Whanganui Land Stability Assessment Areas

Stage 4

Risk Study Report

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Document History and Status

Revision	Date	Author	Reviewed by	Approved by	Status
A	12/10/2018	Doug Mason	P Brabhaharan	Mark Frampton	Issue 1
B	4/12/2018	Doug Mason	P Brabhaharan	Mark Frampton	Issue 2

Revision Details

Revision	Details
A	First issue
B	Minor amendments and definitions added

Executive Summary

Experience from natural hazard events highlights the importance of hazard, vulnerability and risk assessments in land use planning and development, to ensure the future resilience of communities. Whanganui District Council is currently undertaking a review of its District Plan, and has identified the need to manage risks from land instability. Consideration of the extent of land within Whanganui at risk of land slip has identified a list of areas which are prioritised for further study. The Council has commissioned WSP Opus to carry out an assessment of the stability issues on hillslopes in four parts of Whanganui city: the southern part of Durie Hill, the hill areas northwest of the city centre from Victoria Park to Virginia Road, the Putiki area, and Marybank.

Mapping of the distribution and characteristics of slope instability hazards was carried out within those areas. Instability features observed during the mapping include shallow seated topsoil and regolith slides, shallow seated slumps and slides on steep slopes, creep failures of soil and embankments, and localised toppling/slumping on steep bluffs and cliffs.

Qualitative assessment of risks to people and property were assessed on an area-wide basis, and were used to define two levels of land instability susceptibility. Areas classified as type A comprise land that is steep and shows evidence of instability, with a high risk of further instability and damage to property. Council should discourage subdivision and new dwellings in these high-risk areas. Areas classified as type B are marginal slopes, which have shallower slope angles but are still prone to instability. Geotechnical investigations should be carried out prior to any development proposal being submitted for resource consent. The investigations are required for detailed assessment of the slope stability hazards. The investigations and assessment will determine the risk to property from landsliding, and therefore whether the land is suitable for development, with mitigation measures implemented, or whether it is unsuitable for further development.

It is recommended that the results of the mapping are incorporated into the District Plan through overlay maps and by introducing objectives, policies and rules that apply additional considerations and restrictions specific to the land instability issues present in each area. This will help achieve greater resilience of the community to natural hazards through a proactive approach to land use and development in hazard prone areas.

1 Introduction

Whanganui District Council is currently undertaking a staged review of its District Plan, which includes investigating ways to manage natural hazards. The Whanganui district is affected by a number of natural hazards; in particular, parts of the urban area are susceptible to slope instability and erosion. Consideration of the extent of the land within the Whanganui District at risk of land slip has identified a list of Land Stability Assessment Areas which are priorities for further study. These areas are being examined in a staged approach to identify the extent of susceptibility to land instability hazards. This process identifies areas of land susceptible to instability from an areal perspective, to assist the Council in development of land development controls.

WSP Opus has been commissioned to undertake the assessment of slope stability issues within the study areas. The following areas have been investigated as part of this ongoing study, and the following reports prepared:

- ANZAC Parade to Putiki Drive (Opus, 2011);
- Shakespeare Cliff (Opus, 2012);
- Ikitara Road, Bastia Hill and Durie Hill (Opus, 2014);
- Mowhanau and Roberts-Patterson (Opus, 2015).

This report represents the next stage in this process, and summarises the study results for the following areas, as shown on Illustration 1-1 : Study area locations:

- Durie Hill (extension)
- Putiki Drive, Taylor St (extension)
- Victoria Park, St Johns Hill, Virginia Road
- Putiki: Ngatarua Road, Putiki Drive and Hewitts Road
- Marybank

This report details our investigations which included a desk study and reconnaissance level engineering geological mapping of the study area. It provides an appraisal of the stability issues in the area, landslide susceptibility mapping process, and recommendations for measures to manage the effects of land instability hazards for any future developments.

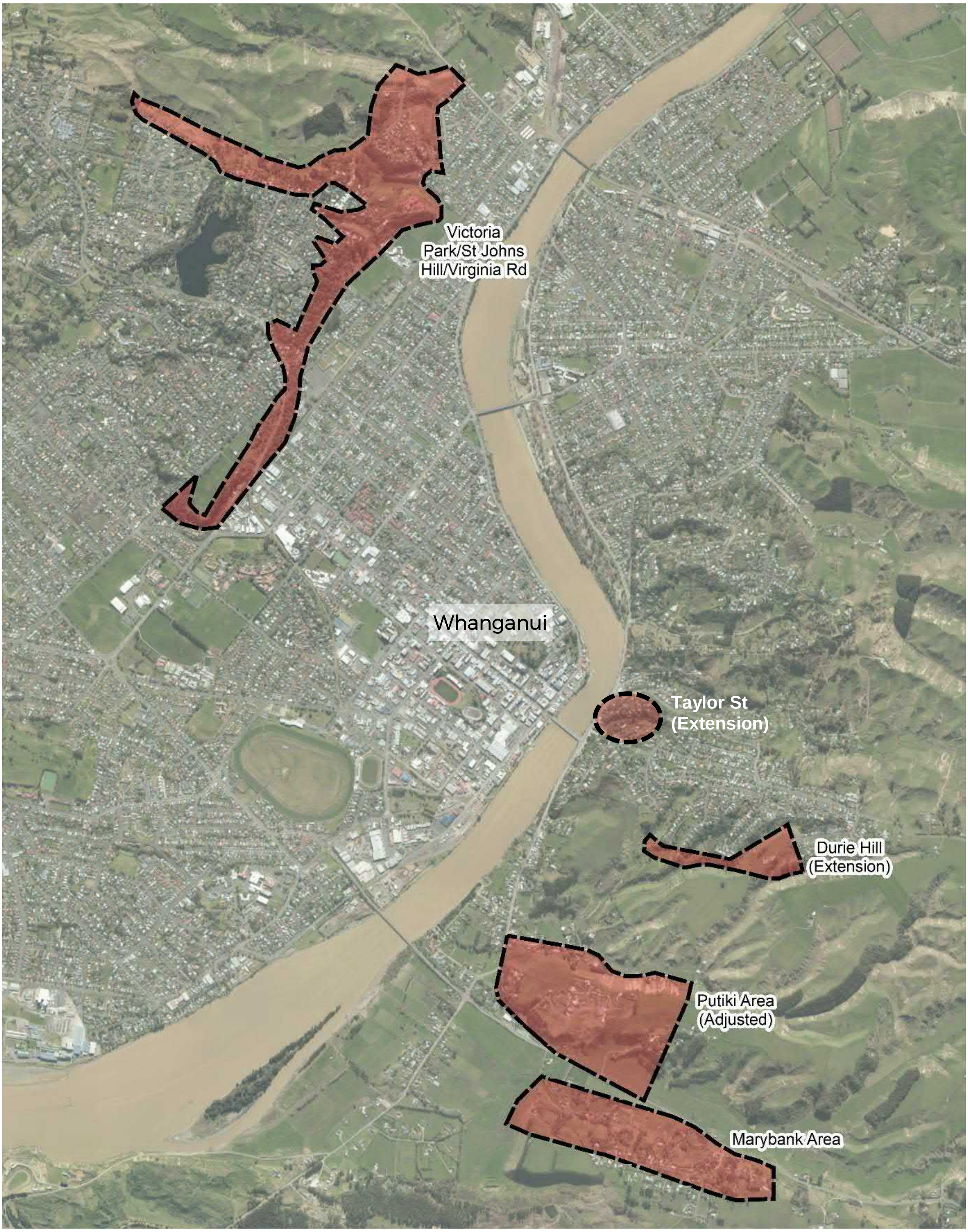

Illustration 1-1 : Study area locations

2 Study methodology

The following points describe the approach taken in carrying out this study:

1 Identify areas with potential for land instability issues for further study.

Whanganui District Council has identified some urban areas within the district with potential for land instability issues, which are being investigated in a staged approach. This study forms the next in that process.

2 Identify the geology and geomorphology of the study areas.

This process involves examination of stereo aerial photographs, a desk study of geology maps and other available information, and reconnaissance-level engineering geological mapping to observe and describe the geology and geomorphology of the study areas, and in particular to identify areas of instability and other hillslope features.

3 Identify past slope instability and areas of known slope instability.

Instability features were identified during the examination of historical aerial photos, and areas of recent or active instability were noted during the reconnaissance mapping and from discussions with local Opus and Council engineers.

4 Characterise the slope angle of hillslopes and the hillside slope angles generally susceptible to instability.

Hillslope characteristics that influence the location and nature of instability features were identified during the desk study and mapping phases and captured onto a GIS[1] platform. The GIS database allows the distribution and extent of instability hazards and affected areas to be mapped spatially. The slope angles were also generated using GIS from available contour and LiDAR[2] data.

5 Carry out a qualitative assessment of the instability hazards and risks.

A simple, area-wide, qualitative risk assessment was carried out to assist in differentiating areas of hillslope based on the slope instability hazards.

6 Develop Land Stability Assessment (LSA) Area classifications.

A classification scheme was developed for the slope hazards, to enable areas of slope to be mapped based on their level of susceptibility to the hazards and the potential for consequent risks.

7 Produce LSA maps.

Maps of the slopes classified as LSA Areas were produced at 1:5,000 scale (Figures A-1 to A-5 in Appendix A).

8 Recommend planning policies and rules to ensure development avoids or mitigates the instability hazard potential.

This report makes recommendations for incorporating the results of this study into its District Plan.

[1] Geographic Information System, a mapping system to manage and analyse data
[2] Light Detection and Ranging, a remote sensing method using lasers to measure the earth's surface

3 Site description

3.1 Geomorphology

This study areas consist of hill suburbs to the east and west of the Whanganui town centre and Whanganui River. The geomorphology of these areas is dominated by flat-topped hills that rise c. 80 m above the river. The hills are remnants of uplifted Quaternary marine terraces, and consist of broad, flat to gently sloping hilltops flanked by moderately steep to very steep hillslopes.

The terraces have been incised since their uplift, resulting in steep gullies and side slopes. Slope angles generally range between 20° and 45°, with localised sections of steeper slopes between 50°and 70°. Occasional steep bluffs and cut slopes sit at steeper angles (i.e., sub-vertical).

The study areas are predominantly under residential land use, and consequently the hillslopes have been modified for residential development with cuts, fills and retaining walls. Parts of the Putiki and Marybank study areas are still under rural or rural-residential land use, with recent subdivision and development underway on the flat-topped hill in the Putiki area.

Vegetation cover of the hillslopes in the study area varies widely, from grass and low scrub cover to native and exotic forest. The engineering geology maps in Appendix B show geomorphic features and vegetation cover across the hillslopes in the study areas.

3.2 Geology

The Whanganui area has been mapped by the New Zealand Geological Survey (1959) and GNS Science (2008).

The geological mapping shows the four study areas are underlain by deposits belonging to the Kai-Iwi Group, the Shakespeare Group, the Rapanui Formation and St Johns Alluvium. These deposits are comprised of conglomerate, sandstone, siltstone, shell beds and marginal marine deposits and are of late Pliocene to Pleistocene age.

Observations made during the engineering geological mapping were that the siltstone and sandstone materials are exposed within the study areas. These formations are described as soft rock (known colloquially as 'Papa' in the central North Island). These rocks are overlain on the hillslopes by variable thicknesses of colluvium, dune sand deposits and topsoil. In areas where outcrop exposures of the soils were observed, these young (Holocene) deposits are generally less than 2 m thick, although this thickness will increase down-slope and in gullies where more extensive fan and slip deposits are likely to accumulate.

4 Investigations

4.1 Desk study

The desk study consisted of a review of available geological maps and reports, and detailed examination of aerial photograph stereo pairs from 1941, 1962, 1993 and 2011. Detailed review of LiDAR terrain data from 2013 and aerial orthophotography from 2016 was also carried out. Geomorphic features identified from the desk study were captured in GIS.

4.2 Engineering geology mapping

This study comprised an appraisal to gain an area-wide understanding of the geology and geomorphology. No intrusive investigations or testing were therefore undertaken as part of this study. To provide information of significant value, these would need to be extensive and costly, given the size of the study area and the range of slope issues. Similarly, the mapping was carried out along publicly-accessible roads and footpaths; individual site or property inspections were not carried out, as this was an area-wide study into the general stability issues.

Site reconnaissance mapping of the hillslopes within the study area was carried out by an engineering geologist. Areas of recent or active instability were noted during the mapping, and areas of historical instability observed from the aerial photos were also examined.

The mapping involved identification of areas of slope instability, typically from landslide scarps, hummocky ground or exposed soil. Many recent scarps were observed, particularly on steep slopes in the semi-rural land in the eastern study areas. These are presumed to date from the large storm event that occurred in the district in June 2015. Some older landslide features were also identified, from degraded scarps and evacuated slopes.

Existing slope mitigation measures, such as retaining walls, were also mapped as they indicate a precedent for past slope instability or show where the natural slopes have been modified. The engineering geological maps are given in Appendix B (Figures B-1 to B-11).

5 Slope hazard characterisation

5.1 Factors influencing instability

5.1.1 Slope materials

The slope materials in the Whanganui area are predominantly siltstone, sandstone and conglomerate of Quaternary age. These are overlain by a surficial zone of soil comprised of highly weathered rock, colluvium, loess and topsoil. These geologically young materials are susceptible to failure, particularly on sparsely vegetated slopes following prolonged or intense rainfall.

The underlying siltstone materials are described as soft rock. These soft rocks typically fail by three progressive failure modes:

1. Slabbing, where slabs 300 mm – 400 mm thick fail along planes subparallel to the slope. Slabbing is typically observed on siltstone slopes of angles greater than 45°.
2. Slaking, where the surface disaggregates, or frets, to form fragments ranging from silt to gravel sized. Slaking is more common in finer-grained rocks (Read and Millar, 1990).
3. Deeper seated instability particularly where there are other unfavourable factors such as high groundwater pressures or undermining of the slope by river erosion.

Sand and gravel materials were observed in parts of the study area, and failure of these surficial materials by translational sliding was mapped within the study areas.

5.1.2 Slope angle

Engineering geological mapping of landslides within the study areas has shown instability is apparent on hillsides with slope angles greater than 40°, and is common where slope angles are greater than 50°. Deeper seated failures are also more common on slopes steeper than 50°. Mapped instability features and slope angles are shown on the engineering geology maps in Appendix B (Figures B-1 to B-11).

In some localised areas, slopes of less than 40° also show instability features. However this was generally restricted to shallow translational failures of topsoil/regolith[3]. Slopes with angles of 30° to 40° are marginally stable and may pose a risk to development.

5.1.3 Storm and earthquake events

The hillslopes are susceptible to instability following periods of prolonged or intense rainfall, due to rising groundwater levels and a consequent increase in pore water pressure within the slope. Strong ground shaking during earthquakes could also trigger slope instability, and there is evidence for earthquake-induced landslides in the Whanganui area (Opus, 2012).

5.1.4 Modification of natural slopes for housing and infrastructure

Excavation into natural slopes may cause instability by over-steepening of the slope, particularly if the excavation is into the toe of a slope. The formation of fill embankments may also contribute to landsliding, due to the increased load on slopes. Evidence of minor deformation of the road/footpath pavement due to downslope movement of the soil at the crest of the slope was observed at Marybank Road in Marybank (Illustration 5-1).

Illustration 5-1 : Minor deformation of pavement on Marybank Road

5.2 Observed instability features

A range of instability features were recorded during the engineering geological mapping. These include:

- Creep failures of soil, leading to cracking and rotation of road pavements at slope crests (e.g. Illustration 5-1);
- Topsoil and regolith slides (e.g. Illustration 5-2);
- Shallow seated slumps and slides on steep slopes (e.g. Illustration 5-3 and Illustration 5-4).

The majority of recent instability features observed during the mapping were shallow seated failures of topsoil, regolith and shallow soft rock materials. Evidence for deep-seated failures in the underlying siltstone was rare.

[3] Surficial layers of unconsolidated soil, colluvium and disturbed/weathered bedrock forming a mantle over less weathered rock.

Instability features such as translational landslides and slumps were commonly observed on slopes steeper than 40° to 45°. Shallower failures of surficial materials were observed on flatter slopes, with angles typically steeper than 30° to 40°.

Illustration 5-2 : Shallow landslides in surficial topsoil/regolith

Illustration 5-3 : Landslide on steep slope

Illustration 5-4 : Slump of siltstone at crest of steep bluff

5.2.1 June 2015 storm event

During the period 19-21 June 2015, the Whanganui District experienced a significant major rainfall event. This resulted in flood frequencies close to or exceeding 1% AEP (1 in 100 year) in several rivers, including the Whanganui River. Very substantial flooding occurred through Whanganui City. Rainfall depths for 48 hours duration exceeded the 1% AEP event over much of the District.

During the rainfall event landslides were triggered on the hillsides of the city and in the wider district. The mapping of landslides and slope deformation features in this study included the assessment of aerial photographs dating from 2016. Fresh or recent slips observed on these photos are presumed to have been triggered by this storm. The locations of the slip scarps and the extent of the debris fans within the study areas are included on the engineering geology maps in Appendix B.

6 Qualitative risk assessment

6.1 Level of assessment

A qualitative assessment of risk to property from failure of the hillslopes has been undertaken. This is based on area-wide observation of instability features and characteristics and is not for individual properties. The actual risks at a particular property may differ. More detailed site-specific information and assessment would be required to confirm the risks at any specific property.

6.2 Assessment method

The qualitative risk assessment has been undertaken with reference to the guidelines for landslide susceptibility, hazard and risk zoning published by the Australian Geomechanics Society (AGS, 2007a, 2007b).

A summary of the qualitative risk assessment is presented in Table 6-1. Explanation of the risk assessment tables and terminology is given in Appendix C.

Table 6-1 : Qualitative risk assessment table (AGS, 2007a)

Likelihood[1]	Consequences to property[2]				
	1 Catastrophic (200%)	2 Major (60%)	3 Medium (20%)	4 Minor (5%)	5 Insignificant (0.5%)
A: Almost certain (10^{-1})	Very high	Very high	Very high	High	Moderate[3]
B: Likely (10^{-2})	Very high	Very high	High	Moderate	Low
C: Possible (10^{-3})	Very high	High	Moderate	Moderate	Very low
D: Unlikely (10^{-4})	High	Moderate	Low	Low	Very low
E: Rare (10^{-5})	Moderate	Low	Low	Very low	Very low
F: Barely credible (10^{-6})	Low	Very low	Very low	Very low	Very low

Notes: [1] Indicative approximate annual probability
[2] Indicative approximate cost of damage as a percentage of the value of the property
[3] For Cell A5, may be subdivided such that a consequence of less than 0.1% is Low Risk

Based on the risk assessment above, two Land Stability Assessment (LSA) areas are proposed to assist the Council in its objective to manage the risks from instability hazards. These areas are discussed below.

7 Land Stability Assessment Areas

7.1 Area A: Areas of high to very high landslide hazard risk

Area A consists of land showing evidence for previous or active slope instability and/or steep slope angles. Observation of instability features from the engineering geological mapping show that the most common forms of slope instability (e.g. shallow slips, soil creep, rotational landslides, rill/gully erosion, cliff slumps or rock fall) predominantly occur on slopes in these areas. These failures also affect the area immediately upslope of these steep slopes (uphill regression of head scarps), and also downhill areas where landslide slip material can accumulate (runout zone). These areas are the most susceptible to land instability and are classified as the highest hazard (Area A).

The recurrence interval for failure is expected to be approximately 10 to 50 years, giving a likelihood of failure of almost certain to likely during the design life of buildings (Table 6-1). Such failures have the potential to cause extensive property damage and would likely require significant engineering works for stabilisation, giving a damage consequence of failure of major to catastrophic. The risk rating for such areas is therefore very high (shown as the darker brown area on Table 6-1), and is unacceptable.

It is recommended that subdivision and new dwellings are actively discouraged within Area A, as the risk of further instability and damage to property or life is very high.

7.2 Area B: Areas of moderate landslide hazard risk

These areas have moderate to steep slope angles of about 30° to 40° but still show some evidence of instability. Failures may occur less frequently on these marginal slopes or may be smaller in extent, depending on site-specific conditions, such as the type and thickness of colluvium and the prevailing groundwater conditions. Therefore the recurrence interval will be variable for marginal slopes – perhaps 50 to 500 years, giving a likelihood of failure of likely to possible. Property damage in more frequent events is likely to be less severe, and any structures built in these areas may not be completely destroyed, giving a damage consequence to property of medium to major. The level of risk to property is therefore moderate to high (shown as the lighter brown area on Table 6-1).

Area B consists of marginal land, with a significant potential landslide hazard, requiring prior geotechnical investigation to confirm its suitability for development. These areas may include areas potentially affected by uphill regression or downhill runout zones. Assessment of the landslide hazard and risk to development should be carried out prior to consideration of any development as part of the consenting process. It is recommended that building consents not be issued unless prior resource consents are obtained for development including geotechnical investigations and assessment that prove their suitability for development with a low risk to the property and life.

The outcome of geotechnical investigations will determine if the risk to property is moderate, high or very high, depending on factors such as the thickness and type of colluvium and groundwater levels. An outcome of very high risk may mean the land will be unsuitable for development (Area A), whereas moderate risk may mean the land can be developed, with mitigation measures designed and implemented to reduce the risk to low if this was practical and feasible. The geotechnical assessment needs to demonstrate that a low risk can be achieved with mitigation.

7.3 LSA Area maps

The zonation of the hillslopes in the study areas are given on Figures A-1 to A-5 in Appendix A at 1:5,000 scale. The engineering geological mapping was carried out at approximately 1:2,500 scale, and consequently the area boundaries are approximate only. The LSA maps should be used only at the scale provided.

Given the area-wide nature of this study, the land outside the LSA areas A and B cannot be guaranteed to have no land instability hazards, and property owners or developers should seek independent advice on stability issues for their particular property.

7.4 Existing modifications to properties

The mapping within the study areas was carried out from examination of aerial photographs and observations from roads. As no access was gained to properties, individual property stability assessments have not been made. The LSA classifications therefore refer to the underlying and surrounding ground and do not take into account modifications to properties or structures already in place as it was not possible to undertake such assessments within the scope of this area-wide study. The actual risks at individual properties may differ, confirmation of which would require more detailed, property-specific information on the subsurface conditions and the efficacy of any existing measures to mitigate instability hazards, which is beyond the scope of this current study.

8 Recommendations

We recommend:

1. Activities on slopes be preceded by site-specific geotechnical investigation and assessment by a competent geotechnical professional (Chartered Professional Engineer or Professional Engineering Geologist) prior to consideration of any development as part of the consenting process, to determine the risk of instability and identify treatment measures.
2. The landslide hazard maps be incorporated into Whanganui District Council's District Plan by way of a Land Stability Assessment overlay on the district planning maps.
3. The areas surrounding current study areas and other areas in the city where slope instability has caused issues in the past be assessed in a similar way as this study to provide uniformity in how these areas are treated in the District Plan.

9 Limitations of the assessment

The slope stability assessment for this study covers only the area shown in Figures A-1 to A-5 in Appendix A. No assessment of hillside stability has been made for properties outside this area.

Engineering geological mapping within the study area was carried out from examination of aerial photographs and observations from roads within the study areas. No access was gained to properties, and therefore individual property stability assessments have not been made.

This study is an area-wide qualitative appraisal to assist with development of land development controls. The qualitative risk assessment of likelihood and consequence of slope instability hazards was carried out from an areal perspective and individual property land risk assessments have not been carried out. The actual risks at a particular property may differ from those shown in this study and would require more detailed site-specific information to confirm.

Property developers or owners should seek their site-specific independent advice on land stability, including for areas outside the type A and type B areas, prior to development.

10 References

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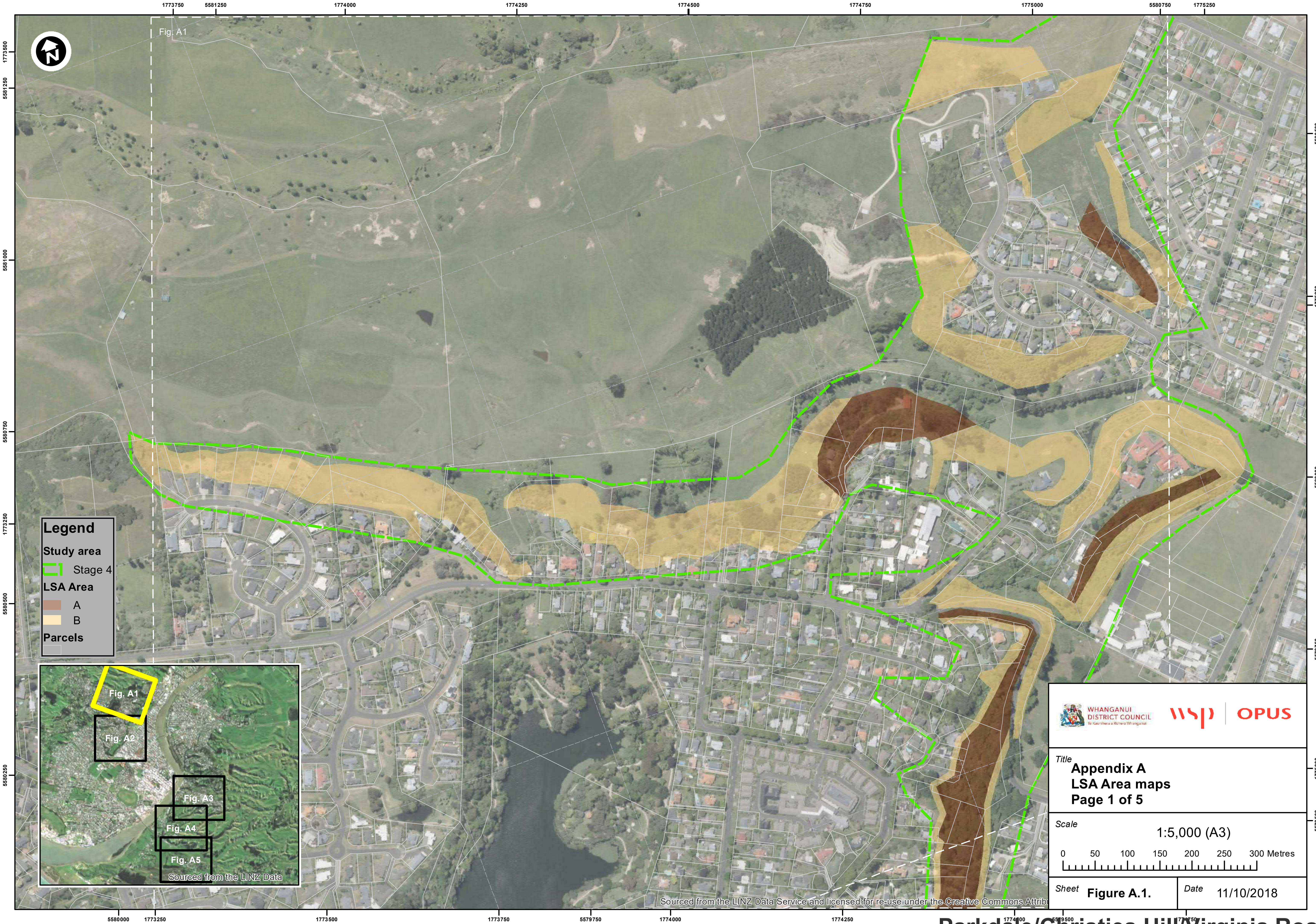
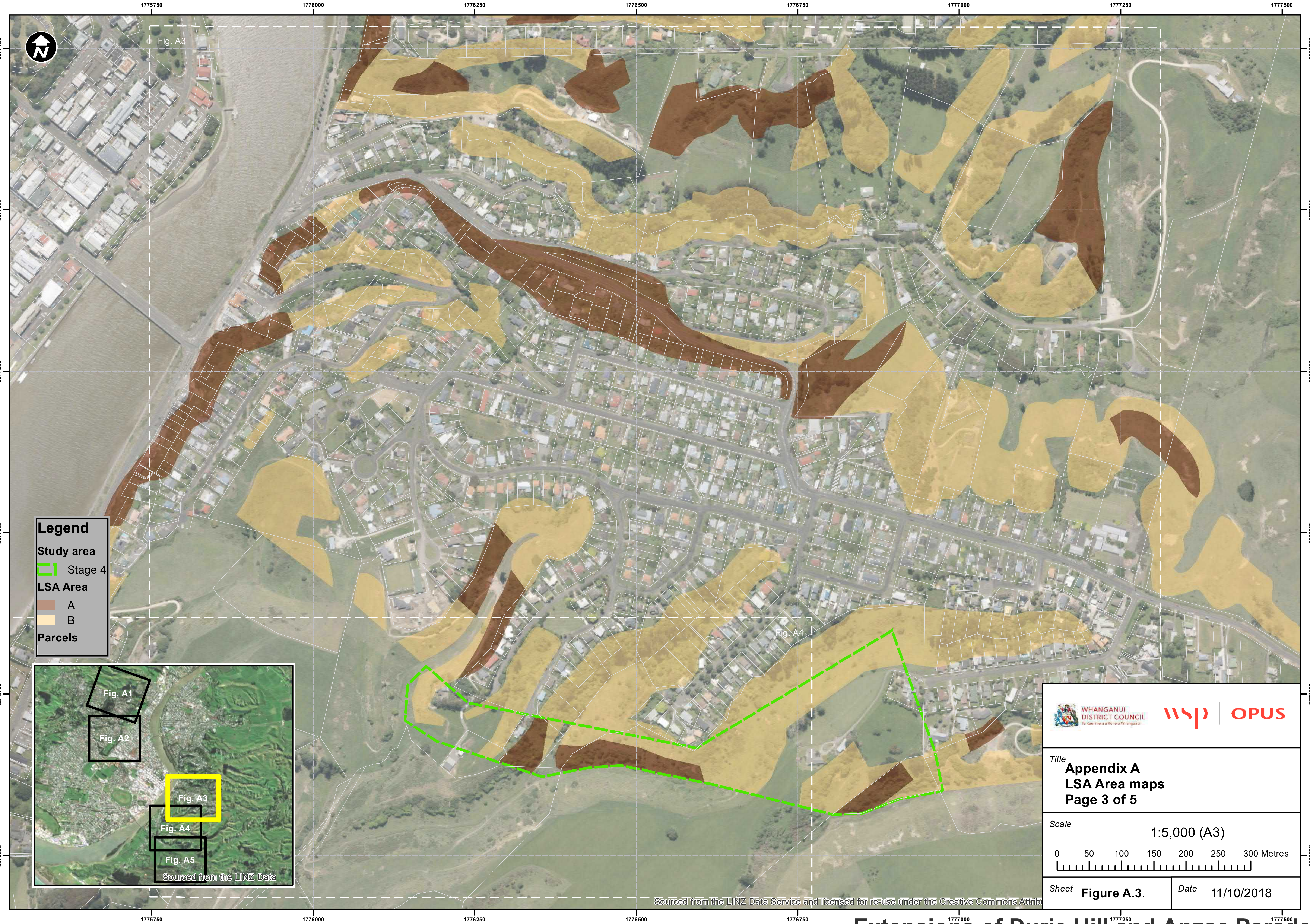
Appendix A
LSA Area maps



Parkdale/Christies Hill/Virginia Road

Victoria Park/Denby Place



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Title
Appendix A
LSA Area maps
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Scale
1:5,000 (A3)
0 50 100 150 200 250 300 Metres

Sheet **Figure A.3.** Date 11/10/2018

Extensions of Durie Hill and Anzac Parade

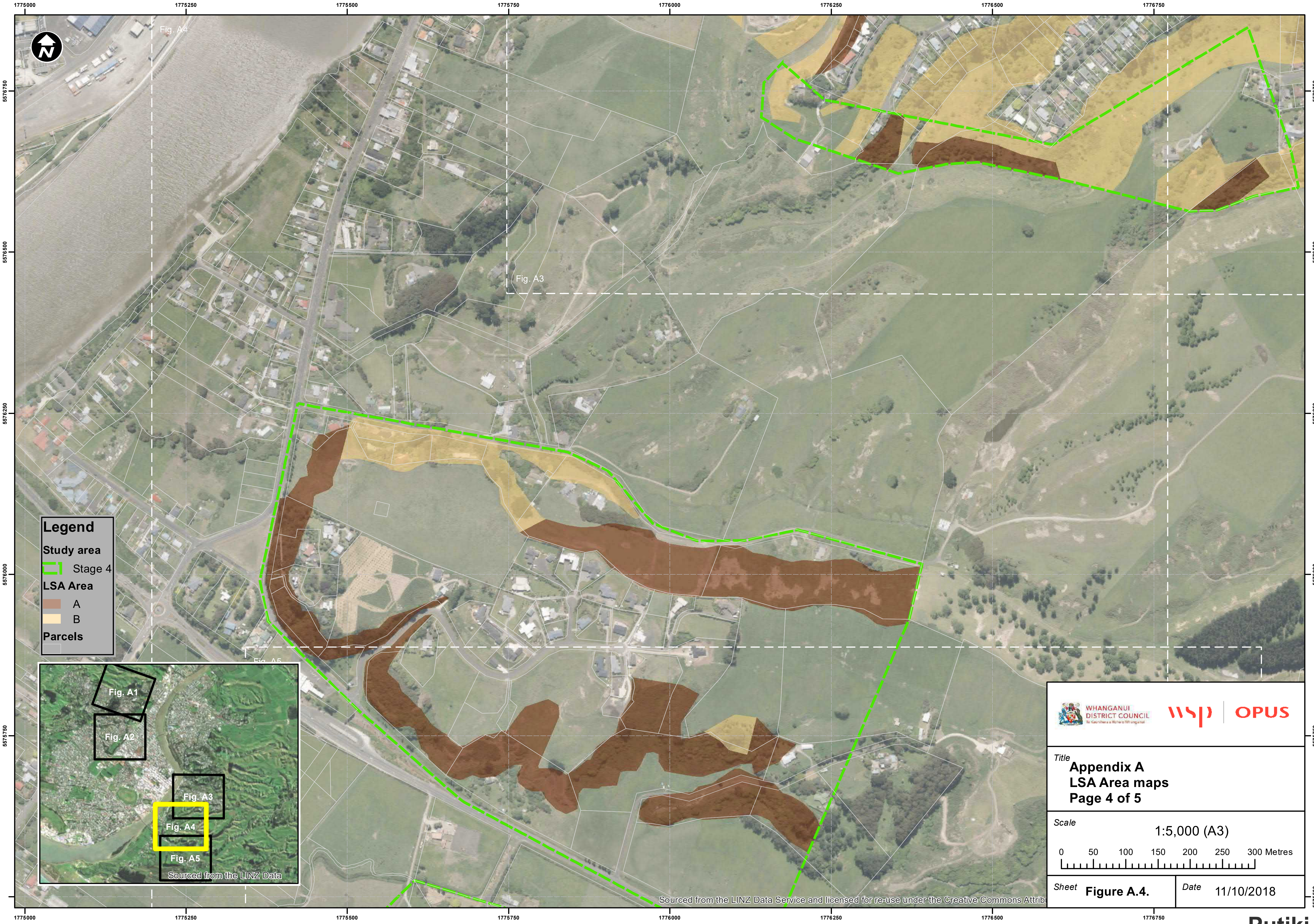

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Fig. A4
Fig. A3
Fig. A5
Legend
Study area
Stage 4
LSA Area
A
B
Parcels
Fig. A1
Fig. A2
Fig. A3
Fig. A4
Fig. A5
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LSA Area maps
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Figure A.4.
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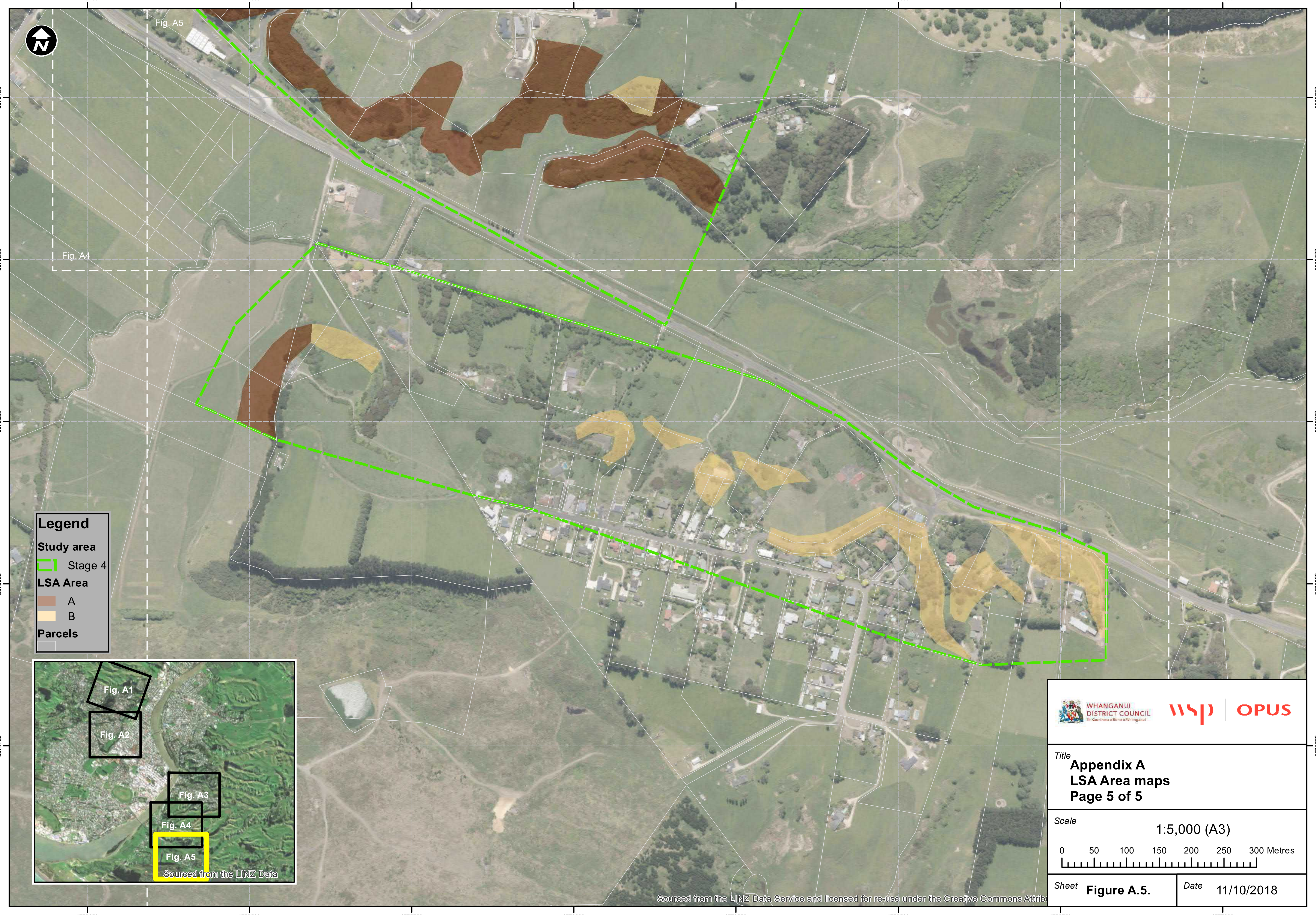
11/10/2018

Putiki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Study area
Stage 4
LSA Area
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Parcels
Fig. A1
Fig. A2
Fig. A3
Fig. A4
Fig. A5
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Figure A.5.
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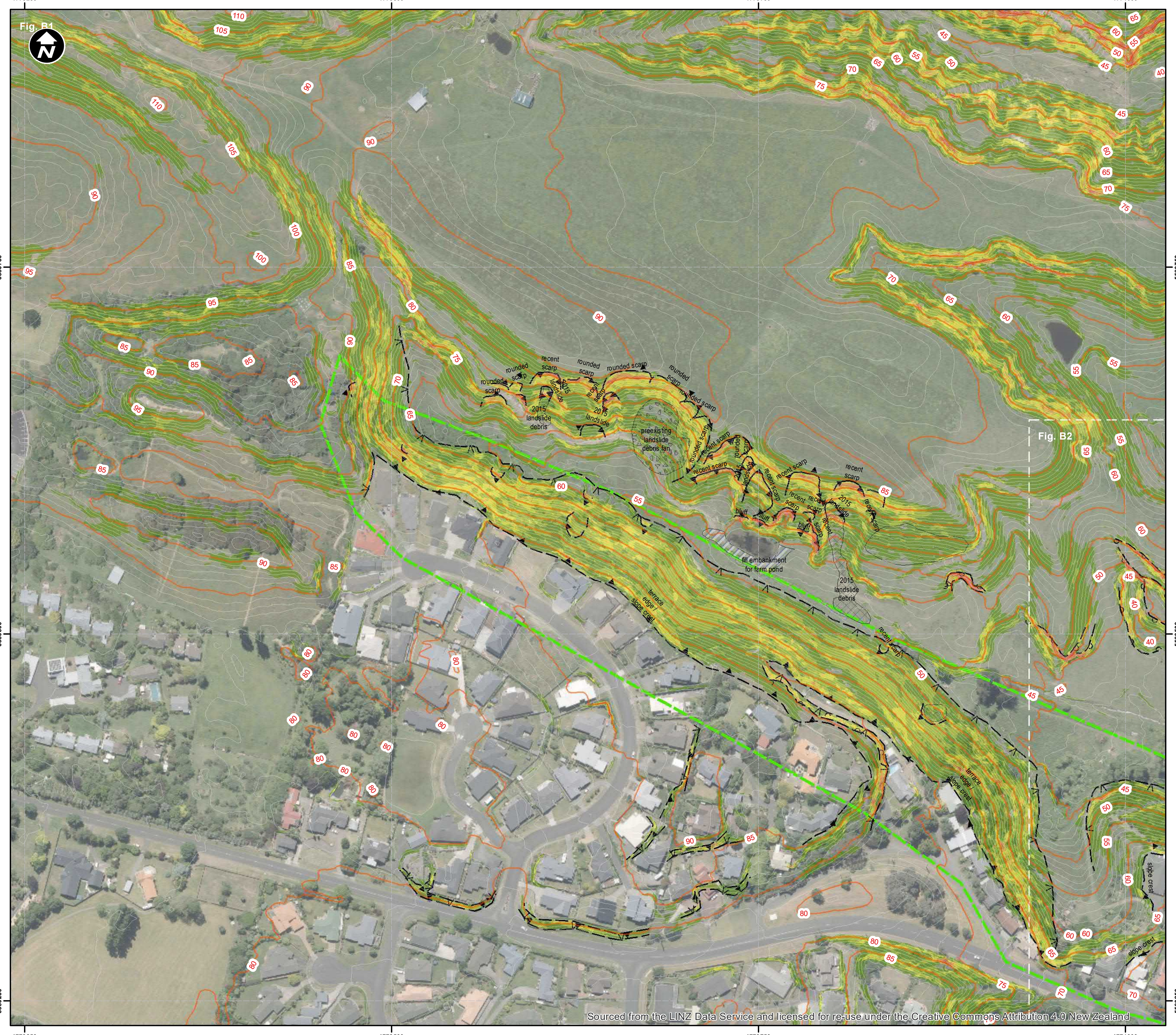
Marybank

Appendix B
Engineering geology maps



Legend

Mapped Slope Features

- tilted tree
- tilted lamp post
- stream
- rill/gully
- slope break, uncertain
- scarp, definite
- scarp, uncertain
- cutting, definite
- cutting, uncertain
- crack, definite
- crack, uncertain
- wall, definite
- landslide area/debris
- hummocky ground
- deflated slope
- fan deposit
- fill

Slope angle (deg.)

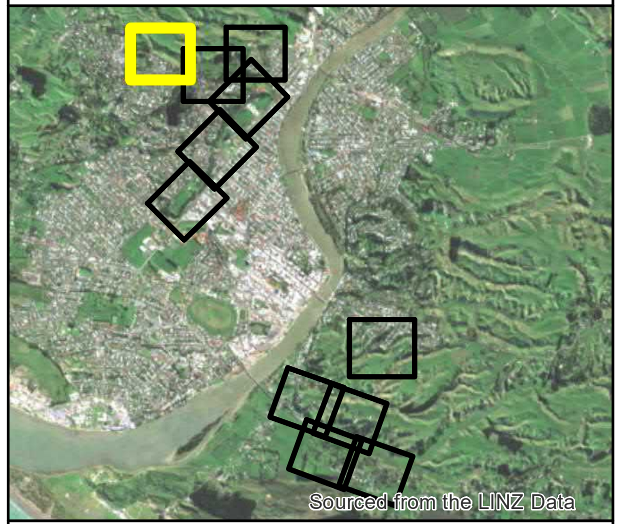
- 0 - 20
- 20 - 30
- 30 - 35
- 35 - 40
- 40 - 45
- 45 - 50
- 50 - 90

LSAA study area

- Stage 4

Contours (1m)

- Major 5m
- Minor 1m



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Engineering geology maps
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Scale
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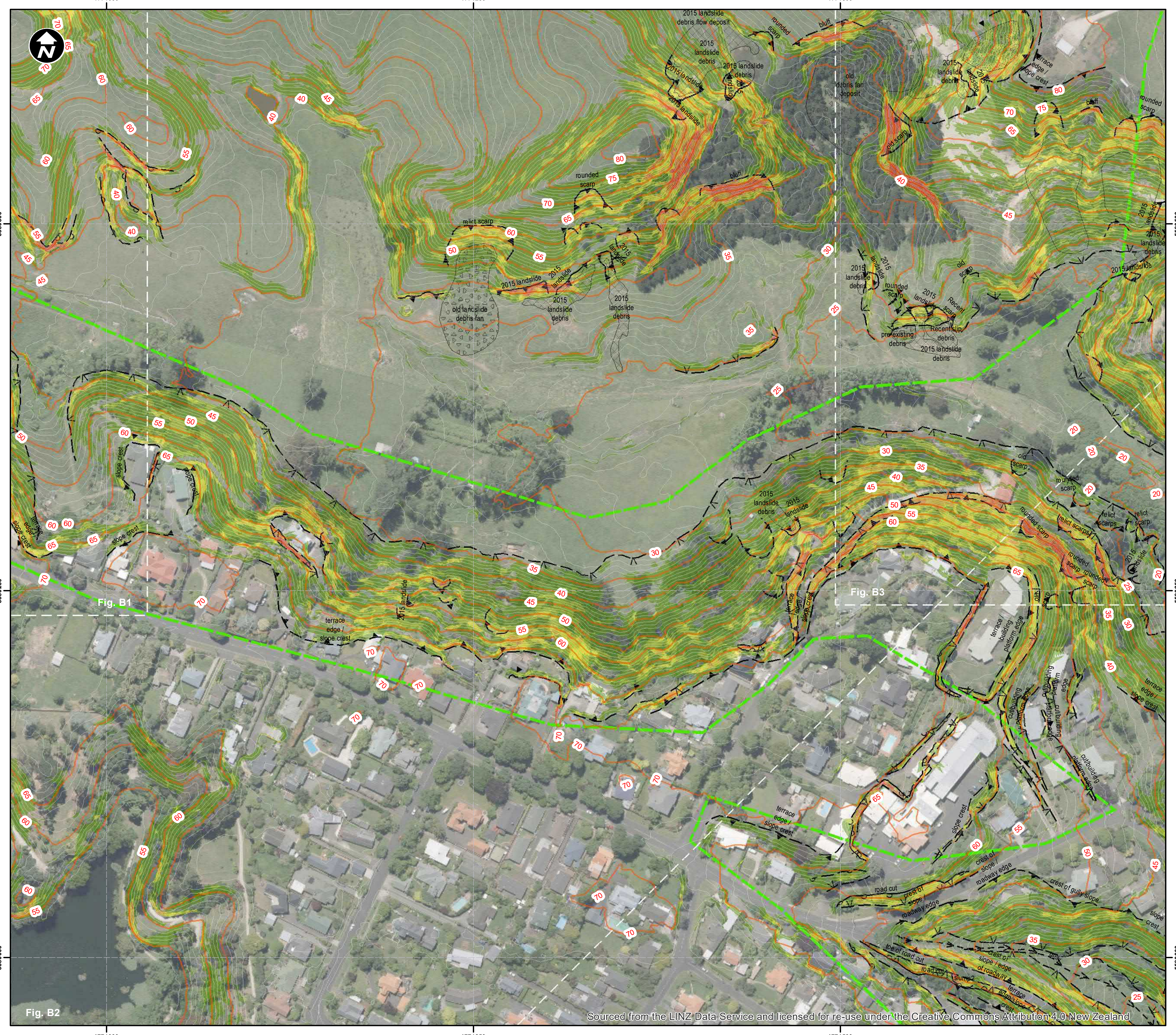
Sheet **Figure B.1.**

Date 11/10/2018



Legend

Mapped Slope Features

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- deflated slope
- fan deposit
- fill

Slope angle (deg.)

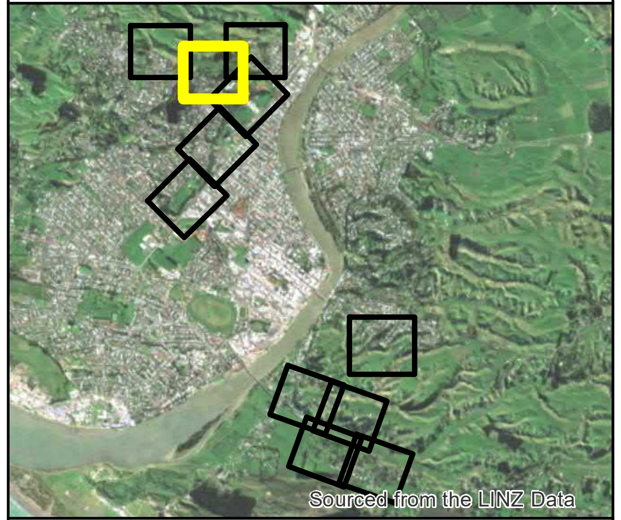
- 0 - 20
- 20 - 30
- 30 - 35
- 35 - 40
- 40 - 45
- 45 - 50
- 50 - 90

LSAA study area

- Stage 4

Contours (1m)

- Major 5m
- Minor 1m



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Scale
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Sheet **Figure B.2.**
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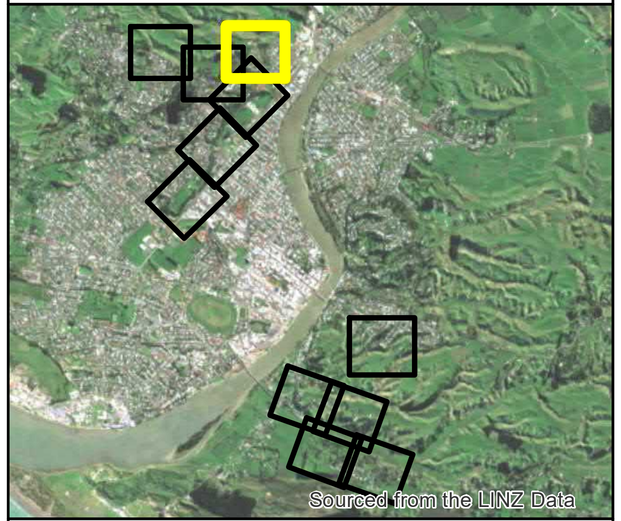
Legend

Mapped Slope Features
- tilted tree
- tilted lamp post
- stream
- rill/gully
- slope break, uncertain
- scarp, definite
- scarp, uncertain
- cutting, definite
- cutting, uncertain
- crack, definite
- crack, uncertain
- wall, definite
- landslide area/debris
- hummocky ground
- deflated slope
- fan deposit
- fill

Slope angle (deg.)
- 0 - 20
- 20 - 30
- 30 - 35
- 35 - 40
- 40 - 45
- 45 - 50
- 50 - 90

LSAA study area
- Stage 4

Contours (1m)
- Major 5m
- Minor 1m



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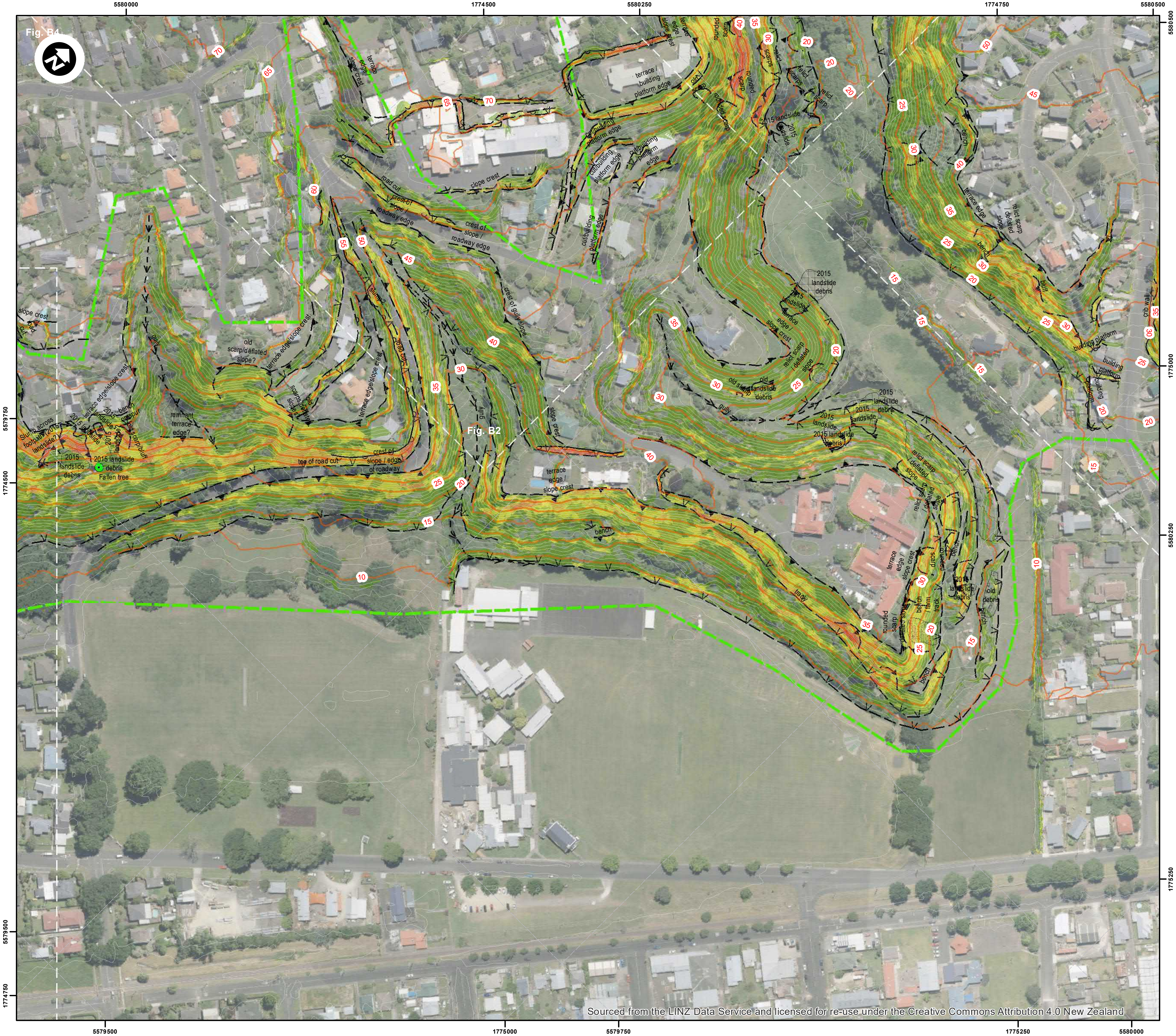
Scale
1:2,500 (A3)
0 50 100 150 Metres

Sheet **Figure B.3.** *Date* 11/10/2018



Legend

Mapped Slope Features

- tilted tree
- tilted lamp post
- stream
- rill/gully
- slope break, uncertain
- scarp, definite
- scarp, uncertain
- cutting, definite
- cutting, uncertain
- crack, definite
- crack, uncertain
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- landslide area/debris
- hummocky ground
- deflated slope
- fan deposit
- fill

Slope angle (deg.)

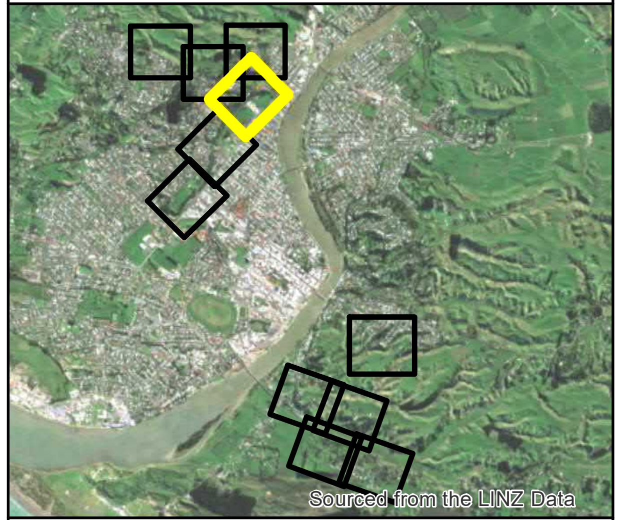
- 0 - 20
- 20 - 30
- 30 - 35
- 35 - 40
- 40 - 45
- 45 - 50
- 50 - 90

LSAA study area

- Stage 4

Contours (1m)

- Major 5m
- Minor 1m



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Scale
1:2,500 (A3)
0 50 100 150 Metres

Sheet **Figure B.4.** Date 11/10/2018

1774000 5579500 1774250 5579750

1774500 5579000 1774750 5579250

5579250 1774000 5579000 1774250 1774500 1774750

Legend

Mapped Slope Features

- tilted tree
- tilted lamp post
- stream
- rill/gully
- slope break, uncertain
- scarp, definite
- scarp, uncertain
- cutting, definite
- cutting, uncertain
- crack, definite
- crack, uncertain
- wall, definite
- landslide area/debris
- hummocky ground
- deflated slope
- fan deposit
- fill

Slope angle (deg.)

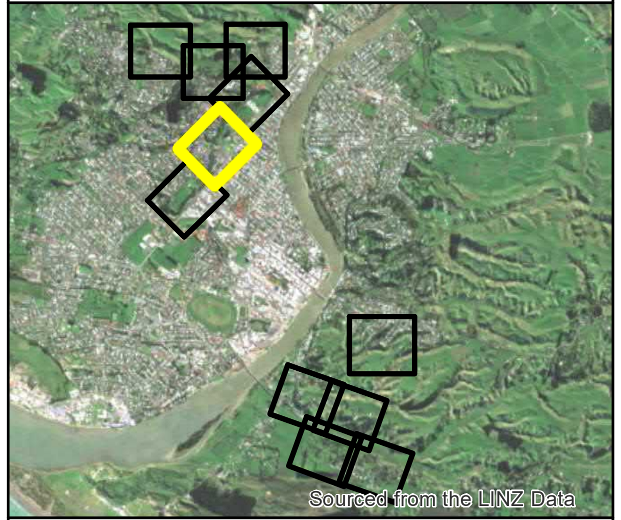
- 0 - 20
- 20 - 30
- 30 - 35
- 35 - 40
- 40 - 45
- 45 - 50
- 50 - 90

LSAA study area

- Stage 4

Contours (1m)

- Major 5m
- Minor 1m



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Scale
1:2,500 (A3)

0 50 100 150 Metres

Sheet **Figure B.5.**

Date 11/10/2018

Legend

Mapped Slope Features

- tilted tree
- tilted lamp post
- stream
- rill/gully
- slope break, uncertain
- scarp, definite
- scarp, uncertain
- cutting, definite
- cutting, uncertain
- crack, definite
- crack, uncertain
- wall, definite
- landslide area/debris
- hummocky ground
- deflated slope
- fan deposit
- fill

Slope angle (deg.)

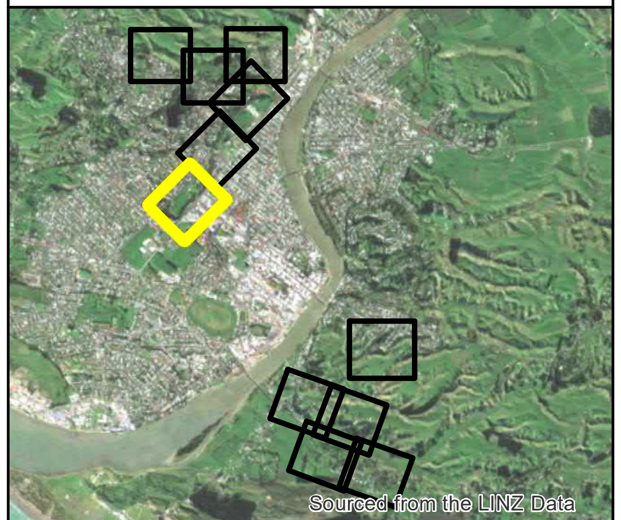
- 0 - 20
- 20 - 30
- 30 - 35
- 35 - 40
- 40 - 45
- 45 - 50
- 50 - 90

LSAA study area

- Stage 4

Contours (1m)

- Major 5m
- Minor 1m



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Scale 1:2,500 (A3)

0 50 100 150 Metres

Sheet **Figure B.6.** *Date* 11/10/2018

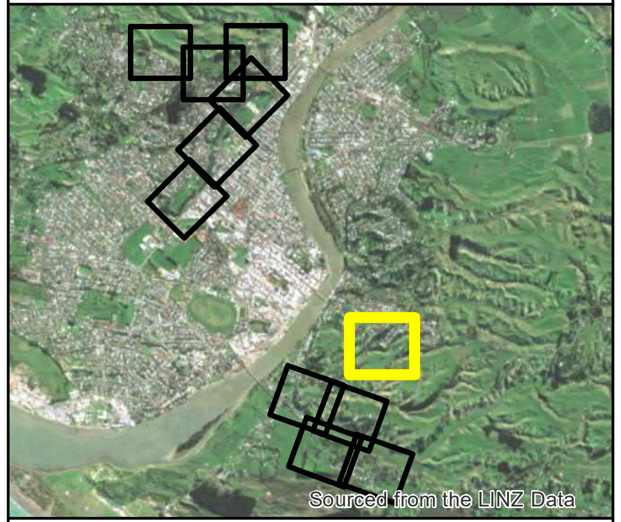
Legend

Mapped Slope Features
- tilted tree
- tilted lamp post
- stream
- rill/gully
- slope break, uncertain
- scarp, definite
- scarp, uncertain
- cutting, definite
- cutting, uncertain
- crack, definite
- crack, uncertain
- wall, definite
- landslide area/debris
- hummocky ground
- deflated slope
- fan deposit
- fill

Slope angle (deg.)
- 0 - 20
- 20 - 30
- 30 - 35
- 35 - 40
- 40 - 45
- 45 - 50
- 50 - 90

LSAA study area
- Stage 4

Contours (1m)
- Major 5m
- Minor 1m



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Scale
1:2,750 (A3)

0 50 100 150 Metres

Sheet **Figure B.7.**

Date 11/10/2018

Legend

Mapped Slope Features

- tilted tree
- tilted lamp post
- stream
- rill/gully
- slope break, uncertain
- scarp, definite
- scarp, uncertain
- cutting, definite
- cutting, uncertain
- crack, definite
- crack, uncertain
- wall, definite
- landslide area/debris
- hummocky ground
- deflated slope
- fan deposit
- fill

Slope angle (deg.)

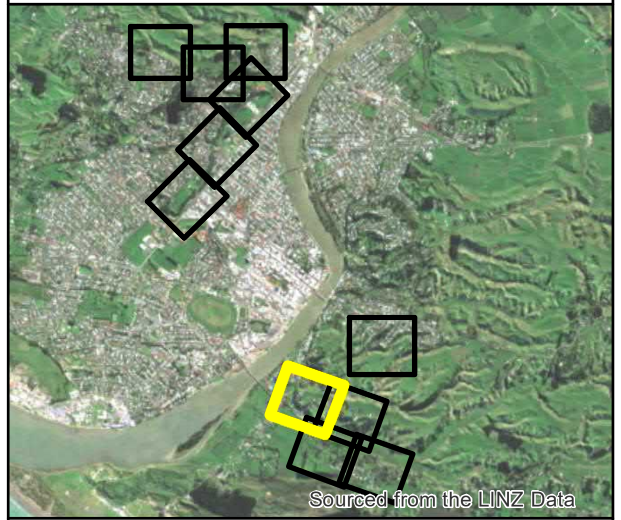
- 0 - 20
- 20 - 30
- 30 - 35
- 35 - 40
- 40 - 45
- 45 - 50
- 50 - 90

LSAA study area

- Stage 4

Contours (1m)

- Major 5m
- Minor 1m



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Scale
1:2,500 (A3)

0 50 100 150 Metres

Sheet **Figure B.8.**

Date 11/10/2018

Legend

Mapped Slope Features

- tilted tree
- tilted lamp post
- stream
- rill/gully
- slope break, uncertain
- scarp, definite
- scarp, uncertain
- cutting, definite
- cutting, uncertain
- crack, definite
- crack, uncertain
- wall, definite
- landslide area/debris
- hummocky ground
- deflated slope
- fan deposit
- fill

Slope angle (deg.)

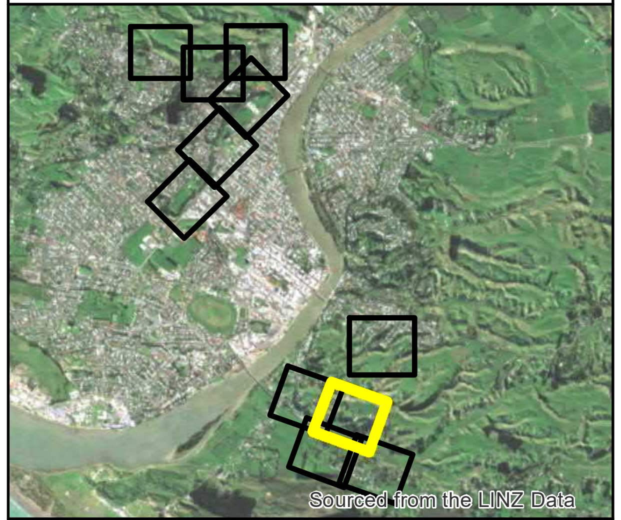
- 0 - 20
- 20 - 30
- 30 - 35
- 35 - 40
- 40 - 45
- 45 - 50
- 50 - 90

LSAA study area

- Stage 4

Contours (1m)

- Major 5m
- Minor 1m



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Scale
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0 50 100 150 Metres

Sheet **Figure B.9.**

Date 11/10/2018

Legend

Mapped Slope Features

- tilted tree
- tilted lamp post
- stream
- rill/gully
- slope break, uncertain
- scarp, definite
- scarp, uncertain
- cutting, definite
- cutting, uncertain
- crack, definite
- crack, uncertain
- wall, definite
- landslide area/debris
- hummocky ground
- deflated slope
- fan deposit
- fill

Slope angle (deg.)

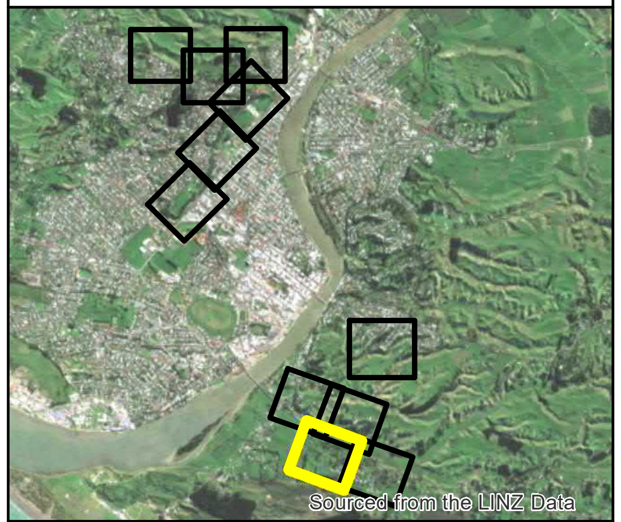
- 0 - 20
- 20 - 30
- 30 - 35
- 35 - 40
- 40 - 45
- 45 - 50
- 50 - 90

LSAA study area

- Stage 4

Contours (1m)

- Major 5m
- Minor 1m



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Sheet **Figure B.10.**

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Legend

Mapped Slope Features

- tilted tree
- tilted lamp post
- stream
- rill/gully
- slope break, uncertain
- scarp, definite
- scarp, uncertain
- cutting, definite
- cutting, uncertain
- crack, definite
- crack, uncertain
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Slope angle (deg.)

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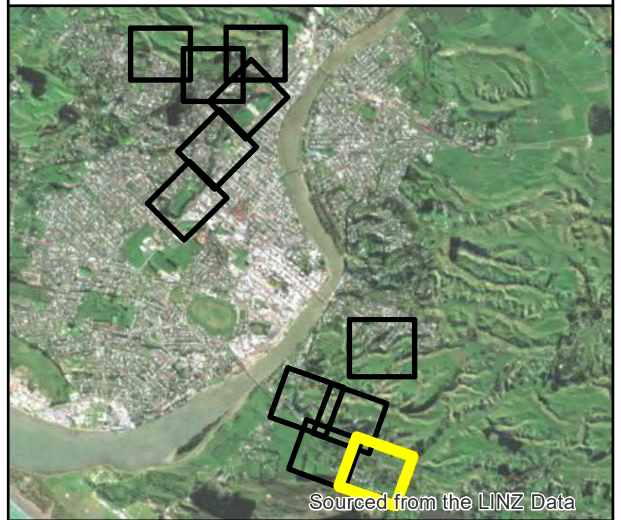
- 35 - 40
- 40 - 45
- 45 - 50
- 50 - 90

LSAA study area

- Stage 4

Contours (1m)

- Major 5m
- Minor 1m



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Scale
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0 50 100 150 Metres

Sheet **Figure B.11.**
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Appendix C
Risk assessment tables

PRACTICE NOTE GUIDELINES FOR LANDSLIDE RISK MANAGEMENT 2007

APPENDIX C: LANDSLIDE RISK ASSESSMENT

QUALITATIVE TERMINOLOGY FOR USE IN ASSESSING RISK TO PROPERTY

QUALITATIVE MEASURES OF LIKELIHOOD

Approximate Annual Probability		Implied Indicative Landslide Recurrence Interval		Description	Descriptor	Level
Indicative Value	**Notional Boundary**					
10^{-1}	$5x10^{-2}$	10 years	20 years	The event is expected to occur over the design life.	ALMOST CERTAIN	A
10^{-2}	$5x10^{-3}$	100 years	200 years	The event will probably occur under adverse conditions over the design life.	LIKELY	B
10^{-3}	$5x10^{-4}$	1000 years	2000 years	The event could occur under adverse conditions over the design life.	POSSIBLE	C
10^{-4}	$5x10^{-5}$	10,000 years	20,000 years	The event might occur under very adverse circumstances over the design life.	UNLIKELY	D
10^{-5}	$5x10^{-6}$	100,000 years	200,000 years	The event is conceivable but only under exceptional circumstances over the design life.	RARE	E
10^{-6}		1,000,000 years		The event is inconceivable or fanciful over the design life.	BARELY CREDIBLE	F

Note: (1) The table should be used from left to right; use Approximate Annual Probability or Description to assign Descriptor, not *vice versa.*

QUALITATIVE MEASURES OF CONSEQUENCES TO PROPERTY

Approximate Cost of Damage		Description	Descriptor	Level
Indicative Value	**Notional Boundary**			
200%	100%	Structure(s) completely destroyed and/or large scale damage requiring major engineering works for stabilisation. Could cause at least one adjacent property major consequence damage.	CATASTROPHIC	1
60%	40%	Extensive damage to most of structure, and/or extending beyond site boundaries requiring significant stabilisation works. Could cause at least one adjacent property medium consequence damage.	MAJOR	2
20%	10%	Moderate damage to some of structure, and/or significant part of site requiring large stabilisation works. Could cause at least one adjacent property minor consequence damage.	MEDIUM	3
5%	1%	Limited damage to part of structure, and/or part of site requiring some reinstatement stabilisation works.	MINOR	4
0.5%		Little damage. (Note for high probability event (Almost Certain), this category may be subdivided at a notional boundary of 0.1%. See Risk Matrix.)	INSIGNIFICANT	5

Notes: (2) The Approximate Cost of Damage is expressed as a percentage of market value, being the cost of the improved value of the unaffected property which includes the land plus the unaffected structures.

(3) The Approximate Cost is to be an estimate of the direct cost of the damage, such as the cost of reinstatement of the damaged portion of the property (land plus structures), stabilisation works required to render the site to tolerable risk level for the landslide which has occurred and professional design fees, and consequential costs such as legal fees, temporary accommodation. It does not include additional stabilisation works to address other landslides which may affect the property.

(4) The table should be used from left to right; use Approximate Cost of Damage or Description to assign Descriptor, not vice versa

APPENDIX C: – QUALITATIVE TERMINOLOGY FOR USE IN ASSESSING RISK TO PROPERTY (CONTINUED)

QUALITATIVE RISK ANALYSIS MATRIX – LEVEL OF RISK TO PROPERTY

LIKELIHOOD		CONSEQUENCES TO PROPERTY (With Indicative Approximate Cost of Damage)				
	Indicative Value of Approximate Annual Probability	**1: CATASTROPHIC 200%**	**2: MAJOR 60%**	**3: MEDIUM 20%**	**4: MINOR 5%**	**5: INSIGNIFICANT 0.5%**
A – ALMOST CERTAIN	10^{-1}	VH	VH	VH	H	M or **L** (5)
B - LIKELY	10^{-2}	VH	VH	H	M	**L**
C - POSSIBLE	10^{-3}	VH	H	M	M	**VL**
D - UNLIKELY	10^{-4}	H	M	**L**	**L**	**VL**
E - RARE	10^{-5}	M	**L**	**L**	**VL**	**VL**
F - BARELY CREDIBLE	10^{-6}	**L**	**VL**	**VL**	**VL**	**VL**

Notes: (5) For Cell A5, may be subdivided such that a consequence of less than 0.1% is Low Risk.
(6) When considering a risk assessment it must be clearly stated whether it is for existing conditions or with risk control measures which may not be implemented at the current time.

RISK LEVEL IMPLICATIONS

Risk Level		Example Implications (7)
VH	VERY HIGH RISK	Unacceptable without treatment. Extensive detailed investigation and research, planning and implementation of treatment options essential to reduce risk to Low; may be too expensive and not practical. Work likely to cost more than value of the property.
H	HIGH RISK	Unacceptable without treatment. Detailed investigation, planning and implementation of treatment options required to reduce risk to Low. Work would cost a substantial sum in relation to the value of the property.
M	MODERATE RISK	May be tolerated in certain circumstances (subject to regulator's approval) but requires investigation, planning and implementation of treatment options to reduce the risk to Low. Treatment options to reduce to Low risk should be implemented as soon as practicable.
L	LOW RISK	Usually acceptable to regulators. Where treatment has been required to reduce the risk to this level, ongoing maintenance is required.
VL	VERY LOW RISK	Acceptable. Manage by normal slope maintenance procedures.

Note: (7) The implications for a particular situation are to be determined by all parties to the risk assessment and may depend on the nature of the property at risk; these are only given as a general guide.

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