

# Appendix A

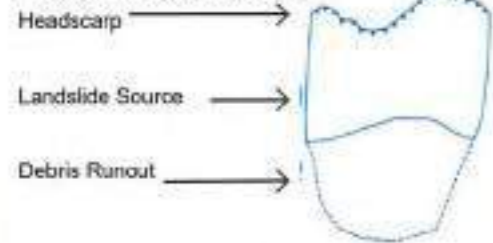
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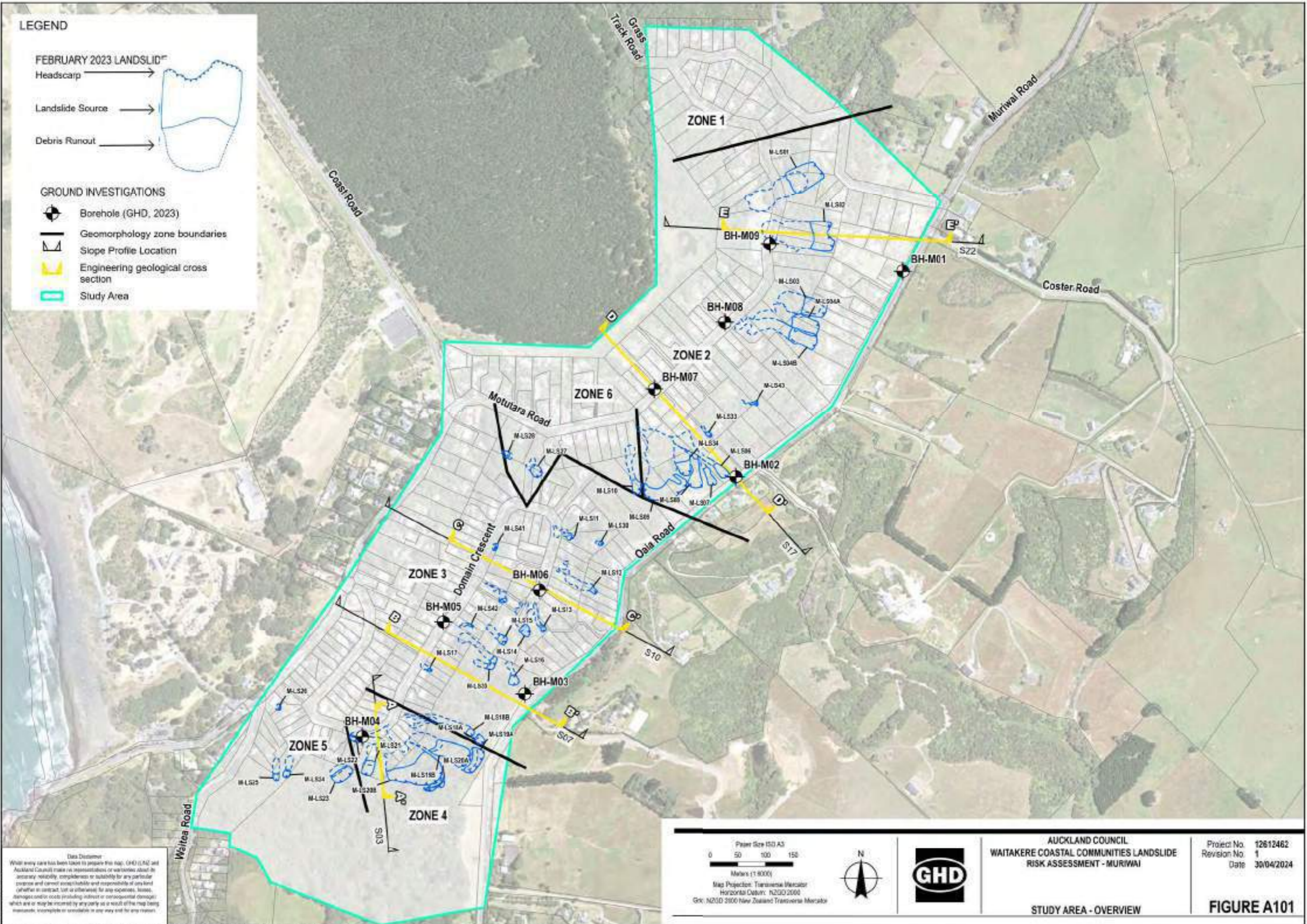
**LEGEND**

**FEBRUARY 2023 LANDSLID<sup>1</sup>**



**GROUND INVESTIGATIONS**

- Borehole (GHD, 2023)
- Geomorphology zone boundaries
- Slope Profile Location
- Engineering geological cross section
- Study Area



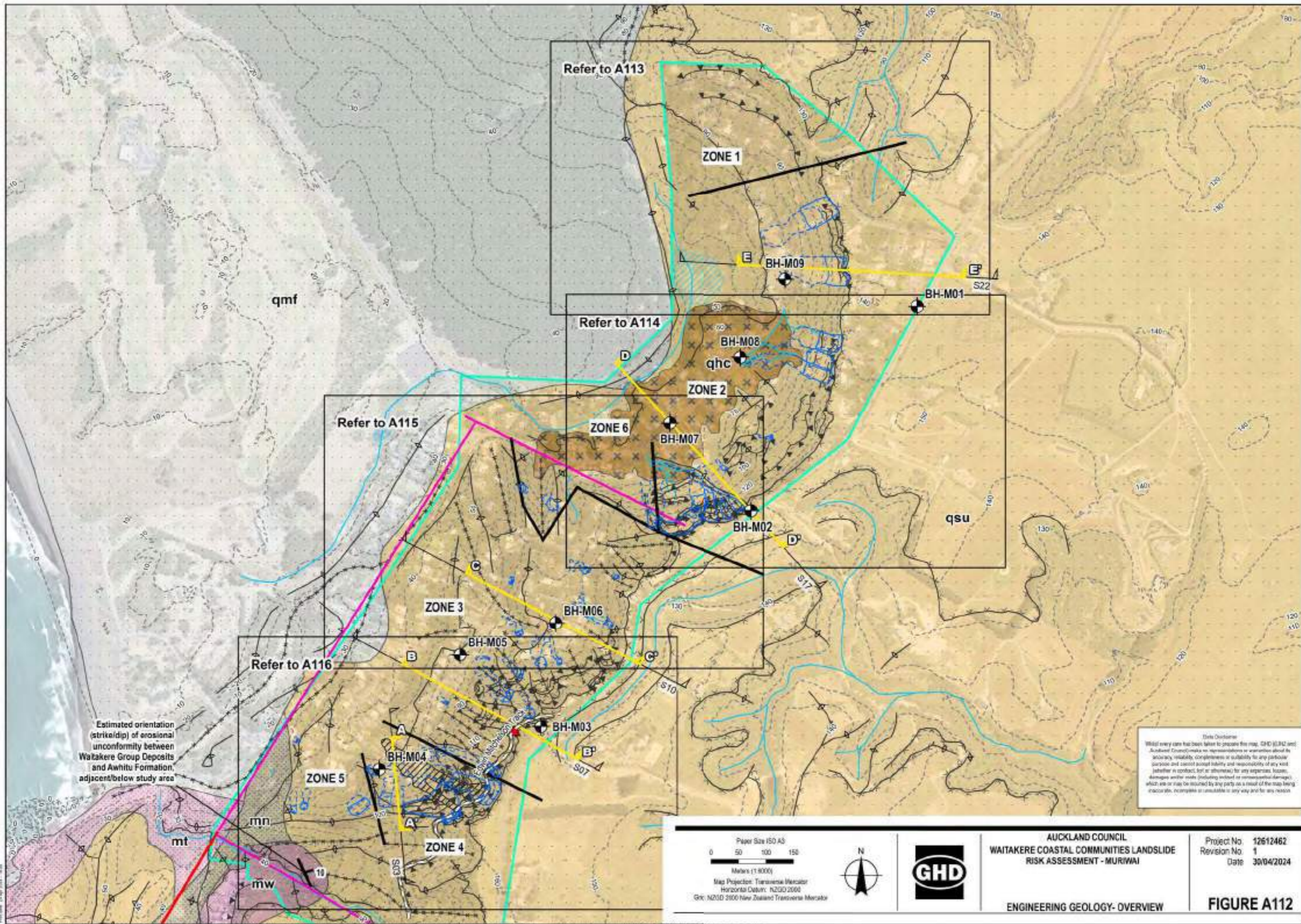
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**WAITAKERE COASTAL COMMUNITIES LANDSLIDE**  
**RISK ASSESSMENT - MURIWAI**

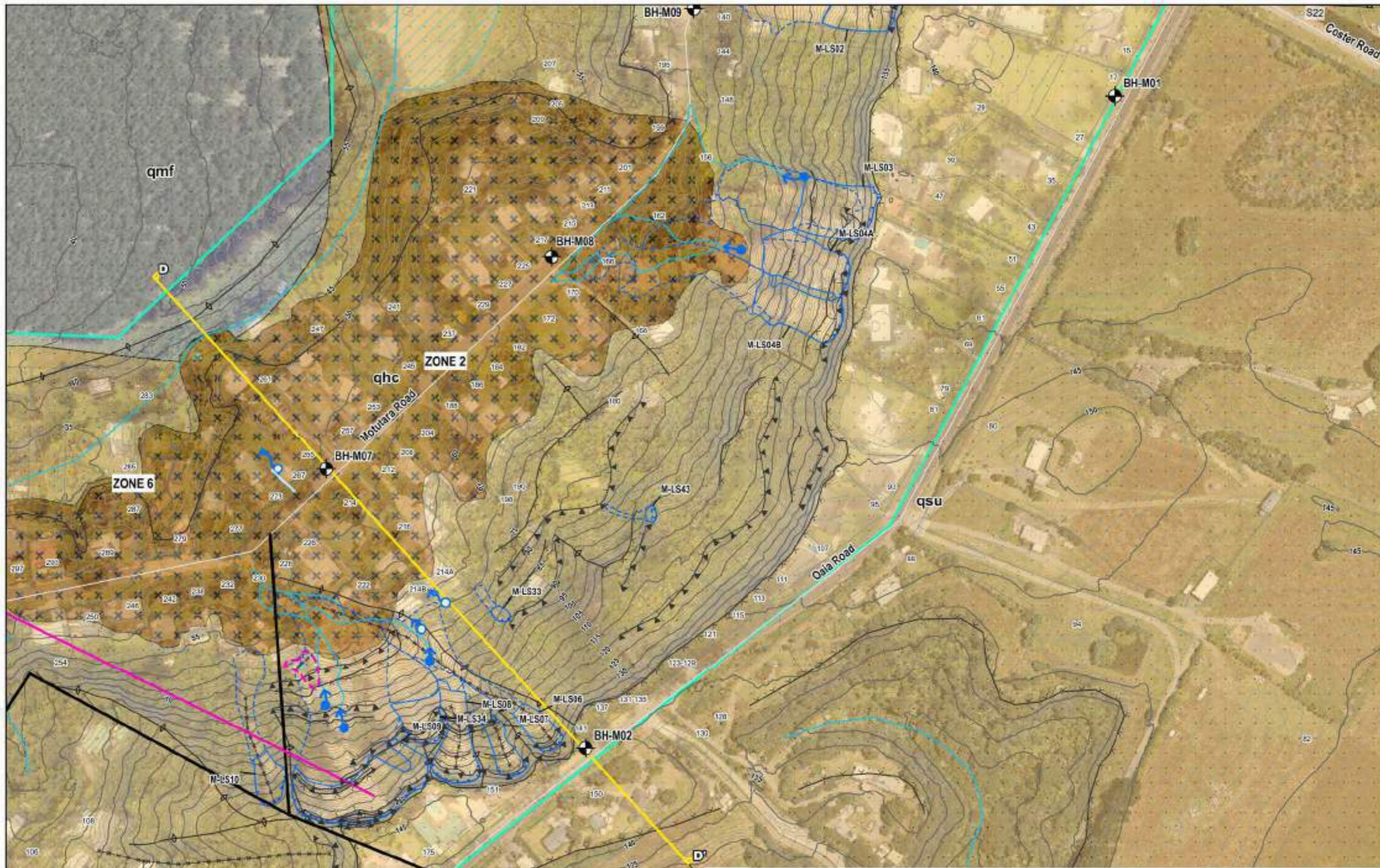
Project No. 12612482  
 Revision No. 1  
 Date 30/04/2024





Data source: World Imagery, Auckland Council, NZL, NZL, Papanui Road, Auckland Council, Address/Planning/Technical, Auckland Council, GHD - Landline, Yellowknife, Western Bankline, Inferred fault, Cemented benches, Structural and geomorphological features, Client/Whitaker File Log, Cross section, seismics, Map.gis, Site sketch 02/2011, GIS - Geopoints, Creativity online  
 File name: 25\_04\_2024\_15:28





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**ENGINEERING GEOLOGY -**  
**CLOSE-UP 2**

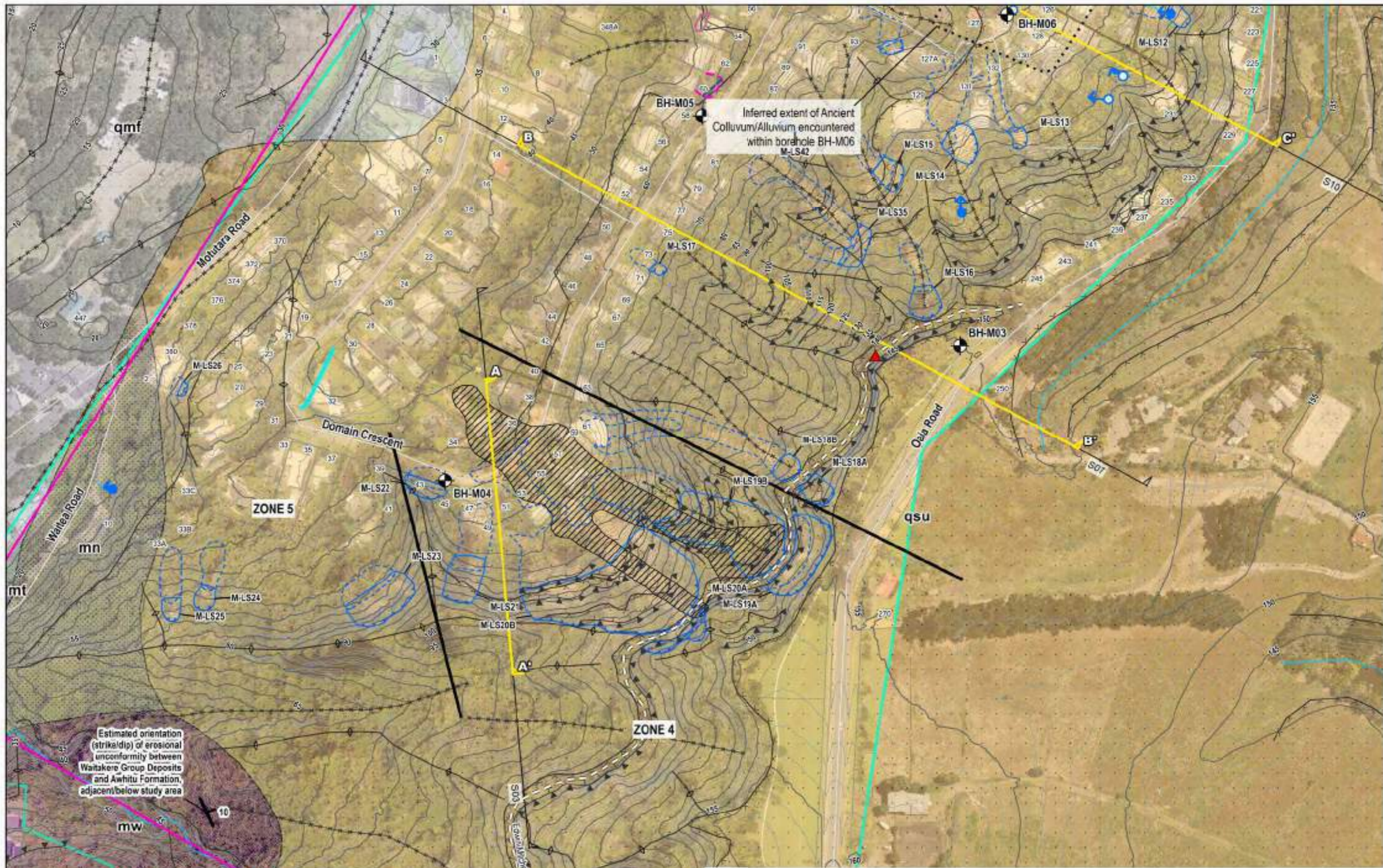
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**FIGURE A114**

Waitakere Coastal Communities Landslide Risk Assessment - Muriwai  
 Project No. 12612482  
 Revision No. 1  
 Date 30/04/2024  
 GHD (L)td  
 Auckland Council  
 Engineering Geology  
 Close-up 2  
 Figure A114







Estimated orientation (strike/dip) of erosional unconformity between Waitakere Group Deposits and Awhitu Formation, adjacent/below study area

Inferred extent of Ancient Colluvium/Alluvium encountered within borehole BH-M06 M-LS42

ZONE 5

ZONE 4

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 Horizontal Datum: NZGD 2000  
 GCS: NZGD 2000 New Zealand Transverse Mercator



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 WAITAKERE COASTAL COMMUNITIES LANDSLIDE  
 RISK ASSESSMENT - MURIWAI

Project No. 12612482  
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ENGINEERING GEOLOGY -  
 CLOSE-UP 4

FIGURE A116

Data source: NZ Imagery, Light Technology Ltd (Information New Zealand), GNSC Community maps (contours, L&D - Parcel, Road, Kubatua Quay), AddressPoint number (parcel data), GHD - Topographic, Landline, Watercourse, Machine Footprint, Infrastructure, oriented (fences, structures and geomorphological features), Open Metadata (air photo, soil, water, services, infrastructure, geology etc.). Created by: [unreadable]



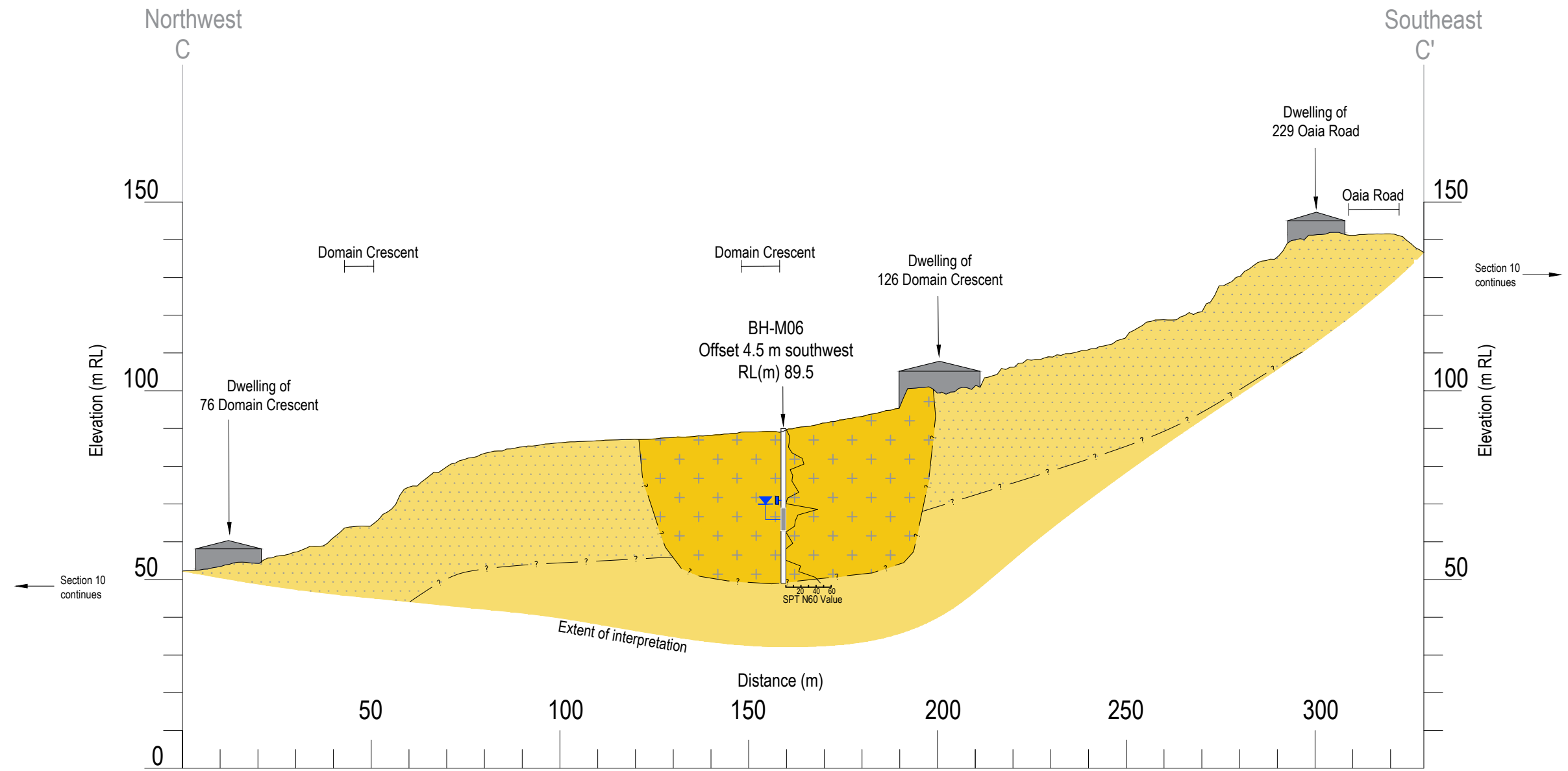


**LEGEND**

|  |   |  |   |
|--|---|--|---|
|  | FILL  |  | INFERRED GEOLOGICAL UNIT BOUNDARY                             |
|  | RECENT COLLUVIUM - POST-2023 LANDSLIDE EVENTS           |  | BOREHOLE TRACE  |
|  | INFERRED ANCIENT HISTORICAL COLLUVIAL/ALLUVIAL DEPOSITS |  | MEASURED GROUNDWATER DIP 28/08/2023 - 29/08/2023              |
|  | MITIWAI SAND FORMATION: AEOLIAN DUNE SANDS              |  | RANGE IN TELEMETERED GROUNDWATER DATA 19/10/2023 - 22/03/2024 |
|  | AWHITU SAND FORMATION: SILT/CLAY*                       |  | PIEZOMETER SCREEN DEPTH                                       |
|  | AWHITU SAND FORMATION: ORGANIC SOIL/PEAT*               |  |   |
|  | AWHITU SAND FORMATION: LESS CEMENTED SAND SPT = <50     |  |   |
|  | AWHITU SAND FORMATION: MORE CEMENTED SAND SPT = 50+     |  |   |
|  | NIHOTUPU FORMATION: SILT/CLAY                           |  |   |

**NOTES**

VERTICAL AND HORIZONTAL SCALE - 1:1  
 BH-M06 - INFERRED ANCIENT HISTORICAL COLLUVIAL/ALLUVIAL DEPOSITS - UNKNOWN LATERAL EXTENT  
 DEPTH OF LESS CEMENTED AWHITU SAND FORMATION INFERRED FROM BOREHOLE DATA AND APPROXIMATED TO TOPOGRAPHICAL SURFACE  
 FOR FURTHER DISCUSSION ON THE ANCIENT COLLUVIUM/ALLUVIUM PLEASE SEE SECTION 4.3 IN APPENDIX B  
 LIMITED INVESTIGATION DATA AVAILABLE, AS SUCH GROUNDWATER SURFACE HAS NOT BEEN INTERPOLATED BETWEEN BOREHOLES



|                     |          |
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**GHD**  
 Level 3, GHD Centre  
 27 Napier Street, Freemans Bay  
 Auckland 1011 New Zealand  
 T 64 9 370 8000 F 64 9 370 8001  
 E akimail@ghd.com W www.ghd.com



Client AUCKLAND COUNCIL

Project WAITAKERE COASTAL COMMUNITIES LANDSLIDE RISK ASSESSMENT - MURIWAI

Status FINAL

Project No. 12576144

Status Code S4















Drawing Title MURIWAI CROSS SECTIONS SECTION C-C' (S10)

Size A1

APPENDIX A122

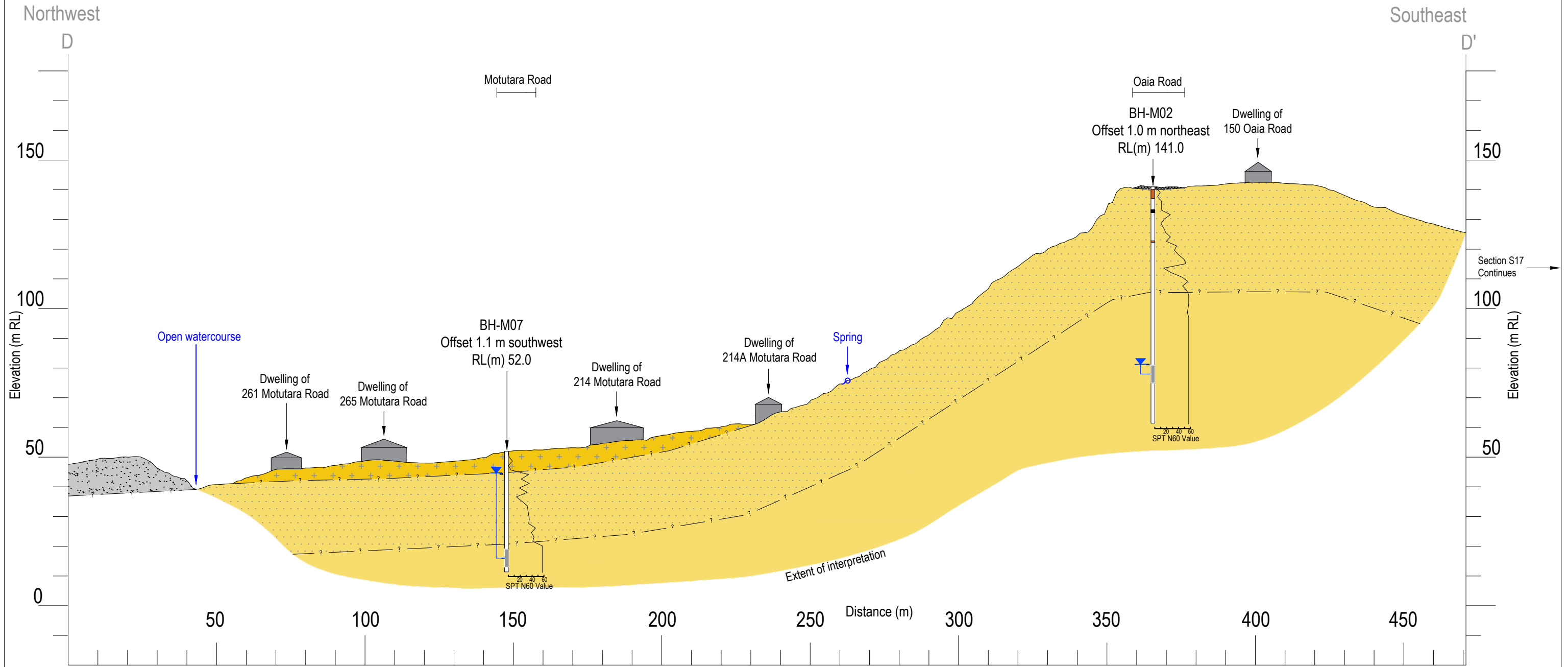
Rev 01

**LEGEND**

|   |   |   |   |
|---|---|---|---|
|  | FILL  |  | INFERRED GEOLOGICAL UNIT BOUNDARY                             |
|  | RECENT COLLUVIUM - POST-2023 LANDSLIDE EVENTS           |  | BOREHOLE TRACE  |
|  | INFERRED ANCIENT HISTORICAL COLLUVIAL/ALLUVIAL DEPOSITS |  | MEASURED GROUNDWATER DIP 28/08/2023 - 29/08/2023              |
|  | MITIWAI SAND FORMATION: AEOLIAN DUNE SANDS              |  | RANGE IN TELEMETERED GROUNDWATER DATA 19/10/2023 - 22/03/2024 |
|  | AWHITU SAND FORMATION: SILT/CLAY*                       |  | PIEZOMETER SCREEN DEPTH                                       |
|  | AWHITU SAND FORMATION: ORGANIC SOIL/PEAT*               |   |   |
|  | AWHITU SAND FORMATION: LESS CEMENTED SAND SPT = <50     |   |   |
|  | AWHITU SAND FORMATION: MORE CEMENTED SAND SPT = 50+     |   |   |
|  | NIHOTUPU FORMATION: SILT/CLAY                           |   |   |

**NOTES**

VERTICAL AND HORIZONTAL SCALE - 1:1  
 DEPTH OF LESS CEMENTED AWHITU SAND FORMATION INFERRED FROM BOREHOLE DATA AND APPROXIMATED TO TOPOGRAPHICAL SURFACE  
 LIMITED INVESTIGATION DATA AVAILABLE, AS SUCH GROUNDWATER SURFACE HAS NOT BEEN INTERPOLATED BETWEEN BOREHOLES



|                     |            |
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**GHD**  
 Level 3, GHD Centre  
 27 Napier Street, Freemans Bay  
 Auckland 1011 New Zealand  
 T 64 9 370 8000 F 64 9 370 8001  
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Project: WAITAKERE COASTAL COMMUNITIES LANDSLIDE RISK ASSESSMENT - MURIWAI

Status: FINAL

Drawing Title: MURIWAI CROSS SECTIONS CROSS SECTION D-D' (S17)

APPENDIX A123

Size: A1

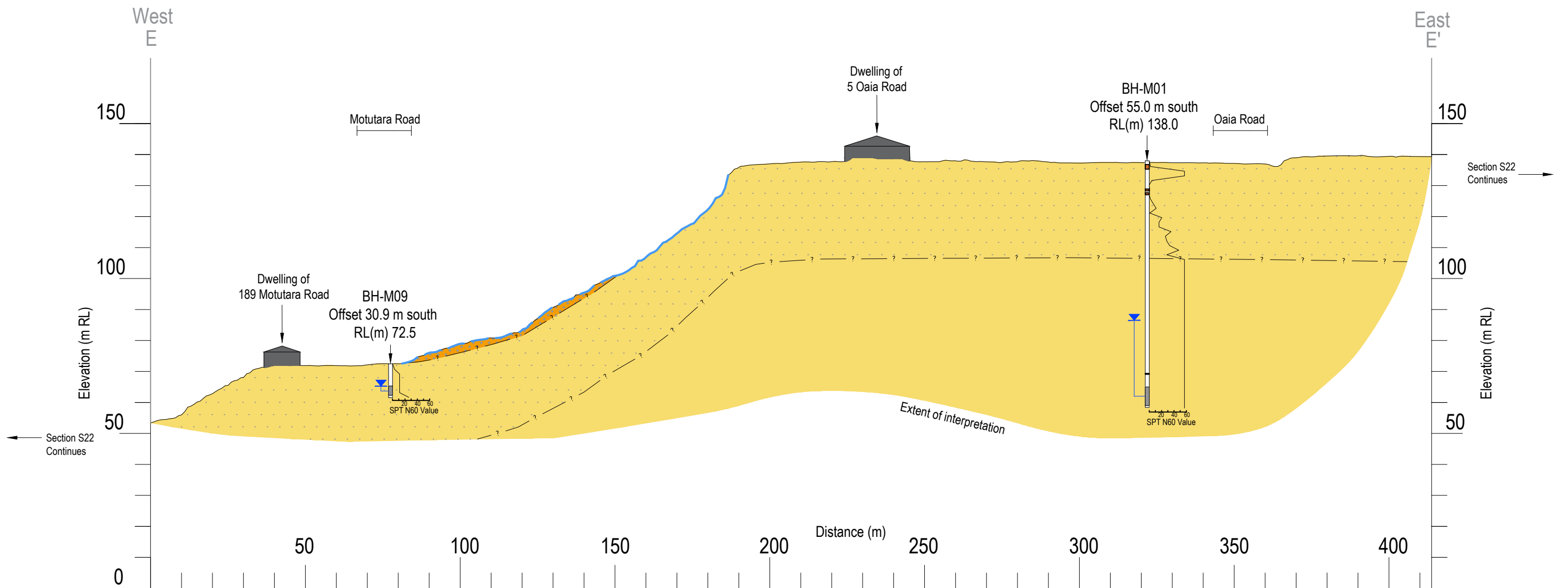
Rev: 01

**LEGEND**

|  |   |  |  |
|--|---|--|--|
|  | FILL  |  | INFERRED GEOLOGICAL UNIT BOUNDARY                        |
|  | RECENT COLLUVIUM - POST-2023 LANDSLIDE EVENTS           |  | APPROXIMATE EXTENT OF LANDSLIDE M-LS02 DEPLETION ZONE    |
|  | INFERRED ANCIENT HISTORICAL COLLUVIAL/ALLUVIAL DEPOSITS |  | APPROXIMATE EXTENT OF LANDSLIDE M-LS02 ACCUMULATION ZONE |
|  | MITIWAI SAND FORMATION: AEOLIAN DUNE SANDS              |  | BOREHOLE TRACE   |
|  | AWHITU SAND FORMATION: SILT/CLAY*                       |  | MEASURED GROUNDWATER DIP 17/04/2024                      |
|  | AWHITU SAND FORMATION: ORGANIC SOIL/PEAT*               |  | PIEZOMETER SCREEN DEPTH                                  |
|  | AWHITU SAND FORMATION: LESS CEMENTED SAND SPT = <50     |  |  |
|  | AWHITU SAND FORMATION: MORE CEMENTED SAND SPT = 50+     |  |  |
|  | NIHOTUPU FORMATION: SILT/CLAY                           |  |  |

**NOTES**

VERTICAL AND HORIZONTAL SCALE - 1:1  
 DEPTH OF LESS CEMENTED AWHITU SAND FORMATION INFERRED FROM BOREHOLE DATA AND APPROXIMATED TO TOPOGRAPHICAL SURFACE  
 REFER TO APPENDIX B, SECTION B4.3.1 'DATA LIMITATIONS' REGARDING POSSIBLE ERROR IN CONTINUOUS READINGS FROM PIEZOMETERS BH-M01 AND BH-M09. THUS, SINGLE READING VALUES HAVE BEEN ILLUSTRATED BELOW



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 Level 3, GHD Centre  
 27 Napier Street, Freemans Bay  
 Auckland 1011 New Zealand  
 T 64 9 370 8000 F 64 9 370 8001  
 E akimail@ghd.com W www.ghd.com



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 Status: FINAL  
 Project No: 12612462  
 Status Code: S4

Drawing Title: MURIWAI CROSS SECTIONS CROSS SECTION E-E' (S22)  
 Drawing No: APPENDIX A124  
 Rev: 01

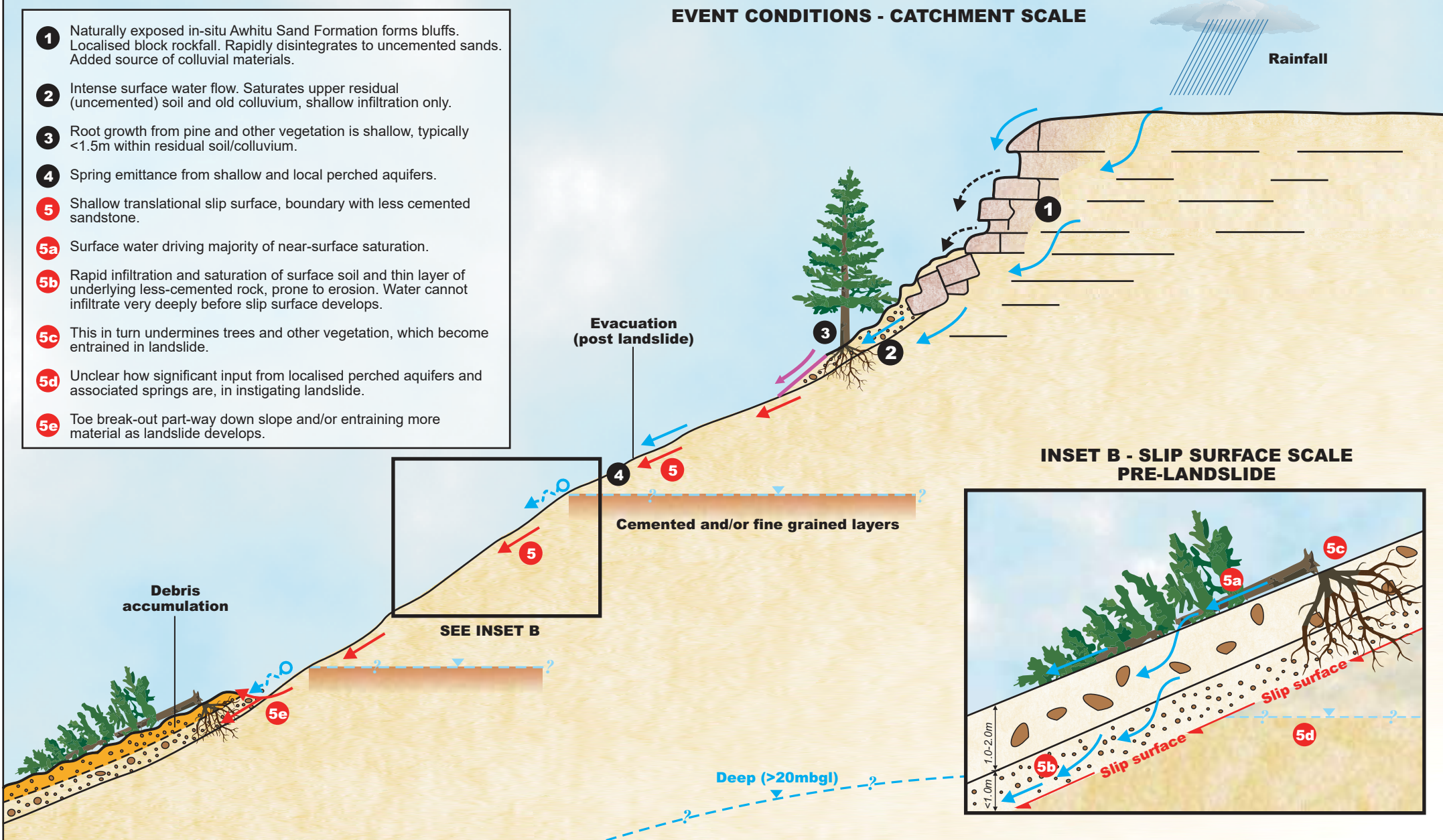






## EVENT CONDITIONS - CATCHMENT SCALE

- 1 Naturally exposed in-situ Awhitu Sand Formation forms bluffs. Localised block rockfall. Rapidly disintegrates to uncemented sands. Added source of colluvial materials.
- 2 Intense surface water flow. Saturates upper residual (uncemented) soil and old colluvium, shallow infiltration only.
- 3 Root growth from pine and other vegetation is shallow, typically <1.5m within residual soil/colluvium.
- 4 Spring emittance from shallow and local perched aquifers.
- 5 Shallow translational slip surface, boundary with less cemented sandstone.
- 5a Surface water driving majority of near-surface saturation.
- 5b Rapid infiltration and saturation of surface soil and thin layer of underlying less-cemented rock, prone to erosion. Water cannot infiltrate very deeply before slip surface develops.
- 5c This in turn undermines trees and other vegetation, which become entrained in landslide.
- 5d Unclear how significant input from localised perched aquifers and associated springs are, in instigating landslide.
- 5e Toe break-out part-way down slope and/or entraining more material as landslide develops.



### LEGEND

- Residual soil and old colluvium
- Less cemented Awhitu Group Sands (N = <50+)
- Strata
- Slip surface
- Isolated rock fall
- Regional groundwater profile
- Perched aquifer
- Water flow
- Surface spring
- Headscarp

Conceptual diagram only -  
not to scale



AUCKLAND COUNCIL  
WAITAKERE COASTAL COMMUNITIES LANDSLIDE RISK ASSESSMENT

Project No. 12612462  
Revision No. 01  
Date 30/04/2024

2023 CYCLONE GABRIELLE LANDSLIDE MECHANISM MODEL, MURIWAI

FIGURE A127



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**GHD**  
 138 Victoria Street, Level 3,  
 Christchurch Central, Canterbury 8013, New Zealand  
 T +64 33780900 F +64 33778575  
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 MURIWAI**

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Drawing Title  
**2023 CYCLONE GABRIELLE  
 LANDSLIDE MECHANISM MODEL,  
 MURIWAI - PHOTO MARK-UP**

Status Code  
**S4**

Drawing No.  
**APPENDIX A128**

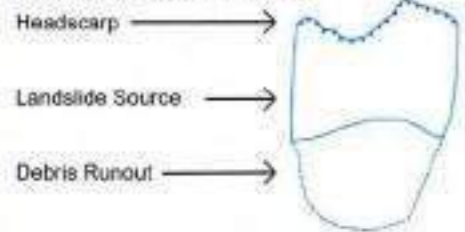
Size  
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Rev  
**0**

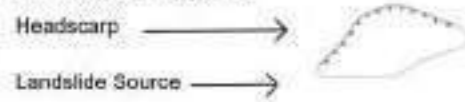
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**LEGEND**

**FEBRUARY 2023 LANDSLIDE**



**INFERRED LANDSLIDE**

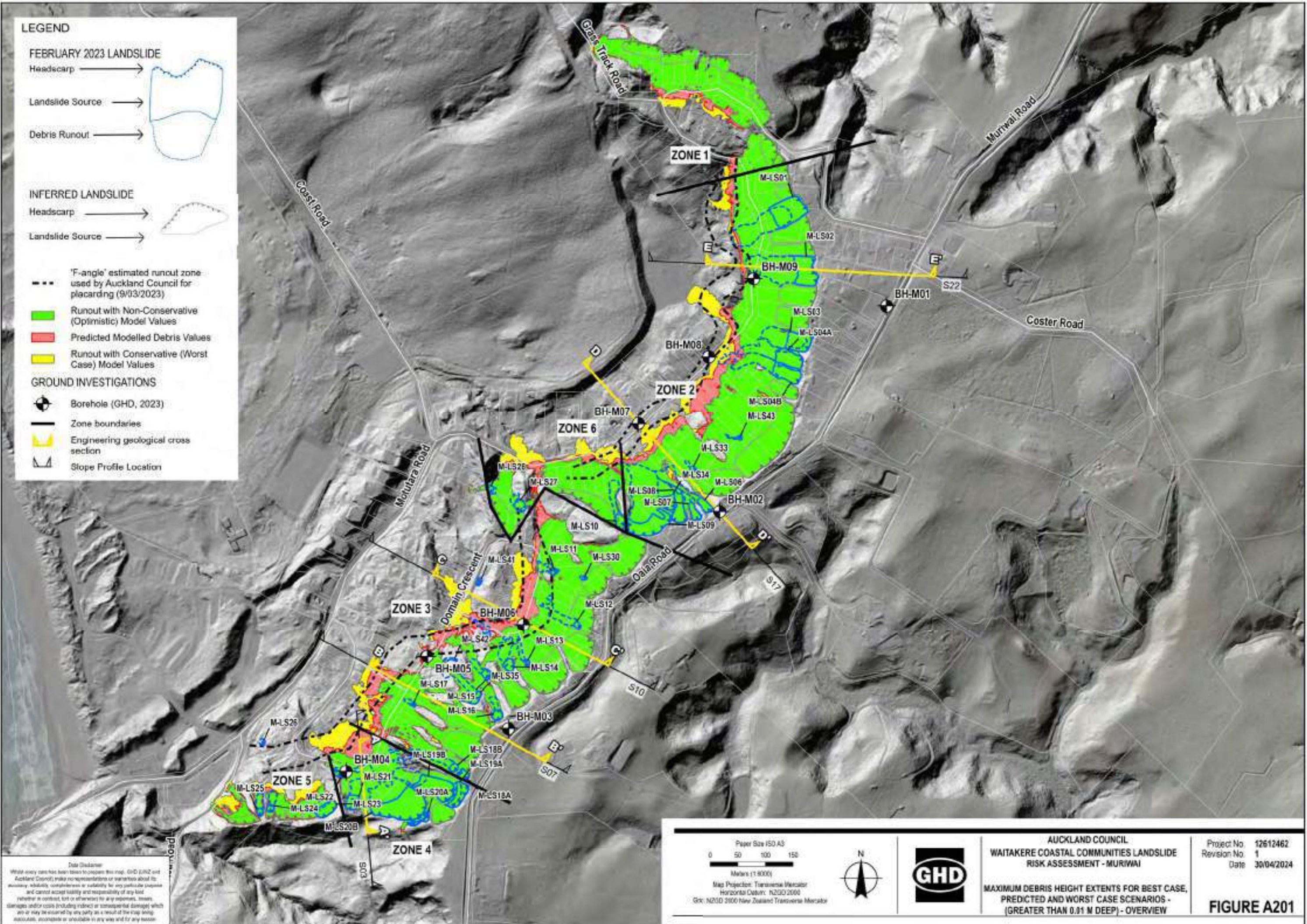


--- 'F-angle' estimated runout zone used by Auckland Council for placarding (9/03/2023)

- Runout with Non-Conservative (Optimistic) Model Values
- Predicted Modelled Debris Values
- Runout with Conservative (Worst Case) Model Values

**GROUND INVESTIGATIONS**

- Borehole (GHD, 2023)
- Zone boundaries
- Engineering geological cross section
- Slope Profile Location



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 Grid: NZGD 2000 New Zealand Transverse Mercator



|   |  |
|---|--|
| <p><b>AUCKLAND COUNCIL</b><br/>                 WAITAKERE COASTAL COMMUNITIES LANDSLIDE<br/>                 RISK ASSESSMENT - MURIWAI</p>                                      | <p>Project No 12612462<br/>                 Revision No 1<br/>                 Date 30/04/2024</p> |
| <p><b>MAXIMUM DEBRIS HEIGHT EXTENTS FOR BEST CASE,<br/>                 PREDICTED AND WORST CASE SCENARIOS -<br/>                 (GREATER THAN 0.31 M DEEP) - OVERVIEW</b></p> |  |
| <p><b>FIGURE A201</b></p>   |  |

Data source: World Imagery Auckland Council; Near: LPS; From: Road Auckland Council; 'F-angle' GHD; Inferred Landslide: February Landslide; RAMS Landslide Predictor; 2023/24; Contact: i@ac.govt.nz

**LEGEND**

**FEBRUARY 2023 LANDSLIDE**

Headscarp →

Landslide Source →

Debris Runout →

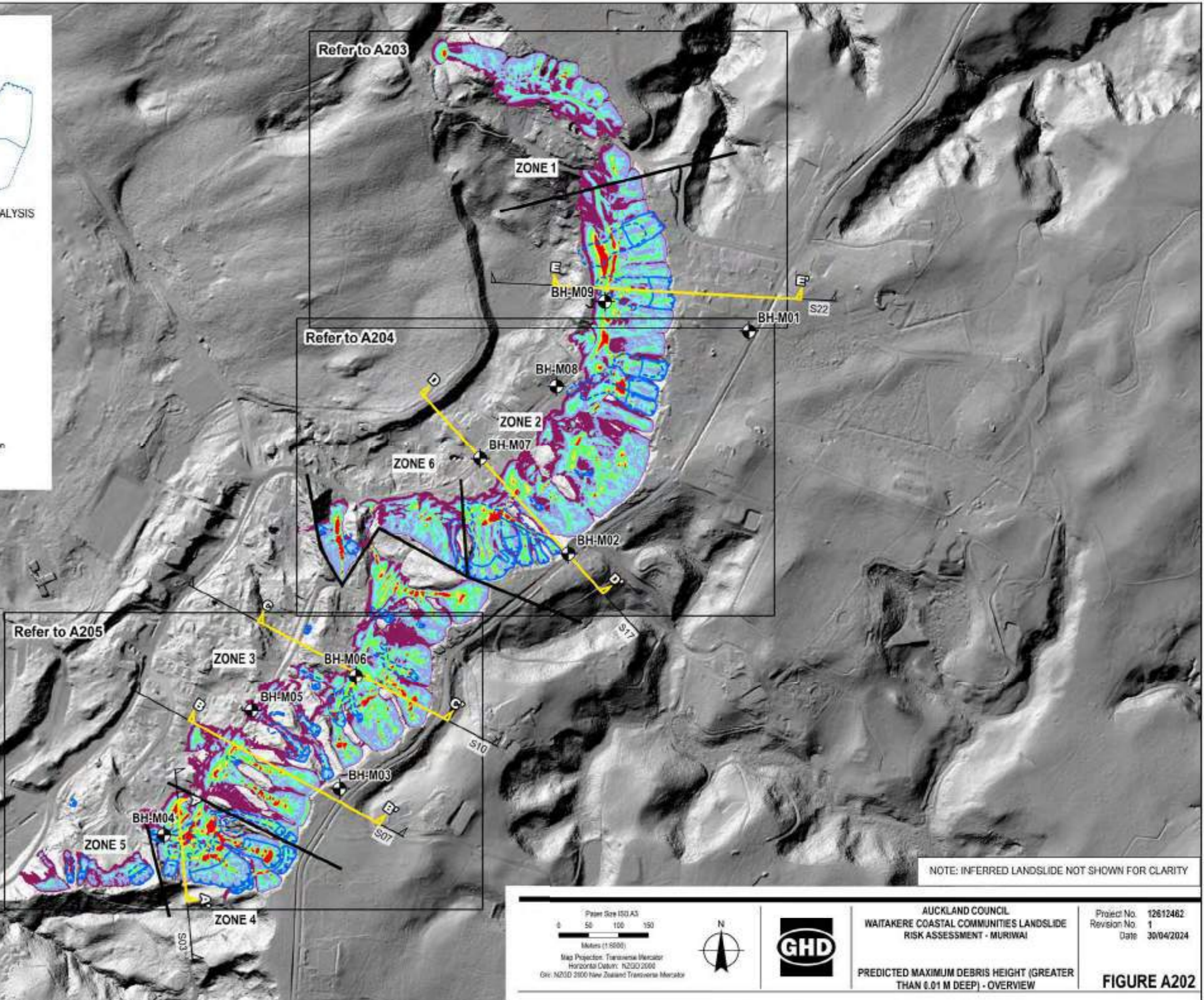
**RAMMS MODELLED DEBRIS FLOW ANALYSIS**

Runout thickness (m)

- 0.01 - 0.3
- 0.3 - 0.6
- 0.6 - 0.9
- 0.9 - 1.2
- 1.2 - 1.5
- 1.5 - 1.8
- 1.8 - 4.14

**GROUND INVESTIGATIONS**

- Borehole (GHD, 2023)
- Zone boundaries
- Engineering geological cross section
- Slope Profile Location



NOTE: INFERRED LANDSLIDE NOT SHOWN FOR CLARITY

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Scale: 1:5000

0 50 100 150 Meters

Map Projection: Transverse Mercator  
 Horizontal Datum: NZOD 2000  
 Grid: NZOD 2000 New Zealand Transverse Mercator



**AUCKLAND COUNCIL**  
**WAITAKERE COASTAL COMMUNITIES LANDSLIDE**  
**RISK ASSESSMENT - MURIWAI**

**PREDICTED MAXIMUM DEBRIS HEIGHT (GREATER THAN 0.01 M DEEP) - OVERVIEW**

Project No. 12612462  
 Revision No. 1  
 Date 30/04/2024

**FIGURE A202**



**LEGEND**

**FEBRUARY 2023 LANDSLIDE**

- Headscarp
- Landslide Source
- Debris Runout

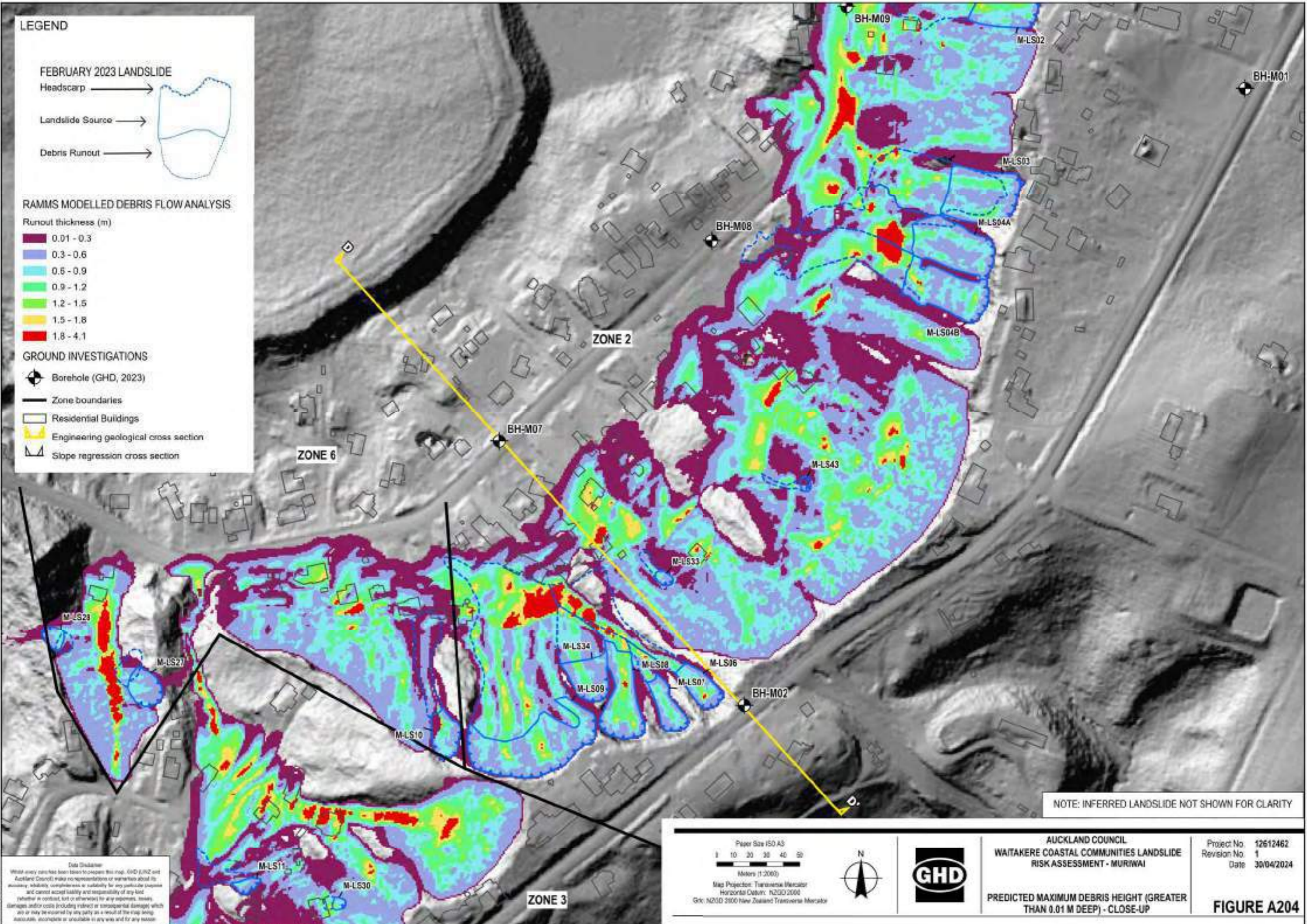
**RAMMS MODELLED DEBRIS FLOW ANALYSIS**

Runout thickness (m)

- 0.01 - 0.3
- 0.3 - 0.6
- 0.6 - 0.9
- 0.9 - 1.2
- 1.2 - 1.5
- 1.5 - 1.8
- 1.8 - 4.1

**GROUND INVESTIGATIONS**

- Borehole (GHD, 2023)
- Zone boundaries
- Residential Buildings
- Engineering geological cross section
- Slope regression cross section



Waitakere District Council, Auckland Council, GHD, 12612462 - Waitakere Coastal Communities Landslide Risk Assessment - Muriwai  
 Project No: 12612462  
 Revision No: 1  
 Date: 30/04/2024  
 FIGURE A204

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 Meters (1:2000)

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 Horizontal Datum: NZGD 2000  
 GCS: NZGD 2000 New Zealand Transverse Mercator



**AUCKLAND COUNCIL**  
**WAITAKERE COASTAL COMMUNITIES LANDSLIDE**  
**RISK ASSESSMENT - MURIWAI**

**PREDICTED MAXIMUM DEBRIS HEIGHT (GREATER THAN 0.01 M DEEP) - CLOSE-UP**

Project No: 12612462  
 Revision No: 1  
 Date: 30/04/2024

**FIGURE A204**

**LEGEND**

**FEBRUARY 2023 LANDSLIDE**

- Headscarp →
- Landslide Source →
- Debris Runout →

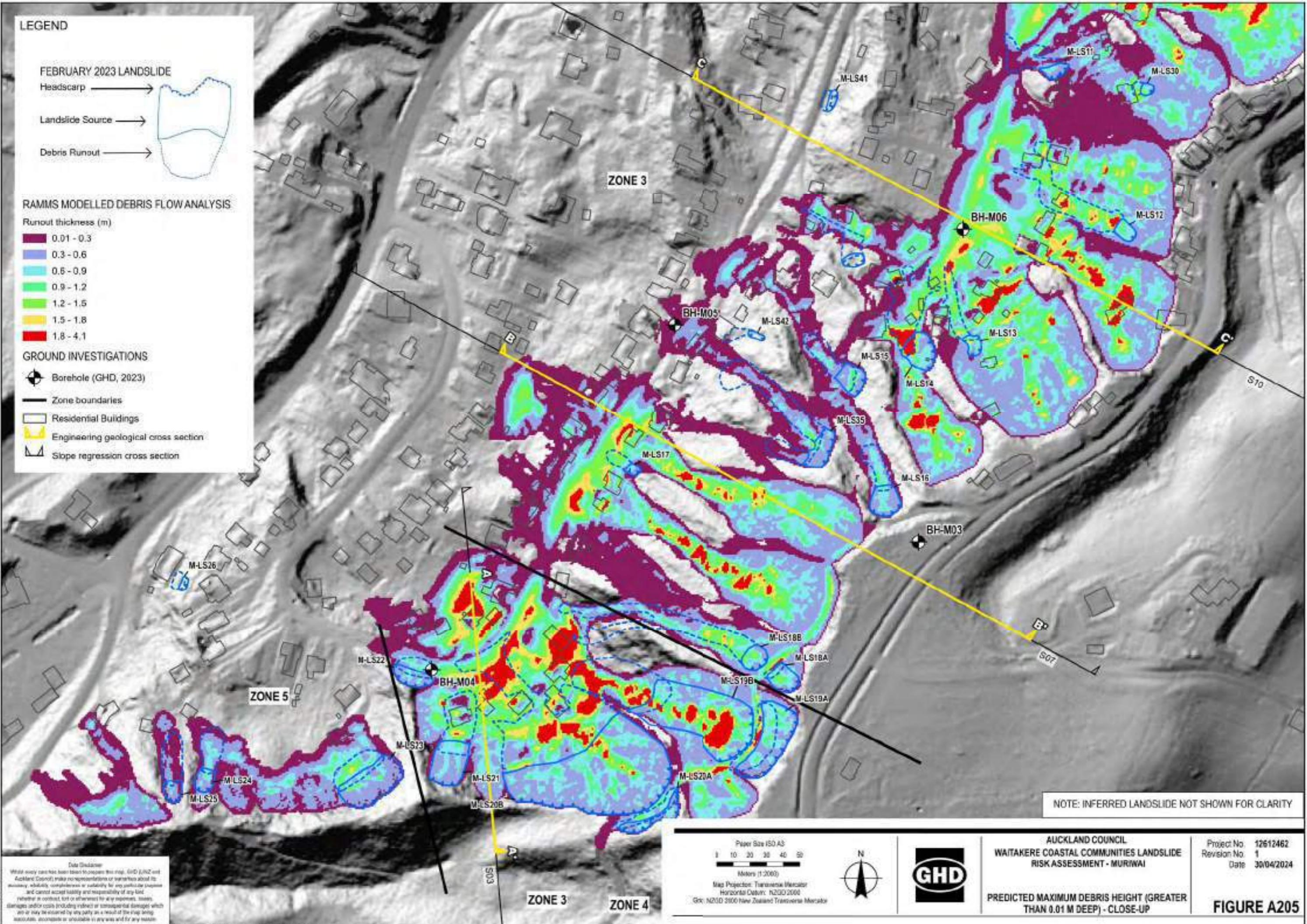
**RAMMS MODELLED DEBRIS FLOW ANALYSIS**

Runout thickness (m)

- 0.01 - 0.3
- 0.3 - 0.6
- 0.6 - 0.9
- 0.9 - 1.2
- 1.2 - 1.5
- 1.5 - 1.8
- 1.8 - 4.1

**GROUND INVESTIGATIONS**

- Borehole (GHD, 2023)
- Zone boundaries
- Residential Buildings
- Engineering geological cross section
- Slope regression cross section



NOTE: INFERRED LANDSLIDE NOT SHOWN FOR CLARITY

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Paper Size ISO A3  
 1 10 20 30 40 50  
 Meters (1:2000)

Map Projection: Transverse Mercator  
 Horizontal Datum: NZGD 2000  
 GCS: NZGD 2000 New Zealand Transverse Mercator



**AUCKLAND COUNCIL**  
**WAITAKERE COASTAL COMMUNITIES LANDSLIDE**  
**RISK ASSESSMENT - MURUWA**

**PREDICTED MAXIMUM DEBRIS HEIGHT (GREATER THAN 0.01 M DEEP) - CLOSE-UP**

Project No 12612462  
 Revision No 1  
 Date 30/04/2024

**FIGURE A205**

Data source: LIDAR Point Cloud, HouseNumber GHD - Inferred location, Tertiary Landfills, RAMMS Landslide Prediction - 2023/04. Created by: [unreadable]

**LEGEND**

**FEBRUARY 2023 LANDSLIDE**

- Headscarp
- Landslide Source
- Debris Runout

**INFERRED LANDSLIDE**

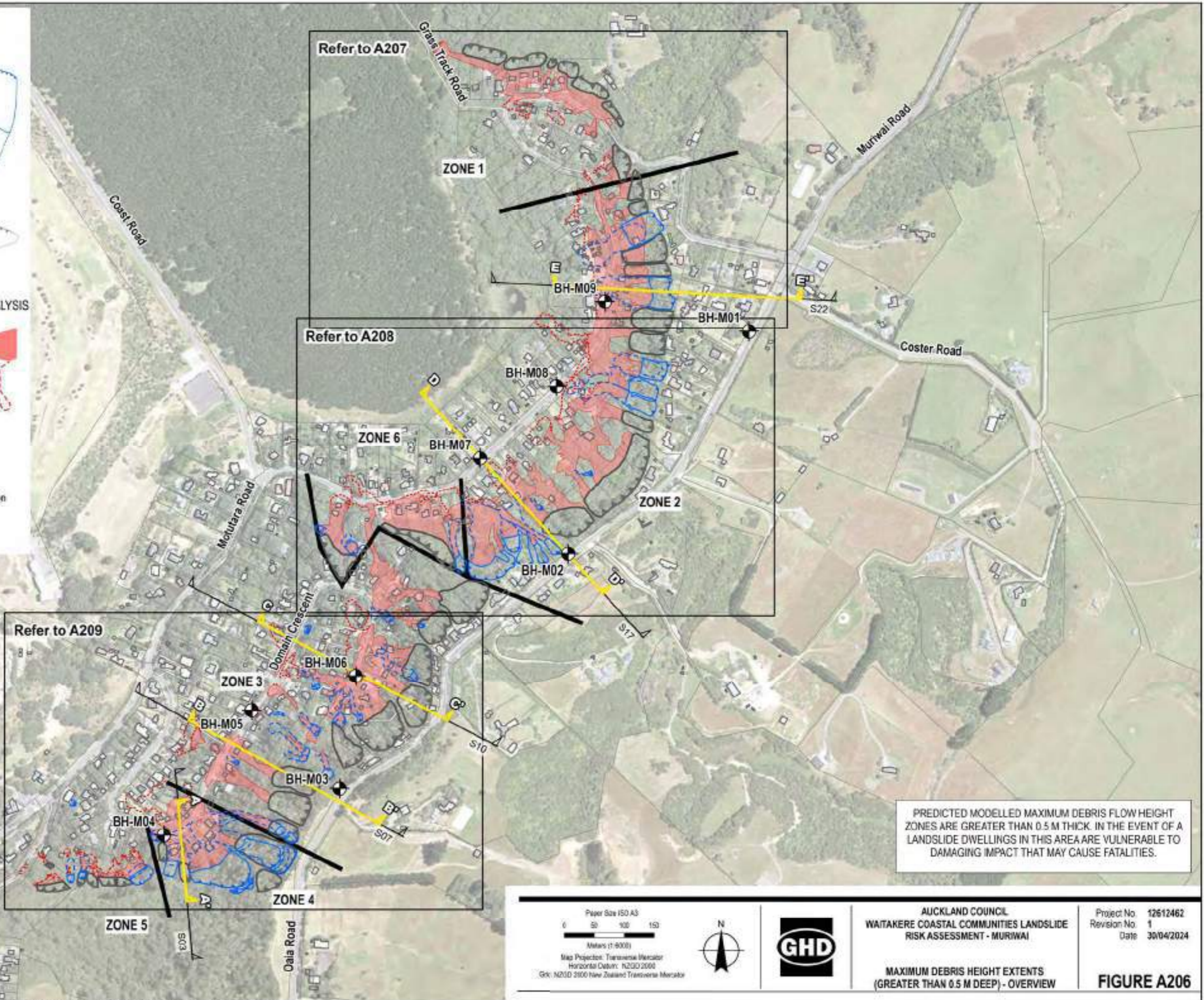
- Headscarp
- Landslide Source

**RAMMS MODELLED DEBRIS FLOW ANALYSIS**

- Predicted Modelled Debris Runout
- Runout with Conservative Model Values

**GROUND INVESTIGATIONS**

- Borehole (GHD, 2023)
- Zone boundaries
- Engineering geological cross section
- Slope Profile Location
- Residential Buildings



PREDICTED MODELLED MAXIMUM DEBRIS FLOW HEIGHT ZONES ARE GREATER THAN 0.5 M THICK. IN THE EVENT OF A LANDSLIDE DWELLINGS IN THIS AREA ARE VULNERABLE TO DAMAGING IMPACT THAT MAY CAUSE FATALITIES.

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Paper Size ISO A3  
 0 50 100 150  
 Meters (1:8000)

Map Projection: Transverse Mercator  
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 GCS: NZGD 2000 New Zealand Transverse Mercator



**AUCKLAND COUNCIL**  
**WAITAKERE COASTAL COMMUNITIES LANDSLIDE**  
**RISK ASSESSMENT - MURWAI**

Project No: 12612462  
 Revision No: 1  
 Date: 30/04/2024

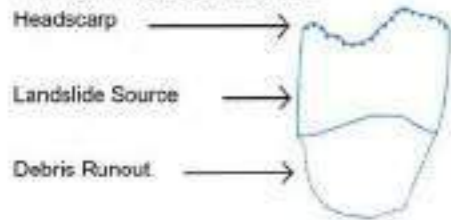
**MAXIMUM DEBRIS HEIGHT EXTENTS**  
**(GREATER THAN 0.5 M DEEP) - OVERVIEW**

**FIGURE A206**

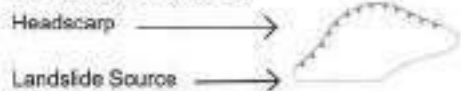


**LEGEND**

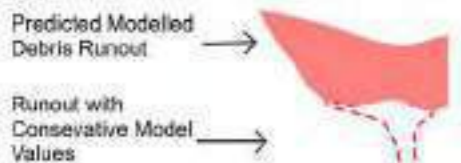
**FEBRUARY 2023 LANDSLIDE**



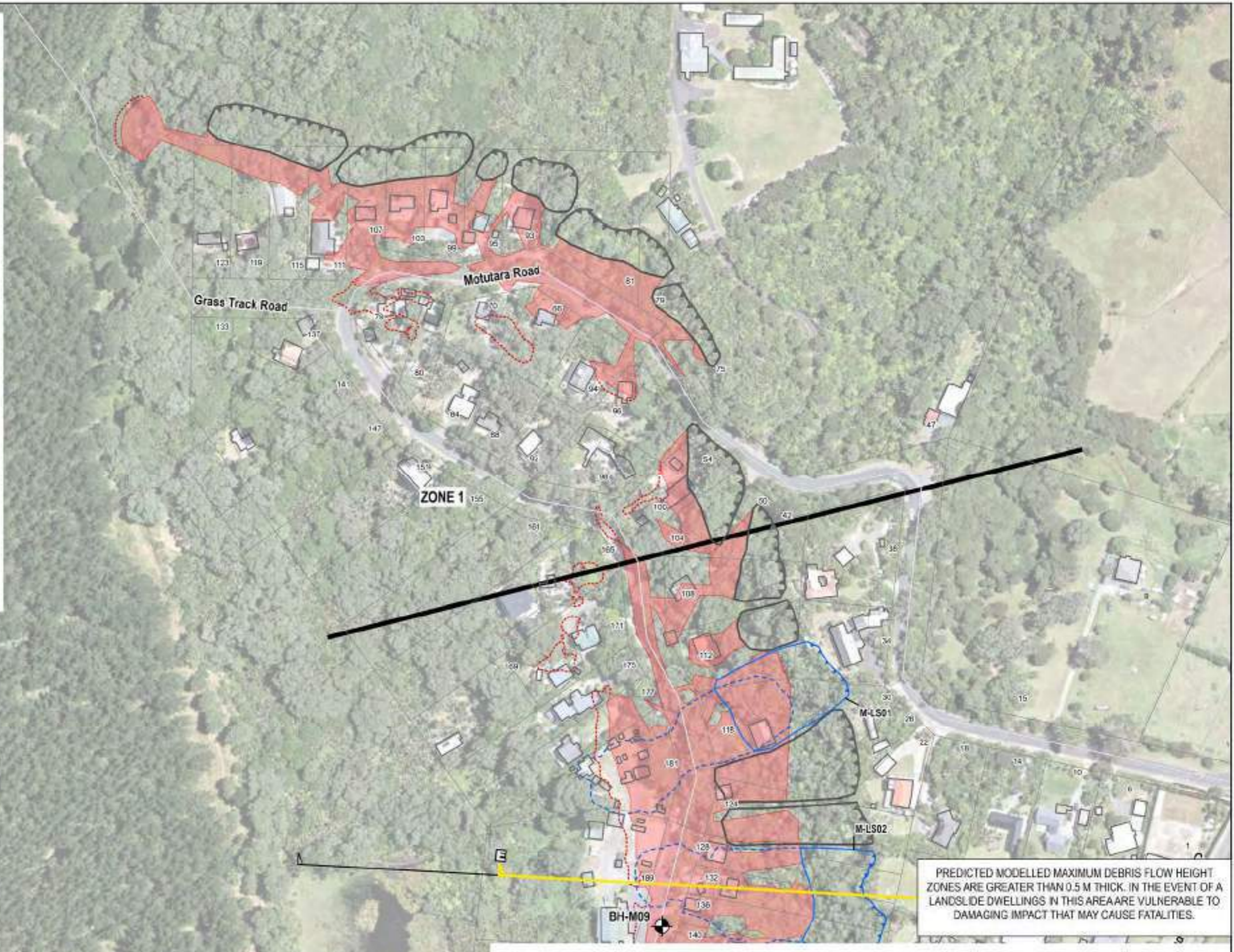
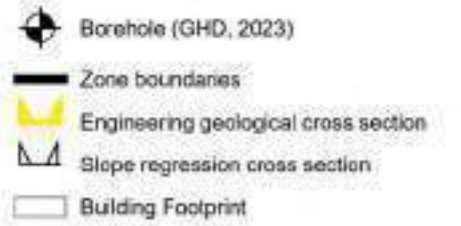
**INFERRED LANDSLIDE**



**RAMMS MODELLED DEBRIS FLOW ANALYSIS**



**GROUND INVESTIGATIONS**



PREDICTED MODELLED MAXIMUM DEBRIS FLOW HEIGHT ZONES ARE GREATER THAN 0.5 M THICK. IN THE EVENT OF A LANDSLIDE DWELLINGS IN THIS AREA ARE VULNERABLE TO DAMAGING IMPACT THAT MAY CAUSE FATALITIES.

Paper Size ISO A3  
 0 10 20 30 40 50  
 Meters (1:2000)  
 Map Projection: Transverse Mercator  
 Horizontal Datum: NZGD 2000  
 GCS: NZGD 2000 New Zealand Transverse Mercator



**AUCKLAND COUNCIL**  
**WAITAKERE COASTAL COMMUNITIES LANDSLIDE**  
**RISK ASSESSMENT - MURIWAI**

Project No: 12612462  
 Revision No: 1  
 Date: 30/04/2024

**MAXIMUM DEBRIS HEIGHT EXTENTS**  
**(GREATER THAN 0.5 M DEEP) - CLOSE-UP**

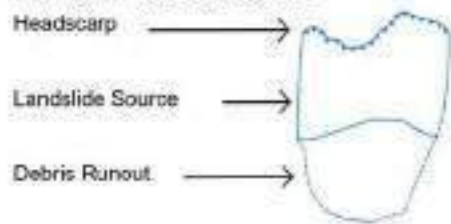
**FIGURE A207**

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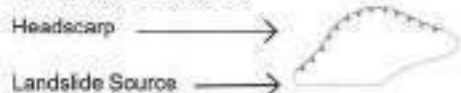
Map source: World Topographic Map, State/2.5m, TomTom, Garmin, Foursquare, METRAG, USGS  
 World Imagery: Aerial Coast, LAZ  
 World Hydro: Esri, NOAA, NGA, OSM, GHD - River Database, February (and other), RAMMS Landslide Prediction - 2023/24, Auckland Council - (Drawing Prepared by GHD) Building footprint, point, Coordinate, none

**LEGEND**

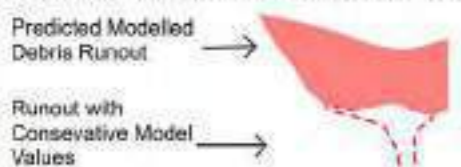
**FEBRUARY 2023 LANDSLIDE**



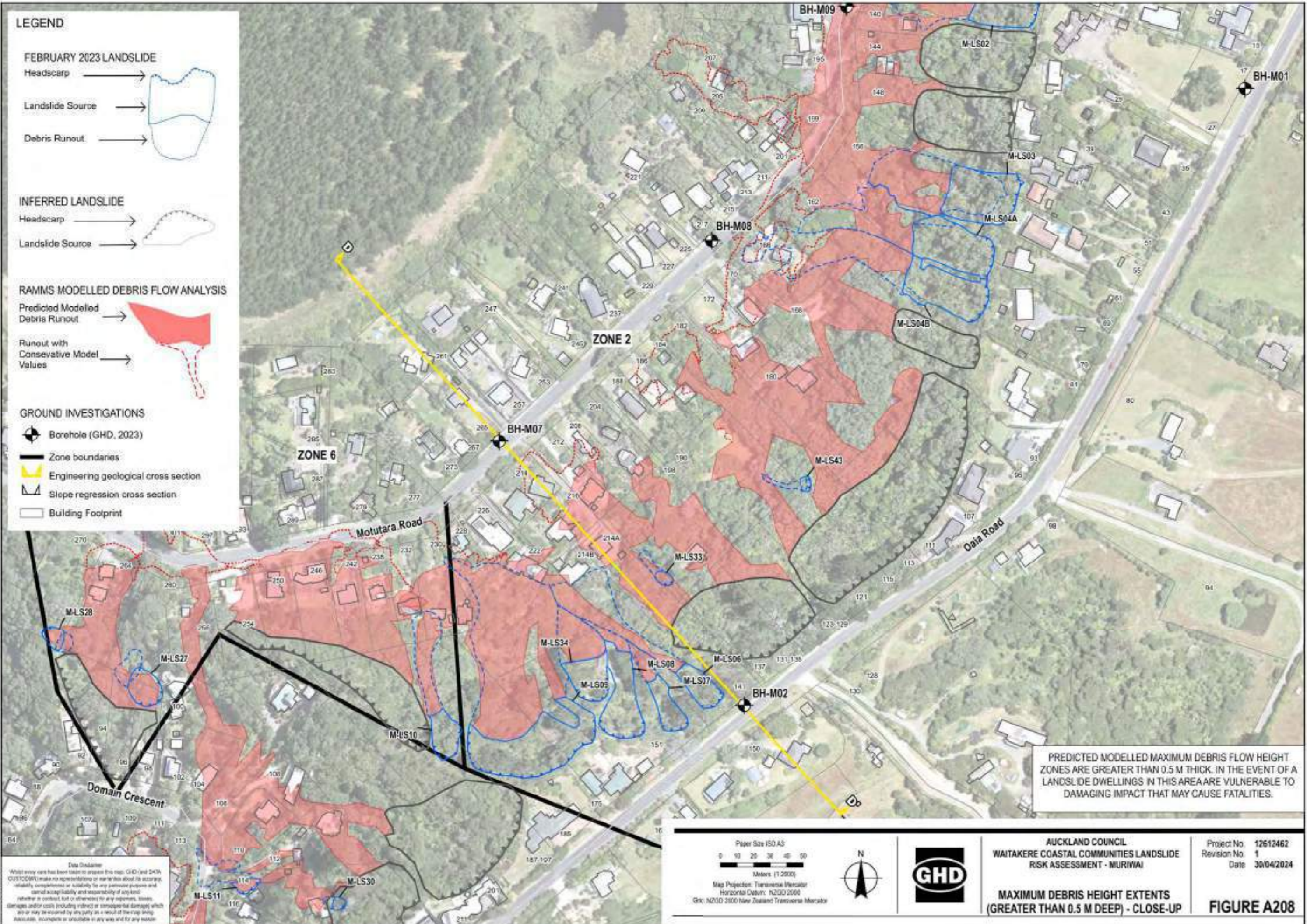
**INFERRED LANDSLIDE**



**RAMMS MODELLED DEBRIS FLOW ANALYSIS**



**GROUND INVESTIGATIONS**



PREDICTED MODELLED MAXIMUM DEBRIS FLOW HEIGHT ZONES ARE GREATER THAN 0.5 M THICK. IN THE EVENT OF A LANDSLIDE DWELLINGS IN THIS AREA ARE VULNERABLE TO DAMAGING IMPACT THAT MAY CAUSE FATALITIES.

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**AUCKLAND COUNCIL**  
**WAITAKERE COASTAL COMMUNITIES LANDSLIDE**  
**RISK ASSESSMENT - MURIWAI**

Project No 12612462  
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 Date 30/04/2024

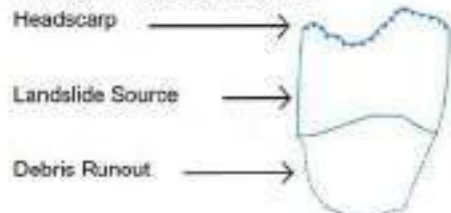
**MAXIMUM DEBRIS HEIGHT EXTENTS**  
**(GREATER THAN 0.5 M DEEP) - CLOSE-UP**

**FIGURE A208**

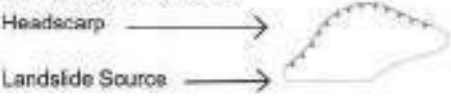
Map source: World Topographic Map, SRTM30, Geo. Trimble, Garmin, Fugro, METRAN, 2018  
 World Imagery: Auckland Council, 2018  
 World Hydro: Esri, NOAA, NGA, 2018; 1:60 - Revised Landline, February 2018, RAMMS Landslide Prediction - 2022/23, Auckland Council - Drawing Power (a GHD) Building footprint, point, Creative Commons

**LEGEND**

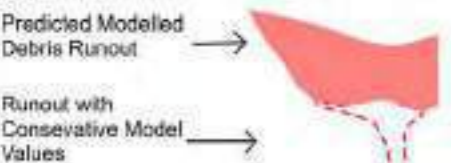
**FEBRUARY 2023 LANDSLIDE**



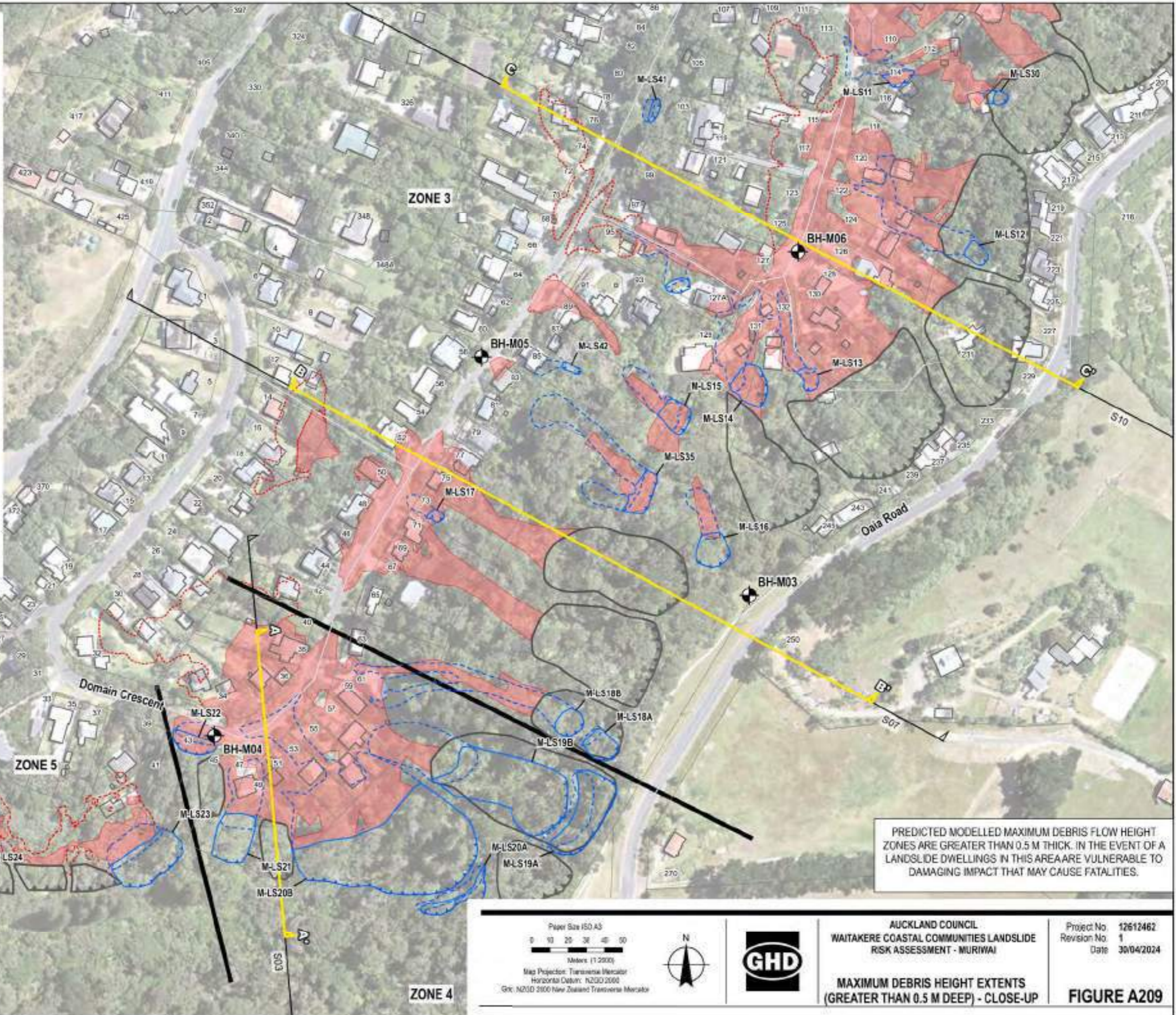
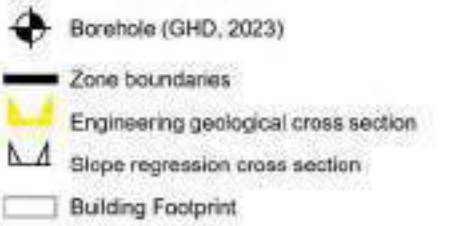
**INFERRED LANDSLIDE**



**RAMMS MODELLED DEBRIS FLOW ANALYSIS**



**GROUND INVESTIGATIONS**



PREDICTED MODELLED MAXIMUM DEBRIS FLOW HEIGHT ZONES ARE GREATER THAN 0.5 M THICK. IN THE EVENT OF A LANDSLIDE DWELLINGS IN THIS AREA ARE VULNERABLE TO DAMAGING IMPACT THAT MAY CAUSE FATALITIES.

Paper Size ISO A3  
 0 10 20 30 40 50  
 Meters (1:2000)  
 Map Projection: Transverse Mercator  
 Horizontal Datum: NZGD 2000  
 GCS: NZGD 2000 New Zealand Transverse Mercator



**AUCKLAND COUNCIL**  
**WAITAKERE COASTAL COMMUNITIES LANDSLIDE**  
**RISK ASSESSMENT - MURIWAI**

Project No 12612462  
 Revision No 1  
 Date 30/04/2024

**MAXIMUM DEBRIS HEIGHT EXTENTS**  
**(GREATER THAN 0.5 M DEEP) - CLOSE-UP**

**FIGURE A209**

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Map source: World Topographic Map, State/2, GCS: Transverse Mercator, NZGD 2000  
 World Imagery, Aerial Court, LAZ  
 World Hydrology, ERI, NZGD 2000, GCS: Transverse Mercator, NZGD 2000  
 World Hydrology, ERI, NZGD 2000, GCS: Transverse Mercator, NZGD 2000



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