel cantilevered beams for deck (Photo taken 11 August 2022).

Photograph 17: View at top of landslip 1 from below deck (looking from east to west) after trimming/ clearing of slope (Photo taken 15 September 2022).

Photograph 18: View under deck looking at foundations after trimming/ clearing of slope for Landslip 1 (Photo taken 15 September 2022).

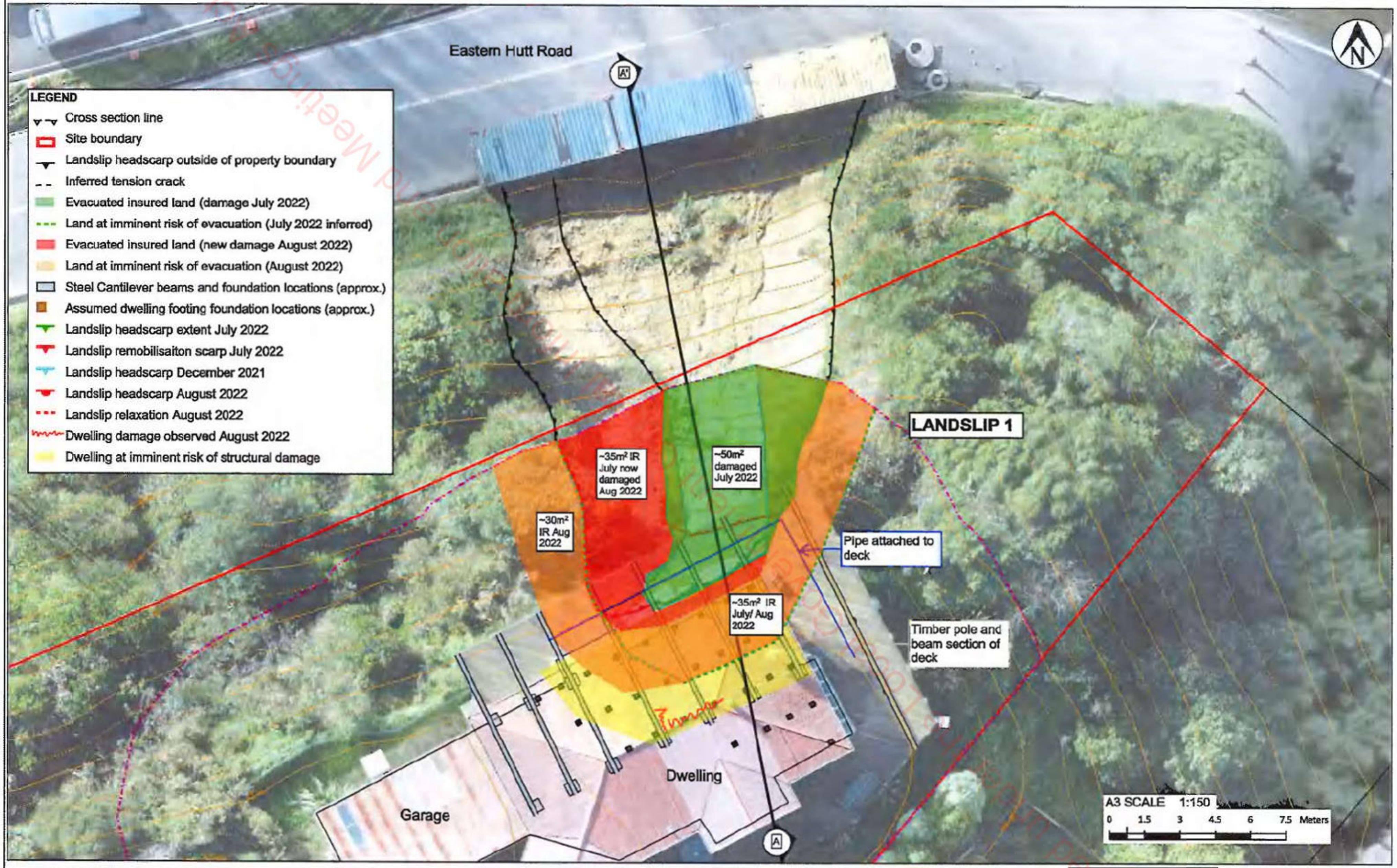
Photograph 19: Landslip 2 within 8 m of clothesline above accessway. View looking north-west (Photo taken 26 July 2022).

Photograph 20: Landslip 2 taken looking north with dwelling in background. (Photo taken 26 July 2022).



Photograph 21: Landslip 3 on the accessway with minor debris inundation onto accessway within 60 m dwelling. View looking north-west. (Photo taken 26 July 2022).

Photograph 22: Landslip 3 close up showing landslip headscarp. (Photo taken 26 July 2022).



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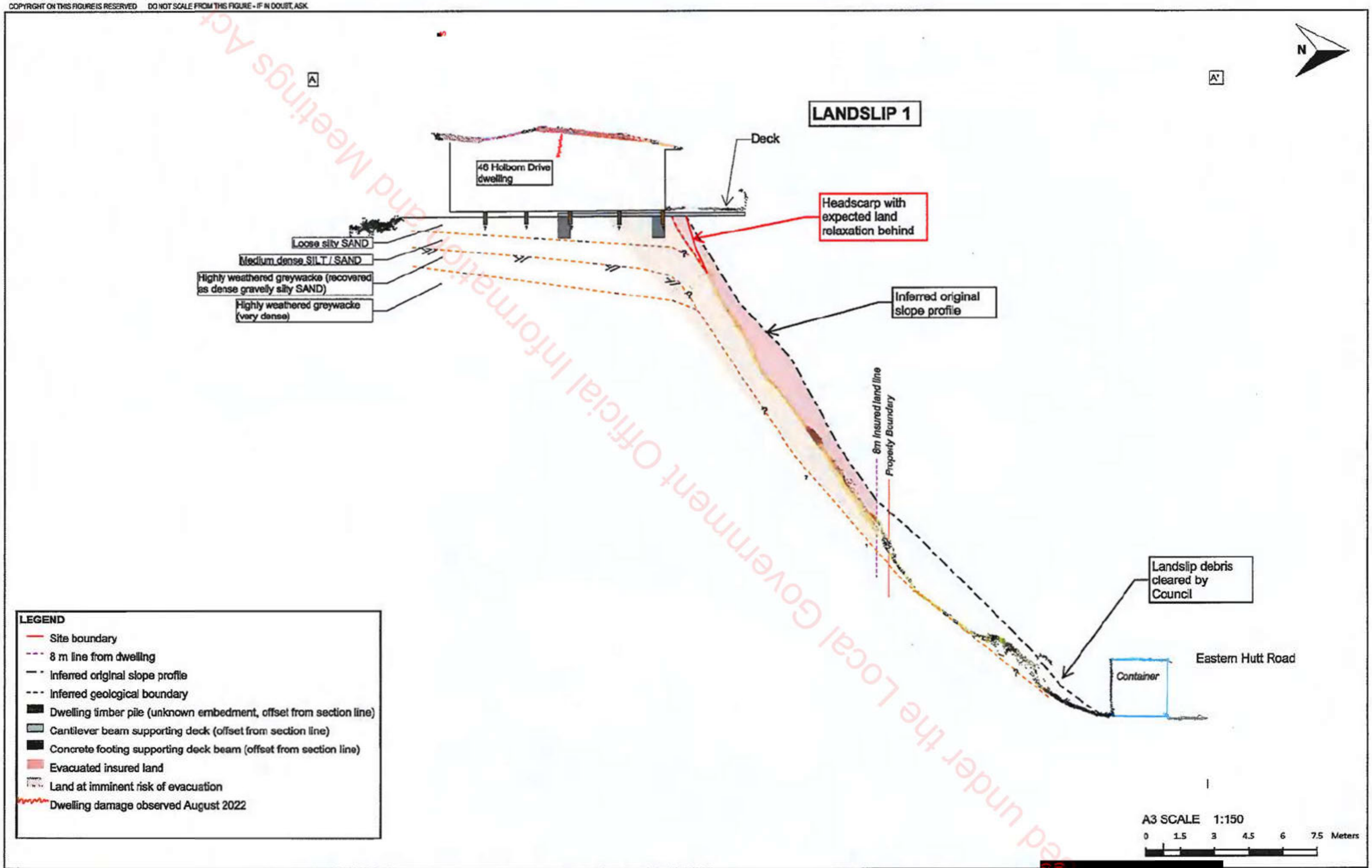
NOTES:
1) Aerial Image and cross section obtained from UAV Flight conducted on 26 July 2022 and 23 August 2022 by T+T for the purposes of this report only
2) Ortho-moasiac aerial imagery and DEM provided by non-georeferenced UAV survey.

REV	DESCRIPTION	GIS	CHK	DATE

LOCATION PLAN

PROJECT No. 1503000.0036
DESIGNED
DRAWN [redacted] Aug. 22
CHECKED Sep. 22
APPROVED DATE

CLIENT [redacted]
PROJECT 46 HOLBORN DRIVE, Stokes Valley, Hutt City
TITLE Insurance Claim No. [redacted]
Annotated aerial photograph - SITE PLAN LANDSLIP 1
SCALE (A3) 1:150 FIG No. SKETCH 1 REV



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NOTES: 1) Aerial image and cross section obtained from UAV Flight conducted on 26 July 2022 and 23 August 2022 by T+T for the purposes of this report only
2) Ortho-mosaic aerial imagery and DEM provided by non-georeferenced UAV survey.
3) Geological profile data interpreted from letter report 'Geotechnical Investigation and Assessment [redacted] affected by the Landslip and proposed remedial options' prepared by s7(2)(a) [redacted] dated 16 June 2022 (Project Number: s7(2)(a) [redacted]

REV	DESCRIPTION	GIS	CHK	DATE

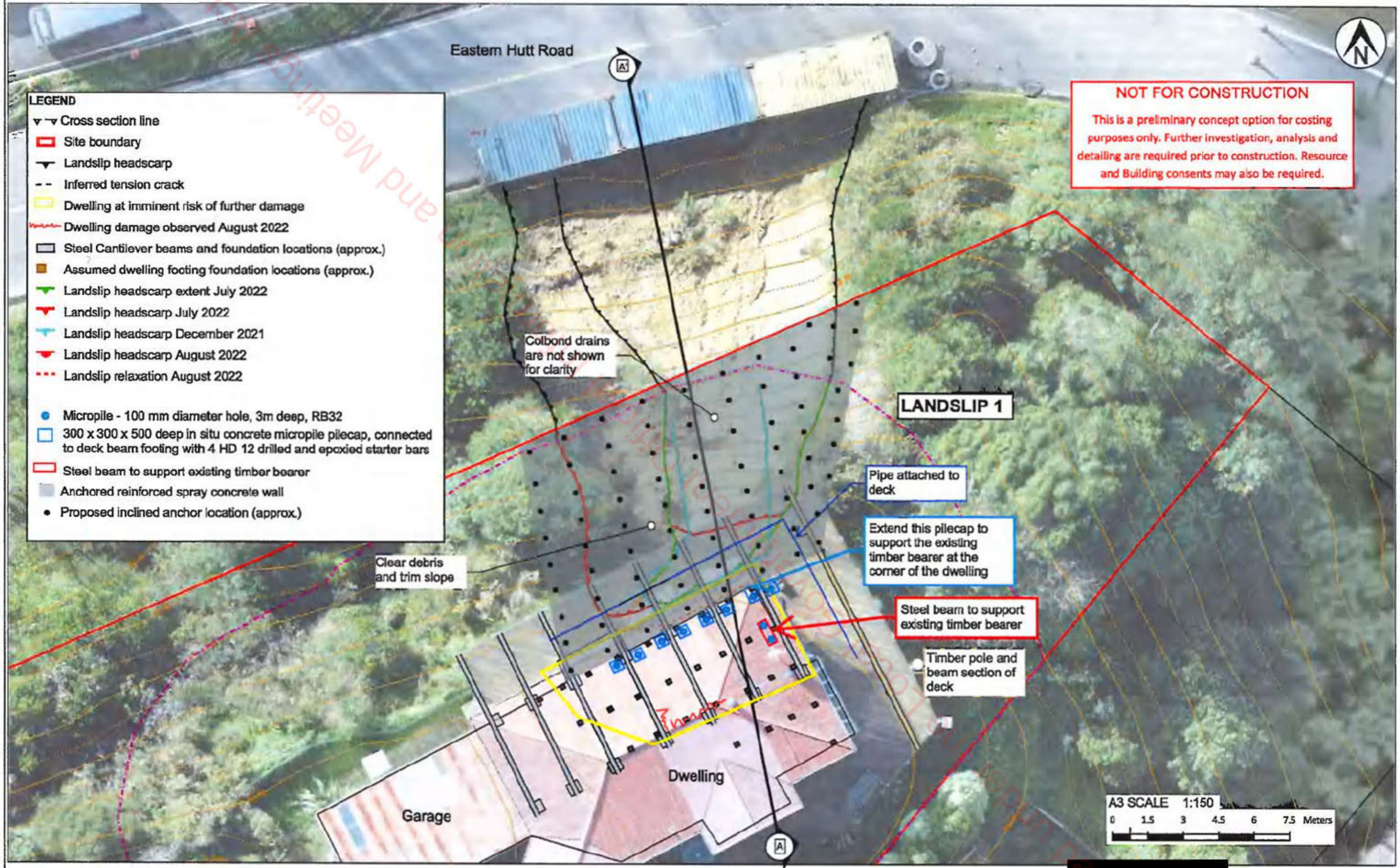
LOCATION PLAN

PROJECT No. 1503000.0036
DESIGNED
DRAWN s7(2)(a) [redacted] 09/22
CHECKED

APPROVED DATE

CLIENT s7(2)(b)(ii) [redacted]
PROJECT 46 Holborn Drive, Stokes Valley, Wellington
TITLE Insurance Claim No s7(2)(b)(ii) [redacted]
CROSS SECTION - LANDSLIP 1

SCALE (A3) 1:150 FIG No. SKETCH 2 REV 1



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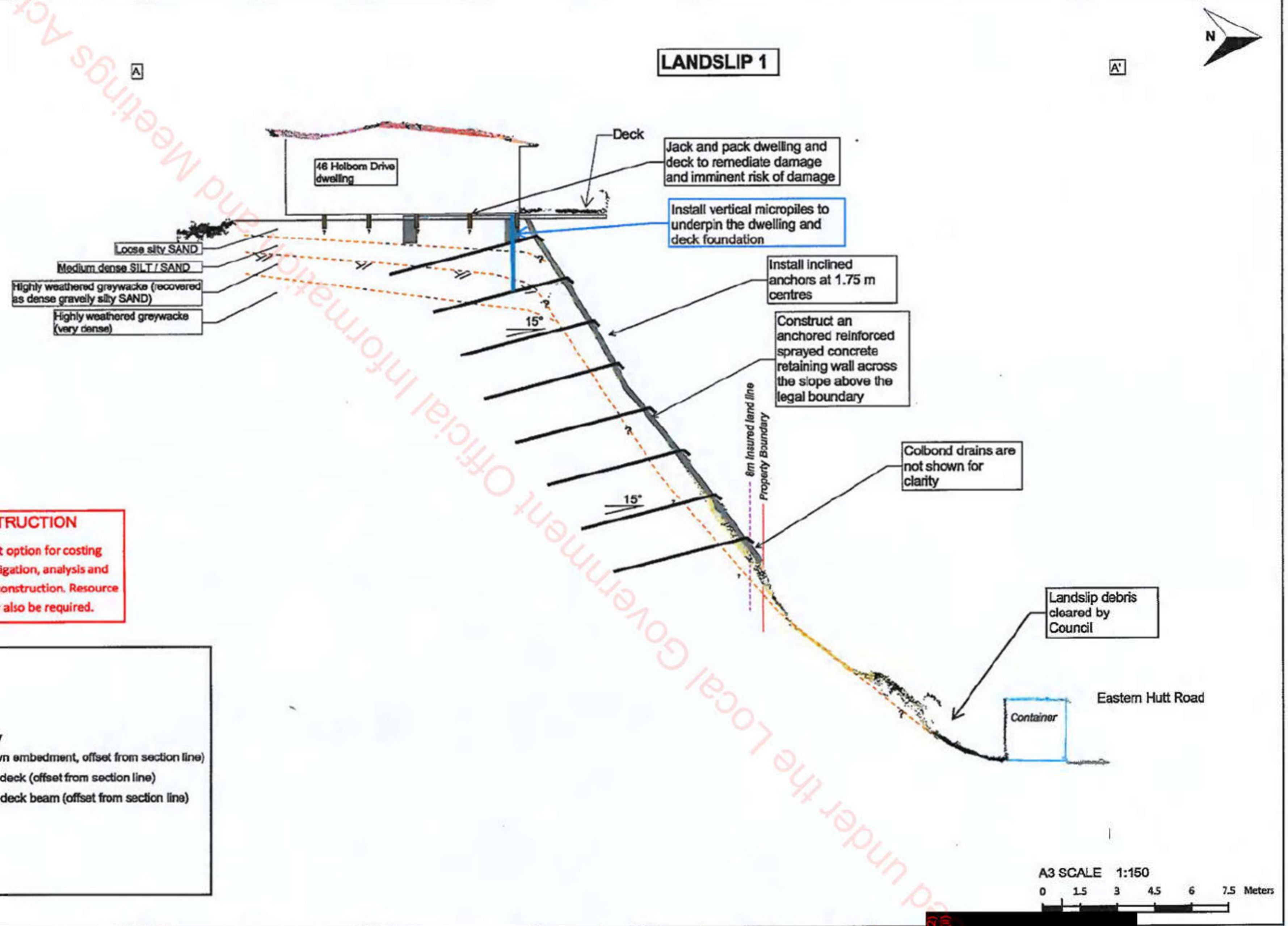
NOTES: 1) Aerial Image and cross section obtained from UAV Flight conducted on 26 July 2022 and 23 August 2022 by T+T for the purposes of this report only
2) Ortho-mosaic aerial imagery and DEM provided by non-georeferenced UAV survey.

REV	DESCRIPTION	GIS	CHK	DATE	LOCATION PLAN	APPROVED	DATE

PROJECT No. 1503000.0036
DESIGNED / DRAWN / CHECKED s7(2)(a) [redacted] ug. 22 / Sep. 22

CLIENT s7(2)(b)(ii) [redacted]
PROJECT 46 HOLBORN DRIVE, Stokes Valley, Hutt City
TITLE Insurance Claim s7(2)(b)(ii) [redacted]
LANDSLIP 1 - CONCEPTUAL REMEDIAL SOLUTION - SITE PLAN
SCALE (A3) 1:150   FIG No. SKETCH 3   REV



NOT FOR CONSTRUCTION

This is a preliminary concept option for costing purposes only. Further investigation, analysis and detailing are required prior to construction. Resource and Building consents may also be required.

LEGEND

- Site boundary
- 8 m line from dwelling
- Inferred geological boundary
- Dwelling timber pile (unknown embedment, offset from section line)
- Cantilever beam supporting deck (offset from section line)
- Concrete footing supporting deck beam (offset from section line)

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NOTES: 1) Aerial image and cross section obtained from UAV Flight conducted on 26 July 2022 and 23 August 2022 by T+T for the purposes of this report only
2) Ortho-moasiac aerial imagery and DEM provided by non-georeferenced UAV survey.
3) Geological profile data interpreted from letter report 'Geotechnical Investigation and Assessmen[redacted]ffected by the Landslip and proposed remedial options' prepared b[redacted]ated 16 June 2022[redacted]

REV	DESCRIPTION	GIS	CHK	DATE	LOCATION PLAN	APPROVED	DATE

PROJECT No. 1503000.0036
DESIGNED / DRAWN / CHECKED [redacted] 09/22

CLIENT [redacted]
PROJECT 46 Holborn Drive, S[redacted] Wellington
TITLE Insurance Claim No[redacted]
LANDSLIP 1 - Conceptual Remedial Solution - Cross Section
SCALE (A3) 1:150 FIG No. SKETCH 4 REV 1

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NOTES: 1) Aerial Image and cross section obtained from UAV Flight conducted on 26 July 2022 by T+T for the purposes of this report only
2) Ortho-moasiac aerial imagery and DEM provided by non-georeferenced UAV survey.

REV	DESCRIPTION	GIS	CHK	DATE

LOCATION PLAN

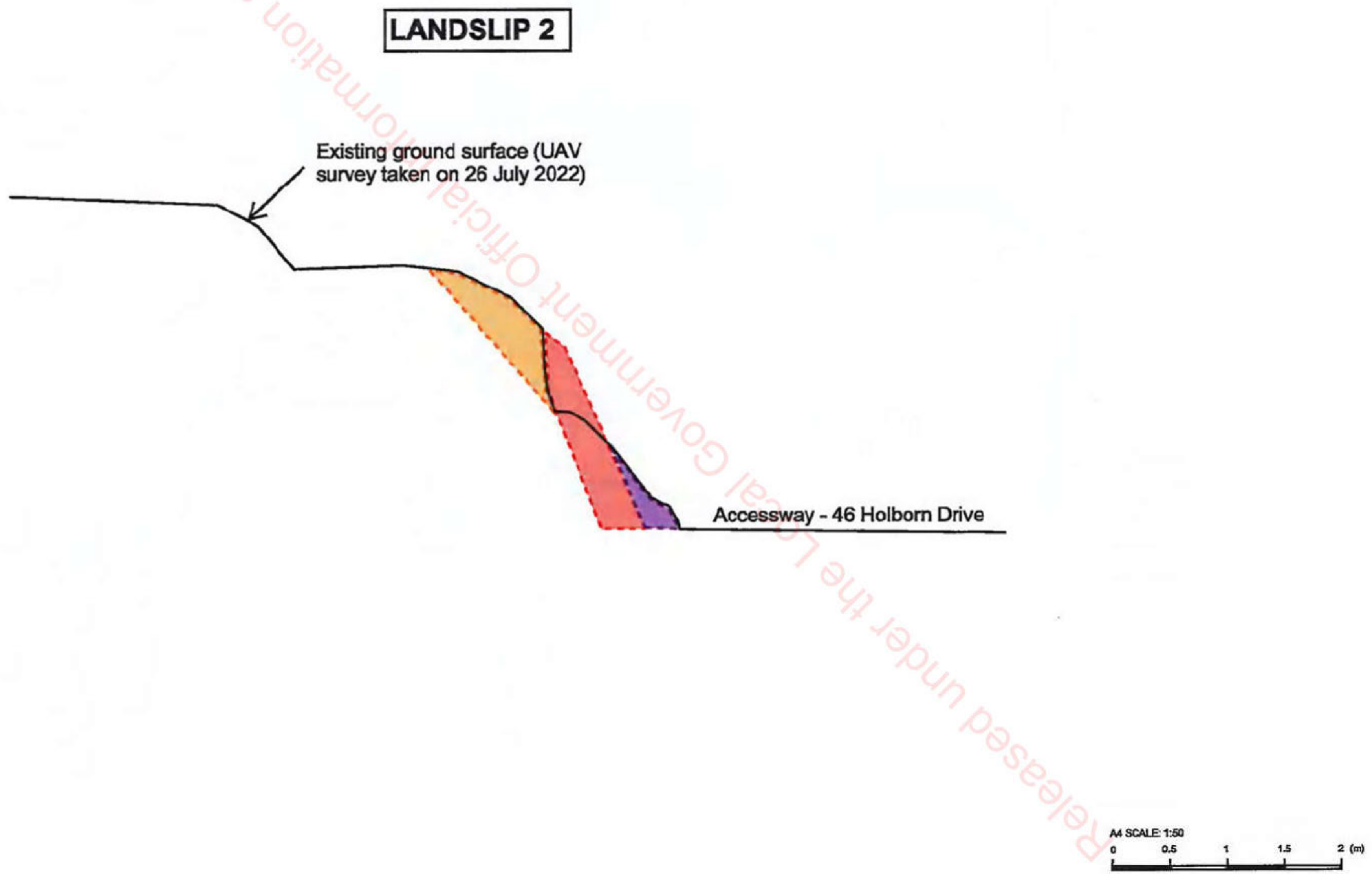
PROJECT No.	1503000.0036	
DESIGNED	[redacted] s7(2)(a)	Sep. 22
DRAWN		
CHECKED		Sep. 22
APPROVED		DATE

CLIENT [redacted] s7(2)(b)(ii) LTD
PROJECT 46 HOLBORN DRIVE, STOKES VALLEY
TITLE Insurance Claim N [redacted] s7(2)(b)(ii)
Annotated aerial photograph SITE PLAN LANDSLIP 2
SCALE (A3) 1:50 FIG No. SKETCH 5 [redacted] s7 REV 1

Tonkin & Taylor	Project: EQC - 46 Holborn Drive, Stokes Valley [redacted]	Computed: [redacted]	Sep. 22	Office	Wellington
		Checked:	Sep. 22		
Description:	Cross Section of Landslip 2	Revised:		Job No:	1503000.0036
File Path:		Checked:		Sheet No:	

Sketch 6 - Cross Section BB'

Insurer Number: C90110859



Tonkin & Taylor

Project: EQC - s7(2)(b)(ii) [redacted]
46 Holborn Drive, Stokes Valley

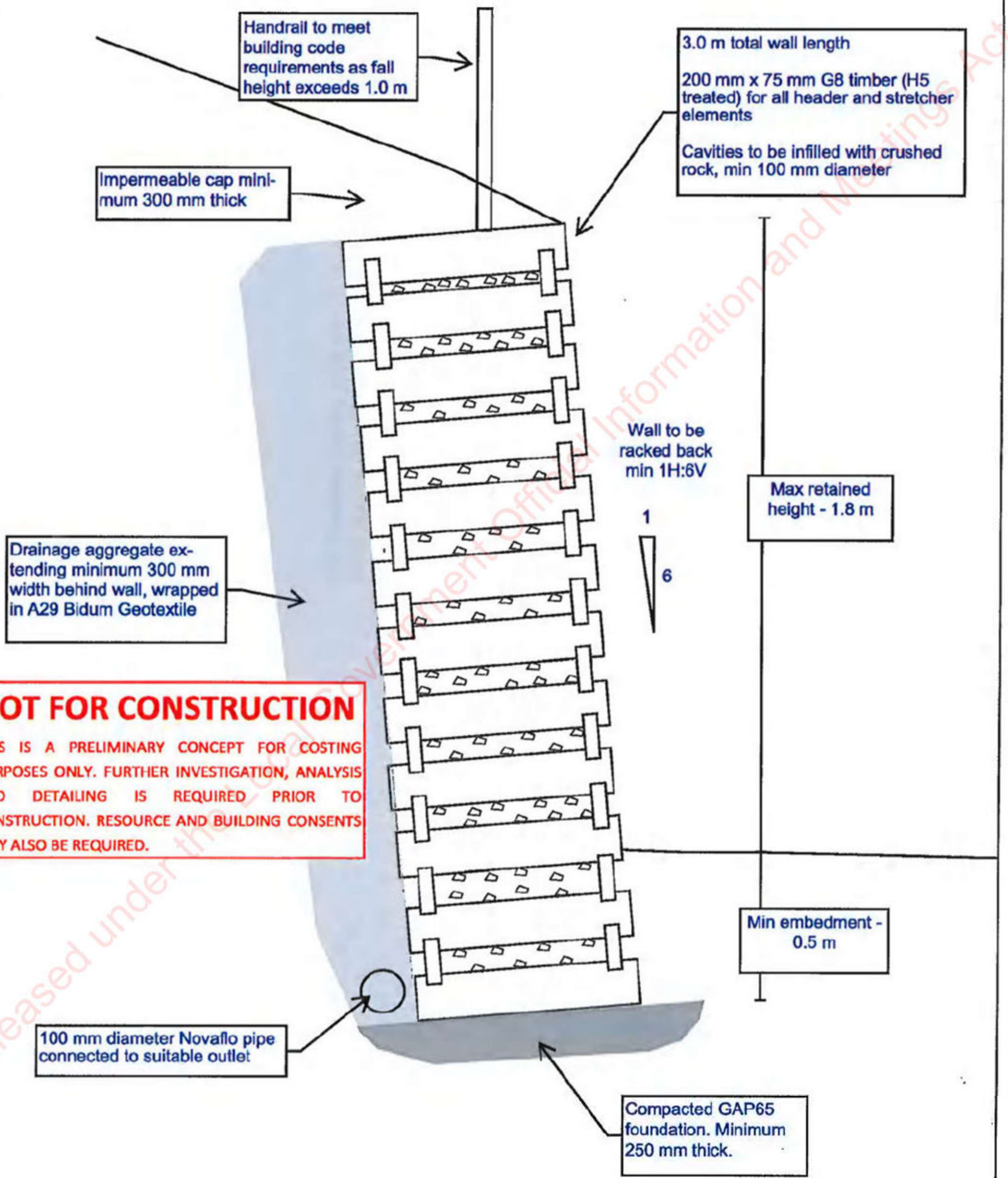
Computed: s7(2)(a) [redacted] 09/2022
Checked: 09/2022

Office: WEL
Job No: 1503000.0036

Description: SKETCH 7 - CONCEPTUAL REMEDIAL SOLUTION LANDSLIP 2 - TYPICAL TIMBER CRIB RETAINING WALL

Revised: 20
Checked: 20
File:
Sheet No.

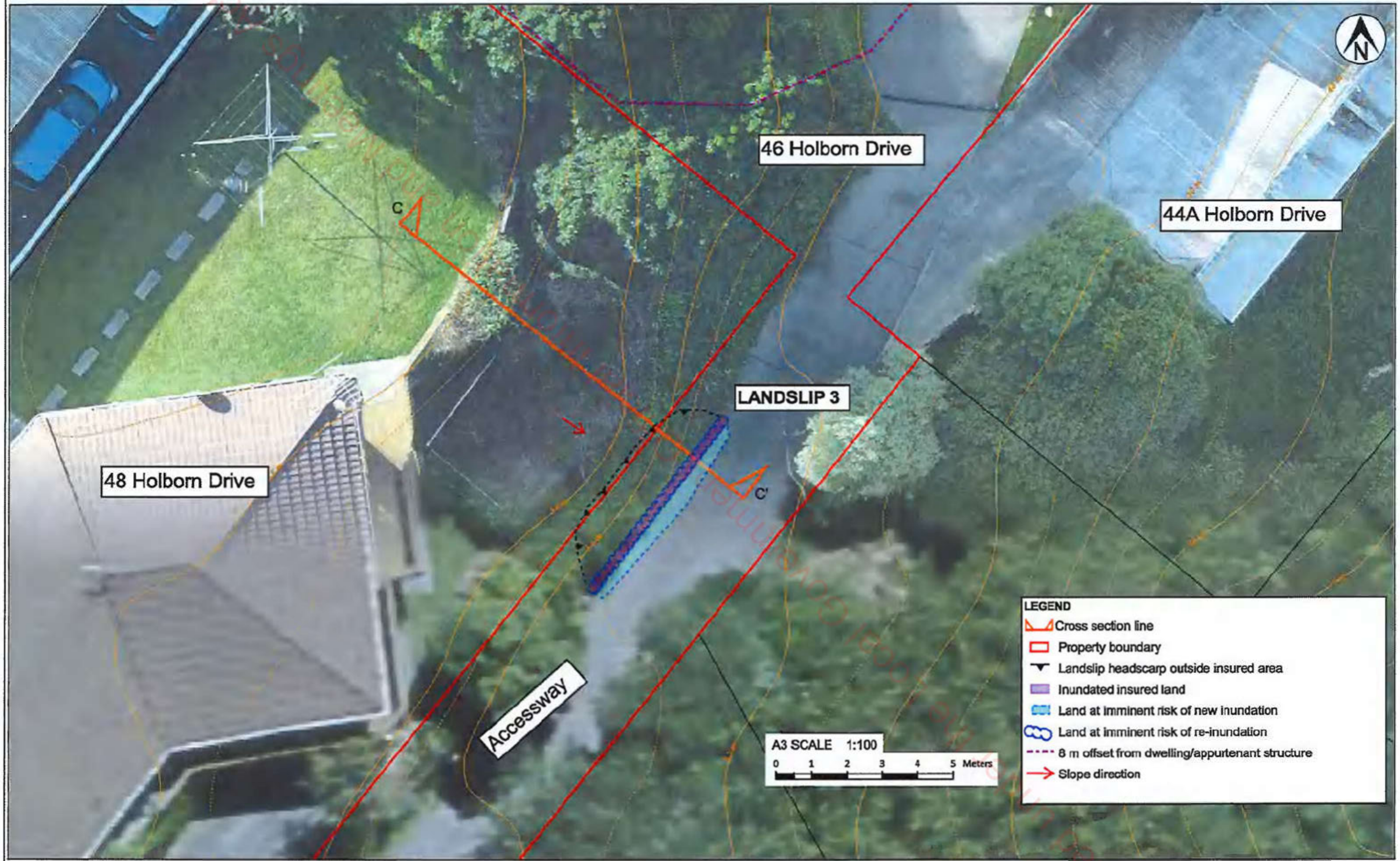
LANDSLIP 2



NOT FOR CONSTRUCTION

THIS IS A PRELIMINARY CONCEPT FOR COSTING PURPOSES ONLY. FURTHER INVESTIGATION, ANALYSIS AND DETAILING IS REQUIRED PRIOR TO CONSTRUCTION. RESOURCE AND BUILDING CONSENTS MAY ALSO BE REQUIRED.

NOT TO SCALE



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NOTES: 1) Aerial image and cross section obtained from UAV Flight conducted on 26 July 2022 by T+T for the purposes of this report only
2) Ortho-mosaic aerial imagery and DEM provided by non-georeferenced UAV survey.

REV	DESCRIPTION	GIS	CHK	DATE

LOCATION PLAN

PROJECT No. [redacted].0036
DESIGNED [redacted] Sep. 22
DRAWN
CHECKED Sep. 22
APPROVED   DATE

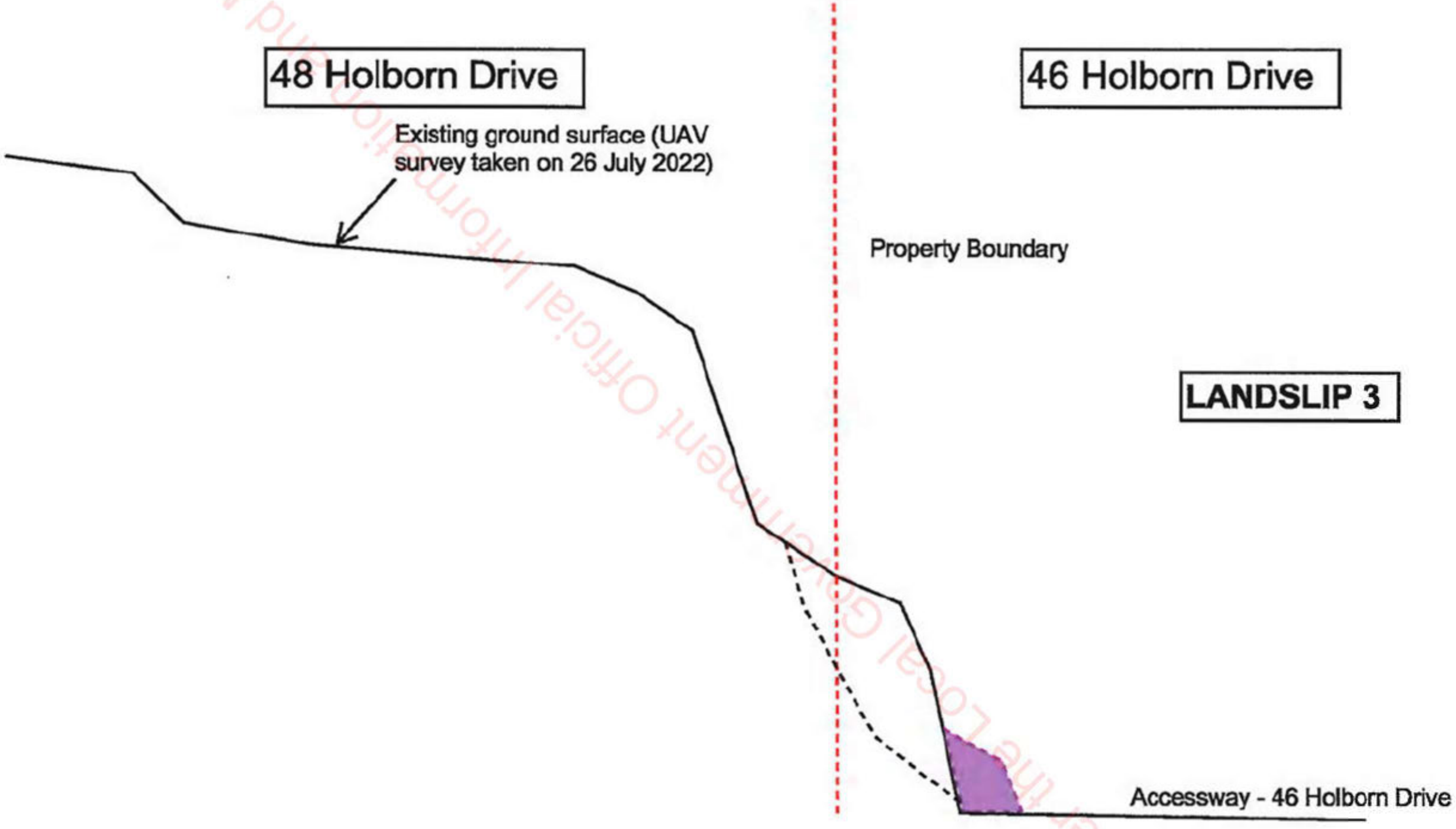
CLIENT [redacted]
PROJECT 46 HOLBORN DRI[redacted] VALLEY
TITLE Insurance Claim No [redacted]
Annotated aerial photograph - LANDSLIP 3
SCALE (A3) 1:100   FIG No. SKETCH 8   REV 1

Tonkin & Taylor	Project: EQC - 46 Holborn Drive, Stokes Valley s7(2)(b)(ii) [redacted]	Computed: s7(2)(a) [redacted]	Sep. 22	Office	Wellington
		Checked:	Sep. 22		
Description:	Cross Section of Landslip 3	Revised:		Job No:	1503000.0036
File Path:		Checked:		Sheet No:	

Sketch 9 - Cross Section CC'

Insurer Number s7(2)(b)(ii) [redacted]

Legend
- Evacuated land
- Inundated land
- I.R. Evacuation



A4 SCALE: 1:50

0 0.5 1 1.5 2 (m)

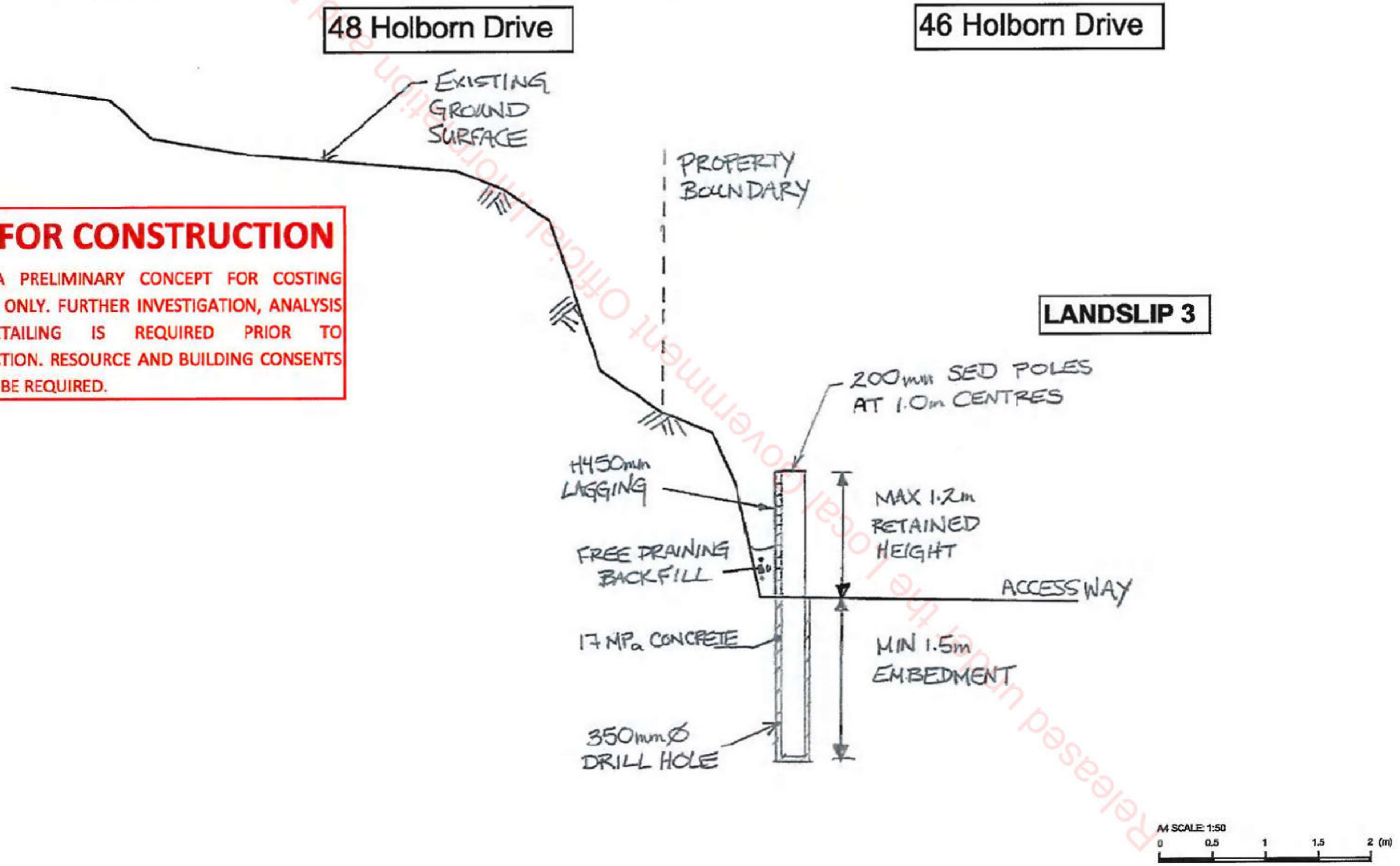
Tonkin & Taylor	Project: EQC - 46 Holborn Drive, Stokes Valley [redacted] s7(2)(b)(ii)	Computed:	[redacted] s7(2)(a)	Sep. 22	Office	Wellington
		Checked:		Sep. 22		
Description:	Cross Section of Landslip 3	Revised:			Job No:	1503000.0036
File Path:		Checked:			Sheet No:	

Sketch 10 - Cross section through conceptual remedial solution

[redacted] s7(2)(b)(ii)

NOT FOR CONSTRUCTION

THIS IS A PRELIMINARY CONCEPT FOR COSTING PURPOSES ONLY. FURTHER INVESTIGATION, ANALYSIS AND DETAILING IS REQUIRED PRIOR TO CONSTRUCTION. RESOURCE AND BUILDING CONSENTS MAY ALSO BE REQUIRED.



Prepared for
Hutt City Council
Co No.: N/A

46 Holborn Drive Slope Re-Assessment and Remedial Works

18-Jan-2023
HCC Geotechnical IIR CSA

46 Holborn Drive Slope Re-Assessment and Remedial Works

Client: Hutt City Council

Co No.: N/A

Prepared by

AECOM New Zealand Limited
Level 19, 171 Featherston Street, Pōneke|Wellington 6011, PO Box 27277, Pōneke|Wellington 6141, New Zealand
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18-Jan-2023

Job No.: 60683486

AECOM in Australia and New Zealand is certified to ISO9001, ISO14001 and ISO45001.

Quality Information

Document	46 Holborn Drive Slope Re-Assessment and Remedial Works
Ref	60683486
Date	18-Jan-2023
Originator	[redacted]
Checker/s	[redacted]
Verifier/s	[redacted]

Revision History

Rev	Revision Date	Details	Approved	
			Name/Position	Signature
0	16-Nov-2022	DRAFT	[redacted] Associated Director - Ground Engineering & Tunnelling	
1	22-Nov-2022	Final - Incorporates Client Feedback	[redacted] Associated Director - Ground Engineering & Tunnelling	
2	21-Dec-2022	Final - Incorporates Client and Abseil Access Feedback	[redacted] Associated Director - Ground Engineering & Tunnelling	
3	18-Jan-2023	Updated to incorporated feedback from HCC	[redacted] Associated Director - Ground Engineering & Tunnelling	[redacted]

Table of Contents

Executive Summary

AECOM New Zealand Limited (AECOM) has been engaged by the Hutt City Council (HCC) to re-assess the risk associated with the slip that has occurred below 46 Holborn Drive, Stokes Valley and discuss possible remedial options. An initial risk assessment was undertaken following site inspections between 22 to 26 July 2022. A further inspection was carried out on 13 October 2022 following the completion of temporary works.

The temporary works have been implemented to ensure the safety of road users along Eastern Hutt Road while a permanent solution/s are designed and constructed. The slope continues to be visually monitored and temporary works remain in place. A Dangerous Building Notice has been issued for the residential dwelling which remains unoccupied.

Further regression of the slope is anticipated to occur if left untreated as a result of stress-relief, heavy and/or prolonged rainfall and seismic shaking. Regression of the upper slope may occur progressively or suddenly with little to no warning (no survey monitoring in place and dwelling uninhabited). Regression of the slip would hinder the ability for vegetation to re-establish and likely undermine the building foundations which are located adjacent to the slip scarp.

Four remedial options have been considered and a summary of the current and residual risk associated with each are presented in Table 1. The safety risk is largely associated with debris/rock hitting a passing car and assessed using New South Wales Government Roads and Maritime Services 'Guide to Slope Risk Analysis' (Version 4, April 2014). The resilience risk associated with the dwelling of 46 Holborn Drive has been assessed using the HCC standard risk matrix.

Based on the current and residual risk associated with the dwelling at 46 Holborn Drive it is recommended the Dangerous Building Notice remains in place until remediation measures, as outlined within this report, are implemented. We consider that on its own, structural works to the dwelling will not be sufficient to uplift the Dangerous Building Notice due to the risk of further slope instability. Based on contractor feedback (s7(2)(b)(ii) [redacted]) we anticipate the dwelling will need to be removed in order to facilitate construction of the remedial works which minimises the risk of further slope instability. Nonetheless, if the dwelling remains, it is our opinion that the building would be safe to occupy when the residual risk is equal to or lower than moderate.

Based on the assessed risk, cost of proposed remedial options and the current situation it is recommended that either:

- An anchored shotcrete wall is installed, as described in section 5.1. Based on feedback from specialist contractor Abseil Access, we consider the removal of the dwelling prior to wall installation will facilitate a safer and more efficient construction phase. If constructed the residual risk to road users and private property of 46 Holborn Drive would likely be reduced to an acceptable level.

  If the dwelling remains in place, there is a risk that the dwelling could sustain damage as a result of the anchoring and shotcreting works. Furthermore, a structural assessment of the building foundation will be required to facilitate the removal of the Dangerous Building Notice, as the house would not have been designed for the new environment (non-compliant with NZS3604). The presence of the dwelling is also likely to extend the construction period. In the interim the temporary containers, traffic management and the associated risk to road users should be monitored.

- The dwelling is removed (or relocated) and reprofiling of the soil slope is undertaken, as described in section 5.2.1. If completed and vegetation is re-established on the profiled slope, then the risk to road users would likely be reduced to an acceptable level.

  The difficulties in removing the building off-site, or to another location on the same parcel of land is iterated in the s7(2)(b)(ii) [redacted] letter dated 11 October 2022. We anticipate other contractors will have similar reservations and difficulties in relocating the building on or off site. In turn, removing the dwelling is likely to require controlled demolition.

Removal of the dwelling and reprofiling of the slope is likely to take less time to complete compared to that of the anchored shotcrete wall and eliminates the risk of the building impacting Eastern Hutt Road.

Both of these solutions could be implemented based on the site investigations and observations completed to date. No further investigations are deemed necessary and unlikely to be required to re-establish a building platform.

The risk assessments associated with the current condition of the slope, anchored shotcrete wall and building removal are presented in Appendix B .

Regardless of the solution implemented it is recommended:

- Fall protection is erected along the crest of the slope to address the fall from height risk
- Temporary loading from machinery and equipment is considered by the temporary works designer/contractor
- The condition of the slope is monitored throughout the construction period
- Containers remain in place and their effectiveness at mitigating runout of debris is monitored

Prior to the removal of the containers (following wall construction), the residual risk should be re-assessed to confirm the objectives have been met.

1.0 Introduction

AECOM New Zealand Limited (AECOM) has been engaged by the Hutt City Council (HCC) to re-assess the risk associated with the slip that has occurred below 46 Holborn Drive, Stokes Valley and discuss possible remedial options. An initial risk assessment was undertaken following site inspections between 22 to 26 July 2022. A further inspection was carried out on 13 October 2022 following the completion of temporary works.

Characteristics of the slope, geotechnical investigations, initial remedial options and previous risk assessments are summarised within the following reports:

- AECOM New Zealand Limited, 2022. Slope Assessment below 46 Holborn Drive. Stokes Valley. Issued 4 August 2022.
- Miyamoto International New Zealand Limited, 2022. 46 Holborn Drive, Stokes Valley, Lower Hutt: Geotechnical Investigation and Assessment of the area affected by the Landslip and proposed remedial options. Issued 16 June 2022.
- Tonkin & Taylor Ltd, 2022a. Claim for Natural Disaster (Landslip) Damage. s7(2)(a) [redacted], 46 Holborn Drive, Stokes Valley, Wellington, 5019. EQC/Insurer Claim Number s7(2)(a) [redacted]. Dated 30 September 2022.
- Spencer Holmes Limited, 2022. 46 Holborn Drive, Stokes Valley, Lower Hutt. Structural Report on Deck Stability. Issued 31 August 2022.
- Tonkin & Taylor, 2022b. Claim for Natural Disaster (Landslip) Damage. s7(2)(a) [redacted] 46 Holborn Drive, Stokes Valley, Lower Hutt, Wellington, 5019. EQC/Insurer Claim Number s7(2)(a) [redacted]. Dated 11 November 2022.

The Tonkin & Taylor Ltd (2022a, 2022b) reports were prepared for the residents of 46 Holborn Drive and their insurers as a part of the Earthquake Commission (EQC). This was provided to HCC and AECOM for review and includes a risk assessment and conceptual remedial design.

This report serves to summarise the following:

- Review of the Tonkin & Taylor Ltd (2022a, 2022b) risk assessments and proposed remedial option
- Existing and residual risks for each remedial option, taking into consideration the impact to both road users and residential dwelling. The risk assessment utilises the New South Wales Government Roads and Maritime Services 'Guide to Slope Risk Analysis' (Version 4, April 2014).
- Remedial options and associated impacts to the dwelling
- Recommendations

2.0 Temporary Works

Temporary works have been undertaken at the slip site at the direction of HCC and support from AECOM engineers. Temporary works completed to date have comprised of:

- Temporary traffic management including a permanent lane closure and periodic road closures (southbound lanes)
- Scaling of loose soil and rock
- Minor vegetation clearance
- Installation of welded steel containers along the slope toe
- Connection of two ground anchors to retrain the container wall in the event of a slope or building collapse

The temporary works have been implemented to ensure the safety of road users along Eastern Hutt Road while a permanent solution/s are designed and constructed. The slope continues to be visually monitored and temporary works remain in place. A Dangerous Building Notice has been issued for the residential dwelling which remains unoccupied.

Photos of the initial slip and current slope condition are provided in Figure 1 and Figure 2

Figure 1 Left: Initial slip (24 July 2022). Right: Slope condition following scaling works (9 September 2022)

Figure 2 View behind the containers following completion of the temporary works

2.1 Dangerous Building Notice

A dangerous building notice was issued by HCC on 22 July 2022 as a result of the slip and remains

s7(2)(a) [redacted]

A structural assessment of the cantilevered deck was completed by Spencer Holmes, however, does not provide comment on the stability of the slip. The deck cantilevers over the slip by approximately 3 m and designed by Sawrey Consulting Engineers in 2002. The assessment states:

"The front line of piles that the deck is connected to is located approximately 1.0m back from the top edge of the slip, and the cantilevered beams of the deck are well secured to these piles.

We are of the opinion that the deck is currently stable, provided that there is no further movement of the slip. However, due to the reduced distance from the front pile to the bank/ scarp head, the stability of the deck is likely to be directly affected by the stability of the hillside. Any further movement of the slip will likely undermine the deck."

The geotechnical risk associated with the dwelling is discussed throughout the report and recommendations are provided in section 6.1.

2.2 Current Situation

We understand that a permanent lane closure for an extended period of time is unacceptable to HCC due to the high road usage and pressure from the community. The road is classed as a major 'arterial' route by One Network Road Classification with an average annual daily traffic count of ~15,450 and ~16,600 for the southbound and northbound carriageways respectively. The road provides the main point of access to the suburbs of Holborn and Stokes Valley to the southeast.

3.0 Ground Conditions and Failure Mechanisms

The slope is approximately 20 m high and situated within both public and private property. Numerous slips have occurred at the site throughout 2021 and 2022 which were assessed by Tonkin & Taylor for insurance claim purposes. The last series of slip/s occurred in July 2022 during a period of prolonged rainfall in the Wellington Region. Following the July 2022 slip and throughout the temporary works AECOM engineers completed site visits to monitor the slope and record site observations which were subsequently provided to HCC via email. These observations were made from Eastern Hutt Road, the property of 46 Holborn Drive, drone photography and an abseil inspection.

A cross section is presented in Appendix A outlining the inferred ground conditions at the site.

3.1 Upper Slope

The upper ~5 m of the slope has been scaled and forms a near vertical slope. This portion of the slope typically comprises of completely weathered greywacke as indicated in Appendix A. During the abseil inspection on 13 October 2022 further slumping was identified towards the southwest of the deck and ponding around the perimeter of the building. The slip is particularly protected from direct rainfall due to the presence of a cantilevered deck, however remains unvegetated.

Further regression of the slope is anticipated to occur if left untreated as a result of stress-relief, heavy and/or prolonged rainfall and seismic shaking. Regression of the upper slope may occur progressively or suddenly with little to no warning (no survey monitoring in place and dwelling uninhabited). Regression of the slip would hinder the ability for vegetation to re-establish and likely undermine the building foundations which are located adjacent to the slip scarp.

3.2 Lower Slope

The lower ~15 m of the slope appears to comprise of highly weathered greywacke (inferred extremely to very weak) and forms a steep slope. Further instabilities may occur during an extreme event as a result of the weak rock mass and/or as a result of persistent and adversely orientated defects.

Seepage at the lower reaches of the slope continues to occur which indicates perched groundwater within the rockmass.

4.0 Risk Assessments

4.1 Existing Risk Assessments

4.1.1 Initial AECOM Risk Assessment

An initial risk assessment carried out by AECOM and utilised the agreed risk matrix which is based on Appendix G of Australasian Geomechanics Society (2000) Landslide Risk Management Concepts and Guidelines. The assessment considered the holistic risk associated with the site (i.e. both private and public asset impacts). The assessments considered both adverse weather and seismic shaking events in accordance with the New Zealand Building Act and Standards. The assessment was completed following the initial slip.

4.1.2 Tonkin & Taylor Risk Assessment (Imminent Risk)

The Tonkin & Taylor Ltd (2022a, 2022b) risk assessments only consider risk to private property and prepared for [redacted] to inform the EQC settlement claim. The assessment considers the 'imminent risk' to the private property based on a 12 months of normal rainfall conditions as a direct result of the slip. The assessment does not consider seismic shaking events. The outcome of the assessment is outlined below:

"The dwelling has been damaged and is considered to be at imminent risk as a direct result of the natural disaster (landslip) that has occurred."

The Tonkin & Taylor (2022b) report also assesses two small slips (landslip 2/3) situated along the accessway which has "*resulted in the evacuation and inundation of insured land*". These two minor instabilities are not indicated to pose an imminent risk to the dwelling. In turn, only 'landslip 1' which poses and immediate risk to the dwelling and safety of road users is considered within this report.

4.2 Risk Re-assessment

We have undertaken a detailed risk assessment using New South Wales Government Roads and Maritime Services 'Guide to Slope Risk Analysis' (Version 4, April 2014). This risk assessment considers the risk to road users by considering the following:

- Static and seismic loading
- Anticipated type of slope failure and size of debris
- Likelihood of material dislodging impacting the dwelling and entering the road corridor
- Temporal probability of road users being present at the time of the failure
- Vulnerability of the vehicles

The resilience risk associated with the dwelling of 46 Holborn Drive has been assessed using the HCC standard risk matrix. Two risk assessments for the dwelling have been carried out:

- One considers both adverse weather and seismic shaking events in accordance with the New Zealand Building Act and Standards for an IL2 structure with a 50-year design life
- The other considers 'imminent risk' as discussed in section 4.1.2 and defined in subpart 6 clause 121 of the Building Act

The risk assessment associated with the current condition and remedial options discussed below is presented in section 6.0. Select risk assessments associated with the instability at 46 Holborn Drive are provided in Appendix B.

5.0 Remedial Solutions

We acknowledge that discussions with the owners of 46 Holborn Drive are ongoing, and a long-term permanent lane closure is unacceptable to HCC. In turn, we have discussed the suitability of some remedial work options and likely impact on the resilience of the dwelling.

We note that in isolation the removal of containers beneath 46 Holborn Drive may provide little relief to traffic congestion if the carriageway is constrained to one lane nearby.

Due to the proximity of the dwelling to the instability and observations made to date, it is unlikely that interim remedial works to the slip surface (e.g. pinned erosion control matting) will adequately reduce the risk to both HCC (road user safety) and dwelling of 46 Holborn Drive.

Interim remedial solutions are not likely to meet Building Act 2004 requirements, and if utilised, should be monitored.

5.1 Deck Removal

Although the cantilevered deck has been assessed as structurally sound in its current condition (section 2.1) the front line of supporting piles is located approximately 1 m from the slip scarp and additional signs of slumping has been observed immediately to the south. Regression of the slip is expected to occur under adverse weather, seismic shaking and as a result of progressive stress relief.

The removal of the deck would lower the safety risk to road users, however, the dwelling would remain perched above the instability and still at risk of partial or total collapse. In turn, the removal of the deck on its' own is not expected to reduce risk levels to an acceptable level.

As a minimum, the partial or complete removal of the cantilevered deck is anticipated to be required to facilitate the installation of retaining structures (e.g. anchored shotcrete wall). Further discussion about the constructability of retaining structures is provided in section 5.2.2. If the deck is removed the slope should be monitored and protected against erosion as the top 4-5 m typically comprises of completely weathered greywacke (soil).

A photo of the deck and proximity of the instability is presented in Figure 3.

Figure 3 View of cantilevered deck and proximity of existing instability

5.2 Long-term Remedial Works (i.e. ≥50 years)

All long-term remedial options implemented by HCC will need to consider the impact to private property and tie-in with the surrounding topography. Most of the remedial options discussed below are anticipated to encroach into private property, and as such, written approval from the landowners should be sought (e.g. anchored solutions).

Long-term remedial solutions can be designed to withstand ultimate limit state events based on their importance and design life. Permanent solutions are likely to require geotechnical and/or structural Producer Statements in order to meet building consent requirements. Producer Statements can be provided by suitably qualified chartered engineers.

5.2.1 Building Relocation / Removal and Reprofiling

This option would involve the relocation of the building away from the slope or removal to prevent the risk of collapse. If repositioned on the same parcel of land it is recommended that the set-back distance is verified through a stability assessment and that the final slope geometry is not adversely loaded. The reconnection of services would need to be completed in accordance with HCC requirements (e.g. certified plumbers, gasfitters and drain layers) and stormwater outfalls directed away from the instability.

We understand the viability of relocating the dwelling has been explored by the landowner and may not be practicable due to the need for jacks and transporters to be operated close to the slope. The difficulties in removing the building off-site, or to another location on the same parcel of land is iterated in the s7(2)(b)(ii) [redacted] letter dated 11 October 2022.

We believe controlled removal of the dwelling could be undertaken provided it is staged and utilises light equipment. A nominal setback distance of 2-3 m from the instability is recommended for all equipment and fall protection measures/controls are implemented prior to works commencing. Alternatively, heavy machinery may be suitable if operated from Eastern Hutt Road and completed in a controlled fashion (e.g. crane removal during a road closure).

This option does not alleviate the risk of slope regression even once the dwelling is removed. Due to the thick sequence of soil at the crest of the slope, remedial measures are recommended prior to the removal of the containers and associated ground anchors. This could include a retaining structure or laying back the soil slope (say 45 degrees) and re-establishing vegetation. For the purpose of the risk assessment it is assumed reprofiling of the soil slope would be undertaken in conjunction with scaling to minimise the risk of instability following building removal.

The approximate extent of the soil slope is presented in Figure 4.

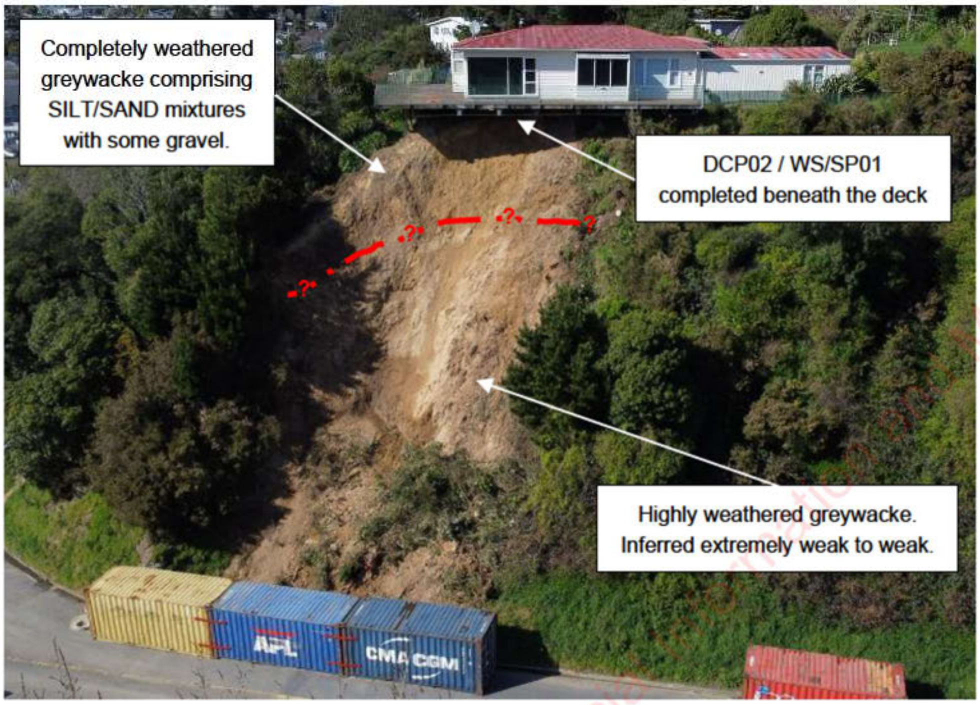


Figure 4 Approximate extent of completely weathered soil

Reprofiling the slope to reduce the risk to road users would result in the reduction of usable land. Substantial retaining structures may be required to construct a suitable building platform if another dwelling was to be constructed. An indicative cross section is provided in Figure 5 indicating the potential impact on private property.

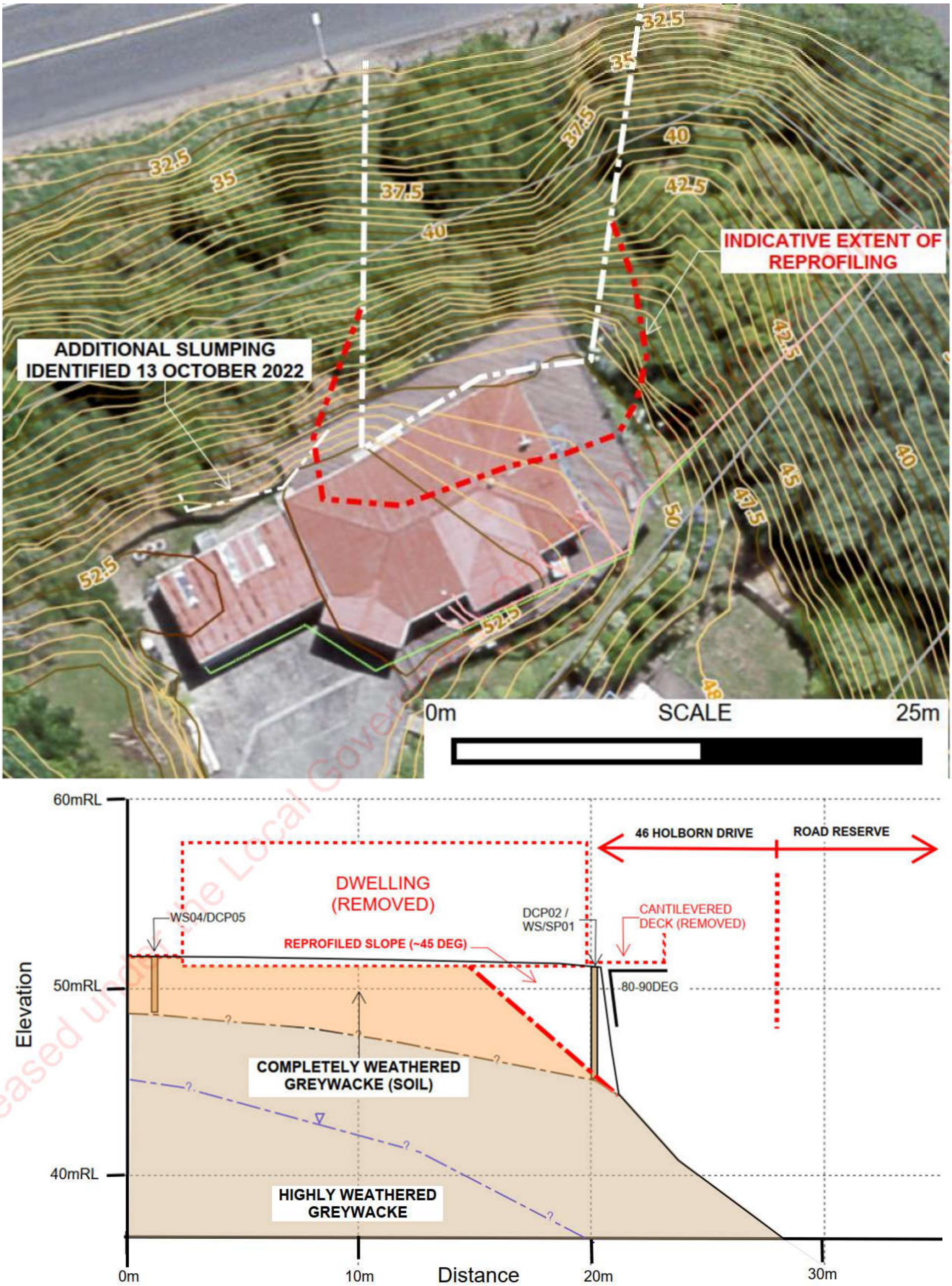


Figure 5 Indicative impact of re-profiling on private property and potential building platform.

The angle which the soil could be laid back should be confirmed using slope stability analysis. If rock was encountered during the excavation process, then the impact may be lessened as a steeper slope angle may be adopted.

5.2.2 Anchored Shotcrete

This option would require the removal of vegetation and scaling of loose material from the slope across the slip site. Anchors would be installed across the slope at regular spacings (typically 1.5-2.5 m) and be bonded into rock. Prior to shotcreting reinforcement would be installed to match the slope profile and distribute loads. The anchored slope can be designed to actively retain the soil and loosened rock mass providing long-term resilience.

Ideally all vegetation would be stripped from the site beneath the shotcrete, however, cutting and treatment of the tree stumps and exposed roots can be tolerated. With sufficient treatment of vegetation, anchors and reinforced concrete this solution can meet a ≥50 year design life. This option would be designed to actively retain the soil slope and private property above.

An example of anchored shotcrete is provided in Figure 6.

Figure 6 Example of anchored shotcrete

We recognise the difficulty in safely delivering this solution, however, similar types of work have been completed in the Wellington Region. We envision the works being completed by either ropes and/or a suspended scaffold system.

If ropes are used, then a hand drill, small A-frame percussion drill rig, or self-drilling anchor rig (SDA) may be suitable. Glass fibre reinforced polymer (GRFP) bars could be used as they are substantially lighter than steel and much safer to handle. However, SDA and GRFP bars are generally not accepted by Waka Kotahi on their projects. This is due to concerns with durability of SDA (<100 years) and brittle failure mechanism of GRFP bars. Acceptance of their use should be explored during the design stage as a part of the safety in design process.

The use of a suspended scaffold system would be more practical than ropes if a substantial amount of reinforcement is required for the shotcrete facing. Suspended scaffolds are typically designed by the contractor and reviewed by the Engineer to Contract prior to implementation.

As discussed in section 5.1 partial or total removal of the deck would likely be required as a minimum in order to position drill rig/s and install scaffold systems. Early contractor feedback received from Abseil Access (email dated 20 December 2022) indicates that the dwelling (in its current state) would present a notable risk to people working on the slope below. The risk would be exacerbated due to the need to suspend scaffold and/or drill rigs from structural members of the dwelling. Construction vibrations as a result of drilling may promote further ravelling and loosening/stress relief of the slip face, and in turn impact adjacent foundations.

Based on [redacted] feedback, we consider that the dwelling, if left in place, would also pose significant challenges during the construction period. Continual monitoring of the slope and dwelling would be required, and trigger action levels established to ensure worker safety. Monitoring of this nature may require frequent or real time surveying of the area and may be difficult to capture when slope works are being conducted (i.e. obscuring monitoring points). These engineering controls would likely result in a prolonged construction period compared to if the dwelling was removed. Therefore, the removal of the dwelling would assist with retaining wall constructability and reduce the risk to workers by eliminating the risk of a complete or partial collapse of the dwelling during construction. If the dwelling remains in place, there is a risk that the dwelling could sustain damage as a result of the anchoring and shotcreting works. We also anticipate the dwellings foundation system would need to be assessed by a chartered structural engineer to verify the integrity of the dwelling following wall construction and extend the project programme. This is due to the wall becoming an integral part to the building's stability, it not originally being designed or built for the current situation and non-compliant with NZS3604 foundation requirements.

Temporary works and associated stability of the slope would remain the responsibility of the contractor, however, both HCC and designer have a duty of care as a PCBU and responsibility to assess these risks throughout the safety in design process. The tender documentation should include and emphasise the existing geotechnical information available, outline of slip history and include item/s for temporary stabilisation and/or working platforms. A price-quality method could be used during the procurement stage to provide emphasis on methodology, safety and track record in delivering similar pieces of work.

5.2.3 Re-profiling and Benching the Existing Slope

This option would involve extensive vegetation clearance and earthworks, excavating the cut slope to a shallower angle and use of localised stabilisation measures such as high tensile mesh, anchors and shotcrete. Due to the height of the slope multiple benches are likely required to minimise the consequence of rockfall and meet stability requirements. Sub-horizontal drains are likely to be required to manage porewater pressures and extend on the order of 15-20 m into the slope. Detailed geotechnical investigations would be required prior to design and likely to comprise of machine drill holes, downhole televiewer recordings and mapping. Excavations would be completed using a top-down approach and likely to be staged to enable geological mapping and stabilisation (as required) throughout construction.

The return period for the design ultimate limit state events should be agreed prior to design, however, in general expected to have a 50-100 year design life. Localised instabilities and rockfall is expected to occur throughout the design life and require maintenance. The residual risks need to be considered and managed throughout the design, construction and maintenance phases.

This solution is unlikely to be suitable for short extents due to the need to tie-in to the existing slope profile at either end. We believe this solution would be better suited to a larger Eastern Hutt Road slope remedial works solution and likely to be a high-cost remedial solution.

An example of re-profiling and benching of an existing slope is provided in Figure 7.

Figure 7 Example of re-profiling and benching

5.2.4 Proprietary Catch Fence

This remedial option would involve installing a ≥2.0 m high catch fence having a capacity of ≥100 kJ along the toe of the existing slope and extend the full length of the instability. The catch fence will be proprietary systems provided by Geobrugg/Macafferri (or similar) and comprise of regularly spaced galvanised steel posts that are anchored into competent rock with high tensile mesh spanning between posts. The fence would prevent the runout of rock, and to a lesser extent soil, from entering the carriageway. The proprietary system/s are typically manufactured overseas and would be shipped to New Zealand (approx. 8–12-week lead time).

Additional upslope slope stabilisation work (e.g. erosion control matting) may be required to minimise the likelihood of soil instability which would otherwise runout into the road. Runout of failed soils would occur due to the mesh having an aperture size on the order of 65-85 mm. Alternative barriers systems could be explored, however would require consultation with supplier to confirm its suitability

If a proprietary system is utilised, this option can be designed for a 50-year design life. Ongoing maintenance is expected to be required. This option does not serve to retain the private property above and reduce the risk posed to the dwelling.

An example of a roadside catch fence is provided in Figure 8.

Figure 8 Example of a roadside catch fence

6.0 Residual Risk

A summary of the current and residual risk associated with each remedial option is presented in Table 1. The safety risk is largely associated with debris/rock hitting a passing car and assessed using New South Wales Government Roads and Maritime Services 'Guide to Slope Risk Analysis' (Version 4, April 2014). The resilience risk associated with the dwelling of 46 Holborn Drive has been assessed using the HCC standard risk matrix.

An indicative cost is provided for each option to assist HCC in evaluating each option. A detailed cost estimate can be provided for each option upon request.

Table 1 Risk assessment summary

Event	Current Condition		Building Removal and Re-profilling	Anchored Shotcrete	Re-profiling and Benching	Catch Fence
	With Containers[1]	Without Containers[2]				
Surficial or localised failures	ARL5	ARL1-2	ARL5	ARL5	ARL5	ARL2-ARL3
Localised kinematic failure of the rock mass	ARL3	ARL1	ARL3[3]	ARL3[3]	ARL4	ARL3
Global instability of the slope	ARL3	ARL3	ARL3	ARL3 to ARL4	ARL3 to ARL4	ARL3
Residual risk to 46 Holborn Drive dwelling	Very High	Very High	N/A	N/A[5]	N/A[4]	Very High
Imminent risk to dwelling (i.e. excluding earthquake)	High	High		High		High
Indicative cost	N/A (current situation)	Very Low	High	High	Very High	Moderate
Impact on dwelling	N/A (current situation)		Very High. Building would be removed and the remaining land may not be suitable for a new dwelling. Additional retaining structures may be required to facilitate construction of a building platform.	High to very high[5]	N/A[4]	None. Fence constructio n would not impact the dwelling.

Notes: 1) Assumes a posted speed of 30km/h due to the presence of containers and temporary traffic management

2) Due to the proximity of the site to the Stokes Valley roundabout and presence of a slip road a speed of ≤50km/h to 80km/h has been considered

3) Assumes loosened rock will be scaled, treated with mesh or encapsulated within the shotcrete extent

4) Solution likely to involve removal of the dwelling

5) Based on the discussion provided in Section 5.2.2 we recommend the dwelling is removed.

6.1 Tolerable Risk

6.1.1 Road User Safety

The RMS risk assessment provides an 'assessed risk level' (ARL) rating, and when considering road user safety, considered a more robust risk assessment compared those previously used. An ARL threshold of 3 has been adopted by Waka Kotahi as a minimum standard for both NCTIR and Mt Messenger Bypass. This threshold has been adopted for other projects in the Wellington Region such as the Ngaio Gorge Stabilisation project which AECOM is also involved in.

A minimum residual ARL of 3 or greater is recommended.

6.1.2 Risk to Dwelling

Based on AS/NZS1170.0 a new build would be considered an importance level 2 structure with a design life of 50 years. The associated return period for a seismic event would be 500 years and corresponds to a peak ground acceleration of 0.68g (NZGS/MBIE Module 1 Appendix A). A 'disastrous' consequence would require the likelihood of failure to be 'rare', or 'unlikely' as a minimum.

Based on the adopted risk matrix we recommend a minimum risk threshold of moderate is adopted.

7.0 Recommendations

7.1 Dangerous Building Notice

Based on the current and residual risk associated with the dwelling at 46 Holborn Drive it is recommended the Dangerous Building Notice remains in place until slope remediation measures are implemented. We consider that on its own, structural works to the dwelling will not be sufficient to uplift the Dangerous Building Notice due to the risk of further slope instability. It is our opinion that the building may be safe to occupy following remedial works when the residual risk is equal to or lower than moderate.

Prior to lifting of the Dangerous Building Notice, and following completion of the slope remedial works, it is recommended the foundation system is assessed by a chartered professional structural engineer to confirm the building may be occupied.

7.2 Recommended Remedial Solution

Based on the assessed risk, cost of proposed remedial options and the current situation it is recommended that either:

- An anchored shotcrete wall is installed, as described in section 5.1. Based on feedback from s7(2)(b)(ii) [redacted] we consider the removal of the dwelling prior to wall installation will facilitate a safer and more efficient construction phase. If constructed the residual risk to road users and private property of 46 Holborn Drive would likely be reduced to an acceptable level.

  If the dwelling remains in place, there is a risk that the dwelling could sustain damage as a result of the anchoring and shotcreting works. Furthermore, a structural assessment of the building foundation will be required to facilitate the removal of the Dangerous Building Notice, as the house would not have been designed for the new environment (non-compliant with NZS3604). The presence of the dwelling is also likely to extend the construction period.In the interim the temporary containers, traffic management and the associated risk to road users should be monitored.

- The dwelling is removed (or relocated) and reprofiling of the soil slope is undertaken, as described in section 5.2.1. If completed and vegetation is re-established on the profiled slope then the risk to road users would likely be reduced to an acceptable level.

  The difficulties in removing the building off-site, or to another location on the same parcel of land is iterated in the s7(2)(b)(ii) [redacted] Ltd letter dated 11 October 2022. We anticipate other contractors will have similar reservations and difficulties in relocating the building on or off site. In turn, removing the dwelling is likely to require controlled demolition.

  Removal of the dwelling and reprofiling of the slope is likely to take less time to complete compared to that of the anchored shotcrete wall and eliminates the risk of the building impacting Eastern Hutt Road.

Both of these solutions could be implemented based on the site investigations and observations completed to date. No further investigations are deemed necessary and unlikely to be required to re-establish a building platform.

The risk assessments associated with the current condition of the slope, anchored shotcrete wall and building removal are presented in Appendix B.

Regardless of the solution implemented it is recommended:

- Fall protection is erected along the crest of the slope to address the fall from height risk
- Temporary loading from machinery and equipment is considered by the temporary works designer/contractor
- The condition of the slope is monitored throughout the construction period
- Containers remain in place and their effectiveness at mitigating runout of debris is monitored

Prior to the removal of the containers (following wall construction), the residual risk should be re-assessed to confirm the objectives have been met.

8.0 Limitations

AECOM has prepared this report for the sole use of Hutt City Council and for a specific purpose, each as expressly stated in the report. No other party should rely on this report without the prior written consent of AECOM. AECOM undertakes no duty, nor accepts any responsibility, to any third party who may rely upon or use this report. This report has been prepared based on the Client's description of its requirements and AECOM's experience, having regard to assumptions that AECOM can reasonably be expected to make in accordance with sound professional principles. AECOM's findings represent its reasonable judgment within the time and budget context of its commission and utilising the information available to it at the time.

No section or element of this report may be removed, reproduced, electronically stored or transmitted in any form by parties other than those for whom the report has been prepared without the written permission of AECOM. All sections in this report must be viewed in the context of the entire report/document including, without limitation, any assumptions made and disclaimers provided. No section in this report may be excised from the body of the report without AECOM's prior written consent.

The recommendations and opinions contained within this inspection report are based on visual geotechnical appraisal and engineering judgment. Inferences about ground conditions across the site are made according to desktop studies, site observations, standard geological principles, and engineering judgment. Therefore, it is not possible to guarantee the ground conditions due to the absence of site-specific investigations. Information provided within the appendices is based on the initial site visit and experience with similar projects.

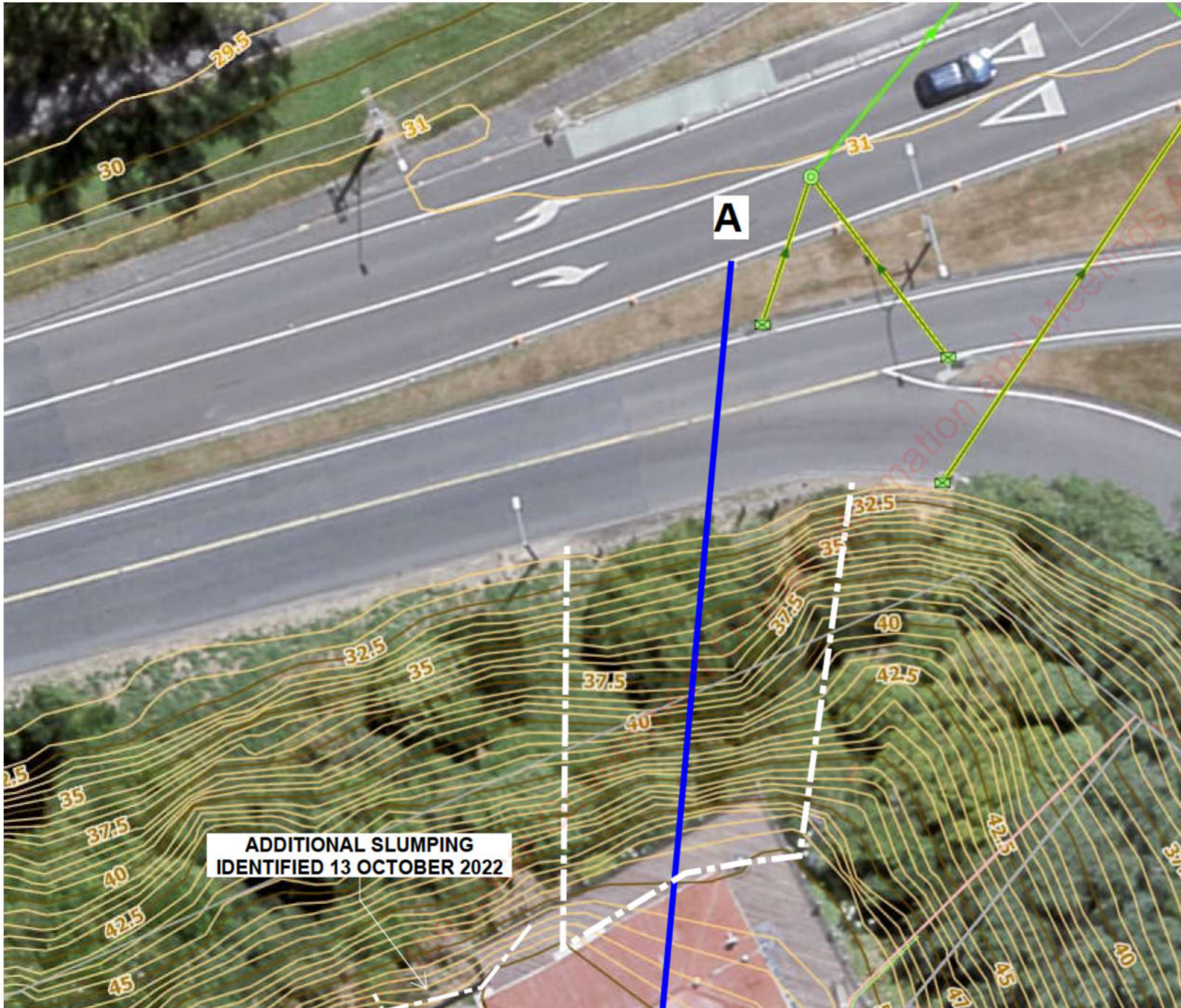
It is considered to be in the best interests of all parties that AECOM is retained to undertake this work. In any event, we should be notified if ground conditions encountered on site differ from those described in this report. Cost estimates have been undertaken to the best of our knowledge, given the restrictions and limits placed on us, and the lack of detailed data available.

AECOM has prepared this report using the standard of reasonable skill, care and diligence required of a consultant performing the same or similar Services. The report should be read in full. No warranty, expressed or implied, is made as to the professional advice included in this report. This report does not alleviate the need for any party to complete their own due diligence.

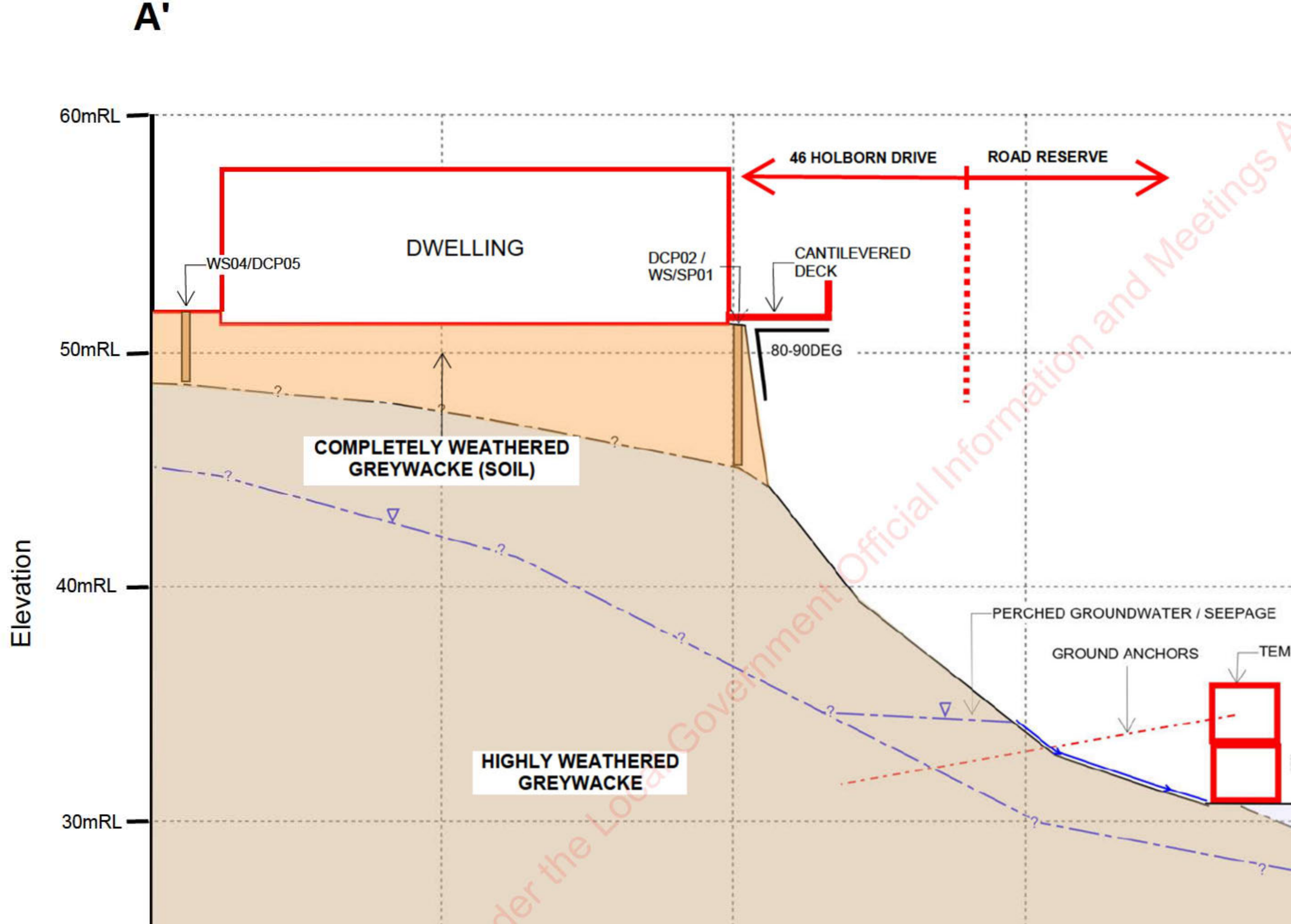
Appendix A

Inferred Ground Conditions

APPENDIX A - 46 HOLBORN DRIVE SITE LOCATION

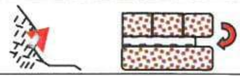
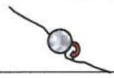
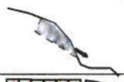
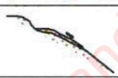
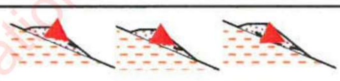
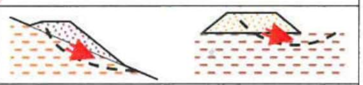
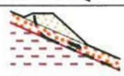
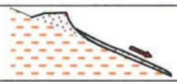
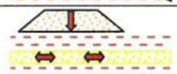
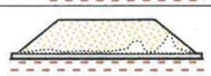
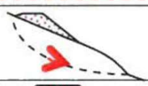
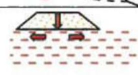
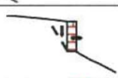
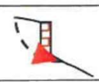
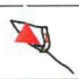
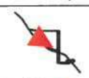


APPENDIX A - 46 HOLBORN DRIVE CROSS SEC



Appendix B

Select Risk Assessments

Common hazard types			
Mechanism	**Typical Circumstances**	**Description**	**Schematic Illustration(s)**
Fall	Steep rock batters	Prior to failure the block is supported at the top and/or rear surfaces and fails in tension., In practice, includes other initial failure types where the travel path is relatively long and the debris can go into trajectory over part of the distance.	
Topple	Columnar or tabular blocks resting on defects dipping out of the face	Prior to failure the block is supported on its basal surface and rotates about its front lower edge or an axis on the basal surface. Includes cases of undercutting where the debris cannot go into trajectory.	
Slide – rotational	In soils or some weak or highly fractured rock masses	Common in cohesive soils. Rupture surface may or may not be circular.	
Boulder roll	Steep soil batters containing boulders	Approximately equidimensional boulders released by erosion or other mechanism which will roll down the slope rather than go into trajectory.	
Slide - translational	Plane and wedge failures in rock	Almost always controlled by discontinuities or material interfaces.	
Spread	Lateral movement of blocks in a massive, jointed rock unit (most commonly sedimentary)	Requires deformation or failure of underlying material or shear at interface.	
Flow	Most commonly in soil slopes with high moisture content or substantial water inflows	Requires high moisture content in cohesive materials. Can also happen in dry cohesionless materials.	
Complex	Combination of above types, usually in different parts of the failed mass	Most common is a combination of rotational and translational.	
Rotational, within embankment	Any, but requires water source	Typically shallow to part width. Can be close to full width on steep side slopes.	
Rotational, through foundations	Soft soils, side slopes with deeper soils.	In soft soils usually during or shortly after construction, but can be delayed if soils have a stiffer crust which can soften when it wets up.	
Translational	Side slopes, especially when steep	Can be on interface with underlying materials at fill base, within underlying soils or at or within underlying rock. Normally on an interface, or defect controlled if in rock. Would normally affect the full width of the fill.	
Collapse	Loose granular fills, especially on side slopes	Requires fill to be very loose and close to saturation. Almost complete loss of shear strength on minor shearing. Only in end-dumped or sidecast fills. Highly mobile.	
Liquefaction	Confined loose sands in foundations, below water table	Earthquake or (possibly) vibration trigger. Often applied (incorrectly) to collapse of quick clays. Most often in natural materials, insitu. Could not happen within an engineered fill.	
Internal erosion	Dispersive or erodible soils, in fills or underlying materials. Most commonly in culvert backfills.	Forms internal voids which may collapse abruptly.	
Reactivation of pre-existing landslide	Fill on side slope, not necessarily steep	Due to loading of head or adverse effects on drainage.	
Spreading of foundations	Soft soils	Blurry distinction between this and rotational failure through foundations, except there won't be a visible scarp. Can be very difficult to distinguish from settlement without prolonged and careful observation.	
Overturning	Thin gravity structures, inadequate design.	Full or part height. Most common mode of failure under live loading.	
Sliding	Gravity structures	Insufficient shear resistance at base. Not common in properly designed structures, unless passive resistance at the toe is removed eg by excavation.	
Bearing	Gravity walls	Not common in modern structures.	
Global foundation failure	Gravity structures.	Weak foundation materials or adverse defects in rock	
Settlement	Gravity structures	Compressible foundations. May have been allowed for in design. Can lead to tilting of wall and damage to any supported structures.	
Shear failure through backfill ('bulging')	Flexible or brittle walls (eg drystone, RSW, gabions)	Common failure mode in flexible structures. May manifest as overturning in thin, rigid structures.	
Bending	Cantilevered pile walls with insufficient strength.	Can only occur in structures with substantial tensile strength.	
Toe breakout	Cantilevered pile walls usually on steep slopes	Insufficient embedment, inadequate rock strength.	
Anchor pullout	Anchored pile walls	Inadequate anchor strength, damage to anchors or loss of surrounding ground.	

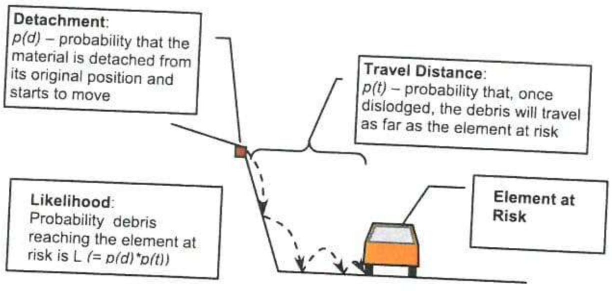


Figure 6. Detachment and Travel Distance Probabilities

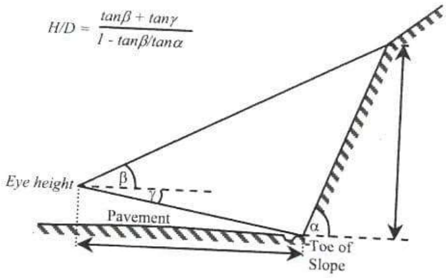


Figure 4. Height Estimation by Triangulation

Table 7. Criteria for allocation of detachment probability

P(d)	Current Slope Condition	Evidence for Previous Failures	Progress of Evolving Mechanisms	Possible Triggering Event
1	A potential mechanism is apparent. Either failure appears imminent or there is evidence that the detachment mechanism is currently active.	The slope may show evidence of earlier repeated failures of the same type.	Failure could be initiated by a very small further progression of the mechanism relative to that which has already occurred.	Failure could be initiated by a triggering event with a short return period (eg 1 year storm).
0.1 (1×10^{-1})	A potential mechanism is apparent and either is active or could easily be activated but failure does not appear imminent. There may be evidence of past distress.	Slopes which have been in existence for some time (ie in the order of decades) may show evidence of occasional previous failures.	Failure could be expected within a few years to a few decades if the mechanism continues to develop at its current rate	Failure could be triggered by a fairly common event (eg 10 year storm).
0.01 (1×10^{-2})	A potential mechanism is apparent, but failure does not appear imminent There may be evidence of past distress.	Slopes which have been in existence for many years (ie usually more than 30 years) *may* show evidence of an earlier failure	The progress of the mechanism is evident, but would require substantial development relative to that which has already occurred before failure would be initiated.	Triggering could be expected to require a severe event (eg 1 in 100 year storm).
0.001 (1×10^{-3})	The potential mechanism can be identified but failure does not appear imminent	Constructed slopes show no evidence of previous failures of the same type. There may be evidence of old failures on natural slopes.	The existence of the mechanism is evident, but would require very substantial development relative to that which has already occurred before failure would be initiated, or failure would require a substantial acceleration of the progress of the mechanism.	Failure would require an unusually severe triggering event
0.0001 (1×10^{-4})	The potential mechanism can be deduced from slope features or geological considerations	Comparable slopes in the same area may show evidence of previous failures of the same type	Where processes are ancient their age may be used to infer (loosely) their probability of recurrence eg landslides formed at around the end of the last ice age (about 10 – 12,000 years ago)	Failure would require an extreme triggering event
0.00001 (1×10^{-5}) and smaller	The potential mechanism can be deduced from slope features or geological considerations	Some comparable slopes in the same area may show evidence of rare previous failures of the same type	The mechanism may only be deduced from long term slope evolution considerations	Failure would require the most extreme of triggering events eg probable maximum flood or maximum credible event

Table 8. Factors affecting potential for failure under live loading

Factor	Considerations
Wall Type	Masonry walls, particularly when unmortared ('drystone'), are prone to brittle failure under load. Walls of this type were commonly used to retain road embankments in the 19th and early 20th centuries and were still being constructed in some areas until about 1960.
Foundations	Foundation materials and design (if any) will constrain the types of mechanism which are possible.
Original condition of wall	Construction standard and geometry of structure. Drystone walls were built to a number of patterns. The most common in smaller walls was with front and rear faces parallel and with a height:thickness ratio of 6:1, subject to a minimum thickness of about 400 mm. Original batter angles would normally have been no steeper than about 80° (1:6).
Current condition of wall	Evidence for the presence of one or more distress modes (see tables and diagrams). The factor of safety against overturning of drystone walls decreases rapidly as the batter angle increases above 80° and may be close to 1 where the wall is near vertical, even without considering live loading.
Condition of retained material	Cracking or subsidence in the pavement or shoulder may indicate the existence of an active or dormant failure mechanism. Evidence of past movement may be disguised by resurfacing or pavement rehabilitation
Extent of development of potential or actual failure mechanisms	Based on a synthesis of the above factors. Consider the degree of development of the mechanism relative to that needed for failure to occur.
Potential live load location	The potential for failure under live loading depends critically on the location of the load. Consider the location of the outer wheelpath relative to the wall crest, constraints on traffic (eg edge lines, visual or physical barriers, road geometry in relation to the possible position of heavy vehicles), local circumstances which may cause traffic to divert towards the wall under normal operating conditions (eg narrow pavement and poor sight distance). Normally the edge line (or edge of the seal if no edge line is present) would be considered the limit of potential live load locations.

Table 9. Likelihood allocation for retaining wall failure under live loading

Wall condition	Live load distance from toe of wall		
	< H/2	**H/2 - H**	**> H**
Significant or major distress evident, apparently active	L1	L2	L3
Significant or major distress evident, not apparently active	L2	L3	L4
Minor distress evident, apparently active	L3	L4	L5
Minor distress evident, not apparently active or poorly constructed wall	L4	L5	L6
Apparently well-constructed wall, no visible distress	L5	L6	L6

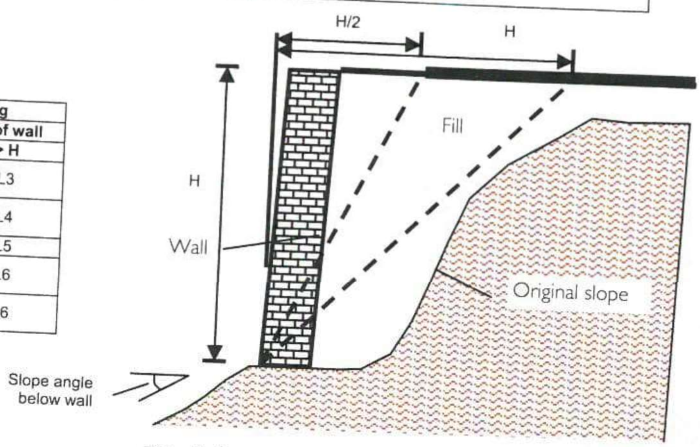
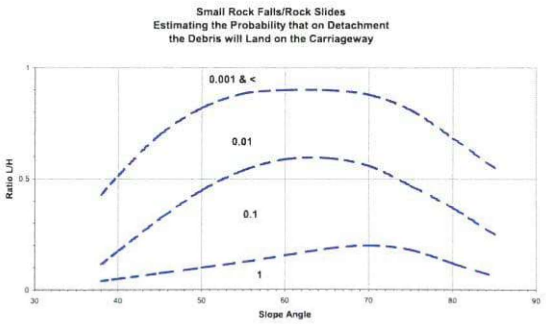


Figure 7. Parameters for Live Loading of Retaining Structures



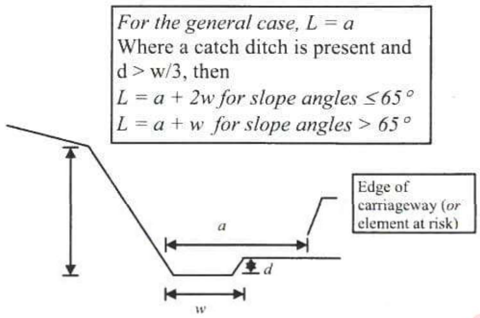


Figure 8. Estimating Travel Distance Probability for Small Rock Falls/Slides Figure 9. Definition of Parameters for Figure 8

Table 11. Temporal probability rating definitions		
Rating	**Probability Range**	**Definition**
T1	> 0.5	Person usually expected to be present as part of the normal pattern of usage (eg residential buildings, some commercial buildings). Road users in the heaviest of urban traffic conditions.
T2	0.1 – 0.5	Person often expected to be present as part of the normal pattern of usage (eg many commercial buildings). Road users on major urban arterial roads and the most heavily trafficked rural roads.
T3	0.01 – 0.1	Person may sometimes be present as part of the normal pattern of usage. Road users on many urban arterial roads and most major rural arterial roads
T4	0.001 – 0.01	Person unlikely to be present even where there is a pattern of usage. Road users on suburban roads and minor rural arterial roads
T5	< 0.001	Person is very unlikely to be present. Road users on the most lightly trafficked roads, road shoulders etc.

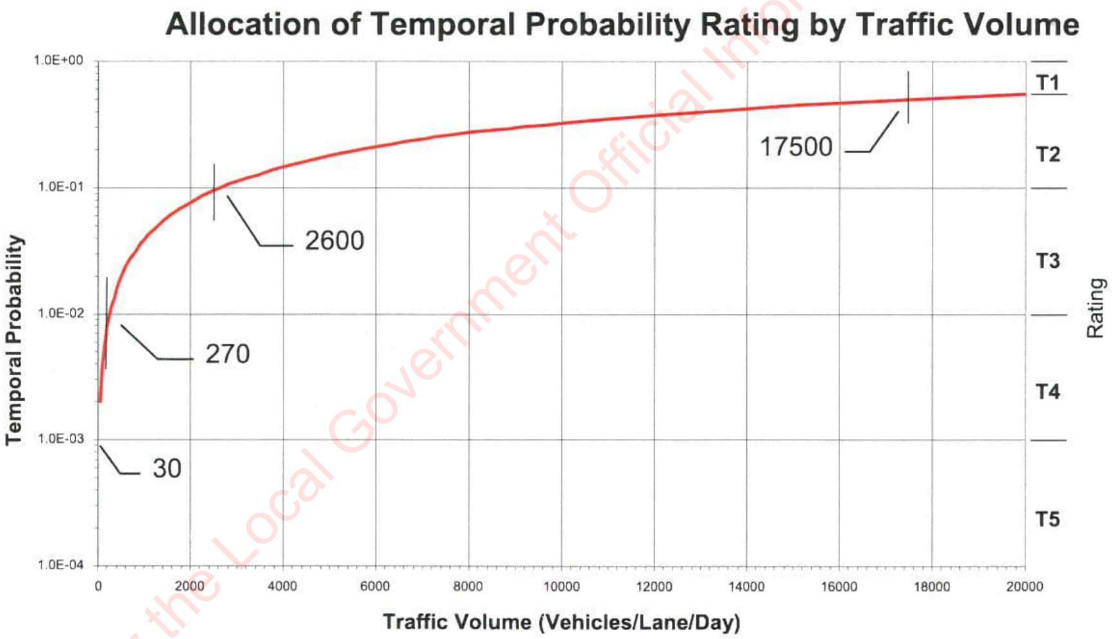


Table 13. Modification of T for direct impact by rockfall					
Case	**T Rating**				
Debris lodging on the road (from Guide Figure 6)	T5	T4	T3	T2	T1
Modified T for debris directly impacting vehicle	T5	T5	T4	T3	T3

Table 14. Modification of T for direct impact by large scale failures			
Modification to T	**Length of Failure Traversed at Posted Speed Limit**		
	≤ 50 km/h	**60 – 90 km/h**	**100 – 110 km/h**
Decrease T (eg T3 ⇒ T4)	< 15 m	< 25 m	< 60 m
T unchanged	15 – 100 m	25 – 250 m	60 – 600 m
Increase T (eg T3 ⇒ T2)	> 100 m	> 250 m	> 600 m

Table 17. Expanded vulnerability table

Vulnerability Rating	People in the Open	People in Buildings	Vehicle Occupants		
			Vehicle Impact with Individual Rock Blocks	Vehicle Impact with Mixed Landslide Debris	Vehicle Crossing Embankment Failure Area
V1	Unable to evade rockfall or other debris (movement very/extremely rapid), or buried	Engulfed in building collapse	Block > 1 m high at highway speeds		Lost into a deep, narrow void
V2	May be able to evade debris	Partial building collapse	Block > 1 m high at urban speeds Block 0.5 – 1 m high at highway speeds		Lost into a shallow void
V3	Most people able to evade debris	Building penetrated, no collapse	Block >1 m high at low speeds Block 0.5 – 1 m high at urban speeds	Loose or wet mixed soil/rock debris at highway speeds	Stepped surface with 0.1 – 0.2 m steps at highway speeds
V4		Building struck, damaged but not penetrated	Block 0.5 – 1 m high at low speeds Block around 0.2 m high at highway speeds	Loose or wet mixed soil/rock debris at urban speeds	Stepped surface with 0.1 – 0.2 m steps at urban speeds Shallow void/depression where guardfence may prevent a vehicle from leaving the road
V5		Building struck, only minor damage etc	Block around 0.2 m high at urban speeds Smaller block at highway speeds	Loose or wet mixed soil/rock debris at low speeds Irregular surface formed by soil or small (<100mm minimum dimension) rock at highway speeds	Stepped surface with 0.1 – 0.2 m steps at low speeds Irregular surface formed by a developing embankment failure at highway speeds

Table 18. Extended vulnerability table - Vehicles impacting single rock blocks

Block Size	Posted Speed Limit		
	Highway Speeds (100 – 110 km/h)	Urban Speeds (60 – 80 km/h)	Low Speeds (≤ 50 km/h)
Minimum dimension >1 m	V1	V2	V3
Minimum dimension 0.5 – 1 m	V2	V3	V4
Minimum dimension 0.2 – 0.5 m	V3	V4	V5
Minimum dimension ≈ 0.2 m	V4	V5	V5*
Minimum dimension ≈ 0.1 m	V5	V5*	V5*

Table 19. Extended Vulnerability Table - Vehicles impacting mixed landslide debris

Debris Type	Posted Speed Limit		
	Highway Speeds (100 – 110 km/h)	Urban Speeds (60 – 80 km/h)	Low Speeds (≤ 50 km/h)
Loose or wet mixed soil/rock debris	V3	V4	V5
Small rock debris (min dim < 0.1 m)	V5	V5*	V5*

Table 20. Extended vulnerability table - Vehicles impacting voids or stepped surfaces

Void or Surface Type	Posted Speed Limit		
	Highway Speeds (100 – 110 km/h)	Urban Speeds (60 – 80 km/h)	Low Speeds (≤ 50 km/h)
Deep, narrow void	V1	V2	V3
Shallow void (0.2 – 0.5 m step)	V2	V3	V4
Stepped surface (0.1 – 0.2 m steps)	V3	V4	V5
Irregular surface (steps < 0.1 m)	V5	V5*	V5*
Shallow void with guardfence or wire rope barrier	V4	V4	V4

Table 21. Resultant velocity (m/s) by fall height and traffic speed

Traffic speed m/s (km/h)	Fall Height (m)									
	5	10	15	20	25	30	40	50	75	100
0 (0)	9.9	14.0	17.2	19.8	22.1	24.3	28.0	31.3	38.4	44.3
13.9 (50)	17.1	19.7	22.1	24.2	26.1	27.9	31.3	34.3	40.8	46.4
16.7 (60)	19.4	21.8	23.9	25.9	27.7	29.4	32.6	35.5	41.8	47.3
19.4 (70)	21.8	24.0	25.9	27.8	29.5	31.1	34.1	36.9	43.0	48.4
22.2 (80)	24.3	26.3	28.1	29.8	31.4	32.9	35.8	38.4	44.3	49.6
25.0 (90)	26.9	28.7	30.3	31.9	33.4	34.8	37.6	40.1	45.8	50.9
27.8 (100)	29.5	31.1	32.7	34.1	35.5	36.9	39.5	41.9	47.4	52.3
30.6 (110)	32.1	33.6	35.0	36.4	37.7	39.0	41.5	43.8	49.0	53.8

Table 22. Vulnerability allocation for vehicle directly impacted by single rock blocks			
Block Size	Resultant Velocity		
	> 25 m/s	15 – 25 m/s	< 15 m/s
Minimum Dimension >1 m	V1	V1	V1
Minimum Dimension 0..5 – 1 m	V1	V1	V2
Minimum Dimension 0.2 – 0.5 m	V1	V2	V3
Minimum Dimension 0.1 – 0.2 m	V2	V3	V3
Minimum Dimension < 0.1 m	V3	V4	V4

Table 24. Vulnerability allocation for retaining wall failure under live loading (road users)					
Slope angle below wall	Wall height				
	< 1 m	1 – 2 m	2 – 3 m	3 – 4 m	> 4 m
> 35°	V2	V2?	V1	V1	V1
25° - 35°	V3	V2	V2	V1	V1
15° - 25°	V4	V3	V2	V1	V1
<15°	V5	V4	V3	V2	V1

Table 26. Consequence ratings for property damage and consequential effects	
Rating	Indicative Criteria
C1	Total direct and indirect costs > $15 million: • Total closure of a Sub-Network Rank 5 or 6 (SN5-SN6) road for an extended period or very high disruption cost (other than road users) • Major infrastructure or property damage (other than road • Very high repair cost
C2	Total direct and indirect costs > $3 million < $15 million: • Total closure of one carriageway of an SN5-6 road or total closure of an SN3–SN4 road for an extended period or large disruption costs • Substantial infrastructure or property damage • High repair cost
C3	Total direct and indirect costs > $0.8 million < $3 million: • Partial or total closure of an SN3-SN4 road for a short period, longer period if reasonable alternatives are available or moderate disruption costs • Moderate infrastructure or property damage • Moderate repair cost
C4	Total direct and indirect costs > $0.2 million < $0.8 million: • Partial or total closure of an SN2 road for a short period or minor disruption costs • Minor infrastructure or property damage • Low repair cost
C5	Total direct and indirect costs < $0.2 million: • Partial or total closure of an SN1 road for a short period or little or no disruption costs • Negligible infrastructure or property damage • Very low – no repair cost

	Table 25. Consequence matrix for risk to life				
	Temporal Probability of an Individual Being Present at the Time of Failure				
Vulnerability	T5	T4	T3	T2	T1
V1	C4	C3	C2	C1	C1
V2	C4	C3	C2	C1	C1
V3	C5	C4	C3	C2	C2
V4	C5	C5	C4	C3	C3
V5	C5	C5	C5	C4	C4

	Table 27. Assessed risk level matrix				
	Consequence Class				
Likelihood	C5	C4	C3	C2	C1
L1	ARL3	ARL2	ARL1	ARL1	ARL1
L2	ARL4	ARL3	ARL2	ARL1	ARL1
L3	ARL5	ARL4	ARL3	ARL2	ARL1
L4	ARL5	ARL5	ARL4	ARL3	ARL2
L5	ARL5	ARL5	ARL5	ARL4	ARL3
L6	ARL5	ARL5	ARL5	ARL5	ARL4

Meanings Attached to the Term 'Road Closure'.

Total closure

This means that the road is closed to traffic in both directions and all traffic has to take an alternate route.

Partial closure

This means that the road is closed to traffic in one direction and either:

- the traffic in one direction has to take an alternate route, or
- the traffic in both directions has to be controlled to allow alternating one-way flows. This may require the construction of earthworks and temporary pavements (for instance, to cross the median in dual carriageway roads or to allow traffic to use the road shoulder for an extended period).

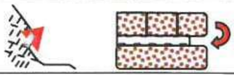
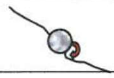
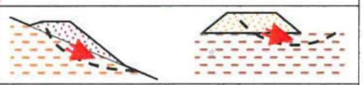
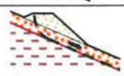
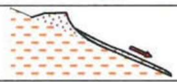
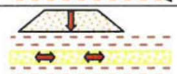
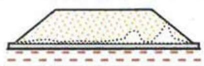
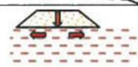
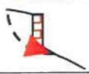
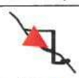
Supplementary Ratings

Table 28. Scale of failure (S) ratings		
Rating	Volume of Failure	Individual Block Size
S1	Volume > 20,000 m³ (eg. 40 m wide x 60 m long x 10 m deep = 24,000 m³)	Individual blocks of > 1m minimum dimension (eg one rock 1 x 1 x 2 m)
S2	Volume > 2,000 m³	Individual blocks of 0.5 – 1 m minimum dimension
S3	Volume > 200 m³	Individual blocks of 0.2 - 0.5 m minimum dimension
S4	Volume > 20 m³	Individual blocks of about 0.2 m minimum dimension
S5	Volume < 20 m³	Individual blocks of about 0.1 m minimum dimension

Table 29. Velocity of failure (R) ratings			
Rating	Description	Velocity (mm/sec)	Typical Velocity
R1	Extremely Rapid		
		5×10^3	5 m/sec
	Very Rapid		
		5×10^1	3 m/min
R2	Rapid		
		5 x 10-1	1.8 m/h
R3	Moderate		
		5×10^{-3}	13 m/month
R4	Slow		
		5×10^{-5}	1.6 m/year
R5	Very Slow		
		5×10^{-7}	16 mm/year
	Extremely Slow		

		Table 30. Event magnitude classification matrix				
		Scale of Failure				
Velocity of Failure		S5	S4	S3	S2	S1
Fast	R1	M3	M2	M2	M1	M1
⇕	R2	M4	M3	M2	M2	M1
	R3	M4	M4	M3	M2	M2
	R4	M5	M4	M4	M3	M2
Slow	R5	M5	M5	M4	M4	M3

	Table 31. Hazard classification matrix				
	Event Magnitude				
Likelihood	M5	M4	M3	M2	M1
L1	H3	H2	H2	H1	H1
L2	H4	H3	H2	H2	H1
L3	H4	H4	H3	H2	H2
L4	H5	H4	H4	H3	H2
L5	H5	H5	H4	H4	H3
L6	H5	H5	H5	H4	H4

Common hazard types			
Mechanism	**Typical Circumstances**	**Description**	**Schematic Illustration(s)**
Fall	Steep rock batters	Prior to failure the block is supported at the top and/or rear surfaces and fails in tension., In practice, includes other initial failure types where the travel path is relatively long and the debris can go into trajectory over part of the distance.	
Topple	Columnar or tabular blocks resting on defects dipping out of the face	Prior to failure the block is supported on its basal surface and rotates about its front lower edge or an axis on the basal surface. Includes cases of undercutting where the debris cannot go into trajectory.	
Slide – rotational	In soils or some weak or highly fractured rock masses	Common in cohesive soils. Rupture surface may or may not be circular.	
Boulder roll	Steep soil batters containing boulders	Approximately equidimensional boulders released by erosion or other mechanism which will roll down the slope rather than go into trajectory.	
Slide - translational	Plane and wedge failures in rock	Almost always controlled by discontinuities or material interfaces.	
Spread	Lateral movement of blocks in a massive, jointed rock unit (most commonly sedimentary)	Requires deformation or failure of underlying material or shear at interface.	
Flow	Most commonly in soil slopes with high moisture content or substantial water inflows	Requires high moisture content in cohesive materials. Can also happen in dry cohesionless materials.	
Complex	Combination of above types, usually in different parts of the failed mass	Most common is a combination of rotational and translational.	
Rotational, within embankment	Any, but requires water source	Typically shallow to part width. Can be close to full width on steep side slopes.	
Rotational, through foundations	Soft soils, side slopes with deeper soils.	In soft soils usually during or shortly after construction, but can be delayed if soils have a stiffer crust which can soften when it wets up.	
Translational	Side slopes, especially when steep	Can be on interface with underlying materials at fill base, within underlying soils or at or within underlying rock. Normally on an interface, or defect controlled if in rock. Would normally affect the full width of the fill.	
Collapse	Loose granular fills, especially on side slopes	Requires fill to be very loose and close to saturation. Almost complete loss of shear strength on minor shearing. Only in end-dumped or sidecast fills. Highly mobile.	
Liquefaction	Confined loose sands in foundations, below water table	Earthquake or (possibly) vibration trigger. Often applied (incorrectly) to collapse of quick clays. Most often in natural materials, insitu. Could not happen within an engineered fill.	
Internal erosion	Dispersive or erodible soils, in fills or underlying materials. Most commonly in culvert backfills.	Forms internal voids which may collapse abruptly.	
Reactivation of pre-existing landslide	Fill on side slope, not necessarily steep	Due to loading of head or adverse effects on drainage.	
Spreading of foundations	Soft soils	Blurry distinction between this and rotational failure through foundations, except there won't be a visible scarp. Can be very difficult to distinguish from settlement without prolonged and careful observation.	
Overturning	Thin gravity structures, inadequate design.	Full or part height. Most common mode of failure under live loading.	
Sliding	Gravity structures	Insufficient shear resistance at base. Not common in properly designed structures, unless passive resistance at the toe is removed eg by excavation.	
Bearing	Gravity walls	Not common in modern structures.	
Global foundation failure	Gravity structures.	Weak foundation materials or adverse defects in rock	
Settlement	Gravity structures	Compressible foundations. May have been allowed for in design. Can lead to tilting of wall and damage to any supported structures.	
Shear failure through backfill ('bulging')	Flexible or brittle walls (eg drystone, RSW, gabions)	Common failure mode in flexible structures. May manifest as overturning in thin, rigid structures.	
Bending	Cantilevered pile walls with insufficient strength.	Can only occur in structures with substantial tensile strength.	
Toe breakout	Cantilevered pile walls usually on steep slopes	Insufficient embedment, inadequate rock strength.	
Anchor pullout	Anchored pile walls	Inadequate anchor strength, damage to anchors or loss of surrounding ground.	

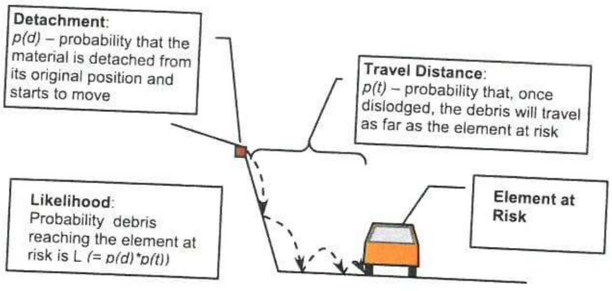


Figure 6. Detachment and Travel Distance Probabilities

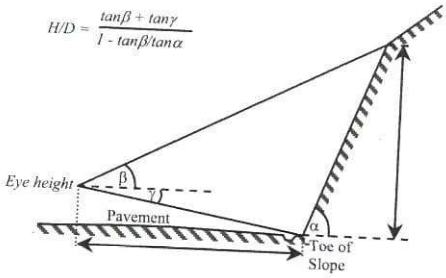


Figure 4. Height Estimation by Triangulation

Table 7. Criteria for allocation of detachment probability

P(d)	Current Slope Condition	Evidence for Previous Failures	Progress of Evolving Mechanisms	Possible Triggering Event
1	A potential mechanism is apparent. Either failure appears imminent or there is evidence that the detachment mechanism is currently active.	The slope may show evidence of earlier repeated failures of the same type.	Failure could be initiated by a very small further progression of the mechanism relative to that which has already occurred.	Failure could be initiated by a triggering event with a short return period (eg 1 year storm).
0.1 (1×10^{-1})	A potential mechanism is apparent and either is active or could easily be activated but failure does not appear imminent. There may be evidence of past distress.	Slopes which have been in existence for some time (ie in the order of decades) may show evidence of occasional previous failures.	Failure could be expected within a few years to a few decades if the mechanism continues to develop at its current rate	Failure could be triggered by a fairly common event (eg 10 year storm).
0.01 (1×10^{-2})	A potential mechanism is apparent, but failure does not appear imminent There may be evidence of past distress.	Slopes which have been in existence for many years (ie usually more than 30 years) *may* show evidence of an earlier failure	The progress of the mechanism is evident, but would require substantial development relative to that which has already occurred before failure would be initiated.	Triggering could be expected to require a severe event (eg 1 in 100 year storm).
0.001 (1×10^{-3})	The potential mechanism can be identified but failure does not appear imminent	Constructed slopes show no evidence of previous failures of the same type. There may be evidence of old failures on natural slopes.	The existence of the mechanism is evident, but would require very substantial development relative to that which has already occurred before failure would be initiated, or failure would require a substantial acceleration of the progress of the mechanism.	Failure would require an unusually severe triggering event
0.0001 (1×10^{-4})	The potential mechanism can be deduced from slope features or geological considerations	Comparable slopes in the same area may show evidence of previous failures of the same type	Where processes are ancient their age may be used to infer (loosely) their probability of recurrence eg landslides formed at around the end of the last ice age (about 10 – 12,000 years ago)	Failure would require an extreme triggering event
0.00001 (1×10^{-5}) and smaller	The potential mechanism can be deduced from slope features or geological considerations	Some comparable slopes in the same area may show evidence of rare previous failures of the same type	The mechanism may only be deduced from long term slope evolution considerations	Failure would require the most extreme of triggering events eg probable maximum flood or maximum credible event

Table 8. Factors affecting potential for failure under live loading

Factor	Considerations
Wall Type	Masonry walls, particularly when unmortared ('drystone'), are prone to brittle failure under load. Walls of this type were commonly used to retain road embankments in the 19th and early 20th centuries and were still being constructed in some areas until about 1960.
Foundations	Foundation materials and design (if any) will constrain the types of mechanism which are possible.
Original condition of wall	Construction standard and geometry of structure. Drystone walls were built to a number of patterns. The most common in smaller walls was with front and rear faces parallel and with a height:thickness ratio of 6:1, subject to a minimum thickness of about 400 mm. Original batter angles would normally have been no steeper than about 80° (1:6).
Current condition of wall	Evidence for the presence of one or more distress modes (see tables and diagrams). The factor of safety against overturning of drystone walls decreases rapidly as the batter angle increases above 80° and may be close to 1 where the wall is near vertical, even without considering live loading.
Condition of retained material	Cracking or subsidence in the pavement or shoulder may indicate the existence of an active or dormant failure mechanism. Evidence of past movement may be disguised by resurfacing or pavement rehabilitation
Extent of development of potential or actual failure mechanisms	Based on a synthesis of the above factors. Consider the degree of development of the mechanism relative to that needed for failure to occur.
Potential live load location	The potential for failure under live loading depends critically on the location of the load. Consider the location of the outer wheelpath relative to the wall crest, constraints on traffic (eg edge lines, visual or physical barriers, road geometry in relation to the possible position of heavy vehicles), local circumstances which may cause traffic to divert towards the wall under normal operating conditions (eg narrow pavement and poor sight distance). Normally the edge line (or edge of the seal if no edge line is present) would be considered the limit of potential live load locations.

Table 9. Likelihood allocation for retaining wall failure under live loading

Wall condition	Live load distance from toe of wall		
	< H/2	**H/2 - H**	**> H**
Significant or major distress evident, apparently active	L1	L2	L3
Significant or major distress evident, not apparently active	L2	L3	L4
Minor distress evident, apparently active	L3	L4	L5
Minor distress evident, not apparently active or poorly constructed wall	L4	L5	L6
Apparently well-constructed wall, no visible distress	L5	L6	L6

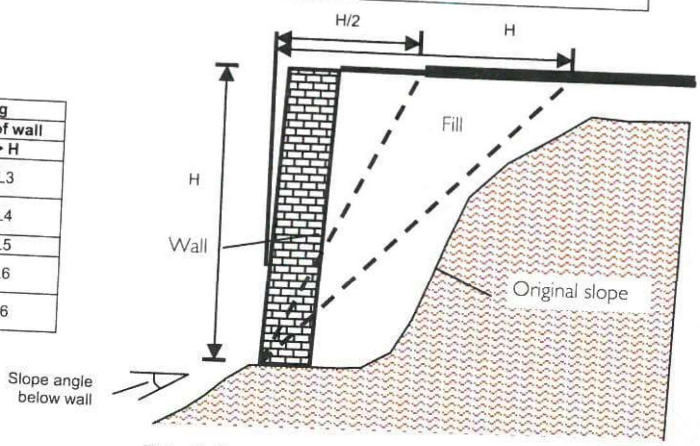
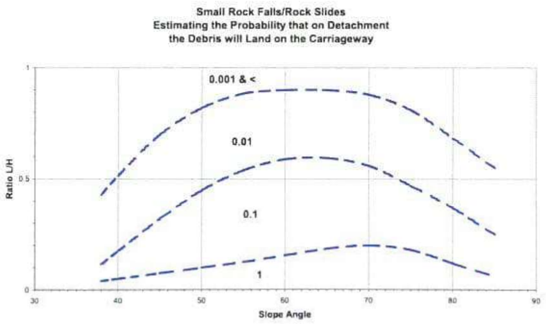


Figure 7. Parameters for Live Loading of Retaining Structures



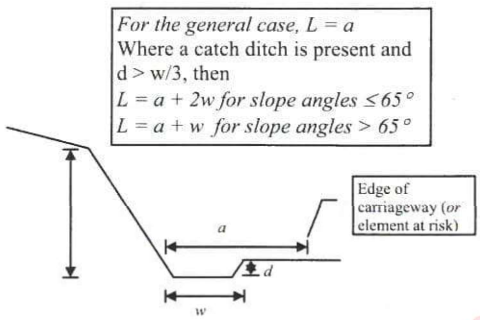


Figure 8. Estimating Travel Distance Probability for Small Rock Falls/Slides Figure 9. Definition of Parameters for Figure 8

Table 11. Temporal probability rating definitions		
Rating	Probability Range	Definition
T1	> 0.5	Person usually expected to be present as part of the normal pattern of usage (eg residential buildings, some commercial buildings). Road users in the heaviest of urban traffic conditions.
T2	0.1 – 0.5	Person often expected to be present as part of the normal pattern of usage (eg many commercial buildings). Road users on major urban arterial roads and the most heavily trafficked rural roads.
T3	0.01 – 0.1	Person may sometimes be present as part of the normal pattern of usage. Road users on many urban arterial roads and most major rural arterial roads
T4	0.001 – 0.01	Person unlikely to be present even where there is a pattern of usage. Road users on suburban roads and minor rural arterial roads
T5	< 0.001	Person is very unlikely to be present. Road users on the most lightly trafficked roads, road shoulders etc.

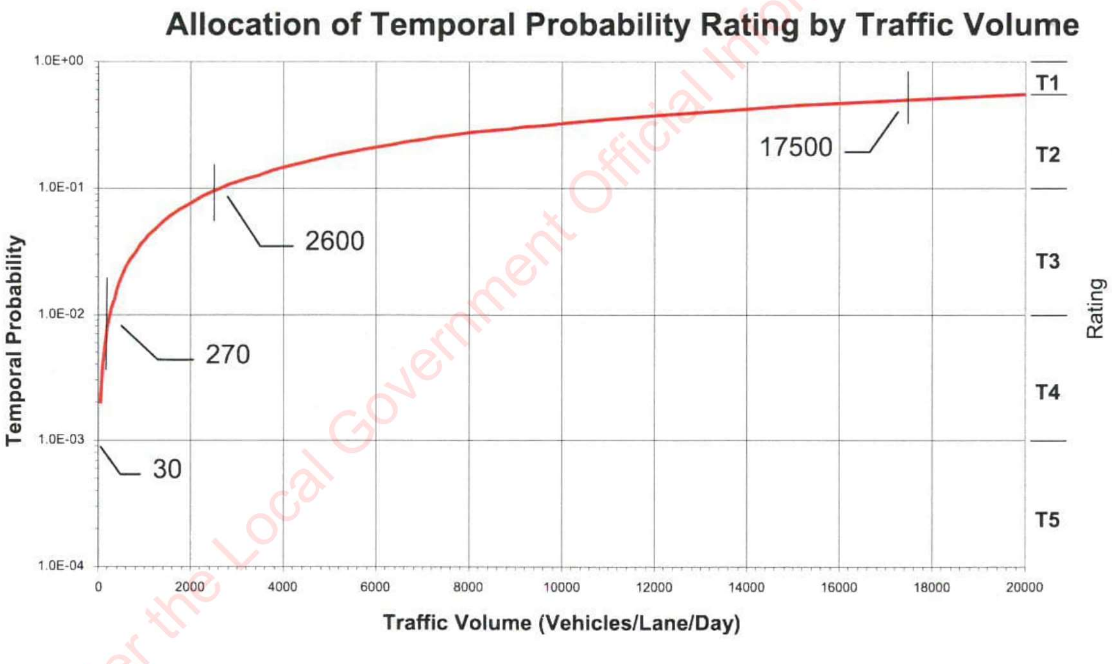


Table 13. Modification of T for direct impact by rockfall					
Case	T Rating				
Debris lodging on the road (from Guide Figure 6)	T5	T4	T3	T2	T1
Modified T for debris directly impacting vehicle	T5	T5	T4	T3	T3

Table 14. Modification of T for direct impact by large scale failures			
Modification to T	Length of Failure Traversed at Posted Speed Limit		
	≤ 50 km/h	60 – 90 km/h	100 – 110 km/h
Decrease T (eg T3 ⇒ T4)	< 15 m	< 25 m	< 60 m
T unchanged	15 – 100 m	25 – 250 m	60 – 600 m
Increase T (eg T3 ⇒ T2)	> 100 m	> 250 m	> 600 m

Table 17. Expanded vulnerability table

Vulnerability Rating	People in the Open	People in Buildings	Vehicle Occupants		
			Vehicle Impact with Individual Rock Blocks	**Vehicle Impact with Mixed Landslide Debris**	**Vehicle Crossing Embankment Failure Area**
V1	Unable to evade rockfall or other debris (movement very/extremely rapid), or buried	Engulfed in building collapse	Block > 1 m high at highway speeds		Lost into a deep, narrow void
V2	May be able to evade debris	Partial building collapse	Block > 1 m high at urban speeds Block 0.5 – 1 m high at highway speeds		Lost into a shallow void
V3	Most people able to evade debris	Building penetrated, no collapse	Block >1 m high at low speeds Block 0.5 – 1 m high at urban speeds	Loose or wet mixed soil/rock debris at highway speeds	Stepped surface with 0.1 – 0.2 m steps at highway speeds
V4		Building struck, damaged but not penetrated	Block 0.5 – 1 m high at low speeds Block around 0.2 m high at highway speeds	Loose or wet mixed soil/rock debris at urban speeds	Stepped surface with 0.1 – 0.2 m steps at urban speeds Shallow void/depression where guardfence may prevent a vehicle from leaving the road
V5		Building struck, only minor damage etc	Block around 0.2 m high at urban speeds Smaller block at highway speeds	Loose or wet mixed soil/rock debris at low speeds Irregular surface formed by soil or small (<100mm minimum dimension) rock at highway speeds	Stepped surface with 0.1 – 0.2 m steps at low speeds Irregular surface formed by a developing embankment failure at highway speeds

Table 18. Extended vulnerability table - Vehicles impacting single rock blocks

Block Size	Posted Speed Limit		
	Highway Speeds (100 – 110 km/h)	**Urban Speeds (60 – 80 km/h)**	**Low Speeds (≤ 50 km/h)**
Minimum dimension >1 m	V1	V2	V3
Minimum dimension 0.5 – 1 m	V2	V3	V4
Minimum dimension 0.2 – 0.5 m	V3	V4	V5
Minimum dimension ≈ 0.2 m	V4	V5	V5*
Minimum dimension ≈ 0.1 m	V5	V5*	V5*

Table 19. Extended Vulnerability Table - Vehicles impacting mixed landslide debris

Debris Type	Posted Speed Limit		
	Highway Speeds (100 – 110 km/h)	**Urban Speeds (60 – 80 km/h)**	**Low Speeds (≤ 50 km/h)**
Loose or wet mixed soil/rock debris	V3	V4	V5
Small rock debris (min dim < 0.1 m)	V5	V5*	V5*

Table 20. Extended vulnerability table - Vehicles impacting voids or stepped surfaces

Void or Surface Type	Posted Speed Limit		
	Highway Speeds (100 – 110 km/h)	**Urban Speeds (60 – 80 km/h)**	**Low Speeds (≤ 50 km/h)**
Deep, narrow void	V1	V2	V3
Shallow void (0.2 – 0.5 m step)	V2	V3	V4
Stepped surface (0.1 – 0.2 m steps)	V3	V4	V5
Irregular surface (steps < 0.1 m)	V5	V5*	V5*
Shallow void with guardfence or wire rope barrier	V4	V4	V4

Table 21. Resultant velocity (m/s) by fall height and traffic speed

Traffic speed m/s (km/h)	Fall Height (m)									
	5	**10**	**15**	**20**	**25**	**30**	**40**	**50**	**75**	**100**
0 (0)	9.9	14.0	17.2	19.8	22.1	24.3	28.0	31.3	38.4	44.3
13.9 (50)	17.1	19.7	22.1	24.2	26.1	27.9	31.3	34.3	40.8	46.4
16.7 (60)	19.4	21.8	23.9	25.9	27.7	29.4	32.6	35.5	41.8	47.3
19.4 (70)	21.8	24.0	25.9	27.8	29.5	31.1	34.1	36.9	43.0	48.4
22.2 (80)	24.3	26.3	28.1	29.8	31.4	32.9	35.8	38.4	44.3	49.6
25.0 (90)	26.9	28.7	30.3	31.9	33.4	34.8	37.6	40.1	45.8	50.9
27.8 (100)	29.5	31.1	32.7	34.1	35.5	36.9	39.5	41.9	47.4	52.3
30.6 (110)	32.1	33.6	35.0	36.4	37.7	39.0	41.5	43.8	49.0	53.8

Table 22. Vulnerability allocation for vehicle directly impacted by single rock blocks			
Block Size	Resultant Velocity		
	> 25 m/s	15 – 25 m/s	< 15 m/s
Minimum Dimension >1 m	V1	V1	V1
Minimum Dimension 0..5 – 1 m	V1	V1	V2
Minimum Dimension 0.2 – 0.5 m	V1	V2	V3
Minimum Dimension 0.1 – 0.2 m	V2	V3	V3
Minimum Dimension < 0.1 m	V3	V4	V4

Table 24. Vulnerability allocation for retaining wall failure under live loading (road users)					
Slope angle below wall	Wall height				
	< 1 m	1 – 2 m	2 – 3 m	3 – 4 m	> 4 m
> 35°	V2	V2?	V1	V1	V1
25° - 35°	V3	V2	V2	V1	V1
15° - 25°	V4	V3	V2	V1	V1
<15°	V5	V4	V3	V2	V1

Table 26. Consequence ratings for property damage and consequential effects	
Rating	Indicative Criteria
C1	Total direct and indirect costs > $15 million: • Total closure of a Sub-Network Rank 5 or 6 (SN5-SN6) road for an extended period or very high disruption cost (other than road users) • Major infrastructure or property damage (other than road • Very high repair cost
C2	Total direct and indirect costs > $3 million < $15 million: • Total closure of one carriageway of an SN5-6 road or total closure of an SN3–SN4 road for an extended period or large disruption costs • Substantial infrastructure or property damage • High repair cost
C3	Total direct and indirect costs > $0.8 million < $3 million: • Partial or total closure of an SN3-SN4 road for a short period, longer period if reasonable alternatives are available or moderate disruption costs • Moderate infrastructure or property damage • Moderate repair cost
C4	Total direct and indirect costs > $0.2 million < $0.8 million: • Partial or total closure of an SN2 road for a short period or minor disruption costs • Minor infrastructure or property damage • Low repair cost
C5	Total direct and indirect costs < $0.2 million: • Partial or total closure of an SN1 road for a short period or little or no disruption costs • Negligible infrastructure or property damage • Very low – no repair cost

	Table 25. Consequence matrix for risk to life				
	Temporal Probability of an Individual Being Present at the Time of Failure				
Vulnerability	T5	T4	T3	T2	T1
V1	C4	C3	C2	C1	C1
V2	C4	C3	C2	C1	C1
V3	C5	C4	C3	C2	C2
V4	C5	C5	C4	C3	C3
V5	C5	C5	C5	C4	C4

	Table 27. Assessed risk level matrix				
	Consequence Class				
Likelihood	C5	C4	C3	C2	C1
L1	ARL3	ARL2	ARL1	ARL1	ARL1
L2	ARL4	ARL3	ARL2	ARL1	ARL1
L3	ARL5	ARL4	ARL3	ARL2	ARL1
L4	ARL5	ARL5	ARL4	ARL3	ARL2
L5	ARL5	ARL5	ARL5	ARL4	ARL3
L6	ARL5	ARL5	ARL5	ARL5	ARL4

Meanings Attached to the Term 'Road Closure'.

Total closure

This means that the road is closed to traffic in both directions and all traffic has to take an alternate route.

Partial closure

This means that the road is closed to traffic in one direction and either:

- the traffic in one direction has to take an alternate route, or
- the traffic in both directions has to be controlled to allow alternating one-way flows. This may require the construction of earthworks and temporary pavements (for instance, to cross the median in dual carriageway roads or to allow traffic to use the road shoulder for an extended period).

Supplementary Ratings

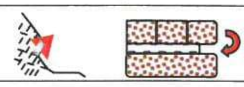
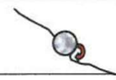
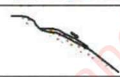
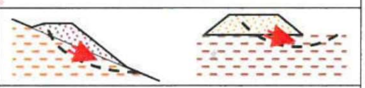
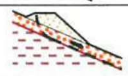
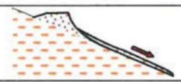
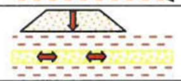
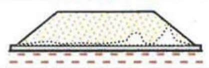
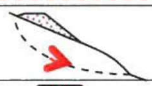
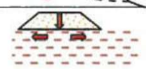
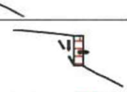
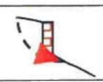
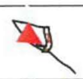
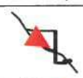
Table 28. Scale of failure (S) ratings		
Rating	Volume of Failure	Individual Block Size
S1	Volume > 20,000 m^3 (eg. 40 m wide x 60 m long x 10 m deep = 24,000 m^3)	Individual blocks of > 1m minimum dimension (eg one rock 1 x 1 x 2 m)
S2	Volume > 2,000 m^3	Individual blocks of 0.5 – 1 m minimum dimension
S3	Volume > 200 m^3	Individual blocks of 0.2 - 0.5 m minimum dimension
S4	Volume > 20 m^3	Individual blocks of about 0.2 m minimum dimension
S5	Volume < 20 m^3	Individual blocks of about 0.1 m minimum dimension

Table 29. Velocity of failure (R) ratings			
Rating	Description	Velocity (mm/sec)	Typical Velocity
R1	Extremely Rapid		
		5×10^3	5 m/sec
	Very Rapid		
		5×10^1	3 m/min
R2	Rapid		
		5 x 10-1	1.8 m/h
R3	Moderate		
		5×10^{-3}	13 m/month
R4	Slow		
		5×10^{-5}	1.6 m/year
R5	Very Slow		
		5×10^{-7}	16 mm/year
	Extremely Slow		

		Table 30. Event magnitude classification matrix				
		Scale of Failure				
Velocity of Failure		S5	S4	S3	S2	S1
Fast	R1	M3	M2	M2	M1	M1
⇕	R2	M4	M3	M2	M2	M1
	R3	M4	M4	M3	M2	M2
	R4	M5	M4	M4	M3	M2
Slow	R5	M5	M5	M4	M4	M3

	Table 31. Hazard classification matrix				
	Event Magnitude				
Likelihood	M5	M4	M3	M2	M1
L1	H3	H2	H2	H1	H1
L2	H4	H3	H2	H2	H1
L3	H4	H4	H3	H2	H2
L4	H5	H4	H4	H3	H2
L5	H5	H5	H4	H4	H3
L6	H5	H5	H5	H4	H4

Common hazard types

Mechanism	Typical Circumstances	Description	Schematic Illustration(s)
Fall	Steep rock batters	Prior to failure the block is supported at the top and/or rear surfaces and fails in tension., In practice, includes other initial failure types where the travel path is relatively long and the debris can go into trajectory over part of the distance.	
Topple	Columnar or tabular blocks resting on defects dipping out of the face	Prior to failure the block is supported on its basal surface and rotates about its front lower edge or an axis on the basal surface. Includes cases of undercutting where the debris cannot go into trajectory.	
Slide – rotational	In soils or some weak or highly fractured rock masses	Common in cohesive soils. Rupture surface may or may not be circular.	
Boulder roll	Steep soil batters containing boulders	Approximately equidimensional boulders released by erosion or other mechanism which will roll down the slope rather than go into trajectory.	
Slide - translational	Plane and wedge failures in rock	Almost always controlled by discontinuities or material interfaces.	
Spread	Lateral movement of blocks in a massive, jointed rock unit (most commonly sedimentary)	Requires deformation or failure of underlying material or shear at interface.	
Flow	Most commonly in soil slopes with high moisture content or substantial water inflows	Requires high moisture content in cohesive materials. Can also happen in dry cohesionless materials.	
Complex	Combination of above types, usually in different parts of the failed mass	Most common is a combination of rotational and translational.	
Rotational, within embankment	Any, but requires water source	Typically shallow to part width. Can be close to full width on steep side slopes.	
Rotational, through foundations	Soft soils, side slopes with deeper soils.	In soft soils usually during or shortly after construction, but can be delayed if soils have a stiffer crust which can soften when it wets up.	
Translational	Side slopes, especially when steep	Can be on interface with underlying materials at fill base, within underlying soils or at or within underlying rock. Normally on an interface, or defect controlled if in rock. Would normally affect the full width of the fill.	
Collapse	Loose granular fills, especially on side slopes	Requires fill to be very loose and close to saturation. Almost complete loss of shear strength on minor shearing. Only in end-dumped or sidecast fills. Highly mobile.	
Liquefaction	Confined loose sands in foundations, below water table	Earthquake or (possibly) vibration trigger. Often applied (incorrectly) to collapse of quick clays. Most often in natural materials, insitu. Could not happen within an engineered fill.	
Internal erosion	Dispersive or erodible soils, in fills or underlying materials. Most commonly in culvert backfills.	Forms internal voids which may collapse abruptly.	
Reactivation of pre-existing landslide	Fill on side slope, not necessarily steep	Due to loading of head or adverse effects on drainage.	
Spreading of foundations	Soft soils	Blurry distinction between this and rotational failure through foundations, except there won't be a visible scarp. Can be very difficult to distinguish from settlement without prolonged and careful observation.	
Overturning	Thin gravity structures, inadequate design.	Full or part height. Most common mode of failure under live loading.	
Sliding	Gravity structures	Insufficient shear resistance at base. Not common in properly designed structures, unless passive resistance at the toe is removed eg by excavation.	
Bearing	Gravity walls	Not common in modern structures.	
Global foundation failure	Gravity structures.	Weak foundation materials or adverse defects in rock	
Settlement	Gravity structures	Compressible foundations. May have been allowed for in design. Can lead to tilting of wall and damage to any supported structures.	
Shear failure through backfill ('bulging')	Flexible or brittle walls (eg drystone, RSW, gabions)	Common failure mode in flexible structures. May manifest as overturning in thin, rigid structures.	
Bending	Cantilevered pile walls with insufficient strength.	Can only occur in structures with substantial tensile strength.	
Toe breakout	Cantilevered pile walls usually on steep slopes	Insufficient embedment, inadequate rock strength.	
Anchor pullout	Anchored pile walls	Inadequate anchor strength, damage to anchors or loss of surrounding ground.	

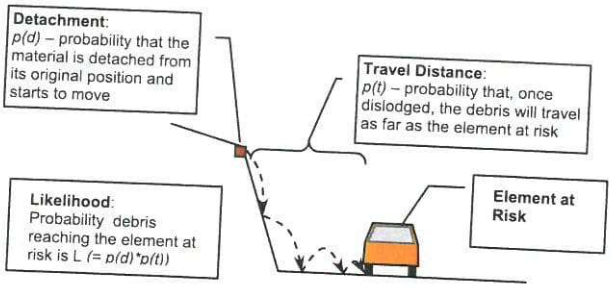


Figure 6. Detachment and Travel Distance Probabilities

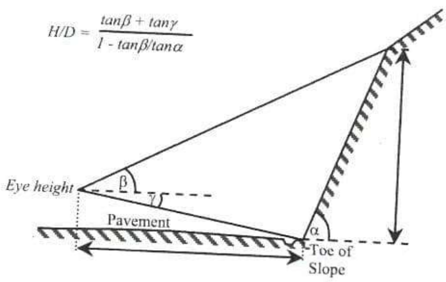


Figure 4. Height Estimation by Triangulation

Table 7. Criteria for allocation of detachment probability

P(d)	Current Slope Condition	Evidence for Previous Failures	Progress of Evolving Mechanisms	Possible Triggering Event
1	A potential mechanism is apparent. Either failure appears imminent or there is evidence that the detachment mechanism is currently active.	The slope may show evidence of earlier repeated failures of the same type.	Failure could be initiated by a very small further progression of the mechanism relative to that which has already occurred.	Failure could be initiated by a triggering event with a short return period (eg 1 year storm).
0.1 (1 x 10^{-1})	A potential mechanism is apparent and either is active or could easily be activated but failure does not appear imminent. There may be evidence of past distress.	Slopes which have been in existence for some time (ie in the order of decades) may show evidence of occasional previous failures.	Failure could be expected within a few years to a few decades if the mechanism continues to develop at its current rate	Failure could be triggered by a fairly common event (eg 10 year storm).
0.01 (1 x 10^{-2})	A potential mechanism is apparent, but failure does not appear imminent There may be evidence of past distress.	Slopes which have been in existence for many years (ie usually more than 30 years) *may* show evidence of an earlier failure	The progress of the mechanism is evident, but would require substantial development relative to that which has already occurred before failure would be initiated.	Triggering could be expected to require a severe event (eg 1 in 100 year storm).
0.001 (1 x 10^{-3})	The potential mechanism can be identified but failure does not appear imminent	Constructed slopes show no evidence of previous failures of the same type. There may be evidence of old failures on natural slopes.	The existence of the mechanism is evident, but would require very substantial development relative to that which has already occurred before failure would be initiated, or failure would require a substantial acceleration of the progress of the mechanism.	Failure would require an unusually severe triggering event
0.0001 (1 x 10^{-4})	The potential mechanism can be deduced from slope features or geological considerations	Comparable slopes in the same area may show evidence of previous failures of the same type	Where processes are ancient their age may be used to infer (loosely) their probability of recurrence eg landslides formed at around the end of the last ice age (about 10 – 12,000 years ago)	Failure would require an extreme triggering event
0.00001 (1 x 10^{-5}) and smaller	The potential mechanism can be deduced from slope features or geological considerations	Some comparable slopes in the same area may show evidence of rare previous failures of the same type	The mechanism may only be deduced from long term slope evolution considerations	Failure would require the most extreme of triggering events eg probable maximum flood or maximum credible event

Table 8. Factors affecting potential for failure under live loading

Factor	Considerations
Wall Type	Masonry walls, particularly when unmortared ('drystone'), are prone to brittle failure under load. Walls of this type were commonly used to retain road embankments in the 19th and early 20th centuries and were still being constructed in some areas until about 1960.
Foundations	Foundation materials and design (if any) will constrain the types of mechanism which are possible.
Original condition of wall	Construction standard and geometry of structure. Drystone walls were built to a number of patterns. The most common in smaller walls was with front and rear faces parallel and with a height:thickness ratio of 6:1, subject to a minimum thickness of about 400 mm. Original batter angles would normally have been no steeper than about 80° (1:6).
Current condition of wall	Evidence for the presence of one or more distress modes (see tables and diagrams). The factor of safety against overturning of drystone walls decreases rapidly as the batter angle increases above 80° and may be close to 1 where the wall is near vertical, even without considering live loading.
Condition of retained material	Cracking or subsidence in the pavement or shoulder may indicate the existence of an active or dormant failure mechanism. Evidence of past movement may be disguised by resurfacing or pavement rehabilitation
Extent of development of potential or actual failure mechanisms	Based on a synthesis of the above factors. Consider the degree of development of the mechanism relative to that needed for failure to occur.
Potential live load location	The potential for failure under live loading depends critically on the location of the load. Consider the location of the outer wheelpath relative to the wall crest, constraints on traffic (eg edge lines, visual or physical barriers, road geometry in relation to the possible position of heavy vehicles), local circumstances which may cause traffic to divert towards the wall under normal operating conditions (eg narrow pavement and poor sight distance). Normally the edge line (or edge of the seal if no edge line is present) would be considered the limit of potential live load locations.

Table 9. Likelihood allocation for retaining wall failure under live loading

Wall condition	Live load distance from toe of wall		
	< H/2	**H/2 - H**	**> H**
Significant or major distress evident, apparently active	L1	L2	L3
Significant or major distress evident, not apparently active	L2	L3	L4
Minor distress evident, apparently active	L3	L4	L5
Minor distress evident, not apparently active or poorly constructed wall	L4	L5	L6
Apparently well-constructed wall, no visible distress	L5	L6	L6

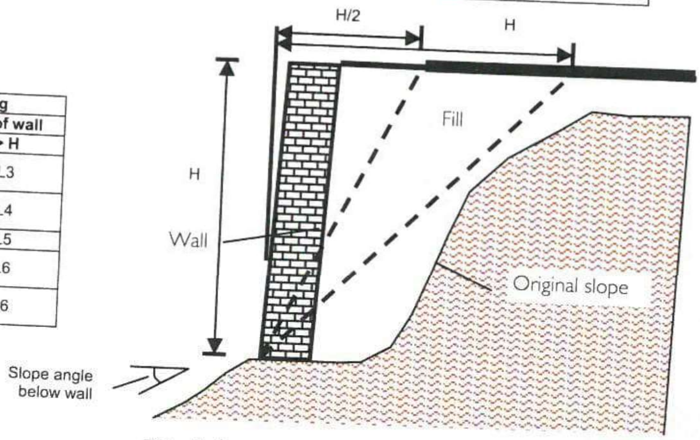
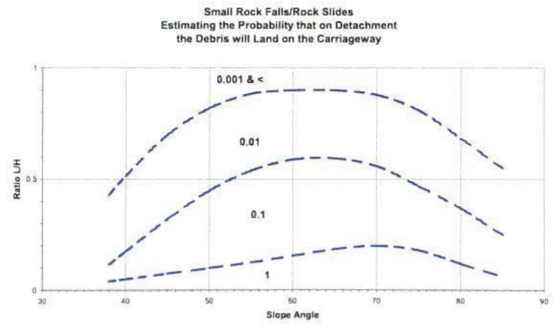


Figure 7. Parameters for Live Loading of Retaining Structures



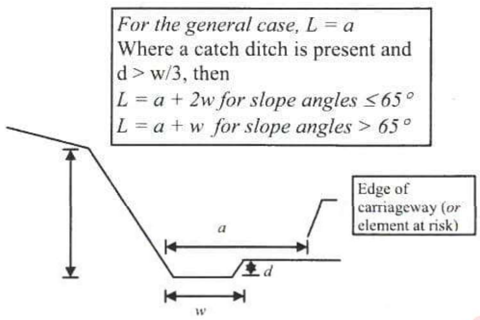


Figure 8. Estimating Travel Distance Probability for Small Rock Falls/Slides Figure 9. Definition of Parameters for Figure 8

Table 11. Temporal probability rating definitions		
Rating	**Probability Range**	**Definition**
T1	> 0.5	Person usually expected to be present as part of the normal pattern of usage (eg residential buildings, some commercial buildings). Road users in the heaviest of urban traffic conditions.
T2	0.1 – 0.5	Person often expected to be present as part of the normal pattern of usage (eg many commercial buildings). Road users on major urban arterial roads and the most heavily trafficked rural roads.
T3	0.01 – 0.1	Person may sometimes be present as part of the normal pattern of usage. Road users on many urban arterial roads and most major rural arterial roads
T4	0.001 – 0.01	Person unlikely to be present even where there is a pattern of usage. Road users on suburban roads and minor rural arterial roads
T5	< 0.001	Person is very unlikely to be present. Road users on the most lightly trafficked roads, road shoulders etc.

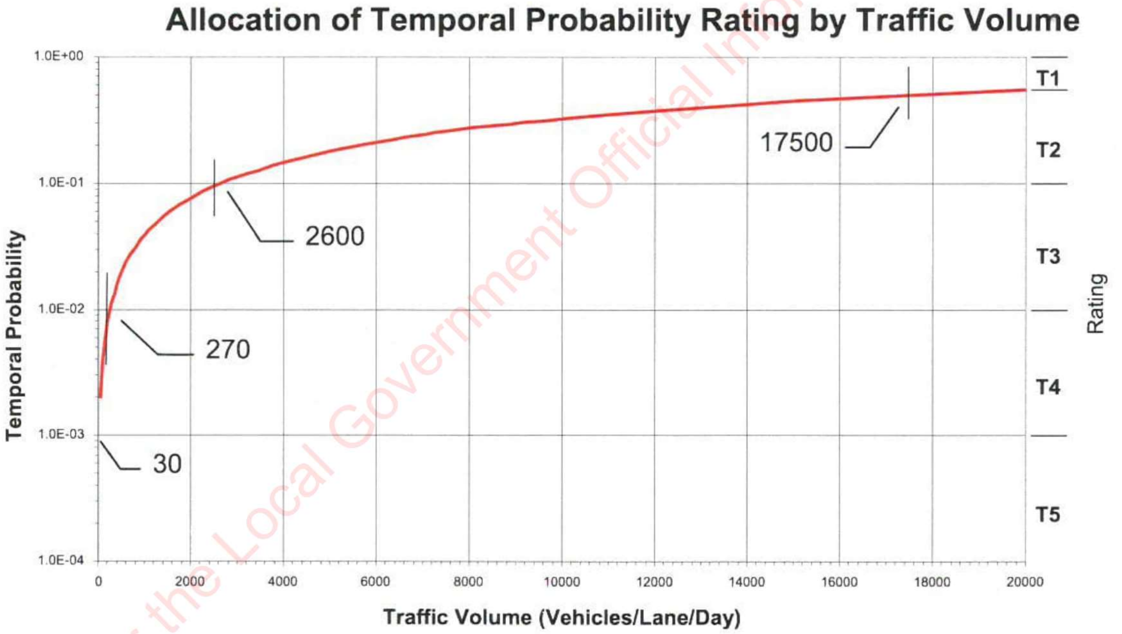


Table 13. Modification of T for direct impact by rockfall					
Case	**T Rating**				
Debris lodging on the road (from Guide Figure 6)	T5	T4	T3	T2	T1
Modified T for debris directly impacting vehicle	T5	T5	T4	T3	T3

Table 14. Modification of T for direct impact by large scale failures			
Modification to T	**Length of Failure Traversed at Posted Speed Limit**		
	≤ 50 km/h	**60 – 90 km/h**	**100 – 110 km/h**
Decrease T (eg T3 ⇒ T4)	< 15 m	< 25 m	< 60 m
T unchanged	15 – 100 m	25 – 250 m	60 – 600 m
Increase T (eg T3 ⇒ T2)	> 100 m	> 250 m	> 600 m

Table 17. Expanded vulnerability table					
Vulnerability Rating	**People in the Open**	**People in Buildings**	**Vehicle Occupants**		
			Vehicle Impact with Individual Rock Blocks	**Vehicle Impact with Mixed Landslide Debris**	**Vehicle Crossing Embankment Failure Area**
V1	Unable to evade rockfall or other debris (movement very/extremely rapid), or buried	Engulfed in building collapse	Block > 1 m high at highway speeds		Lost into a deep, narrow void
V2	May be able to evade debris	Partial building collapse	Block > 1 m high at urban speeds Block 0.5 – 1 m high at highway speeds		Lost into a shallow void
V3	Most people able to evade debris	Building penetrated, no collapse	Block >1 m high at low speeds Block 0.5 – 1 m high at urban speeds	Loose or wet mixed soil/rock debris at highway speeds	Stepped surface with 0.1 – 0.2 m steps at highway speeds
V4		Building struck, damaged but not penetrated	Block 0.5 – 1 m high at low speeds Block around 0.2 m high at highway speeds	Loose or wet mixed soil/rock debris at urban speeds	Stepped surface with 0.1 – 0.2 m steps at urban speeds Shallow void/depression where guardfence may prevent a vehicle from leaving the road
V5		Building struck, only minor damage etc	Block around 0.2 m high at urban speeds Smaller block at highway speeds	Loose or wet mixed soil/rock debris at low speeds Irregular surface formed by soil or small (<100mm minimum dimension) rock at highway speeds	Stepped surface with 0.1 – 0.2 m steps at low speeds Irregular surface formed by a developing embankment failure at highway speeds

Table 18. Extended vulnerability table - Vehicles impacting single rock blocks			
Block Size	**Posted Speed Limit**		
	Highway Speeds (100 – 110 km/h)	**Urban Speeds (60 – 80 km/h)**	**Low Speeds (≤ 50 km/h)**
Minimum dimension >1 m	V1	V2	V3
Minimum dimension 0.5 – 1 m	V2	V3	V4
Minimum dimension 0.2 – 0.5 m	V3	V4	V5
Minimum dimension ≈ 0.2 m	V4	V5	V5*
Minimum dimension ≈ 0.1 m	V5	V5*	V5*

Table 19. Extended Vulnerability Table - Vehicles impacting mixed landslide debris			
Debris Type	**Posted Speed Limit**		
	Highway Speeds (100 – 110 km/h)	**Urban Speeds (60 – 80 km/h)**	**Low Speeds (≤ 50 km/h)**
Loose or wet mixed soil/rock debris	V3	V4	V5
Small rock debris (min dim < 0.1 m)	V5	V5*	V5*

Table 20. Extended vulnerability table - Vehicles impacting voids or stepped surfaces			
Void or Surface Type	**Posted Speed Limit**		
	Highway Speeds (100 – 110 km/h)	**Urban Speeds (60 – 80 km/h)**	**Low Speeds (≤ 50 km/h)**
Deep, narrow void	V1	V2	V3
Shallow void (0.2 – 0.5 m step)	V2	V3	V4
Stepped surface (0.1 – 0.2 m steps)	V3	V4	V5
Irregular surface (steps < 0.1 m)	V5	V5*	V5*
Shallow void with guardfence or wire rope barrier	V4	V4	V4

Table 21. Resultant velocity (m/s) by fall height and traffic speed										
Traffic speed m/s (km/h)	**Fall Height (m)**									
	5	**10**	**15**	**20**	**25**	**30**	**40**	**50**	**75**	**100**
0 (0)	9.9	14.0	17.2	19.8	22.1	24.3	28.0	31.3	38.4	44.3
13.9 (50)	17.1	19.7	22.1	24.2	26.1	27.9	31.3	34.3	40.8	46.4
16.7 (60)	19.4	21.8	23.9	25.9	27.7	29.4	32.6	35.5	41.8	47.3
19.4 (70)	21.8	24.0	25.9	27.8	29.5	31.1	34.1	36.9	43.0	48.4
22.2 (80)	24.3	26.3	28.1	29.8	31.4	32.9	35.8	38.4	44.3	49.6
25.0 (90)	26.9	28.7	30.3	31.9	33.4	34.8	37.6	40.1	45.8	50.9
27.8 (100)	29.5	31.1	32.7	34.1	35.5	36.9	39.5	41.9	47.4	52.3
30.6 (110)	32.1	33.6	35.0	36.4	37.7	39.0	41.5	43.8	49.0	53.8

Table 22. Vulnerability allocation for vehicle directly impacted by single rock blocks			
Block Size	Resultant Velocity		
	> 25 m/s	15 – 25 m/s	< 15 m/s
Minimum Dimension >1 m	V1	V1	V1
Minimum Dimension 0..5 – 1 m	V1	V1	V2
Minimum Dimension 0.2 – 0.5 m	V1	V2	V3
Minimum Dimension 0.1 – 0.2 m	V2	V3	V3
Minimum Dimension < 0.1 m	V3	V4	V4

Table 24. Vulnerability allocation for retaining wall failure under live loading (road users)					
Slope angle below wall	Wall height				
	< 1 m	1 – 2 m	2 – 3 m	3 – 4 m	> 4 m
> 35°	V2	V2?	V1	V1	V1
25° - 35°	V3	V2	V2	V1	V1
15° - 25°	V4	V3	V2	V1	V1
<15°	V5	V4	V3	V2	V1

Table 26. Consequence ratings for property damage and consequential effects	
Rating	Indicative Criteria
C1	Total direct and indirect costs > $15 million: • Total closure of a Sub-Network Rank 5 or 6 (SN5-SN6) road for an extended period or very high disruption cost (other than road users) • Major infrastructure or property damage (other than road • Very high repair cost
C2	Total direct and indirect costs > $3 million < $15 million: • Total closure of one carriageway of an SN5-6 road or total closure of an SN3–SN4 road for an extended period or large disruption costs • Substantial infrastructure or property damage • High repair cost
C3	Total direct and indirect costs > $0.8 million < $3 million: • Partial or total closure of an SN3-SN4 road for a short period, longer period if reasonable alternatives are available or moderate disruption costs • Moderate infrastructure or property damage • Moderate repair cost
C4	Total direct and indirect costs > $0.2 million < $0.8 million: • Partial or total closure of an SN2 road for a short period or minor disruption costs • Minor infrastructure or property damage • Low repair cost
C5	Total direct and indirect costs < $0.2 million: • Partial or total closure of an SN1 road for a short period or little or no disruption costs • Negligible infrastructure or property damage • Very low – no repair cost

Table 25. Consequence matrix for risk to life					
	Temporal Probability of an Individual Being Present at the Time of Failure				
Vulnerability	T5	T4	T3	T2	T1
V1	C4	C3	C2	C1	C1
V2	C4	C3	C2	C1	C1
V3	C5	C4	C3	C2	C2
V4	C5	C5	C4	C3	C3
V5	C5	C5	C5	C4	C4

Table 27. Assessed risk level matrix					
	Consequence Class				
Likelihood	C5	C4	C3	C2	C1
L1	ARL3	ARL2	ARL1	ARL1	ARL1
L2	ARL4	ARL3	ARL2	ARL1	ARL1
L3	ARL5	ARL4	ARL3	ARL2	ARL1
L4	ARL5	ARL5	ARL4	ARL3	ARL2
L5	ARL5	ARL5	ARL5	ARL4	ARL3
L6	ARL5	ARL5	ARL5	ARL5	ARL4

Meanings Attached to the Term 'Road Closure'.

Total closure

This means that the road is closed to traffic in both directions and all traffic has to take an alternate route.

Partial closure

This means that the road is closed to traffic in one direction and either:

- the traffic in one direction has to take an alternate route, or
- the traffic in both directions has to be controlled to allow alternating one-way flows. This may require the construction of earthworks and temporary pavements (for instance, to cross the median in dual carriageway roads or to allow traffic to use the road shoulder for an extended period).

Supplementary Ratings

Table 28. Scale of failure (S) ratings		
Rating	Volume of Failure	Individual Block Size
S1	Volume > 20,000 m^3 (eg. 40 m wide x 60 m long x 10 m deep = 24,000 m^3)	Individual blocks of > 1m minimum dimension (eg one rock 1 x 1 x 2 m)
S2	Volume > 2,000 m^3	Individual blocks of 0.5 – 1 m minimum dimension
S3	Volume > 200 m^3	Individual blocks of 0.2 - 0.5 m minimum dimension
S4	Volume > 20 m^3	Individual blocks of about 0.2 m minimum dimension
S5	Volume < 20 m^3	Individual blocks of about 0.1 m minimum dimension

Table 29. Velocity of failure (R) ratings			
Rating	Description	Velocity (mm/sec)	Typical Velocity
R1	Extremely Rapid		
		5 x 10^3	5 m/sec
	Very Rapid		
		5 x 10^1	3 m/min
R2	Rapid		
		5 x 10-1	1.8 m/h
R3	Moderate		
		5 x 10^{-3}	13 m/month
R4	Slow		
		5 x 10^{-5}	1.6 m/year
R5	Very Slow		
		5 x 10^{-7}	16 mm/year
	Extremely Slow		

Table 30. Event magnitude classification matrix						
		Scale of Failure				
Velocity of Failure		S5	S4	S3	S2	S1
Fast	R1	M3	M2	M2	M1	M1
⇕	R2	M4	M3	M2	M2	M1
	R3	M4	M4	M3	M2	M2
	R4	M5	M4	M4	M3	M2
Slow	R5	M5	M5	M4	M4	M3

Table 31. Hazard classification matrix					
	Event Magnitude				
Likelihood	M5	M4	M3	M2	M1
L1	H3	H2	H2	H1	H1
L2	H4	H3	H2	H2	H1
L3	H4	H4	H3	H2	H2
L4	H5	H4	H4	H3	H2
L5	H5	H5	H4	H4	H3
L6	H5	H5	H5	H4	H4

Measures of Likelihood

Level	Descriptor	Description	Annual Probability of Occurrence	
A	Almost Certain	The event is on-going, or is expected to occur during the next year	100%	< 1 year
B	Very Likely	The event is expected to occur.	20% to 100%	1-5 years
C	Likely	The event is expected to occur under somewhat adverse conditions	5% to 20%	5-20 years
D	Possible	The event is expected to occur under adverse conditions	1 to 5%	20-100 years
E	Unlikely	The event is expected to occur under high to extreme conditions	0.2 to 1%	100-500years
F	Rare	The event could occur under extreme conditions	Less than 0.2%	>500 years

Measures of Consequence

Level	Descriptor	Example Descriptions (Damage to Private Property)	Example Descriptions (Damage to HCC Assets)
1	Catastrophic	Large scale damage to multiple properties	Arterial routes and lifelines blocked an extended length of time (several days) – significant effects to communities for extended periods
2	Disastrous	Large scale damage involving private property and dwellings requiring major engineering works for stabilisation	Both lanes of local road blocked/slipped for an extended length of time (several days); or arterial route blocked causing major and extended delays to traffic; major emergency works
3	Major	Extensive damage to property but dwelling not involved	Both lanes of local road temporarily blocked/slipped (few hours to a day) or one lane of arterial route blocked with major delays; significant emergency works
4	Medium	Moderate damage to private land	One lane of road blocked/slipped with some emergency works necessary *or* several metres of footpath destroyed; no alternative access available
5	Low	Limited damage to private land	Half of one lane of road blocked for a short period of time; emergency works limited to clean up only *or* footpath destroyed over several metres; alternative access is available
6	Minor	No damage	Shoulder of road damaged/blocked only; reinstatement works can be delayed *or* footpath locally undermined but still usable; reinstatement works can be delayed

Risk Matrix for Failure for further undermining

		Consequences to Property/Assets					
		1: Catastrophic	2: Disastrous	3: Major	4: Medium	5: Low	6: Minor
Likelihood	A – Almost Certain	VH	VH	VH	H	H	M
	B – Very L kely	VH	VH	H	H	M	L
	C – Likely	VH	H	H	M	L	L
	D – Possible	VH	H	M	L	VL-L	VL
	E – Unl kely	H	M	L	VL	VL	VL
	F –Rare	M	L	VL	VL	VL	VL

Risk Level Implications

Risk Level		Implications for Risk Management
VH	Very High Risk	Detailed investigation, design, planning, and implementation of treatment options to reduce risk to acceptable levels: May involve very high costs.
H	High Risk	Detailed investigation, design, planning, and implementation of treatment options to reduce risk to acceptable levels.
M	Moderate Risk	Broadly tolerable provided treatment plan is implemented to maintain or reduce risks. May require investigation and planning of treatment options.
L	Low Risk	Acceptable. Treatment requirements to be defined to maintain or reduce risk
VL	Very Low Risk	Acceptable. Manage by normal maintenance procedures

Notes:

1. The examples of consequence given should only be used as a general guide. The implications for a particular situation may be required to be specifically determined.
2. The risk matrices above are based on those given in Appendix G of AGS (2000): *Landslide Risk Management Concepts and Guidelines*

Measures of Likelihood

Level	Descriptor	Description	Annual Probability of Occurrence	
A	Almost Certain	The event is on-going, or is expected to occur during the next year	100%	< 1 year
B	Very Likely	The event is expected to occur.	20% to 100%	1-5 years
C	Likely	The event is expected to occur under somewhat adverse conditions	5% to 20%	5-20 years
D	Possible	The event is expected to occur under adverse conditions	1 to 5%	20-100 years
E	Unlikely	The event is expected to occur under high to extreme conditions	0.2 to 1%	100-500years
F	Rare	The event could occur under extreme conditions	Less than 0.2%	>500 years

Measures of Consequence

Level	Descriptor	Example Descriptions (Damage to Private Property)	Example Descriptions (Damage to HCC Assets)
1	Catastrophic	Large scale damage to multiple properties	Arterial routes and lifelines blocked an extended length of time (several days) – significant effects to communities for extended periods
2	Disastrous	Large scale damage involving private property and dwellings requiring major engineering works for stabilisation	Both lanes of local road blocked/slipped for an extended length of time (several days); or arterial route blocked causing major and extended delays to traffic; major emergency works
3	Major	Extensive damage to property but dwelling not involved	Both lanes of local road temporarily blocked/slipped (few hours to a day) or one lane of arterial route blocked with major delays; significant emergency works
4	Medium	Moderate damage to private land	One lane of road blocked/slipped with some emergency works necessary *or* several metres of footpath destroyed; no alternative access available
5	Low	Limited damage to private land	Half of one lane of road blocked for a short period of time; emergency works limited to clean up only *or* footpath destroyed over several metres; alternative access is available
6	Minor	No damage	Shoulder of road damaged/blocked only; reinstatement works can be delayed *or* footpath locally undermined but still usable; reinstatement works can be delayed

Risk Matrix for Failure for further undermining

		Consequences to Property/Assets					
		1: Catastrophic	2: Disastrous	3: Major	4: Medium	5: Low	6: Minor
Likelihood	A – Almost Certain	VH	VH	VH	H	H	M
	B – Very L kely	VH	VH	H	H	M	L
	C – Likely	VH	H	H	M	L	L
	D – Possible	VH	H	M	L	VL-L	VL
	E – Unl kely	H	M	L	VL	VL	VL
	F –Rare	M	L	VL	VL	VL	VL

Risk Level Implications

Risk Level		Implications for Risk Management
VH	Very High Risk	Detailed investigation, design, planning, and implementation of treatment options to reduce risk to acceptable levels: May involve very high costs.
H	High Risk	Detailed investigation, design, planning, and implementation of treatment options to reduce risk to acceptable levels.
M	Moderate Risk	Broadly tolerable provided treatment plan is implemented to maintain or reduce risks. May require investigation and planning of treatment options.
L	Low Risk	Acceptable. Treatment requirements to be defined to maintain or reduce risk
VL	Very Low Risk	Acceptable. Manage by normal maintenance procedures

Notes:

1. The examples of consequence given should only be used as a general guide. The implications for a particular situation may be required to be specifically determined.
2. The risk matrices above are based on those given in Appendix G of AGS (2000): *Landslide Risk Management Concepts and Guidelines*

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29 July 2022

Colin Lunn
Hutt City Council,
30 Laings Road,
Lower Hutt 5040,
New Zealand

Dear Colin

Slope assessment below 60 Holborn Drive, Stokes Valley

1.0 Introduction

AECOM New Zealand Limited (AECOM) has been engaged by the Hutt City Council (HCC) to assess a slip that has occurred below 60 Holborn Street, Stokes Valley. A risk assessment has been undertaken using the agreed HCC initial inspection report risk matrix which is based on Appendix G of Australasian Geomechanics Society (2000) Landslide Risk Management Concepts and Guidelines. A copy of the risk matrix is provided in Appendix C.

AECOM geotechnical engineers completed a site visit on 22-26 July 2022, to assess the ground conditions, identify possible trigger mechanisms and carry out a risk assessment.

2.0 Ground Conditions

2.1.1 Geological setting

The Wellington geological map (Begg & Mazengarb, 1996) for the area (Figure 1) describes the site to comprise of alternating sandstone/argillite, with conglomerate and minor pillow basalt, chert, diamicite, and limestone (collectively termed greywacke).

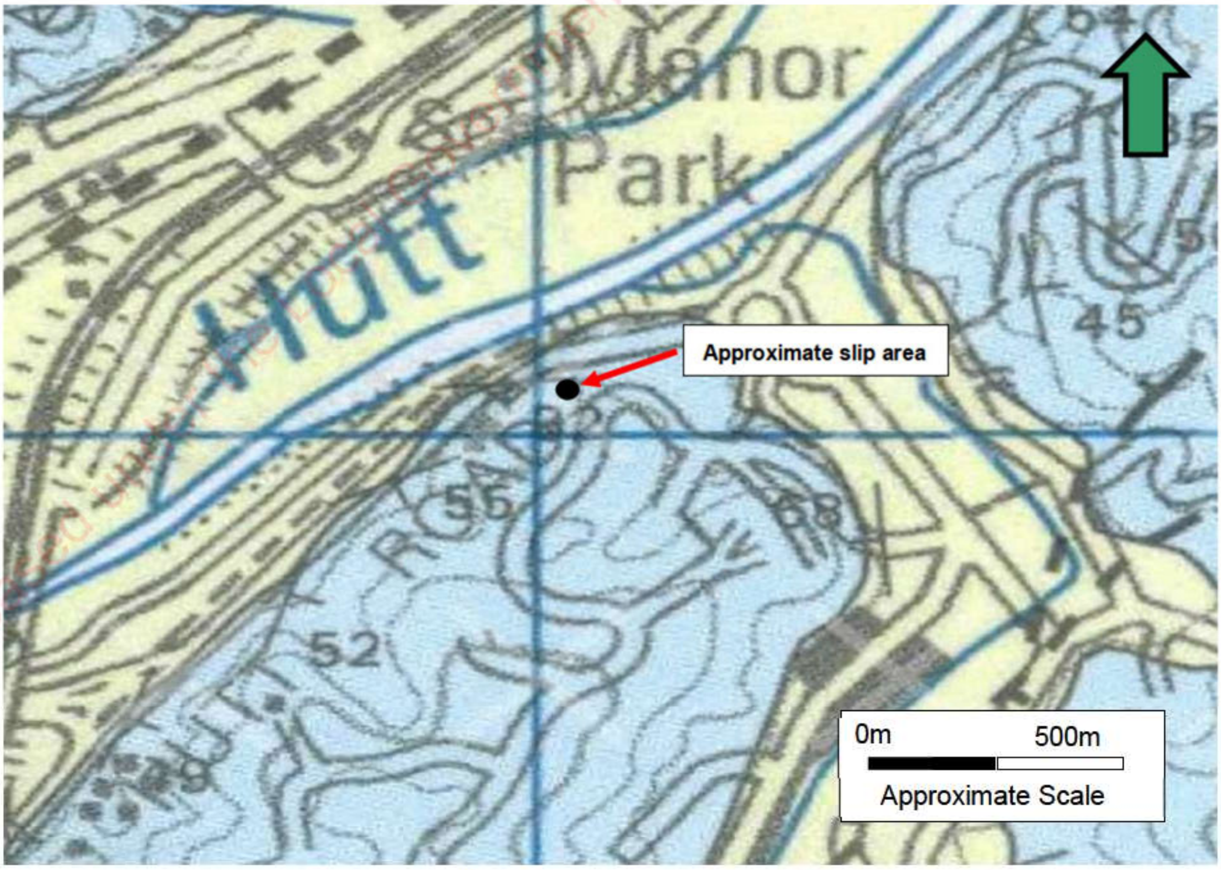

Figure 1 Location of failure at 60 Holborn Street (Begg & Mazengarb, 1996)

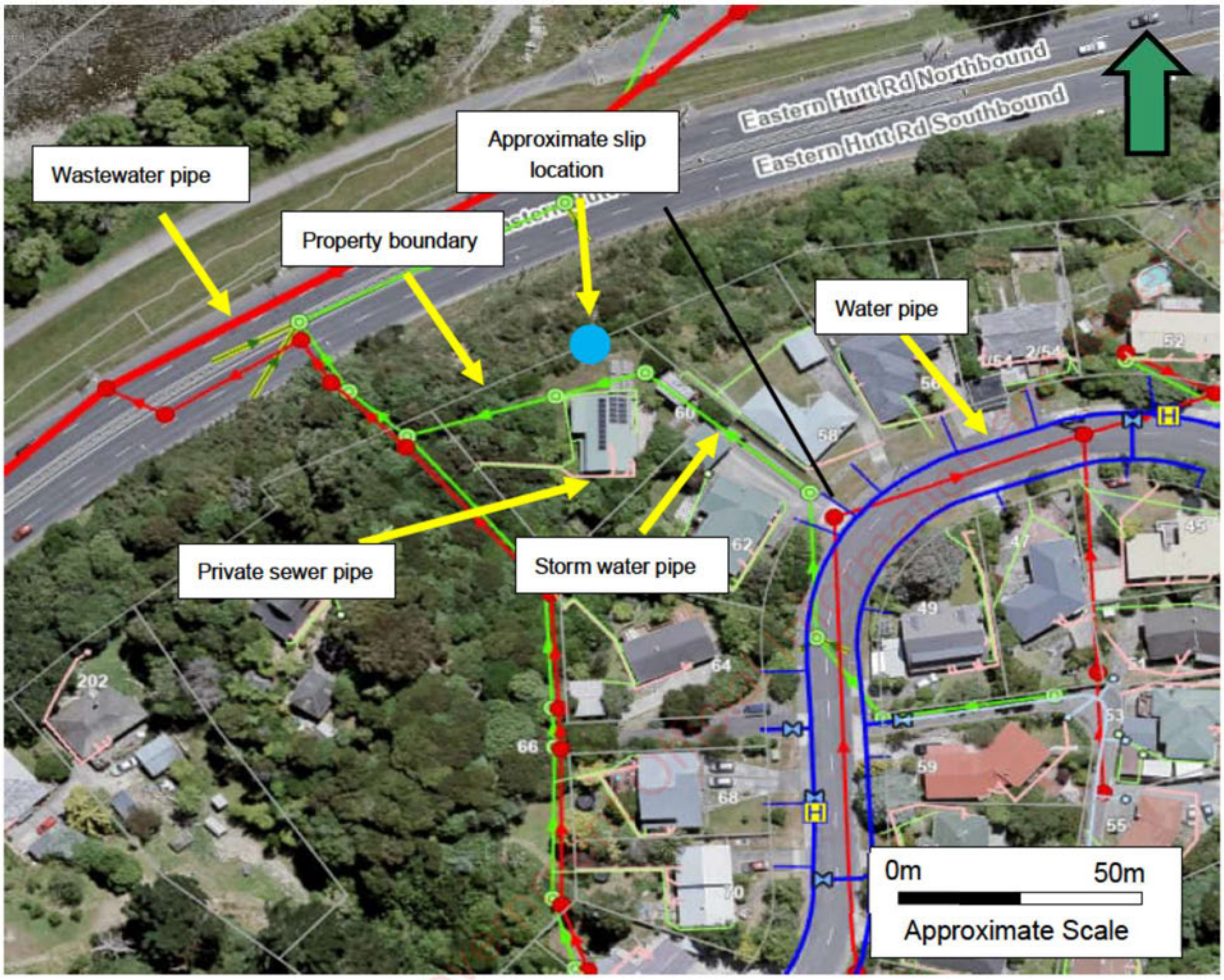

Figure 2 Site location plan (source: HCC Webmaps & NZGD)

2.1.2 Geotechnical investigations

No publicly available geotechnical investigations are situated within 250m of the site.

3.0 Site Observations

Findings of the site inspections carried out between 22-26 July 2022 are outlined below, with a marked-up photograph of the site presented in Appendix A. Supplementary photographs are provided in Appendix B and a typical cross-section is presented in Figure 4.

- Slip occurred in the evening of 21 July 2022.
- Slipped debris on the Eastern Hutt Road was cleared around 2:30am (22 July 2022).
- Between 2:30am to 11am more debris accumulated at the toe of slope, and some spread over the southbound lane.
- Debris appears to be soil with medium-sized rock fragments (Appendix A).
- The upper 3-4m of the slope is nearly vertical (80-90 degrees) and with pronounced tension cracks on the ground above (Appendix A).
- Tension cracks are visible on the surface above, the cracks are about 5m away from the building footprint.
- There is an area of ground subsidence noted and below this are overhanging trees that can potentially come down any time (Appendix A)
- Underground stormwater pipe runs below the property going towards the southwest towards dense vegetation as shown in the site location plan above (Figure 2).

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- HCC webmaps indicate the slip to be located within private property and some within public land as shown in Figure 2.
- The total width of the affected area is approximately 33.2m along Eastern Hutt Road.
- Major rock outcrop is visible at about 16m above the road as shown in the marked-up photo (Appendix A)
- The surrounding slopes are well vegetated and comprise of small to medium-sized shrubs, trees, and grass.

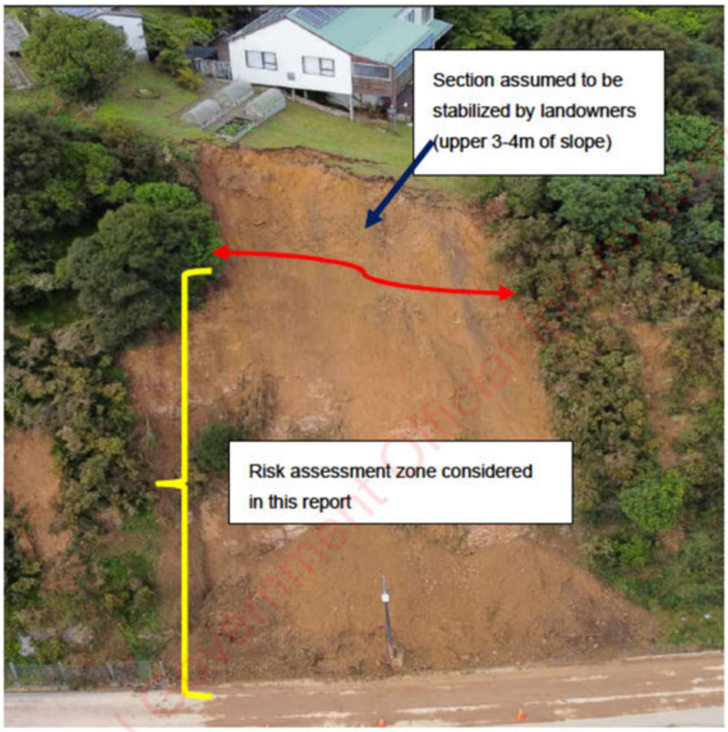

Figure 3 Risk assessment zone (AECOM)

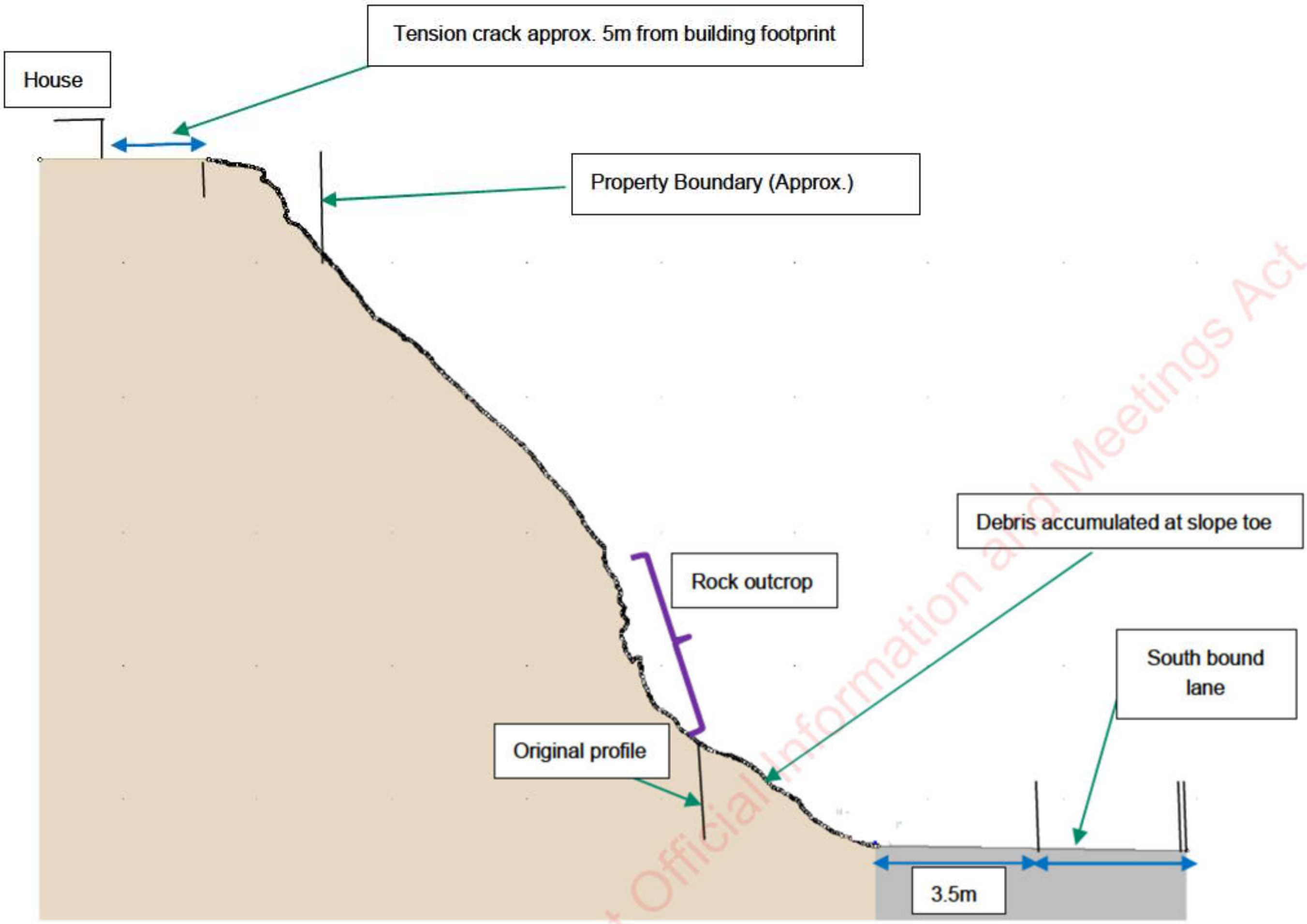

Figure 4 Typical cross section

4.0 Trigger Mechanism

Intense and heavy rainfall during the winter months and ongoing weathering were identified as triggering mechanisms. The instability is expected to experience further regression and dropouts as a result of periodic rainfall events and/or moderate to large seismic shaking.

5.0 Risk Assessment

A risk assessment for the site is provided in Appendix C and utilises the HCC standard template. The risk posed due to localised failure in the mid-section of the slope (assuming that the top 3-4m of the slope has been stabilised already by the landowners – refer to Figure 3) is considered to be **very high.** The consequences associated with the instability of the middle section of the slope are identified to be major due to the proximity of the Eastern Hutt Road to the slope. Falling debris will cause temporary closure of the southbound lanes or block one lane causing major delays. Due to the presence of containers at the toe of the slope the impact on HCC assets following further dropout is expected to be minimised (i.e. minor). However, it is acknowledged that the containers have reduced Eastern Hutt Road to one lane (southbound traffic) and are considered a temporary solution.

The risk posed due to global instability (large-scale failure), which can have disastrous consequences for both privately owned and HCC assets, is considered to be **medium**. The temporary containers placed at the toe of the slope are expected to be ineffective in mitigating the consequences resulting in partial or full blockage of Eastern Hutt Road.

6.0 Remedial Works

Based on the risk assessment it is recommended remedial works are undertaken to protect road users and private property. Remedial work options have been proposed which take into consideration the location, type of failure/damage, and the likelihood of future/ongoing instability/damage. Each option acknowledges the potential restrictions imposed by the road beneath, work at heights and traffic management plans required for the duration of the works.

The remedial options below primarily consider the risk posed to HCC-owned assets. We anticipate remedial works will be undertaken across the upper reaches of the slope to minimise the risk associated with 60 Holborn Drive. Any remedial works undertaken should consider controls and physical works undertaken by the residents of 60 Holborn Drive towards the crest of the slope

6.1 Option 1: Temporary options

6.1.1 Placing welded containers along the toe of the slope

This option would include placing containers (2.4m x 6m x 2.4m high) along the toe of the slope to capture the entire area affected having an approximate length of 34m along the Eastern Hutt Road. The containers will be welded together and filled with concrete cubes to prevent sliding and overturning during debris impact. The containers will minimize the risk of debris falling from above to encroach the southbound lanes of Eastern Hutt Road.

This temporary solution would occupy one of the southbound lanes, reducing the road to one trafficable lane. This solution does not reduce the risk associated with further instability or damage to private property (60 Holborn Drive).

The works could be directed by HCC to a local maintenance contractor with the appropriate skills to undertake the works and supervised by AECOM personnel. This option presents itself as a low-cost but a high to very high residual risk solution.

6.2 Permanent options

Prior to any permanent works being undertaken, it is recommended clearing of loose rock and soil (scaling) is undertaken. Scaling is considered necessary to create a safe working environment and would be undertaken via abseiling and hand tools. Temporary mesh may a suitable alternative to scaling.

Services are not expected to adversely impact the proposed remedial works. As indicated in Figures 2 and 4, remedial works undertaken on the slope and anchors towards the toe of the slope may encroach into private property.

Both options required detailed design and construction monitoring to be undertaken by a suitably qualified geotechnical engineer.

6.2.1 Option 2: Catch fence along the Easter Hutt Road

This remedial option would involve installing a 2m high catch fence having a capacity of 100KJ (approx.) along the toe of the existing slope covering a length of approximately 34m along the shoulder of Eastern Hutt Road. The catch fence may comprise of proprietary systems provided by Geobrugg/Macafferri (or similar), a system comprising of regularly spaced galvanised steel post anchored into competent rock and high tensile mesh. The fence would prevent the runout of rockfall from entering the carriageway, however, require maintenance once debris has accumulated. The proprietary system/s are typically manufactured overseas and would be shipped to New Zealand (approx. 8–12-week lead time).

If a proprietary system is utilised this option can be designed for a 50-year design life, however ongoing maintenance is expected to be required. This option only addresses risk to HCC-owned assets and road users. The residual risk to private property is assessed as very high. The residual risk to HCC-owned assets is very low. This option is considered a high-cost remedial option.

6.2.2 Option 3: Steel post (steel UC) with each post tied back into the slope

This remedial option would involve installing 2m high steel posts at regular spacings (approx. 2m) along the toe of the slope. The posts would be placed in bored holes to approximately 3m depth and encased in concrete. High tensile steel mesh will be installed between the posts, secured using shackles and serve to minimise debris runout into Eastern Hutt Road. The posts may also be anchored into the slope to minimise fence/post displacements during significant rockfall events. Similar structures are present along Eastern Hutt Road.

This option mitigates the need for importing proprietary systems and the associated delays, however unable to be rated to a specific energy level without full-scale testing.

If a proprietary system is utilised this option can be designed for a 50-year design life, however ongoing maintenance is expected to be required. This option only addresses risk to HCC-owned assets and road users. The residual risk to private property is assessed as very high. The residual risk to HCC-owned assets is low. This option is considered a high-cost remedial option.

7.0 Conclusion and Recommendation

To minimise the risk to HCC-owned assets and road users it is recommended a proprietary catch fence system is installed along the toe of the instability. The construction of any remedial works directed by HCC should consider controls and physical works undertaken by the residents of 60 Holborn Drive towards the crest of the slope.

It is recommended that scaling and/or temporary meshing is undertaken to ensure the safety of workers throughout the construction of permeant remedial works. A summary of the risk assessment and remedial works is presented in Table 1 and Table 2.

Table 1 Risk assessment summary (current condition)

Event	Element at Risk	Likelihood of Occurrence	Consequence	Current Risk Level
Localised failure in the mid-section (assuming top 3-4m are stabilized by T&T)	Road corridor, road users, private landowner	*Almost certain*	*Low* –. Runout and debris will fall on the road which will cause road closure and cause disruption to traffic.	***Very High***
Large scale / global instability of the slope	Road corridor, road users, private landowner	*Unlikely*	*Disastrous* – Large scale failure resulting in extensive damage to the private property and road below. Road closed for an extended period	***Medium***

Table 2 Remedial options, indicative costing and associated residual risks

Remedial Options	Indicative Cost[1]	Residual Risk Following Remedial Works	
		60 Holborn Drive (Dwelling / Private property)	HCC-owned Assets and Road Users
Option 1 – Placing containers along the toe of the slope	*NA (already done by Fulton Hogan)*	***Very High***	***Low***
Option 2 – Catch fence along the Eastern Hutt Road	*$300-350K*	***Very High***	
Option 3 – *Steel post (steel UC) with each post tied back into the slope*	*$350-400K*	***Very High***	

1) Note that this price assumes a suitably experienced contractor would undertake the construction. The estimate includes engineering design, building consent, and construction monitoring fees where appropriate. It is recommended that a detailed site investigation be carried out to confirm the preferred option. The preferred remedial option and associated cost estimates should be further refined during detailed design.

AECOM

[redacted]

Geotechnical Engineer

[redacted]

Principal Geotechnical Engineer

Appendix A - Marked up photo
Appendix B - Site photographs
Appendix C - Risk Assessment

Limitations

The recommendations and opinions contained within this inspection report are based on visual geotechnical appraisal and engineering judgment. Inferences about ground conditions across the site are made according to desktop studies, site and observations, standard geological principles, and engineering judgment. Therefore, it is not possible to guarantee the ground conditions due to the absence of site-specific investigations. Information provided within the appendices is based on the initial site visit and experience with similar projects.

The estimated costs for the remediation options are indicative only and should be revisited in the detailed design stage. Each option includes a sum for the traffic management requirements, detailed design/monitoring, consenting and construction monitoring where appropriate. Additionally, the indicative costs are based upon the following assumptions:

- All figures are GST exclusive and based upon previous tendered rates from previous similar-sized projects.
- A contingency sum of 10% is included for each option.
- Accuracy of the above estimates is of the order of +/- 20%.

It is considered to be in the best interests of all parties that AECOM is retained to undertake this work. In any event, we should be notified if ground conditions encountered on site differ from those described in this report. Cost estimates have been undertaken to the best of our knowledge, given the restrictions and limits placed on us, and the lack of detailed data available.

This report has been prepared for the particular project and purpose described in the brief of this report, and no responsibility is accepted for the use of any part of this report in any other context or any other purpose.

Appendix A - Site Markup

Site notes

1. Slip occurred in the evening of 21 July 2022.
2. Debris fell on the Eastern Hutt road which was cleared around 2:30am (22 July 2022).
3. Between 2:30am to 11am more slip debris has accumulated at the toe and some spread over the SB lane.
4. Debris appears to be soil with some medium-sized rock fragments.
5. Major rock outcrop is noted about 16m from the road.
6. The upper 3-4m of the slope is nearly vertical)(80-90deg) and with pronounced tension cracks on the ground above the slope.
7. Tension cracks are visible on the surface as indicated in the left photo, the cracks are about 5m away from the building footprint.
8. There is an area of ground subsidence noted (refer to left photo)and below this are overhanging trees which can potentially come down anytime.

12. A high risk of further failure is likely.
13. An underground storm water pipe runs below the property and goes southwest toward the dense vegetation

Appendix B - Site photographs

Figure 5 Aerial view of the slip

Figure 6 Upper 3-4m of the slope

Figure 7 Aerial view of the Eastern Hutt Road

Figure 8 60 Holborn street property view

Figure 9 Rock outcrop in the middle section

Figure 10 Debris accumulated along the shoulder

Note: 1) The risk assessment of the mid section (assumes that the top 3-4m of the slope have already been stabilized by landowners per the recommendations of EQC consultant)

Scenarios Considered

Large scale global instability of the slope

Localized failure in the mid section.

Appendix C – Risk Assessment

Measures of Likelihood for further undermining

Level	Descriptor	Description	Annual Probability of Occurrence
A	Almost Certain	The event is on-going or is expected to occur during the next year	100%
B	Very L kely	The event is expected to occur.	20% to 100%
C	Likely	The event is expected to occur under somewhat adverse conditions	5% to 20%
D	Possible	The event is expected to occur under adverse conditions	1 to 5%
E	Unlikely	The event is expected to occur under high to extreme conditions	0.2 to 1%
F	Rare	The event could occur under extreme conditions	Less than 0.2%

Measures of Consequence for further undermining

Level	Descriptor	Example Descriptions (Damage to Private Property)	Example Descriptions (Damage to HCC Assets)
1	Catastrophic	Large scale damage to multiple properties	Arterial routes and lifelines blocked an extended length of time (several days) – significant effects to communities for extended periods
2	Disastrous	Large scale damage involving private property and dwellings requiring major engineering works for stabilisation	Both lanes of local road blocked/slipped for an extended length of time (several days); or arterial route blocked causing major and extended delays to traffic; major emergency works
3	Major	Extensive damage to property but dwelling not involved	Both lanes of local road temporarily blocked/slipped (few hours to a day) or one lane of arterial route blocked with major delays; significant emergency works
4	Medium	Moderate damage to private land	One lane of road blocked/slipped with some emergency works necessary *or* several metres of footpath destroyed; no alternative access available
5	Low	Limited damage to private land	Half of one lane of road blocked for a short period of time; emergency works limited to clean up only *or* footpath destroyed over several metres; alternative access is available
6	Minor	No damage	Shoulder of road damaged/blocked only; reinstatement works can be delayed *or* footpath locally undermined but still usable; reinstatement works can be delayed

Risk Matrix for Failure for further undermining

		Consequences to Property/Assets					
		1: Catastrophic	2: Disastrous	3: Major	4: Medium	5: Low	6: Minor
Likelihood	A – Almost Certain	VH	VH	VH	H	H	M
	B – Very L kely	VH	VH	H	H	M	L
	C – Likely	VH	H	H	M	L	L
	D – Possible	VH	H	M	L	VL-L	VL
	E – Unlikely	H	M	L	VL	VL	VL
	F – Rare	M	L	VL	VL	VL	VL

Risk Level Implications

Risk Level		Implications for Risk Management
VH	Very High Risk	Detailed investigation, design, planning, and implementation of treatment options to reduce risk to acceptable levels. May involve very high costs.
H	High Risk	Detailed investigation, design, planning, and implementation of treatment options to reduce risk to acceptable levels.
M	Moderate Risk	Broadly tolerable provided treatment plan is implemented to maintain or reduce risks. May require investigation and planning of treatment options.
L	Low Risk	Acceptable. Treatment requirements to be defined to maintain or reduce risk
VL	Very Low Risk	Acceptable. Manage by normal maintenance procedures

Notes:

1. The examples of consequence given should only be used as a general guide. The implications for a particular situation may be required to be specifically determined.
2. The risk matrices above are based on those given in Appendix G of AGS (2000): *Landslide Risk Management Concepts and Guidelines*

Prepared for
Hutt City Council
Co No.: N/A

AECOM

60 Holborn Drive
Geotechnical Review

13-Mar-2023
HCC Geotechnical IIR CSA

60 Holborn Drive Geotechnical Review

Client: Hutt City Council

Co No.: N/A

Prepared by

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AECOM in Australia and New Zealand is certified to ISO9001, ISO14001 and ISO45001.

Quality Information

Document 60 Holborn Drive Geotechnical Review

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Date 13-Mar-2023

Originator [redacted]

Checker/s [redacted]

Verifier/s [redacted]

Revision History

Rev	Revision Date	Details	Approved	
			Name/Position	Signature
0	13/03/2023	For information	[redacted] Associated Director - Ground Engineering & Tunnelling	[redacted]

Table of Contents

Executive Summary

AECOM New Zealand Limited (AECOM) has been engaged by Hutt City Council (HCC) to re-assess the risk to the building associated with the landslip that has occurred below 60 Holborn Drive, Stokes Valley, review the status of the Dangerous Building Notice and assess if the building may be occupied. The re-assessment is to include a review of a stability assessment report prepared by Ian R Brown Associates Ltd (IRBA) and their responses to questions posed by HCC.

The landslide is reported to have occurred on 21 July 2022 following a heavy rainfall event. An initial site inspection was carried out by an AECOM engineering geologist on 22 July 2022.

On the advice of AECOM in a letter dated 28 July 2022, a Dangerous Building Notice was issued to the owners of the building by HCC on 29 July 2022 and to date the building remains unoccupied.

It is noted that the definition of a dangerous building refers to "*in the ordinary course of events*" and excludes earthquakes. Hence abnormal rain events and earthquakes, while posing a higher risk to the stability of the slope, are not to be considered in the assessment.

Based on our review of the IRBA report and site observations of the landslip we make the following comments:

- Since the landslip occurred some regression of the headscarp has occurred and tension cracking has continued to develop closer to the building, observed to be within 2m of the foundation on 12 August 2022.
- Since the scaling works were carried out in September 2022, there has been no observable regression of the landslip or deterioration of the landslip, despite an abnormally wet winter and heavy rainfall events in December 2022 and February 2023.
- The slope stability analyses by IRBA and AECOM indicate that slip surfaces that pass beneath the existing building have a factor of safety exceeding 1.5 under static conditions. The risk to the building under static conditions is considered to be low.
- The slope stability analyses by AECOM under ULS seismic loading indicate some instability of the foundation at the front edge of the building may occur that could lead to some damage to the building.

A structural assessment of the building was carried out by AECOM in October 2022 and concluded that it was safe to occupy in accordance with S121 of the Building Act, subject to confirmation in a report submitted by a Chartered Professional Geotechnical Engineer.

In our report dated 22 November 2022, we recommended that *"Based on the current and residual risk associated with the dwelling at 60 Holborn Drive it is recommended the Dangerous Building Notice remains in place until slope remediation measures are implemented. It is our opinion that the building would be safe to occupy following slope remedial works when the risk is equal to or lower than moderate"*.

The above recommendation was based on observations of the slope condition prior to and during the scaling works. Initial observations indicated that the uppermost 4 m to 5 m of the slope appeared to be very unstable and we considered that it was almost certain that the headscarp of the landslip would regress within the next 12 months and result in damage to the dwelling. The report issued by T&T in September 2022, based on observations prior to the scaling works, agreed that regression of the headscarp would occur in the next 12 months. Regression of the headscarp did occur prior to scaling works and tension cracks were observed to develop to within 2 m of the building foundation.

Following the scaling and re-profiling of the headscarp in September 2022, the slope had only been observed for a few months prior to issue of our re-assessment report in November. Over this period there had been little rainfall and therefore the performance of the slope after heavy rainfall events had not been evaluated. Our level of confidence in how the slope would behave, and in particular how much further regression would occur, was insufficient at the time for us to recommend lifting the Dangerous Building Notice.

Since issuing our report in November 2022 there have been a number of heavy rainfall events. Observations made since then have indicated no further regression of the headscarp or deterioration of the landslip. Based on this observational approach and having regard to the findings of the recent

borehole investigation, which have provided additional confidence in our ground model and strength parameters, we consider the risk of further regression of the headscarp under static conditions to be low.

Based on our geotechnical assessment, we consider the existing building does not meet the requirements of a dangerous building, as defined in Section 121 of the Building Act, and that the house is safe to occupy now.

It should be noted that the seismic loading used for assessing the stability of the slope regarding the building and that for route resilience of the road below is different. As such remedial measures proposed for route resilience are still considered appropriate, subject to agreement on the level of resilience required.

Visual inspections of the landslip and adjacent slopes are recommended after significant rainfall and seismic events until proposed remedial measures are installed. If the slope condition worsens, the building and its foundation system should be assessed by a Chartered professional structural engineer to confirm it remains structurally sound.

1.0 Introduction

AECOM New Zealand Limited (AECOM) has been engaged by Hutt City Council (HCC) to re-assess the risk to the building associated with the landslip that has occurred below 60 Holborn Drive, Stokes Valley ,review the status of the Dangerous Building Notice and assess if the building may be occupied. The re-assessment is to include a review of a stability assessment report prepared by Ian R Brown Associates Ltd (IRBA) and their responses to questions posed by HCC.

The landslide is reported to have occurred on 21 July 2022 following a heavy rainfall event. An initial site inspection was carried out by an AECOM engineering geologist on 22 July 2022.

On the advice of AECOM in a letter dated 28 July 2022, a Dangerous Building Notice was issued to the owners of the building by HCC on 29 July 2022 and to date the building remains unoccupied.

Characteristics of the slope, initial remedial options and previous assessments are summarized within the following documents:

- Letter - AECOM New Zealand Limited. Slips at 46 and 60 Holborn Drive – Dangerous Building Notice. Issued 28 July 2022.
- Letter Report - AECOM New Zealand Limited. Slope Assessment Below 60 Holborn Drive, Stokes Valley. Issued 4 August 2022.
- Letter Report - AECOM New Zealand Limited. Slope Condition Re-assessment (60 Holborn Drive, Stokes Valley). Issued 18 August 2022.
- Report - Tonkin & Taylor Ltd. Claim for Natural Disaster (Landslip) Damage. [redacted], 60 Holborn Drive, Stokes Valley, Hutt City. EQC/Insurer Claim Number [redacted] Dated 1 September 2022.
- Report - AECOM New Zealand Limited. Structural Inspection Report for 60 Holborn Drive. Issued 15 November 2022.
- Report - AECOM New Zealand Limited. 60 Holborn Drive Slope Re-assessment and Remedial Works. Issued 22 November 2022.
- Report – Ian R Brown and Associates Limited. Slope Stability Assessment 60 Holborn Drive, Stokes Valley, Lower Hutt. Issued February 2023.

A timeline summarizing the main events that have occurred and issue of documents with relevant comments is summarized in Table 1 below.

Table 1 Timeline

Date	Item	Comment
21/07/2022	Slip occurred	
22/07/2022	AECOM engineers visited site.	Visits occurred from 22 to 26 July 2022.
22/07/2022	Dangerous Building Notice issued by HCC	
26/07/2022	T&T site inspection	Assess claim for natural disaster damage.
28/07/2022	Letter - AECOM New Zealand Limited. Slips at 46 and 60 Holborn Drive – Dangerous Building Notice.	*"The uppermost 4 m to 5 m appears to be very unstable and we consider that it is almost certain that the slip will regress within the next 12 months and result in damage to the dwelling. We recommend that until suitable remedial measures are implemented at each property to adequately mitigate the risk to the dwellings, HCC should issue a further Dangerous Building Notice to the owners of both properties".*
29/07/2022	Dangerous Building Notice issued by HCC	

Date	Item	Comment
4/08/2022	Letter Report - AECOM New Zealand Limited. Slope Assessment Below 60 Holborn Drive, Stokes Valley.	*"The risk posed due to the instability at the upper reaches of the slope would see further regression of the nearly vertical scarp towards the property in an event of heavy rainfall or moderate to large seismic shaking".* Scaling and/or temporary meshing is also recommended.
11/08/2022	T&T site inspection	Assess claim for natural disaster damage.
12/08/2022	AECOM engineers visited site.	
18/08/2022	Letter Report - AECOM New Zealand Limited. Slope Condition Re-assessment (60 Holborn Drive, Stokes Valley).	*"Tension cracks have regressed towards the northern-most foundations and are approximately 2m from the closest foundation pole. We recommend that until suitable remedial measures are implemented, HCC should issue a further Dangerous Building Notice to the owner of the property".*
1/09/2022	Report - Tonkin & Taylor Ltd. Claim for Natural Disaster (Landslip) Damage. s7(2)(a) [redacted], 60 Holborn Drive, Stokes Valley, Hutt City. EQC/Insurer Claim Number s7(2)(b)(ii) [redacted].	T&T state that *"Within the following 12 months (under normal annual rainfall conditions) and as a direct result of the landslip that has occurred there is an imminent risk of regression of the landslip headscarp. The dwelling has not been damaged and is not considered to be at imminent risk as a direct result of the natural disaster (landslip) that has occurred".*
1/09/2022 - 8/09/2022	Scaling of landslip by Abseil Access.	Re-profiling of headscarp, removal of selected vegetation and loose soils / rock from slope.
13/10/2022	AECOM structural engineers visited site.	Structural assessment of dwelling.
15/11/2022	Report - AECOM New Zealand Limited. Structural Inspection Report for 60 Holborn Drive.	*"The house is considered safe to occupy with respect to clause (1a) of Section 121 Subpart 6 of the New Zealand Building Act 2004, subject to confirmation in a report submitted by a Chartered Professional Geotechnical Engineer".*
22/11/2022	Report - AECOM New Zealand Limited. 60 Holborn Drive Slope Re-assessment and Remedial Works.	*"Based on AS/NZS1170.0 a new build would be considered an importance level 2 structure with a design life of 50 years. The associated return period for a seismic event would be 500 years and corresponds to a peak ground acceleration of 0.68g (NZGS/MBIE Module 1 Appendix A). A 'disastrous' consequence would require the likelihood of failure to be 'rare', or 'unlikely' as a minimum. Based on the current and residual risk associated with the dwelling at 60 Holborn Drive it is recommended the Dangerous Building Notice remains in place until slope remediation measures are implemented. It is our opinion that the building would be safe to occupy following slope remedial works when the risk is equal to or lower than moderate".*
27/02/2023	Report received by HCC – Ian R Brown and Associates Limited. Slope Stability Assessment 60 Holborn Drive, Stokes Valley, Lower Hutt.	IRBA state that *"The overall stability of the site does not appear to have changed following the July 2022 landslide. We agree with the Tonkin and Taylor Ltd conclusion that the dwelling has not been damaged and is not considered to be at imminent risk as a direct result of the natural disaster (landslip) that has occurred. We conclude that the building is not dangerous and is safe to occupy".*

Date	Item	Comment
20/02/2023 - 23/02/2023	Borehole BH01 carried out at 58 Holborn Drive	The rock mass is typically weak to very weak with frequent discontinuities and intermittent shears (gouge infill or extremely weak).
7/03/2023	BH01 downhole televiewer results received	The results of the downhole televiewer indicate two main joint sets and presence of two shear zones.

The approximate location of the borehole carried out in February 2023 is shown in Figure 1 below and the findings indicate the depth to highly weathered greywacke is approximately 3 m below ground level. The results of the downhole televiewer indicate two main joint sets and presence of two shear zones as summarized below.

Two principal joint sets were identified from the downhole televiewer

- JS1 = 50/325 (dip/dip direction). This joint set is roughly parallel to the average slope batter (55/335)
- JS2 = 50/150 (dip/dip direction). This joint dips into the slope and may match bedding previously identified on the slope below No. 60 Holborn Drive
- Other less frequent random joint sets are present

Shear details

- Extremely weak shear zone(?) between 16.5-17.7m depth = 30/052. Dips into the slope.
- 200mm wide shear zone at ~24m depth = 37/137. Dips into the slope.

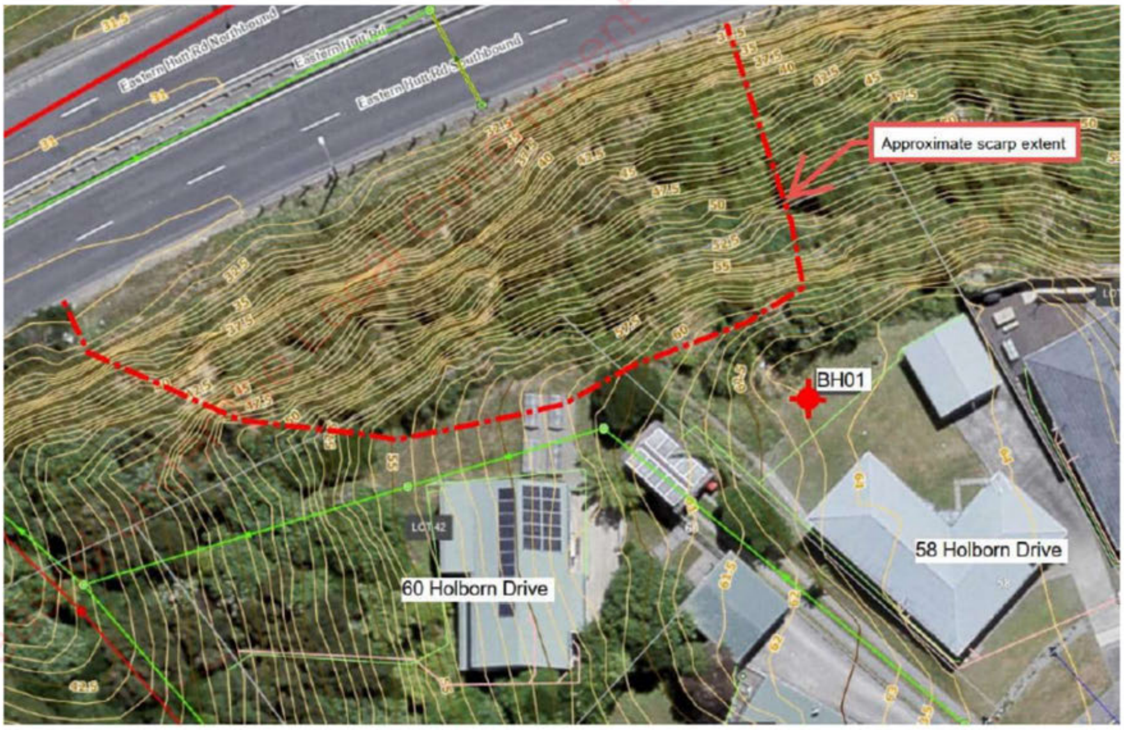


Figure 1 Approximate borehole location

2.0 Slope stability and assessment

2.1 IRBA assessment

The ground model developed by IRBA has been based on UAV photography obtained after the upper part of the landslide had been scaled but prior to the borehole being completed. Removal of landslide debris and re-profiling of the headscarp has revealed the apparent presence of in situ greywacke at a higher level than initially modelled by AECOM. However, this uppermost rock was noted to be dilated during the scaling inspections by AECOM and therefore the strength parameters for this upper greywacke are likely to be lower than that for the greywacke that forms the lower part of the slope.

Nevertheless, in the static load case, the IRBA slope stability assessment results in a factor of safety (FoS) of 1.8 which is similar to the 1.6 indicated from the AECOM analysis.

For the seismic case, which is excluded when assessing a Dangerous Building Notice, IRBA have applied a reduction factor to the peak ground acceleration (PGA) to derive the horizontal seismic coefficient (Kh) of 0.27 adopted for the ultimate limit state (ULS) earthquake. Details on how they have derived the reduction factor are not provided, however, based on a 1 in 500-year event PGA of 0.68 (MBIE Module 1) it would appear a reduction factor of 0.4 has been used. Whilst this is in accordance with industry practice, it is noted that higher reduction factors may be applied. The results of pseudo-static stability analyses are critically dependent on the value of Kh selected and this is often difficult to determine and subject to engineering judgement.

The conclusions of the IRBA report state that:

- the present slope configuration appears stable
- the dwelling has not been damaged and is not considered to be at imminent risk as a direct result of the natural disaster (landslip) that has occurred
- the building is not dangerous and is safe to occupy

2.2 AECOM assessment

An independent slope stability analysis has been undertaken using SLIDE2 v.9.020 (Rocsience software) based on the observations made prior to the borehole data being available. The assessment is based on conservative soil and rock parameters and considers the current condition under static and seismic conditions and the ground model developed during our previous assessments, with minor revisions from observations during the scaling works.

The results of the static assessment indicate the FoS for slip surfaces that pass beneath the existing building exceed 1.5. This is in general agreement with the IRBA analyses and indicates the ground beneath the building is stable under static loading conditions.

The results of the seismic assessment indicate that for a horizontal loading of 0.27 the FoS of slip circles below 1 (i.e., indicative of instability), occur below the front edge of the existing building. As such some instability of the foundation may occur during a seismic event that could lead to some damage to the building.

The difference in our assessment and the assessment carried out by IRBA is largely an interpretation of the ground model, specifically depth to greywacke rock, and selection of strength parameters. This results in AECOM slope failure surfaces that are closer to the building foundation than assessed by IRBA.

The results of the stability analyses are presented in Appendix A.

The findings of the borehole investigation carried out in February 2022 indicate the depth to highly weathered greywacke is approximately 3 m below ground level. The results of the downhole televiewer indicate two main joint sets and presence of two shear zones. Based on the findings of the investigation we conclude that:

- The ground model and material strength parameters adopted in the AECOM slope stability analyses are appropriate.
- Kinematic failure of the rock mass due the presence of joints/shears under static/long term loading is considered to be unlikely based on the performance of the slope to date.
- Under moderate to large seismic shaking there is an elevated risk of wedge failure (intersection of JS1 and shear encountered at ~16.5m depth) and progressive unravelling of the slope (JS1).
- Based on the condition and strength of the rock, failure through the rock mass is a credible failure mechanism under seismic loading.

3.0 Discussion and recommendations

3.1 Dangerous building

Section 121 of the Building Act defines a dangerous building as:

(1) A building is dangerous for the purposes of this Act if, —

(a) in the ordinary course of events (excluding the occurrence of an earthquake), the building is likely to cause—

(I) injury or death (whether by collapse or otherwise) to any persons in it or to persons on other property; or

(ii) damage to other property; or

(b) in the event of fire, injury, or death to any persons in the building or to persons on other property is likely.

It is noted that the definition of a dangerous building refers to "*in the ordinary course of events*" and excludes earthquakes. Hence abnormal rain events and earthquakes, while posing a higher risk to the stability of the slope, are not to be considered in the assessment.

Based on our review of the IRBA report and site observations of the landslip we make the following comments:

- Since the landslip occurred some regression of the headscarp has occurred and tension cracking has continued to develop closer to the building, observed to be within 2m of the foundation on 12 August 2022.
- Since the scaling works were carried out in September 2022, there has been no observable regression of the landslip or deterioration of the landslip, despite an abnormally wet winter and heavy rainfall events in December 2022 and February 2023.
- The slope stability analyses by IRBA and AECOM indicate that slip surfaces that pass beneath the existing building have a factor of safety exceeding 1.5 under static conditions. The risk to the building under static conditions is considered to be low.
- The slope stability analyses by AECOM under ULS seismic loading indicate some instability of the foundation at the front edge of the building may occur that could lead to some damage to the building.

Based on the above geotechnical assessment, we consider the existing building does not meet the requirements of a dangerous building, as defined in Section 121 of the Building Act.

A structural assessment of the building was carried out by AECOM in October 2022 and concluded that it was safe to occupy in accordance with S121 of the Building Act, subject to confirmation in a report submitted by a Chartered Professional Geotechnical Engineer.

In our report dated 22 November 2022, we recommended that *"Based on the current and residual risk associated with the dwelling at 60 Holborn Drive it is recommended the Dangerous Building Notice remains in place until slope remediation measures are implemented. It is our opinion that the building would be safe to occupy following slope remedial works when the risk is equal to or lower than moderate"*.

The above recommendation was based on observations of the slope condition prior to and during the scaling works. Initial observations indicated that the uppermost 4 m to 5 m of the slope appeared to be very unstable and we considered that it was almost certain that the headscarp of the landslip would regress within the next 12 months and result in damage to the dwelling. The report issued by T&T in September 2022, based on observations prior to the scaling works, agreed that regression of the headscarp would occur in the next 12 months. Regression of the headscarp did occur prior to scaling works and tension cracks were observed to develop to within 2 m of the building foundation.

The scaling works did not reveal any significant improvement in the slope condition that enabled us to amend our opinion from previous assessments. The greywacke exposed in the upper 4 m to 5 m was observed to be dilated and readily removed. These observations confirmed our initial assumptions regarding our shallow ground model and strength parameters used in our analyses. We considered the regression of the headscarp was still a risk under static conditions after heavy rainfall events and could lead to loss of support to the foundations at the front of the building. Whilst the building did not meet the requirements of a dangerous building, we adopted a more conservative approach, given the uncertainties in the deep-seated failure mechanism and the relatively short period that the slope had been observed since the scaling works had been completed.

Following the scaling and re-profiling of the headscarp, the slope had only been observed for a few months prior to issue of our re-assessment report in November 2022. Over this period there had been little rainfall and therefore the performance of the slope after heavy rainfall events had not been evaluated. Our level of confidence in how the slope would behave, and in particular how much further regression would occur, was insufficient at the time for us to recommend lifting the Dangerous Building Notice.

Since issuing our report in November 2022 there have been a number of heavy rainfall events. Observations made since then have indicated no further regression of the headscarp or deterioration of the landslip. Based on this observational approach and having regard to the findings of the recent borehole investigation, which have provided additional confidence in our ground model and strength parameters, we consider the risk of further regression of the headscarp under static conditions to be low.

3.2 Comment on IRBA responses

With respect to the responses received from IRBA in italics below by email dated 28 February 2023 to the questions posed by HCC, we provide the following comment:

1. Danger arising from the proposed remedial works.

Our report shows that the house site has adequate stability under ULS earthquake loading conditions. It is unlikely that the works would lead to any unusual loading on the slope that would be of concern. Other areas of danger could arise from the operations; however, they should be managed by appropriate health and safety plans.

Our analyses using a weighted PGA approach under ULS loading conditions indicates some instability of the foundation at the front edge of the building may occur that could lead to some damage to the building. We agree that it is unlikely the proposed remedial works would lead to any unusual loading on the slope that would be of concern.

2. Impact of house occupation on proposed works.

Again, appropriate health and safety measures should be put in place to manage potential impacts.

We agree with the above statement.

3. Whether the house is safe to occupy now.

Our assessment of current stability does not rely on future work that Hutt City Council may carry out. We have concluded that the house is safe to occupy now.

Our assessment indicates the house site has an adequate factor of safety under static loading and serviceability limit state (SLS) seismic loading. Under ULS loading some instability of the foundation may occur that could lead to some damage to the building. Therefore, we conclude that the house is safe to occupy now.

It should be noted that the seismic loading used for assessing the stability of the slope regarding the building and that for route resilience of the road below is different. As such remedial measures proposed for route resilience are still considered appropriate, subject to agreement on the level of resilience required.

Visual inspections of the landslip and adjacent slopes are recommended after significant rainfall and seismic events until proposed remedial measures are installed. If the slope condition worsens, the building and its foundation system should be assessed by a Chartered professional structural engineer to confirm it remains structurally sound.

4.0 Limitations

AECOM has prepared this report for the sole use of Hutt City Council and for a specific purpose, each as expressly stated in the report. No other party should rely on this report without the prior written consent of AECOM. AECOM undertakes no duty, nor accepts any responsibility, to any third party who may rely upon or use this report. This report has been prepared based on the Client's description of its requirements and AECOM's experience, having regard to assumptions that AECOM can reasonably be expected to make in accordance with sound professional principles. AECOM's findings represent its reasonable judgment within the time and budget context of its commission and utilising the information available to it at the time.

No section or element of this report may be removed, reproduced, electronically stored, or transmitted in any form by parties other than those for whom the report has been prepared without the written permission of AECOM. All sections in this report must be viewed in the context of the entire report/document including, without limitation, any assumptions made, and disclaimers provided. No section in this report may be excised from the body of the report without AECOM's prior written consent.

The recommendations and opinions contained within this inspection report are based on visual geotechnical appraisal and engineering judgment. Inferences about ground conditions across the site are made according to desktop studies, site observations, standard geological principles, and engineering judgment. Therefore, it is not possible to guarantee the ground conditions due to the absence of site-specific investigations. Information provided within the appendices is based on the initial site visit and experience with similar projects.

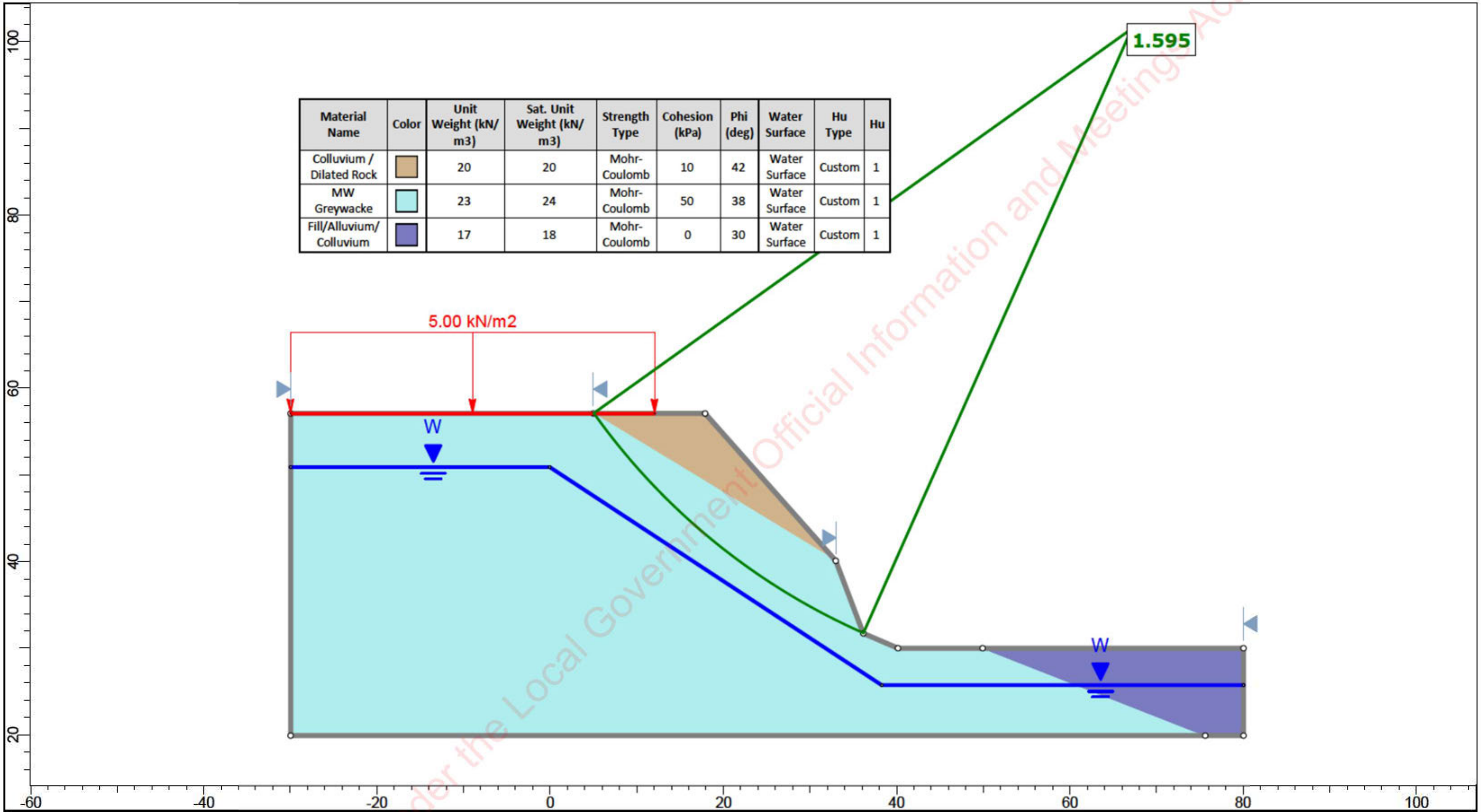
It is in the best interests of all parties that AECOM is retained to undertake this work. In any event, we should be notified if ground conditions encountered on site differ from those described in this report. Cost estimates have been undertaken to the best of our knowledge, given the restrictions and limits placed on us, and the lack of detailed data available.

AECOM has prepared this report using the standard of reasonable skill, care and diligence required of a consultant performing the same or similar Services. The report should be read in full. No warranty, expressed or implied, is made as to the professional advice included in this report. This report does not alleviate the need for any party to complete their own due diligence.

Appendix A

Slope Stability Analyses

Material Name	Color	Unit Weight (kN/m3)	Sat. Unit Weight (kN/m3)	Strength Type	Cohesion (kPa)	Phi (deg)	Water Surface	Hu Type	Hu
Colluvium / Dilated Rock		20	20	Mohr-Coulomb	10	42	Water Surface	Custom	1
MW Greywacke		23	24	Mohr-Coulomb	50	38	Water Surface	Custom	1
Fill/Alluvium/ Colluvium		17	18	Mohr-Coulomb	0	30	Water Surface	Custom	1



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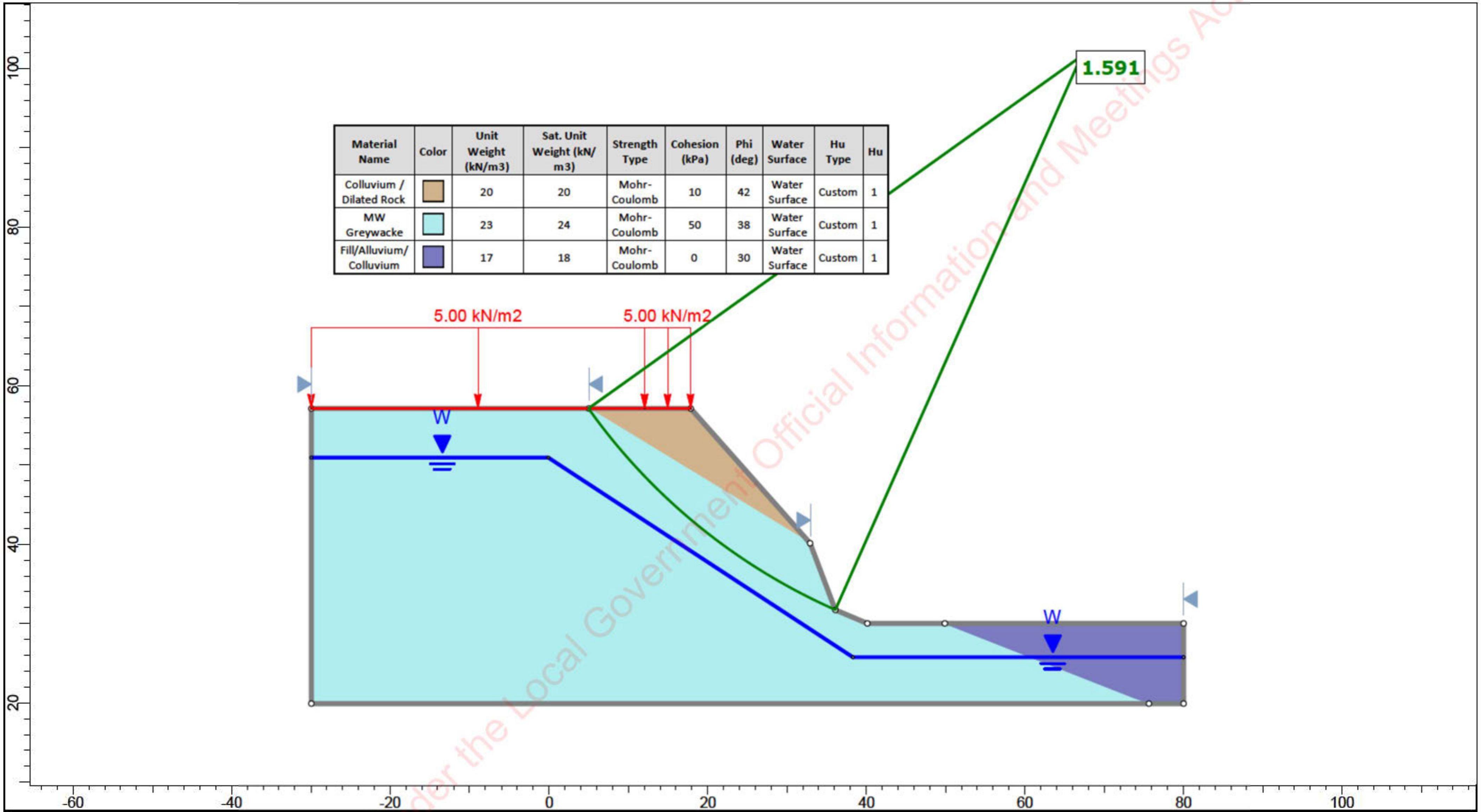
SLIDEINTERPRET 9.020

Project	SLIDE - An Interactive Slope Stability Program		
Group	Group 1	Scenario	Master Scenario
Drawn By		Company	
Date	25/01/2023, 1:02:52 pm	File Name	SLIDE Check (Deep-seated Failure).slmd



Material Name	Color	Unit Weight (kN/m3)	Sat. Unit Weight (kN/m3)	Strength Type	Cohesion (kPa)	Phi (deg)	Water Surface	Hu Type	Hu
Colluvium / Dilated Rock		20	20	Mohr-Coulomb	10	42	Water Surface	Custom	1
MW Greywacke		23	24	Mohr-Coulomb	50	38	Water Surface	Custom	1
Fill/Alluvium/ Colluvium		17	18	Mohr-Coulomb	0	30	Water Surface	Custom	1

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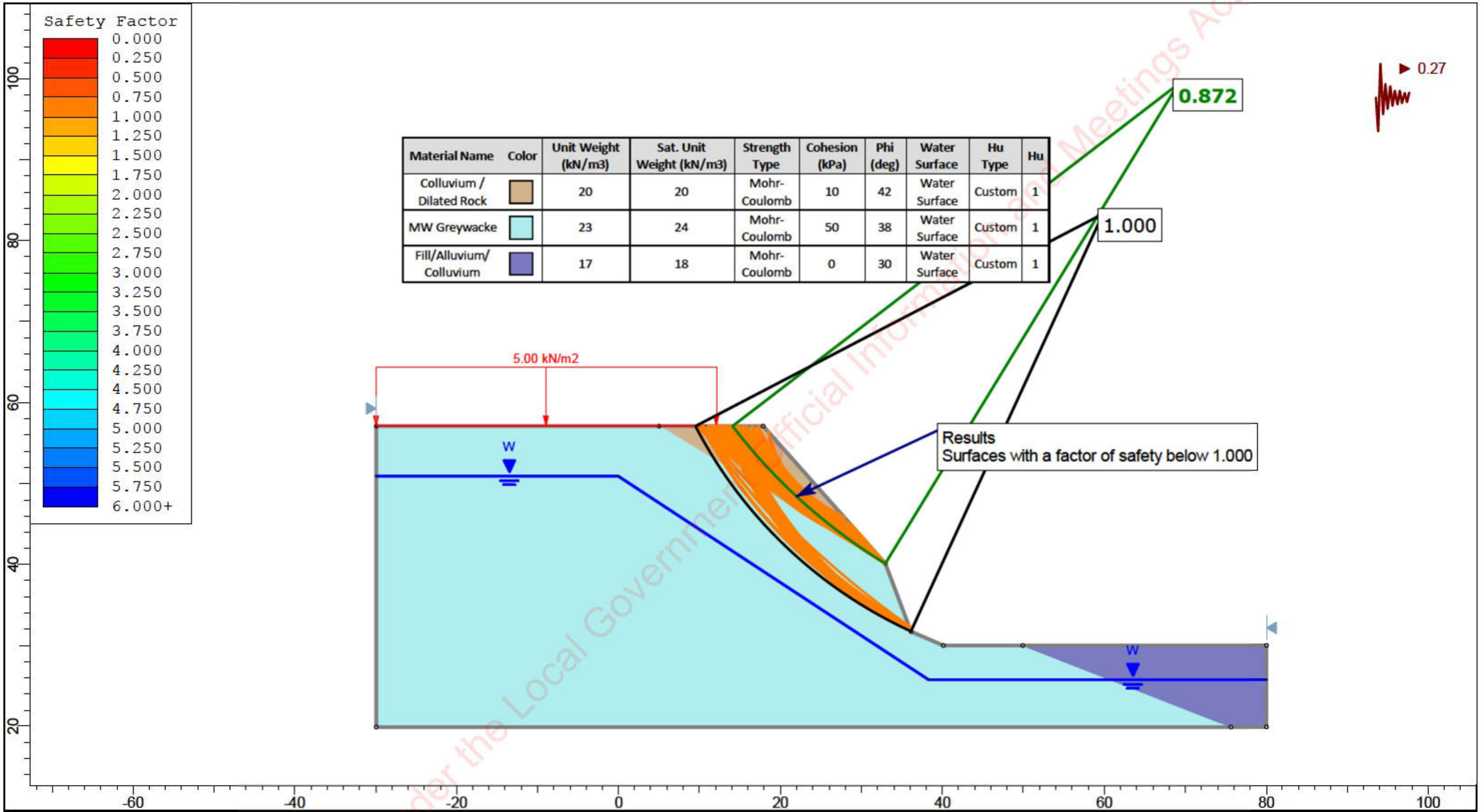
Project	SLIDE - An Interactive Slope Stability Program		
Group	Group 1	Scenario	5kPa Surcharge
Drawn By		Company	
Date	25/01/2023, 1:02:52 pm	File Name	SLIDE Check (Deep-seated Failure).slmd

SLIDEINTERPRET 9.020



Material Name	Color	Unit Weight (kN/m3)	Sat. Unit Weight (kN/m3)	Strength Type	Cohesion (kPa)	Phi (deg)	Water Surface	Hu Type	Hu
Colluvium / Dilated Rock		20	20	Mohr-Coulomb	10	42	Water Surface	Custom	1
MW Greywacke		23	24	Mohr-Coulomb	50	38	Water Surface	Custom	1
Fill/Alluvium/ Colluvium		17	18	Mohr-Coulomb	0	30	Water Surface	Custom	1

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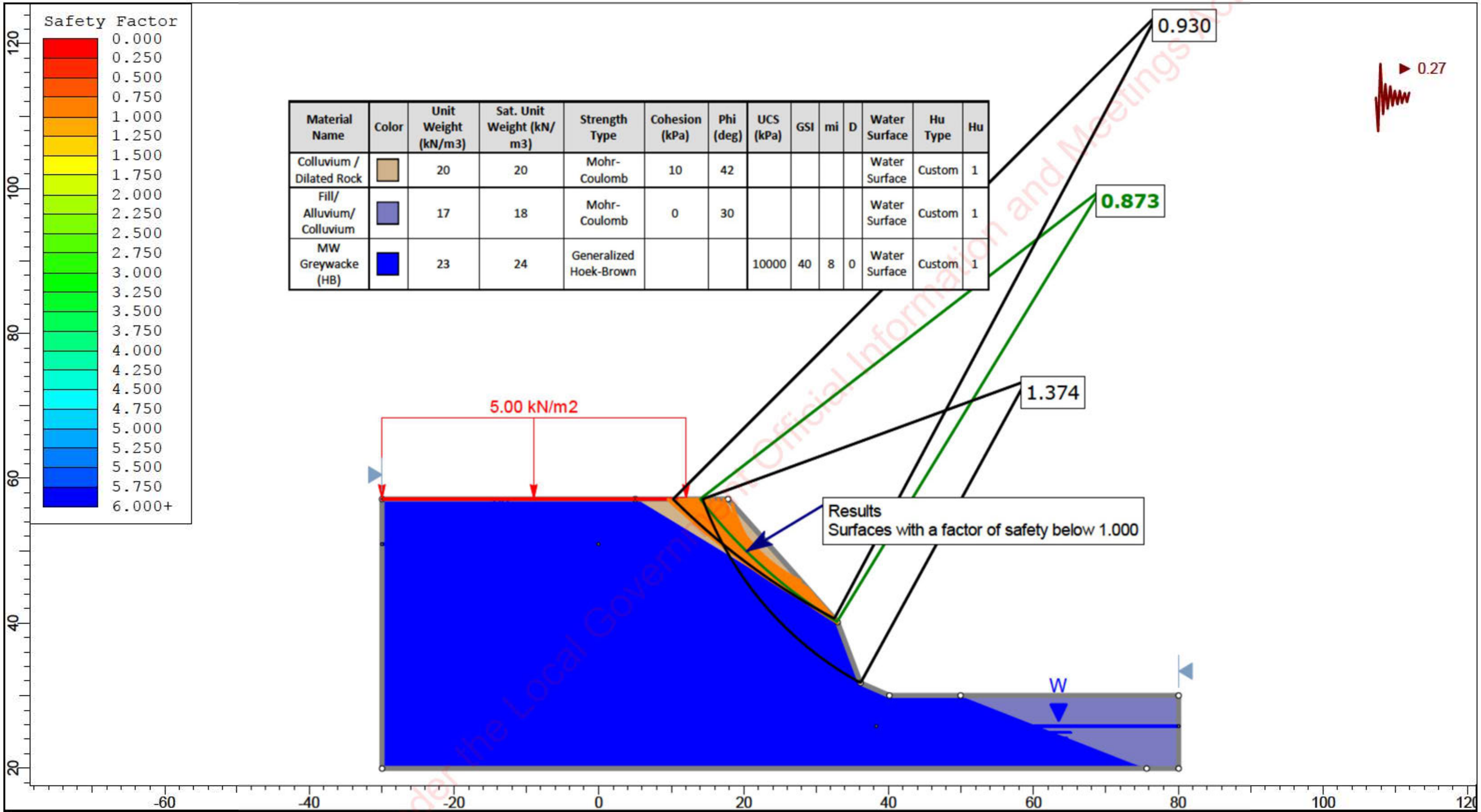
Project	SLIDE - An Interactive Slope Stability Program		
Group	M-C Parameters	Scenario	IRBA Check 0.27g
Drawn By		Company	
Date	25/01/2023, 1:02:52 pm	File Name	SLIDE Check (Deep-seated Failure).slmd

SLIDEINTERPRET 9.020



Material Name	Color	Unit Weight (kN/m3)	Sat. Unit Weight (kN/m3)	Strength Type	Cohesion (kPa)	Phi (deg)	UCS (kPa)	GSI	mi	D	Water Surface	Hu Type	Hu
Colluvium / Dilated Rock		20	20	Mohr-Coulomb	10	42					Water Surface	Custom	1
Fill/ Alluvium/ Colluvium		17	18	Mohr-Coulomb	0	30					Water Surface	Custom	1
MW Greywacke (HB)		23	24	Generalized Hoek-Brown			10000	40	8	0	Water Surface	Custom	1

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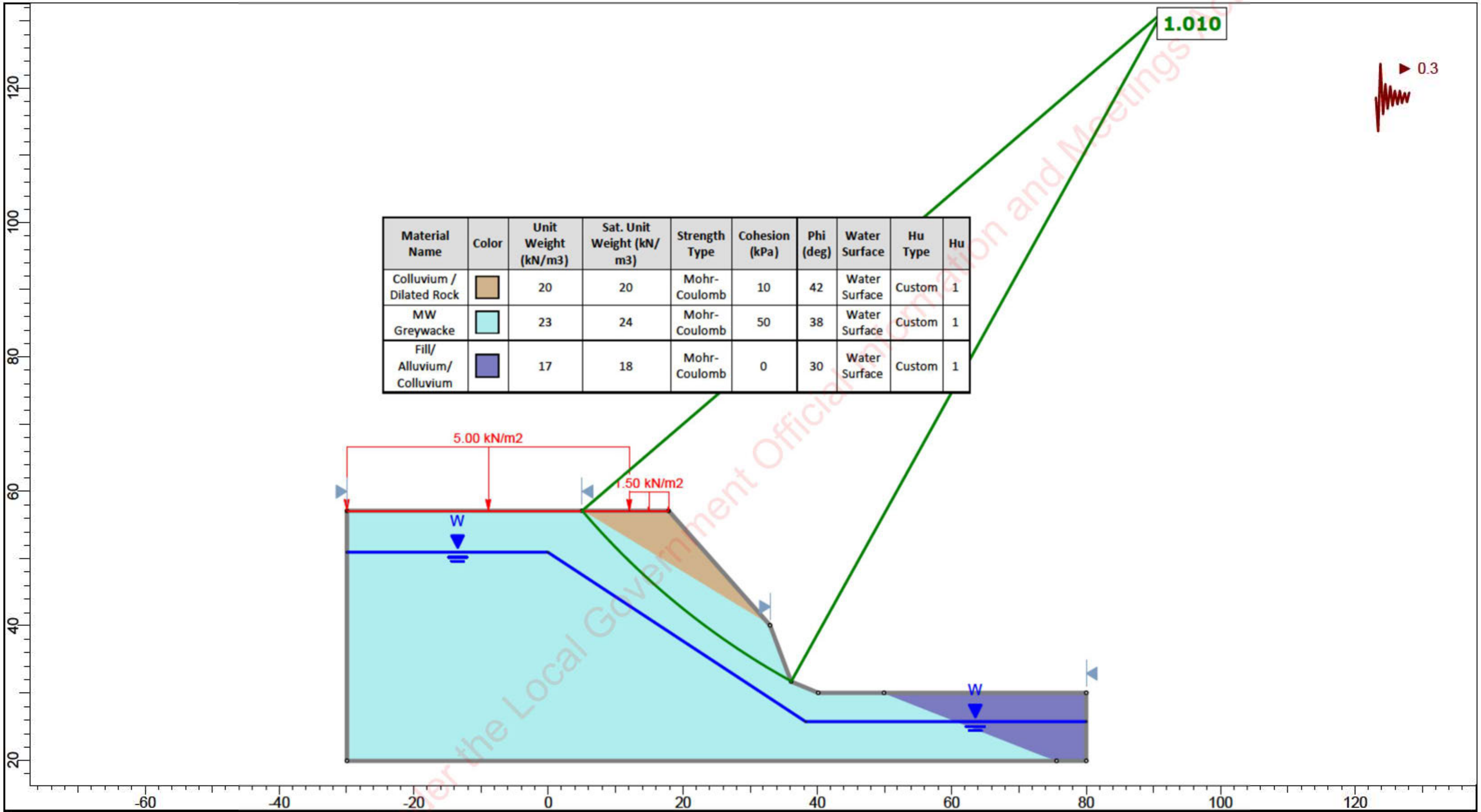
SLIDEINTERPRET 9.020

Project	SLIDE - An Interactive Slope Stability Program		
Group	HB Parameters	Scenario	IRBA Check 0.27g
Drawn By		Company	
Date	25/01/2023, 1:02:52 pm	File Name	SLIDE Check (Deep-seated Failure).slmd



Material Name	Color	Unit Weight (kN/m3)	Sat. Unit Weight (kN/m3)	Strength Type	Cohesion (kPa)	Phi (deg)	Water Surface	Hu Type	Hu
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Fill/ Alluvium/ Colluvium		17	18	Mohr-Coulomb	0	30	Water Surface	Custom	1

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SLIDEINTERPRET 9.020

Project	SLIDE - An Interactive Slope Stability Program		
Group	Group 1	*Scenario*	Ac
Drawn By		*Company*	
Date	25/01/2023, 1:02:52 pm	*File Name*	SLIDE Check (Deep-seated Failure).slmd

60 Holborn Drive Slope Re-Assessment and Remedial Works

22-Nov-2022
HCC Geotechnical IIR CSA

aecom.com

Delivering a better world

60 Holborn Drive Slope Re-Assessment and Remedial Works

Client: Hutt City Council

Co No.: N/A

Prepared by

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22-Nov-2022

Job No.: 60683486

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Quality Information

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Date	22-Nov-2022
Originator	s7(2)(a) [redacted]
Checker/s	s7(2)(a) [redacted]
Verifier/s	s7(2)(a) [redacted]

Revision History

Rev	Revision Date	Details	Approved	
			Name/Position	Signature
0	23-Sep-2022	For Client Review (Issued as Letter Report)	s7(2)(a) [redacted] Associated Director - Ground Engineering & Tunnelling	
1	15-Nov-2022	For Information	s7(2)(a) [redacted] Associated Director - Ground Engineering & Tunnelling	
2	22-Nov-2022	Final - updated following further HCC feedback	s7(2)(a) [redacted] Associated Director - Ground Engineering & Tunnelling	s7(2)(a) [redacted]

Table of Contents

Executive Summary

AECOM New Zealand Limited (AECOM) has been engaged by the Hutt City Council (HCC) to re-assess the risk associated with the slip that has occurred below 60 Holborn Drive, Stokes Valley and provide interim and long-term remedial options. An initial risk assessment was undertaken following a site inspection on 22 July 2022 and a reassessment following the completion of temporary works.

The temporary works have been implemented to ensure the safety of road users along Eastern Hutt Road while a permanent solution/s are designed and constructed. The slope continues to be visually monitored and temporary works remain in place. A Dangerous Building Notice has been issued for the residential dwelling which remains unoccupied.

At the time of reporting HCC have advised that the landowners are not intending to complete remedial works on the slip (email dated 7 November 2022). Nonetheless, any solution implemented by the owners of 60 Holborn Drive will likely have a direct impact on the risk to road users and HCC assets.

Further regression of the slope is anticipated to occur if left untreated as a result of stress-relief, heavy and/or prolonged rainfall and seismic shaking. Regression of the upper slope may occur progressively or suddenly with little to no warning (no survey monitoring in place and dwelling uninhabited). Regression of the slip would hinder the ability for vegetation to re-establish and potentially undermine the building foundations. Progressive or localised failures will reduce the distance of the slip to the dwelling foundations and likely increase the building's vulnerability with time. Furthermore, in accordance with the Intergovernmental Panel on Climate Change Assessment Report 6 New Zealand is expected to experience more extreme weather events more often.

A summary of the current and residual risk associated with each remedial option discussed within the report are presented in Table 1. The safety risk is largely associated with debris/rock hitting a passing car and assessed using New South Wales Government Roads and Maritime Services 'Guide to Slope Risk Analysis' (Version 4, April 2014). The resilience risk associated with the dwelling of 60 Holborn Drive has been assessed using the HCC standard risk matrix.

Based on the current and residual risk associated with the dwelling at 60 Holborn Drive it is recommended the Dangerous Building Notice remains in place until slope remediation measures are implemented. It is our opinion that the building would be safe to occupy when the residual risk is equal to or lower than moderate.

Based on the assessed risk, cost of proposed remedial options and the current situation it is recommended that an anchored shotcrete wall is installed, as described in section 5.2.1. If constructed the residual risk to road users and dwelling of 60 Holborn Drive would likely be reduced to an acceptable level.

The risk assessments associated with the current condition of the slope and anchored shotcrete wall are presented in Appendix B.

Regardless of the solution implemented it is recommended:

- Fall protection is erected along the crest of the slope to address the fall from height risk
- Temporary loading from machinery and equipment is considered by the temporary works designer/contractor
- The condition of the slope is monitored throughout the construction period
- Containers remain in place and their effectiveness at mitigating runout of debris is monitored

Prior to the removal of the containers (following wall construction), the residual risk should be re-assessed to confirm the objectives have been met.

1.0 Introduction

AECOM New Zealand Limited (AECOM) has been engaged by the Hutt City Council (HCC) to re-assess the risk associated with the slip that has occurred below 60 Holborn Drive, Stokes Valley and provide interim and long-term remedial options. An initial risk assessment was undertaken following a site inspection on 22 July 2022 and a reassessment following the completion of temporary works.

Characteristics of the slope, initial remedial options and previous risk assessments are summarised within the following reports:

- AECOM New Zealand Limited, 2022a. Slope Assessment Below 60 Holborn Drive, Stokes Valley. Issued 4 August 2022.
- AECOM New Zealand Limited, 2022b. Slope Condition Re-assessment (60 Holborn Drive, Stokes Valley). Issued 18 August 2022.
- Tonkin & Taylor Ltd, 2022. Claim for Natural Disaster (Landslip) Damage. s7(2)(a) [redacted], 60 Holborn Drive, Stokes Valley, Hutt City. EQC/Insurer Claim Number s7(2)(b)(ii) [redacted] Dated 1 September 2022.

The Tonkin & Taylor Ltd (2022) report was prepared for the residents of 60 Holborn Drive and their insurers as a part of the Earthquake Commission (EQC). This was provided to HCC and AECOM for review and includes a risk assessment and conceptual remedial design.

This report serves to summarise the following:

- Review of the Tonkin & Taylor Ltd (2022) risk assessment and proposed remedial option
- Existing and residual risks for each remedial option, taking into consideration the impact to both road users and residential dwelling. The risk assessment utilises the New South Wales Government Roads and Maritime Services 'Guide to Slope Risk Analysis' (Version 4, April 2014).
- Review of the Dangerous Building Notice requirements issued to the owners of 60 Holborn Drive (dated 29 July 2022)
- Interim and long-term remedial options
- Recommendations

2.0 Temporary Works

Temporary works have been undertaken at the slip site at the direction of HCC and support from AECOM engineers. Temporary works completed to date have comprised of:

- Temporary traffic management including a permanent lane closure and periodic road closures (southbound lanes)
- Scaling of loose soil and rock
- Recontouring of head scarp and removal of slumped soils
- Removal of an overhanging garden bed
- Vegetation clearance
- Installation of welded steel containers along the slope toe

The temporary works have been implemented to ensure the safety of road users along Eastern Hutt Road while a permanent solution/s are designed and constructed. The slope continues to be visually monitored and temporary works remain in place. A Dangerous Building Notice has been issued for the residential dwelling which remains unoccupied.

Photos of the initial slip and current slope condition are provided in **Figure 1**.

Figure 1 Left: Initial slip (21 July 2022). Right: Current slope condition following temporary works (14 September 2022)

2.1 Dangerous Building Notice

A dangerous building notice was issued by HCC on 29 July 2022 as a result of the slip. The requirements of the notice are outlined below:

A warranted council officer and structural engineer inspected the building on 22 July 2022. Subsequently a geotechnical report was provided to Council on 29 July 2022 concluding that there are significant risks caused by the recent slip that require further remedial work before the building can be occupied.

You are required to take the following action to reduce or remove the danger:

1. Submit a report from a Chartered Professional Geotechnical Engineer confirming whether

a. The building is not dangerous and is safe to occupy or

b. The remedial work required to ensure the building is not dangerous for occupation. This should include preliminary methodology and timeline for the work to be completed.

2. The premise will not be occupied until Council has reviewed the report and confirmed that the building is safe for occupation.

The geotechnical risk associated with the dwelling is discussed throughout the report and recommendations are provided in section 7.0.

2.2 Current Situation

We understand HCC is in frequent communication with the landowner to understand their desired remedial solution which is required to lift the Dangerous Building Notice. At the time of reporting HCC have advised that the landowners are not intending to complete remedial works on the slip (email dated 7 November 2022). Nonetheless, any solution implemented by the owners of 60 Holborn Drive will likely have a direct impact on the risk to road users and HCC assets. Any private remedial works are expected to take at least 6-12 months to complete.

We understand that a permanent lane closure for an extended period of time is unacceptable to HCC due to the high road usage and pressure from the community. The road is classed as a major 'arterial' route by One Network Road Classification with an average annual daily traffic count of ~15,450 and ~16,600 for the southbound and northbound carriageways respectively. The road provides the main point of access to the suburbs of Holborn and Stokes Valley to the southeast.

3.0 Ground Conditions and Failure Mechanisms

The slope is approximately 25 m high and situated within both public and private property. The slip occurred on the evening of 21 July 2022 during a period of prolonged rainfall in the Wellington Region.

Following the initial slip and throughout the temporary works AECOM engineers completed site visit to monitor the slope and record site observations which were subsequently provided to HCC via email. These observations were made from Eastern Hutt Road, the property of 60 Holborn Drive, drone photography and an abseil inspection.

A cross section is presented in Appendix A outlining the inferred ground conditions at the site.

3.1 Upper Slope

The upper ~10-15 m of the slope has been partially scaled and forms a ~60 degree slope with local undulations. This portion of the slope typically comprises of loosened/dilated rock (highly weathered greywacke) and colluvium as shown in Figure 2. Throughout the abseil inspection on 13 October 2022 ongoing fretting of the slope was observed and the lateral extents of the slip appear to have increased slightly due to the regression of the scarp (particularly evident towards No. 58 Holborn Drive). Debris is deposited on top of the containers at the slope toe and by the median barriers indicating rockfall is still making its way into the carriageway (Figure 3). The slope remains unvegetated due to the instability and no retaining or erosion control measures are currently in place.

Figure 2 Dilated rock mass and loose colluvium ravelling from the upper reaches of the slope

Figure 3 Debris accumulation on the containers

Further regression of the slope is anticipated to occur if left untreated as a result of stress-relief, heavy and/or prolonged rainfall and seismic shaking. Regression of the upper slope may occur progressively or suddenly with little to no warning (no survey monitoring in place and dwelling uninhabited). Regression of the slip would hinder the ability for vegetation to re-establish and potentially undermine the building foundations. Progressive or localised failures will reduce the distance of the slip to the dwelling foundations and likely increase the building's vulnerability with time. Furthermore, in accordance with the Intergovernmental Panel on Climate Change Assessment Report 6 New Zealand is expected to experience more extreme weather events more often.

3.2 Lower Slope

The lower ~10m of the slope has shown little to no signs of instability and currently forms a ~70 degree slope. Although obscured by debris, this portion of the slope typically comprises of moderately weathered (or better) greywacke rock.

Failure through this rock mass would likely to be governed by persistent and adversely orientated defects during an extreme event.

3.3 Other Observations

Highly to moderately weathered rock outcrops beneath a portion of the house indicating the building to be founded on both soil and rock. The property slopes gently to the west. Tension cracks are evident along the western perimeter of the building and up to ~200 mm of subsidence was identified, as presented in Figure 4. Although this subsidence appears to be gradual and independent of the instability along Eastern Hutt Road, it provides further evidence that the soil in the vicinity of the dwelling may be marginally stable.

Figure 4 Left: Tension cracks along the western perimeter of the building. Right: ~200 mm of subsidence

4.0 Risk Assessments

4.1 Existing Risk Assessments

4.1.1 Initial AECOM Risk Assessment

Initial risk assessments carried out by AECOM have utilised the agreed risk matrix which is based on Appendix G of Australasian Geomechanics Society (2000) Landslide Risk Management Concepts and Guidelines. These risk assessments have considered the holistic risk associated with the site (i.e. both private and public asset impacts). The assessments consider both adverse weather and seismic shaking events in accordance with the New Zealand Building Act and Standards. These assessments were completed following the initial slip, and again during the temporary/emergency works.

4.1.2 Tonkin & Taylor Risk Assessment (Imminent Risk)

The Tonkin & Taylor Ltd (2022) risk assessment only considers risk to private property and was prepared for [redacted] to inform the EQC settlement claim. The assessment considers the 'imminent risk' to the private property based on a 12 months of normal rainfall conditions as a direct result of the slip. The assessment does not consider seismic shaking events. The outcome of the assessment is outlined below:

"The dwelling has not been damaged and is not considered to be at imminent risk as a direct result of the natural disaster (landslip) that has occurred.

There is a risk of landslips on adjacent slopes due to future storm or earthquake events. However, this risk is not considered imminent (under normal annual rainfall conditions) within the next 12 months as a direct result of the natural disaster (landslip) that has occurred. We recommend that the property owners seek further advice and engage a geotechnical specialist to assess the stability risk of the adjacent slopes and implement remedial work if required."

4.2 Risk Re-assessment

We have undertaken a detailed risk assessment using New South Wales Government Roads and Maritime Services (RMS) 'Guide to Slope Risk Analysis' (Version 4, April 2014). This risk assessment considers the risk to road users by considering the following:

- Static and seismic loading
- Anticipated type of slope failure and size of debris
- Likelihood of material dislodging impacting the dwelling and entering the road corridor
- Temporal probability of road users being present at the time of the failure
- Vulnerability of the vehicles

The resilience risk associated with the dwelling of 60 Holborn Drive has been assessed using the HCC standard risk matrix. Two risk assessments for the dwelling have been carried out:

- One considers both adverse weather and seismic shaking events in accordance with the New Zealand Building Act and Standards for an IL2 structure with a 50-year design life
- The other considers 'imminent risk' as discussed in section 4.1.2 and defined in subpart 6 clause 121 of the Building Act

The risk assessment associated with the current condition and remedial options discussed below is presented in section 6.0. Select risk assessments associated with the instability at 60 Holborn Drive are provided in Appendix B.

5.0 Remedial Solutions

We acknowledge that discussions with the owners of 60 Holborn Drive are ongoing and a long-term permanent lane closure is unacceptable to HCC. In turn, we have outlined possible interim and long-term solutions which eliminates the need for containers across the toe of the slip.

Prior to implementing interim or long-term remedial works beneath 60 Holborn Drive, HCC should consider the risk at neighbouring slips and the remedial works programme to minimise cost implications and impact to road users. We note that in isolation the removal of containers beneath 60 Holborn Drive may provide little relief to traffic congestion if the carriageway is constrained to one lane nearby.

5.1 Interim Remedial Works (i.e. ~6-12 months)

Interim remedial solutions are expected to provide some resilience to the slope and reduce the risk to road users to an acceptable level that allows the removal of containers. This may provide enough time to enable private remedial works to be designed and/or constructed which could provide HCC with an opportunity to coordinate remedial works for the lower reaches of the slope.

Interim remedial solutions are not likely to meet Building Act 2004 requirements and should be monitored.

5.1.1 Pinned Erosion Control Matting

Pinned erosion control matting such as MacMat R, Greenax or a similar approved product would be applied across the entire extent of the slip. This option would protect the slope from further erosion and saturation of exposed soils. Once installed, hydroseeding the treated area would encourage vegetation growth and help bind surficial soils together.

The erosion control matting would be secured using anchors and expected to be ~2-3 m long. Anchors would be installed ~3 m behind the crest and at the toe of the slope at regular spacings (2-3 m). Intermittent anchors and wire rope may be required to adequately secure the mesh to the slip face and anchor heads. The position of crestal and intermittent slope anchors should consider the likely position of any permanent retaining wall works that may be completed by the owners of 60 Holborn Drive.

Anchors at the toe could be replaced with roadside concrete barriers to prevent runout of soil instabilities which may occur beneath the mesh, however, anticipated to impact lane widths. Localised instabilities are anticipated to occur beneath the mesh; however, debris will be secured to the slope by the mesh and debris runout minimised by anchors at the slope toe.

On its own, reliance on vegetation to stabilise the slope cannot be guaranteed to meet a ≥50 year design life. This option does not serve to actively retain the private property above.

This arrangement would mitigate the need for containers at the toe of the slope and may be incorporated into permanent works.

An example of pinned erosion control matting is provided in Figure 5.

Figure 5 Example of pinned erosion control matting

5.2 Long-term Remedial Works (i.e. ≥50 years)

All long-term remedial options will need to consider the impact and tie-in with the private remedial works undertaken along the upper reaches of the slope. In the instance remedial encroach into private property, written approval from the landowners should be sought (e.g. anchored solutions).

Long-term remedial solutions can be designed to withstand ultimate limit state events based on their importance and design life. Permanent solutions are likely to require geotechnical and/or structural Producer Statements in order to meet building consent requirements. Producer Statements can be provided by suitably qualified chartered engineers.

5.2.1 Anchored Shotcrete

This option would require the removal of vegetation and scaling of loose material from the slope across the slip site. Anchors would be installed across the slope at regular spacings (typically 1.5-2.5 m) and be bonded into rock. Prior to shotcreting reinforcement would be installed to match the slope profile and distribute loads. The anchored slope can be designed to actively retain the soil and loosened rock mass providing long-term resilience.

Ideally all vegetation would be stripped from the site beneath the shotcrete, however, cutting and treatment of the tree stumps and exposed roots can be tolerated. With sufficient treatment of vegetation, anchors and reinforced concrete this solution can meet a ≥50 year design life. This option would be designed to actively retain the soil slope and private property above.

An example of anchored shotcrete is provided in Figure 6.

Figure 6 Example of anchored shotcrete

5.2.2 Re-profiling and Benching the Existing Slope

This option would involve extensive vegetation clearance, excavating the cut slope to a shallower angle and use of localised stabilisation measures such as high tensile mesh, anchors and shotcrete. The option would involve extensive earthworks and require private property acquisition. Due to the height of the slope multiple benches are likely required to minimise the consequence of rockfall and meet stability requirements. Sub-horizontal drains are likely to be required to manage porewater pressures and extend on the order of 15-20 m into the slope. Detailed geotechnical investigations would be required prior to design and likely to comprise of machine drill holes, downhole televiewer recordings and mapping. Excavations would be completed using a top-down approach and likely to be staged to enable geological mapping and stabilisation (as required) throughout construction.

The return period for the design ultimate limit state events should be agreed prior to design, however, in general expected to have a 50-100 year design life. Localised instabilities and rockfall is expected to occur throughout the design life and require maintenance. The residual risks need to be considered and managed throughout the design, construction and maintenance phases.

This solution is unlikely to be suitable for short extents due to the need to tie-in to the existing slope profile at either end. We believe this solution would be better suited to a larger Eastern Hutt Road slope remedial works solution and likely to be a high-cost remedial solution. Due to the height of the slope it is anticipated private property will need to be procurement and potentially demolition of some dwellings (such as 60 Holborn Drive).

An example of re-profiling and benching of an existing slope is provided in Figure 7.

Figure 7 Example of re-profiling and benching

5.2.3 Proprietary Catch Fence

This remedial option would involve installing a ≥2.0 m high catch fence having a capacity of ≥100 kJ along the toe of the existing slope and extend the full length of the instability. The catch fence will be proprietary systems provided by Geobrugg/Macafferri (or similar) and comprise of regularly spaced galvanised steel posts that are anchored into competent rock with high tensile mesh spanning between posts. The fence would prevent the runout of rock, and to a lesser extent soil, from entering the carriageway. The proprietary system/s are typically manufactured overseas and would be shipped to New Zealand (approx. 8–12-week lead time).

Additional upslope slope stabilisation work (e.g. erosion control matting) may be required to minimise the likelihood of soil instability which would otherwise runout into the road. Runout of failed soils would occur due to the mesh having an aperture size on the order of 65-85 mm. Alternative barriers systems could be explored, however would require consultation with supplier to confirm its suitability

If a proprietary system is utilised, this option can be designed for a 50-year design life. Ongoing maintenance is expected to be required. This option does not serve to retain the private property above.

An example of a roadside catch fence is provided in Figure 8.

Figure 8 Example of a roadside catch fence

6.0 Residual Risk

A summary of the current and residual risk associated with each remedial option is presented in Table 1. The safety risk is largely associated with debris/rock hitting a passing car and assessed using New South Wales Government Roads and Maritime Services 'Guide to Slope Risk Analysis' (Version 4, April 2014). The resilience risk associated with the dwelling of 60 Holborn Drive has been assessed using the HCC standard risk matrix.

An indicative cost is provided for each option to assist HCC in evaluating each option. A detailed cost estimate can be provided for each option upon request.

Table 1 Risk assessment summary

Event	Current Condition		Pinned Erosion Control Matting	Anchored Shotcrete	Re-profiling and Benching	Catch Fence
	With Containers[1]	Without Containers[2]				
Surficial or localised failures	ARL5	ARL2	ARL4	ARL5	ARL5	ARL2-ARL3
Localised kinematic failure of the rock mass	ARL3	ARL1	ARL2	ARL3[3]	ARL4	ARL3
Global instability of the slope	ARL3	ARL3	ARL3	ARL3 to ARL4	ARL3 to ARL4	ARL3
Residual risk to 60 Holborn Drive dwelling	High	High	High	Low	N/A[4]	High
Imminent risk to dwelling (i.e. excluding earthquake)	High	High	High	Low		High
Indicative cost	N/A (current situation)	Very Low	Low	High	Very High	Moderate
Impact on dwelling	None		Little to none. Anchors/pins would be ~3 m below foundation level and positioned to avoid existing infrastructure.		Very high. Dwelling likely to be demolished as a result of the works.	None

Notes: 1) Assumes a posted speed of 30km/h due to the presence of containers and temporary traffic management
2) Assumes a posted speed of 80km/h (posted speed limit of Eastern Hutt Road)
3) Assumes loosened rock will be scaled, treated with mesh or encapsulated within the shotcrete extent
4) Solution l kely to involve demolition of the dwelling

6.1 Tolerable Risk

6.1.1 Road User Safety

The RMS risk assessment provides an 'assessed risk level' (ARL) rating, and when considering road user safety, considered a more robust risk assessment compared those previously used. An ARL threshold of 3 has been adopted by Waka Kotahi as a minimum standard for both NCTIR and Mt Messenger Bypass. This threshold has been adopted for other projects in the Wellington Region such as the Ngaio Gorge Stabilisation project which AECOM is also involved in.

A minimum residual ARL of 3 or greater is recommended.

6.1.2 Risk to Dwelling

Based on AS/NZS1170.0 a new build would be considered an importance level 2 structure with a design life of 50 years. The associated return period for a seismic event would be 500 years and corresponds to a peak ground acceleration of 0.68g (NZGS/MBIE Module 1 Appendix A). A 'disastrous' consequence would require the likelihood of failure to be 'rare', or 'unlikely' as a minimum.

Based on the adopted risk matrix we recommend a minimum risk threshold of moderate is adopted.

7.0 Recommendations

7.1 Dangerous Building Notice

A structural inspection was completed by AECOM engineers on 13 October 2022 and personnel were accompanied by an HCC representative. The landowner, [redacted] was also present during the inspection. A structural report outlining the findings of the inspection has been provided to HCC for review. The structural assessment concludes that the dwelling remains structurally sound in its current condition, however, does not account for further regression of the slip or undermining of the foundations. The risk of further instability or regression is discussed throughout this report.

Based on the current and residual risk associated with the dwelling at 60 Holborn Drive it is recommended the Dangerous Building Notice remains in place until slope remediation measures are implemented. It is our opinion that the building would be safe to occupy following slope remedial works when the risk is equal to or lower than moderate.

7.2 Recommended Remedial Solution

Based on the assessed risk, cost of proposed remedial options and the current situation it is recommended that an anchored shotcrete wall is installed, as described in section 5.2.1. If constructed the residual risk to road users and dwelling of 60 Holborn Drive would likely be reduced to an acceptable level.

The risk assessments associated with the current condition of the slope and anchored shotcrete wall are presented in Appendix B.

Regardless of the solution implemented it is recommended:

- Fall protection is erected along the crest of the slope to address the fall from height risk
- Temporary loading from machinery and equipment is considered by the temporary works designer/contractor
- The condition of the slope is monitored throughout the construction period
- Containers remain in place and their effectiveness at mitigating runout of debris is monitored

Prior to the removal of the containers (following wall construction), the residual risk should be re-assessed to confirm the objectives have been met.

8.0 Limitations

AECOM has prepared this report for the sole use of Hutt City Council and for a specific purpose, each as expressly stated in the report. No other party should rely on this report without the prior written consent of AECOM. AECOM undertakes no duty, nor accepts any responsibility, to any third party who may rely upon or use this report. This report has been prepared based on the Client's description of its requirements and AECOM's experience, having regard to assumptions that AECOM can reasonably be expected to make in accordance with sound professional principles. AECOM's findings represent its reasonable judgment within the time and budget context of its commission and utilising the information available to it at the time.

No section or element of this report may be removed, reproduced, electronically stored or transmitted in any form by parties other than those for whom the report has been prepared without the written permission of AECOM. All sections in this report must be viewed in the context of the entire report/document including, without limitation, any assumptions made and disclaimers provided. No section in this report may be excised from the body of the report without AECOM's prior written consent.

The recommendations and opinions contained within this inspection report are based on visual geotechnical appraisal and engineering judgment. Inferences about ground conditions across the site are made according to desktop studies, site observations, standard geological principles, and engineering judgment. Therefore, it is not possible to guarantee the ground conditions due to the absence of site-specific investigations. Information provided within the appendices is based on the initial site visit and experience with similar projects.

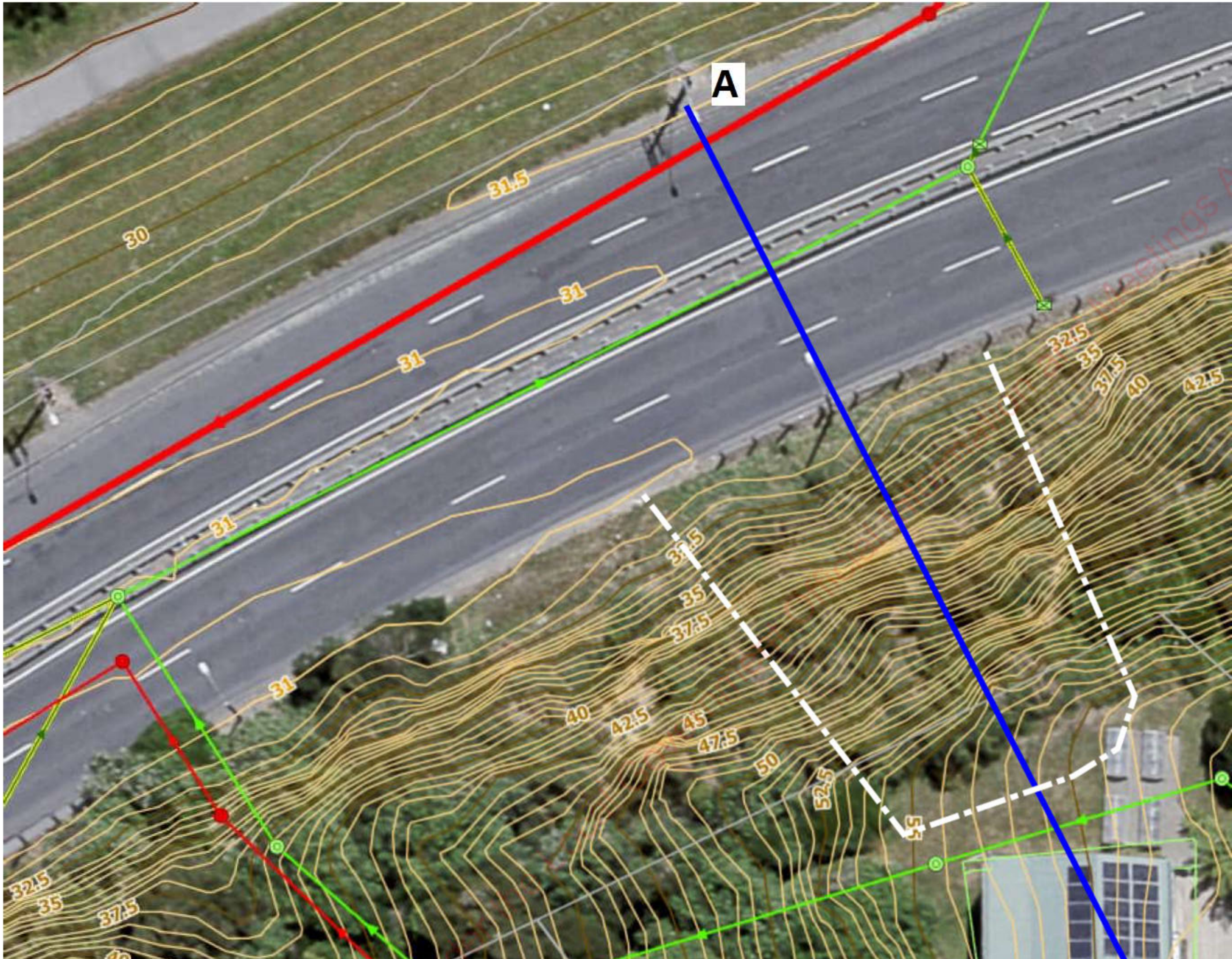
It is considered to be in the best interests of all parties that AECOM is retained to undertake this work. In any event, we should be notified if ground conditions encountered on site differ from those described in this report. Cost estimates have been undertaken to the best of our knowledge, given the restrictions and limits placed on us, and the lack of detailed data available.

AECOM has prepared this report using the standard of reasonable skill, care and diligence required of a consultant performing the same or similar Services. The report should be read in full. No warranty, expressed or implied, is made as to the professional advice included in this report. This report does not alleviate the need for any party to complete their own due diligence.

Appendix A

Inferred Ground Conditions

APPENDIX A - 60 HOLBORN DRIVE SITE LOCATION



APPENDIX A - 60 HOLBORN DRIVE CROSS SE

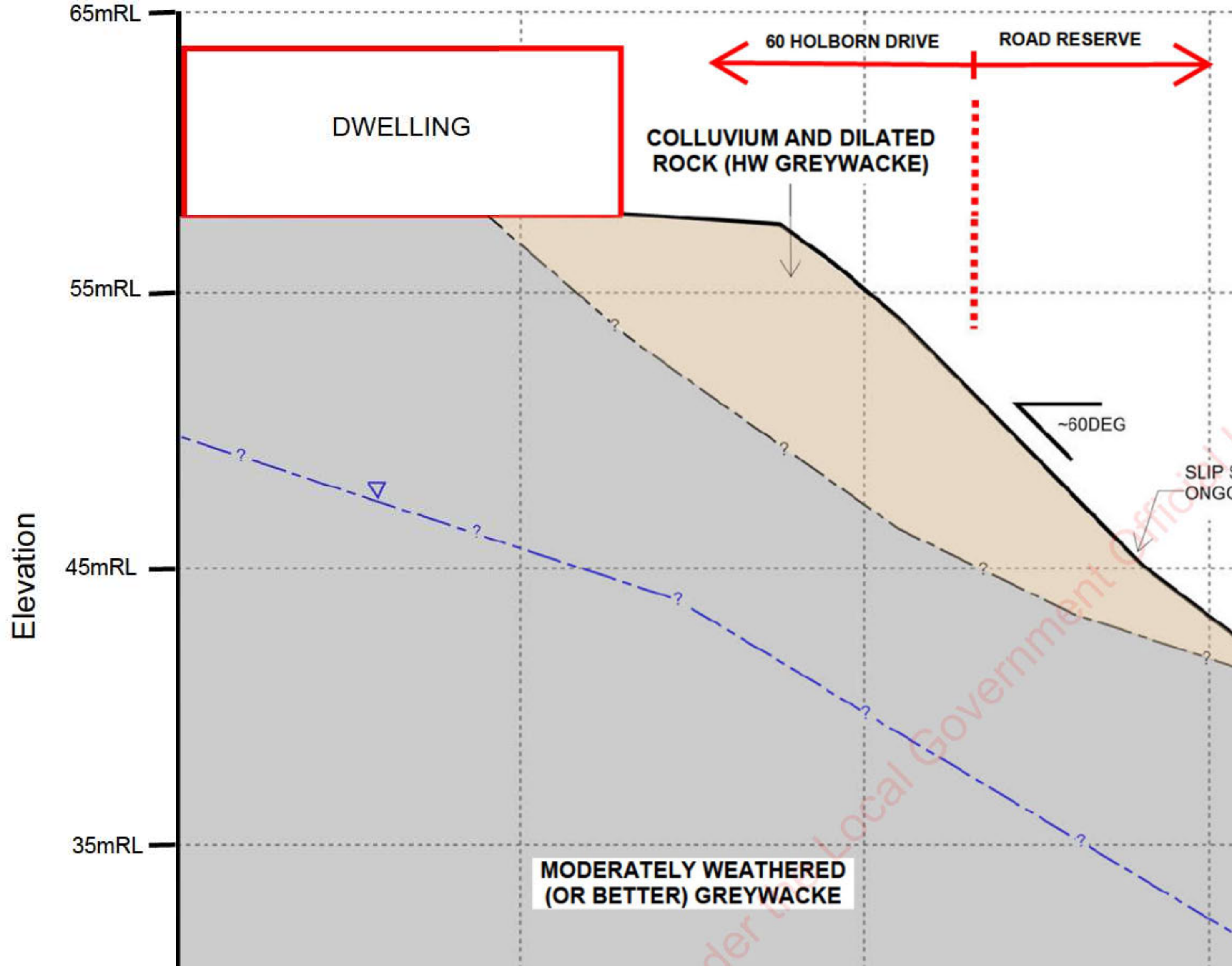
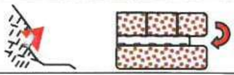
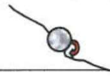
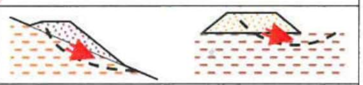
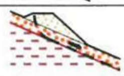
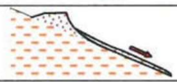
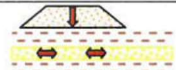
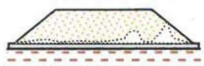
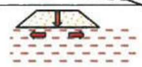
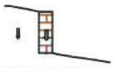
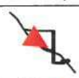


FIGURE 1: PROXIMITY OF THE SLIP TO 60 HOLB

Appendix B

Select Risk Assessments

Common hazard types			
Mechanism	**Typical Circumstances**	**Description**	**Schematic Illustration(s)**
Fall	Steep rock batters	Prior to failure the block is supported at the top and/or rear surfaces and fails in tension., In practice, includes other initial failure types where the travel path is relatively long and the debris can go into trajectory over part of the distance.	
Topple	Columnar or tabular blocks resting on defects dipping out of the face	Prior to failure the block is supported on its basal surface and rotates about its front lower edge or an axis on the basal surface. Includes cases of undercutting where the debris cannot go into trajectory.	
Slide – rotational	In soils or some weak or highly fractured rock masses	Common in cohesive soils. Rupture surface may or may not be circular.	
Boulder roll	Steep soil batters containing boulders	Approximately equidimensional boulders released by erosion or other mechanism which will roll down the slope rather than go into trajectory.	
Slide - translational	Plane and wedge failures in rock	Almost always controlled by discontinuities or material interfaces.	
Spread	Lateral movement of blocks in a massive, jointed rock unit (most commonly sedimentary)	Requires deformation or failure of underlying material or shear at interface.	
Flow	Most commonly in soil slopes with high moisture content or substantial water inflows	Requires high moisture content in cohesive materials. Can also happen in dry cohesionless materials.	
Complex	Combination of above types, usually in different parts of the failed mass	Most common is a combination of rotational and translational.	
Rotational, within embankment	Any, but requires water source	Typically shallow to part width. Can be close to full width on steep side slopes.	
Rotational, through foundations	Soft soils, side slopes with deeper soils.	In soft soils usually during or shortly after construction, but can be delayed if soils have a stiffer crust which can soften when it wets up.	
Translational	Side slopes, especially when steep	Can be on interface with underlying materials at fill base, within underlying soils or at or within underlying rock. Normally on an interface, or defect controlled if in rock. Would normally affect the full width of the fill.	
Collapse	Loose granular fills, especially on side slopes	Requires fill to be very loose and close to saturation. Almost complete loss of shear strength on minor shearing. Only in end-dumped or sidecast fills. Highly mobile.	
Liquefaction	Confined loose sands in foundations, below water table	Earthquake or (possibly) vibration trigger. Often applied (incorrectly) to collapse of quick clays. Most often in natural materials, insitu. Could not happen within an engineered fill.	
Internal erosion	Dispersive or erodible soils, in fills or underlying materials. Most commonly in culvert backfills.	Forms internal voids which may collapse abruptly.	
Reactivation of pre-existing landslide	Fill on side slope, not necessarily steep	Due to loading of head or adverse effects on drainage.	
Spreading of foundations	Soft soils	Blurry distinction between this and rotational failure through foundations, except there won't be a visible scarp. Can be very difficult to distinguish from settlement without prolonged and careful observation.	
Overturning	Thin gravity structures, inadequate design.	Full or part height. Most common mode of failure under live loading.	
Sliding	Gravity structures	Insufficient shear resistance at base. Not common in properly designed structures, unless passive resistance at the toe is removed eg by excavation.	
Bearing	Gravity walls	Not common in modern structures.	
Global foundation failure	Gravity structures.	Weak foundation materials or adverse defects in rock	
Settlement	Gravity structures	Compressible foundations. May have been allowed for in design. Can lead to tilting of wall and damage to any supported structures.	
Shear failure through backfill ('bulging')	Flexible or brittle walls (eg drystone, RSW, gabions)	Common failure mode in flexible structures. May manifest as overturning in thin, rigid structures.	
Bending	Cantilevered pile walls with insufficient strength.	Can only occur in structures with substantial tensile strength.	
Toe breakout	Cantilevered pile walls usually on steep slopes	Insufficient embedment, inadequate rock strength.	
Anchor pullout	Anchored pile walls	Inadequate anchor strength, damage to anchors or loss of surrounding ground.	

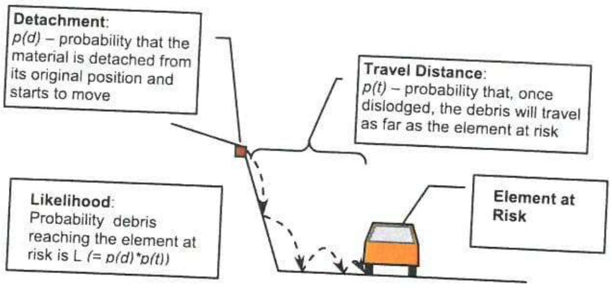


Figure 6. Detachment and Travel Distance Probabilities

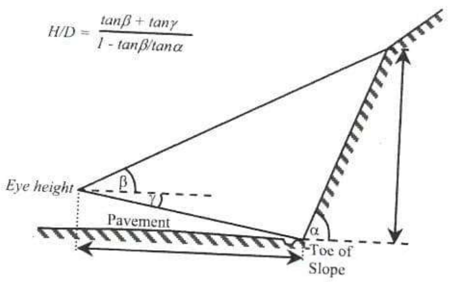


Figure 4. Height Estimation by Triangulation

Table 7. Criteria for allocation of detachment probability

P(d)	Current Slope Condition	Evidence for Previous Failures	Progress of Evolving Mechanisms	Possible Triggering Event
1	A potential mechanism is apparent. Either failure appears imminent or there is evidence that the detachment mechanism is currently active.	The slope may show evidence of earlier repeated failures of the same type.	Failure could be initiated by a very small further progression of the mechanism relative to that which has already occurred.	Failure could be initiated by a triggering event with a short return period (eg 1 year storm).
0.1 (1 x 10^{-1})	A potential mechanism is apparent and either is active or could easily be activated but failure does not appear imminent. There may be evidence of past distress.	Slopes which have been in existence for some time (ie in the order of decades) may show evidence of occasional previous failures.	Failure could be expected within a few years to a few decades if the mechanism continues to develop at its current rate	Failure could be triggered by a fairly common event (eg 10 year storm).
0.01 (1 x 10^{-2})	A potential mechanism is apparent, but failure does not appear imminent There may be evidence of past distress.	Slopes which have been in existence for many years (ie usually more than 30 years) *may* show evidence of an earlier failure	The progress of the mechanism is evident, but would require substantial development relative to that which has already occurred before failure would be initiated.	Triggering could be expected to require a severe event (eg 1 in 100 year storm).
0.001 (1 x 10^{-3})	The potential mechanism can be identified but failure does not appear imminent	Constructed slopes show no evidence of previous failures of the same type. There may be evidence of old failures on natural slopes.	The existence of the mechanism is evident, but would require very substantial development relative to that which has already occurred before failure would be initiated, or failure would require a substantial acceleration of the progress of the mechanism.	Failure would require an unusually severe triggering event
0.0001 (1 x 10^{-4})	The potential mechanism can be deduced from slope features or geological considerations	Comparable slopes in the same area may show evidence of previous failures of the same type	Where processes are ancient their age may be used to infer (loosely) their probability of recurrence eg landslides formed at around the end of the last ice age (about 10 – 12,000 years ago)	Failure would require an extreme triggering event
0.00001 (1 x 10^{-5}) and smaller	The potential mechanism can be deduced from slope features or geological considerations	Some comparable slopes in the same area may show evidence of rare previous failures of the same type	The mechanism may only be deduced from long term slope evolution considerations	Failure would require the most extreme of triggering events eg probable maximum flood or maximum credible event

Table 8. Factors affecting potential for failure under live loading

Factor	Considerations
Wall Type	Masonry walls, particularly when unmortared ('drystone'), are prone to brittle failure under load. Walls of this type were commonly used to retain road embankments in the 19th and early 20th centuries and were still being constructed in some areas until about 1960.
Foundations	Foundation materials and design (if any) will constrain the types of mechanism which are possible.
Original condition of wall	Construction standard and geometry of structure. Drystone walls were built to a number of patterns. The most common in smaller walls was with front and rear faces parallel and with a height:thickness ratio of 6:1, subject to a minimum thickness of about 400 mm. Original batter angles would normally have been no steeper than about 80° (1:6).
Current condition of wall	Evidence for the presence of one or more distress modes (see tables and diagrams). The factor of safety against overturning of drystone walls decreases rapidly as the batter angle increases above 80° and may be close to 1 where the wall is near vertical, even without considering live loading.
Condition of retained material	Cracking or subsidence in the pavement or shoulder may indicate the existence of an active or dormant failure mechanism. Evidence of past movement may be disguised by resurfacing or pavement rehabilitation
Extent of development of potential or actual failure mechanisms	Based on a synthesis of the above factors. Consider the degree of development of the mechanism relative to that needed for failure to occur.
Potential live load location	The potential for failure under live loading depends critically on the location of the load. Consider the location of the outer wheelpath relative to the wall crest, constraints on traffic (eg edge lines, visual or physical barriers, road geometry in relation to the possible position of heavy vehicles), local circumstances which may cause traffic to divert towards the wall under normal operating conditions (eg narrow pavement and poor sight distance). Normally the edge line (or edge of the seal if no edge line is present) would be considered the limit of potential live load locations.

Table 9. Likelihood allocation for retaining wall failure under live loading

Wall condition	Live load distance from toe of wall		
	< H/2	**H/2 - H**	**> H**
Significant or major distress evident, apparently active	L1	L2	L3
Significant or major distress evident, not apparently active	L2	L3	L4
Minor distress evident, apparently active	L3	L4	L5
Minor distress evident, not apparently active or poorly constructed wall	L4	L5	L6
Apparently well-constructed wall, no visible distress	L5	L6	L6

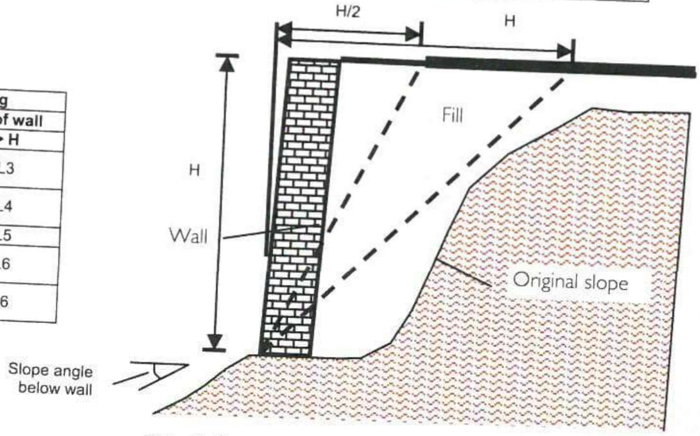
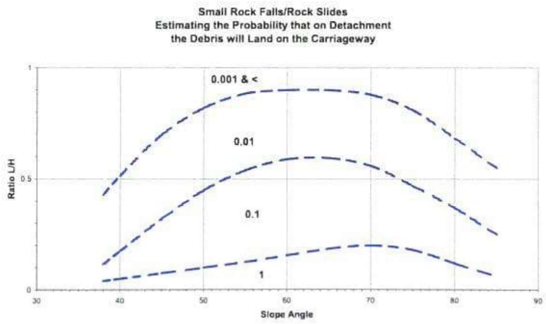


Figure 7. Parameters for Live Loading of Retaining Structures



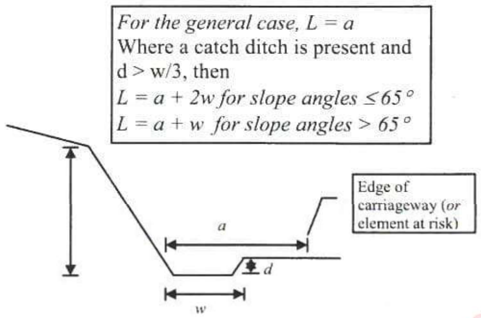


Figure 8. Estimating Travel Distance Probability for Small Rock Falls/Slides Figure 9. Definition of Parameters for Figure 8

Table 11. Temporal probability rating definitions

Rating	Probability Range	Definition
T1	> 0.5	Person usually expected to be present as part of the normal pattern of usage (eg residential buildings, some commercial buildings). Road users in the heaviest of urban traffic conditions.
T2	0.1 – 0.5	Person often expected to be present as part of the normal pattern of usage (eg many commercial buildings). Road users on major urban arterial roads and the most heavily trafficked rural roads.
T3	0.01 – 0.1	Person may sometimes be present as part of the normal pattern of usage. Road users on many urban arterial roads and most major rural arterial roads
T4	0.001 – 0.01	Person unlikely to be present even where there is a pattern of usage. Road users on suburban roads and minor rural arterial roads
T5	< 0.001	Person is very unlikely to be present. Road users on the most lightly trafficked roads, road shoulders etc.

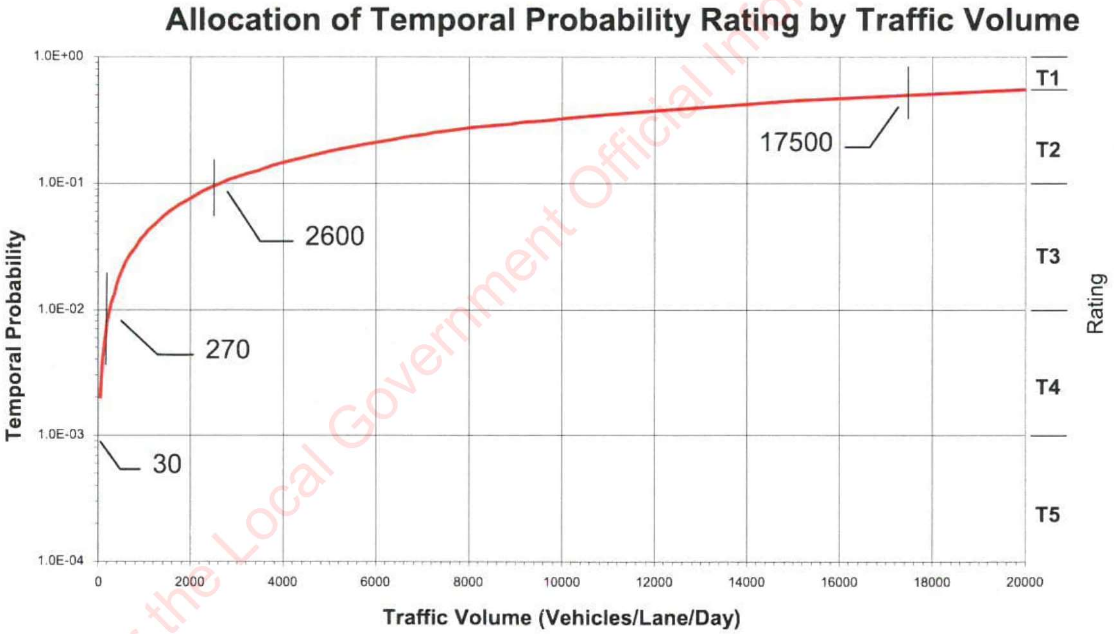


Table 13. Modification of T for direct impact by rockfall

Case	T Rating				
Debris lodging on the road (from Guide Figure 6)	T5	T4	T3	T2	T1
Modified T for debris directly impacting vehicle	T5	T5	T4	T3	T3

Table 14. Modification of T for direct impact by large scale failures

Modification to T	Length of Failure Traversed at Posted Speed Limit		
	≤ 50 km/h	60 – 90 km/h	100 – 110 km/h
Decrease T (eg T3 ⇒ T4)	< 15 m	< 25 m	< 60 m
T unchanged	15 – 100 m	25 – 250 m	60 – 600 m
Increase T (eg T3 ⇒ T2)	> 100 m	> 250 m	> 600 m

Table 17. Expanded vulnerability table

Vulnerability Rating	People in the Open	People in Buildings	Vehicle Occupants		
			Vehicle Impact with Individual Rock Blocks	**Vehicle Impact with Mixed Landslide Debris**	**Vehicle Crossing Embankment Failure Area**
V1	Unable to evade rockfall or other debris (movement very/extremely rapid), or buried	Engulfed in building collapse	Block > 1 m high at highway speeds		Lost into a deep, narrow void
V2	May be able to evade debris	Partial building collapse	Block > 1 m high at urban speeds Block 0.5 – 1 m high at highway speeds		Lost into a shallow void
V3	Most people able to evade debris	Building penetrated, no collapse	Block >1 m high at low speeds Block 0.5 – 1 m high at urban speeds	Loose or wet mixed soil/rock debris at highway speeds	Stepped surface with 0.1 – 0.2 m steps at highway speeds
V4		Building struck, damaged but not penetrated	Block 0.5 – 1 m high at low speeds Block around 0.2 m high at highway speeds	Loose or wet mixed soil/rock debris at urban speeds	Stepped surface with 0.1 – 0.2 m steps at urban speeds Shallow void/depression where guardfence may prevent a vehicle from leaving the road
V5		Building struck, only minor damage etc	Block around 0.2 m high at urban speeds Smaller block at highway speeds	Loose or wet mixed soil/rock debris at low speeds Irregular surface formed by soil or small (<100mm minimum dimension) rock at highway speeds	Stepped surface with 0.1 – 0.2 m steps at low speeds Irregular surface formed by a developing embankment failure at highway speeds

Table 18. Extended vulnerability table - Vehicles impacting single rock blocks

Block Size	Posted Speed Limit		
	Highway Speeds (100 – 110 km/h)	**Urban Speeds (60 – 80 km/h)**	**Low Speeds (≤ 50 km/h)**
Minimum dimension >1 m	V1	V2	V3
Minimum dimension 0.5 – 1 m	V2	V3	V4
Minimum dimension 0.2 – 0.5 m	V3	V4	V5
Minimum dimension ≈ 0.2 m	V4	V5	V5*
Minimum dimension ≈ 0.1 m	V5	V5*	V5*

Table 19. Extended Vulnerability Table - Vehicles impacting mixed landslide debris

Debris Type	Posted Speed Limit		
	Highway Speeds (100 – 110 km/h)	**Urban Speeds (60 – 80 km/h)**	**Low Speeds (≤ 50 km/h)**
Loose or wet mixed soil/rock debris	V3	V4	V5
Small rock debris (min dim < 0.1 m)	V5	V5*	V5*

Table 20. Extended vulnerability table - Vehicles impacting voids or stepped surfaces

Void or Surface Type	Posted Speed Limit		
	Highway Speeds (100 – 110 km/h)	**Urban Speeds (60 – 80 km/h)**	**Low Speeds (≤ 50 km/h)**
Deep, narrow void	V1	V2	V3
Shallow void (0.2 – 0.5 m step)	V2	V3	V4
Stepped surface (0.1 – 0.2 m steps)	V3	V4	V5
Irregular surface (steps < 0.1 m)	V5	V5*	V5*
Shallow void with guardfence or wire rope barrier	V4	V4	V4

Table 21. Resultant velocity (m/s) by fall height and traffic speed

Traffic speed m/s (km/h)	Fall Height (m)									
	5	**10**	**15**	**20**	**25**	**30**	**40**	**50**	**75**	**100**
0 (0)	9.9	14.0	17.2	19.8	22.1	24.3	28.0	31.3	38.4	44.3
13.9 (50)	17.1	19.7	22.1	24.2	26.1	27.9	31.3	34.3	40.8	46.4
16.7 (60)	19.4	21.8	23.9	25.9	27.7	29.4	32.6	35.5	41.8	47.3
19.4 (70)	21.8	24.0	25.9	27.8	29.5	31.1	34.1	36.9	43.0	48.4
22.2 (80)	24.3	26.3	28.1	29.8	31.4	32.9	35.8	38.4	44.3	49.6
25.0 (90)	26.9	28.7	30.3	31.9	33.4	34.8	37.6	40.1	45.8	50.9
27.8 (100)	29.5	31.1	32.7	34.1	35.5	36.9	39.5	41.9	47.4	52.3
30.6 (110)	32.1	33.6	35.0	36.4	37.7	39.0	41.5	43.8	49.0	53.8

Table 22. Vulnerability allocation for vehicle directly impacted by single rock blocks			
Block Size	**Resultant Velocity**		
	> 25 m/s	**15 – 25 m/s**	**< 15 m/s**
Minimum Dimension >1 m	V1	V1	V1
Minimum Dimension 0..5 – 1 m	V1	V1	V2
Minimum Dimension 0.2 – 0.5 m	V1	V2	V3
Minimum Dimension 0.1 – 0.2 m	V2	V3	V3
Minimum Dimension < 0.1 m	V3	V4	V4

Table 24. Vulnerability allocation for retaining wall failure under live loading (road users)					
Slope angle below wall	**Wall height**				
	< 1 m	**1 – 2 m**	**2 – 3 m**	**3 – 4 m**	**> 4 m**
> 35°	V2	V2?	V1	V1	V1
25° - 35°	V3	V2	V2	V1	V1
15° - 25°	V4	V3	V2	V1	V1
<15°	V5	V4	V3	V2	V1

Table 26. Consequence ratings for property damage and consequential effects	
Rating	**Indicative Criteria**
C1	Total direct and indirect costs > $15 million: • Total closure of a Sub-Network Rank 5 or 6 (SN5-SN6) road for an extended period or very high disruption cost (other than road users) • Major infrastructure or property damage (other than road • Very high repair cost
C2	Total direct and indirect costs > $3 million < $15 million: • Total closure of one carriageway of an SN5-6 road or total closure of an SN3–SN4 road for an extended period or large disruption costs • Substantial infrastructure or property damage • High repair cost
C3	Total direct and indirect costs > $0.8 million < $3 million: • Partial or total closure of an SN3-SN4 road for a short period, longer period if reasonable alternatives are available or moderate disruption costs • Moderate infrastructure or property damage • Moderate repair cost
C4	Total direct and indirect costs > $0.2 million < $0.8 million: • Partial or total closure of an SN2 road for a short period or minor disruption costs • Minor infrastructure or property damage • Low repair cost
C5	Total direct and indirect costs < $0.2 million: • Partial or total closure of an SN1 road for a short period or little or no disruption costs • Negligible infrastructure or property damage • Very low – no repair cost

	Table 25. Consequence matrix for risk to life				
	Temporal Probability of an Individual Being Present at the Time of Failure				
Vulnerability	**T5**	**T4**	**T3**	**T2**	**T1**
V1	C4	C3	C2	C1	C1
V2	C4	C3	C2	C1	C1
V3	C5	C4	C3	C2	C2
V4	C5	C5	C4	C3	C3
V5	C5	C5	C5	C4	C4

	Table 27. Assessed risk level matrix				
	Consequence Class				
Likelihood	**C5**	**C4**	**C3**	**C2**	**C1**
L1	ARL3	ARL2	ARL1	ARL1	ARL1
L2	ARL4	ARL3	ARL2	ARL1	ARL1
L3	ARL5	ARL4	ARL3	ARL2	ARL1
L4	ARL5	ARL5	ARL4	ARL3	ARL2
L5	ARL5	ARL5	ARL5	ARL4	ARL3
L6	ARL5	ARL5	ARL5	ARL5	ARL4

Meanings Attached to the Term 'Road Closure'.

Total closure

This means that the road is closed to traffic in both directions and all traffic has to take an alternate route.

Partial closure

This means that the road is closed to traffic in one direction and either:

- the traffic in one direction has to take an alternate route, or
- the traffic in both directions has to be controlled to allow alternating one-way flows. This may require the construction of earthworks and temporary pavements (for instance, to cross the median in dual carriageway roads or to allow traffic to use the road shoulder for an extended period).

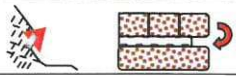
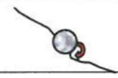
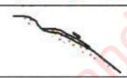
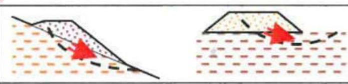
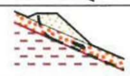
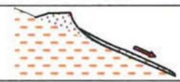
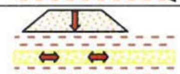
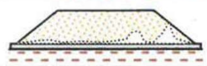
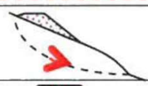
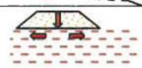
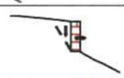
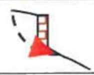
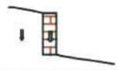
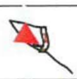
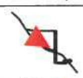
Supplementary Ratings

Table 28. Scale of failure (S) ratings		
Rating	**Volume of Failure**	**Individual Block Size**
S1	Volume > 20,000 m^3 (eg. 40 m wide x 60 m long x 10 m deep = 24,000 m^3)	Individual blocks of > 1m minimum dimension (eg one rock 1 x 1 x 2 m)
S2	Volume > 2,000 m^3	Individual blocks of 0.5 – 1 m minimum dimension
S3	Volume > 200 m^3	Individual blocks of 0.2 - 0.5 m minimum dimension
S4	Volume > 20 m^3	Individual blocks of about 0.2 m minimum dimension
S5	Volume < 20 m^3	Individual blocks of about 0.1 m minimum dimension

Table 29. Velocity of failure (R) ratings			
Rating	**Description**	**Velocity (mm/sec)**	**Typical Velocity**
R1	Extremely Rapid		
		5×10^3	5 m/sec
	Very Rapid		
		5×10^1	3 m/min
R2	Rapid		
		5 x 10-1	1.8 m/h
R3	Moderate		
		5×10^{-3}	13 m/month
R4	Slow		
		5×10^{-5}	1.6 m/year
R5	Very Slow		
		5×10^{-7}	16 mm/year
	Extremely Slow		

		Table 30. Event magnitude classification matrix				
		Scale of Failure				
Velocity of Failure		**S5**	**S4**	**S3**	**S2**	**S1**
Fast	**R1**	M3	M2	M2	M1	M1
⇕	**R2**	M4	M3	M2	M2	M1
	R3	M4	M4	M3	M2	M2
	R4	M5	M4	M4	M3	M2
Slow	**R5**	M5	M5	M4	M4	M3

	Table 31. Hazard classification matrix				
	Event Magnitude				
Likelihood	**M5**	**M4**	**M3**	**M2**	**M1**
L1	H3	H2	H2	H1	H1
L2	H4	H3	H2	H2	H1
L3	H4	H4	H3	H2	H2
L4	H5	H4	H4	H3	H2
L5	H5	H5	H4	H4	H3
L6	H5	H5	H5	H4	H4

Common hazard types			
Mechanism	**Typical Circumstances**	**Description**	**Schematic Illustration(s)**
Fall	Steep rock batters	Prior to failure the block is supported at the top and/or rear surfaces and fails in tension., In practice, includes other initial failure types where the travel path is relatively long and the debris can go into trajectory over part of the distance.	
Topple	Columnar or tabular blocks resting on defects dipping out of the face	Prior to failure the block is supported on its basal surface and rotates about its front lower edge or an axis on the basal surface. Includes cases of undercutting where the debris cannot go into trajectory.	
Slide – rotational	In soils or some weak or highly fractured rock masses	Common in cohesive soils. Rupture surface may or may not be circular.	
Boulder roll	Steep soil batters containing boulders	Approximately equidimensional boulders released by erosion or other mechanism which will roll down the slope rather than go into trajectory.	
Slide - translational	Plane and wedge failures in rock	Almost always controlled by discontinuities or material interfaces.	
Spread	Lateral movement of blocks in a massive, jointed rock unit (most commonly sedimentary)	Requires deformation or failure of underlying material or shear at interface.	
Flow	Most commonly in soil slopes with high moisture content or substantial water inflows	Requires high moisture content in cohesive materials. Can also happen in dry cohesionless materials.	
Complex	Combination of above types, usually in different parts of the failed mass	Most common is a combination of rotational and translational.	
Rotational, within embankment	Any, but requires water source	Typically shallow to part width. Can be close to full width on steep side slopes.	
Rotational, through foundations	Soft soils, side slopes with deeper soils.	In soft soils usually during or shortly after construction, but can be delayed if soils have a stiffer crust which can soften when it wets up.	
Translational	Side slopes, especially when steep	Can be on interface with underlying materials at fill base, within underlying soils or at or within underlying rock. Normally on an interface, or defect controlled if in rock. Would normally affect the full width of the fill.	
Collapse	Loose granular fills, especially on side slopes	Requires fill to be very loose and close to saturation. Almost complete loss of shear strength on minor shearing. Only in end-dumped or sidecast fills. Highly mobile.	
Liquefaction	Confined loose sands in foundations, below water table	Earthquake or (possibly) vibration trigger. Often applied (incorrectly) to collapse of quick clays. Most often in natural materials, insitu. Could not happen within an engineered fill.	
Internal erosion	Dispersive or erodible soils, in fills or underlying materials. Most commonly in culvert backfills.	Forms internal voids which may collapse abruptly.	
Reactivation of pre-existing landslide	Fill on side slope, not necessarily steep	Due to loading of head or adverse effects on drainage.	
Spreading of foundations	Soft soils	Blurry distinction between this and rotational failure through foundations, except there won't be a visible scarp. Can be very difficult to distinguish from settlement without prolonged and careful observation.	
Overturning	Thin gravity structures, inadequate design.	Full or part height. Most common mode of failure under live loading.	
Sliding	Gravity structures	Insufficient shear resistance at base. Not common in properly designed structures, unless passive resistance at the toe is removed eg by excavation.	
Bearing	Gravity walls	Not common in modern structures.	
Global foundation failure	Gravity structures.	Weak foundation materials or adverse defects in rock	
Settlement	Gravity structures	Compressible foundations. May have been allowed for in design. Can lead to tilting of wall and damage to any supported structures.	
Shear failure through backfill ('bulging')	Flexible or brittle walls (eg drystone, RSW, gabions)	Common failure mode in flexible structures. May manifest as overturning in thin, rigid structures.	
Bending	Cantilevered pile walls with insufficient strength.	Can only occur in structures with substantial tensile strength.	
Toe breakout	Cantilevered pile walls usually on steep slopes	Insufficient embedment, inadequate rock strength.	
Anchor pullout	Anchored pile walls	Inadequate anchor strength, damage to anchors or loss of surrounding ground.	

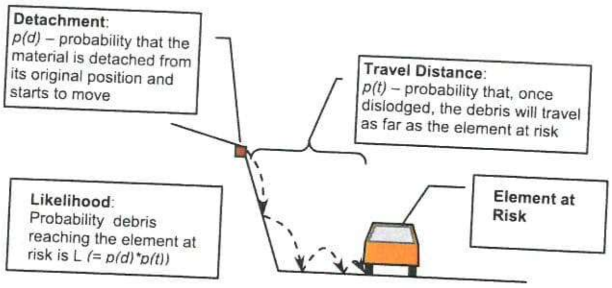


Figure 6. Detachment and Travel Distance Probabilities

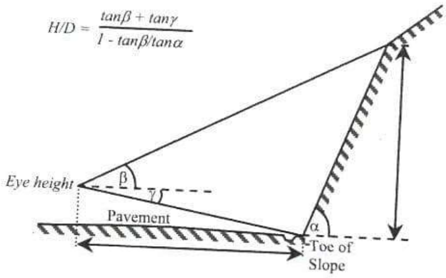


Figure 4. Height Estimation by Triangulation

Table 7. Criteria for allocation of detachment probability

P(d)	Current Slope Condition	Evidence for Previous Failures	Progress of Evolving Mechanisms	Possible Triggering Event
1	A potential mechanism is apparent. Either failure appears imminent or there is evidence that the detachment mechanism is currently active.	The slope may show evidence of earlier repeated failures of the same type.	Failure could be initiated by a very small further progression of the mechanism relative to that which has already occurred.	Failure could be initiated by a triggering event with a short return period (eg 1 year storm).
0.1 (1×10^{-1})	A potential mechanism is apparent and either is active or could easily be activated but failure does not appear imminent. There may be evidence of past distress.	Slopes which have been in existence for some time (ie in the order of decades) may show evidence of occasional previous failures.	Failure could be expected within a few years to a few decades if the mechanism continues to develop at its current rate	Failure could be triggered by a fairly common event (eg 10 year storm).
0.01 (1×10^{-2})	A potential mechanism is apparent, but failure does not appear imminent There may be evidence of past distress.	Slopes which have been in existence for many years (ie usually more than 30 years) *may* show evidence of an earlier failure	The progress of the mechanism is evident, but would require substantial development relative to that which has already occurred before failure would be initiated.	Triggering could be expected to require a severe event (eg 1 in 100 year storm).
0.001 (1×10^{-3})	The potential mechanism can be identified but failure does not appear imminent	Constructed slopes show no evidence of previous failures of the same type. There may be evidence of old failures on natural slopes.	The existence of the mechanism is evident, but would require very substantial development relative to that which has already occurred before failure would be initiated, or failure would require a substantial acceleration of the progress of the mechanism.	Failure would require an unusually severe triggering event
0.0001 (1×10^{-4})	The potential mechanism can be deduced from slope features or geological considerations	Comparable slopes in the same area may show evidence of previous failures of the same type	Where processes are ancient their age may be used to infer (loosely) their probability of recurrence eg landslides formed at around the end of the last ice age (about 10 – 12,000 years ago)	Failure would require an extreme triggering event
0.00001 (1×10^{-5}) and smaller	The potential mechanism can be deduced from slope features or geological considerations	Some comparable slopes in the same area may show evidence of rare previous failures of the same type	The mechanism may only be deduced from long term slope evolution considerations	Failure would require the most extreme of triggering events eg probable maximum flood or maximum credible event

Table 8. Factors affecting potential for failure under live loading

Factor	Considerations
Wall Type	Masonry walls, particularly when unmortared ('drystone'), are prone to brittle failure under load. Walls of this type were commonly used to retain road embankments in the 19th and early 20th centuries and were still being constructed in some areas until about 1960.
Foundations	Foundation materials and design (if any) will constrain the types of mechanism which are possible.
Original condition of wall	Construction standard and geometry of structure. Drystone walls were built to a number of patterns. The most common in smaller walls was with front and rear faces parallel and with a height:thickness ratio of 6:1, subject to a minimum thickness of about 400 mm. Original batter angles would normally have been no steeper than about 80° (1:6).
Current condition of wall	Evidence for the presence of one or more distress modes (see tables and diagrams). The factor of safety against overturning of drystone walls decreases rapidly as the batter angle increases above 80° and may be close to 1 where the wall is near vertical, even without considering live loading.
Condition of retained material	Cracking or subsidence in the pavement or shoulder may indicate the existence of an active or dormant failure mechanism. Evidence of past movement may be disguised by resurfacing or pavement rehabilitation
Extent of development of potential or actual failure mechanisms	Based on a synthesis of the above factors. Consider the degree of development of the mechanism relative to that needed for failure to occur.
Potential live load location	The potential for failure under live loading depends critically on the location of the load. Consider the location of the outer wheelpath relative to the wall crest, constraints on traffic (eg edge lines, visual or physical barriers, road geometry in relation to the possible position of heavy vehicles), local circumstances which may cause traffic to divert towards the wall under normal operating conditions (eg narrow pavement and poor sight distance). Normally the edge line (or edge of the seal if no edge line is present) would be considered the limit of potential live load locations.

Table 9. Likelihood allocation for retaining wall failure under live loading

Wall condition	Live load distance from toe of wall		
	< H/2	H/2 - H	> H
Significant or major distress evident, apparently active	L1	L2	L3
Significant or major distress evident, not apparently active	L2	L3	L4
Minor distress evident, apparently active	L3	L4	L5
Minor distress evident, not apparently active or poorly constructed wall	L4	L5	L6
Apparently well-constructed wall, no visible distress	L5	L6	L6

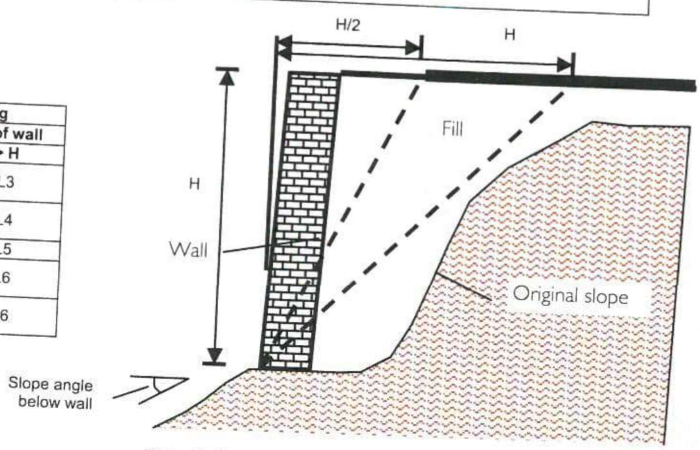
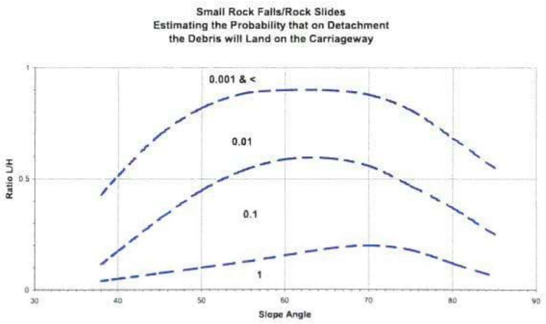


Figure 7. Parameters for Live Loading of Retaining Structures



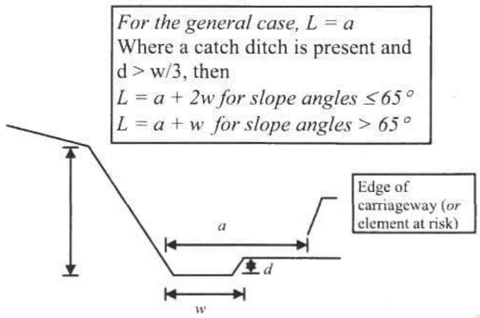


Figure 8. Estimating Travel Distance Probability for Small Rock Falls/Slides Figure 9. Definition of Parameters for Figure 8

Table 11. Temporal probability rating definitions		
Rating	**Probability Range**	**Definition**
T1	> 0.5	Person usually expected to be present as part of the normal pattern of usage (eg residential buildings, some commercial buildings). Road users in the heaviest of urban traffic conditions.
T2	0.1 – 0.5	Person often expected to be present as part of the normal pattern of usage (eg many commercial buildings). Road users on major urban arterial roads and the most heavily trafficked rural roads.
T3	0.01 – 0.1	Person may sometimes be present as part of the normal pattern of usage. Road users on many urban arterial roads and most major rural arterial roads
T4	0.001 – 0.01	Person unlikely to be present even where there is a pattern of usage. Road users on suburban roads and minor rural arterial roads
T5	< 0.001	Person is very unlikely to be present. Road users on the most lightly trafficked roads, road shoulders etc.

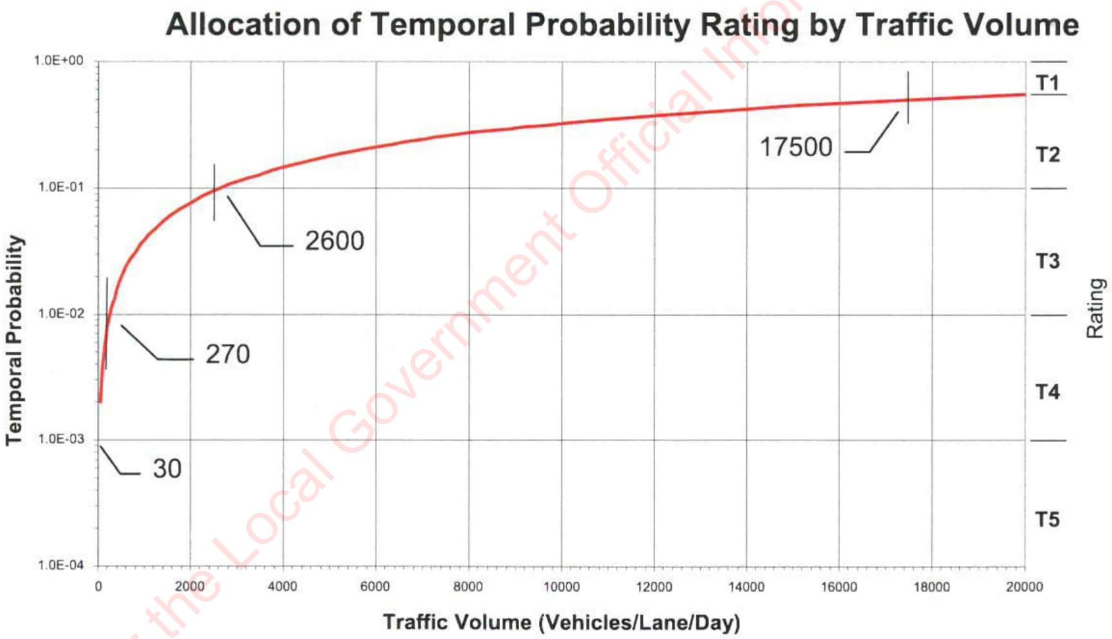


Table 13. Modification of T for direct impact by rockfall					
Case	**T Rating**				
Debris lodging on the road (from Guide Figure 6)	T5	T4	T3	T2	T1
Modified T for debris directly impacting vehicle	T5	T5	T4	T3	T3

Table 14. Modification of T for direct impact by large scale failures			
Modification to T	**Length of Failure Traversed at Posted Speed Limit**		
	≤ 50 km/h	**60 – 90 km/h**	**100 – 110 km/h**
Decrease T (eg T3 ⇒ T4)	< 15 m	< 25 m	< 60 m
T unchanged	15 – 100 m	25 – 250 m	60 – 600 m
Increase T (eg T3 ⇒ T2)	> 100 m	> 250 m	> 600 m

Table 17. Expanded vulnerability table

Vulnerability Rating	People in the Open	People in Buildings	Vehicle Occupants		
			Vehicle Impact with Individual Rock Blocks	Vehicle Impact with Mixed Landslide Debris	Vehicle Crossing Embankment Failure Area
V1	Unable to evade rockfall or other debris (movement very/extremely rapid), or buried	Engulfed in building collapse	Block > 1 m high at highway speeds		Lost into a deep, narrow void
V2	May be able to evade debris	Partial building collapse	Block > 1 m high at urban speeds Block 0.5 – 1 m high at highway speeds		Lost into a shallow void
V3	Most people able to evade debris	Building penetrated, no collapse	Block >1 m high at low speeds Block 0.5 – 1 m high at urban speeds	Loose or wet mixed soil/rock debris at highway speeds	Stepped surface with 0.1 – 0.2 m steps at highway speeds
V4		Building struck, damaged but not penetrated	Block 0.5 – 1 m high at low speeds Block around 0.2 m high at highway speeds	Loose or wet mixed soil/rock debris at urban speeds	Stepped surface with 0.1 – 0.2 m steps at urban speeds Shallow void/depression where guardfence may prevent a vehicle from leaving the road
V5		Building struck, only minor damage etc	Block around 0.2 m high at urban speeds Smaller block at highway speeds	Loose or wet mixed soil/rock debris at low speeds Irregular surface formed by soil or small (<100mm minimum dimension) rock at highway speeds	Stepped surface with 0.1 – 0.2 m steps at low speeds Irregular surface formed by a developing embankment failure at highway speeds

Table 18. Extended vulnerability table - Vehicles impacting single rock blocks

Block Size	Posted Speed Limit		
	Highway Speeds (100 – 110 km/h)	Urban Speeds (60 – 80 km/h)	Low Speeds (≤ 50 km/h)
Minimum dimension >1 m	V1	V2	V3
Minimum dimension 0.5 – 1 m	V2	V3	V4
Minimum dimension 0.2 – 0.5 m	V3	V4	V5
Minimum dimension ≈ 0.2 m	V4	V5	V5*
Minimum dimension ≈ 0.1 m	V5	V5*	V5*

Table 19. Extended Vulnerability Table - Vehicles impacting mixed landslide debris

Debris Type	Posted Speed Limit		
	Highway Speeds (100 – 110 km/h)	Urban Speeds (60 – 80 km/h)	Low Speeds (≤ 50 km/h)
Loose or wet mixed soil/rock debris	V3	V4	V5
Small rock debris (min dim < 0.1 m)	V5	V5*	V5*

Table 20. Extended vulnerability table - Vehicles impacting voids or stepped surfaces

Void or Surface Type	Posted Speed Limit		
	Highway Speeds (100 – 110 km/h)	Urban Speeds (60 – 80 km/h)	Low Speeds (≤ 50 km/h)
Deep, narrow void	V1	V2	V3
Shallow void (0.2 – 0.5 m step)	V2	V3	V4
Stepped surface (0.1 – 0.2 m steps)	V3	V4	V5
Irregular surface (steps < 0.1 m)	V5	V5*	V5*
Shallow void with guardfence or wire rope barrier	V4	V4	V4

Table 21. Resultant velocity (m/s) by fall height and traffic speed

Traffic speed m/s (km/h)	Fall Height (m)									
	5	10	15	20	25	30	40	50	75	100
0 (0)	9.9	14.0	17.2	19.8	22.1	24.3	28.0	31.3	38.4	44.3
13.9 (50)	17.1	19.7	22.1	24.2	26.1	27.9	31.3	34.3	40.8	46.4
16.7 (60)	19.4	21.8	23.9	25.9	27.7	29.4	32.6	35.5	41.8	47.3
19.4 (70)	21.8	24.0	25.9	27.8	29.5	31.1	34.1	36.9	43.0	48.4
22.2 (80)	24.3	26.3	28.1	29.8	31.4	32.9	35.8	38.4	44.3	49.6
25.0 (90)	26.9	28.7	30.3	31.9	33.4	34.8	37.6	40.1	45.8	50.9
27.8 (100)	29.5	31.1	32.7	34.1	35.5	36.9	39.5	41.9	47.4	52.3
30.6 (110)	32.1	33.6	35.0	36.4	37.7	39.0	41.5	43.8	49.0	53.8

Table 22. Vulnerability allocation for vehicle directly impacted by single rock blocks			
Block Size	Resultant Velocity		
	> 25 m/s	15 – 25 m/s	< 15 m/s
Minimum Dimension >1 m	V1	V1	V1
Minimum Dimension 0..5 – 1 m	V1	V1	V2
Minimum Dimension 0.2 – 0.5 m	V1	V2	V3
Minimum Dimension 0.1 – 0.2 m	V2	V3	V3
Minimum Dimension < 0.1 m	V3	V4	V4

Table 24. Vulnerability allocation for retaining wall failure under live loading (road users)					
Slope angle below wall	Wall height				
	< 1 m	1 – 2 m	2 – 3 m	3 – 4 m	> 4 m
> 35°	V2	V2?	V1	V1	V1
25° - 35°	V3	V2	V2	V1	V1
15° - 25°	V4	V3	V2	V1	V1
<15°	V5	V4	V3	V2	V1

Table 26. Consequence ratings for property damage and consequential effects	
Rating	Indicative Criteria
C1	Total direct and indirect costs > $15 million: • Total closure of a Sub-Network Rank 5 or 6 (SN5-SN6) road for an extended period or very high disruption cost (other than road users) • Major infrastructure or property damage (other than road • Very high repair cost
C2	Total direct and indirect costs > $3 million < $15 million: • Total closure of one carriageway of an SN5-6 road or total closure of an SN3–SN4 road for an extended period or large disruption costs • Substantial infrastructure or property damage • High repair cost
C3	Total direct and indirect costs > $0.8 million < $3 million: • Partial or total closure of an SN3-SN4 road for a short period, longer period if reasonable alternatives are available or moderate disruption costs • Moderate infrastructure or property damage • Moderate repair cost
C4	Total direct and indirect costs > $0.2 million < $0.8 million: • Partial or total closure of an SN2 road for a short period or minor disruption costs • Minor infrastructure or property damage • Low repair cost
C5	Total direct and indirect costs < $0.2 million: • Partial or total closure of an SN1 road for a short period or little or no disruption costs • Negligible infrastructure or property damage • Very low – no repair cost

	Table 25. Consequence matrix for risk to life				
	Temporal Probability of an Individual Being Present at the Time of Failure				
Vulnerability	T5	T4	T3	T2	T1
V1	C4	C3	C2	C1	C1
V2	C4	C3	C2	C1	C1
V3	C5	C4	C3	C2	C2
V4	C5	C5	C4	C3	C3
V5	C5	C5	C5	C4	C4

	Table 27. Assessed risk level matrix				
	Consequence Class				
Likelihood	C5	C4	C3	C2	C1
L1	ARL3	ARL2	ARL1	ARL1	ARL1
L2	ARL4	ARL3	ARL2	ARL1	ARL1
L3	ARL5	ARL4	ARL3	ARL2	ARL1
L4	ARL5	ARL5	ARL4	ARL3	ARL2
L5	ARL5	ARL5	ARL5	ARL4	ARL3
L6	ARL5	ARL5	ARL5	ARL5	ARL4

Meanings Attached to the Term 'Road Closure'.

Total closure

This means that the road is closed to traffic in both directions and all traffic has to take an alternate route.

Partial closure

This means that the road is closed to traffic in one direction and either:

- the traffic in one direction has to take an alternate route, or
- the traffic in both directions has to be controlled to allow alternating one-way flows. This may require the construction of earthworks and temporary pavements (for instance, to cross the median in dual carriageway roads or to allow traffic to use the road shoulder for an extended period).

Supplementary Ratings

Table 28. Scale of failure (S) ratings		
Rating	Volume of Failure	Individual Block Size
S1	Volume > 20,000 m^3 (eg. 40 m wide x 60 m long x 10 m deep = 24,000 m^3)	Individual blocks of > 1m minimum dimension (eg one rock 1 x 1 x 2 m)
S2	Volume > 2,000 m^3	Individual blocks of 0.5 – 1 m minimum dimension
S3	Volume > 200 m^3	Individual blocks of 0.2 - 0.5 m minimum dimension
S4	Volume > 20 m^3	Individual blocks of about 0.2 m minimum dimension
S5	Volume < 20 m^3	Individual blocks of about 0.1 m minimum dimension

Table 29. Velocity of failure (R) ratings			
Rating	Description	Velocity (mm/sec)	Typical Velocity
R1	Extremely Rapid		
		5 x 10^3	5 m/sec
	Very Rapid		
		5 x 10^1	3 m/min
R2	Rapid		
		5 x 10-1	1.8 m/h
R3	Moderate		
		5 x 10^{-3}	13 m/month
R4	Slow		
		5 x 10^{-5}	1.6 m/year
R5	Very Slow		
		5 x 10^{-7}	16 mm/year
	Extremely Slow		

		Table 30. Event magnitude classification matrix				
		Scale of Failure				
Velocity of Failure		S5	S4	S3	S2	S1
Fast	R1	M3	M2	M2	M1	M1
⇕	R2	M4	M3	M2	M2	M1
	R3	M4	M4	M3	M2	M2
	R4	M5	M4	M4	M3	M2
Slow	R5	M5	M5	M4	M4	M3

	Table 31. Hazard classification matrix				
	Event Magnitude				
Likelihood	M5	M4	M3	M2	M1
L1	H3	H2	H2	H1	H1
L2	H4	H3	H2	H2	H1
L3	H4	H4	H3	H2	H2
L4	H5	H4	H4	H3	H2
L5	H5	H5	H4	H4	H3
L6	H5	H5	H5	H4	H4

AECOM HUTT CITY TE AWA KAIRANGI

Measures of Likelihood

Level	Descriptor	Description	Annual Probability of Occurrence	
A	Almost Certain	The event is on-going, or is expected to occur during the next year	100%	< 1 year
B	Very Likely	The event is expected to occur.	20% to 100%	1-5 years
C	Likely	The event is expected to occur under somewhat adverse conditions	5% to 20%	5-20 years
D	Possible	The event is expected to occur under adverse conditions	1 to 5%	20-100 years
E	Unlikely	The event is expected to occur under high to extreme conditions	0.2 to 1%	100-500years
F	Rare	The event could occur under extreme conditions	Less than 0.2%	>500 years

Measures of Consequence

Level	Descriptor	Example Descriptions (Damage to Private Property)	Example Descriptions (Damage to HCC Assets)
1	Catastrophic	Large scale damage to multiple properties	Arterial routes and lifelines blocked an extended length of time (several days) – significant effects to communities for extended periods
2	Disastrous	Large scale damage involving private property and dwellings requiring major engineering works for stabilisation	Both lanes of local road blocked/slipped for an extended length of time (several days); or arterial route blocked causing major and extended delays to traffic; major emergency works
3	Major	Extensive damage to property but dwelling not involved	Both lanes of local road temporarily blocked/slipped (few hours to a day) or one lane of arterial route blocked with major delays; significant emergency works
4	Medium	Moderate damage to private land	One lane of road blocked/slipped with some emergency works necessary *or* several metres of footpath destroyed; no alternative access available
5	Low	Limited damage to private land	Half of one lane of road blocked for a short period of time; emergency works limited to clean up only *or* footpath destroyed over several metres; alternative access is available
6	Minor	No damage	Shoulder of road damaged/blocked only; reinstatement works can be delayed *or* footpath locally undermined but still usable; reinstatement works can be delayed

Risk Matrix for Failure for further undermining

		Consequences to Property/Assets					
		1: Catastrophic	2: Disastrous	3: Major	4: Medium	5: Low	6: Minor
Likelihood	A – Almost Certain	VH	VH	VH	H	H	M
	B – Very L kely	VH	VH	H	H	M	L
	C – Likely	VH	H	H	M	L	L
	D – Possible	VH	H	M	L	VL-L	VL
	E – Unl kely	H	M	L	VL	VL	VL
	F –Rare	M	L	VL	VL	VL	VL

Risk Level Implications

Risk Level		Implications for Risk Management
VH	Very High Risk	Detailed investigation, design, planning, and implementation of treatment options to reduce risk to acceptable levels: May involve very high costs.
H	High Risk	Detailed investigation, design, planning, and implementation of treatment options to reduce risk to acceptable levels.
M	Moderate Risk	Broadly tolerable provided treatment plan is implemented to maintain or reduce risks. May require investigation and planning of treatment options.
L	Low Risk	Acceptable. Treatment requirements to be defined to maintain or reduce risk
VL	Very Low Risk	Acceptable. Manage by normal maintenance procedures

Notes:

1. The examples of consequence given should only be used as a general guide. The implications for a particular situation may be required to be specifically determined.
2. The risk matrices above are based on those given in Appendix G of AGS (2000): *Landslide Risk Management Concepts and Guidelines*

AECOM HUTT CITY

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	C – Likely	VH	H	H	M	L	L
	D – Possible	VH	H	M	L	VL-L	VL
	E – Unl kely	H	M	L	VL	VL	VL
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IRBA

GEOLOGICAL ENGINEERING CONSULTANTS

Slope stability assessment 60 Holborn Drive, Stokes Valley, Lower Hutt

February 2023

for s7(2)(a) [redacted]

Project Number 1541

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Contents

Introduction

Ian R Brown Associates Ltd (IRBA) were engaged by [redacted] to investigate and provide advice on the stability of the land at 60 Holborn Drive, Stokes Valley. The north-western part of the site has been affected by a landslide that occurred on 21 July, 2022. The landslide also involved the adjacent road reserve and impacted the Eastern Hutt Road below.

On 29 July, 2022, Hutt City Council issued the owners of 60 Holborn Drive with a Dangerous Building Notice, under sections 121 to 128A of the Building Act 2004. The Notice requires the owners to:

> *Submit a report from a Chartered Professional Geotechnical Engineer confirming whether.*
>
> *a. The building is not dangerous and is safe to occupy or*
> *b. The remedial work required to ensure the building is not dangerous for occupation. This should include preliminary methodology and timeline for the work to be completed.*

Prior to IRBA's involvement, two reports on the landslide have been prepared by other consultants. On 1 September, 2022, an engineering geologist from Tonkin & Taylor Ltd provided a report that informed [redacted] insurers, [redacted]

On 22 November, 2022, AECOM New Zealand Limited reported on the landslide for Hutt City Council. The November report followed two earlier reports AECOM New Zealand Limited provided for Hutt City Council in August 2022.

At some time following the July landslide, contractors working for Hutt City Council have carried out work on the landslide area. They have scaled loose soil and rock from the slope, cleared vegetation, re-contoured the head scarp, removed slumped soils, and removed an overhanging garden bed.

Geological setting

The site is located on a rock spur bounded to the north-west by the Hutt River. The active Wellington Fault runs parallel to the Hutt River towards its right bank, and both fault displacement and fluvial processes have contributed to the truncation of the rock spur. The rock exposed in the slope face is known as greywacke, a term used to describe slightly metamorphosed interbedded sandstones and siltstones that underlie much of the Wellington region (Begg and Johnston 2000).

It is apparent that the rock spur has been resistant to river action given the relatively constricted part of the Hutt Valley. Stability has also not been affected by strong ground shaking during either regional earthquakes, or earthquakes associated with the nearby Wellington Fault.

The truncated rock spur is shown on Figure 1. We have obtained the 2013 regional LiDAR data from Land Information New Zealand[1] and built a digital elevation model that shows the topography of the area before the landslide. The house at 60 Holborn Drive is shown on a gentle south facing slope that steepens away from the house towards an east west trending valley.

[1] https://www.linz.govt.nz/products-services/data/types-linz-data/elevation-data

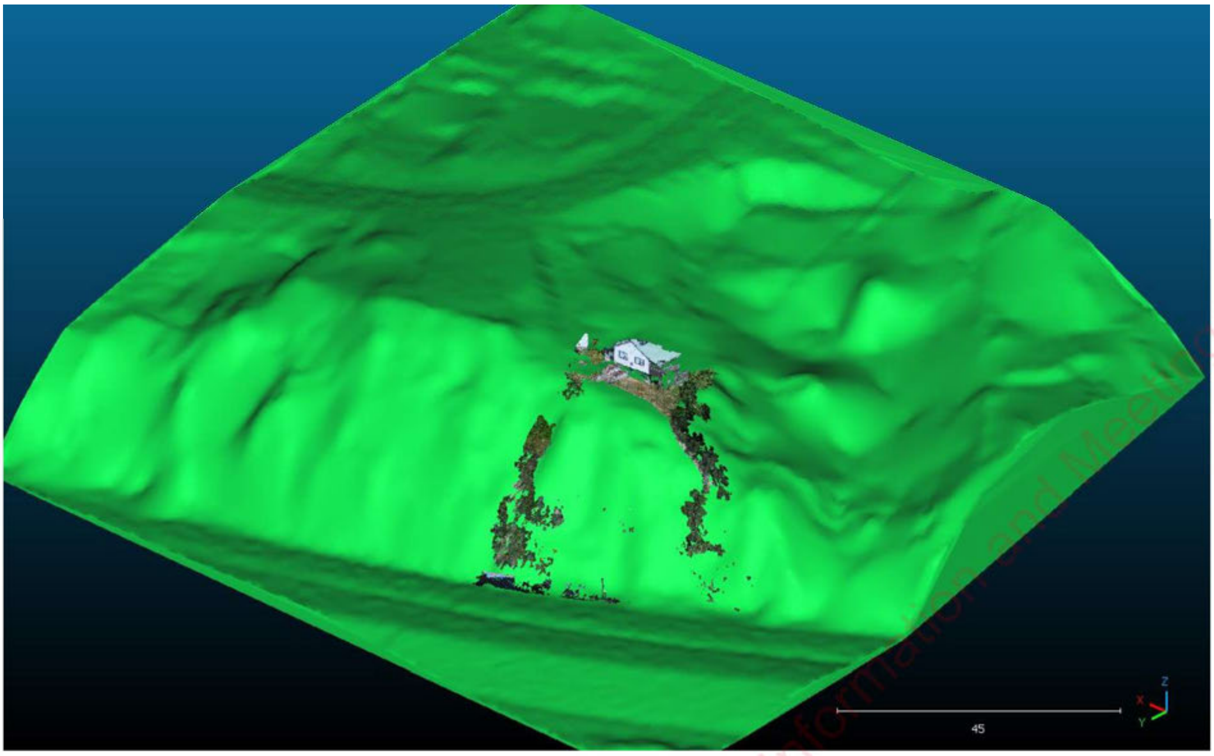


Figure 1 Perspective view, 2013 LiDAR data

Site investigations

On January 25, 2023, IRBA staff carried out a UAV flight over the landslide area, and captured vertical photographs that were processed using Pix4Dmapper[2] ortho photogrammetry software. One of the outputs from Pix4Dmapper is a point cloud, with accurately located points on the ground and other objects in the photographs. An overall view of the point cloud as projected in CloudCompare[3] is shown in Figure 2.

On February 6, IRBA staff inspected two shallow trenches that had been excavated using hand held implements. The trenches extended from near the edge of the landslide scarp to the line of the house foundations. The material exposed was fill; they did not show any evidence of discontinuities that might be expected if tension cracks had extended across the area.

We did note that there had been displacement of ground downslope from a manhole located below the garage at 60 Holborn Drive. The manhole is located at a change of direction of the stormwater pipe that runs from the street, down the driveway, then across the slope below the house.

IRBA staff visited the property during a period of relatively high intensity rainfall on February 14, 2023. The objective of the visit was to observe overland flow paths. The unsealed driveway from Holborn Drive had water flowing in each wheel track. This was intercepted by the surface drain at the garage door, and was discharged into the stormwater system. There were no obvious paths that surface water could follow that would discharge near the edge of the slope.

[2] https://www.pix4d.com/product/pix4dmapper-photogrammetry-software/
[3] CloudCompare documentation at https://www.cloudcompare.org/doc/wiki/index.php/Main_Page

Figure 2 Perspective view, point cloud

On February 17, 2023, IRBA staff used an iPhone 13 Pro Max to capture a detailed point cloud of the unsupported excavated slope behind the lower level of the house. The data were processed using the Scaniverse[4] application. These data were integrated into the CloudCompare model, as shown on Figure 3.

Figure 3 Point cloud - excavation for house foundations

[4] https://scaniverse.com/

Slope model

From inspection of the point cloud using our January 25 data, we can see a layer (c. 1m thick) of colluvial material at the top of the slope (Figure 4). Note the scale bar at the bottom right corner of the figure. There is also a thin veneer of fill above the colluvium probably resulting from earthworks, including stormwater drain construction, placed at the time of preparation for land subdivision.

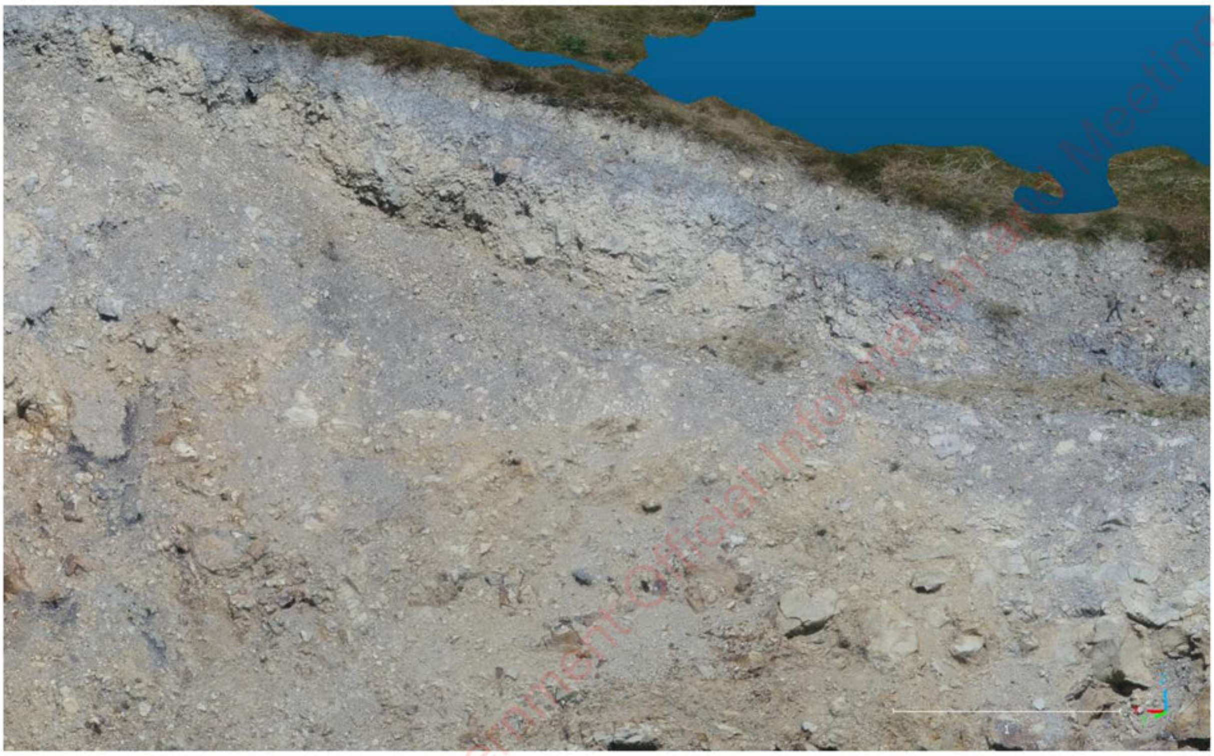


Figure 4 Colluvium exposed at top of slope

Figure 4 also shows *in situ* greywacke exposed in the lower right corner of the point cloud image. This provides evidence that *in situ* rock is present at a much higher level than had been assumed by both Tonkin and Taylor Ltd, and AECOM New Zealand Limited. However, they would not have had the benefit of observing the slope following scaling and clean up by Hutt City Council contractors.

A view of the rock exposed a little further down the slope (Figure 5) shows the structure of the exposed greywacke. This image overlaps with the bottom right area of Figure 1. We can see what appears to be bedding trending across the slope, and steeply dipping fractures (joints) that strike nearly normal to the slope. The rock mass can be described as blocky, with blocks formed by the intersection of joints and bedding.

The attitude of joints in the greywacke exposed below the house was measured using a clinometer. The major joint set is near parallel to the excavated slope, and has a mean resultant plane orientation of about 71° dip and 266° dip direction. This is consistent with the joint orientations shown in the point cloud of the landslide scarp (Figure 5).

The house foundations at 60 Holborn Drive are timber poles and timber piles 175mm and 150mm diameter. The main part of the house is located on a bench cut into the slope, hence the rock exposure shown in Figure 3. About midway along the length of the bench, there is a contact with overlying colluvium that dips to the south. The north half of the house is located on greywacke, and the southern half on colluvium.

Figure 5 Rock exposed in slope, below and adjacent to view in Figure 4

The slope model that applied at the time of the July 2022 landslide comprised a thin layer of colluvium and fill overlying a steeply dipping rock surface. The landslide coincided with a period of heavy rainfall that lead to high pore water pressures at the rock/colluvium interface. The resulting increase in effective stress then caused shear failure in the colluvium.

As discussed earlier, there is no obvious overland flow path around this part of the slope that would cause build-up of water in the slope, or lead to erosion. However, the trench containing the stormwater pipe could have acted as a conduit for water from much further up hill. We understand that it is unlikely the trench backfill would include water barriers, as are now standard practice. The trench is well located to contribute water into what was a vulnerable part of the slope.

The current slope model has been simplified by the removal of the low strength cover material following the July 2022 landslide. There is rock exposed to a high level on the slope, and behind the house, with only a thin veneer of colluvium and fill that does not extend to the house foundations.

Slope stability

To help our understanding of slope stability, both before and after the July 2022 landslide, we have prepared a digital 3D model using the point cloud data discussed earlier. The data were loaded into TSLOPE[5], a program for limit equilibrium slope stability analysis. The program can analyse slopes in both 2D (sections) and 3D.

The 3D model, and the results of analyses using TSLOPE are presented in Appendix 1. All the analyses we carried out used the Spencer method, as it provides full force and moment equilibrium in the solution.

The house foundations have been modelled to impose a vertical uniform load of 10kPa across the house footprint. This is a conservative approximation; if we had more detail information available we could model the foundations as point loads at each pile location, and also take into account the pile resistance to potential slope failure.

The TSLOPE model comprises two materials with the following properties:

Colluvium	Density 19 kN/m^3 Mohr Coulomb strength parameters; cohesion = 20 kPa angle of friction, Ø = 35°
Greywacke	Density 22 kN/m^3 Hoek-Brown failure criterion parameters: Intact compressive strength 5 MPa GSI 40 m_i 13 D 0.1

We have estimated these material properties based on our experience at similar sites in the Wellington region, including back analysis of failed slopes to derive Hoek-Brown parameters.

A 2D slope case was used to calibrate the July 2022 landslide. This is shown on Figure A3. We have modelled a high groundwater surface, 2m below the 2013 LiDAR derived topography. The calculated factor of safety was less than one, indicating that the slope was unstable.

The current slope model is shown in FigureA4. There is only a thin colluvium cover near the crest of the slope, and the loading from the house is shown on greywacke. There is no groundwater included in the analysis. A 2D search for a critical failure surface is shown, and the factor of safety calculated at 1.83. The critical failure surface does not extend far enough into the slope to intersect the house foundations.

The same slope as in FigureA4 was then subject to a pseudostatic horizontal force to represent earthquake loading. The ultimate limit state (ULS) earthquake has an estimated seismic coefficient of 0.27. The analysis shows the factor of safety decreases to 1.23. We also calculated a critical seismic coefficient that applies when there is a factor of safety of 1.0. The critical seismic coefficient for the slope in FigureA4 is 0.378.

We made an equivalent 3D slope case to the 2D slope case shown in FigureA4. FigureA6 shows that there is a small 3D effect that enhances the stability compared with a 2D analysis. The factor of safety calculated under ULS shaking was 1.41.

[5] TSLOPE - https://tagasoft.com/

Conclusions and recommendations

The July 2022 landslide that removed part of the land at the northern boundary of 60 Holborn Drive was shallow, and does not appear to have involved much, if any, of the *in situ* greywacke rock. The landslide failure surface was at or near the interface with *in situ* greywacke and overlying colluvium and fill. The landslide triggering mechanism involved high pore water pressures acting on the failure surface, most likely due to water seeping out of the stormwater trench excavated into the crest of the slope.

The present slope configuration appears stable. In the time since the landslide occurred, there have been several significant rainfall events. The slope appears to be free draining, as the rock joints that run normal to the slope indicate a high permeability rock mass and without the low permeability colluvium cover, pore water pressures are not able to build up in the slope.

The house at 60 Holborn Drive is mainly founded on *in situ* greywacke, and since July 2022 there have been no indications of movement of the structure that might be attributed to slope displacement. We have also shown with slope stability calculations that a deep seated slope failure through greywacke that would impact the house is unlikely. Deep seated failures in these rocks are unusual. Slope failures in *in situ* greywacke are generally shallow surficial rock falls controlled by unfavourable rock structure.

The overall stability of the site does not appear to have changed following the July 2022 landslide. We agree with the Tonkin and Taylor Ltd conclusion that *the dwelling has not been damaged and is not considered to be at imminent risk as a direct result of the natural disaster (landslip) that has occurred.*

We conclude that the building is not dangerous and is safe to occupy.

The land around and to the east of the stormwater manhole is vulnerable to landsliding, extending across the property boundary to the east. Should a landslide develop there, then we would not expect that to impact the house. A similar failure mechanism to that of the July 2022 landslide is possible, with high pore water pressures resulting from water flowing down the stormwater trench. We recommend that work is carried out on the stormwater system to stop this occurring.

The exposed face following the landslide is expected to shed small blocks of rock from time to time, and the colluvium at the top of the slope may also show local instability. Subsequent to Tonkin and Taylor Ltd's reporting, the work carried out by Hutt City Council where the slope has been trimmed back to observed tension cracks, has reduced the imminent risk of regression of the landslide headscarp.

We understand that Hutt City Council plan to carry out appropriate slope protection works to take care of further potential local instability.

References

Begg JG, Johnston MR (comp) (2000). Geology of the Wellington Area. QMAP 1:250,000 geological map sheet 10, GNS.

Applicability

This report has been prepared for the benefit of s7(2)(a) [redacted] with respect to the brief given to Ian R Brown Associates Ltd. It may not be relied upon in other contexts or for any other purpose without our prior review and agreement.

Opinions and recommendations contained in this report have been derived from the information and data gathered during the course of our investigations.

No liability is accepted by Ian R Brown Associates Ltd nor by any Director, or any other servant or agent of the company, in respect of the use of this report (or any information contained therein) by any person for any purpose other than that specified in the brief.

Appendix 1 Slope stability analysis

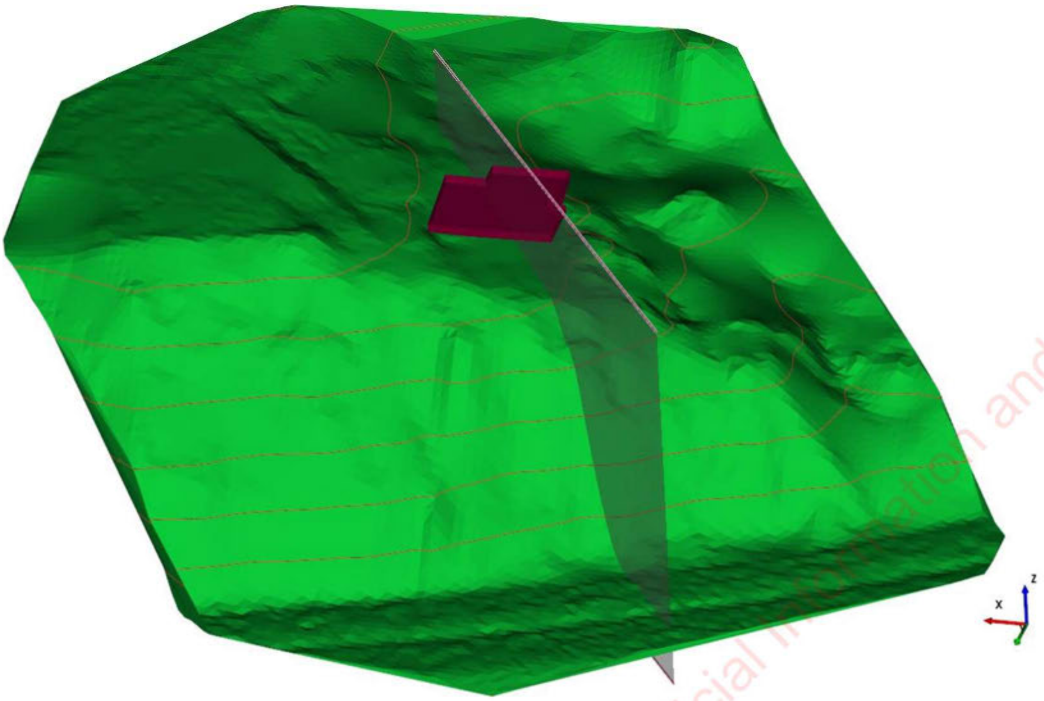


Figure A1   3D model used for slope stability analyses, 2013 topography.

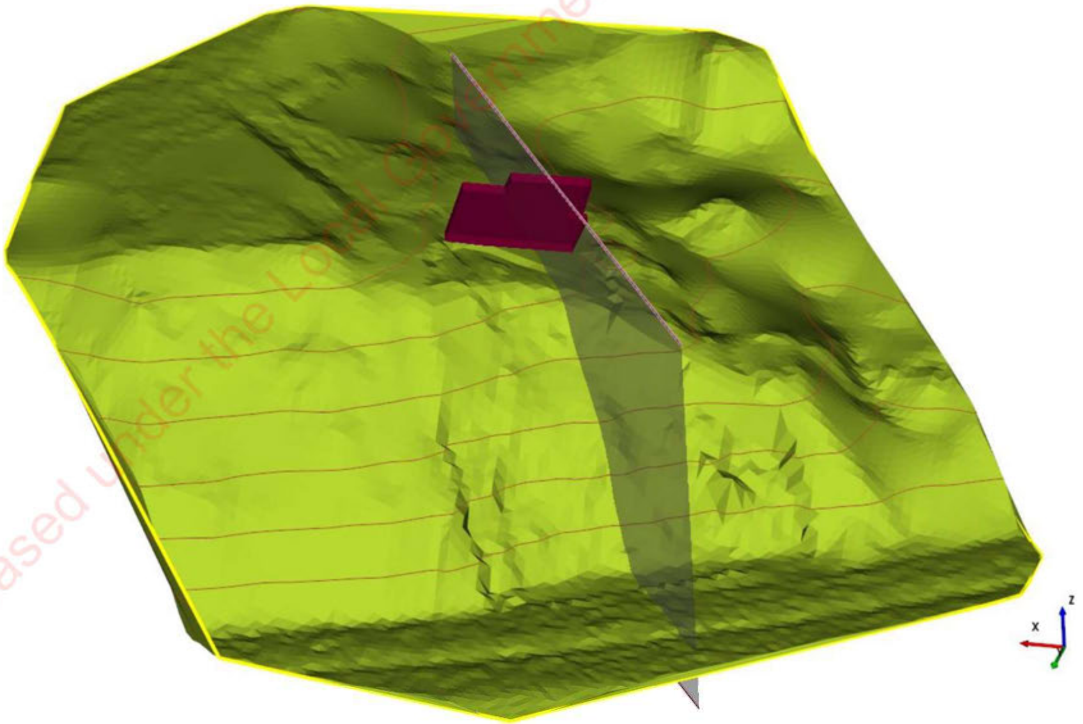


Figure A2   3D model used for slope stability analyses, 2023 topography.

Red shape – house foundation
Grey panel – cross section location for 2D slope cases

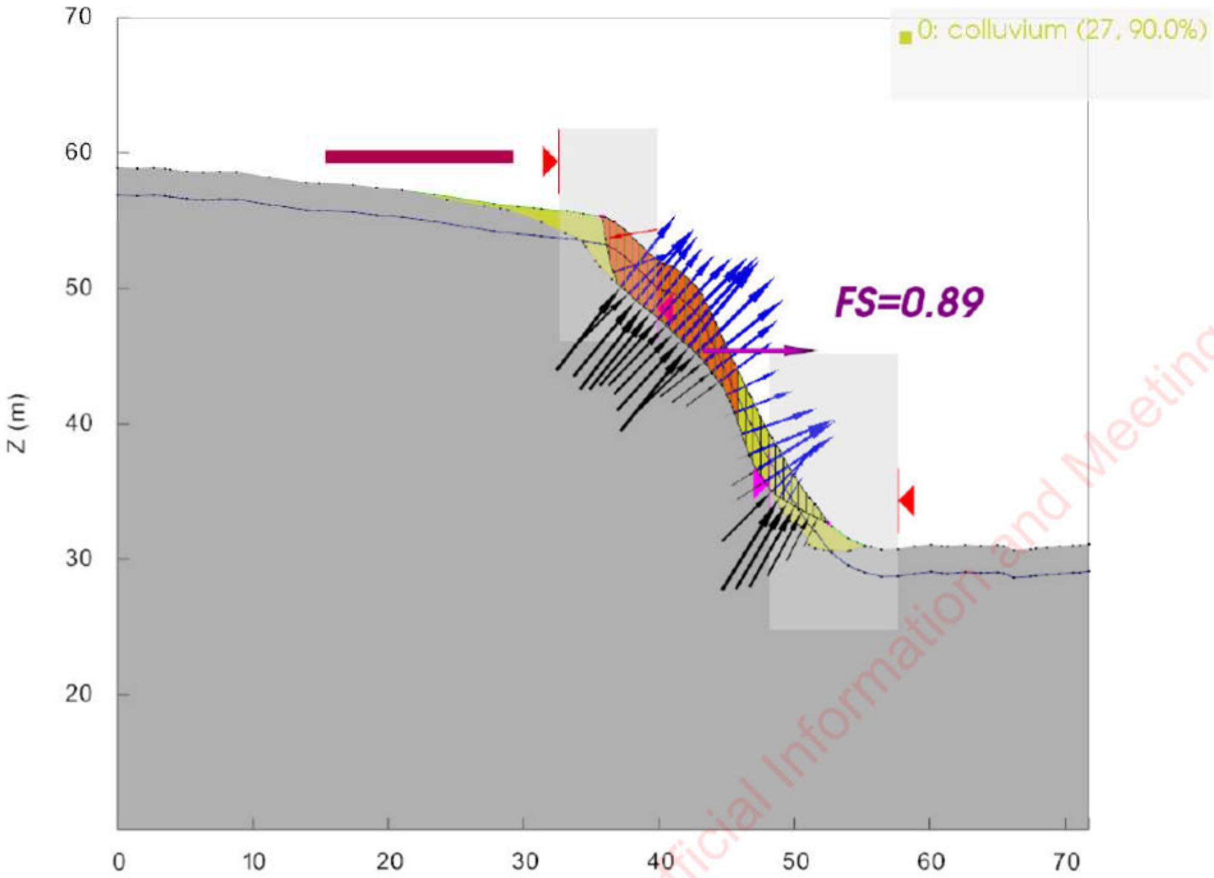


Figure A3 2D slope case, July 2022 landslide

FS (factor of safety) calculated at 0.89
Black arrows – effective normal stress on failure surface
Blue arrows – pore pressure on failure surface
Red polygon – vertical uniform load acting on ground surface
Vertical slices discretise the slope; red colour indicates tension between slices
Grey panels show limits for failure surface search

	colluvium
	greywacke

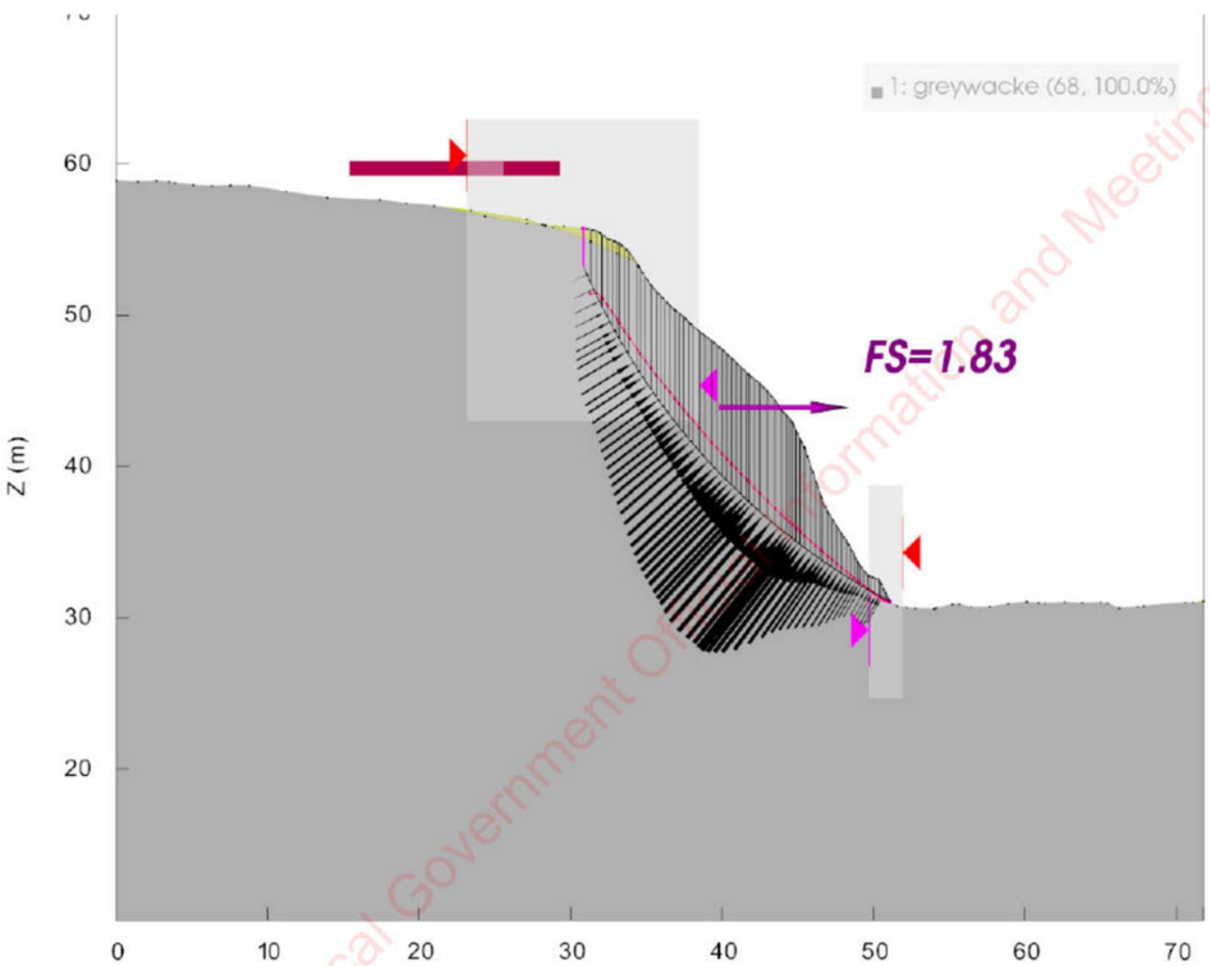


Figure A4 2D slope case, January 2023 topography

FS (factor of safety) calculated at 1.83
Black arrows – effective normal stress on failure surface
Red polygon – vertical uniform load acting on ground surface
Grey panels show limits for failure surface search

	colluvium
	greywacke

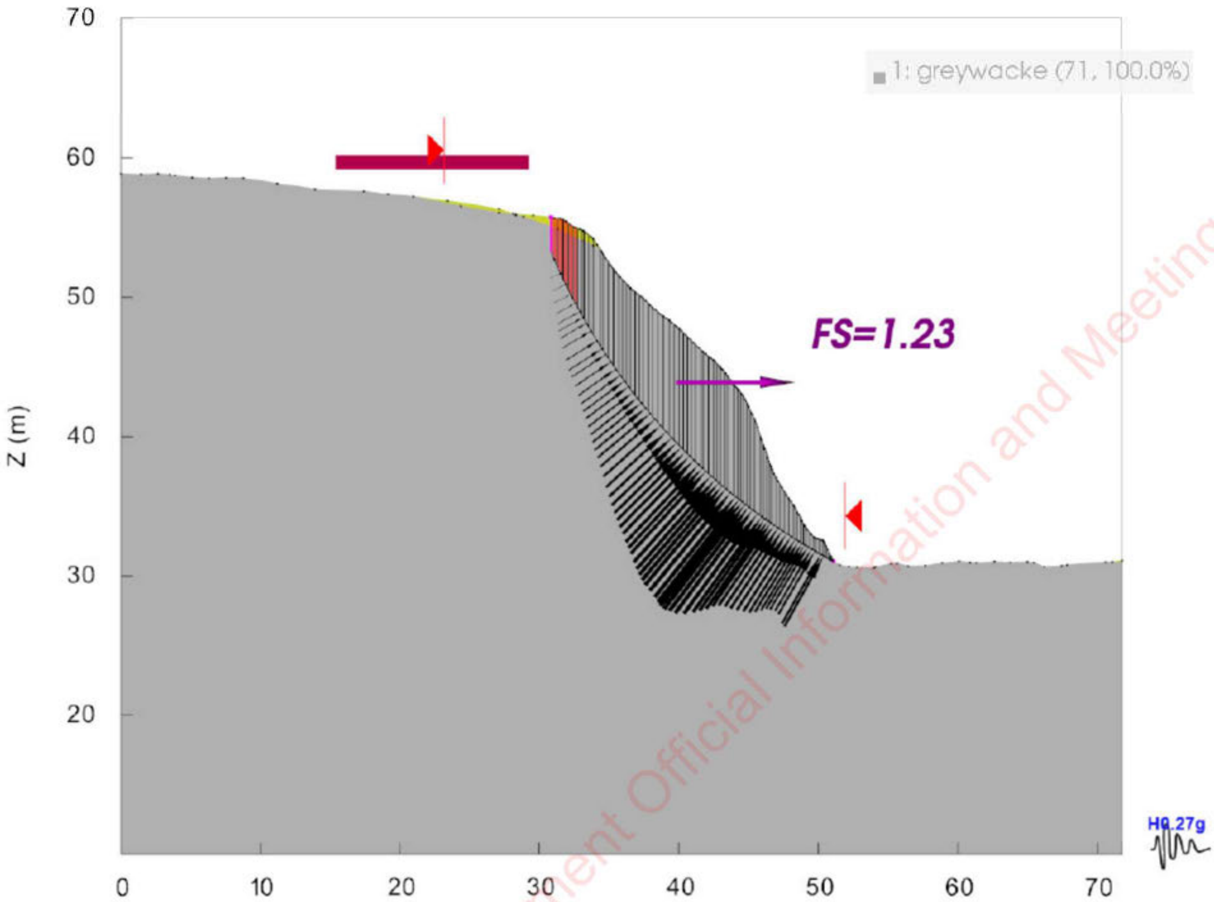


Figure A5   2D slope case, January 2023 topography, ULS earthquake

FS (factor of safety) calculated at 1.23
Black arrows – effective normal stress on failure surface
Red polygon – vertical uniform load acting on ground surface
Vertical slices discretise the slope; red colour indicates tension between slices

	colluvium
	greywacke

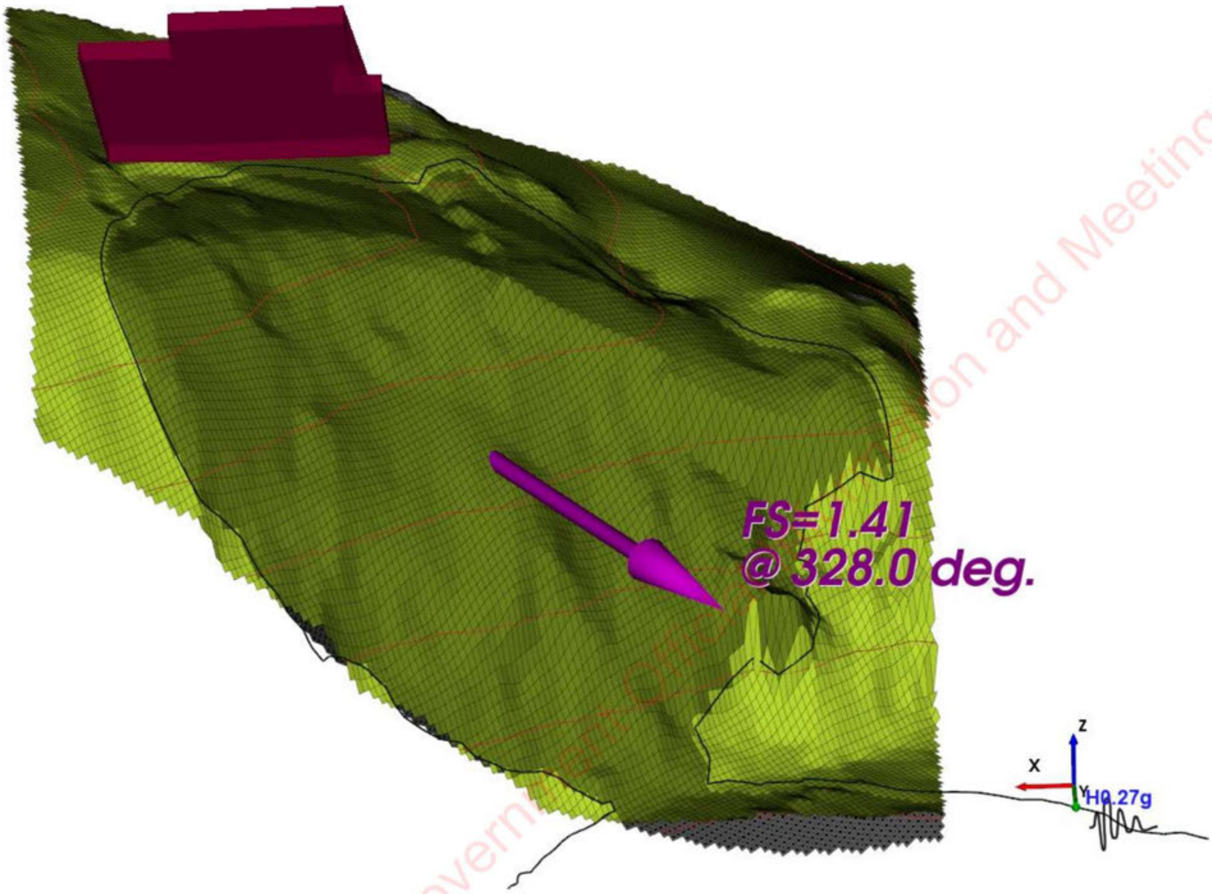


Figure A6 3D slope case, January 2023 topography, ULS earthquake

FS (factor of safety) calculated at 1.41 at a bearing of 328 degrees

Tonkin+Taylor

Job No: 1502000.0428
1 September 2022

[redacted]

By Email

Claim for Natural Disaster (Landslip) Damage
[redacted] 60 Holborn Drive, Stokes Valley, Hutt City
EQC/Insurer Claim Number [redacted]

1 Introduction

As requested, Tonkin & Taylor Ltd (T+T) inspected the subject property on 26 July 2022 and a re-inspection on 11 August 2022 to assess the claim for natural disaster damage. In particular the visits were undertaken to determine whether physical loss or damage to property is imminent as a direct result of the natural disaster that has occurred.

This claim relates to a rainfall event, triggering a landslip that occurred on 21 July 2022 with continued land movement over the following days to weeks since.

There have been three previous claims reported for this property dated:

1. March 2000 as a result of earthquake damage (EQC Claim [redacted] information dated 25 August 2000).
2. August 2004 as a result of soil movements due to settlement of fill (T+T Ref: 83453 report dated 20 September 2004). A Scala investigation was undertaken on 27 August 2004 to confirm the sub surface ground conditions and soil movement mechanisms.
3. a). August 2009 as a result of landslip (GHD Limited Ref: 51/282767 report dated 8 October 2009)
   b). August 2009 as a result of earthquake or any previous landslip events (T+T Ref: 85000.6737 report dated 12 February 2010).

The review of the information provided indicates the areas affected in the above claims are not related to the recent landslip that has occurred. No further summary of this information is included in this report.

2 Site description

The property is located on the northern side of Holborn Drive, upslope of Eastern Hutt Road. A steep escarpment forms the slope between Eastern Hutt Road and the property above. This property is legally described as Lot 42 DP 24219 26A/407, and is located on moderately steep (30° - 60°) land that slopes down towards the west and is upslope of a steep slope that drops away to the north down the escarpment to Eastern Hutt Road. A split level two storey dwelling with decks attached is located in the middle of the property, with a garage located in the northeast that is accessed down a driveway along the north eastern property boundary off Holborn Drive. A Hutt City Council (HCC) stormwater pipe is located under the driveway and garage before it turns at a manhole behind the garage and then travels downslope in a south westerly direction.

A landslip has occurred on the north facing escarpment slope adjacent to the dwelling, resulting in evacuation of land within 8m of the dwelling. Visible tension cracks extend parallel along the slope on the grassed area and displacement of land has occurred behind the headscarp region. The landslip continues down the slope beyond the property boundary across HCC land and landslip debris has accumulated on Eastern Hutt Road at the base of the slope. There appears to be no observed damage to the dwelling, decks or HCC stormwater pipeline. We understand from the property owner a CCTV inspection of the HCC stormwater pipe has been undertaken and no damage was reported.

The published geology of the area[1] indicates that the site is underlain by Rakaia Terrane formation comprised of alternating sandstone/argillite (greywacke). Based on site observations, the slope appears to comprise a thin layer of silty gravel colluvium overlying in situ greywacke rock, as rock outcrops were observed on the slopes below. A scala penetrometer investigation undertaken on 27 August 2004 at the top of the slope inferred that the area comprises approximately 0.8 m of fill overlying soil and weathered rock. Additional scala tests were undertaken on the western side of the dwelling with a weathered rock surface inferred to be at a varying depth of approximately 1.3 to 2.1 m below ground level. The escarpment on the north side and downslope of the property is formed in highly weathered highly jointed greywacke rock.

There is evidence of older instability (slumping), settlement of fill on the western slopes below the dwelling however this has been addressed in prior claims and reporting.

The location of the landslip and the extent of the damage are shown on the attached sketches and photographs. The conclusions and recommendations in this report are based on a visual assessment of the site only. It must be appreciated that subsurface conditions may vary from those inferred in this report.

An unmanned aerial vehicle (UAV) survey was conducted as a part of the inspection to create an ortho-mosaic aerial image and digital elevation model (DEM) for use in this report. This data has not been georeferenced to cadastral survey and should not be used for design purposes.

Property boundaries are based on Land Information New Zealand (LINZ) information overlain on aerial imagery.

3 Property damage

The damage to the property consists of an approximately 25 m wide landslip adjacent to the northern side of the dwelling which has resulted in:

- Evacuation of insured land within 8 m of the dwelling.

4 EQC considerations

We consider the damage bullet pointed above to be natural disaster (landslip) damage as defined by the Earthquake Commission Act 1993 (EQC Act).

[1] Begg, J.G., Johnston, M.R. (compilers) 2000: Geology of the Wellington area. Institute of Geological & Nuclear Sciences 1:250,000 geological map 10. 1 sheet + 64 p. Lower Hutt, New Zealand. Institute of Geological & Nuclear Sciences Limited.

5 Imminent risk

Within the following 12 months (under normal annual rainfall conditions) and as a direct result of the landslip that has occurred there is an imminent risk of regression of the landslip headscarp resulting in:

- Evacuation of additional insured land within 8 m of the dwelling.

The dwelling has not been damaged and is not considered to be at imminent risk as a direct result of the natural disaster (landslip) that has occurred.

There is a risk of landslips on adjacent slopes due to future storm or earthquake events. However, this risk is not considered imminent (under normal annual rainfall conditions) within the next 12 months as a direct result of the natural disaster (landslip) that has occurred. We recommend that the property owners seek further advice and engage a geotechnical specialist to assess the stability risk of the adjacent slopes and implement remedial work if required.

6 Conceptual remedial works

The information in the following section is provided solely to [redacted] or EQC claim settlement purposes. The conceptual remedial works are for [redacted] cost estimation only, to enable [redacted] to assess the likely costs of repairing the damaged insured property and/or, the cost of preventing damage to insured property that is considered imminent as a direct result of the natural disaster that has occurred. The conceptual remedial works, and drawings, are NOT FOR CONSTRUCTION.

There may be an alternative remedial works solution which is more cost effective or appropriate for the property owner and wider property (beyond EQC insured land). It may be possible to implement an alternative solution to work in collaboration with Hutt City Council regarding the entire affected escarpment slope.

The conceptual remedial solution is developed within the constraints of working solely within the property boundary. Due to the location of the HCC stormwater pipe collaboration with the council will be required to ensure any potential relocation of this pipe is identified and designed for appropriately.

It is not practical to reinstate the evacuated land, a conceptual remedial works solution that removes imminent risk to insured property, could comprise the following:

- Establish access to the site via Holborn Drive, remove garage for machinery access within property boundary.
- Prepare the working area, ensure safety for working above the Eastern Hutt Road corridor for the road users below. Communication, collaboration and approvals required with HCC to consider controls required for HCC owned assets including stormwater network.
- Construct an in-ground reinforced concrete palisade retaining wall having the following dimension / characteristics / properties:
  - 25 m long wall
  - 5 m maximum retained height, 10 m total pile length embedded into moderately weathered rock
  - 900 mm diameter reinforced concrete piles (no. 15) with 3% steel at 1.8 m centres
  - 25 m long, 1000 mm wide x 600 mm deep reinforced concrete capping beam with 3% steel linking all pile heads together.
- Hand rail to Building Code requirements

- Trim headscarp area to approximately 1:1.5 slope and remove loose debris and vegetation (estimate 35 m^3) and dispose off-site
- Hydroseed exposed surface
- Reinstate damage caused by construction work and traffic, reinstate garage.

A drawing of this conceptual remedial works solution is shown in Sketch 3 and 4.

Additional information for cost estimation:

Construction Issues	**Easy**	**Moderate**	**Hard**	**N/A**
Construction access	☐	☐	☒	☐
Earthworks required	☐	☐	☒	☐
Constructability/Reinstatement	☐	☐	☒	☐

Construction methodology and sequencing of the remedial works will be required to ensure the slope and dwelling are secured to safely undertake any proposed works along with consideration of the HCC service locations. Access to the site is possible along the driveway, removal of the garage would be required to set up machinery and equipment for construction. Consideration and collaboration with HCC would be required for working above the Eastern Hutt Road corridor and for relocation of the stormwater pipe network.

A building and/or Resource consent, is likely to be required and this should be confirmed with the Local Authority prior to any remedial works being undertaken.

Subsurface investigation, engineering design and subsequent sign off by a chartered professional engineer is likely to be required as part of the building consent application. Regular inspections by a Chartered Engineer may also be necessary during the works to enable sign - off in accordance with the 2004 Building Act and the conditions of the building consent. Failure to obtain the required consents could mean that the building works have to be removed.

All remedial solutions should consider safety in design. Any construction works should be undertaken in a safe and appropriate manner, including the allowance for all necessary protection and temporary stabilisation works as required to ensure the safety of all persons working or present on site during construction.

We estimate the cost (excluding GST) to design and consent the proposed solution will be as follows:

Geotechnical engineering investigation, design and drawings	[redacted]
Survey	
Building/Resource consents	
Construction observations and Producer Statements	
Project Management	
TOTAL (Excluding GST)	

*The construction cost estimate for the proposed conceptual remedial solution will be provided by the cost estimator.

7 Summary of Information

Is this natural disaster damage?	Yes (Landslip)
Land within 8 m of dwelling or appurtenant structures	
Area of insured land **damaged:** Evacuated: Inundated:	 66 m^2 N/A
Area of insured land **at imminent risk** Evacuation: New inundation: Re-inundation:	 46 m^2 N/A N/A
Main access way within 60 m of dwelling	**N/A**
Retaining walls supporting or protecting insured buildings and/or land located within 60 m of dwelling (or an appurtenant structure)	**N/A**
Dwelling and appurtenant structure(s)	
Has the dwelling or appurtenant structure been damaged as a result of the natural disaster?	No
Is damage to the dwelling (or appurtenant structure) imminent as the direct result of a natural disaster?	No
Services within 60 m of dwelling on insured land	**N/A**
Bridges or culverts situated on insured land	**N/A**
Conceptual remedial works:	
To remove imminent risk to property; trim loose landslip material from top of slope and construct an in-ground concrete reinforced palisade wall, with capping beam within the property boundary, with consideration of the HCC stormwater service location/ relocation.	[redacted] construction costs* (excluding GST)

*To be assessed by the cost estimator

8 Applicability

This report was produced for [redacted] for the sole purpose of assisting [redacted] to determine whether EQC has any liabilities under the Earthquake Commission Act 1993 and it may not be relied upon in other contexts or for any other purpose, or by any person other than [redacted] without our prior written agreement.

Yours sincerely

For Tonkin & Taylor Ltd

[redacted]

[redacted]

Engineering Geologist Principal Consultant

Reviewed by [redacted] and authorised for T+T by [redacted] (Project Director)

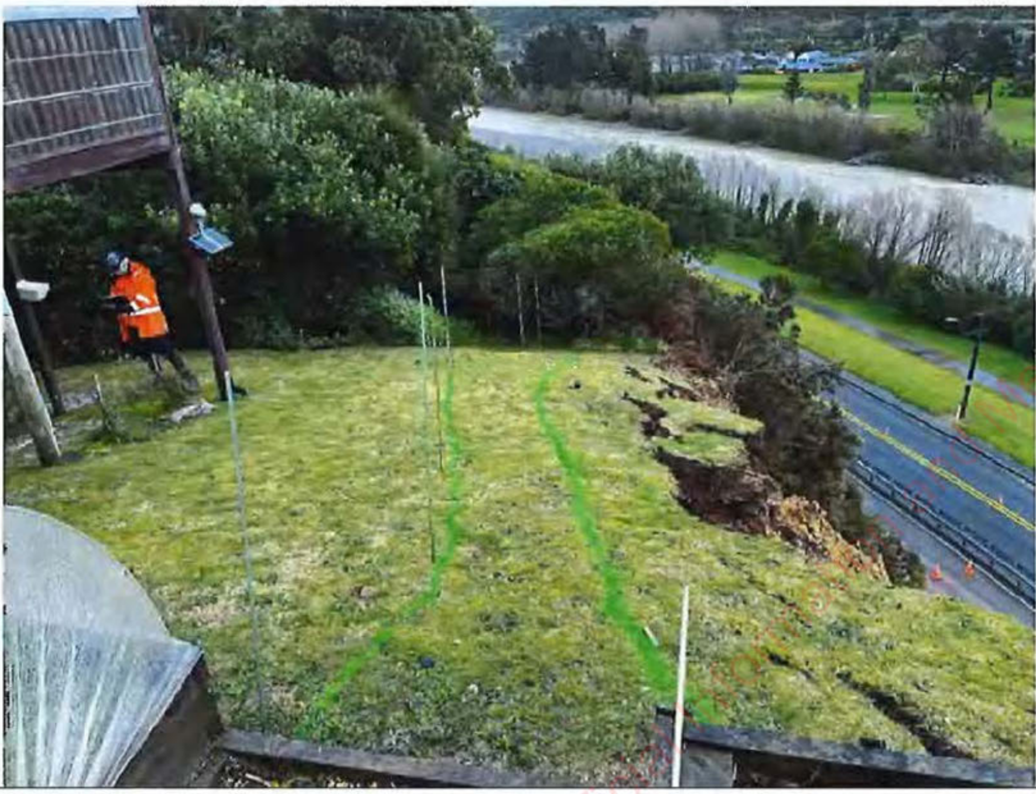
Attached: Photographs (1 – 7)
Annotated aerial photograph (Sketch 1)
Sketches (2 – 4)

1-Sep-22
t:\auckland\projects\1502000\1502000.0428\issueddocuments\t+t [redacted] final report.docx

Photographs 1-8 – 60 Holborn Drive, Stokes Valley, Hutt City Stokes Valley, Hutt City – 26 July 2022 and 11 August 2022

Photograph 1: View facing east from property, showing tension crack in the foreground (arrow). Taken 26 July 2022.

Photograph 2: View looking west along the length of the landslip headscarp and tension cracking. Taken 26 July 2022.



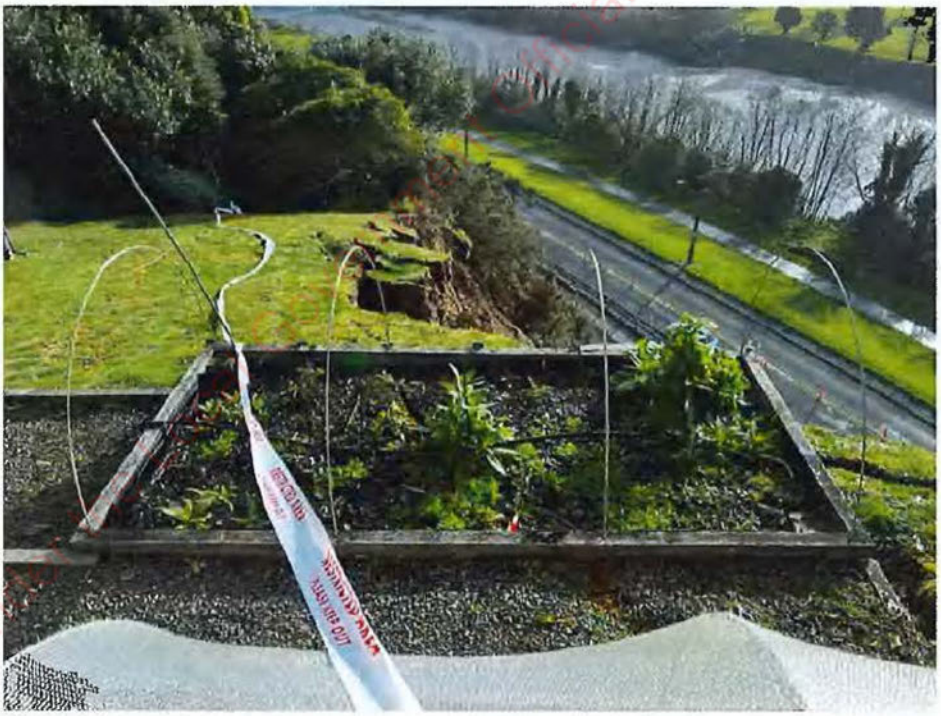
Photograph 3: View looking west along the length of the area behind the observed landslip headscarp. Taken 26 July 2022.

Photograph 4: View from Eastern Hutt Road looking up to the property. Taken 26 July 2022.

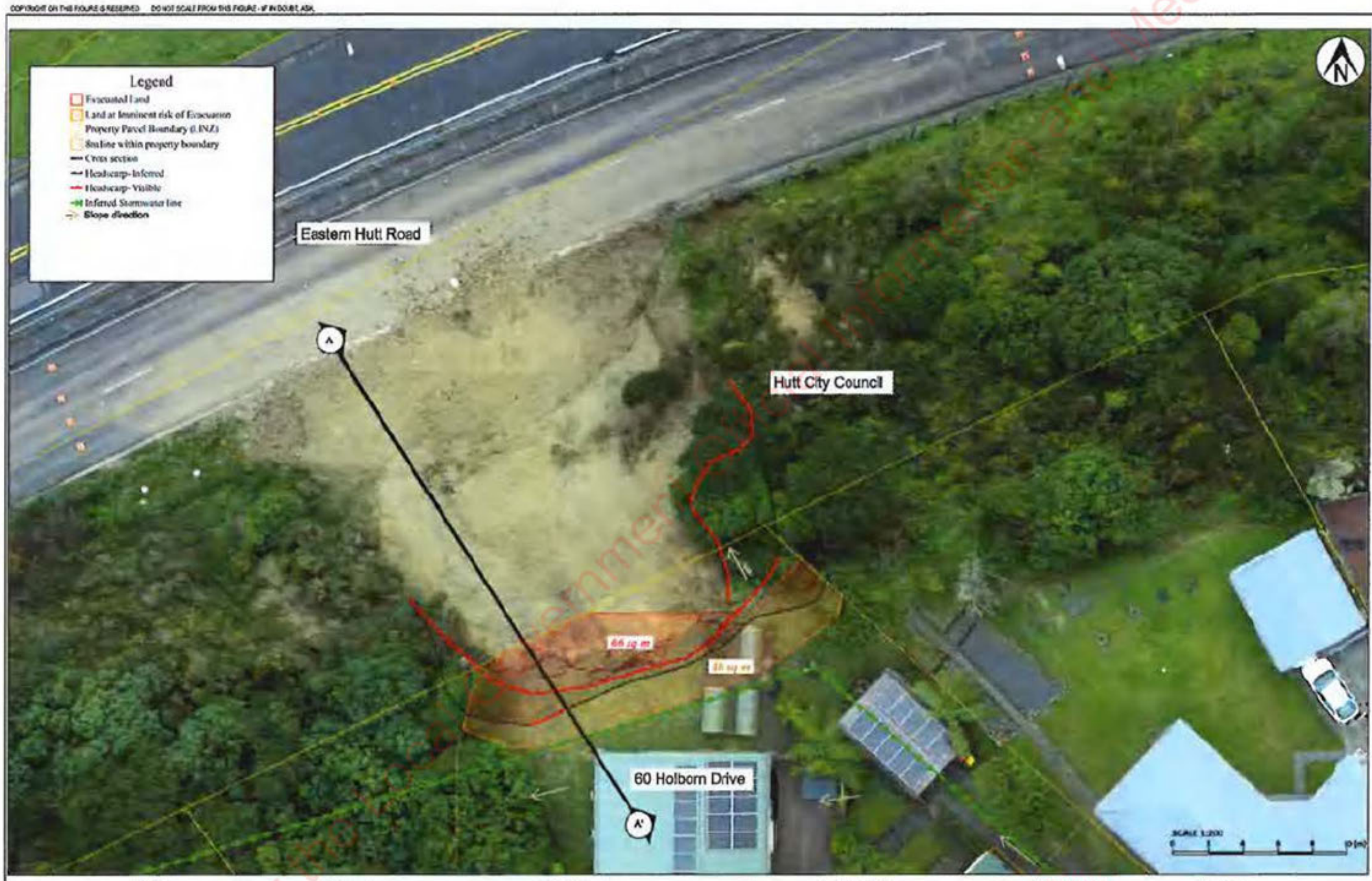
Photograph 5: View facing east from above, showing entire landslip. Taken 26 July 2022.

Photograph 6: View facing directly down from above, showing landslip headscarp. Taken 26 July 2022.

Photograph 7: View facing up to the east, showing landslip headscarp and material. Taken 26 July 2022.



Photograph 8: View looking west along the length of the area behind the observed landslip headscarp. Taken 11 August 2022.



Tonkin+Taylor

Exceptional thinking together www.tonkintaylor.co.nz

NOTES: 1) Aerial Image and cross section obtained from UAV Flights conducted on 26 July 2022 and 11 August 2022 by T+T for the purposes of this report only
2) Ortho-mosaic aerial imagery and DEM provided by non-georeferenced UAV survey.

REV	DESCRIPTION	GD	CHK	DATE	LOCATION FURV	APPROVED	DATE

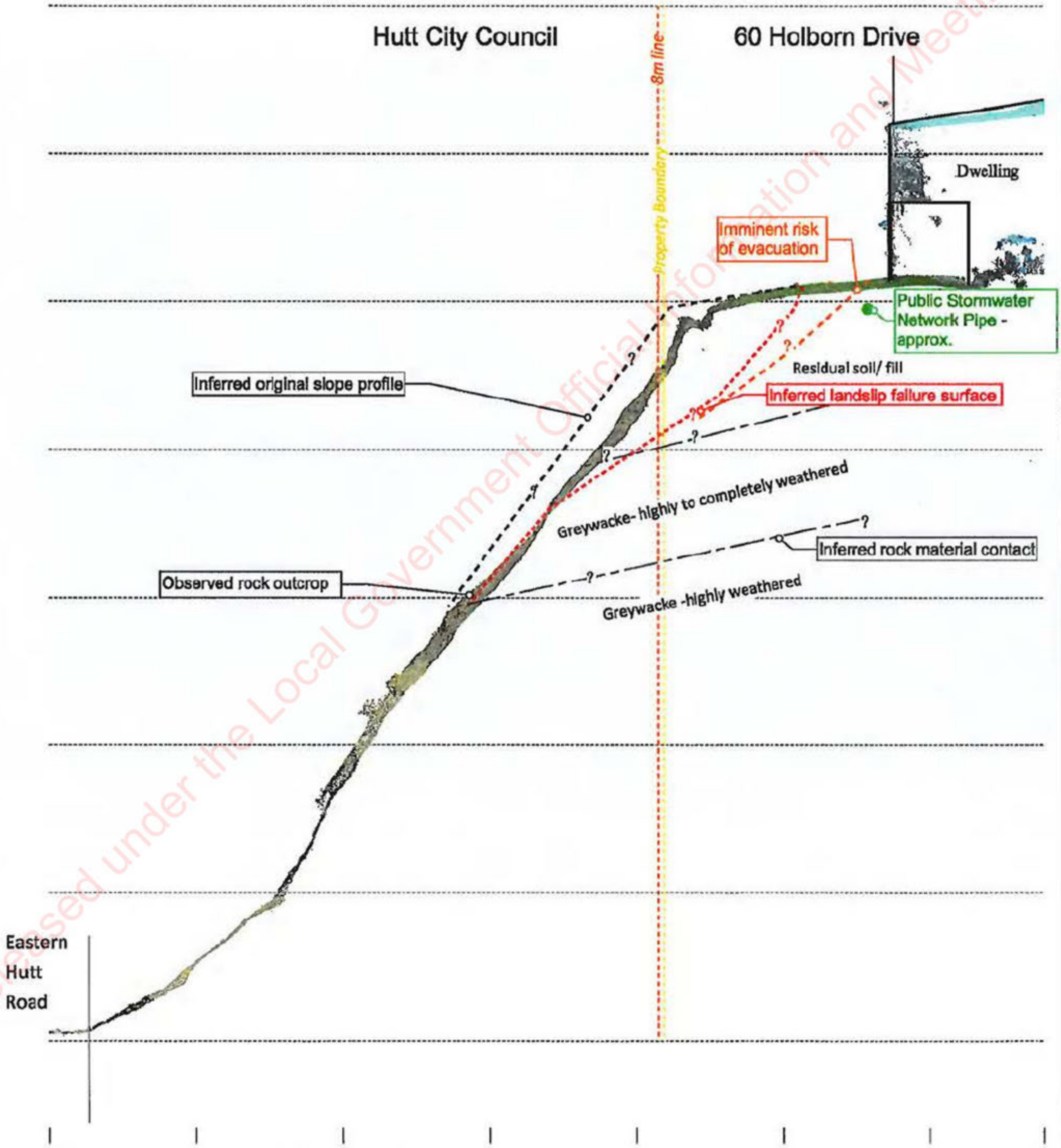
PROJECT No. 1502000.0428
CLIENT s7(2)(b)(ii) [redacted]
DESIGNED / DRAWN / CHECKED s7(2)(a) [redacted]
PROJECT 60 HOLBORN DRIVE, Stokes Valley, Hutt City
TITLE ANNOTATED AERIAL FIGURE
SCALE (A3) 1:200
FIG No. SKETCH 1
REV

SKETCH 2: Cross Section AA'

60 Holborn Drive, Stokes Valley

TT; 1502000.0428

[redacted]

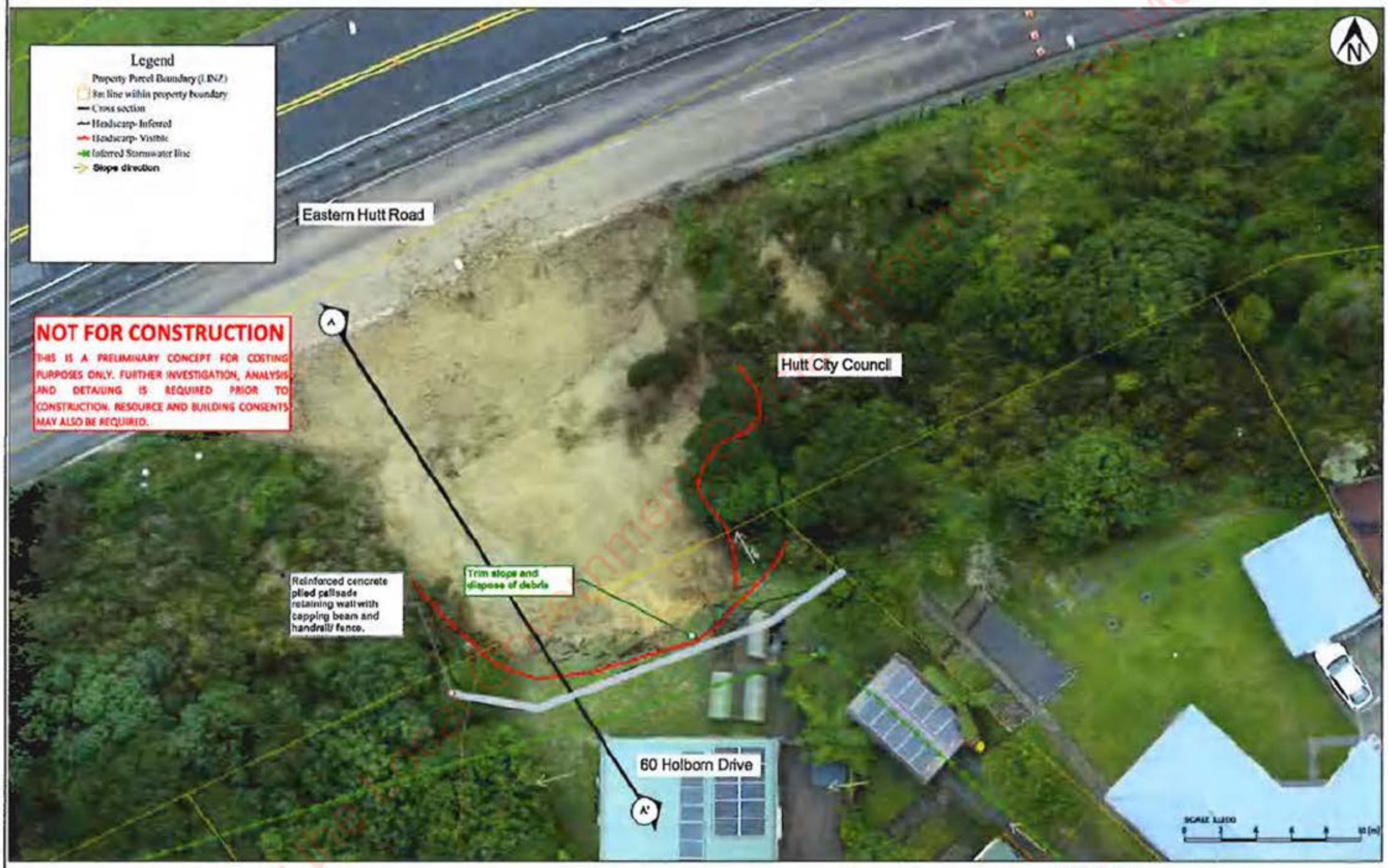


NOTE: Cross section data obtained from UAV Flight conducted on 26 July 2022 by T+T for the purposes of this report only

SCALE 1:200

0 2 4 6 8 10 (m)

COPYRIGHT ON THIS FIGURE IS RESERVED DO NOT SCALE FROM THIS FIGURE - IF IN DOUBT ASK.



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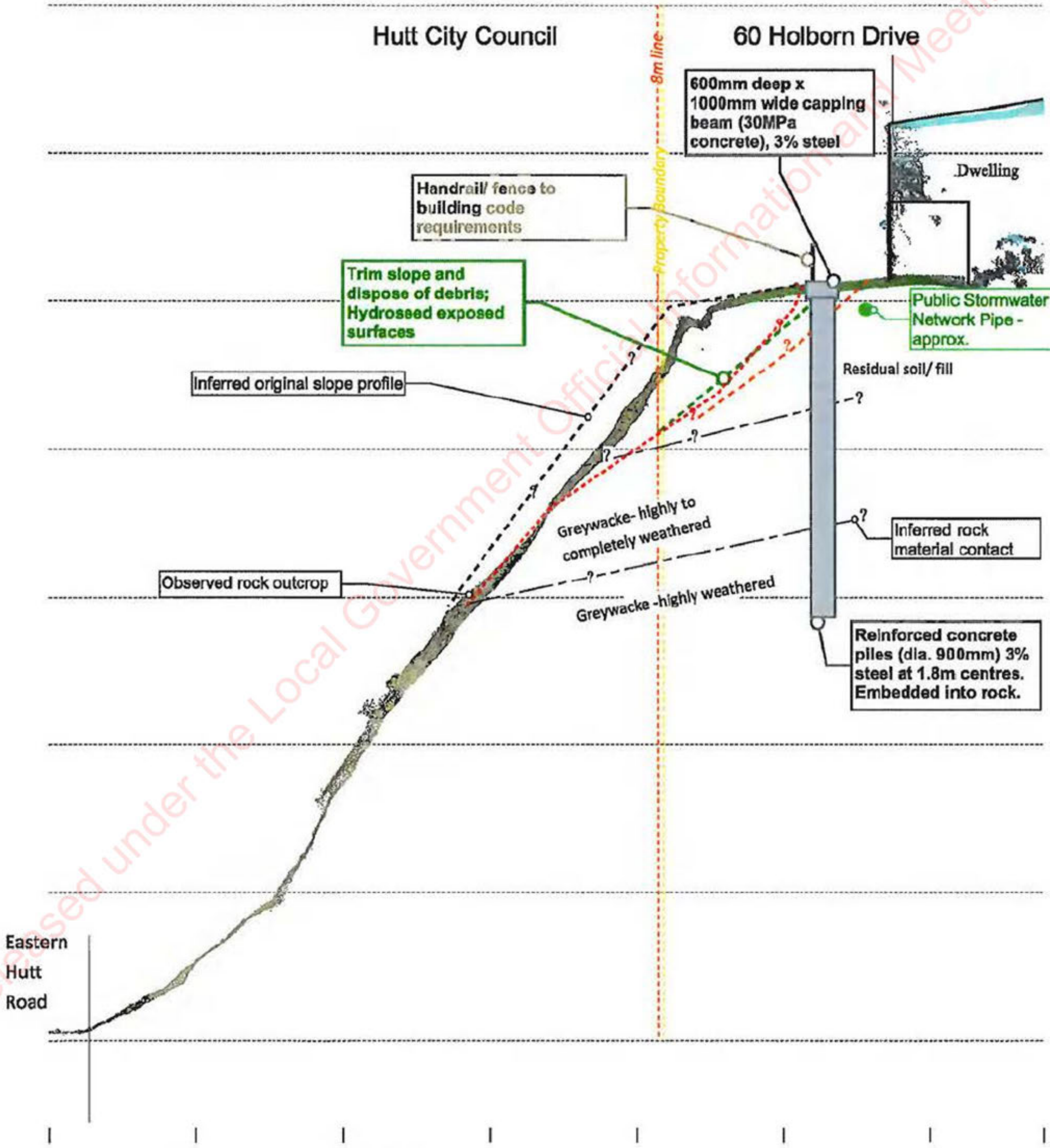
NOTES: 1) Aerial Image and cross section obtained from UAV Flights conducted on 26 July 2022 and 11 August 2022 by T+T for the purposes of this report only
2) Ortho-mosaic aerial imagery and DEM provided by non-georeferenced UAV survey.

REV	DESCRIPTION	GD	CHK	DATE	LOCATION PLAN	APPROVED	DATE

PROJECT No.	1502000.0426
DESIGNED	s7(2)(a) [redacted]
DRAWN	
CHECKED	
CLIENT	s7(2)(b)(ii) [redacted]
PROJECT	60 HOLBORN DRIVE, Stokes Valley, Hutt City
TITLE	CONCEPTUAL REMEDIAL SOLUTION PLAN
SCALE (A3)	1:200
FIG No.	SKETCH 3
REV	

SKETCH 4: Cross Section AA' - Conceptual Remedial Solution
60 Holborn Drive, Stokes Valley
TT: 1502000.0428
s7(2)(b)(ii) [redacted]

NOT FOR CONSTRUCTION
This is a preliminary design for costing purposes only. Further investigation, analysis and detailing are required prior to construction. Resource and Building consents may also be required.



NOTE: Cross section data obtained from UAV Flight conducted on 26 July 2022 by T+T for the purposes of this report only

SCALE 1:200
0 2 4 6 8 10 (m)

From:	[redacted]
To:	[redacted]
Cc:	[redacted]
Subject:	RE: 60 Holborn Drive, Stokes Valley, Lower Hutt [redacted]
Date:	Thursday, 15 September 2022 5:11:49 pm
Attachments:	Holborn Drive - Stokes Valley Road Services As-Built S2357.pdf Holborn Drive - Stokes Valley Road Services As-Built S2356.pdf Holborn Drive Services As-Built S2350.pdf image001.png

---

Hi [redacted]

Found attached asbuilts of the public SW.

S2350 is the plan drawing. Plan has Lot numbers. 60 Holborn is Lot 42

S2357 has long section for SW line 8, which runs around the back of no 60 Holborn.

S2356 has long section for SW line 6, which 66 and down onto Eastern Hutt Rd

They are typical as builts from the 60's and don't have a lot of detail. There is invert levels on the long sections

Thanks

[redacted]

From: [redacted]

Sent: Thursday, 15 September 2022 3:28 pm

To: [redacted]

Cc: [redacted]

Subject: 60 Holborn Drive, Stokes Valley, Lower Hutt [redacted]

Hi All - Additional information being requested under this OIA

[redacted] – do you know if you can locate an as-built of this S/W drain in the HCC system.

Also I will request from HCC if they have the engineers assessment of the slip face and the position of the public storm water drain in relation to the slip

My comments at this stage are

Request	**Comment**	**Action**
WSP report prepared for Hutt City Council in 2015 to assess the slope hazard	This report will likely be with HCC	HCC responsibility
How deep the storm water drains are below the surface?	Perhaps the as-built long section may provide or WWL can measure depth to invert	[redacted] – if you are able to locate an as-built
Can copies of any construction records for the storm water system on the	Likely any construction records will be with HCC Perhaps a subdivision file or	HCC responsibility

property be made available?	similar	
Please provide any additional information on the storm water drains - seep stops etc.	May be something on the as-builts but if not then it will be assumed there are none	s7(2)(a) [redacted] – if you are able to locate an as-built
In addition, on 22 July Hutt City Council had Drain Doctor inspect the storm water pipe that runs pretty much parallel to the slip. Could your client please provide a copy of the video taken by Drain Doctor?	WWL did CCTV camera a small length of the drain but I have requested a full camera inspection including the portion of the drain down the slope as far as practical to camera.	s7(2)(a) [redacted] – can provide CCTV of the portion we have already CCTV inspected

s7(2)(a) [redacted]
Customer Planning Engineer - Wellington Water
Mob s7(2)(a) [redacted]

From: Derek Kerite <Derek.Kerite@huttcity.govt.nz>
Sent: Thursday, 15 September 2022 1:15 pm
To: s7(2)(a) [redacted]
Cc: Bradley Cato <Bradley.Cato@huttcity.govt.nz>; Paul Pugh <Paul.Pugh@huttcity.govt.nz>; Jon Kingsbury <Jon.Kingsbury@huttcity.govt.nz>
Subject: FW: [EXTERNAL] FW: 60 Holborn Drive, Stokes Valley, Lower Hutt s7(2)(a) [redacted]

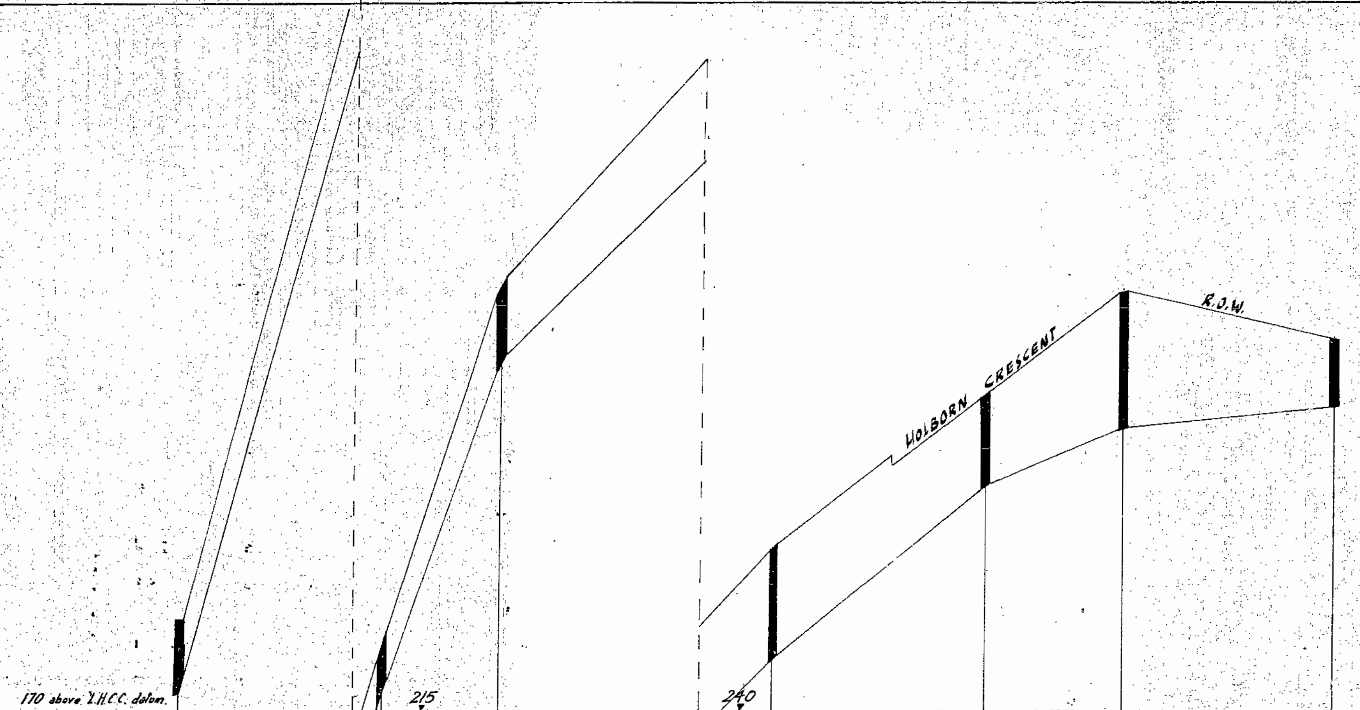
Hi s7(2)(a) [redacted]

Further to my email on 9 September, there has been more information requested below in relation to drains in and around 60 Holborn Drive. We would like to respond as soon as possible, so would appreciate a quick response.

Regards,

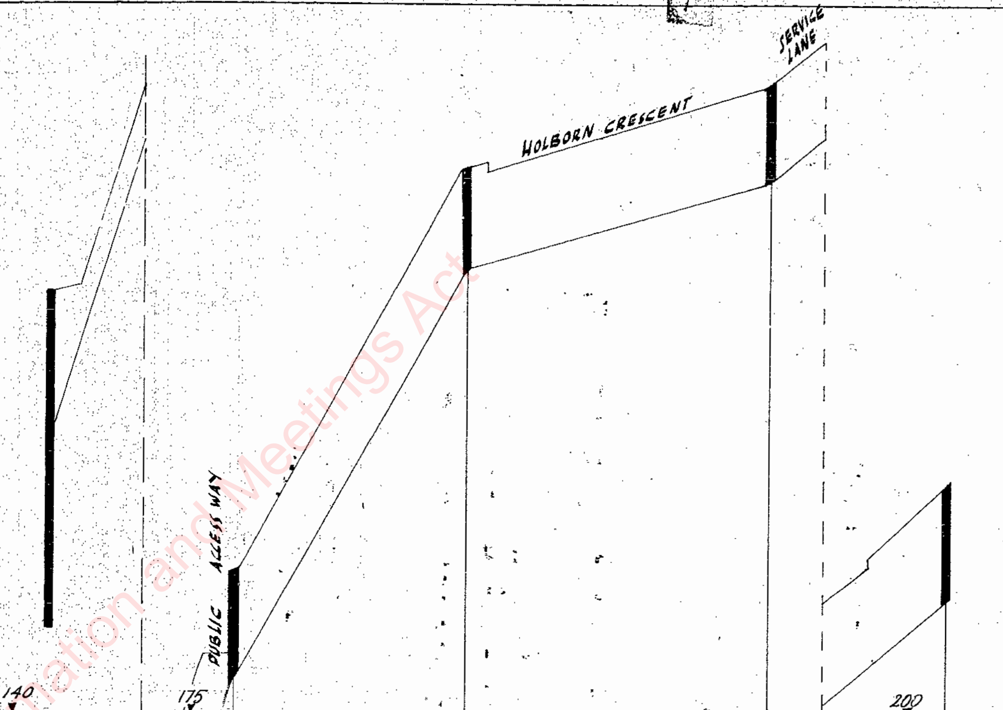
Derek Kerite
Head of Regulatory Services

Hutt City Council, 30 Laings Road, Lower Hutt 5010
P: M: s7(2)(a) [redacted] **W:** www.huttcity.govt.nz



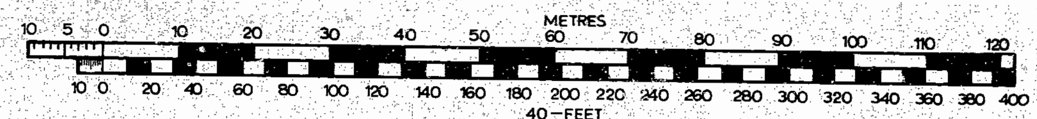
INVERT LEVEL	170.33	9" φ	215.65	9" φ	230.39	9" φ	242.23	9" φ	249.75	9" φ	252.37	9" φ	253.23
GROUND LEVEL OR MAN-HOLE LID LEVEL	174.00		217.85		233.74		247.13		253.75		258.30		256.31
DISTANCE	0		90		141		261		353		413		505
MAN-HOLE NUMBER	35		36 Shallow Type		37		38		39		40		41

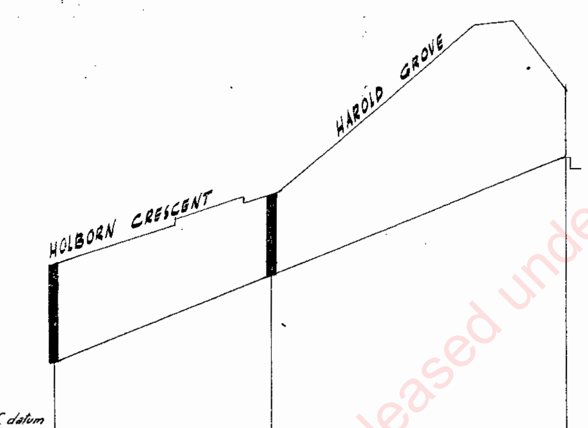
LINE 8



INVERT LEVEL	143.67 / 137.67	15" φ	176.53	15" φ	194.36	15" φ	198.22	9" φ	204.98
GROUND LEVEL OR MAN-HOLE LID LEVEL	158.34		181.10		198.87		202.50		210.05
DISTANCE	0		81		182		315		394
MAN-HOLE NUMBER	20		21		22		23		24

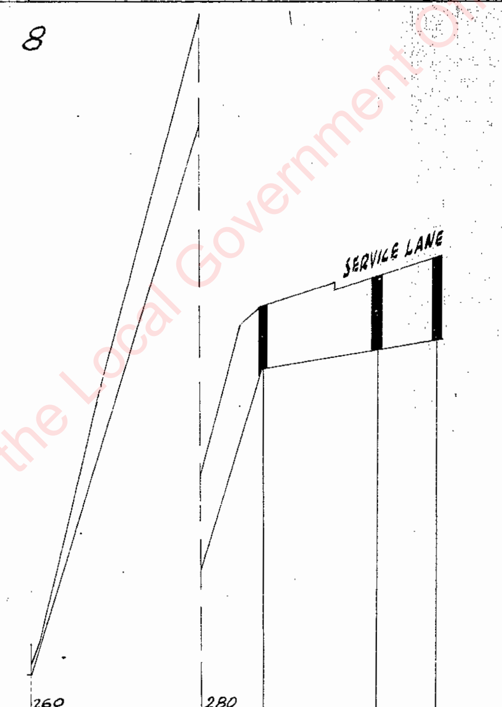
LINE 9





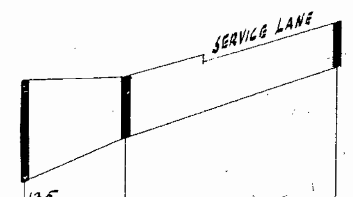
INVERT LEVEL	196.22	15" φ	202.12	15" φ	207.22
GROUND LEVEL OR MAN-HOLE LID LEVEL	202.50		205.43	213.1	
DISTANCE	0		96		225
MAN-HOLE NUMBER	23		25		Head Wall

LINE 10



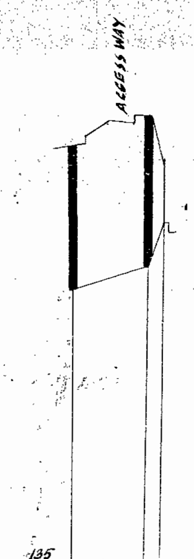
INVERT LEVEL	261.9	9" φ	295.14	9" φ	295.98	9" φ	296.38
GROUND LEVEL OR MAN-HOLE LID LEVEL			297.88		299.01		299.96
DISTANCE	0		100		149		175
MAN-HOLE NUMBER	Head Wall		51		52		53

LINE 12



INVERT LEVEL	136.22	9" φ	138.09	9" φ	141.08
GROUND LEVEL OR MAN-HOLE LID LEVEL	140.56		140.79		143.08
DISTANCE	0		44		136
MAN-HOLE NUMBER	17		18		19

LINE 13



INVERT LEVEL	142.18	9" φ	143.22	145.08
GROUND LEVEL OR MAN-HOLE LID LEVEL	148.40		149.72	147.78
DISTANCE	0		31	38
MAN-HOLE NUMBER	7		55	H.Wall

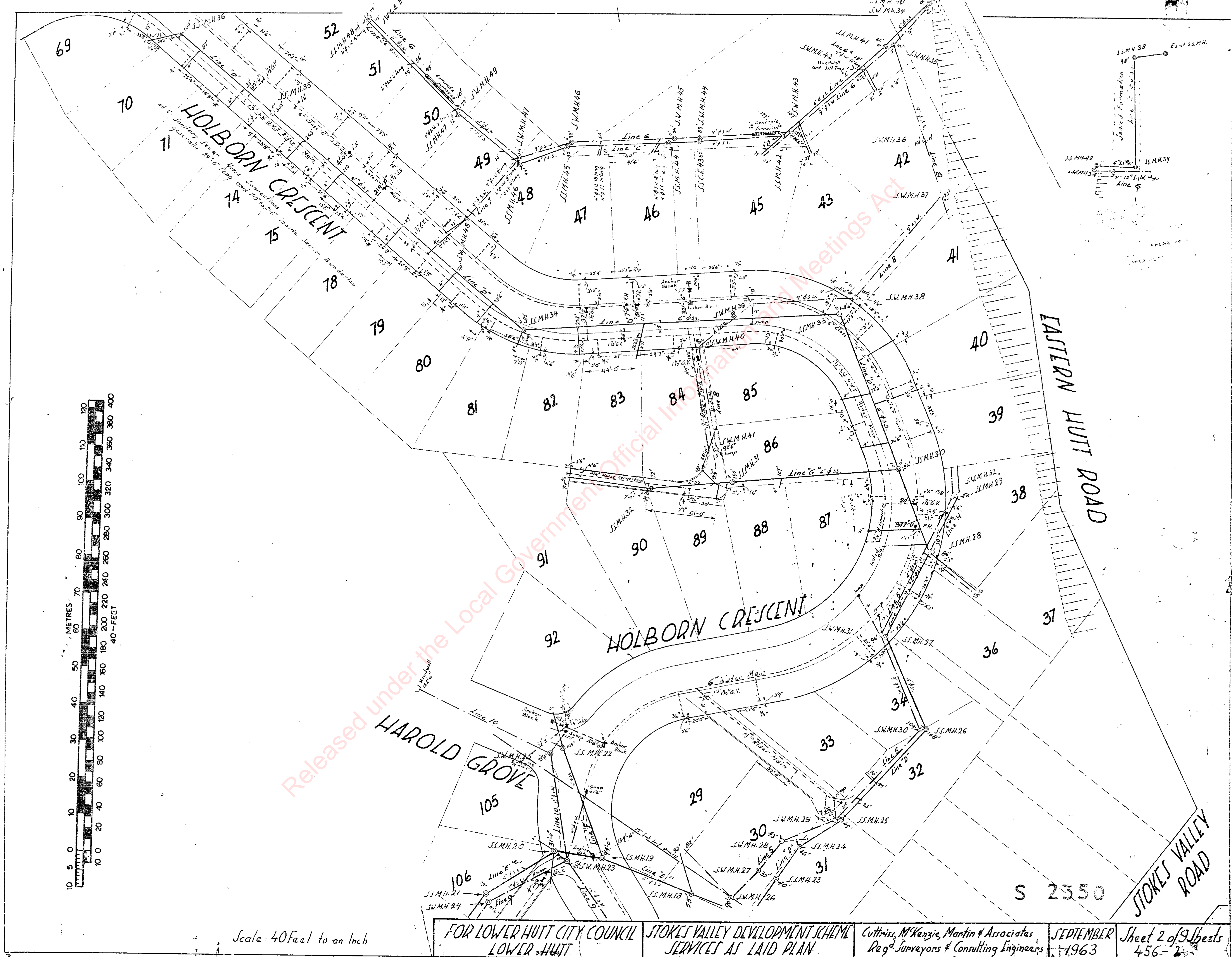
LINE 14

S 2357

LONGITUDINAL SECTIONS STORMWATER DRAINS

Scale: Horizontal 40 Feet to an Inch
Vertical 4 Feet to an Inch

FOR LOWER HUTT CITY COUNCIL LOWER HUTT	STOKES VALLEY DEVELOPMENT SCHEME SERVICES AS LAID	Cuttriss, McKenzie, Martin & Associates Regd Surveyors & Consulting Engineers	September 1963	Sheet 9 of 9 Sheets 456-2


HOLBORN CRESCENT
HOLBORN CRESCENT
HAROLD GROVE
EASTERN HUTT ROAD
STOKES VALLEY ROAD
all 4" Sanitary Sewer House Connections generally 34'0" long and PVC to 9'0" inside section boundaries
METRES
FEET
S 2350
Scale 40 Feet to an Inch
FOR LOWER HUTT CITY COUNCIL LOWER HUTT
STOKES VALLEY DEVELOPMENT SCHEME SERVICES AS LAID PLAN
Cuttriss, McKenzie, Martin & Associates Regd Surveyors & Consulting Engineers
SEPTEMBER 1963
Sheet 2 of 9 Sheets
456-2

From: [redacted]
To: Official Information [redacted]
Cc: [redacted]
Subject: RE: Stormwater - 60 Holborn Dr - OIR
Date: Tuesday, 13 September 2022 1:53:29 pm
Attachments: image001.png
image002.png
image003.jpg
Details - Group by Address.xlsx
image004.png

Hi team,

We have searched our archives in Tableau for the stormwater main on Holborn Drive (highlighted below). There were only two service requests that popped up (see attached).

[redacted] Can you please advise about the details and outcome of HCC437245, a job pre Wellington Water Alliance.

Kind Regards,

[redacted]
Customer Experience Team

Tel [redacted] Mob [redacted]
Private Bag 39804, Wellington Mail Centre 5045
Level 4, 25 Victoria Street, Petone, Lower Hutt
www.wellingtonwater.co.nz

From: [redacted]
Sent: Friday, 9 September 2022 6:37 pm
To: [redacted]
Cc: [redacted]
Subject: Stormwater - 60 Holborn Dr - OIR

[redacted] check in with [redacted] – she is already looking - cheers

[redacted]
Customer Planning Engineer - Wellington Water
Mob [redacted]

From: [redacted]
Sent: Friday, 9 September 2022 5:11 pm
To: [redacted]

[redacted]
[redacted] Official Information <official.information@wellingtonwater.co.nz>
Subject: RE: Stormwater - 60 Holborn Dr - OIR

Kia ora

Just looping in our Official Information Team into this thread.

[redacted] can you please check our records for any historical flooding reports?

Nga mihi

[redacted]

From: [redacted]
Sent: Friday, 9 September 2022 11:37 am
To: [redacted]
Cc: [redacted]
Subject: Stormwater - 60 Holborn Dr - OIR

Hi [redacted]

Can you please be aware of the OIR and HCC need our assistance. Can you recall flooding issues.

[redacted] can you please search the HCC CRM's for historic flooding (Holborn Drive)

[redacted] can you please arrange with urgency a comprehensive CCTV of both s/w lines and down the bank. It will be best if you (or Andrew Curry) are present so we can see first-hand the CCTV outcome.

[redacted]
Customer Planning Engineer - Wellington Water
Mob [redacted]

From: Derek Kerite <Derek.Kerite@huttcity.govt.nz>
Sent: Friday, 9 September 2022 11:03 am
To: [redacted]
Subject: Stormwater - 60 Holborn

Hi [redacted]

We have an urgent OIR we need your assistance with – the request is copied below.

"We also note that a storm water drain flows through the Property and down the hillside where the slip has occurred. We understand that in the past there has been flooding issues at the road level where the storm water drain discharges the water from above. Could you please advise what actions the Council has taken in the past (if any) in relation to that flooding? Please also advise if any investigation has been undertaken regarding the storm water drain to ensure there is no leakage of water from the drain which could have caused increased instability in the hillside around the slip."

Are you able to investigate and pass on any relevant information. We are on a tight timeframe so would appreciate a quick turnaround

Regards,
DK

Derek Kerite
Head of Regulatory Services

Hutt City Council, 30 Laings Road, Lower Hutt 5010
P: **M:** s7(2)(a) [redacted] **W:** www.huttcity.govt.nz

Susan Sales

From: Official Information
Sent: Wednesday, 28 September 2022 8:42 am
To: s7(2)(a) [redacted] Official Information
Subject: RE: HCC OIA- 60 Holborn Drive, Stokes Valley, Lower Hutt s7(2)(a) [redacted]

Morena s7(2)(a) [redacted]

Thank you for the update.

We will check in with s7(2)(a) [redacted] with regards to communication to HCC.

Nga mihi nui
s7(2)(a) [redacted]

From: s7(2)(a) [redacted]
Sent: Tuesday, 27 September 2022 1:28 pm
To: Official Information <official.information@wellingtonwater.co.nz>
Subject: FW: HCC OIA- 60 Holborn Drive, Stokes Valley, Lower Hutt s7(2)(a) [redacted]

Information relating to 60 Holborn Drive

From: s7 [redacted]
Sent: Thursday, 22 September 2022 8:15 am
To: s7(2)(a) [redacted]
Subject: FW: HCC OIA- 60 Holborn Drive, Stokes Valley, Lower Hutt s7(2)(a) [redacted]

Good morning s7(2)(a) [redacted]

Please find the email below from s7(2)(a) [redacted] as the latest correspondence concerning a request for information for 60 Holborn Drive in Stokes Valley.

Many thanks
s7(2)(a) [redacted]

From: s7(2)(a) [redacted]
Sent: Wednesday, 21 September 2022 3:54 pm
To: s7(2)(a) [redacted]
Cc: s7(2)(a) [redacted]
s7(2)(a) [redacted]
Subject: HCC OIA- 60 Holborn Drive, Stokes Valley, Lower Hutt s7(2)(a) [redacted]

Hi s7(2)(a) [redacted]

COG – Undertaking CCTV – hopefully this week

s7(2)(a) [redacted] has provided as-built plan (attached)

No information has been forwarded

s7(2)(a) [redacted]
Customer Planning Engineer - Wellington Water

Susan Sales

From: [redacted]
Sent: Friday, 23 September 2022 12:54 pm
To: [redacted]
Cc: [redacted]
Subject: RE: 60 Holborn Drive, Stokes Valley, Lower Hutt [redacted]

Morning [redacted]

I will look into it, the manhole is also buried so will have to locate it and dig it up 😊

Cheers

[redacted]

Wellington Water

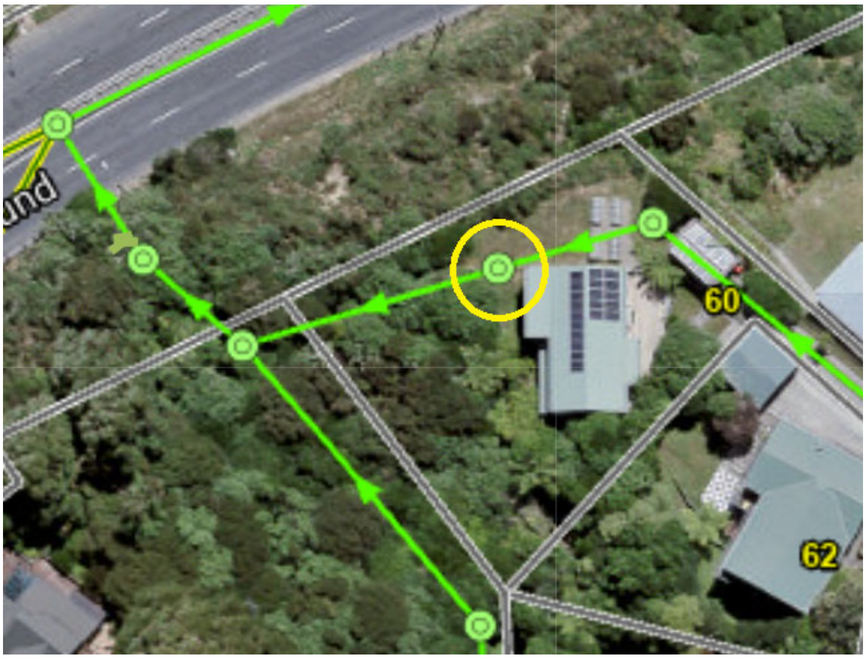
[redacted]

Private Bag 39804, Wellington Mail Centre 5045
Level 4, 25 Victoria Street, Petone, Lower Hutt
www.wellingtonwater.co.nz

From: [redacted]
Sent: Thursday, 22 September 2022 3:03 pm
To: [redacted]
Cc: [redacted]
Subject: 60 Holborn Drive, Stokes Valley, Lower Hutt ([redacted]

Hi [redacted]

Agree as you mention there is one fault with the benching in the first s/w manhole. How soon can we get a repair



[redacted]

Customer Planning Engineer - Wellington Water

[redacted]

From: [redacted]
Sent: Thursday, 22 September 2022 2:53 pm
To: [redacted]
Subject: HCC OIA- 60 Holborn Drive, Stokes Valley, Lower Hutt [redacted]

Hi [redacted]

CCTV completed the storm water pipe is without fault.

[redacted]

Customer Planning Engineer - Wellington Water

Mob [redacted]

From: [redacted]
Sent: Wednesday, 21 September 2022 3:54 pm
To: [redacted]
Cc: [redacted]
Subject: HCC OIA- 60 Holborn Drive, Stokes Valley, Lower Hutt [redacted]

H [redacted]

COG – Undertaking CCTV – hopefully this week

[redacted] has provided as-built plan (attached)

No information has been forwarded

[redacted]

Customer Planning Engineer - Wellington Water

s7(2)(a) [redacted]

From: s7(2)(a) [redacted]
Sent: Wednesday, 21 September 2022 1:27 pm
To: s7(2)(a) [redacted]
Cc: s7(2)(a) [redacted]
Subject: FW: HCC OIA- 60 Holborn Drive, Stokes Valley, Lower Hutt s7(2)(a) [redacted]

Hi s7(2)(a) [redacted]

Could we please discuss the request below concerning 60 Holborn Drive in SV, and whether you have been involved in this earlier.

Many thanks
s7(2)(a) [redacted]

From: s7(2)(a) [redacted]
Sent: Wednesday, 21 September 2022 11:47 am
To: s7(2)(a) [redacted]
s7(2)(a) [redacted]
s7(2)(a) [redacted]
Subject: RE: HCC OIA- 60 Holborn Drive, Stokes Valley, Lower Hutt s7(2)(a) [redacted]

Hi s7(2)(a) [redacted]

I am forwarding on to s7(2)(a) [redacted] and s7(2)(a) [redacted] to provide the information for this request.

Regards,
s7(2)(a) [redacted]

s7(2)(a) [redacted]
Chief Advisor, Stormwater & Climate Resilience
Network Development & Delivery
Wellington Water s7(2)(a) [redacted]

From: Official Information <official.information@wellingtonwater.co.nz>
Sent: Wednesday, 21 September 2022 11:42 am
To: s7 [redacted]
Cc: Official Information <official.information@wellingtonwater.co.nz>
Subject: FW: HCC OIA- 60 Holborn Drive, Stokes Valley, Lower Hutt s7(2)(a) [redacted])

Kia ora s7(2)(a) [redacted]

The HCC are seeking help from us for an urgent OIA request.

Can you please assist us with the following information, with regard to storm water drains?

Further to this matter, our clients have been made aware of a WSP New Zealand report that was prepared for Hutt City Council in 2015 that our clients understand assessed the slope hazard in Stokes Valley. We understand that WSP New Zealand was named Opus at the time the report was prepared.

Could you please provide request a copy of that report from your client and provide it to us?

Also, in our earlier letter dated 30 August 2022 we requested further information from Hutt City Council and understand that information will be provided in due course. One of our requests related to the storm water drain on our client's property. Our client now has more specific requests relating to the storm water drain, specifically:

- How deep the storm water drains are below the surface?
- Can copies of any construction records for the storm water system on the property be made available?
- Please provide any additional information on the storm water drains - seep stops etc.

Hopefully specifying the information will assist Hutt City Council staff in compiling their response to our earlier requests. In addition, on 22 July Hutt City Council had Drain Doctor inspect the storm water pipe that runs pretty much parallel to the slip. Could your client please provide a copy of the video taken by Drain Doctor?

We appreciate your help and look forward to hearing from you.

Nga mihi nui

s7(2)(a) [redacted]

From: Derek Kerite <Derek.Kerite@huttcity.govt.nz>
Sent: Thursday, 15 September 2022 1:15 pm
To: s7 [redacted]
Cc: Bradley Cato <Bradley.Cato@huttcity.govt.nz>; Paul Pugh <Paul.Pugh@huttcity.govt.nz>; Jon Kingsbury <Jon.Kingsbury@huttcity.govt.nz>
Subject: FW: [EXTERNAL] FW: 60 Holborn Drive, Stokes Valley, Lower Hutt s7(2)(a) [redacted]

Hi s7(2)(a) [redacted]

Further to my email on 9 September, there has been more information requested below in relation to drains in and around 60 Holborn Drive. We would like to respond as soon as possible, so would appreciate a quick response.

Regards,

s7(2)(g) [redacted]

Susan Sales

From: [redacted]
Sent: Friday, 23 September 2022 12:54 pm
To: [redacted]
Cc:
Subject: RE: 60 Holborn Drive, Stokes Valley, Lower Hutt [redacted]

Morning [redacted]

I will look into it, the manhole is also buried so will have to locate it and dig it up 😊

Cheers

[redacted]

Wellington Water

[redacted]

Private Bag 39804, Wellington Mail Centre 5045
Level 4, 25 Victoria Street, Petone, Lower Hutt
www.wellingtonwater.co.nz

From: [redacted]
Sent: Thursday, 22 September 2022 3:03 pm
To: [redacted]
Cc: [redacted]
Subject: 60 Holborn Drive, Stokes Valley, Lower Hutt [redacted])

Hi [redacted]

Agree as you mention there is one fault with the benching in the first s/w manhole. How soon can we get a repair

Susan Sales

From: rfs@huttcity.govt.nz
Sent: Friday, 22 July 2022 10:28 am
To: craig.ewart@huttcity.govt.nz; hcc Customer
Subject: Problem reported successfully

Thank you for bringing this issue/problem to our attention.

We will take the appropriate action to remedy this situation. Your request has been logged as an *Stormwater* with below details

Enquiry Number: *576505*

Current Status: *Call Logged*

Logged Date: *2022-07-22T10:28:12*

Subject: *SW-P1 Urgent Fault*

Description: *: Please camera the storm water main shown in photo 093201 for possible damage as a result of the landslip next to the man hole cover. Please forward all findings to Craig.Ewart@huttcity.govt.nz ph* s7(2)(a) [redacted] *- emailing photos to Customer ww*

Location: *60 Holborn Drive, STOKES VALLEY*

Site: *Holborn Drive*

Customer Contact Name: *Craig Ewert*

Customer Phone: s7(2)(a) [redacted]

Customer Alt Number:

Customer Email: *craig.ewart@huttcity.govt.nz*

Pin location picture:

Susan Sales

From: Official Information
Sent: Monday, 31 October 2022 11:53 am
To: s7(2)(a) [redacted]
Cc: Official Information
Subject: FW: HCC OIA- 60 Holborn Drive, Stokes Valley, Lower Hutt s7(2)(a) [redacted]

Hey s7(2)(a) [redacted]

Just letting you know, that s7(2)(a) [redacted] ended up providing the information to HCC.

Please refer to him for any further information.

Thanks
s7(2)(a) [redacted]

From: s7(2)(a) [redacted]
Sent: Friday, 30 September 2022 3:39 pm
To: Official Information <official.information@wellingtonwater.co.nz>
Subject: HCC OIA- 60 Holborn Drive, Stokes Valley, Lower Hutt s7(2)(a) [redacted]

Hi s7(2)(a) [redacted]

Information has been advised to HCC (Derek Kerite).
Please close out this OIA

s7(2)(a) [redacted]
Customer Planning Engineer - Wellington Water
s7(2)(a) [redacted]

From: Official Information <official.information@wellingtonwater.co.nz>
Sent: Wednesday, 28 September 2022 3:54 pm
To: s7 [redacted] Official Information <official.information@wellingtonwater.co.nz>
Subject: RE: HCC OIA- 60 Holborn Drive, Stokes Valley, Lower Hutt s7(2)(a) [redacted]

Hi s7(2)(a) [redacted]

Can you please confirm that you will be providing the remaining outstanding information to Derek and we will close this request off at our end?

We look forward to hearing from you.

Many Thanks
s7(2)(a) [redacted]

From: s7(2)(a) [redacted]
Sent: Wednesday, 28 September 2022 1:00 pm
To: Official Information <official.information@wellingtonwater.co.nz>
Subject: HCC OIA- 60 Holborn Drive, Stokes Valley, Lower Hutt s7(2)(a) [redacted]

Hi s7(2)(a) [redacted]

Wellington Water has CCTVéd the 225mm storm water main and found it to be fault free. This has been advised to HCC (Derek Kerite).

The as-built drawing (long section) would suggest the drain when laid, was approx 1m deep through No 60. Reference manhole 35, 36 & 37 through Lot 42 (No 60)

Construction techniques if such information exists, would be held with HCC as a subdivision file or similar. The drawings are dated 1963 so information may be scarce.

Request	Comment	Action
WSP report prepared for Hutt City Council in 2015 to assess the slope hazard	This report will likely be with HCC	HCC responsibility
How deep the storm water drains are below the surface?	Perhaps the as-built long section may provide or WWL can measure depth to invert	s7(2)(a) [redacted] – if you are able to locate an as-built
Can copies of any construction records for the storm water system on the property be made available?	Likely any construction records will be with HCC Perhaps a subdivision file or similar	HCC responsibility
Please provide any additional information on the storm water drains - seep stops etc.	May be something on the as-builts but if not then it will be assumed there are none	s7(2)(a) [redacted] – if you are able to locate an as-built
In addition, on 22 July Hutt City Council had Drain Doctor inspect the storm water pipe that runs pretty much parallel to the slip. Could your client please provide a copy of the video taken by Drain Doctor?	WWL did CCTV camera a small length of the drain but I have requested a full camera inspection including the portion of the drain down the slope as far as practical to camera.	s7(2)(a) [redacted] – can provide CCTV of the portion we have already CCTV inspected

s7(2)(a) [redacted]

Customer Planning Engineer - Wellington Water

[redacted] s7(2)(a) [redacted]

From: Official Information <official.information@wellingtonwater.co.nz>
Sent: Wednesday, 28 September 2022 9:07 am
To: s7(2)(a) [redacted]
Cc: Official Information <official.information@wellingtonwater.co.nz>
Subject: FW: HCC OIA- 60 Holborn Drive, Stokes Valley, Lower Hutt s7(2)(a) [redacted]

Morena s7(2)(a) [redacted]

Sorry for any confusion, as we appear to have been caught up in this request.

We understand that you have been dealing with this request and seek clarification, whether you will be providing all related information to Derek Kerite from HCC.

Can you please advise?

We look forward to hearing from you.

Nga mihi nui

s7(2)(a) [redacted]

LGOIMA Administration Assistant - Chief Executive's Office

Wellington Water

Private Bag 39804, Wellington Mail Centre 5045
Level 4, 25 Victoria Street, Petone, Lower Hutt

out of Scope
[redacted]

Susan Sales

From: [redacted]
Sent: Monday, 25 July 2022 12:41 pm
To: Craig.Ewart@huttcity.govt.nz
Cc: [redacted]
Subject: FW: 60 Holborn Drive

Afternoon [redacted],

Here is the CCTV footage of the stormwater main of 60 Holborn Drive,

Cheers

[redacted]

Wellington Water

[redacted]

Private Bag 39804, Wellington Mail Centre 5045
Level 4, 25 Victoria Street, Petone, Lower Hutt
www.wellingtonwater.co.nz

Wellington Water is owned by the Hutt, Porirua, Upper Hutt and Wellington city councils, South Wairarapa District Council and Greater Wellington Regional Council. We manage their drinking water, waste water and stormwater services.

From: Drain Doctor <office@draindoctor.co.nz>
Sent: Monday, 25 July 2022 12:05 pm
To: [redacted]
Subject: 60 Holborn Drive

Hi [redacted]

Please see link for cctv footage.

https://youtu.be/ZAp_rg1jhcM

- YouTube

and share it all with friends, family, and the world on YouTube.

youtu.be

Kind Regards

Susan Sales

From: [redacted]
Sent: Tuesday, 18 October 2022 12:09 pm
To: Bradley Cato; Jekkie Suwanposee
Cc: [redacted]
Subject: 60 Holborn Drive, Stokes Valley, Lower Hutt [redacted]) - a copy of video of the drain

Hi Brad

Will be delivered this afternoon to your council customer service desk

[redacted]
Customer Planning Engineer - Wellington Water
[redacted] [redacted]

From: Bradley Cato <Bradley.Cato@huttcity.govt.nz>
Sent: Monday, 17 October 2022 2:51 pm
To: Jekkie Suwanposee <Jekkie.Suwanposee@huttcity.govt.nz>; [redacted]
Subject: RE: [EXTERNAL] 60 Holborn Drive, Stokes Valley, Lower Hutt [redacted]) - a copy of video of the drain

Hi john – just checking if the below has been dropped off?

Regards
Brad

Bradley Cato
Chief Legal Officer

Hutt City Council, 30 Laings Road, Lower Hutt 5010
P: M: [redacted] **W:** www.huttcity.govt.nz

HUTT CITY
TE AWA KAIRANGI

From: [redacted]@wellingtonwater.co.nz>
Sent: Thursday, 13 October 2022 3:41 PM
To: Jekkie Suwanposee <Jekkie.Suwanposee@huttcity.govt.nz>
Cc: [redacted]@wellingtonwater.co.nz>
Subject: [EXTERNAL] 60 Holborn Drive, Stokes Valley, Lower Hutt [redacted]) - a copy of video of the drain

Hi Jekkie

The CCTV footage is on a USB stick. Happy to drop this to your council reception desk

[redacted]

Customer Planning Engineer - Wellington Water

[redacted]

From: Jekkie Suwanposee <Jekkie.Suwanposee@huttcity.govt.nz>
Sent: Wednesday, 12 October 2022 3:28 pm
To: [redacted]
Cc: Derek Kerite <Derek.Kerite@huttcity.govt.nz>; Bradley Cato <Bradley.Cato@huttcity.govt.nz>
Subject: RE: [EXTERNAL] 60 Holborn Drive, Stokes Valley, Lower Hutt [redacted]) - a copy of video of the drain

Hi [redacted]
On behalf of Derek Kerite, can we please have a copy of the video of the drains from your company?
Please let us know when you want us to come to collect it.
Many thanks.

Cheers

Jekkie

Jekkie Suwanposee
Team Coordinator

Hutt City Council, 30 Laings Road, Lower Hutt 5040
P: [redacted] M: [redacted] W: www.huttcity.govt.nz

From: s7 [redacted]
Sent: Friday, 30 September 2022 3:37 PM
To: Derek Kerite <Derek.Kerite@huttcity.govt.nz>
Subject: [EXTERNAL] 60 Holborn Drive, Stokes Valley, Lower Hutt s7(2)(a) [redacted])

Hi Derek – an update and close off from Wellington Water.

As advised, Wellington Water CCTVéd the 225mm storm water main and found it to be without fault.

The as-built drawing (long section) would suggest when laid, the drain was approx 1m deep through No 60. Reference manhole 35, 36 & 37 through Lot 42 (No 60).

Attached as-builts of the public SW.
Plan S2350 - is the plan drawing. Plan has Lot numbers. No 60 Holborn is Lot 42
Plan S2357 - has long section for SW line 8, which runs around the back of no 60 Holborn.
Plan S2356 - has long section for SW line 6, down to Eastern Hutt Rd

These are typical as-builts from the 1960's and don't have much detail. No construction techniques shown on the drawings.

Construction techniques if such information exists, would be held with HCC as a subdivision file or similar. The drawings are dated 1960's so information may be scarce.

Request	Comment	Action
WSP report prepared for Hutt City Council in 2015 to assess the slope hazard	This report will likely be with HCC	HCC responsibility
How deep the storm water drains are below the surface?	Perhaps the as-built long section may provide or WWL can measure depth to invert	as-built attached
Can copies of any construction records for the storm water system on the property be made available?	Likely any construction records will be with HCC Perhaps a subdivision file or similar	HCC responsibility
Please provide any additional information on the storm water drains - seep stops etc.	May be something on the as-builts but if not then it will be assumed there are none	No construction detail on the as-built
In addition, on 22 July Hutt City Council had Drain Doctor inspect the storm water pipe that runs pretty much parallel to the slip. Could your client please provide a copy of the video taken by Drain Doctor?	WWL did CCTV camera a small length of the drain a full camera inspection including the portion of the drain down the slope required.	CCTV inspection completed by Wellington Water. Results advised to HCC.

s7(2)(a) [redacted]

Customer Planning Engineer - Wellington Water

[redacted] s7(2)(a) [redacted]

Out of Scope [redacted]

Susan Sales

From: [redacted]
Sent: Friday, 23 September 2022 1:45 pm
To: [redacted]
Cc: [redacted]
Subject: 60 Holborn Drive, Stokes Valley, Lower Hutt [redacted]

Hi [redacted]

55m from your entry manhole

[redacted]

Customer Planning Engineer - Wellington Water

[redacted] [redacted]

From: [redacted]
Sent: Friday, 23 September 2022 12:54 pm
To: [redacted]
Cc: [redacted]
Subject: RE: 60 Holborn Drive, Stokes Valley, Lower Hutt [redacted]

Morning [redacted]

I will look into it, the manhole is also buried so will have to locate it and dig it up 😊

Cheers

[redacted] [redacted]

Wellington Water

[redacted]

Private Bag 39804, Wellington Mail Centre 5045
Level 4, 25 Victoria Street, Petone, Lower Hutt

www.wellingtonwater.co.nz

From: [redacted]
Sent: Thursday, 22 September 2022 3:03 pm
To: [redacted]
Cc: [redacted]
Subject: 60 Holborn Drive, Stokes Valley, Lower Hutt [redacted]

Hi Ray

Agree as you mention there is one fault with the benching in the first s/w manhole. How soon can we get a repair

address	council_name	water_type	request_id	comm_description	Day of created	status	Priority	allocation	responsible_user	details	Data_Source
Eastern hutt rd, lower hutt, 5019	HCC	Stormwater	HCC578426	Instructed Works	09 Aug 2022	30 in progress	P4	007-LOWH-SW-RETC	Anon .	Instructed Works Eastern Hutt Road	Maximo

Susan Sales

From: s7(2)(a) [redacted]
Sent: Wednesday, 3 November 2021 9:15 am
To: s7(2)(a) [redacted]
Subject: FW: WW:VHCA – PHI -→ Further to the discussion yesterday re providing a spreadsheet to show progress.
Attachments: Wellington Water - Tracker 2021.10.29.xlsx

Importance: High

Hi s7(2)(a) [redacted] got this attachment yesterday – it will help for your presentation tomorrow – we may need s7(2)(a) [redacted] s7(2)(a) [redacted] to walk us through it.

s7(2)(a) [redacted]

Wellington Water: VHCA - PHI

Summary Status report on GIS/Shapefile meters

Gravity Pipe Asset Inspection Summary

		Wastewater (m)				*Stormwater (m)*				*To*	
		P1	*P2 & P3*	*Total*	*%*	*P1*	*P2 & P3*	*Total*	*%*	*P1*	*P1 %*
1	Original Scope - P1	33,900		33,900	38%	55,600		55,600	62%	89,500	
1.1	Current Scope - P1-P3 (as of Sept 21)	28,057	53,563	81,620	52%	55,667	18,613	74,280	48%	83,724	
2	Visited in the field (P1 - P3 & other)	20,021	18,049	38,071	47%	50,157	23,522	73,678	99%	70,178	84%
3	Unable to be completed without significant work (on hold/removed by client) - P1-P3	3,739	-	3,739	5%	4,936	1,042	5,978	8%	8,675	10%
4	Escalated for civil works to be undertaken before revisiting	5,251	938	6,189	8%	16,007	2,632	18,639	25%	21,257	25%
5	Successfully surveyed in the field - (P1 - P3 & other)	11,031	17,111	28,142	34%	29,214	19,848	49,062	66%	40,245	48%
6	Batched and submitted (GIS length)	9,290	4,868	14,159	17%	28,654	861.17	29,515	40%	37,944	45%
	Batches submitted (Surveyed m)	9178	5082	14260	0	24772	878	25649	0	33950	
7	P1 meters still to visit	8,077		8,077	29%	5,307		5,307	10%	13,385	16%

From: s7(2)(a) [redacted]
Sent: Tuesday, 2 November 2021 5:08 pm
To s7(2)(a) [redacted]
Cc s7(2)(a) [redacted]
Subject: FW: WW:VHCA – PHI -◊ Further to the discussion yesterday re providing a spreadsheet to show progress.

Intergroup progress update

Ngā Mihi

s7(2)(a) [redacted]

CPEng CMEngNZ IntPE(NZ)

s7(2)(a) [redacted]

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Level 3, GHD Centre, 27 Napier St, Freemans Bay, Auckland 1011
s7(2)(a) [redacted]

Connect

From s7(2)(a) [redacted]
Sent: Tuesday, 2 November 2021 4:43 pm
To: s7(2)(a) [redacted]
Cc s7(2)(a) s7(2)(a) [redacted]
Subject: WW:VHCA – PHI -◊ Further to the discussion yesterday re providing a spreadsheet to show progress.

Hi s7(2)(a) [redacted]

Please find attached a spreadsheet to show InterGroup's progress in the gravity asset scope up to the end of last week, as per discussion at yesterday's meeting.

Please note that it is a work in progress, showing only a snapshot in time with sections that still need to be fully updated, so it is to be used only as a high level summary of work to date.

Please let me know if you have any queries.

Kind Regards,
s7(2)(a) [redacted]
Project Manager – Wellington Water Project

INTERGROUP

s7(2)(a) [redacted]
Physical: 191 Gracefield Rd, Lower Hutt, Wellington
Postal: P.O.Box 39005, Wellington Mail Centre Postal P.O.Box 39005, Wellington Mail Centre