BEFORE THE HEARINGS PANEL

IN THE MATTER	of the Resource Management Act 1991
AND	
IN THE MATTER	of proposed Plan Change G: Aokautere Urban Growth to the Palmerston North City Council District Plan

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SECTION 42A TECHNICAL REPORT OF ERIC BIRD
ON BEHALF OF PALMERSTON NORTH CITY COUNCIL

TECHNICAL – GEOTECHNICAL

Dated 15 SEPTMEBER 2023

TABLE OF CONTENTS

A. EXECUTIVE SUMMARY

1. The key conclusions of my section 42A technical report are:

   (a) In the northern part of the plan change area, elevated flat-topped terraces form the majority of the area proposed for development. These terraces are bisected by incised streambeds in steep sided gullies. These gully sides often exhibit existing slope instability, which is further exacerbated by active stream erosion in the gullies. The southern part of the site is hilly and does not feature any flat, terraced features, and also exhibits slope instability.

   (b) In general, terraces such as those in the plan change area would be naturally stable at slopes of around 20° or less while slopes steeper than 30° appear very susceptible to instability. Slope angle analysis has been carried out, based on projecting 20° and 30° lines upward from the base of each gully and provides a high-level assessment to identify areas where slope instability is more (or less) likely. The base of the gullies used for the analysis reflects future erosion within the gullies. This slope analysis defines land classes that inform the requirements for further geotechnical assessment of the slope instability hazard. In broad terms, the steeper the slope, the more extensive the requirements are for geotechnical assessment, and the more restrictive the controls are on subdivision and development. These land classes and the corresponding requirements for further assessment of slope instability have been reflected in the proposed plan change provisions.

   (c) The lower, southwestern portion of the site along Valley Views and Turitea Road is relatively flat and lower lying than the remainder of the site and does not exhibit slope instability of any significance. The liquefaction hazard in this area is undetermined due to the absence of geotechnical data. Future subdivision or development should assess the potential for liquefaction.

   (d) There is evidence of filling of land within the plan change area. It is not known what material was used for filling, nor whether engineering controls were carried out during filling. Where uncontrolled fill is present within the PCG area, it should be characterised prior to any development.

B. INTRODUCTION

2. My name is Eric Bird. I am an Engineering Geologist.

3. I have over 15 years of experience in natural hazard management. I have worked in numerous roles in natural hazard assessment and management, including carrying out engineering assessments following storm and earthquake events, as well as working in advisory roles for central and local government on disaster response and hazard management, and carrying out numerous hazard studies for future land use planning. I have also spent 10 years as the Technical Director for one of the major insurance providers during the Canterbury Earthquake recovery, overseeing the assessment, repair and reconstruction of $4.5B of residential housing claims.

4. I have been engaged by Palmerston North City Council (**Council**) in relation to proposed Plan Change G (**PCG**), which seeks to rezone a new greenfield growth area in Aokautere for residential development and inserts an accompanying structure plan and provisions (objectives, policies and rules) into the District Plan.

5. I have been involved with PCG since 2021. My role has involved overseeing the spatial analysis for slope stability assessment and providing advice on the implementation of this analysis into the District Plan.

6. I am also familiar with the earlier work undertaken by my colleagues at Tonkin and Taylor, who initially conducted a site visit and preliminary assessment of geotechnical hazards.[1] The findings of that study were incorporated into the Structure Plan for PCG.[2]

7. As part of my role I authored the following reports:

   (a) *Aokautere slope stability: considerations for consenting, dated May 2022.* This report summarised earlier studies carried out by Tonkin and Taylor and presented recommendations to inform requirements for future subdivision, including documenting the need for any further investigation and assessment work that may be required during development (the "2022 Assessment").

[1] *2020, Tonkin + Taylor Ltd, Preliminary Site Observations for Proposed Aokautere Redevelopment.*
[2] Palmerston North Aokautere Masterplan, at section 2.3, pp 38-44.

(b) Earlier Tonkin and Taylor studies included:

(i) *2005, Tonkin + Taylor, Development of land which is, or is likely to be, subject to erosion or slippage: policy document.* This report made recommendations to PNCC for the management of slippage hazards, including introducing classes of land based on slope angles and proximity to these slopes.

(ii) *2020, Tonkin + Taylor Ltd, Preliminary Site Observations for Proposed Aokautere Redevelopment.* This study comprised a preliminary geotechnical assessment of the Aokautere area for future residential and rural-residential development. This report summarised the geotechnical hazards present throughout the site of the proposed Aokautere Development Area. The study comprised a desktop review of readily available relevant information and a site walkover.

(iii) *2021, Tonkin + Taylor Ltd, Memo- Aokautere Development - Geotechnical input for set-back contours*. This desktop, spatial data based assessment carried out slope angle analysis for the Aokautere area, to map slope stability hazard classes consistent with the approach introduced in the 2005 T+T report.

(iv) *2023, Tonkin + Taylor Ltd, Memo- Aokautere Development - Geotechnical input for set-back contours*. This study updated the 2021 slope angle assessment by incorporating the more recent recommendations and findings from GHD to reflect predicted stream erosion and assess its effects on slope angle analysis.

8. The reports described above are at ached to my s 42A report as **Attachments A-E**.

C. CODE OF CONDUCT

9. I confirm that I have read and agree to comply with the Code of Conduct for Expert Witnesses contained in the Environment Court Practice Note 2023. I confirm that I have stated the reasons for my opinions I express in this report, and have considered all the material facts that I am aware of that might alter or detract from those opinions.

10. Statements expressed in this report are within the scope of my expertise, except where I rely on the technical advice I have referred to in paragraph [15] of this report.

11. I have all the information necessary to assess the application within the scope of my expertise and am not aware of any gaps in the information or my knowledge.

12. I am familiar with the plan change area, having visited it on 16 March 2023.

D. SCOPE

13. In my section 42A report I provide an overview of natural hazards within the Aokautere area, including the following issues:

    (a) The causes of slope stability hazards and factors which influence slope stability hazards;

    (b) Planning mitigation measures for addressing slope stability hazards;

    (c) The potential for uncontrolled fill within the PCG area; and

    (d) Liquefaction potential of land within the PCG area.

14. In preparing this report, I have reviewed and considered the following information:

    (a) The proposed Structure Plan for PCG and related provisions; and

    (b) Submissions from interested parties.

15. In addition to my own observations, I rely on the technical evidence of

    (a) Mr Tony Miller

    (b) Ms Reiko Baugham

    (c) Ms Anita Copplestone.

16. I have reviewed submissions and further submissions on PCG. Of particular note when considering my field of expertise are the submissions relating to:

    (a) Slope instability (referred to as various terms within submissions, including 'landslides', 'slumping', 'slippage', 'slips', and 'land instability'); and

(b) Erosion and stormwater issues, as these influence slope stability for the reasons I set out below.

E. BACKGROUND

17. PCG seeks to rezone a new greenfield growth area to the south-east of Palmerston North for residential development and inserts an accompanying structure plan and provisions (objectives, policies, and rules) into the District Plan. The plan change will provide for additional housing supply in Aokautere (and the City), to help meet growth projections for Palmerston North over the medium to long term, while addressing the specific topography and environmental issues in Aokautere.

18. Various parts of the PCG area are underlain by different geologies. These geologies influence the types of landforms present:

(a) The northern part of the site comprises late Pleistocene beach sands and marginal marine gravels. These are formed into elevated flat-topped terraces, bisected by incised streambeds, and form the majority of the site proposed for development. The streambeds are in steep sided gullies, and these gully sides often exhibit existing slope instability.

(b) The southern part of the site (referred to as the 'Waters block') is early Pleistocene river deposits of pumiceous sand and gravel. This portion of the site is hilly and does not feature any flat, terraced features.

(c) The lower, southwestern portion of the site along Valley Views and Turitea Road is comprised of late Pleistocene to Holocene (more recent) river deposits of gravel and sand. This portion of the site is relatively flat and lower lying than the remainder of the site and does not exhibit slope instability of any significance.

19. The main geotechnical hazard present in the northern part where the majority of the development is proposed is slope instability.

20. Other geotechnical hazards may exist within the PCG area, including uncontrolled fill materials (potentially leading to set lement). Liquefaction hazard may also exist in the lower southwestern portion of the site along Valley Views and Turitea Road.

21. Following earlier work in 2005 in which Tonkin and Taylor made recommendations to PNCC for the management of slippage hazards on a district-wide level, we were engaged by the Council to carry out slope angle analysis for instability, carry out an assessment of areas of potentially uncontrolled fill, and provide recommendations for future development in Aokautere. This work was undertaken to inform requirements for future subdivision in Aokautere, including outlining any further investigation and assessment work that may be required for development within the PCG area.

F. ASSUMPTIONS AND METHODOLOGY – SLOPE ANGLE ANALYSIS

22. Slope instability is primarily influenced by the strength of a soil, the weight of the soil, the height and angle of the slope, and the amount of water within the soil.

23. Vegetation can also influence slope stability, as roots can alter the strength of the soil mass, and vegetation cover can influence water content within soil and the rate at which water enters the soil.

24. At a high level, the likelihood for slope instability can be estimated by carrying out analysis of slope angles. The higher the slope angle, the more likely there will be instability. In general, terraces such as those in the PCG study area would be naturally stable at slopes of around 20° or less while slopes steeper than 30° appear very susceptible to instability.

25. The other factors influencing slope instability (soil weight, strength, and water content), are usually assessed at a site-specific level, as they will vary depending on the site.

26. I oversaw the spatial analysis on slope angles undertaken by Tonkin and Taylor within the PCG study area, using a Digital Elevation Model (DEM) based on LiDAR data. The analysis has considered the steepness of gully slopes by projecting 20° and 30° lines from the base of each gully upward to the overlying terrace. This methodology is described in *Aokautere Development - Geotechnical input for set-back contours (2023).* In summary:

    (a) The base of each gully was taken from LiDAR data and represented the lowest point in each gully, typically the streambed.

(b) Where these projected slope lines bisected the terrace surface, a line was then plote d on a map. These plote d line features represent the position of a 20° and a 30° slope set back, relative to the toe, or base, of the gully slope.

(c) The plote d lines then provide a geospatial perspective to inform the judgement of appropriate risk classifications when considering future development of the project area.

(d) Land inside the 20° line, away from the terrace edge (i.e. where projected lines are shallower than 20°) has been labelled 'Class A, B and C' land. Land between the 20° and 30° lines is labelled as 'Class D' land, and land steeper than 30° is labelled as 'Class E' land.

(e) Previous versions of the slope angle analysis further subdivided land inside the 20° line (hence the A, B, and C classifications), however for this study all of this land is grouped together as it is generally subject to the same issues. The proposed PCG provisions also group these together, referring to these areas as 'Developable Land' on the basis that it is unlikely that slope stability hazards would preclude development in these areas. In turn, Class D and E land is categorised as "Limited Developable Land". This lat er category reflects the increased likelihood of slope instability in these areas, and therefore the likelihood of limitations being necessary for any development in these areas.

27. The land classes based on this slope analysis for the PCG area are shown in the proposed PCG provisions in Map 10.1A, which displays Developable Land and Limited Developable Land. The 30° line is included within Limited Developable Land to delineate Class D from Class E land. Map 10.1A is an update of the existing Map 10.1 in the operative plan and extends to cover the area within the Aokautere Structure Plan.

28. It should be noted that the spatial analysis is a high-level assessment to identify areas where slope instability is more (or less) likely. As such, it is a screening tool intended to inform the requirements for further assessment. It does not take into account the specifics of an individual site or consider other geotechnical hazards. Site-specific investigation and assessment is still required at subdivision and land use stages of development, as outlined in the PCG provisions.

29. The slope angle analysis is particularly useful for areas with flat topped terraces (such as where the majority of the residential development is proposed), however it can yield less reliable results where the terrain is undulating and hilly, such as the Waters block in the southern part of the PCG site. This is because it does not account for any mid-slope changes in slope which are common in hilly areas.

30. I carried out a site visit on 16 March 2023, and evidence of existing slope instability was observed at various locations around the site on the gully sides/terrace edges. This is consistent with the results of the slope angle analysis. Instability was particularly evident in areas of pastureland, and less so in forested areas.

G. ASSUMPTIONS AND METHODOLOGY – FILL AREAS

31. Uncontrolled fill has previously been identified by the Council within the PCG site. Uncontrolled fill poses challenges for development as when additional loads are applied (e.g. by further fill placement or building construction) these ground conditions can produce large total and differential set lements, if the fill has not been selected and placed with engineering controls. This has the potential to damage buildings and other infrastructure founded on these materials. In some cases, ongoing creep setl ement may occur, even without additional loads being applied. Depending on the nature and content of the fill material, there also may be associated soil contamination.

32. Various LiDAR datasets are available for the PCG study area, which enable the compilation of a Digital Elevation Model (DEM); a digital model representing the surface of the land. As part of our reporting on PCG, Tonkin and Taylor have carried out an exercise to identify areas likely to contain fill by subtracting the 2006 DEM from the 2018 DEM. Where the resulting values are negative, the land levels have been reduced by the resultant value by excavation and removal of land, and where the resulting values are positive, the land levels have been raised by that value.

33. Based on this DEM analysis, the filling of two gullies is clearly evident at the head of Gully 1 and its previous tributary gully to the east (now predominantly filled in). The centre of each gully has been filled in to over 5m in depth. The fill appears to have been sourced from adjacent terraces.

34. The surrounding elevated terraces have been reduced in height, indicating that these areas are likely to be the source of the fill material used.

35. The DEM analysis highlights some areas of the site where filling has taken place. It does not consider the material used for filling, nor whether engineering controls (such as compaction or construction monitoring and testing) were carried out during filling. Again, as with slope stability, site-specific investigation and assessment relating to infilled areas will be required at later stages, as reflected through the PCG provisions.

H. ASSUMPTIONS AND METHODOLOGY – LIQUEFACTION

36. Liquefaction is influenced by seismicity, soil type, and the presence of groundwater. The geotechnical reporting on PCG also considered the potential for liquefaction in the PCG site.

37. The raised terraces in the northern part of the site are unlikely to be subject to liquefaction due to the soil type and their elevated nature.

38. In the Turitea Stream valley bordering the northeast side of Turitea Road, there are two distinct terraces: The geological map for the area shows the upper terrace as late Pleistocene river deposits of gravel and sand. The lower terrace is mapped as Holocene river deposits of gravel, sand, clay and peat. Both of these geological units are known to have liquefiable soils.

39. It appears that there is current development taking place on the upper terrace.

40. The upper terrace is elevated approximately 8 – 12 m above the lower terrace.

41. The depth to groundwater in the Turitea Stream valley is unknown.

42. There are not currently any geotechnical investigations available for this valley area in the New Zealand Geotechnical database.

43. On the basis that there is no geotechnical information or groundwater data for this area, both the upper and lower terrace areas should be classified as ***Liquefaction Category is Undetermined*** in accordance with the MBIE/MfE Guidance (2017) at this time. This category reflects the fact that insufficient information exists to determine whether liquefaction is possible or is unlikely.

I. FURTHER ASSESSMENT

44. Following submissions, further assessment by GHD has bet er particularised the active stream erosion occurring in most of the gullies in the PCG area. The geology underlying the terraces comprises beach sands and marginal marine gravels, which are typically uniformly fine-grained sediments that are relatively erodible. The outcomes of the GHD analysis is described in the section 42A report of Reiko Baugham and Tony Miller.

45. Stream erosion increases the likelihood of slope instability, as it lowers the streambed relative to the upper terrace slopes and therefore steepens the overall slope angle. In this scenario, instability often initially appears as localised slippage into the streambed that progressively migrates up the slope. Erosion also removes the toe of the slope, resulting in increased likelihood of instability, particularly on steep slopes.

46. Following GHD's further analysis, the slope angle assessment has been revised to include updated streambed erosion projections. In revisiting the slope angle assessment, the new streambed erosion figures were used to analyse two scenarios:

    (a) The 'minimum' scenario where engineering works are proposed in streambeds to minimise erosion that is already occurring from existing development and to address future erosion risk from the development of the PCG area; and

    (b) The 'maximum' scenario where no engineering works are proposed to manage erosion, and therefore the current erosion rates continue.

47. To carry out the analysis, the base of the gully was lowered by GHD's projected streambed erosion figures, with 20° and 30° lines projected from the recalculated base of each gully upward to the overlying terrace. The methodology as described in [26] was utilised. This analysis resulted in updated 'minimum' and 'maximum' setbacks for slope instability, depending on the erosion scenario. The updated 20° and 30° lines reflect the long-term elevation of the streambed. At many locations on the two northern-most promontories (adjacent to gullies 1 and 3), and at intermit ent points on other terraces, this has increased the recommended setback distance from the terrace edges. This occurs more consistently where the 'maximum' erosion values are used; as opposed to where in-stream interventions are in place to manage erosion.

48. I have also been involved in ongoing multi-disciplinary discussions in response to submissions regarding the Structure Plan, including the locations and requirements for perimeter swales, stormwater ponds, walking tracks, and transport and service routes. My advice has focussed on the geotechnical aspects of these topics and the extent to which options affect the impacts of natural hazards in the PCG area.

J. SUBMISSIONS

49. I have considered the submissions and further submissions for PCG. I have identified the key issues, which I address by reference to submissions in detail below.

50. A large number of submit ers identify the link between large rainfall events, streambed erosion, and slope instability (Ray and Judy Stevens, Russell Poole, Inga Hunter, Ee Kheng Ang, Bret Guthrie, Anthony and Rosemary Gear, Gill Welch, Christine Scot , Elizabeth Fisher, Colin Perrin, Sara Burgess, Prasika Reddy, Gaylene Tiffin, Susan and Yann Le Moigne, Elizabeth Endres). Many of their submissions observe either directly or indirectly that streambed erosion results in a higher incidence of slope instability. This is an accurate observation, as streambed erosion steepens the overall slope and removes the support from the toe of a slope, often resulting in increased instability, particularly on already steep slopes.

51. The gully slopes in the PCG area are steep, and in most locations, the potential for slope instability would be increased by streambed erosion lowering the elevation of the streambed. My observations of the slope instability within the PCG area are therefore consistent with the submite r's observations. In areas where streambed erosion is evident, localised slope instability along the banks of the streambed is occurring.

52. The relationship between erosion and slope instability has been addressed in the updated slope angle analysis, by projecting the streambed elevations down in line with GHD's predicted erosion figures, as described in [46] and [47], above. The slope angle analysis therefore reflects the long-term elevation of the streambed by accounting for predicted erosion, and results in 20° and 30° lines that increase the setback distance from the terrace edges. As described above, the setback lines define the areas of Developable Land and Limited Developable Land (including Class D and E), which enable controls to be placed on subdivision and development in these areas, in order to

prevent housing or other infrastructure from being damaged by, or causing, slope instability.

53. Map 10.1A of the PCG provisions has been updated to reflect the slope analysis scenario which accounts for mitigation being in place, i.e. the 'minimum' scenario. Ms Baugham and Mr Miller discuss the stormwater management controls proposed to manage erosion. Updated Map 10.1A is included with this report as **Attachment F**.

54. A number of submite rs comment on the potential increased slope instability hazard of locating stormwater retention ponds on the terraces (Ee Kheng Ang S30.001, Anthony and Rosemary Gear S39.007, Steve Welch S65, Elizabeth Fisher S80.001). The development of any such infrastructure on the terraces is subject to the same controls as subdivision and any other development, in order to prevent infrastructure from being damaged by, or causing, slope instability.

55. Some submit ers have raised concerns regarding seismically induced retention pond failure due to earthquakes, should ponds be located on terraces. In my opinion, seismically induced failure resulting in flooding is an extremely unlikely event- any earthquake greater than the design thresholds for the pond embankments would need to coincide with the few occasions that the stormwater ponds would be full. I am of the view that these two events coinciding would be an extremely rare event. Further commentary on these mat ers is provided by Ms Baugham and Mr Miller in their section 42A report.

56. I note that no submissions discussed liquefaction or uncontrolled fill.

K. RECOMMENDATIONS

57. Land that is beyond the 20° line (i.e. away from the terrace edge) is likely to be suitable for residential development, as slippage is not likely to occur. It has been labelled 'Developable Land' in the proposed PCG provisions (Map 10.1A).

58. The Structure Plan and implementing provisions contemplate that residential or commercial subdivision and development will only take place on Developable Land, and within Limited Developable Land, only on Class D land. Mr Burns discusses how the slope analysis (and Map 10.1A) has been reflected in the Structure Plan.

59. An assessment of the slope instability hazard early in the subdivision process is preferable to an applicant or developer carrying out at the assessment at the point of land use development and/or building. This is because it is more cost effective (assessing a single large area, rather than many individual lots), it provides for consistent treatment of the hazard, it allows for area-wide works to be carried out in a coordinated manner, and it prevents the subdivision of lots that may not be able to be built on due to a slope instability hazard. For this reason, I support the notified provisions that require geotechnical assessment at the point of subdivision.

60. I also support Ms Copplestone's subsequent recommendations to insert controls on residential and commercial land use, which require that geotechnical reporting and the implementation of any resultant recommendations, is undertaken as a necessary precursor to any subsequent development of land and buildings.

61. Applications for the subdivision of Developable Land should be accompanied by a geotechnical report which summarises the results of a walk-over survey and a geological/geomorphological assessment (which describes how the landform has been formed, what it is made up of and what slope processes are, or are likely to be, active) and provides an informed opinion on the suitability of the land for the intended purpose.

62. Any geotechnical assessment of Developable Land would be expected to be carried out by a suitably qualified and experienced geotechnical specialist, and in my opinion, would include most or all of the following steps:

    (a) Walk over inspection of the site and the surrounding land and assessment of local topography.

    (b) Inspection of aerial photographs taken at various times to provide insight into the local geomorphology and evidence of any previous instability or filling.

    (c) Review of geological data (maps, bulletins).

    (d) Enquiry after local information about observed instability or set lement of the ground.

    (e) Review of existing data about the soil and rock profile (look for nearby exposures) or perform some simple subsurface investigation.

(f) Examination of the soil profile to confirm if the soil is in-situ and not colluvium or fill.

(g) Examination of the existing survey records for evidence of slippage or erosion.

(h) Consideration of any other geotechnical constraints or hazards which could affect the site.

(i) An opinion stated by a geotechnical specialist as to the stability and suitability of the land for development, identifying any setbacks if necessary.

63. Land that is between the 20° and 30° lines is labelled in our slope angle analysis as Class D land. It is also referred to as such in the proposed plan change provisions.

64. There is likely to be some Class D where development can proceed following geotechnical assessment, and anecdotally we hear from the Council that this is the case. For example, some land developers with appropriate geotechnical input are developing sites up to 23° within Aokatuere. For this reason, I am comfortable that the amended provisions recommended by Ms Copplestone provide for development of Limited Developable land as a permit ed activity, subject to confirmation that the appropriate geotechnical assessment had been undertaken to confirm the suitability of the land for development, and works to implement any recommendations had been completed, at the subdivision stage. My recommendations for the geotechnical investigations are set out below.

65. Due to the steepness of the slope(s) in Class D areas, applications for subdivision, building or other development (such as excavation, filling, removal of vegetation, disposal of stormwater or domestic wastewater into or over the area) should be supported by a geotechnical report which includes a stability assessment demonstrating that the proposed development will not accelerate, worsen or result in the land being subject to, or likely to be subject to, erosion or slippage, to the satisfaction of Council.

66. A geotechnical assessment on Class D land would be expected to be carried out by a suitably qualified and experienced geotechnical specialist and would include:

(a) Topographic survey (if not already available).

(b) A description of the geology and geomorphology of the area.

(c) Inspection of aerial photographs taken at various times to provide insight into the local geomorphology and evidence of any previous instability or filling.

(d) Enquiry after local information about observed instability or set lement of the ground.

(e) Definition of the nature and continuity of the strata over the whole area of land which is proposed to be developed (buildings, access and services) and to a depth below which slipping is most unlikely, by means of test pit and/or drilling and/or augering (unless existing exposures are adequate).

(f) Assessment of the relative strength and the sensitivity of the soil in each stratum in which, or interface on which, sliding is possible.

(g) Assessment of likely groundwater levels and piezometric pressures in the strata during extreme infiltration conditions.

(h) Consideration of any other geotechnical constraints or hazards which could affect the site.

(i) An opinion stated by a geotechnical specialist as to the stability and suitability of the land for development, including specifying setbacks if required.

67. Land that is beyond the 30° line is labelled in our slope angle analysis Class E land. It is also labelled Class E in the PCG provisions and is a subset of Limited Developable Land.

68. It is not expected that residential development will take place on Class E land. As I note above, I understand that this restriction has been reflected in the Structure Plan.

69. According to the slope analysis undertaken to inform Map 10.1A, much of the land in rural-residential areas is Class E land. There is likely to be potential to develop these lots, as they differ from the higher density residential lots in a couple of ways:

(a) The larger lot sizes offer significantly more flexibility in selecting building locations, and there may be areas of lower slope angles that are not identified in our high-level analysis.

(b) The significantly larger lot sizes provide more area and flexibility to carry out earthworks and other work to create stable building platforms (such as the creation of cut and fill platforms and construction of retaining walls).

70. Given that much of the rural-residential zoned land is Class E land, I recommend that the requirements in the PCG provisions to undertake geotechnical and earthwork reports at the point of rural-residential subdivision, are retained.

71. The Structure Plan contemplates infrastructure (e.g. roads or services) being located over Class E land in places. In my opinion this can be achieved using engineering controls such as placing engineered fills, constructing retaining walls and re-contouring slopes as necessary. Such work would require the involvement of a suitably qualified and experienced geotechnical specialist, and the assessment and analysis would be expected to be detailed, and specific to the work being proposed. For this reason, I have recommended that the location, design and construction of roading and essential services in the gully areas (which will be zoned Conservation and Amenity Zone), is supported by a geotechnical assessment.

72. Where uncontrolled fill is present within the PCG area, it should be characterised prior to any development. This will require a combination of site investigations and review of historic information. Options are available for developing filled land such as preloading, ground improvement or piling, however, the feasibility of appropriate options will only be determined following geotechnical assessment of the filled land.

73. I would expect a geotechnical assessment on land with uncontrolled fill to include:

(a) A description of the geology and geomorphology of the area.

(b) Review of historic information such as aerial photos, anecdotal reports or other records.

(c) Definition of the nature and continuity of the strata over the whole area of land which is proposed to be developed (buildings, access and services). The depth, spatial extent, strength, variability, and material/s should all be identified and where possible, quantified. Fill materials should be assessed by means of test pit and/or drilling and/or augering.

(d) Assessment of the relative strength of the fill material and the underlying stratum by means of borehole standard penetration tests, cone penetration tests or scala penetrometers (for shallow soil profiles).

(e) Assessment of likely groundwater levels and the effects of fluctuating or changing groundwater.

(f) An opinion stated by a geotechnical specialist as to the suitability of the land for development, along with recommendations on any mitigation work or foundations that are required.

(g) Consideration of any other geotechnical constraints or hazards which could affect the site.

74. I support the plan provisions requiring these mat ers to be addressed at the point of subdivision of land involving uncontrolled fill.

75. Any proposal for rural residential development in the Turitea Stream valley area should assess the potential for liquefaction, following the framework laid out in the MBIE/MfE (2017) guidance. I support the inclusion of plan provisions which implement this recommendation at the point of subdivision.

Eric Bird

15 September 2023

L. REFERENCES

- MBIE/MfE. 2017. Planning and engineering guidance for potentially liquefaction-prone land.

M. APPENDICES

- **Attachment A:** Aokautere slope stability: considerations for consenting, dated May 2022.
- **Attachment B:** 2005, Tonkin + Taylor, Development of land which is, or is likely to be, subject to erosion or slippage: policy document.
- **Attachment C:** 2020, Tonkin + Taylor Ltd, Preliminary Site Observations for Proposed Aokautere Redevelopment.
- **Attachment D:** 2021, Tonkin + Taylor Ltd, Memo- Aokautere Development - Geotechnical input for set-back contours.
- **Attachment E:** 2023, Tonkin + Taylor Ltd, Memo- Aokautere Development – (revised) Geotechnical input for set-back contours.
- **Attachment F**: Updated Map 10.1A.

Attachment A

Tonkin+Taylor

Job No: 85442.0300
12 May 2022

Palmerston North City Council
32 The Square
Palmerston North 4410

Attention: Michael Duindam

Dear Michael

Aokautere slope stability: considerations for consenting

1 Introduction

This letter report presents the findings of our geotechnical site assessment for the proposed Aokautere development project. It presents a summary of our site walkover and geo-hazard assessment, the results of slope angle analysis for instability, assessment of areas of potential uncontrolled fill, along with recommended considerations for future development. Geohazards have been assessed with regard to the proposed Structure Plan, in order to inform requirements for future subdivision, including any further investigation and assessment work that may be required for development.

This report builds on our previous work to include a summary of our previous reporting, summarise the slope angle analysis undertaken, provide recommendations on managing slope stability hazards, provide comments on liquefaction, and provide an assessment and discussion on fill materials. It should be read in conjunction with our 2020 report[1].

1.1 Context

1.2 Site location

The proposed development contains approximately 490 ha (4.9 km^2) of land southeast of Palmerston North. The majority of the area comprises farmland pasture.

[1] 2020, Tonkin & Taylor Ltd, Preliminary Site Observations for Proposed Aokautere Redevelopment. Reference 85442.0080.

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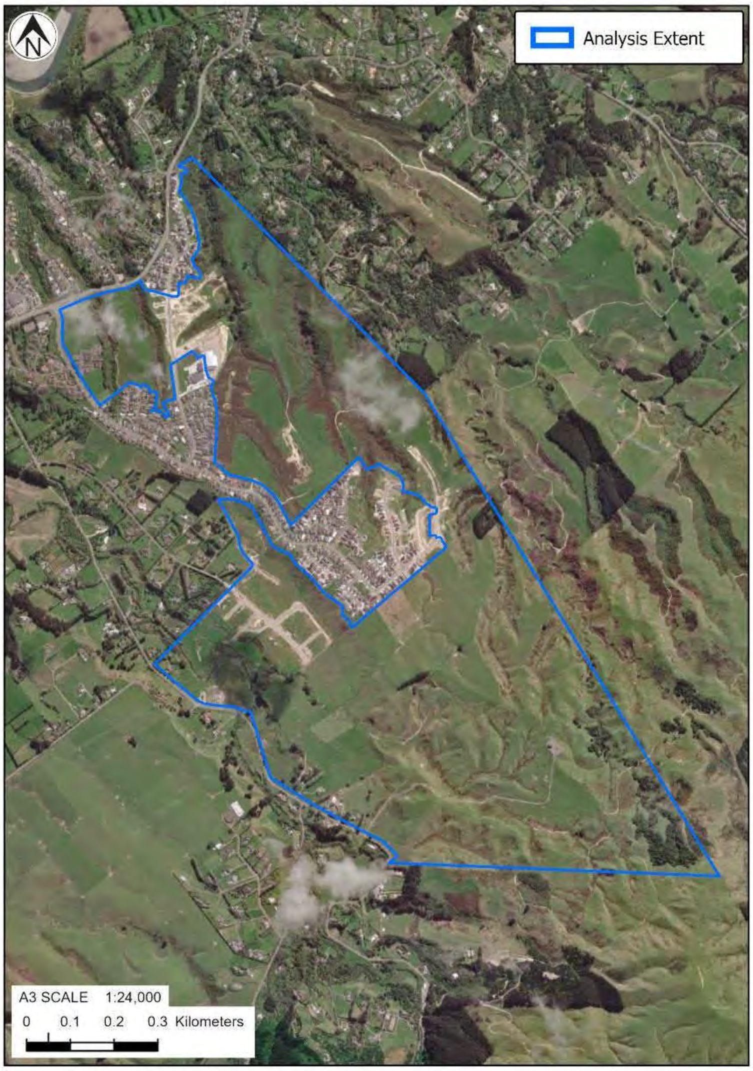


Figure 1.1: Aokautere development area site location.

1.3 Geology

The Palmerston North regional area lies on the boundary between the older (late Jurassic/ Early Cretaceous) exposed greywacke basement rocks (Esk Head belt) in the Tararua ranges to the southeast and the younger (Pleistocene and Holocene) alluvial river deposits of gravel, sand and silts to the north west (refer geological plan in Appendix A).

The Esk Head belt (Te) forms the base of the Tararua mountain range which is present on the far south-eastern corner of the Waters property.

To the northwest of the Esk Head belt, towards Turitea, early Pleistocene alluvial river gravels and sands (eQa) have been deposited.

Further northwest, up to the cliffs adjacent to the Manawatu River, are Pleistocene age gravels and sands more representative of marginal marine/ beach deposits (Q5b). Cutting through these beach deposits and river gravels is a prominent flat river cut terrace containing gravels and silts eroded from the Tararua Ranges and deposited in a paleo-channel (Q2a). These geological materials underlie the majority of the site.

Younger Holocene deposits of river silts and sands (Q1a) are found in the many smaller river cut terraces formed from the meandering watercourses which loosely follows the Turitea Stream, formed in the Q2a paleo-channel.

The published geology[2] of the investigation area is shown in Appendix A which indicates the regional surface geology.

1.4 Previous work

Tonkin & Taylor Ltd (T+T) has undertaken previous geotechnical studies for Palmerston North City Council (PNCC) to support planning and development in the Aokautere area and these are summarised in the sections below.

2005 slope stability reporting

In 2005, T+T provided PNCC with general advice on the development of land subject to slope instability[3]. The intention of that advice was to provide guidelines and practical solutions for constraints associated with potential slope instability, to help inform the building consent and subdivision consent process. The report did not include any analysis of specific areas of land. In that report, T+T recommended particular nominal slope angles to delineate the risks associated with slope instability for various classes of land, shown in Figure 1.2.

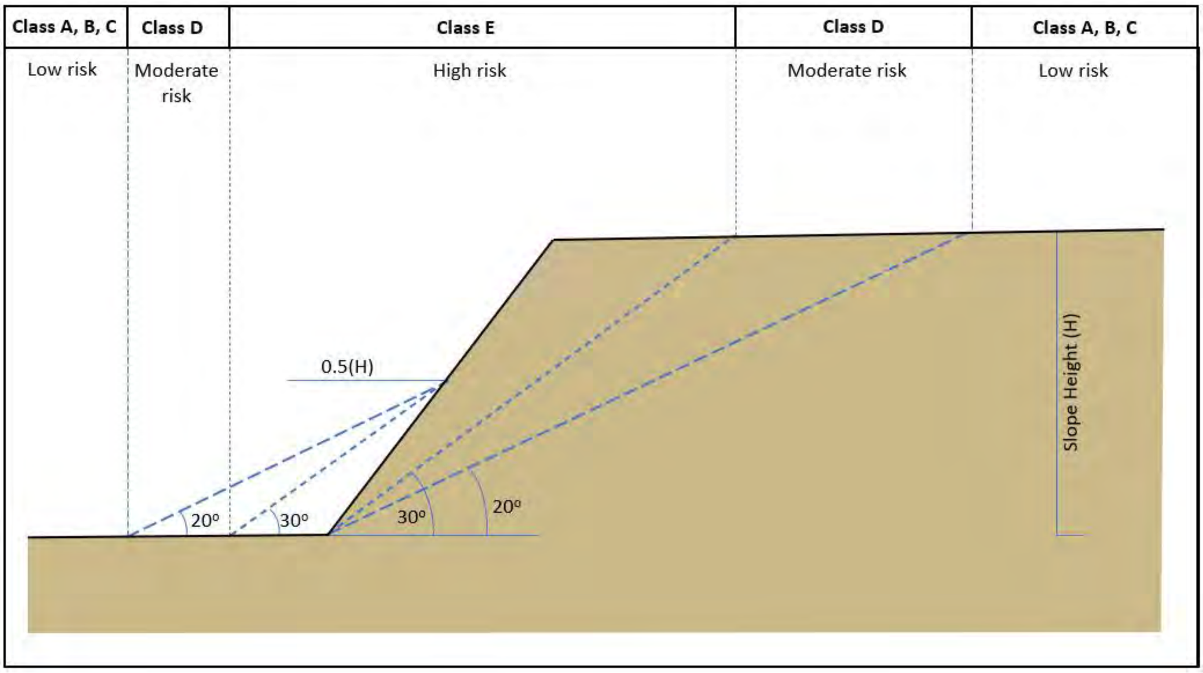


Figure 1.2: Land hazard classes (adapted from T+T, 2005).

These land classes are further explained in Table 1.1, which has been adapted from our 2005 report. In the operative District Plan, land in the existing Aokautere Development Area is divided into two categories: 'Developable' and 'Limited Developable Land'[4]. Classes A, B and C are categorised as 'Developable Land', whilst Classes D and E are categorised as 'Limited Developable Land'.

[2] Lee, J.M., Begg, J.G. (compilers) 2002: *Geology of the Wairarapa area*. Institute of Geological & Nuclear Sciences 1:250,000 geological map 11. 1 sheet + 66 p. Lower Hutt, New Zealand. Institute of Geological & Nuclear Sciences Limited.
[3] 2005, Tonkin + Taylor, Development of land which is, or is likely to be, subject to erosion or slippage: policy document. Reference number 82096.001.
[4] Map 10.1, Palmerston North City Council District Plan.

Table 1.1: Land hazard class descriptions (adapted from T+T, 2005)

Classes A & B (Not at Risk)	This land has an overall slope of less than 11 degrees, does not exhibit any evidence of erosion or shrinkage, and is not likely to be subject to erosion, provided the slope is not subject to river bank erosion.
Class C (Low Risk)	This land has an overall slope of between 11 and 20 degrees, does not exhibit evidence of erosion, or slippage, or inundation from landslip debris, but could be subject to erosion or slippage, if not developed carefully. This land is not likely to be subject to erosion or slippage and is unlikely to be adversely effected by upslope land slippage inundating the site or downslope land slippage removing, or removing support to, the land.
Class D (Moderate Risk)	This land is steep (i.e. steeper than 20 degrees), and/or is either subject to erosion or slippage, or is likely to be subject to erosion or slippage.
Class E (High Risk)	This land is very steep to precipitous (i.e. steeper than 30 degrees) and/or is either subject to erosion or slippage, or is likely to be subject to erosion or slippage.

2020 preliminary geo-hazard assessment

In 2020, T+T carried out a preliminary geotechnical assessment of the Aokautere area for future residential and rural-residential development[5]. This report summarised the geotechnical hazards present throughout the site. The study area was expanded to include a larger area than covered in the Palmerston North City District Plan for the Aokautere Development Area. The study comprised a desktop review of readily available relevant information and a site walkover.

T+T undertook a site walkover during 26-28 September 2018 (Voss property and north) and 17 October 2019 (Water's property). Mapping and site walkover observations (Appendix A: Figures 4a and 4b reproduced from our 2020 report) were collected for the majority of the undeveloped sites marked for future proposed development, where access approval was granted by the landowner. Photographs of areas of interest are provided in Appendix B (reproduced from our 2020 report). A copy of the original geohazard assessment is included in Appendix A.

During the site walkover observations, particular attention was given to hazards associated with ground instability, water flows and soft ground conditions as summarised in Table 1.2. The assessment and management of slope instability and uncontrolled fill hazards are discussed further below.

[5] 2020, Tonkin & Taylor Ltd, Preliminary Site Observations for Proposed Aokautere Redevelopment. Reference 85442.00820.

Table 1.2: Summary of observations and associated hazards

Site observations	Associated hazards
Evidence of landslip, both recent and historic	Potential slope and land instability.
Evidence of land creep	Potential slope and land instability. May indicate future landslip failures.
Slope direction and gradients	Provides land fall direction indicating areas of water runoff catchments.
Watercourses, both current and ephemeral	Potential for erosion of land along with erosion induced landslips. Path of water runoff may indicate areas of saturated ground. Potential for flood inundation.
Saturated ground conditions and swamp land	Settlement of ground and potential for flood inundation.
Groundwater outflows	Potential for instability on slopes, erosion, internal gully erosion.
Uncontrolled fill	Settlement of ground and loss of bearing.

2 Slope stability

T+T have undertaken a slope assessment in the Aokautere area, and this work has been used as the basis for the analysis described below.

2.1 Current slope angle analysis

T+T have carried out preliminary slope angle analysis[6] for the Aokautere area, to map slope stability hazard classes consistent with the approach introduced in the 2005 T+T report. The study area is shown in Figure 1. The results of this analysis are included in Appendix C. Two lines have been mapped; a 20° line showing the extent of Class C land, and a 30° line showing the extent of Class D land. Class A, B, and C land has been hatched on the map. It should be noted that this analysis is a high-level screening tool to identify areas where slope instability is more (or less) likely. It does not take into account the specifics of an individual site.

The analysis has been completed by initially generating false 20° and 30° slopes from the base of the gullies and identifying where these intercept the true slope. This method relies on a consistent slope profile and does not take into consideration any mid slope geometry changes/terraces. This method often resulted in the extent of Class C or D land being identified mid-slope, downslope of a steeper slope. An additional secondary analysis was therefore applied, where slope steepness was used to identify slopes 30° or steeper which were then classified as Class D or E land. It is noted that the secondary analysis does not accommodate a 'set back' from the base of the mid-slope features, and that this should be quantified during the site-specific geotechnical assessment through assessment of local site topography. Subsequent analysis was conducted, projecting 20° and 30° lines downslope from the mid-point on the slope, for the terrace on the south side of Pacific Drive. This analysis demonstrated that the current slope baseline is appropriate.

Figure 2.1 below schematically illustrates the analysis we have adopted to provide land class categorisation for the purposes of PNCC's District Planning.

[6] The digital elevation model used for this analysis was derived from the LiDAR survey undertaken between 29/08/2018 and 28/09/18. The accuracy specification for that survey is +/- 0.10m vertical and +/- 0.5m horizontal. The elevation model data is a 1m grid, in NZTM map projection with NZVD16 vertical datum.

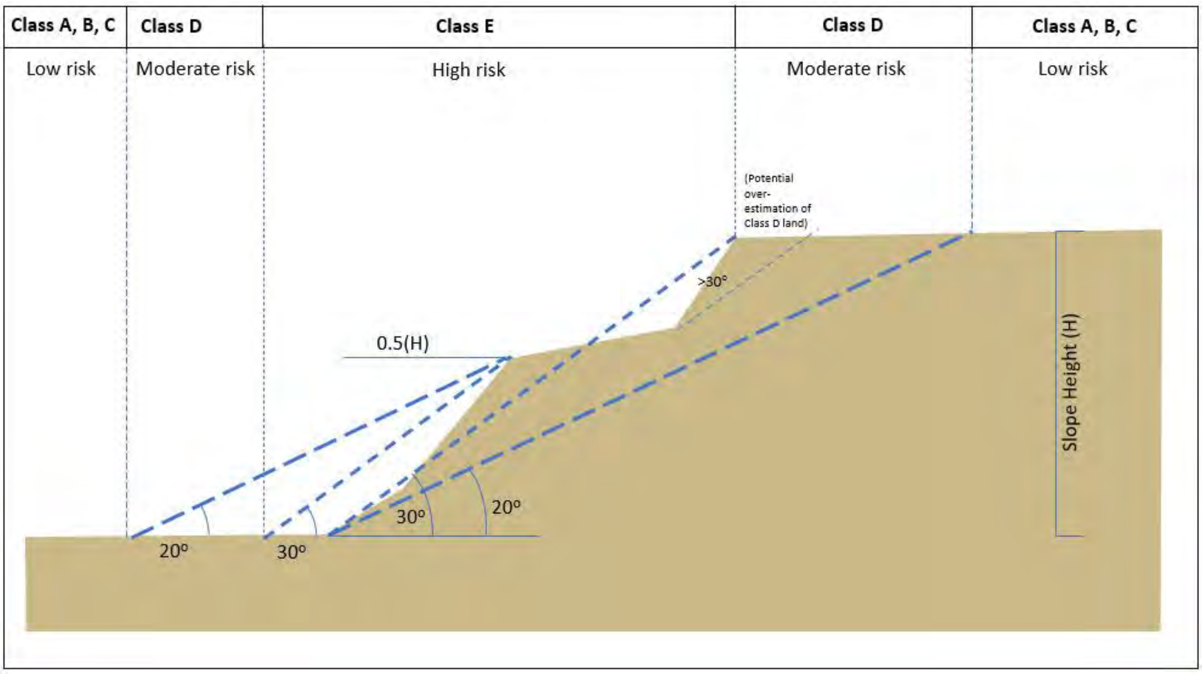


Figure 2.1: Schematic illustration of slope analysis methodology.

2.2 Slope stability- proposed assessment and management

In conjunction with our work carrying out slope angle analysis on the Aokautere area, PNCC requested that we consider whether the operative Palmerston North City Council District Plan approach is appropriate to use for the Aokautere area, covered in our 2020 study. The study area is not currently included in the District Plan map for the Aokautere Development Area.

In the operative District Plan, land in the existing Aokautere Development Area is divided into two categories: 'Developable' and 'Limited Developable Land'. Classes A, B and C are categorised as 'Developable Land', whilst Classes D and E are categorised as 'Limited Developable Land'. For Developable Land, the construction of residential dwellings is a Permitted Activity, whereas for Limited Developable Land, the only Permitted Activities are landscape works, reserves and drainage and water supply works.

In the current District Plan, Class D land (between the 20 and 30° lines) is currently combined with Class E land. However, there is likely to be some land in Class D where development can proceed following geotechnical assessment, and anecdotally we hear from PNCC that this is the case; some land developers with appropriate geotechnical input are developing sites up to 23 degrees. Whereas for Class E land, with slope angles of over 30 degrees, the slope instability hazard is greater, and the land is less likely to be able to be safely or cost-effectively developed.

In our view, it would help to provide better regulatory certainty and clarity on the requirements for geotechnical assessment if the two categories currently in the District Plan were amended to three categories that more precisely reflect the land instability hazard. An additional category to subdivide Class D and E sites could be considered, as summarised below (along with placeholder suggestions for the revised category names):

- Land that is likely developable: Class A, B and C land.
- Land that is possibly developable: Class D land.
- Land that is unlikely to be developable: Class E land.

It should be noted that whether land is 'developable' is a subjective judgment. Even the most steep land can be developed; it just requires significant engineering and stabilisation works, such as re-contouring slopes, retaining earth etc.

The following suggested provisions for each category have been largely adopted from our 2005 report.

2.2.1 Land that is likely developable

For Class A and B land, the land is not expected to be at risk of slippage, so should not require geotechnical slope stability assessment for resource or building consent (although for some sites geotechnical input may still be required for other matters, such as soft soils or uncontrolled fill).

For Class C land, the angle from the toe of the slope is 11 to 20 degrees, so erosion or slippage is not considered likely to occur, and no erosion or mass movement is evident. But the land is considered to be sufficiently sensitive that erosion or slippage could occur due to cutting and/or filling and/or site disposal of stormwater and/or effluent waste water.

Accordingly, applications for development of Class C land should be accompanied by a geotechnical report which summarises the results of a walk-over survey and a geological/geomorphological assessment (which describes how the landform has been formed, what it is made up of and what slope processes are, or are likely to be, active) and provides an informed opinion on the suitability of the land for the intended purpose.

The geotechnical assessment of Class C land would be expected to include most or all of the following steps:

1. Walk over inspection of the site and the surrounding land and assessment of local topography.
2. Inspection of aerial photographs taken at various times to provide insight into the local geomorphology and evidence of any previous instability or filling.
3. Review of geological data (maps, bulletins).
4. Enquiry after local information about observed instability or settlement of the ground.
5. Seek existing data about the soil and rock profile (look for nearby exposures) or perform some simple subsurface investigation.
6. Examination of the soil profile to confirm if the soil is in-situ and not colluvium or fill.
7. Examination of the existing survey records for evidence of slippage or erosion.
8. Consideration of any other geotechnical constraints or hazards which could affect the site.
9. An opinion stated by a geotechnical specialist as to the stability and suitability of the land for development, identifying any setbacks if necessary.

2.2.2 Land that is possibly developable

Class D land has an angle from the toe of the slope that is generally steeper than 20 degrees but less than 30 degrees. Accordingly, due to the steepness of the slope(s), applications for subdivision, building or other development (such as excavation, filling, removal of vegetation, disposal of stormwater or domestic wastewater into or over the area) should be supported by a geotechnical report which includes a stability assessment demonstrating that the proposed development will not accelerate, worsen or result in the land being subject to, or likely to be subject to, erosion or slippage, to the satisfaction of Council.

In certain areas, there may be design solutions which allow the land to be developed. Examples include placing engineered fills, constructing retaining walls and re-contouring slopes. The specific design solutions that are appropriate for a given area and proposed activity will not be known until site-specific investigation and analysis is carried out.

A geotechnical assessment on Class D land would be expected to include:

1 Topographic survey (if not already available).
2 A description of the geology and geomorphology of the area.
3 Inspection of aerial photographs taken at various times to provide insight into the local geomorphology and evidence of any previous instability or filling.
4 Enquiry after local information about observed instability or settlement of the ground.
5 Definition of the nature and continuity of the strata over the whole area of land which is proposed to be developed (buildings, access and services) involved and to a depth below which slipping is most unlikely, by means of test pit and/or drilling and/or augering (unless existing exposures are adequate).
6 Assessment of the relative strength and the sensitivity of the soil in each stratum in which, or interface on which, sliding is possible.
7 Assessment of likely groundwater levels and piezometric pressures in the strata during extreme infiltration conditions.
8 Consideration of any other geotechnical constraints or hazards which could affect the site.
9 An opinion stated by a geotechnical specialist as to the stability and suitability of the land for development, including specifying setbacks if required.

2.2.3 Land that is unlikely to be developable

This land exhibits evidence of past or present erosion or slippage, or has a slope gradient over 30 degrees and/or is subject to processes (e.g. removal of toe support), such that erosion or slippage is considered likely to occur in future. Accordingly, development of this land presents an identifiable hazard to property and could also, in some circumstances, threaten life.

On, above and below this land, it is unlikely that subdivision, building or other development (such as excavation, filling, removal of vegetation, disposal of stormwater or wastewater) could be carried out without substantial topographic modification of the existing slopes to ensure stability. As such, Class E land is unlikely to be able to be cost-effectively developed into residential lots.

Any proposed development would require substantial geotechnical engineering input and analysis, significantly more than the requirements listed above for Class D land. The requirements for geotechnical engineering input will vary depending on the proposed development and should be tailored to address the slope stability aspects that are critical for the proposed development.

Where infrastructure such as roads are planned to be located over Class E land, this could be achieved by placing engineered fills, constructing retaining walls and re-contouring slopes as necessary. Such work would require the involvement of a suitably qualified and experienced geotechnical specialist.

2.2.4 Rural-residential areas

The southern portion of the Aokautere area is proposed for lower density, rural-residential development with larger lot sizes (around a hectare). According to our slope analysis, much of this land is Class E land. There is likely to be more potential to develop these lots, as they differ from the higher density residential lots in a couple of ways:

1 The much larger lot sizes offer significantly more flexibility in selecting building locations, and there may be areas of lower slope angles that are not identified in our high-level analysis.
2 The significantly larger lot sizes provide more area and flexibility to carry out earthworks and other work to create stable building platforms (such as the creation of cut and fill platforms and construction of retaining walls).

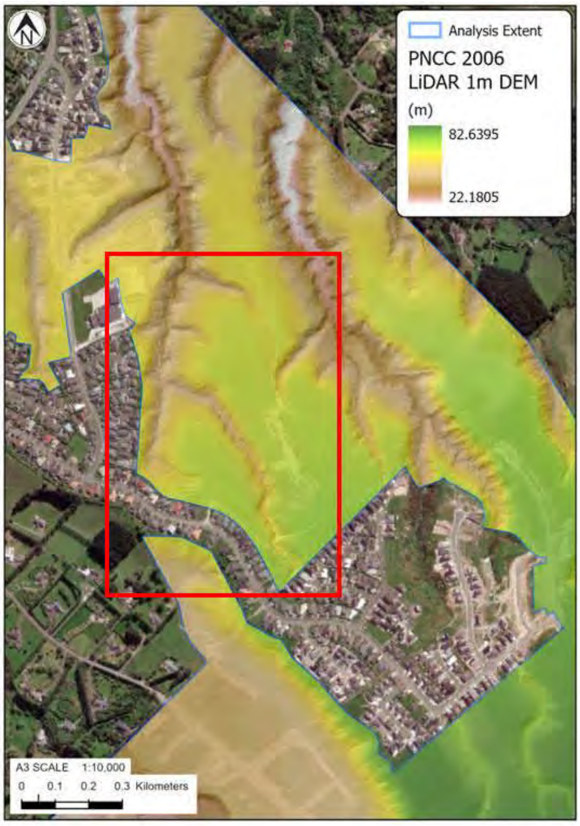
In addition, this area is a more undulating hilly landscape (as opposed to the elevated, relatively level terraces elsewhere), therefore the simplified analysis methodology that we have conducted may result in a conservative delineation of Class E from other classes of land. Site specific geotechnical assessment is therefore necessary in this area to identify suitable building platforms and specify any other necessary design requirements.

3 Uncontrolled fill

Uncontrolled fill has previously been identified by PNCC within the Aokautere area. Uncontrolled fill poses challenges for development as when additional loads are applied (e.g. by further fill placement or building construction) these ground conditions can produce large total and differential settlements. This has the potential to damage buildings and other infrastructure founded on these materials. In some cases, ongoing creep settlement may occur, even without additional loads being applied. Depending on the nature and content of the fill material, there also may be associated soil contamination.

3.1 Identification of potential areas of uncontrolled fill

Two LiDAR derived Digital Elevation Models (DEM) are available for the area, from 2006 and 2018. Where land has been filled between 2006 and 2018, it has a higher elevation in the 2018 Digital DEM, and where land has been excavated, it has a lower elevation in the 2018 DEM. The DEM for 2006 and 2018 are shown in Figure 3.1, below.



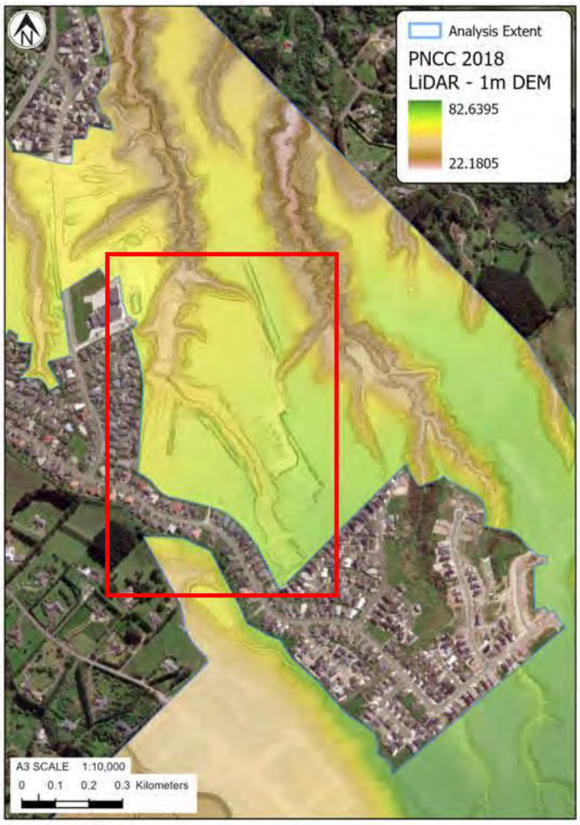


Figure 3.1: Digital elevation models: Left hand image shows 2006 topography, right hand image shows 2018 topography. The red boxes show the focus area.

We have carried out an exercise to identify areas likely to contain fill by subtracting the 2006 DEM from the 2018 DEM. Where the resulting values are negative, the land levels have been reduced by the resultant value by excavation and removal of land, and where the resulting values are positive, the land levels have been raised by that value. The results of this analysis are shown in Figure 3.2. A detailed version of this map is reproduced in Appendix D.

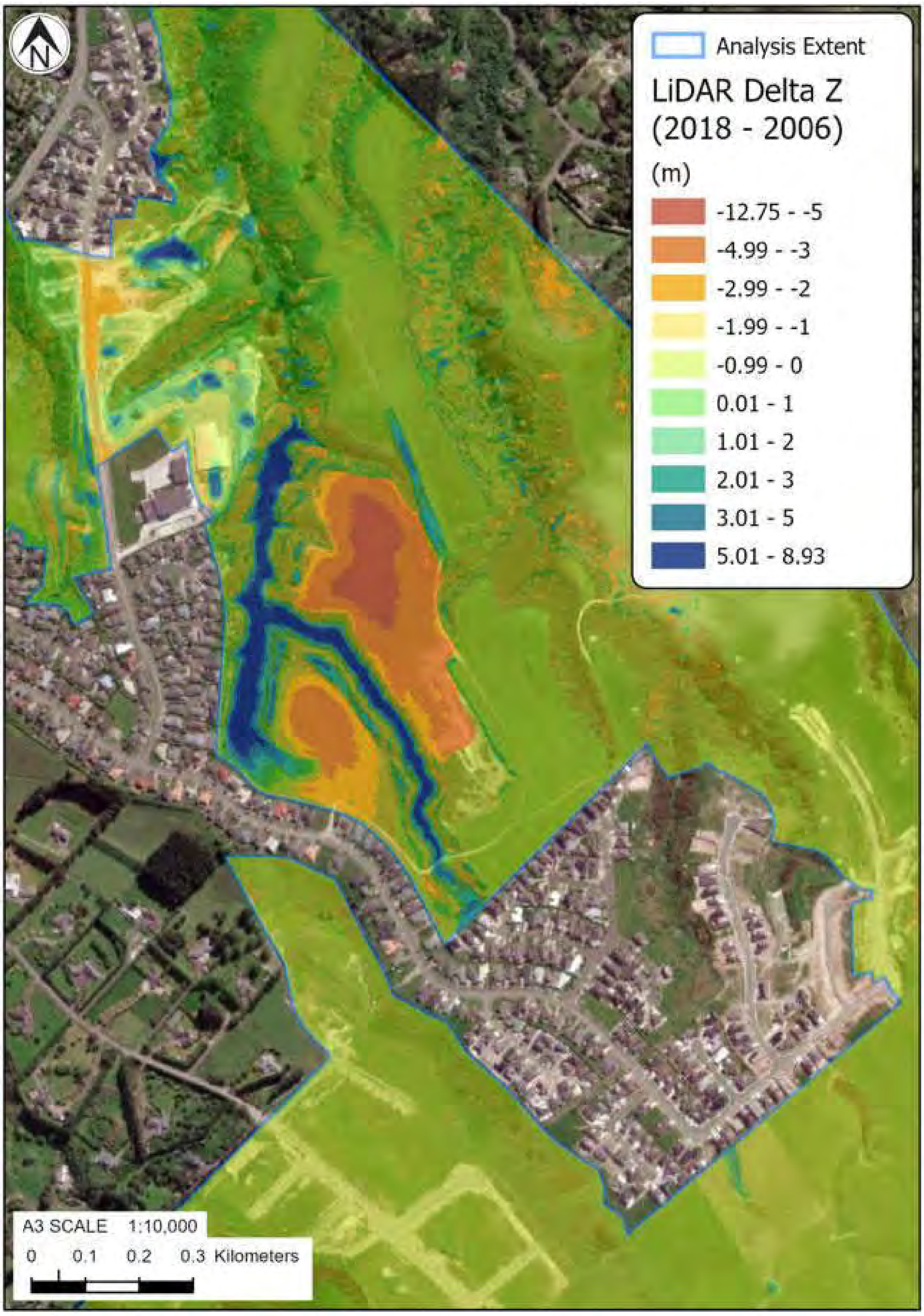


Figure 3.2: Image showing the difference between the 2018 DEM and the 2006 DEM. Positive values indicated land levels that have been raised by filling, negative values indicate land that has been lowered by excavation.

3.1.1 Proposed assessment and management of uncontrolled fill

Where earth fills are present, the soil supporting residential foundations cannot be assumed to be 'good ground' in accordance with NZS3604: 2011[7]. This does not apply where a certificate of suitability for earth fill for residential development has been issued in accordance with NZS4431[8], i.e.

[7] Standards New Zealand. NZS3604: 2011. Timber-framed buildings. Section 3.1.3.
[8] Standards New Zealand. NZS4431: 1989. Code of practice for earth fill for residential development.

where the fill has been placed with appropriate engineering controls and records. NZS3604:2011 is the standard used for the construction of the majority of residential dwellings in New Zealand. Therefore, where there is uncontrolled fill, NZS3604:2011 cannot be used and any residential construction will require specific engineering design, and the involvement of suitably qualified geotechnical professionals.

We have not carried out any geotechnical assessment of the filled land.

Where uncontrolled fill is present, prior to any development it should be characterised. This is likely to require a combination of site investigations and review of historic information. Options are available for developing filled land such as preloading, ground improvement or piling. The feasibility of appropriate options would be determined following geotechnical assessment of the filled land.

A geotechnical assessment on land with uncontrolled would be expected to include:

1 A description of the geology and geomorphology of the area. Review of historic information such as aerial photos, anecdotal reports or other records.
2 Definition of the nature and continuity of the strata over the whole area of land which is proposed to be developed (buildings, access and services). The depth, spatial extent, strength, variability, and material/s should all be identified and where possible, quantified. Fill materials should be assessed by means of test pit and/or drilling and/or augering.
3 Assessment of the relative strength of the fill material and the underlying stratum by means of borehole standard penetration tests, cone penetration tests or scala penetrometers (for shallow soil profiles).
4 Assessment of likely groundwater levels and the effects of fluctuating or changing groundwater.
5 An opinion stated by a geotechnical specialist as to the suitability of the land for development, along with recommendations on any mitigation work or foundations that are required.
6 Consideration of any other geotechnical constraints or hazards which could affect the site.

Although the assessment of contamination is not within the scope of geotechnical assessment, T+T have provided PNCC a Ground Contamination Desk Top Study report[9]. This report notes that uncontrolled fill has a possibility of containing contaminants. Therefore, particular attention should be paid to identifying fill materials and in some cases assessment of possible contaminants may be necessary.

4 Liquefaction

PNCC have requested we consider the potential for liquefaction in the Turitea Stream valley bordering the northeast side of Turitea Road. The geological map for the Aokautere area is available in Appendix A, and the location and topography of the valley adjacent to Turitea Road is shown in Figure 4.1 below. The upper terrace is mapped as late Pleistocene river deposits of gravel and sand. The lower terrace is mapped as Holocene river deposits of gravel, sand, clay and peat. The upper terrace is elevated approximately 8 – 12 m above the lower terrace.

There are not currently any geotechnical investigations available for this valley area in the New Zealand Geotechnical database. It appears there is some residential development taking place on the upper terrace at the southern end of Valley Views, but there is no geotechnical information available.

The depth to groundwater in this area is unknown.

[9] Aokautere Redevelopment – Ground Contamination Desk Study, T+T, June 2020, report ref; 85442.0080v2.

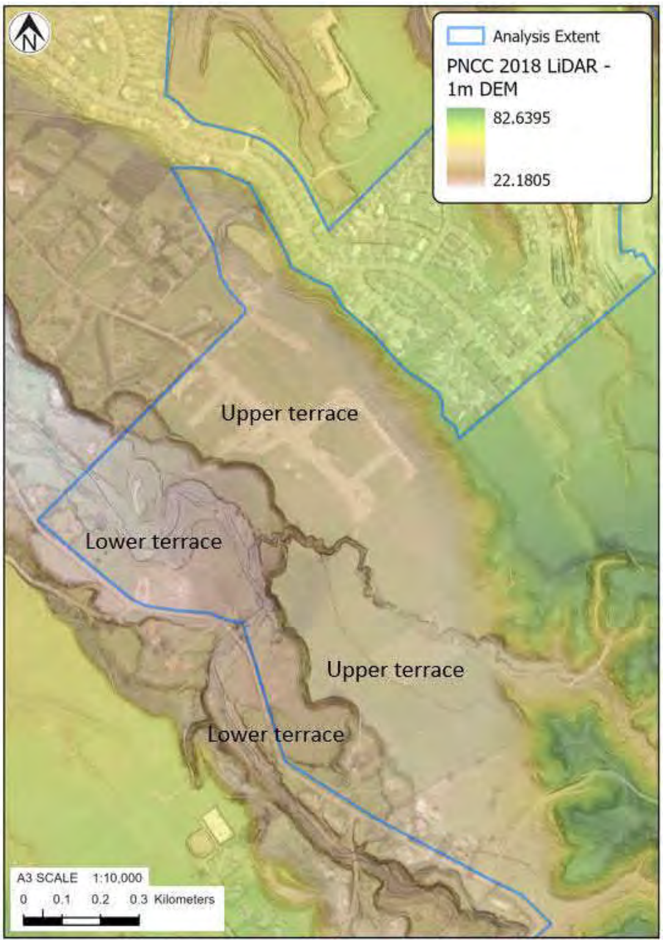


Figure 4.1: Topography of the Turitea Stream valley.

On the basis that there is no geotechnical information or groundwater data for this area, both the upper and lower terrace areas should be classified as Liquefaction Category is Undetermined in accordance with the MBIE/MfE Guidance (2017)[10] at this time. Any development in these areas should assess the potential for liquefaction, following the framework laid out in the MBIE/MfE (2017) guidance.

Assigning a category of Liquefaction Category is Undetermined is a valid assessment under MfE guidance. The guidance contemplates progressively more detailed assessments of liquefaction, beginning at 'Level A- Basic desktop assessment' through to 'Level D- Site specific Assessment'. At Level A, the three resultant categories are Liquefaction Category is Undetermined, Liquefaction Damage is Unlikely, and Liquefaction Category is Undetermined. The category Liquefaction Category is Undetermined is therefore useful as a starting point for identifying where more detailed assessment is required as part of planning or development.

[10] MBIE/MfE. 2017. Planning and engineering guidance for potentially liquefaction-prone land.

5 Applicability

This report has been prepared for the exclusive use of our client Palmerston North City Council, with respect to the particular brief given to us and it may not be relied upon in other contexts or for any other purpose, or by any person other than our client, without our prior written agreement.

Tonkin & Taylor Ltd

Environmental and Engineering Consultants

Authorised for Tonkin & Taylor Ltd by:

Mike Jacka
Technical Director

Report prepared by: Eric Bird, Engineering Geologist

ERBI
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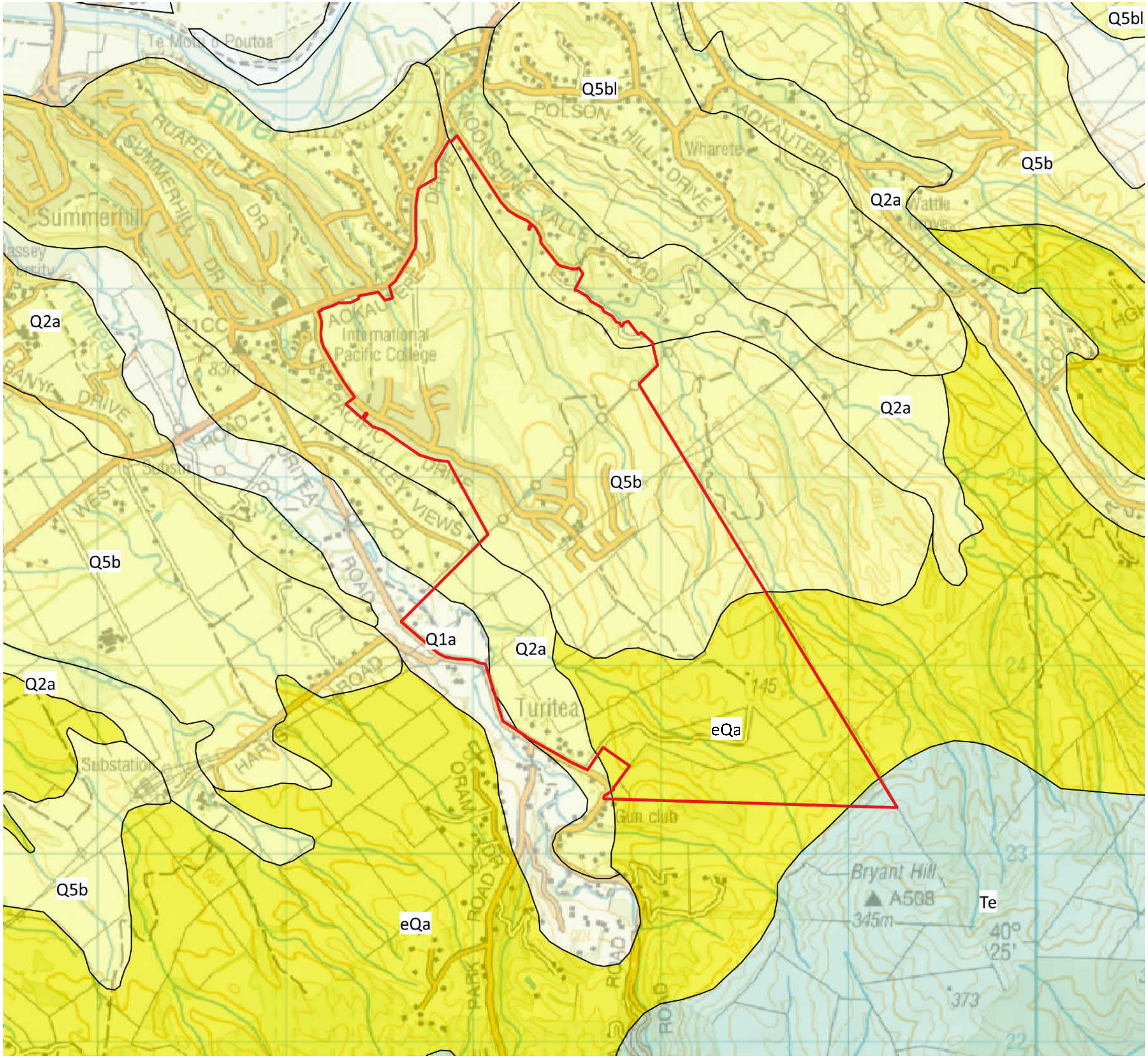
Appendix A: Geological map, site observations and hazard mapping



Legend

Key	Published description (Age)	Site observations
Te	Esk Head Belt: Sandstone and Mudstone (Late Jurassic to early Cretaceous)	Exposed boulders and outcrops
eQa	River deposits of pumiceous sand and gravel (early Pleistocene)	River gravels and silts, trace weathered volcanic gravel.
Q5b / Q5bl	Beach deposits of sand and gravel (late Pleistocene)	Beach sand and marginal marine gravels.
Q2a	River deposits of gravel and sand (late Pleistocene)	River gravels and silts.
Q1a	River deposits of gravel, sand, clay and peat (Holocene)	Silts and swamp.

Simplified Geology

	Indurated sandstone
	Pumiceous sand
	Sand and gravel
	Gravel sand and peat

Proposed Development Boundary

A3 SCALE: 1:20,000

0 210 420 630 840 1,050 (m)

N

1. Geological Boundaries,Inactive Faults,Active Faults GNS Science, Lower Hutt, New Zealand.
2. geotiffs Eagle Technology, LINZ
3. Property Boundary sourced from the LINZ Data Service and licensed for re-use under the Creative Commons Attribution 3.0 New Zealand licence.

Created On:	18/12/2019
Created By:	ELiddle
Approved By:	
TT Proj Ref: 85442.0080	
TT Map Ref: TTMAPREF1433463001.902	

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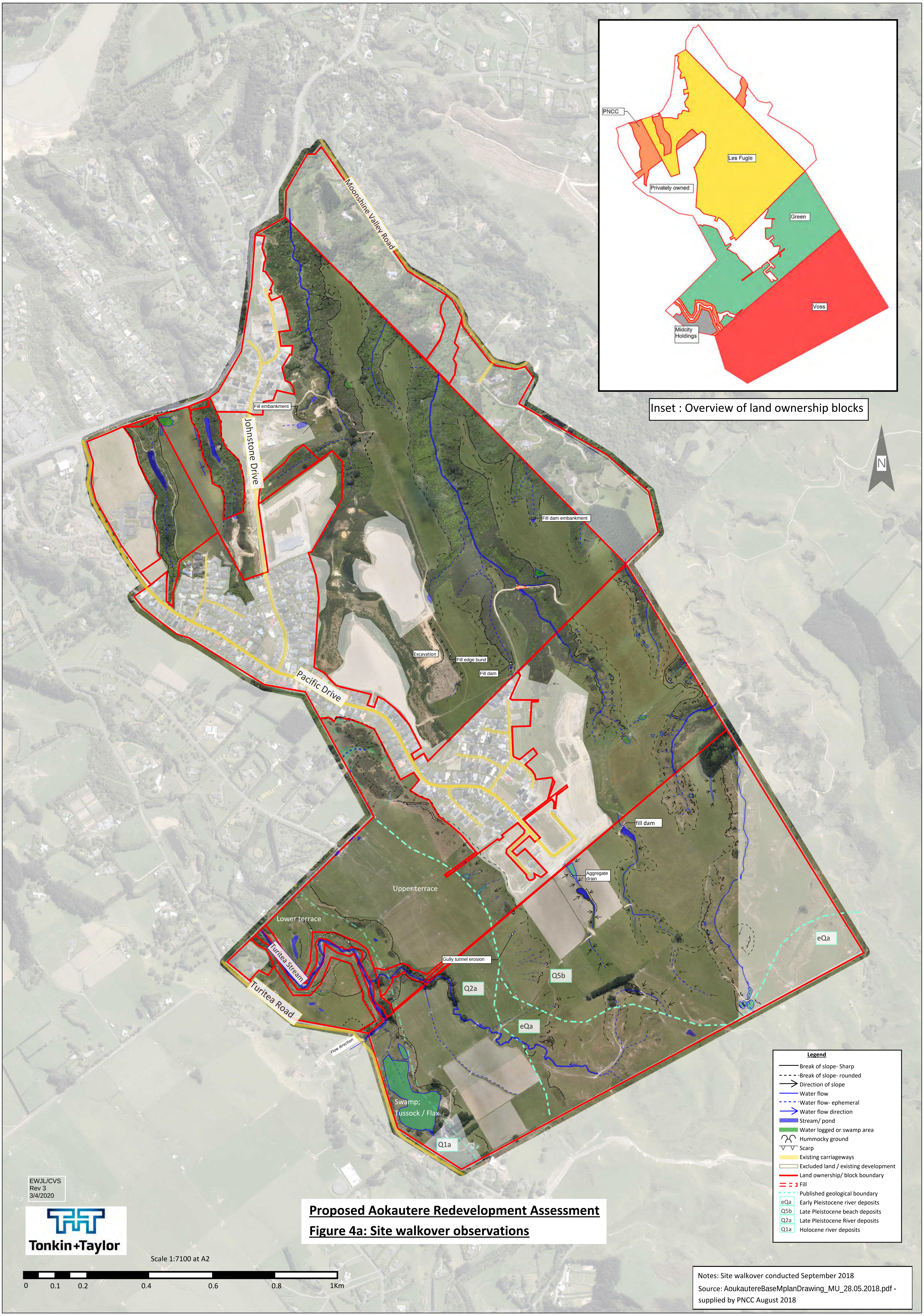
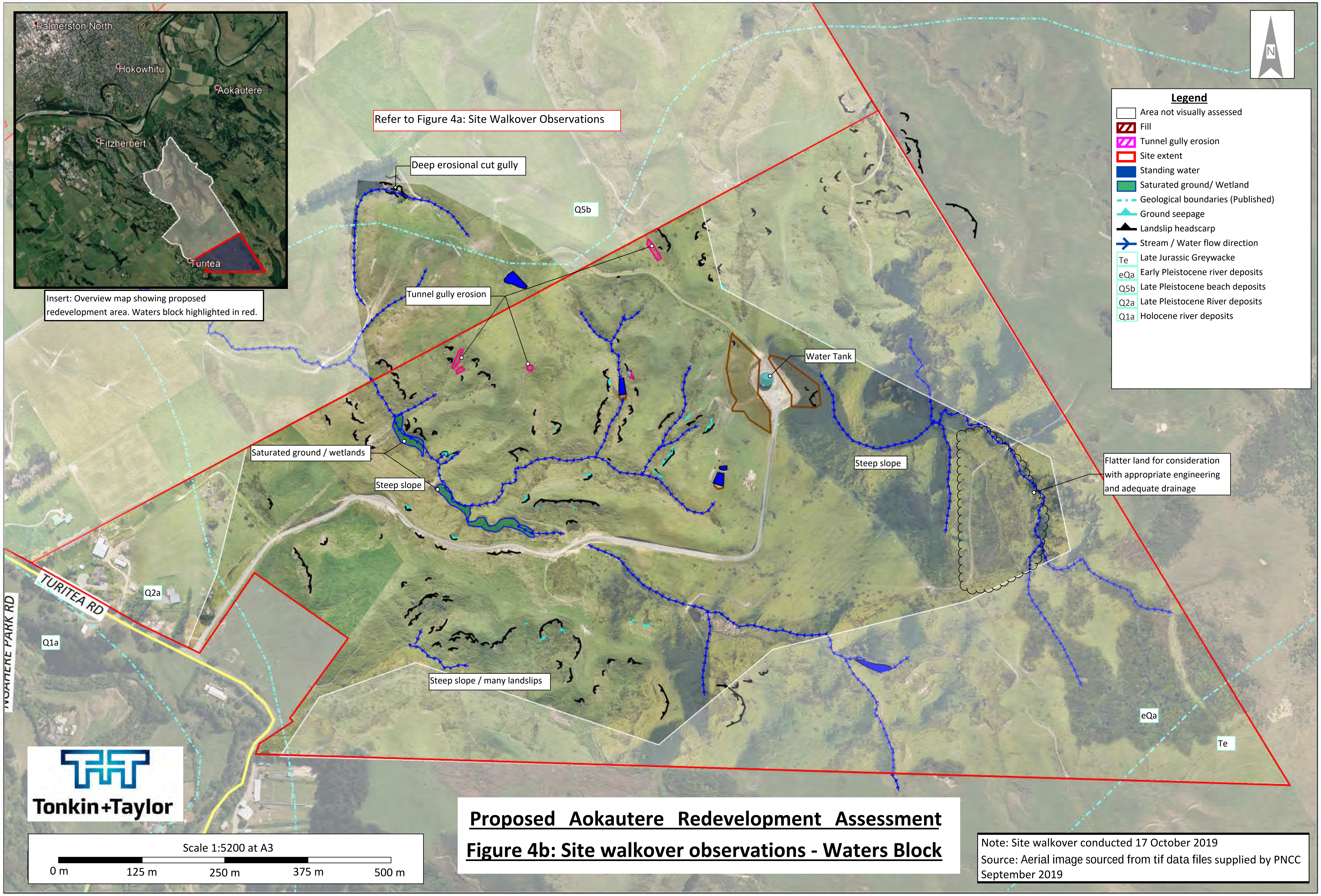
PALMERSTON NORTH CITY COUNCIL
PRELIMINARY SITE ASSESSMENT
PROPOSED AOKAUTERE REDEVELOPMENT
GEOLOGICAL MAP

FIGURE No.
3



Proposed Aokautere Redevelopment Assessment

Figure 4a: Site walkover observations



Proposed Aokautere Redevelopment Assessment

Figure 4b: Site walkover observations - Waters Block

Note: Site walkover conducted 17 October 2019
Source: Aerial image sourced from tif data files supplied by PNCC September 2019

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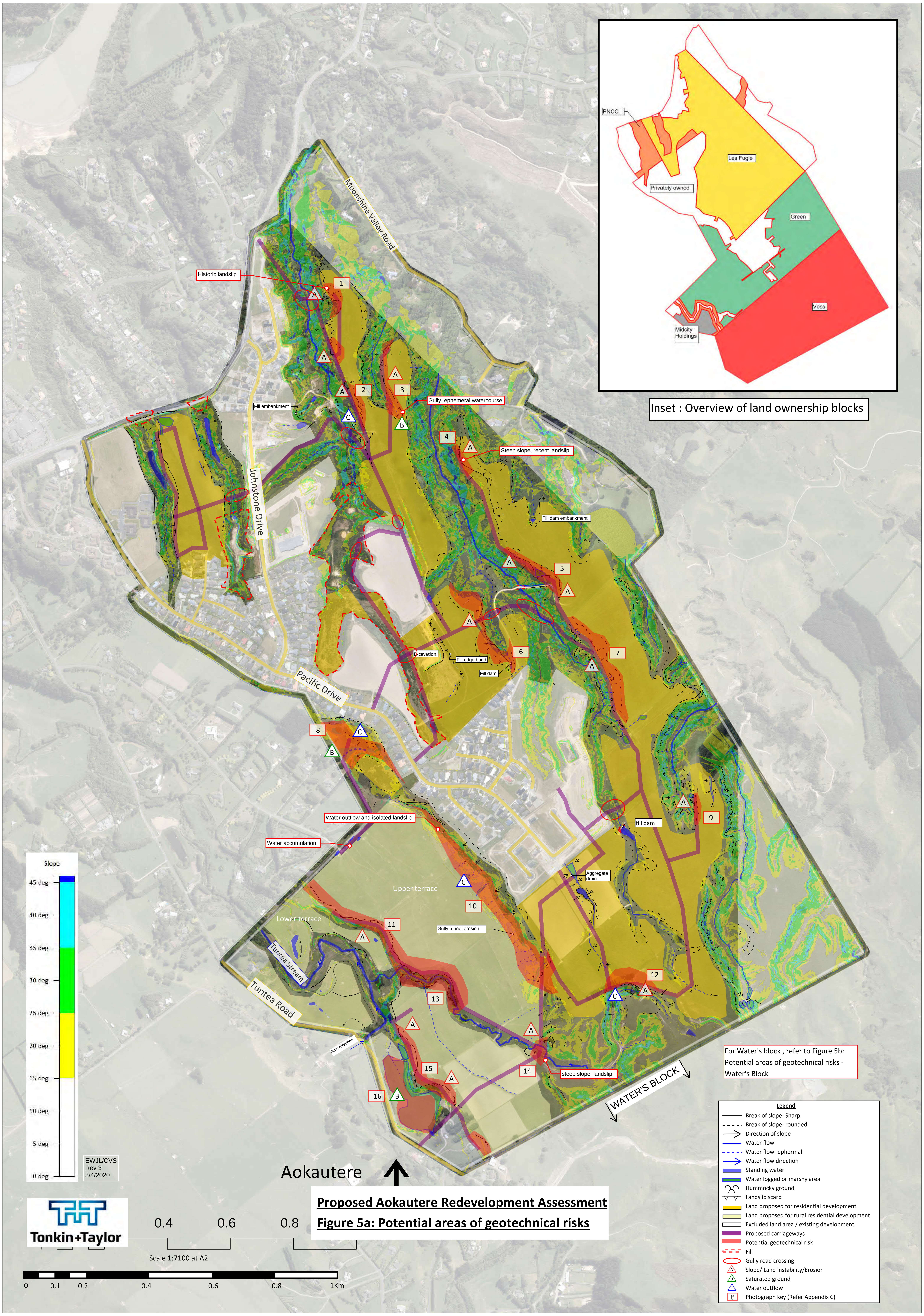
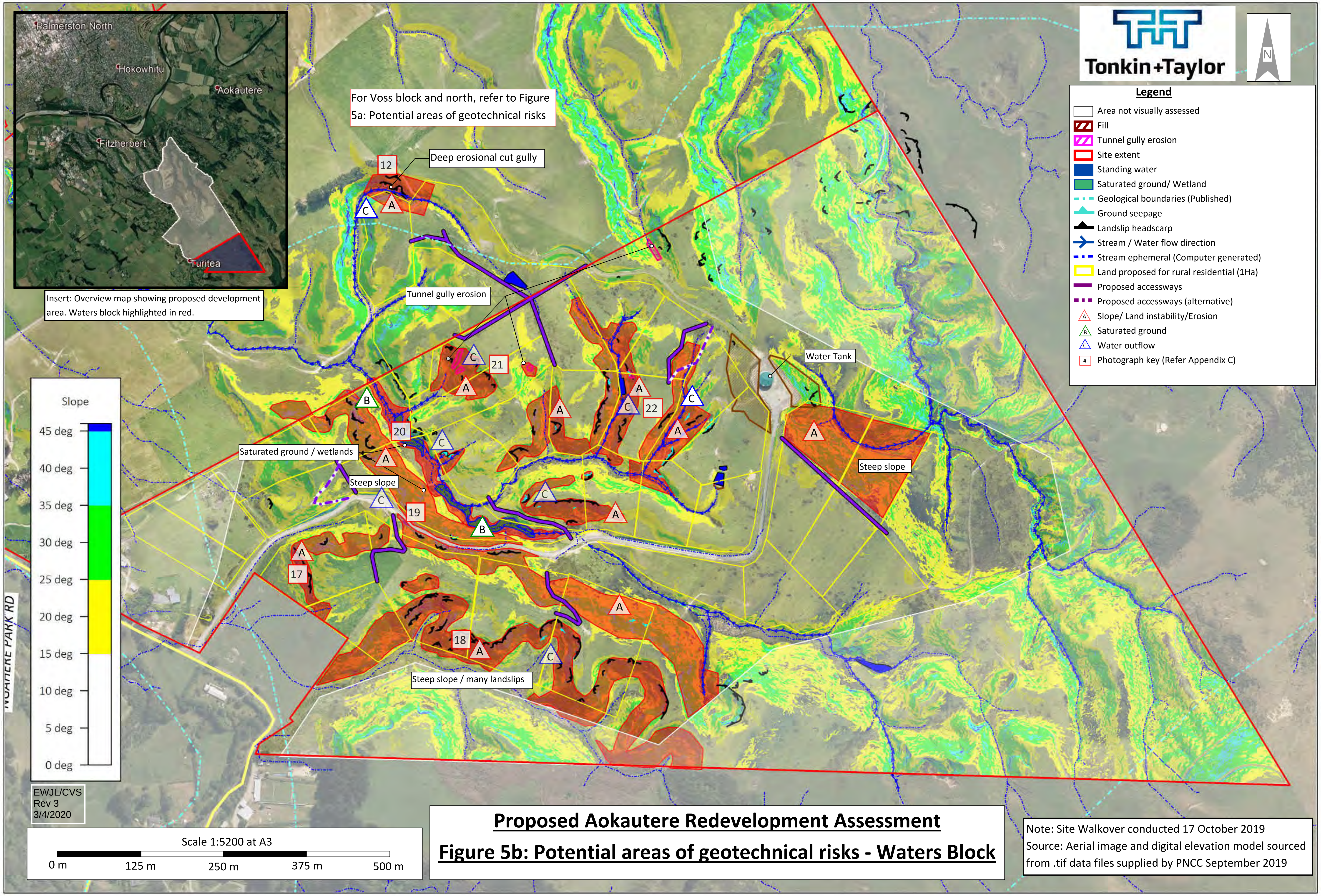
3/4/2020



Proposed Aokautere Redevelopment Assessment

Figure 5a: Potential areas of geotechnical risks



Proposed Aokautere Redevelopment Assessment

Figure 5b: Potential areas of geotechnical risks - Waters Block

Note: Site Walkover conducted 17 October 2019
Source: Aerial image and digital elevation model sourced from .tif data files supplied by PNCC September 2019

Appendix B: 2020 Site visit photos

Photograph 1: Les Fugle block; hummocky ground

Photograph 2: Les Fugle block; hummocky ground

Photograph 3: Les Fugle block, top of gully and watercourse with soft ground

Photograph 3b: Les Fugle block, watercourse at base of gully

Photograph 4: Les Fugle block; recent landslip

Photograph 5: Les Fugle block; hummocky ground

Photograph 6: Les Fugle block, standing water created by fill dam.

Photograph 7: Green block; historic landslip scarp

Photograph 8: Green block; saturated hummocky land

Photograph 8b: Green block; saturated hummocky land

Photograph 8c: Green block; saturated soft land and standing water

Photograph 9: Voss block; recent landslip scarp and saturated ground

Photograph 9b: Voss block; recent landslips and saturated ground

Photograph 10: Voss block: water induced landslips and watercourses

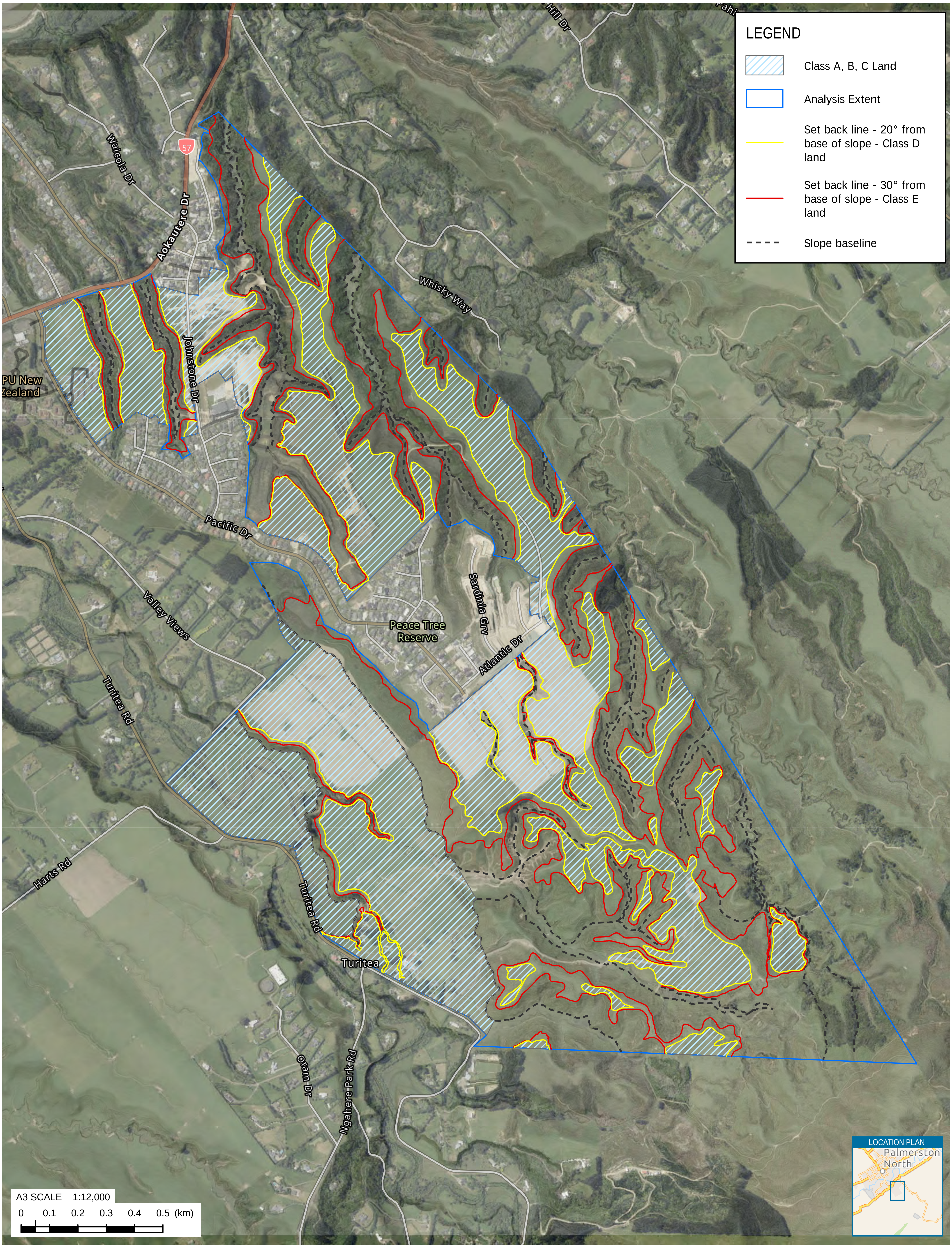
Photograph 11: Voss block; steep hummocky river terrace slope

Photograph 12: Voss block; steep water-cut gully with recent landslips

	
Photograph 13: PNCC block; steep water-cut gully with recent landslips	Photograph 14: Voss block, landslip scarp and watercourse (photograph from UAV footage)
	
Photograph 15: Voss block; steep slope with landslips	Photograph 16: Voss block; saturated ground and swampland
	
Photograph 17: Waters block; Steep slope and landslip headscarps	Photograph 18: Waters block; Steep slopes and multiple landslip headscarps
	
Photograph 19: Waters block; Steep slope, water seepage, multiple landslip headscarps	Photograph 20: Waters block; Streams and saturated surrounding land.

	
Photograph 21: Waters block; Tunnel gully erosion	Photograph 22: Waters block; Steep slopes, landslide headscarps and watercourse

Appendix C: Slope Angle Analysis



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REV	DESCRIPTION	GIS	CHK	DATE
0	First version	DXLR	EDA	11/11/21

PROJECT No.	85442.0300	
DESIGNED	DXLR	NOV.21
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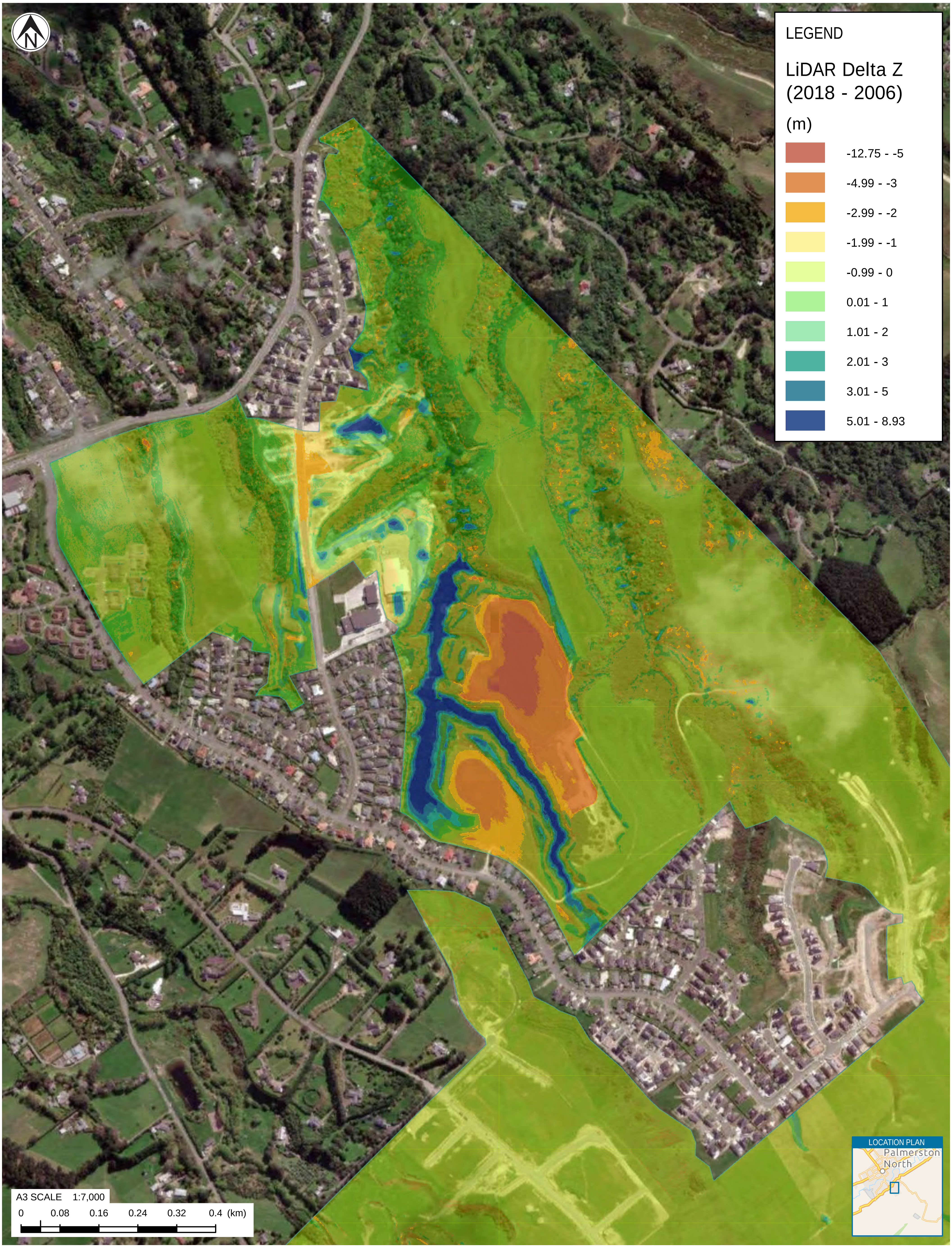
CLIENT **PALMERSTON NORTH CITY COUNCIL**
PROJECT **AOKUTERE RESIDENTIAL LAND DEVELOPMENT**
TITLE POTENTIAL SET BACK FROM STEEP SLOPES WITHIN THE AOKUTERE LAND DEVELOPMENT AREA
SCALE (A3) 1:12,000 FIG No. FIGURE 1. REV 1

Appendix D: Fill Assessment



DO NOT SCALE FROM THIS FIGURE.

\\ttgroup.local\corporate\Wellington\TT Projects\85442\85442.0300\WorkingMaterial\GIS\MapDocuments\P85442-0300_AokautereLandHazardAnalysis.aprx Layout: P85442-0300_AokautereTopography 2021-Dec-22 8:46 am Drawn by DXLR

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0	First version	DXLR				

PROJECT No.	85442.0300	
DESIGNED	DXLR	DEC.21
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CHECKED		DEC.21

CLIENT **PALMERSTON NORTH CITY COUNCIL**

PROJECT **AOKAUTERE RESIDENTIAL LAND DEVELOPMENT**

TITLE CHANGE IN ELEVATION BETWEEN 2006 AND 2018

SCALE (A3) 1:7,000 FIG No. FIGURE 3. REV 1

Attachment B

REPORT

PALMERSTON NORTH CITY COUNCIL

**Development of Land which is, or is likely to be, subject to Erosion or Slippage
Policy Document**

Report prepared for:

PALMERSTON NORTH CITY COUNCIL

Report prepared by:

TONKIN & TAYLOR LTD

Distribution:

PALMERSTON NORTH CITY COUNCIL	5 copies
TONKIN & TAYLOR LTD (FILE)	1 copy

August 2005

Job no: 82096.001

Table of contents

1. Introduction

The main purpose of the Policy Document is to provide clear guidelines and practical solutions to questions relating to the issuing of building consents for buildings on land which is, or is likely to be, subject to erosion or slippage within the Palmerston North City boundary.

In addition, the Policy Document is to cover the matter of subdivision consent approvals on land which is, or is likely to be, subject to erosion or slippage.

Although the Policy Document will sit outside the District Plan, it is intended that this Policy Document will be an extension of the urban land use capability (ULUC) survey which covers part (Aokautere) of the City. The approach used within the District Plan to manage land in the Aokautere Development Area has been endorsed by the Council through its decisions on submissions to the District Plan which became fully operative in March 2005.

2. Statutory responsibilities in relation to land stability hazard

There are two primary pieces of legislation which define the responsibilities of Council for the management of land hazards including erosion and slippage. These are the Resource Management Act 1991 (RMAct) and the Building Act 2004 (BAct).

2.1 Resource Management Act 1991

The overall purpose of the RMAct is to promote the sustainable management of natural and physical resources and Council has responsibilities under the Act for the avoidance and mitigation of natural hazards.

The specific functions of Council are defined under Section 31 of the RMA, and include the avoidance and mitigation of natural hazards through the control of land use and subdivision.

> *Section 31(1)(b) of the RM Act states that every territorial authority has, as a function:*
>
> *The control of any actual or potential effects of the use, development, or protection of land, including for the purpose of the avoidance or mitigation of natural hazards.*

To carry out these functions, Council must produce a District Plan which describes how resource management issues will be managed to achieve the sustainable management of natural and physical resources. Section 73(4) of the Act requires a local authority to amend its District Plan to give effect to a regional policy statement if the statement contains a provision to which the plan does not give effect and the statement is reviewed under section 79, thereby ensuring the integrated management of the natural and physical resources of the region and district.

With respect to the subdivision and use of land, Council has requirements relevant to the avoidance or mitigation of natural hazards. Section 106 (1) specifies that a consent authority may refuse to grant a subdivision consent, or may grant a subdivision consent subject to conditions, if it considers that -

"(a) the land in respect of which a consent is sought, or any structure on the land, is or is likely to be subject to material damage by erosion, falling debris, subsidence, slippage, or inundation from any source; or

(b) any subsequent use that is likely to be made of the land is likely to accelerate, worsen, or result in material damage to that land, other land, or structure, by erosion, falling debris, subsidence, slippage, or inundation from any source."

Conditions applied under section 106(1) must be for the purposes of avoiding, remedying or mitigating the effects referred to in section 106(1).

2.2 Building Act 2004

The purpose of the BAct is to provide the necessary controls over building works, use and safety. Under this Act the obligations for managing building works in relation to natural hazards are solely the responsibility of the District Council.

The BAct requires Council to refuse the granting of a building consent for construction of a building, or major alterations to a building, if:

Section 71(1)

(a) the land on which the building work is to be carried out is subject or is likely to be subject to 1 or more natural hazards; or

(b) the building work is likely to accelerate, worsen, or result in a natural hazards on that land or any other property.

Unless *(2) the building consent authority is satisfied that adequate provision has been or will be made to:*

(a) protect the land, building work, or other property referred to in that subsection from the natural hazard or hazards; or

(b) restore any damage to that land or other property as a result of the building work.

(3) In this section and sections 72 to 74, ***natural hazard*** *means any of the following:*

(a) erosion (including coastal erosion, bank erosion, and sheet erosion)

(b) falling debris (including soil, rock, snow, and ice)

(c) subsidence

(d) inundation (including flooding, overland flow, storm surge, tidal effects, and ponding)

(e) slippage.

72 Building consent for building on land subject to natural hazards must be granted in certain cases

Despite section 71, a building consent authority must grant a building consent if the building consent authority considers that:

(a) *the building work to which an application for a building consent relates will not accelerate, worsen, or result in a natural hazard on the land on which the building work is to be carried out or any other property; and*

(b) *the land is subject or is likely to be subject to one or more natural hazards; and*

(c) *it is reasonable to grant a wavier or modification of the building code in respect of the natural hazard concerned.*

73 ***Conditions on building consents granted under section 72***

(1) *A building consent authority that grants a building consent under section 72 must include, as a condition of the consent, that the building consent authority will, on issuing the consent, notify the consent to:*

(a) *in the case of an application made by, or on behalf of, the Crown, the appropriate Minister and the Surveyor-General; and*

(b) *in the case of an application made by, or on behalf of, the owners of Maori land, the Registrar of the Maori Land Court; and*

(c) *in any other case, the Registrar-General of Land.*

(2) *The notification under subsection (1)(a) or (b) must be accompanied by a copy of the project information memorandum that relates to the building consent in question.*

(3) *The notification under subsection (1)(c) must identify the natural hazard concerned.*

2.3 Community expectations

Prior to the RMAct and the BAct, subdivision and building in potentially hazardous areas was controlled by the Town and Country Planning Act 1977 and the Local Government Act 1974.

The Abbotsford landslip disaster and subsequent commission of enquiry highlighted the very much greater expectation the public has of local authorities, and the demand for councils to put more effort into their land subdivision and building permit control. Parliament, anxious to protect property owners from the considerable loss that could result if land disappeared underneath them, obliged with Sections 274 and 641 of the Local Government Amendment Act in 1979. That Act made it difficult, if not impossible, for local authorities to allow subdivision or to issue building permits on land that was likely to be subject to, amongst other hazards, erosion and slippage.

With the advent of the Local Government Amendment Act (1979), councils found administering subdivisional and building permit applications in terms of Sections 274 and 641 a bitter pill to swallow. Local authorities were suddenly faced with refusing building permits on land where they had earlier allowed subdivision to proceed, and developers and land owners saw potential profits threatened and brought pressure to bear. The public who found themselves restricted in hazard prone areas resented the loss of land value and loss of "freedom" to do what they wanted.

Accordingly, despite the clear conclusions and recommendations of the Commission of Enquiry into the Abbotsford Landslip Disaster which reported in November 1980, less than a year later the Local Government Amendment Act was yet again amended with Section 641(a) (now Section 72 of the BAct) which allows a local authority to issue a building permit where the land is subject to erosion, subsidence, slippage or inundation and not be under any civil liability (Rogers and Taylor 1986).

No amount of controls on development can produce zero risk in the urban areas of Palmerston North City, and we do not believe that the community expects that to be achieved.

What the community can rightly expect, however, is that the actual and potential hazards are properly identified, and that the potential consequences are clearly explained.

3 Land subject to erosion or landslippage

3.1 Geology and geomorphology

The City area includes urban and rural land which encompasses steep greywacke hillslopes to the east (Tararua Range) and a series of terraces over the balance of the City (DSIR, 1967). These river cut terraces, made up of gravels, sands and silt (mainly marine sediments), are blanketed by variable thicknesses of loess (wind blown silt). The terraces are locally incised by streams draining toward the Manawatu River.

With respect to erosion or slippage, there are two basic landform types (Cowie, 1974) which present a hazard to urban development. These are:

3.1.1 Landform A - Moderate to steep slopes of the foothills and main range of the Tararua Range

Whilst the bedrock (greywacke) materials are inherently very strong, these ranges are up-hrust east of, and along, a major geological fault and the western side of the ranges are consequently oversteep. Accordingly, even under a full forest cover these slopes were probably adjusting to being oversteep by slippage to reduce the overall slope angles to achieve stability. With the forest cover removed (albeit in places now replaced by plantation forest) the slopes are even more susceptible to slippage in the form of shallow debris slides. Whilst on some of the steep slopes evidence of past instability is clearly seen by the landslip scars and debris lobes, all slopes steeper than about 20° should be considered to be susceptible (i.e. likely to be subject) to slippage under low frequency rainstorm or seismic events. Slopes steeper than 30° appear to be very susceptible to slippage under higher frequency (i.e. more common) rainstorm events.

3.1.2 Landform B - Moderate to precipitous slopes, being both old (relic) and present banks of the Manawatu River (and also, around the Ashurst area, the Pohangina River), and the banks and sides of tributary streams and gullies

The current riverbanks are generally oversteep due to currently active, or recent, downcutting and/or erosion at the toe of the banks. When the banks become no longer actively eroded at the toe, they become, over a long time period, progressively more gently sloping due to erosion and slippage of the slopes themselves. Generally these old (relic) river banks, as well as the gully and valley sides of the streams draining the alluvial terraces, become stable (with respect to landslip and gully erosion) at slopes of about 18° (1 vertical to 3 horizontal) to 20° (Jessen, 1989). Slopes steeper than 30° appear very susceptible to slippage.

3.2 Delineation of areas subject to, or likely to be subject to, erosion or slippage

Council has recognised, for a long time, that within the City boundary there exist areas of actual or potential hazard, and in 1989 commissioned the then DSIR Division of Land and Soil Sciences Aokautere to identify, evaluate and document the natural hazards and other physical constraints to development. This ULUC survey (Jessen, 1989) was restricted to the Aokautere area, and the hazard areas identified by the survey (generally Class C, D & E Land) have been incorporated in the District Plan on maps (Map 10.1, Aokautere Development Area; Map 10.7.6.2, Cliff Protection Lines) and development restrictions apply to the areas of natural hazard so identified.

3.3 District Plan provisions

3.3.1 Natural hazards

Section 22 of the District Plan addresses natural hazards through a number of stated objectives of policies, and Section 22.9 deals with land instability hazards. These are mainly to identify the areas of hazard and put in place appropriate controls on development. Land delineated as (ULUC) Classes D & E are described as undevelopable, and although Class C land is regarded as developable, it requires engineering design to ensure any structure can be safely established on it.

3.3.2 Subdivision

The District Plan recognises (Section 7.1, p 7-4) that in some cases it is necessary to prevent subdivision or strictly control it in order to avoid adverse effects, and 'the recognition of natural hazards in the design and implementation of subdivisions' is a resource management issue (7.2) specifically identified in the District Plan.

To address this issue, and achieve the stated objective (1)" to ensure that subdivision of land and buildings is consistent with integrated management of the use, development and protection of land and other natural and physical resources", Council has a policy (1.4) "to avoid the intensive urban subdivision of land which is subject to significant physical limitations and/or natural hazards". Council also has a policy (1.5) to enable the subdivision of rural land where; (c) liability to erosion, subsidence, slippage or inundation from any source; and (d) the stability of the land

and its suitability to provide a foundation for the erection of buildings (if necessary, and the reconstruction of the land for that purpose), are among those matters recognised and provided for.

Council also has a stated objective (2) "to ensure that subdivision is carried out in a manner which recognises and gives due regard to the natural and physical characteristics of the land and its future use and development, and avoids, remedies or mitigates any adverse effects on the environment". One of the policies (2.4) to achieve this objective is " to improve land utilisation, to safeguard people, property and the environment from the adverse effects of unstable land by ensuring that:

1. Disturbance to the natural land form, existing vegetation (examples included), natural drainage and significant natural features is minimised, and historic and cultural features are protected commensurate with achieving an efficient and aesthetically pleasing subdivision design and site layout.
2. Earthworks withstand and remain stable under anticipated loads.
3. Safe and adequate building sites, roading and sites for activities in the context of an enhancement of the physical landform and the preservation of significant natural, historic and cultural features are produced.
4. Planning and design of earthworks is carried out after thorough investigation of the nature on the existing land, its ability to support the construction proposed and its general suitability for subdivision.
5. Earthworks are to be designed and constructed to (amongst other matters):
   - provide safe and adequate building platforms and foundation for roads and services;
   - provide for the adequate control of stormwater;
   - avoid the likelihood of erosion and instability;
   - not unnecessarily alter the natural landscape;
   - remain safe and stable for the duration of the intended land use;
   - not unnecessarily rely on artificial or human-built structures for stability; and where such structures are employed these shall remain safe and stable for the duration of the intended land use;
   - cater for the natural groundwater flows and be geotechnically sound.
6. In Aokautere, earthworks, and in particular the restructuring of land, are to be the subject of specific design by a registered engineer experienced in soil mechanics or geotechnical matters and shall take into account the predicted improvements to soil slope and stability which will be achieved and the impact on existing vegetation and landscape values.

The principal methods used to implement the policies are District Plan Rules. For example in the Residential and Rural Zones, minimum contiguous areas of developable or stable land are specified as performance conditions for controlled activities. However, in some cases reliance on the provisions of the statute itself will implement policies. For instance, Section 106 (of the RM Act 1991) in respect of refusal of consent or the imposition of conditions in respect of natural hazards and Section 220 in respect of the imposition of certain subdivision conditions.

3.3.3 Building

In addressing the issue of building on land prone to landslip or erosion hazards, it is noted that objective 1 of the residential section of the District Plan, page 10-5, and its related policy 1.4, relate to avoidance of development in areas subject to natural hazards. This policy framework forms the basis for controls which are imposed through the residential section of the District Plan.

With the erosion and slippage hazard identified by the ULUC survey in the Aokautere area, a special series of controls are applied in that area as a precondition to the development or placement of a dwelling on a particular section. In the Aokautere Development Area as shown on Map 10.1 Rule (R) 10.7.1.1 (d) of the District Plan states that there must be a minimum net site area of 400 m2 of developable land or land for which a restructured land resource consent has been granted, the explanation being that it is essential that there is sufficient usable or restructured land to ensure that there is a stable building platform on which to safely establish a dwelling and associated facilities such as garaging and open space.

In addition to the application of R 10.7.1.1 the District Plan also seeks to avoid the development of residential land which is prone to stability and erosion hazards in the vicinity of Anzac Park. The plan seeks to achieve this through:

- the application of R 10.7.6.2 which defines an area prone to an identified stability and erosion hazard and prohibits development within this area, and;
- avoiding residential development of land identified as (ULUC) Classes D & E through the application of R 10.8.1.7.

R 10.7.6.2 recognises the fact that the banks of the Manawatu River in this area are being actively eroded forming unstable near-vertical cliffs. These unstable cliffs present a particular threat to any structures sited close to the edge of the cliffs.

3.4 Identification of areas subject to erosion or landslippage

3.4.1 General

Council has acknowledged its "duty of care" through imposing on itself Policies 1.1 and 1.2 of Section 22.3 of the natural hazard section of the District Plan, these being:

1.1 *"to identify any land subject to the effects of a natural hazard"*

1.2 *"to educate the community with regard to the existence, nature and threats posed by natural hazards".*

A fundamental objective of this Policy Document is to provide a guideline which will assist Council in its administration of subdivision and building consent applications by delineating in general terms the degree of land instability existing in the various parts of the city, and by setting out the extent of further investigations which should be carried out to support subdivisional and building consent applications in those delineated parts.

All developments on sloping land need to consider the stability of the land. However, slopes will vary in their landslip hazard potential, and it is reasonable that the level of investigation should reflect the relative hazard potential.

The philosophy adopted in this Policy Document is to identify development criteria (effectively performance standards) appropriate to the various levels of apparent hazard potential. This should enable the identification of an at risk site without placing overly onerous and conservative investigation and site assessment requirements on sites which are likely to be relatively stable. It is also intended that, with the exception of those areas delineated on maps within the District Plan as being unsuitable for development, development on high risk sites is not prevented, provided that adequate investigation, assessment and design has been carried out to reduce the risks of instability to an acceptable level, to the satisfaction of Council.

3.4.2 Landslip hazard potential

Palmerston North City is fortunate in having a relatively simple, though not necessarily uniform, geology and geomorphology, and consequential landslip hazard potential.

Although the ULUC study utilised a factor overlay, or sieve mapping (rock type, soil type, slope angle, landform and erosion severity) technique in determining areas of relative land hazard increasing in severity from Class A to Class E, the classes derived from the ULUC study are determined essentially by slope alone, as per:

Class	Slope angle (in degrees)
A	0 - 7
B	7 - 11
C	11 - 20
D	20 - 35
E	35 - 45+

As the ULUC classes also encompasses flood hazard as well as erosion and slippage, Class E also includes some flat land.

Accordingly, for Palmerston North City, slope angle alone can be taken as a clear indication of erosion or slippage potential. This has been confirmed by air photo interpretation and field reconnaissance. However, in addition to slope angle, other slope factors, together with water, geological and climatic factors, will also affect the relative landslip hazard potential of a particular site, as set out in Table 2.1.

Table 2.1 – Schematic illustration of factors which will affect the landslip hazard potential of a particular site.

LESS PRONE TO INSTABILITY			
			MORE PRONE TO INSTABILITY
	SLOPE FACTORS		
	SLOPE ANGLE		
Flat to shallow <11°	Shallow to moderate 11-20°	Steep 20-30°	Very Steep to precipitous >30°
	SLOPE HEIGHT (H)		
Low Slope (i.e. H<1.5 m)			High Slope (i.e. H>20 m)
	SLOPE SHAPE		
Uniform gradient	Convex or Concave		Overhanging
	SLOPE COVER		
Full vegetation cover			Exposed soil/rock
	WATER		
	GROUNDWATER		
Water table at depth Fully drained slope			Fully saturated slope Poorly drained slope
	SURFACE WATER		
No overland flow Covered/protected slope			Inundated slopes Slope subject to erosion
	GEOLOGICAL FACTORS		
	SOIL TYPE		
Fully drained sediments Engineered fill	Sandy soils, loess	Clayey soils	Saturated soils (all types) Uncontrolled fill
	ROCK TYPE		
Unweathered greywacke	Weathered greywacke	Coarse sediments	Fine sediments
	EARTHQUAKE		
Static conditions			Large earthquake loading
	CLIMATIC FACTORS		
Sheltered slope (uniform temperature and saturation) Low rainfall			Exposed slope (freeze thaw and wetting/drying) High rainfall

Mapping hazard areas is an effective method of presenting important information to the public, to developers, and to regulatory authorities. However, where the hazard can be simply described, as is the case for Palmerston North City, it may be better to describe the hazard rather than present it pictorially. Descriptive identification of hazard areas has the advantage that it can encompass small areas which may not be picked up on maps because of the mapping scale, and the onus for the inclusion or exclusion of specific areas therefore becomes the responsibility of applicants rather than Council. Mapping is, however, clearly appropriate in areas of complex geology and/or geomorphology, and also if Council is wanting to alert existing landowners to actual or potential hazards. For Palmerston North City, however, it is considered that landslip hazard maps based on general information only would result in either an over simplification of a hazard at any particular site, or the arbitrary application of rules which may be inappropriate for a given site.

Accordingly, the recommended approach to the identification of erosion and slippage hazard within the City boundary, takes the slope basis of the ULUC Survey and applies this to the whole of the City area as follows:

Classes A & B (Not at Risk)	This land has an overall slope of less than 11 degrees, does not exhibit any evidence of erosion or shrinkage, and is not likely to be subject to erosion or slippage being further away from (i.e. above or below) a line projecting at 20 degrees from the foot of a slope to the top of that slope, and a line projecting downslope at 20ı from the mid-point of the slope, provided the slope is not subject to river bank erosion.
Class C (Low Risk)	(Low Risk) This land has an overall slope of between 11 and 20 degrees, does not exhibit evidence of erosion, or slippage, or inundation from landslip debris, but could be subject to erosion or slippage, if not developed carefully. This land is not likely to be subject to erosion or slippage, and is unlikely to be adversely effected by upslope landslippage inundating the site or downslope landslippage removing, or removing support to, the land.
Class D & E (Moderate to High Risk)	This land is steep, and/or very steep to precipitous, (i.e. steeper than 20 degrees) and/or is either subject to erosion or slippage, or is likely to be subject to erosion or slippage. This land includes more gently sloping land which is within (i.e. above and below) a line projecting at 20 degrees from the foot of the slope to the top of the slope, and a line projecting downslope at 20ı from the mid-point of the slope.

The various land hazard classes are shown diagrammatically on Figure 2.1.

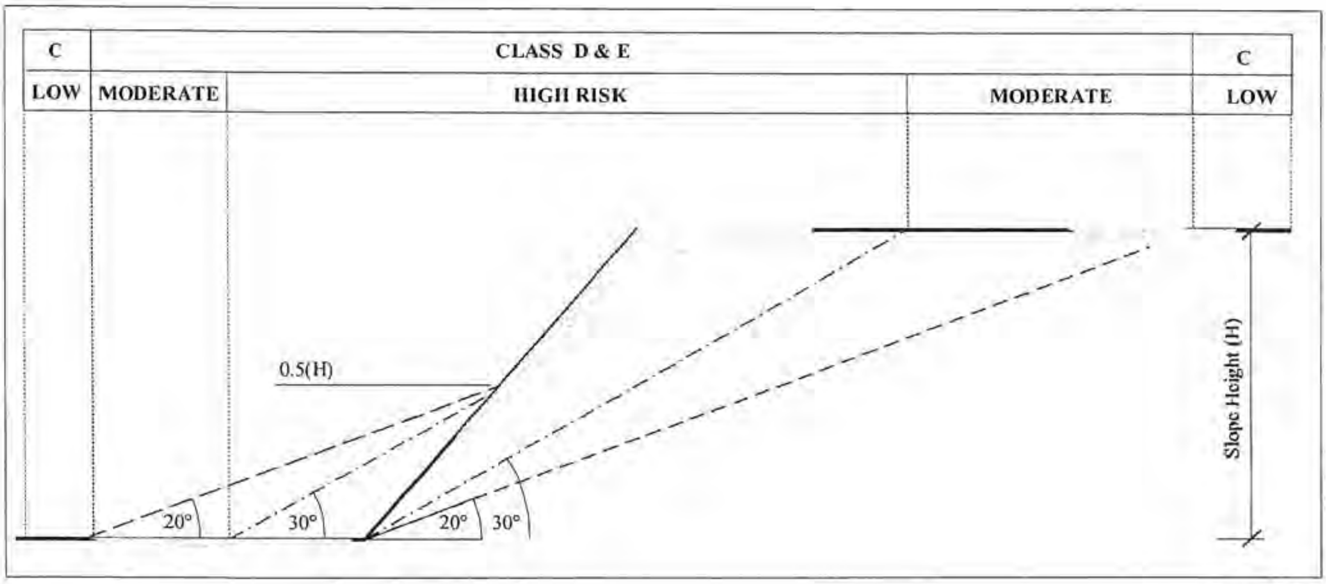

FIGURE 2.1

Where the foot of the slope is subject to active erosion, the rate at which the bank is regressing also needs to be determined and taken into account.

The areas generally identified as Class D & E within the City boundary, to the extent that available topographic (Council 1:5000 ortho photo series) and soils (1:63360 Map; Cowie, 1974) information allows have been mapped using ARC view (Council's GIS system) and are shown on Map 82096-1. However, for specific sites the land to which this classification applies should be identified and confirmed by detailed topographic information submitted by the applicant, and the areas depicted on the map (82096-1) should be taken as indicative only. There may be areas of Class D & E land outside of these areas mapped, and within those broad areas mapped as D & E there may be areas of land which are not subject to, nor likely to be subject to, erosion or slippage.

4 The role of geotechnical reports

In discharging its duty of care in dealing with land which is, or is likely to be, subject to erosion or slippage, is it common practice for Council to require applicants to submit a geotechnical report in support of their application for resource consent. However, Council must also be satisfied that the factual information contained in a geotechnical report adequately addresses the issues of erosion and/or slippage, and that the opinions expressed by the author(s) of the geotechnical report are substantiated. The level of geotechnical investigation should reflect the relative landslip hazard, not the value of the proposed development.

A copy of Schedule 2A of NZS 4404:2004 Land Development and Subdivision Engineering (Statement of Professional Opinion as to Suitability of land for Building Construction) is attached as appendix one to this document.

5 Development criteria

5.1 General

The following are recommended development criteria applying to the land classes defined in Section 2. It is important to note that these criteria apply only to erosion or slippage. Even where these matters have been addressed to the satisfaction of Council, site specific geotechnical investigations may still be required to satisfy Council as to the adequacy of foundation conditions with respect to bearing capacity and settlement (under both static or seismic loads), including the risk of liquefaction (Rogers et al, 1986). Flood risk may also need to be determined, which would include the main floodways and secondary, or overland, flow paths.

In addition to erosion and slippage of natural ground triggered by rainfall and/or seismic events, development works can accelerate, worsen or result in erosion and/or slippage. These works include oversteepening the land by cutting; surcharging the land by filling; increasing groundwater levels and/or piezometric pressures by putting stormwater and/or effluent waste water onto or into the land; and removal of vegetation (principally removing the effective cohesion provided by the roots).

5.2 Class A & B Land - No landslip hazard potential

As this land is not considered to be at risk from erosion or slippage, no geotechnical report is required to support development applications for resource consent or building consent.

5.3 Class C Land - Low landslip hazard potential

This land has a slope gradient (11 to 20 degrees) such that erosion or slippage is not considered likely to occur, and no erosion or mass movement is evident, but is considered to be sufficiently sensitive that erosion or slippage could occur due to cutting and/or filling and/or site disposal of stormwater and/or effluent waste water.

Accordingly, applications for development of this land should be accompanied by a brief geotechnical report which summarises the results of a walk-over survey and a geological/geomorphological assessment (which describes how the particular landform has been formed, what it is made up of and what slope processes are, or are likely to be, active) and provides an informed opinion on the suitability of the land for the intended purpose.

The geological/geomorphological assessment should entail most or all of the following steps, and the brief report should specifically address the expected effects of the subdivisional and/or building development on the land.

The geotechnical assessment of low risk land would be expected to include most or all of the following steps:

- walk over inspection of the site and the surrounding land,
- inspection of aerial photographs taken at various times to provide insight into the local geomorphology and evidence of any previous instability,
- review of geological data (maps, bulletins),

- enquiry after local information about stability/instability of the ground,
- seek existing data about the soil and rock profile (look for nearby exposures) or perform some simple subsurface investigation,
- examination of the soil profile to confirm that if the soil is in-situ and not colluvium,
- examination of the existing survey records for evidence of slippage or erosion.

5.4 Class D & E Land - Moderate to high landslip hazard potential

5.4.1 Moderate landslip hazard potential

This land is steeper than 20 degrees but does not exhibit any evidence of prior instability. Accordingly, due to the steepness of the slope(s), applications for subdivision, building or other development (such as excavation, filling, removal of vegetation, disposal of stormwater or domestic wastewater into or over the area) will be allowed to proceed through the issuing of the necessary consents only if supported by a geotechnical report which includes a stability assessment demonstrating that the proposed development will not accelerate, worsen or result in the land being subject to, or likely to be subject to, erosion or slippage, to the satisfaction of Council:

A geotechnical assessment on moderate risk land would be expected to include:

a Topographic survey (if not already available).

b A description of the geology and geomorphology of the area.

c Definition of the nature and continuity of the strata over the whole area of land which is proposed to be developed (buildings, access and services) involved and to a depth below which slipping is most unlikely, by means of test pit and/or drilling and/or augering (unless existing exposures are adequate).

d Assessment of the relative strength and the sensitivity of the soil in each stratum in which, or interface on which, sliding is possible.

e Assessment of likely groundwater levels and piezometric pressures in the strata during extreme infiltration conditions.

f An opinion stated by a geotechnical specialist as to the stability and suitability of the land for development.

5.4.2 High landslip hazard potential

This land exhibits evidence of past or present erosion or slippage, or has a slope gradient over 30 degrees and/or is subject to processes (e.g. removal of toe support), such that erosion or slippage is considered likely to occur in future. Accordingly, development of this land presents an identifiable hazard to property and could also, in particular circumstances, threaten life.

On, above and especially below this land, no subdivision, building or other development including excavation, filling, removal of vegetation, disposal of stormwater or domestic wastewater into or over the area will be permitted unless a geotechnical report including a stability analysis is produced to the satisfaction of Council.

The geotechnical report must demonstrate that the proposed development area will not be subject to erosion, or slippage, or inundation by debris from upslope, and how the proposed development, through preventative works or other measures, will ensure that any structure will not become damaged by erosion or slippage arising on or off the site, or that development will not accelerate or worsen, erosion or slippage.

A geotechnical report on high risk land would be expected to include:

a Topographic Survey (if not already available)

b A description of the geology and geomorphology of the area.

c Definition of the nature and continuity of the strata over the whole area of land involved, and to a depth below which slipping is most likely, by means of test pips and/or continuous recovery core drilling (unless existing exposures are adequate).

d Determination of the peak and residual shear strength parameters (either from laboratory tests or back analysis of relevant slope failures) and the sensitivity of the soil in each stratum in which, or interface on which, sliding is possible.

e Assessment of groundwater levels and piezometric pressures in the strata during extreme infiltration conditions.

f Analysis of possible failure mechanisms, relevant to the specific geology and geomorphology of the site using effective stresses.

g An opinion stated by a geotechnical specialist as to the stability of the ground and the preventative (or remedial) measures to be incorporated in the development.

The geotechnical reports requirements for the various hazard classes are summarised in Table 4.1.

Table 4.1 – Summary of reporting requirements for landslip hazard classes

Landslip hazard classes		Landslip hazard potential	Geotechnical reporting (1)
A & B	Development of land with slope angles (1) of < 11°	Negligible	Not required
C	Development of land with slope angles (1) of 11° - 20°	Low	Required 2
D & E	Development of land with slope angles (1) of 20° - 30°	Moderate	Required 3
D & E	Development of land with slope angles (1) of > 30°	High	Required 4
D & E	Development of land within lines projecting at 20° (refer Figure 2.1) above or below any slope > 20°	Low - Moderate	Required 3
D & E	Development of land within lines projecting at 30° (refer Figure 2.1) above or below any slope > 20°	Moderate - High	Required 4
D & E	Development of land exhibiting evidence of instability	High	Required 4
	Development of filled ground (> than 0.5m thick)	Low -High	Required 2

Notes:

1. For slopes, or slope components, greater than 1.5 m in height
2. Brief geotechnical report, walkover survey
3. Geotechnical report, stability assessment
4. Geotechnical investigation which includes a detailed stability analysis.

Even with a thorough geotechnical report which includes a stability analysis, complete avoidance of all risk is not possible and no guarantee of absolute safety can be provided. Site development works in particular need to be carefully planned to ensure development does not result in erosion or slippage (PNCC, 1996a).

Works which can be undertaken to protect or restore the land (Turner, 1996) include earthworks (to reduce slope angles or place buttress fills), drainage works (buttress or counterfort drains aligned down the true slope angle are particularly effective), retaining structures, erosion protection structures, and planting (PNCC, 1996b).

5.5 Subdivision and building consents

5.5.1 Refusal to grant consent

Where, as a result of walk-over surveys and/or geotechnical investigations, the land in question is found to be subject to, or is likely to be subject to erosion or slippage or inundation by debris from upslope, Council shall refuse to grant a subdivision consent (S106 RM Act 1991) or a building consent (S72 Building Act 2004), unless the effects will be avoided, remedied or mitigated (then Council may grant a subdivision consent), or unless adequate provision is made to protect the land or building work (then Council may grant a building consent). In addition, if the building work will not accelerate or worsen the situation or affect the land, then Council shall grant a building consent subject to the title being notated that the land is subject to, or is likely to be subject to, erosion or slippage or inundation by debris from upslope, pursuant to Section 72 of the Building Act 2004.

5.5.2 Section 72 of the Building Act, 2004

Section 72 of the Building Act came into being to save Councils from being sued by landowners who had purchased Council approved sections but on which Council could not approve buildings to be built because of land hazard (Rogers, 1982).

Section 72 does, however, allow the landowner to be the arbiter of his or her own destiny, provides a mechanism for alerting subsequent landowners of the hazard, and absolves Council from civil liability.

On currently vacant land subject to, or likely to be subject to, erosion and/or slippage, Council shall refuse to grant a consent for building unless it is satisfied that adequate provision is made to protect the land or building work. If provision is not made, then Council may elect not to issue any building consent, not even under Section 72.

Any application pursuant to Section 72 of the Building Act 2004 must be accompanied by a geotechnical report from a recognised geotechnical specialist that addresses in particular the effect of the building work on the stability of the land and any other property, and how it can comply with the Building Code.

5.5.3 Cut and fill slopes

All subdivisional and building consents should be conditional on all cut and fill slopes steeper than 1 in 3 (18 degrees) being retained or otherwise stabilised. This should ensure that building damage and land boundary disputes are unlikely to arise due to cut or fill slope instability.

5.5.4 Development of filled ground

Irrespective of whether or not fill has been certified as suitable for residential purposes, all building consents should be conditional upon a requirement that all foundations will be taken down through any topsoil layers to found in material suitable (with respect to bearing capacity and settlement) to support the particular structure.

6 Applicability

This report has been prepared for the benefit of Palmerston North City Council with respect to the particular brief given to us and it may not be relied upon in other contexts or for any other purpose without our prior review and agreement.

TONKIN & TAYLOR LTD

Environmental and Engineering Consultants

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Nick Rogers

Project Coordinator

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15 August 2005

Attachment C

REPORT

Preliminary Site Observations for Proposed Aokautere Redevelopment

Prepared for
Palmerston North City Council

Prepared by
Tonkin & Taylor Ltd

Date
February 2020

Job Number
85442.0080.v2

Exceptional thinking together

www.tonkintaylor.co.nz

Document Control

Title: Preliminary Site Observations for Proposed Aokautere Redevelopment					
Date	**Version**	**Description**	**Prepared by:**	**Reviewed by:**	**Authorised by:**
20/12/2018	v1	First draft for review	EJWL/CVS	CMW	
10/2/2020	v2	Update report to include Water's block –draft for review	EJWL	CMW	

Distribution:

Palmerston North City Council 1 PDF copy

Tonkin & Taylor Ltd (FILE) 1 electronic copy

Table of contents

1 Introduction

This report presents the findings of our preliminary geotechnical site assessment for the proposed Aokautere redevelopment project. Tonkin & Taylor Ltd (T+T) was engaged to undertake this work by the Palmerston North City Council (PNCC) in accordance with the terms and conditions contained in our proposal dated 21 August 2018 and additional variation (No 2) proposal dated 16 October 2019.

The objective of this assessment is to provide a high-level evaluation to identify the possible geotechnical risks involved in developing land for residential and rural residential developments.

1.1 Supplied information

Information supplied by PNCC prior and during the investigation comprised of:

- August 2018
  - Five report files relating to the development area including fill assessments and resource consent enforcements
  - A workshop report (Aokautere Structure Plan PNCC Workshop 2)
  - Unmanned Aerial Vehicle (UAV) video footage of a flyover conducted 30 March 2018
  - Annotated aerial photographs of the proposed area including but not limited to:
  - Property boundaries of landowners involved
  - Topographic contours
  - A map of the zones of proposed development including access carriageways
  - A digital elevation model (DEM)
- September 2019
  - Geospatial Information Systems (GIS) files of the assessment area.

2 Site description

The proposed development contains approximately 490 ha (4.9 km^2) of land south east of Palmerston North.

Ownership of the land as at November 2019 is divided into the following blocks, (refer to Appendix A; Figure 1):

Land block owners	Overview of land	Area
Les Fugle	Flat topped hills with water eroded vegetated gullies	101 ha
Voss	Rolling hills with some water eroded gullies to the northeast. Flat level river terraces to the south west.	101 ha
Green	Flat topped to gentle rolling hills to the north east. Flat level river terraces to the south west.	58 ha
Midcity Holdings Ltd	Low lying river terrace	5 ha
Waters	Flat topped hills with river cut valleys, flat terracing to the south	104 ha
PNCC	Vegetated gullies flanking waterways to the south west. Vegetated gullies and walking paths to the north.	28 ha
Privately owned	Residentially developed land.	93 ha

The area is broadly 4km by 1.5km and slopes gently upwards to the south. The land can be typically divided into two topographies:

1. Water cut and eroded gullies in elevated flat to rolling hills within the eastern and southern sides of the site.
2. Flat, river and stream formed terraces adjacent to and including a section of the Turitea Stream within the south western side of the site.

2.1 Proposed redevelopment

According to supplied information and observations made onsite the proposed redevelopment land use can be divided into the following groups (refer Appendix A; Figures 2a and 2b):

Proposed development	Area
Residential	87 ha
Rural residential	102 ha
(Native vegetation) Green space	161 ha
Existing development or excluded land	140 ha

These proposed land areas will be connected by approximately 13km of carriageways.

3 Geology

The Palmerston North regional area lies on the boundary between the older (late Jurassic/ Early Cretaceous) exposed greywacke basement rocks (Esk Head belt) in the Tararua ranges to the south east with the younger (Holocene) alluvial river deposits of gravel, sand and silts to the north west (Refer Appendix A: Figure 3).

The Esk Head belt (Te) forms the base of the Tararua mountain range. These rocks have been deformed and uplifted through the Wellington Fault which runs NE-SW along the eastern side of the Tararua Ranges. This stratigraphy is present on the far south-eastern corner of the Waters property.

To the northwest of the Esk Head belt, towards Turitea in the southwest of the site, early Pleistocene alluvial river gravels and sands (eQa) are present. These are assumed to have been deposited as erosional runoff deposits during the uplift and formation of the Tararua Ranges.

Further northwest, up to the cliffs adjacent to the Manawatu River, are gravels and sands more conclusive to marginal marine/ beach deposits indicating a paleo-shoreline (Q5b) is present. Cutting through these beach deposits and river gravels is a prominent flat river cut terrace containing gravels and silts eroded from the Tararua Ranges and deposited in a paleo-channel (Q2a). These geological materials underlie the majority of the site.

Younger Holocene deposits of river silts and sands (Q1a) are found in the many smaller river cut terraces formed from the meandering watercourses which loosely follows the Turitea Stream, formed in the Q2a paleo-channel.

The published geology[1] of the investigation area is shown in Appendix 1: Figure 3 which indicates the regional surface geology.

[1] Lee, J.M., Begg, J.G. (compilers) 2002: *Geology of the Wairarapa area*. Institute of Geological & Nuclear Sciences 1:250,000 geological map 11. 1 sheet + 66 p. Lower Hutt, New Zealand. Institute of Geological & Nuclear Sciences Limited.

3.1 Faults

Active faults have been identified within 15km of the assessment area as shown in Table 1.

Table 1: Active faults

Fault name	Location relative to the assessment area	Recurrence interval (years)	Last occurrence (years)
Wellington Fault	7km southeast	850	335-485
Northern Ohariu Fault	9km southwest	2600	<4000
Ruahine Fault	13km east	3700	<1800

4 Assessment methodology

4.1 Desktop study

Historic aerial photographs were reviewed (1950, 1965 and 1995) of the site and surrounding areas. This confirmed the predominant usage of the land over that time period has been farmland pasture. Many gullies in the northern section of the site were bare of vegetation with observable historic landslips. Later revegetation and infilling were also observed in the photographs. Urban development along Pacific Drive became noticeable in 1995. The large water tank and associated roading on the Water's property was constructed in 2017.

The digital elevation model (DEM) supplied by PNCC was utilised to produce a slope gradient map. This produced map was overlaid with the supplied proposed redevelopment plan and aerial photograph mapping.

4.2 Mapping and observations

T+T undertook a site walkover during 26-28 September 2018 (Voss property and north) and 17 October 2019 (Water's property). Mapping and site walkover observations (Appendix A: Figures 4a and 4b) were collected for the majority of the undeveloped sites marked for future proposed development, where access approval was granted by the landowner and safety considered. Photographs of areas of interest are provided in Appendix B.

During the site walkover observations, particular attention was given to hazards associated with ground instability, water flows and soft ground conditions as summarised in Table 2.

Table 2: Summary of observations and associated hazards

Site observations	Associated hazards	Map ID (Refer Appendix A: Figures 5a and 5b)
Evidence of landslip, both recent and historic	Potential slope and land instability	A
Evidence of land creep	Potential slope and land instability. May indicate future landslip failures	A
Slope direction and gradients	Provides land fall direction indicating areas of water runoff catchments	←
Watercourses, both current and ephemeral	Potential for erosion of land along with erosion induced landslips. Path of water runoff may indicate areas of saturated ground. Potential for flood inundation.	
Saturated ground conditions and swamp land	Settlement of ground and potential for flood inundation.	B
Groundwater outflows	Potential for instability on slopes, erosion, internal gully erosion	C
Uncontrolled fill	Settlement of ground and loss of bearing	- - - - - -

4.3 Geo-hazards identified

The associated hazards consist of the following geotechnical issues to be considered for consenting:

- Slope and land instability
- Erosion including tunnel gully erosion
- Uncontrolled fill, settlement
- Flooding/high groundwater table
- Soft soils/Peat, settlement

Detailed descriptions of the geotechnical issues are provided in Appendix C.

5 Geo-hazard assessment

By using the above methodology, a geotechnical hazard risk assessment was undertaken.

To produce the overall maps (Refer Appendix A: Figures 5a and 5b) and the associated areas of potential geotechnical risks, a range of assessment factors were considered. These are outlined in Table 3.

Table 3: Assessment factors for geotechnical risk

Maps	Description
Aerial image map	Overview of land topography and possible geotechnical hazards.

Site mapping observations	Ground truthing of new and previously identified possible geotechnical hazards.
Slope gradient map	Identification of land which may require geotechnical remediation for development.
Proposed residential, rural residential and carriageway areas	Relevancy of observations with identified possible geotechnical hazards.

All the walkover mapping field observations and notes are presented in Appendix A: Figures 4a and 4b. All the site observations presented are visual only and no intrusive investigation or lab testing was conducted.

5.1 Geomorphology risk

As described in Section 2 the topography and geomorphology of the area can be divided into two main types. These are described in more detail below in relation to land ownership blocks (refer to Appendix A: Figure 1).

5.1.1 Elevated flat to rolling hills

Les Fugle and the north-eastern Green and Voss blocks consist of level plains in the north west to gentle rolling hills in the south east. The hills become steeper with deeper water cut and eroded gullies towards the east within the Waters property. Water cut valleys have incised up to 35 m depth, these valleys hold ephemeral streams and continuous watercourses predominantly flowing south to north towards the Manawatu River. Watercourses within the southern area of the Voss block and within the Waters block predominantly flow from the south towards the northwest in the direction of the Turitea Stream.

Valleys in the Les Fugle and Green block are in the process of revegetation, the Voss and Waters block valleys are generally bare of vegetation. Signs of historic and recent landslips are evident, especially in the valleys of the eastern Voss and Waters blocks. These landslips are likely triggered by erosion at the foot of the valley and from surface water runoff which was visible along many ridges.

Water retention within the top-soil was observed to be greater in the Les Fugle and Green blocks compared to the Voss and Water's block. This may be indicative of a different subsurface geology.

5.1.2 Flat river terraces

Bi-secting the Green, Voss and north-western corner of the Water's block is an upper level river cut terrace with an associated 35m high, 20° to 30° slope. This slope shows evidence of multiple ground water outflows which form shallow water cut valleys saturating land downslope. Minor landslips where present at the head of these outflows. This terrace provides approximately 40 ha ($0.4km^2$) of flat level ground. Near the boundary between Green and Voss blocks is a water cut gully approximately 200m long ranging in depth from 0.5m to 13m deep with steep 80-90° slopes.

A second observable lower river cut terrace runs adjacent to the Turitea Stream alongside the PNCC and Midcity Holdings property. The terrace forms a 13m high moderately steep (30° to 45°) slope with evidence of recent and historic landslips. Within this lower terrace is evidence of multiple river cuts, saturated ground and swampland.

5.2 Geotechnical risk

The following geotechnical hazards (Table 4), described in Section 4 and Appendix C, are shown on maps in Appendix A; Figures 5a and 5b in red. These areas may be considered for limited development/consenting restrictions and are to be addressed during development.

Table 4: Geotechnical hazard areas to be addressed

<table>
<tr><th>ID*</th><th>Geotechnical hazard</th><th>Urban Residential</th><th>Rural residential</th><th>Infrastructure</th></tr>
<tr><td>1</td><td>Slope and land instability
Erosion</td>
<td rowspan="17">Consequences:
Damage to service connections due to ground and building deformations.

Community disruption and displacement due to damage to buildings then the complex and lengthy process of repairing and rebuilding.

Large magnitude total and differential settlement due to soft soil, peat, and/or uncontrolled fill.

Loss of foundation-bearing capacity, resulting in settlement/slope instability.

Stretch of the foundation due to slope instability, pulling the structure apart.

Additional design cost

Development consideration:
Additional site specific geotechnical investigations, Enhanced foundations; Ground improvement</td>
<td rowspan="17">Consequences:
Damage to service connections due to ground deformations.

Additional design cost

Limited land use

Development consideration:
Additional site specific geotechnical investigations, Limited land use, Placement of the proposed structures away from hazard</td>
<td rowspan="17">Consequences:
Damage to roads (cracking due to settlement/slope instability, sinkholes due to erosion).

Damage to underground services due to ground deformation (e.g. ‘three waters’, utility networks).

Disruption of stormwater drainage.

Community disruption and displacement – initially due to damage to infrastructure, then the complex and lengthy process of repairing and rebuilding.

Additional design cost

Development considerations:
Placement of proposed infrastructure away from hazard; Slope stabilisation; Additional site specific investigation; Ground improvement; Additional resilience; Redundant utility and road networks</td></tr>
<tr><td>2</td><td>Slope and land instability
Erosion
Tunnel gully erosion</td></tr>
<tr><td>3</td><td>Slope and land instability
Erosion
Uncontrolled fill</td></tr>
<tr><td>4</td><td>Slope and land instability
Erosion</td></tr>
<tr><td>5</td><td>Slope and land instability
Erosion</td></tr>
<tr><td>6</td><td>Slope and land instability
Erosion</td></tr>
<tr><td>7</td><td>Slope and land instability
Erosion</td></tr>
<tr><td>8</td><td>Slope and land instability
Tunnel gully erosion
Flooding
Soft soil/Peat
Uncontrolled Fill</td></tr>
<tr><td>9</td><td>Slope and land instability
Tunnel gully erosion
Flooding
Soft soil/Peat</td></tr>
<tr><td>10</td><td>Slope and land instability
Erosion
Tunnel gully erosion</td></tr>
<tr><td>11</td><td>Slope and land instability
Erosion</td></tr>
<tr><td>12</td><td>Slope and land instability
Erosion</td></tr>
<tr><td>13</td><td>Slope and land instability
Erosion</td></tr>
<tr><td>14</td><td>Slope and land instability
Erosion</td></tr>
<tr><td>15</td><td>Slope and land instability
Erosion</td></tr>
<tr><td>16</td><td>Flooding
Soft soil/Peat</td></tr>
<tr><td>17</td><td>Slope and land instability
Erosion</td></tr>
</table>

18	Slope and land instability Erosion			
19	Slope and land instability Erosion			
20	Slope and land instability Flooding Soft soil/Peat			
21	Slope and land instability Erosion Tunnel gully erosion			
22	Slope and land instability Erosion			
Fill	Uncontrolled fill			

*Refer to Appendix B for documented photographs of site observations.

6 Conclusions

T+T has undertaken a site walkover and desktop assessment of geo-hazards for Palmerston North City Council. The results of this assessment are considered suitable to aid PNCC in the assessment and management of geotechnical-related risk and provide guidance for the Proposed Aokautere Redevelopment.

Appendix A, Figures 5a and 5b, identifies potential areas of geotechnical risks for the Proposed Aokautere Redevelopment. Site specific information is required to refine the assessment. Land use and development within these areas shall be assessed by Chartered Engineer.

It is the responsibility of the future developer to address and ensure there will be no additional or exacerbation of hazards on-site or off-site as a result of any proposed development.

7 Further work

There are various potential opportunities for PNCC to take an active role in managing geotechnical related risk, while also facilitating development by simplifying site-specific ground investigation and foundation design requirements where appropriate. We would be happy to work with PNCC to explore how these could be implemented. Possible examples include:

- Defining succinct geotechnical information requirements for resource and building consent applications, which focus on resolving the key uncertainties in the geotechnical hazards relevant for each development area.
- Undertaking ground investigations and/or soil testing across parts of the development area. This would provide greater certainty in the assessment and could allow some types of development to proceed relying only on the existing information without the need for site-specific investigations (where appropriate, and subject to a requirement for robust foundations).

8 Applicability

This report has been prepared for the exclusive use of our client Palmerston North City Council, with respect to the particular brief given to us and it may not be relied upon in other contexts or for any other purpose, or by any person other than our client, without our prior written agreement.

Recommendations and opinions in this report are based on data from surface observations only. The nature and continuity of subsoil away from the surface observation and below the surface are inferred and it must be appreciated that actual conditions could vary from the assumed model.

Tonkin & Taylor Ltd

Report prepared by:	Report prepared by:
....	....
Enzo Liddle Engineering Geologist	Christopher Sandoval Geotechnical Engineer

Authorised for Tonkin & Taylor Ltd by:

....

Mike Jacka
Project Director

Reviewed by Kate Williams (Senior Engineering Geologist)

EJWL
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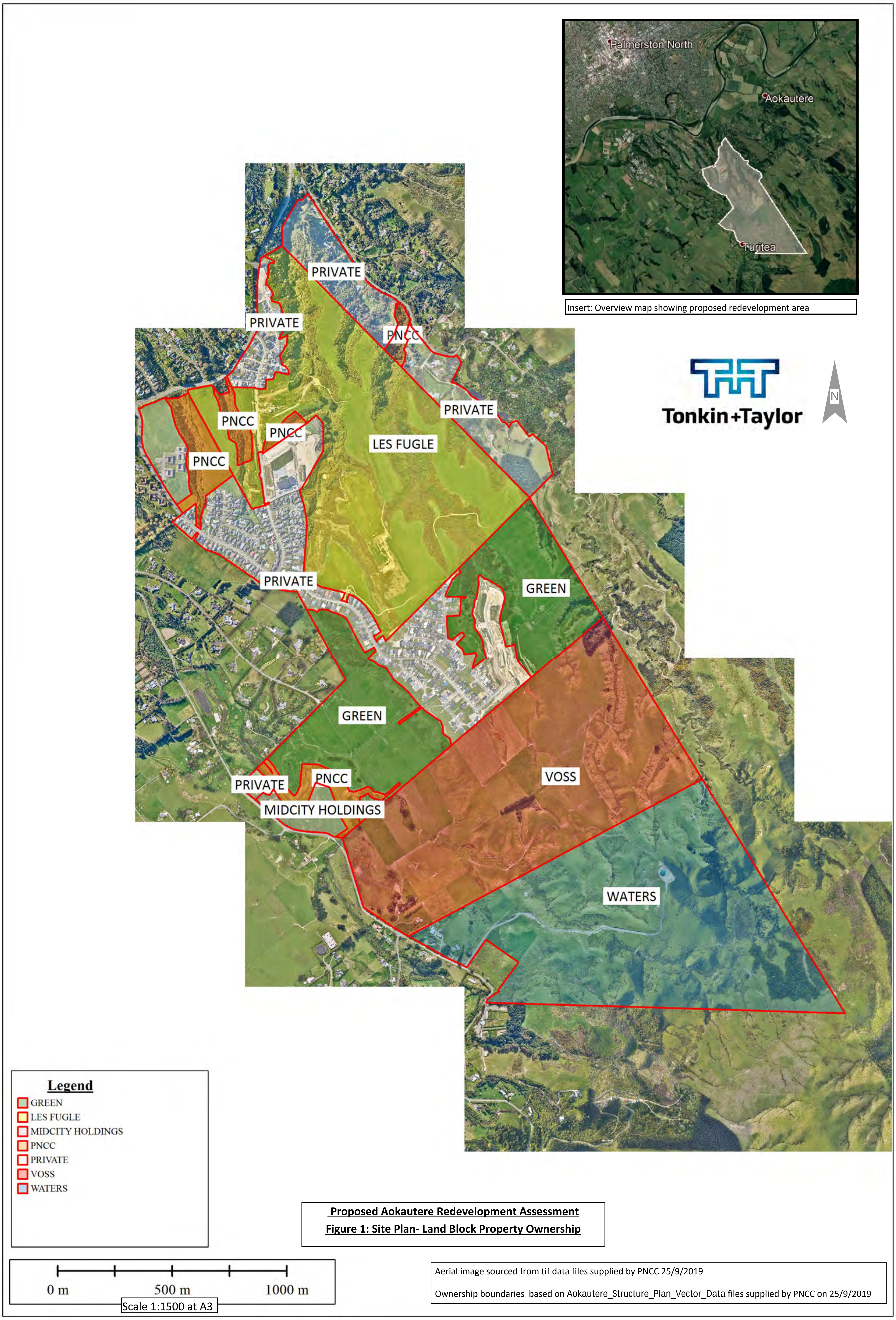
Appendix A: Figures

- **Figure 1 - Site Plan- Land block property ownership**
- **Figure 2a - Proposed development zoning**
- **Figure 2b - Proposed development zoning - Waters block**
- **Figure 3 - Geological map**
- **Figure 4a - Site walkover observations**
- **Figure 4b - Site walkover observations - Waters block**
- **Figure 5a - Potential areas of geotechnical risks**
- **Figure 5b - Potential areas of geotechnical risks –Waters block**



Proposed Aokautere Redevelopment Assessment

Figure 1: Site Plan- Land Block Property Ownership

Aerial image sourced from tif data files supplied by PNCC 25/9/2019

Ownership boundaries based on Aokautere_Structure_Plan_Vector_Data files supplied by PNCC on 25/9/2019

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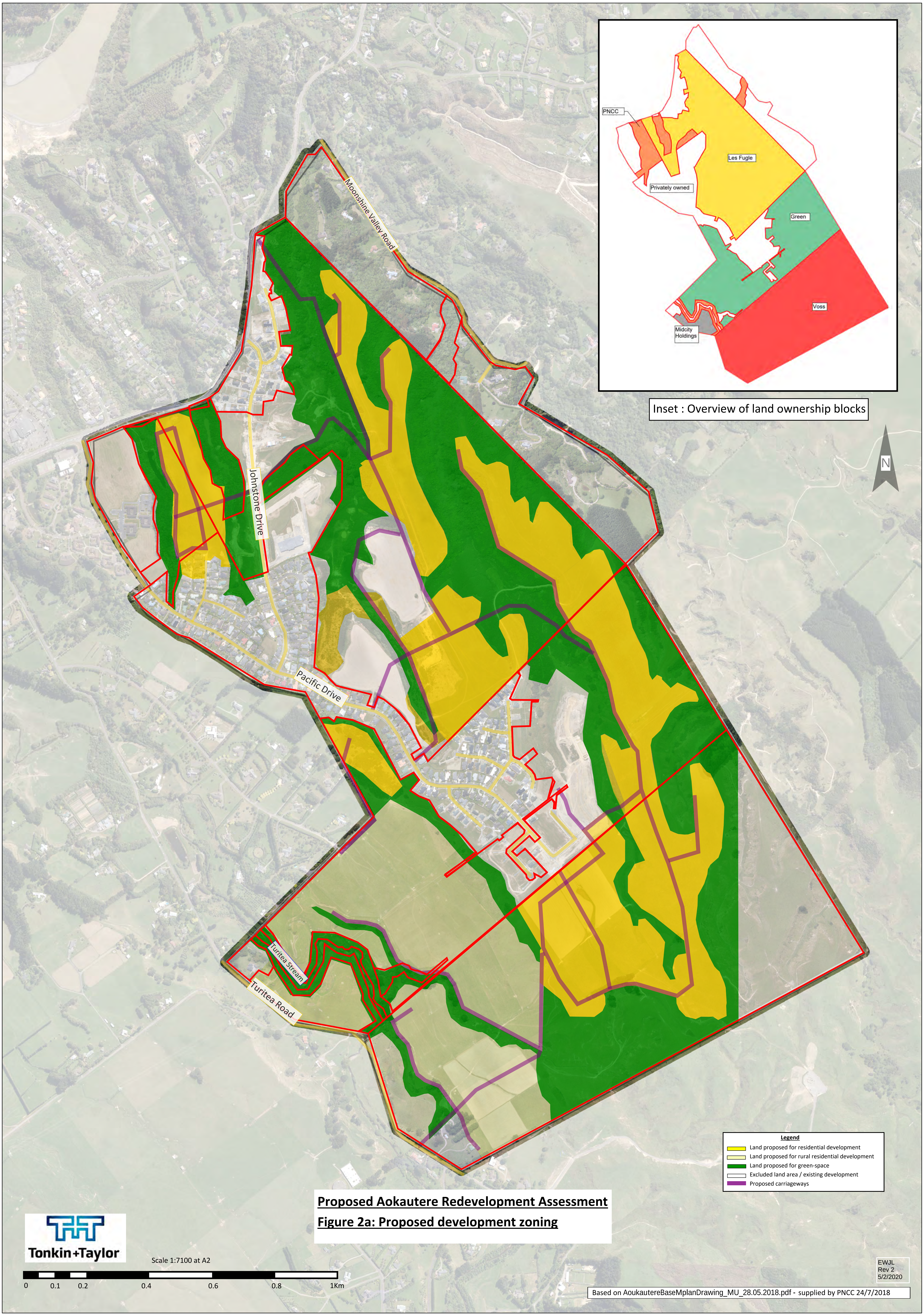
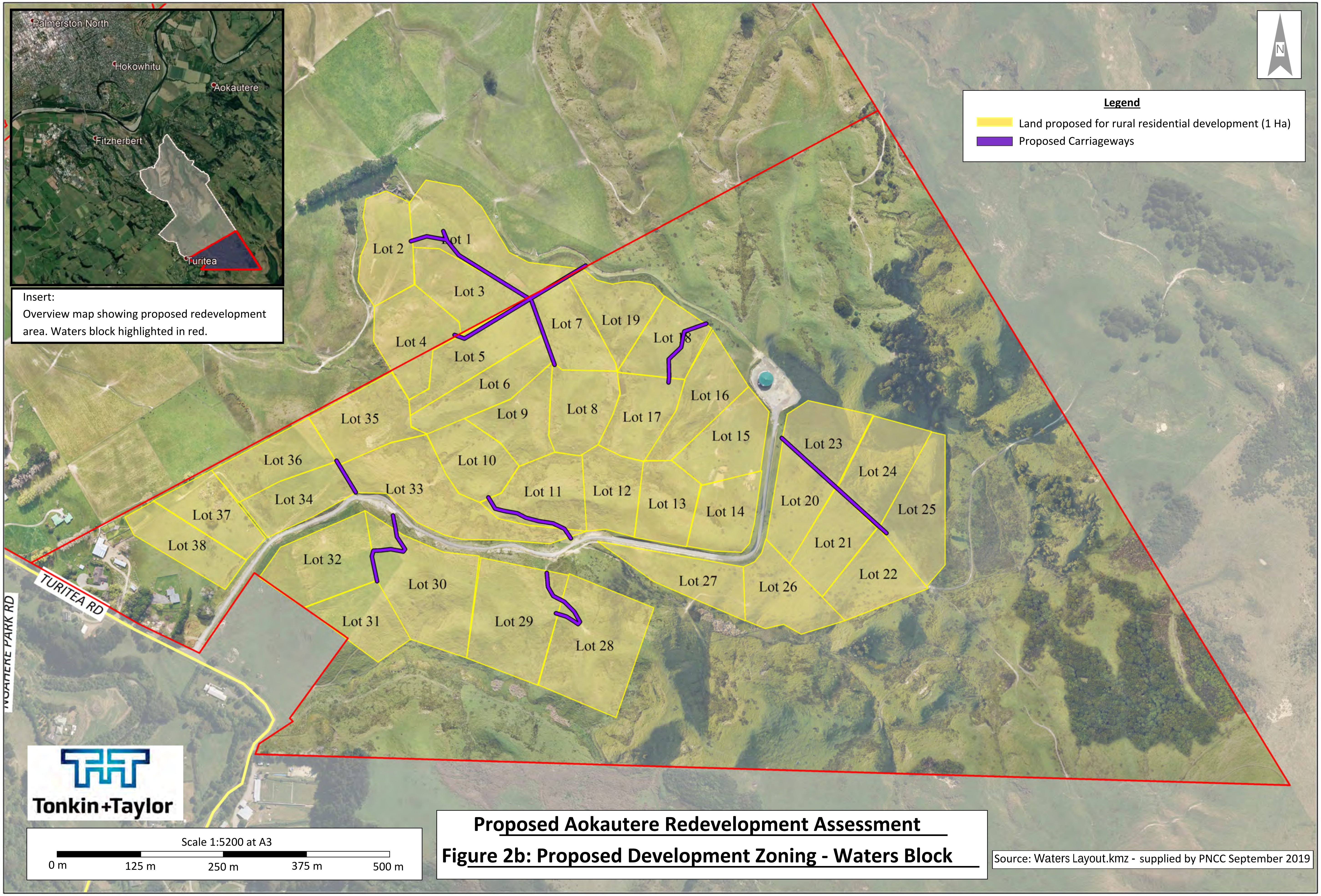


Proposed Aokautere Redevelopment Assessment

Figure 2a: Proposed development zoning



Proposed Aokautere Redevelopment Assessment

Figure 2b: Proposed Development Zoning - Waters Block

Source: Waters Layout.kmz - supplied by PNCC September 2019

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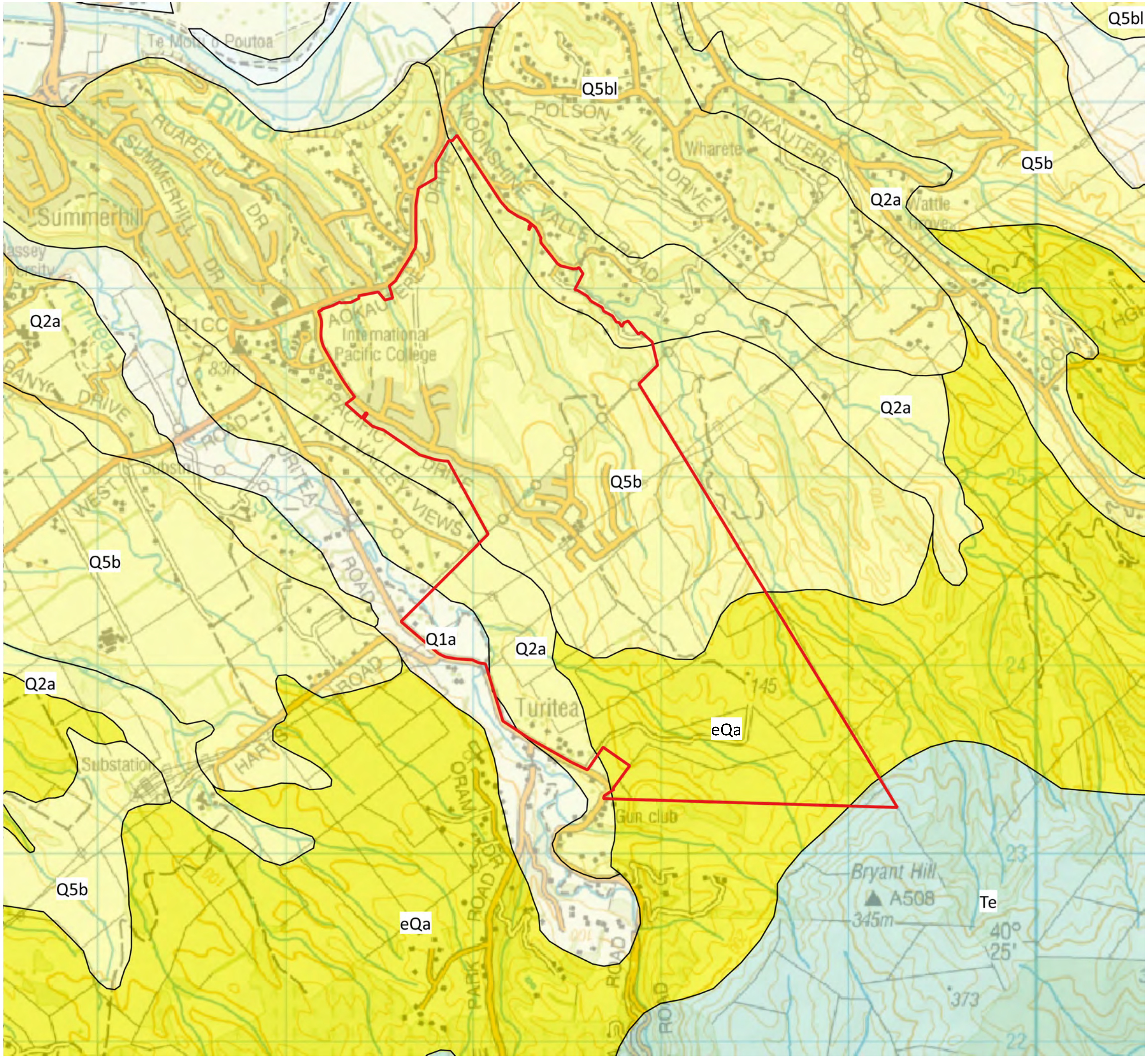

Legend

Key	Published description (Age)	Site observations
Te	Esk Head Belt: Sandstone and Mudstone (Late Jurassic to early Cretaceous)	Exposed boulders and outcrops
eQa	River deposits of pumiceous sand and gravel (early Pleistocene)	River gravels and silts, trace weathered volcanic gravel.
Q5b / Q5bl	Beach deposits of sand and gravel (late Pleistocene)	Beach sand and marginal marine gravels.
Q2a	River deposits of gravel and sand (late Pleistocene)	River gravels and silts.
Q1a	River deposits of gravel, sand, clay and peat (Holocene)	Silts and swamp.

Simplified Geology

	Indurated sandstone
	Pumiceous sand
	Sand and gravel
	Gravel sand and peat

Proposed Development Boundary

A3 SCALE: 1:20,000

0 210 420 630 840 1,050 (m)

N

1. Geological Boundaries,Inactive Faults,Active Faults GNS Science, Lower Hutt, New Zealand.
2. geotiffs Eagle Technology, LINZ
3. Property Boundary sourced from the LINZ Data Service and licensed for re-use under the Creative Commons Attribution 3.0 New Zealand licence.

Created On:	18/12/2019
Created By:	ELiddle
Approved By:	
TT Proj Ref:	85442.0080
TT Map Ref:	TTMAPREF1433463001.902

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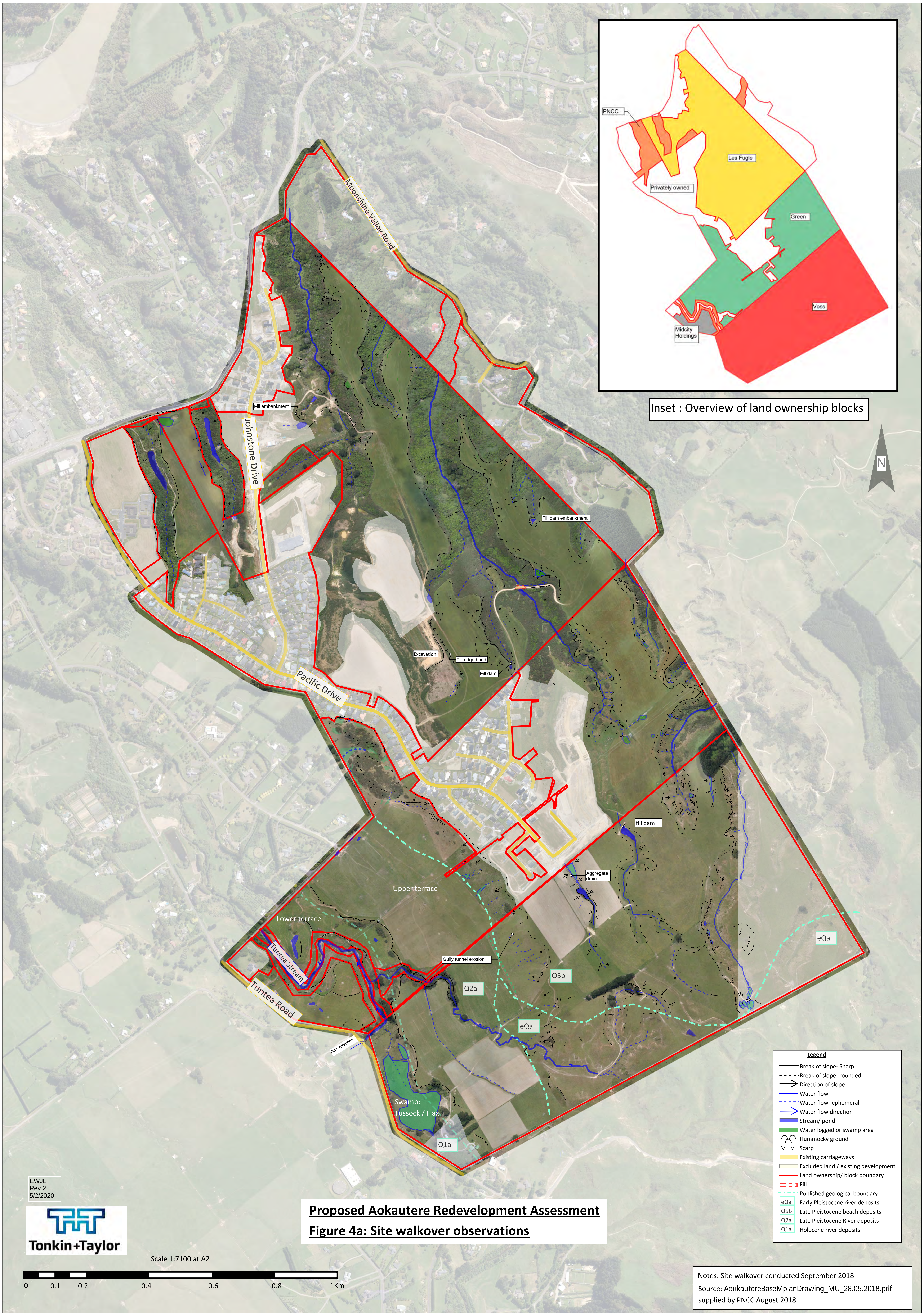
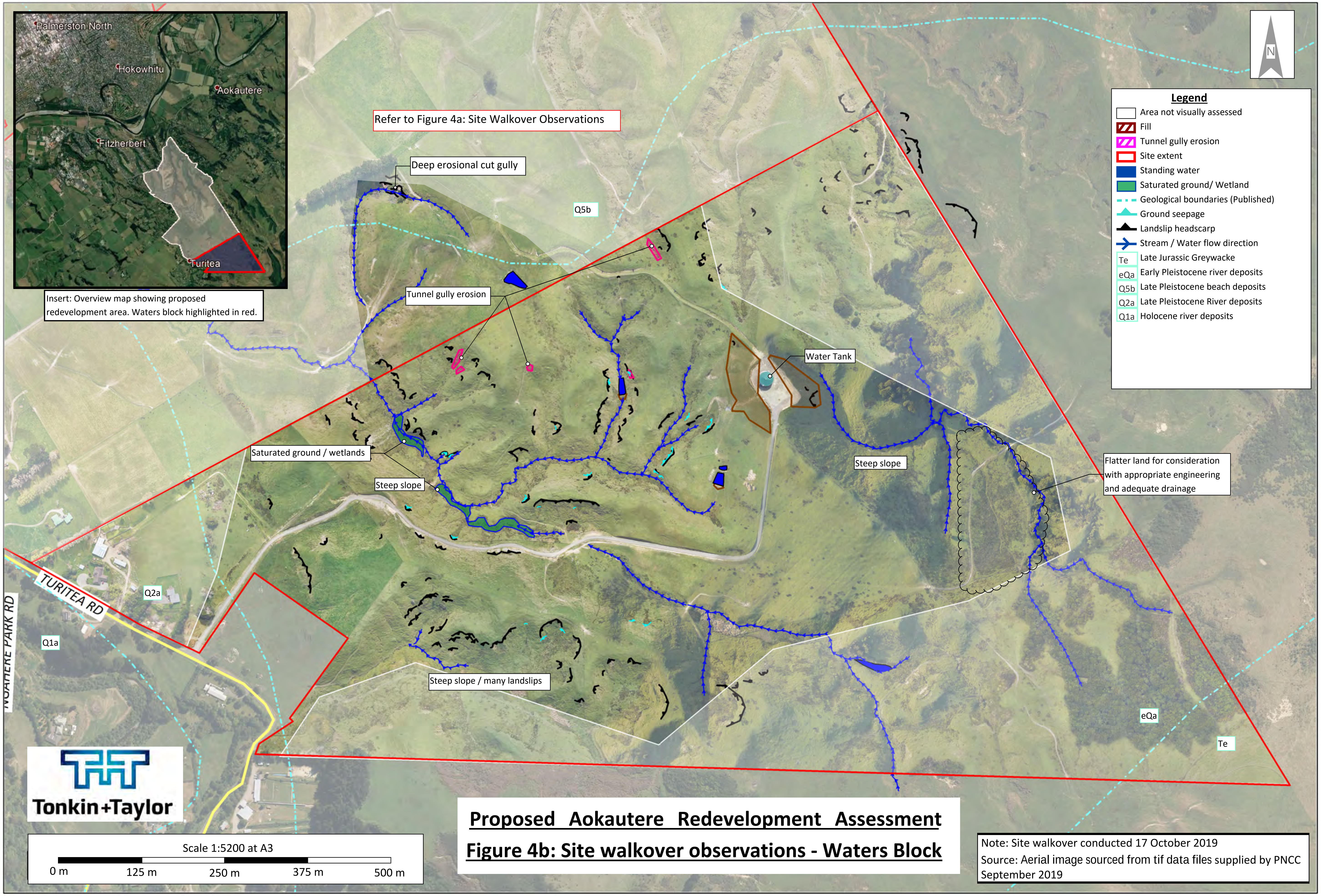
PALMERSTON NORTH CITY COUNCIL
PRELIMINARY SITE ASSESSMENT
PROPOSED AOKAUTERE REDEVELOPMENT
GEOLOGICAL MAP

FIGURE No.
3



Proposed Aokautere Redevelopment Assessment

Figure 4a: Site walkover observations



Proposed Aokautere Redevelopment Assessment

Figure 4b: Site walkover observations - Waters Block

Note: Site walkover conducted 17 October 2019
Source: Aerial image sourced from tif data files supplied by PNCC September 2019

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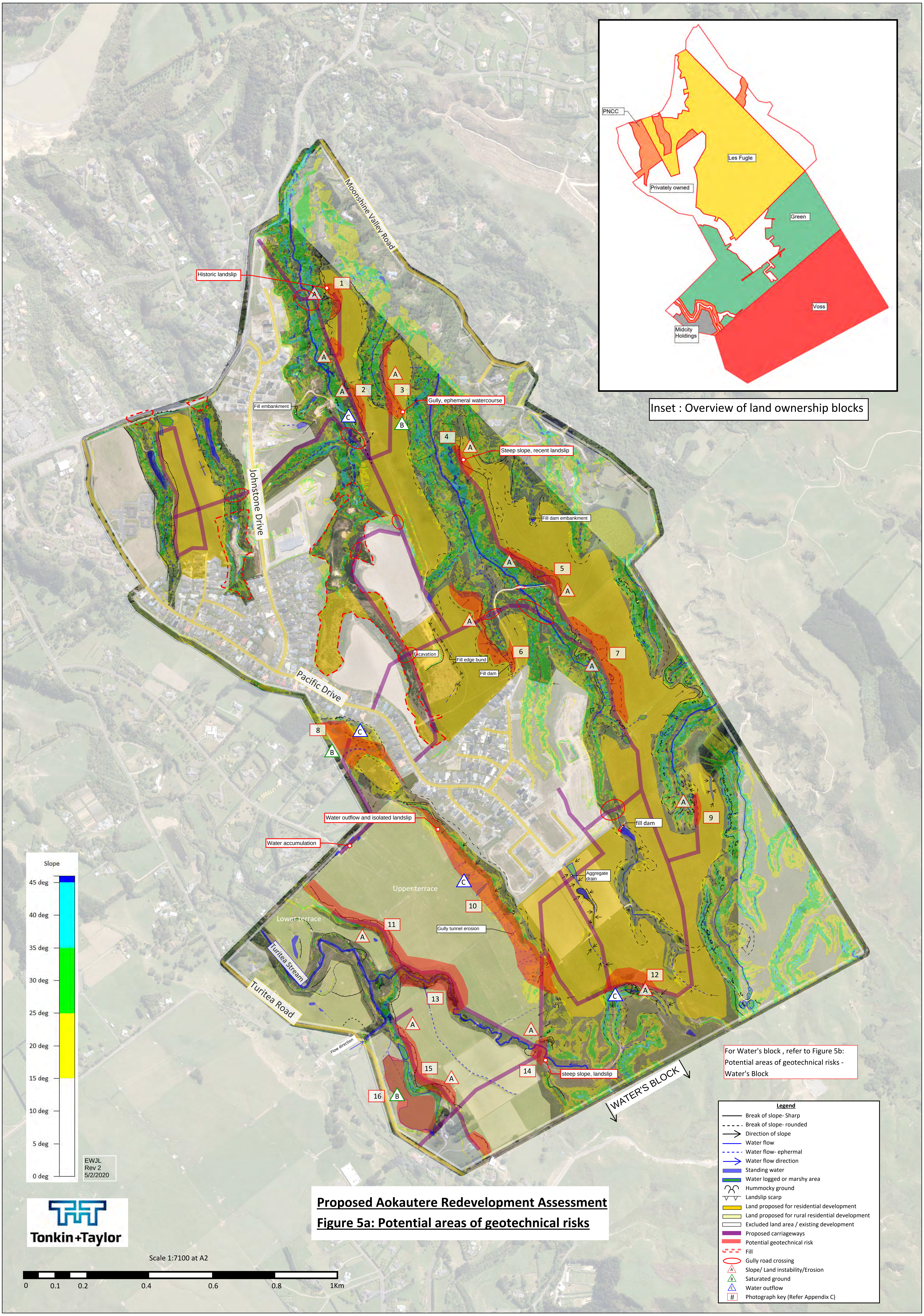
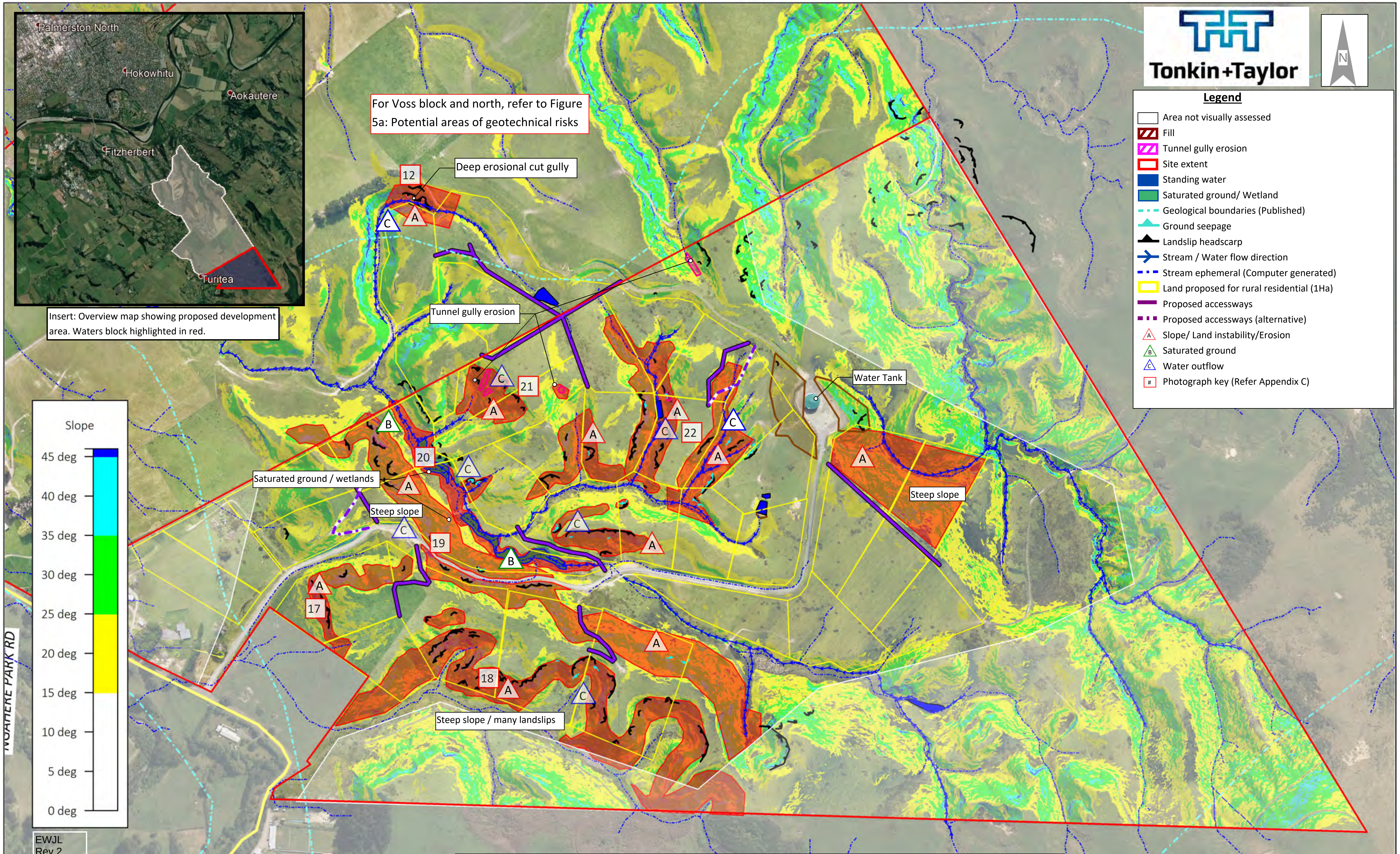
Rev 2
5/2/2020



Proposed Aokautere Redevelopment Assessment

Figure 5a: Potential areas of geotechnical risks



Proposed Aokautere Redevelopment Assessment

Figure 5b: Potential areas of geotechnical risks - Waters Block

Note: Site Walkover conducted 17 October 2019
Source: Aerial image and digital elevation model sourced from .tif data files supplied by PNCC September 2019

Appendix B: Photographs of site observations

Photograph 1: Les Fugle block; hummocky ground

Photograph 2: Les Fugle block; hummocky ground

Photograph 3: Les Fugle block, top of gully and watercourse with soft ground

Photograph 3b: Les Fugle block, watercourse at base of gully

Photograph 4: Les Fugle block; recent landslip

Photograph 5: Les Fugle block; hummocky ground

Photograph 6: Les Fugle block, standing water created by fill dam.

Photograph 7: Green block; historic landslip scarp

Photograph 8: Green block; saturated hummocky land

Photograph 8b: Green block; saturated hummocky land

Photograph 8c: Green block; saturated soft land and standing water

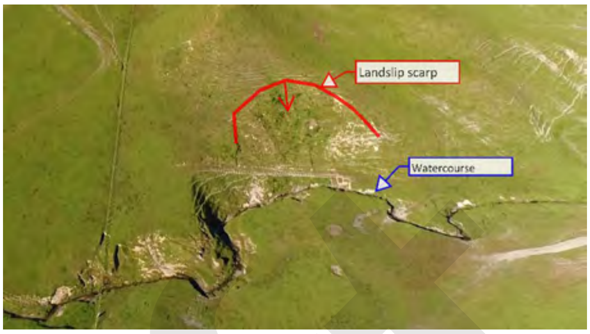
Photograph 9: Voss block; recent landslip scarp and saturated ground

Photograph 9b: Voss block; recent landslips and saturated ground

Photograph 10: Voss block: water induced landslips and watercourses

Photograph 11: Voss block; steep hummocky river terrace slope

Photograph 12: Voss block; steep water-cut gully with recent landslips

	
Photograph 13: PNCC block; steep water-cut gully with recent landslips	Photograph 14: Voss block, landslip scarp and watercourse (photograph from UAV footage)
	
Photograph 15: Voss block; steep slope with landslips	Photograph 16: Voss block; saturated ground and swampland
	
Photograph 17: Waters block; Steep slope and landslip headscarps	Photograph 18: Waters block; Steep slopes and multiple landslip headscarps
	
Photograph 19: Waters block; Steep slope, water seepage, multiple landslip headscarps	Photograph 20: Waters block; Streams and saturated surrounding land.

	
Photograph 21: Waters block; Tunnel gully erosion	Photograph 22: Waters block; Steep slopes, landslide headscarps and watercourse

Appendix C: Geotechnical hazard descriptions

Slope and land instability

Slope failures are major natural hazards occurring both globally and locally. They are referred to as the downslope movement of rock debris and soil in response to gravitational stresses. Slope failures are generally classified according to the type of downslope movement namely falls, slides, and creep.

Common causes of slope failure include:

- Slope steepness/gradients
- Excessive water in slopes adding weight, erosion, and reducing strength
- Modifications (excavations and removal of the slope's base, loading of the slope or crest, surface or groundwater manipulation, and irrigation)
- Seismic loading

Erosion

Erosion is the loss or displacement of land along a watercourse, through runoff or surface overland flow water or ground water seepage. Gullies are permanent erosional features. The gullies function as sediment sources, stores, and conveyors that link hillslopes to downstream water channels and flow paths.

Changes in land use, may accelerate gully expansion by head cutting, sidewall collapse, tunnelling, and other processes, which lead to widespread land degradation and potential damage to structures and infrastructure.

Tunnel gully erosion

Tunnel gully erosion is a process involving the removal of subsurface soil layers by water. The water moves down through the soil profile until it reaches a less permeable layer where it concentrates to form a downslope channel (tunnels). As the tunnel widens the risk of ground surface collapse increases, which can then often continue as gully erosion and increase the risk of losing larger areas of pasture and productive land.

Tunnel gully erosion is likely to be found where there is a variation in the permeability within the soil profile such as a free draining soil or subsoil overlying an impermeable layer. It often occurs towards the base of colluvial slopes, which are lower slopes formed by previous mass movement and slope instability.

Uncontrolled fill

Uncontrolled fill consists of soil placed without documentation and without engineering input. There are various areas of know uncontrolled fill located within the area (refer Appendix A: Figures 4a and 4b). There is risk of subsidence and differential settlement of structures, as a result of uncontrolled fill.

The following reports document a portion of land formed by uncontrolled fill and the ground conditions:

- David Napier (2007), Filling Assessment Report, Barthos Properties Abbey Road Extension, dated March 2007
- Abuild (2012), Peer Review, Earthworks Review, Pacific Drive, Palmerston North, ref 8566,Dated 13 February 2012

Flooding/High groundwater

The assessment areas physical landscape presents varying levels of flood risk. During high rainfall events flooding can occur within minutes of the event and can result in significant damage. Property and structures located adjacent to a river and stream corridor are more susceptible to damage from flooding. Buildings located in ponding and shallow surface water flow areas are also susceptible to damage from flooding. Furthermore, development within, river and stream corridors can adversely affect the structural integrity of existing flood mitigation structures and works and increase the potential for damage and loss of life.

Soft soils/Peat

Soft and very soft sediments were identified as a potential geological hazard in the assessment area. When additional loads are applied (e.g. by fill placement or building construction) they can produce large total and differential settlements. This has the potential to damage buildings and other infrastructure founded on these materials.

Soft and very soft sediments are usually formed when fine grained materials are deposited in a low energy environment (e.g. settle out of suspension in a standing water body such as a lake or swamp).

Two distinct environmental settings within the area that are conducive to the formation of layers or beds of soft to very soft sediments. These areas are:

1. Current or historical swamps; and

2. Stream and river deltas.

Appendix D: Supplied files

File Name	File Format	Supplier	Date supplied
Aokautere Structure Plan Workshop Aerial	pdf	PNCC	24/7/2018
Aokautere Structure Plan Workshop Flightpath	pdf	PNCC	24/7/2018
Aokautere Structure Plan Workshop Owner detail	pdf	PNCC	24/7/2018
Aokautere Structure Plan Workshop Reserves	pdf	PNCC	24/7/2018
Aokautere Structure Plan Workshop Topography	pdf	PNCC	24/7/2018
Aokautere Structure Plan Workshop Waters	pdf	PNCC	24/7/2018
Aokautere Structure Plan Workshop Zoning	pdf	PNCC	24/7/2018
Flightpath01_YouTube1080	mp4	PNCC	24/7/2018
Flightpath02_YouTube1080	mp4	PNCC	24/7/2018
Flightpath03_YouTube1080	mp4	PNCC	24/7/2018
Aokautere Structure Plan_Workshop 2_28.05.18	pdf	PNCC	24/7/2018
Aokautere Workshop 1_Record_4 April 2018	pdf	PNCC	24/7/2018
AokautereBaseMplanDrawing_MU_28.05.2018	pdf	PNCC	24/7/2018
ABuild Report for LU 404 Pacific Drive Final Report (784577)	pdf	PNCC	24/7/2018
David Napier March 2007	pdf	PNCC	24/7/2018
Environment Court 2014NZEnvC198 Final Enforcement Order	pdf	PNCC	24/7/2018
Environment Court ENV-2015-WLG-000018 Change to Enforcement Order	pdf	PNCC	24/7/2018
Pacific Farms Ltd ÔÇô 28 Abby Road Earthworks and Subdivision, Time Extension Application Part A (881320)	pdf	PNCC	24/7/2018
Pacific Farms Ltd ÔÇô 28 Abby Road Earthworks and Subdivision, Time Extension Application Part B (881323)	pdf	PNCC	24/7/2018
DEM	tif	PNCC	1/11/2018
Aokautere_Structure_Plan_Vector_Data	Folder containing various files including .spx, .gdbtablx	PNCC	25/09/2019
ShareData V2	Folder containing various files including .las , .shp, .asc, .tif	PNCC	25/09/2019
Waters Layout	.kmz	Hudson Associates Landscape Architects	9/10/2019

Draft

Attachment D

Memo

To:	**Victoria Edmonds**	**Job No:**	**85442.0300**
From:	**Elyse Armstrong**	**Date:**	**22 September 2021**
cc:	**Nick Peters, Mike Jacka, Enzo Liddle, Daniel Le Roux**		
Subject:	**Aokautere Development - Geotechnical input for set-back contours - Rev A**		

1 Scope of work

This memorandum accompanies a GIS spatial output showing the location (as a line) where a 23° angle from the base of the gullies transects the areas of land yet to be developed in the Aokautere Development in Palmerston North, as requested by Palmerston North City Council (PNCC) to assist with estimation of future development potential in areas yet to be developed.

T+T has read ABuild's report[1] and provided commentary to PNCC on the limitations of adopting a generic 23° setback from the base of gullies, compared to what has been outlined in ABuild's report. We note that we have not peer-reviewed ABuild's report, nor has T+T undertaken a detailed geotechnical slope analysis as part of this work. The area that has been included in this spatial output is outlined in green, illustrated in Figure 1.1, and as requested by PNCC.

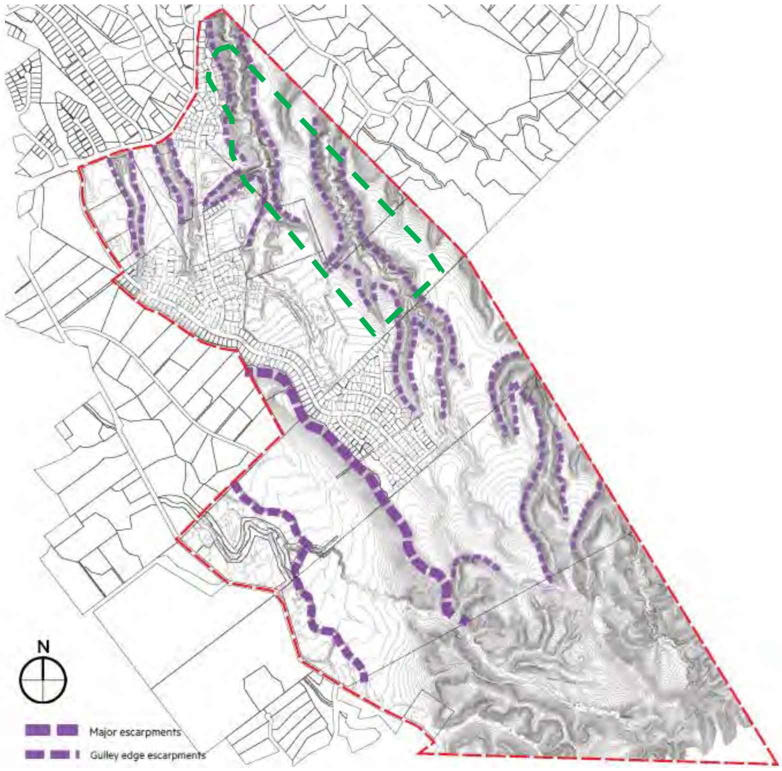


Figure 1.1 – Extent of the Aokautere Development area included in the GIS spatial output.

[1] ABuild, Geotechnical Investigation, Stages 6, 7 & 8 – Pacific Drive, Fitzherbert, Palmerston North, Nov 2020, Ref: 12792.A

2 Background

We understand that following a report T+T provided to PNCC in 2005 titled ‘Development of Land which is, or is likely to be, subject to Erosion or Slippage’[2], PNCC have previously adopted a delineation between developable land and non-developable land area, within the Aokautere Development area, based on a 30° angle from the base of the slopes. This line represents the delineation between ‘Moderate Landslip Hazard’ to ‘High Risk Landslip Hazard’ areas as outlined in T+T’s report[1] (ref: Figure 2.1 below).

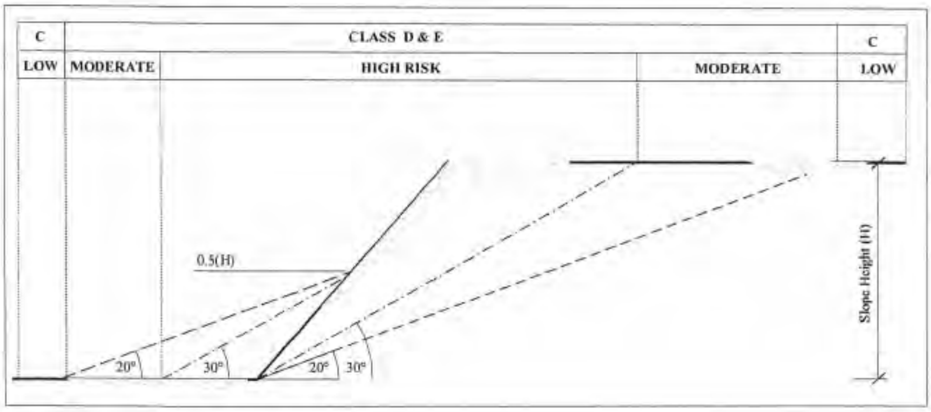


Figure 2.1: Figure 2.1 from T+T report[1].

The delineation between the ‘Low’, ‘Moderate’ and ‘High Risk’ zones was recommended to PNCC to require different levels of site-specific geotechnical assessment and reporting for development of individual lots (refer Table 4.1 of 2005 report[1]). This memorandum and accompanying spatial output does not supersede that report and its recommendations.

3 Spatial output

Attached to this memorandum (Appendix A) is a PDF output of the spatial analysis of the area outlined in green from Figure 1.1 where adoption of a 23° angle from the base of the gullies has been undertaken to illustrate an indicative setback line from the slope edges.

4 Limitations

The attached spatial output is based on publicly available Digital Elevation Model (DEM) files. The DEM file that has been used, has been derived from LiDAR generating a 1m grid. However, there are numerous areas where dense vegetation cover has resulted in ‘noise’ in the DEM resulting in an artificially smooth slope profile in places requiring a level of engineering judgement to be used for the indicative setback line.

The indicative setback line provided has been principally derived from the base of the gullies, and does not necessarily address location-specific characteristics (such as mid-slope steepening) that should be considered during a more detailed slope stability assessment. Figure 4.1 below shows the differences in adopting a 23° setback based on “base of gully” compared to a location-specific assessment of the slope geometry which accounts for mid-slope steeping. These two approaches result in significantly different locations for the setback line. Where obvious substantial mid-slope changes were identified in the DEM and air photo, we have adjusted the setback line for account for these. However, the spatial output attached to this memorandum is unlikely to have captured all mid-slope characteristics due to the limited detail in the high-level assessment undertaken.

[2] Development of Land which is, or is likely to be, subject to Erosion or Slippage, Aug 2005, Tonkin & Taylor, Ref:82096.001

Furthermore, the scale of the assessment and map output is such that the drawn location of the indicative setback line is approximate only (within about ±5m).

As mentioned previously, no geotechnical slope stability analysis has been completed as part of this indicative setback line. The purpose of this setback line is to assist PNCC in estimating future areas of potential developments. We understand that this line does not directly imply a “no build zone” or a “safe to build zone”, and that site-specific geotechnical assessments will still be required to determine the appropriate building platform.

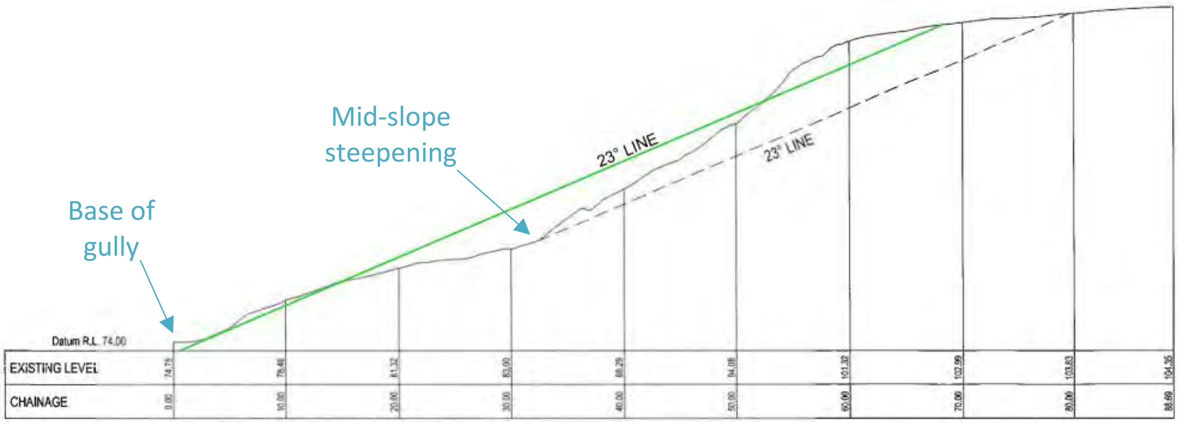


Figure 4.1: Cross-section illustrating the variable outcomes of generically adopting a 23° from base of gully.

5 Discussion of impact

We understand that ABuild have undertaken site-specific investigations and assessment of the slopes within Stages 6, 7 & 8 (located further south of the area discussed in this memo) for development of individual lots[1]. This more detailed analysis concluded that a setback from the gully edges based on a 23° angle from site-specific changes in slope was appropriate to achieve an acceptable Factor of Safety (FoS) of >1.5 under static conditions at these specific sites.

Following ABuild’s geotechnical investigations and detailed slope stability analysis, we understand that PNCC would like to adopt a 23° angle from the base of the slopes to better align with the setback distances likely to be adopted in practice. This setback information will assist in determining an indicative delineation between developable and non-developable land, for estimating the future land development potential in the Aokautere land development area. We note that the criteria of 23° from the base of the slope is a generic application of other geotechnical assessments being undertaken in the wider development, and would require further ratification during site-specific analysis to determine an appropriate setback from the edge of the slopes yet to be developed.

We have not reviewed ABuild’s report and slope stability analysis, and have not reviewed the geotechnical investigation data in detail. We have not undertaken any slope stability analysis to assess and comment on the suitability of a 23° angle. However, for the purposes of our brief provided to us by PNCC, we consider a 23° angle to be a more conservative approach for estimating potential developable land areas than the 30° angle specified in the 2005 T+T report. We note that the 30° angle was intended to delineate between ‘Moderate Landslip Hazard’ and ‘High Risk Landslip Hazard’, and this might not necessarily align exactly with what is considered developable in practice by land developers at the current time. The 23° derived setback better aligns with the assessments that are being undertaken by the local developers, and therefore may provide a closer estimate to land areas that will be developed in the future. It is possible that detailed site-specific analysis for individual lots may indicate that different setback distances are appropriate on a case-by-case basis. The purpose of this memorandum and spatial output is a GIS exercise only, to help inform Council’s understanding of future land development potential.

6 Further assessment

T+T can undertake a more detailed assessment of the slopes within the subject area and provide comment on the suitability of adopting a 23° line compared to a 30° line outlined in our 2005 report[2], however this is beyond the scope of this memorandum.

7 Applicability

This memorandum has been prepared for the exclusive use of our client PNCC, with respect to the particular brief given to us and it may not be relied upon in other contexts or for any other purpose, or by any person other than our client, without our prior written agreement.

Tonkin & Taylor Ltd

Authorised for Tonkin & Taylor Ltd by:

Mike Jacka

Project Director

Memorandum prepared by: Elyse Armstrong, Engineering Geologist

22-Sep-21
\\ttgroup.local\corporate\wellington\tt projects\85442\85442.0300\workingmaterial\memorandum for set back line_rev a.docx

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PROJECT No. 85442.0300

DESIGNED	DXLR	SEP.21
DRAWN	DXLR	SEP.21
CHECKED	EDA	SEP.21

20-Sep-2021

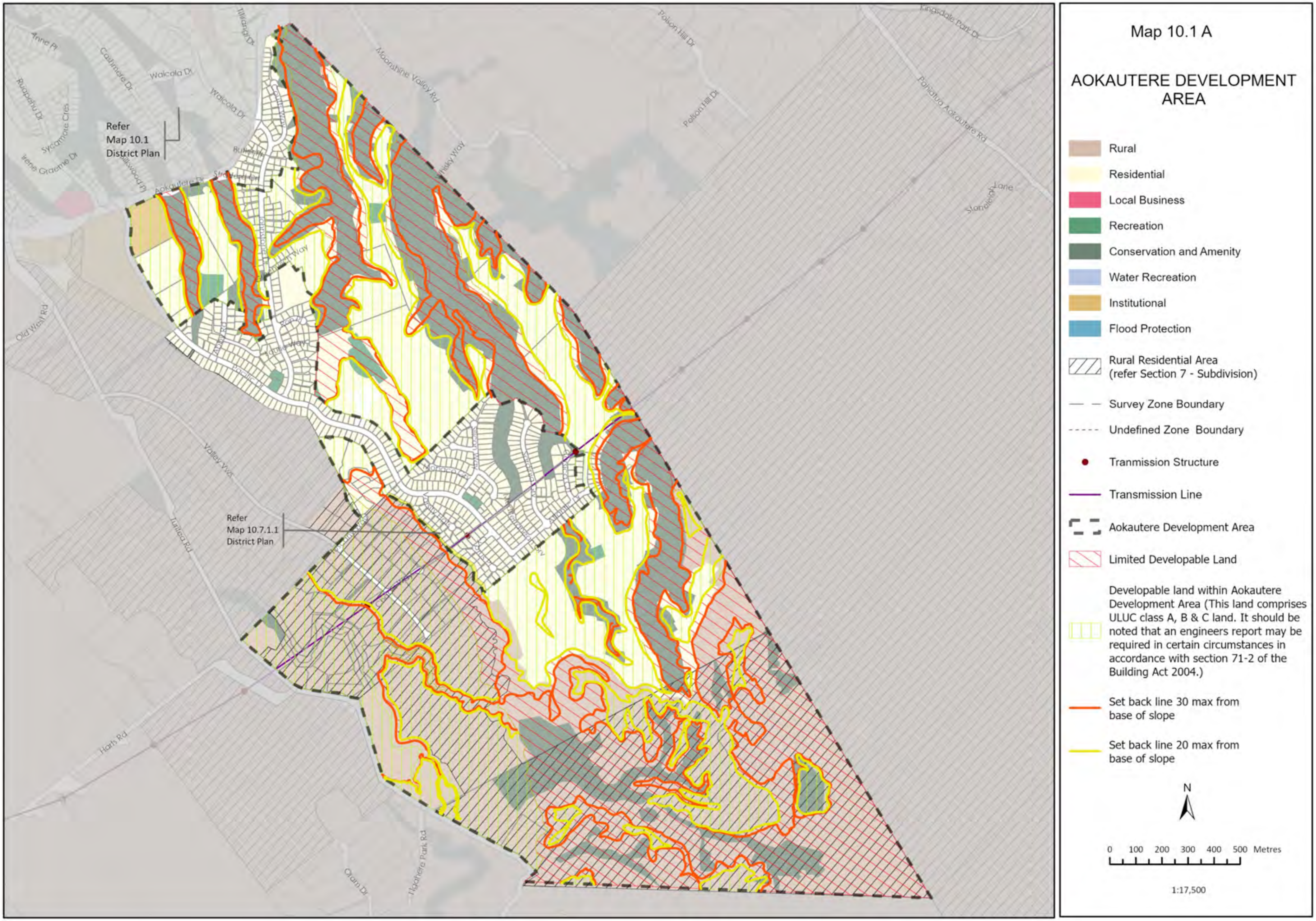
APPROVED DATE

CLIENT **PALMERSTON NORTH CITY COUNCIL**

PROJECT **AOKAUTERE RESIDENTIAL LAND DEVELOPMENT**

TITLE POTENTIAL SET BACK FROM STEEP SLOPES WITHIN THE AOKAUTERE LAND DEVELOPMENT AREA

SCALE (A4) 1:8,000 FIG No. FIGURE 1. REV 1


Map 10.1 A
AOKAUTERE DEVELOPMENT AREA
Rural
Residential
Local Business
Recreation
Conservation and Amenity
Water Recreation
Institutional
Flood Protection
Rural Residential Area (refer Section 7 - Subdivision)
Survey Zone Boundary
Undefined Zone Boundary
Tranmission Structure
Transmission Line
Aokautere Development Area
Limited Developable Land
Developable land within Aokautere Development Area (This land comprises ULUC class A, B & C land. It should be noted that an engineers report may be required in certain circumstances in accordance with section 71-2 of the Building Act 2004.)
Set back line 30 max from base of slope
Set back line 20 max from base of slope
N
0 100 200 300 400 500 Metres
1:17,500
Refer Map 10.1 District Plan
Refer Map 10.7.1.1 District Plan

Attachment E

Tonkin+Taylor

Memo

To:	**Anita Copplestone**	**Job No:**	**85442.0300**
From:	**Daniel le Roux (original), Rachael Nilsson (updated)**	**Date:**	**27 July 2023**
cc:	**Eric Bird**		
Subject:	**Slope analysis methodology for Aokautere development area - Rev 2**		

1 Purpose

The purpose of this memo is to outline the spatial analysis methodology used to inform the creation of threshold lines within the Aokautere development area. This supersedes the memo dated 20 October 2021 to include downcutting values assessed by GHD. These line features represent the position of a 20° and a 30° slope set back, relative to the toe, or base, of the gully slope, and consider future downcutting values as assessed by GHD. These lines are intended to provide geospatial perspective to inform the judgement of appropriate risk classifications when considering future development of the project area.

The original approach used in our memo (dated 20 October 2021) adopted the existing elevations of stream beds as the base of a slope. However, GHD have identified future downcutting of streambeds as an issue, which will have implications on future slope stability. We have therefore revised our analysis to all for the impacts of future downcutting of streambeds on slope stability.

2 Data inputs

2.1 DEM

The digital elevation model used for this analysis was derived from the LiDAR survey undertaken between 29/08/2018 and 28/09/18. The accuracy specification for that survey is +/- 0.10m vertical and +/- 0.5m horizontal. The elevation model data is a 1m grid, in NZTM map projection with NZVD16 vertical datum.

2.2 Slope base position

To calculate the setback angle for slopes across the site, the key piece of spatial information is the positions of the 'toe' or 'base' of the slopes (i.e., baselines). These are different to the centerline of the gully. The DEM and derived slope raster informed the manual definition of the position of the slope baselines. For ideal model results, the slope baseline should be positioned as close as possible to the base of the slope. Where the base of gully was narrow enough a single baseline was used for both sides of the gully. Where the base of gully was wider, two baseline features were created – one for each slope. Some slopes were not gullies and so only required a baseline for a single direction.

2.3 GHD's Technical Memorandum (subsequent analysis)

GHD undertook a stream erosion assessment on the area and prepared a technical memorandum which outlines existing/future erosion and downcutting values.[1] This presented a range of potential downcutting values for some gullies, and proposed a number of mitigation measures to reduce future downcutting.

We have adopted the downcutting values from the GHD report; where mitigation measures have been proposed, we have used the downcutting predictions with the mitigations in place. Where no mitigation measures are proposed, we have used the values reflecting no mitigation. This process involved georeferencing and digitising gully lines and assigning downcutting values.

Where GHD provided a range of downcutting values (*e.g., potential 0.5 to 1.2m downcutting predicted)*, a 'minimum' and 'maximum' value were used representing the outer bounds of this range. Where GHD specified "up to 4m" of downcutting, it is assumed that the 'minimum' downcutting is 0m. For the purpose of this analysis, we have assessed the terms 'future' and 'existing' downcutting to have equivalent meanings.

Appendix B specifies the values extracted from this report. The results from this were considered in addition to the original analysis.

2.4 Analysis area

The analysis area represents the Aokautere development area and excludes regions that have clearly already undergone development.

[1] GHD (22 June 2023) *Stormwater Expert Evidence – Stream Erosion Assessment Summary (Rev 1)*

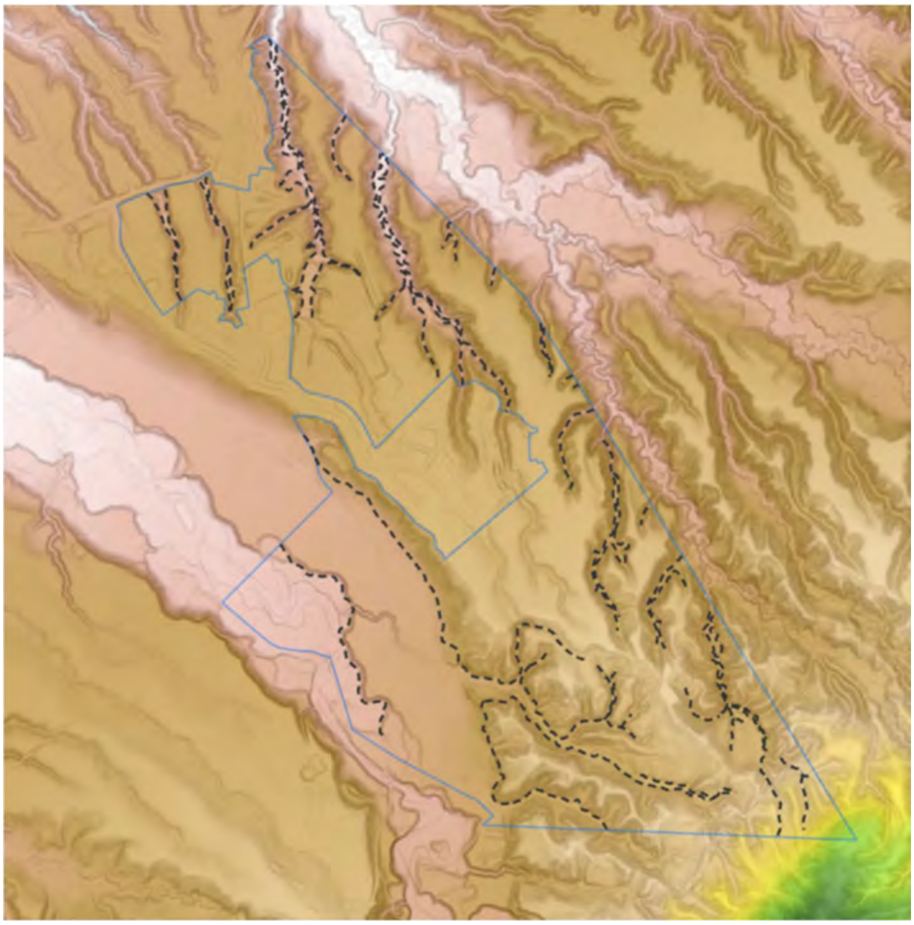


Figure 1: the range of input data, with baselines as a dashed black line, and the analysis area as a blue line

3 Raster Analysis

In this assessment, raster analysis was used to integrate the DEM and slope calculations. This enabled identification of areas where topography exceeds a defined angle set back.

- Slope baseline elevation values extracted from DEM. **(*c*)**
    - Where GHD had quantified existing/future downcutting values, this was subtracted from the elevation values for both the minimum and maximum scenarios.
- Euclidian distance from slope baseline within analysis area **(*d*)**
- Slope threshold values in gradient (20° = 0.364; 30° = 0.577) **(*m*)**
- Euclidian allocation – for each 1m grid square within analysis area, apply the value ***c***, the closest baseline elevation value. This is to allow the theoretical slope gradients to be normalised to the height of the baseline. The assumption here is that the closest slope baseline point is the most appropriate location from which to calculate the relationship between the threshold slopes and the actual topography.
- The threshold slopes, extending up from the baselines at the defined gradients, are therefore defined by the line equation $y = mx + c$.
- Where the subtraction of the threshold slope from the DEM yields a positive value, this indicates topography is beyond/above the defined angle set back.

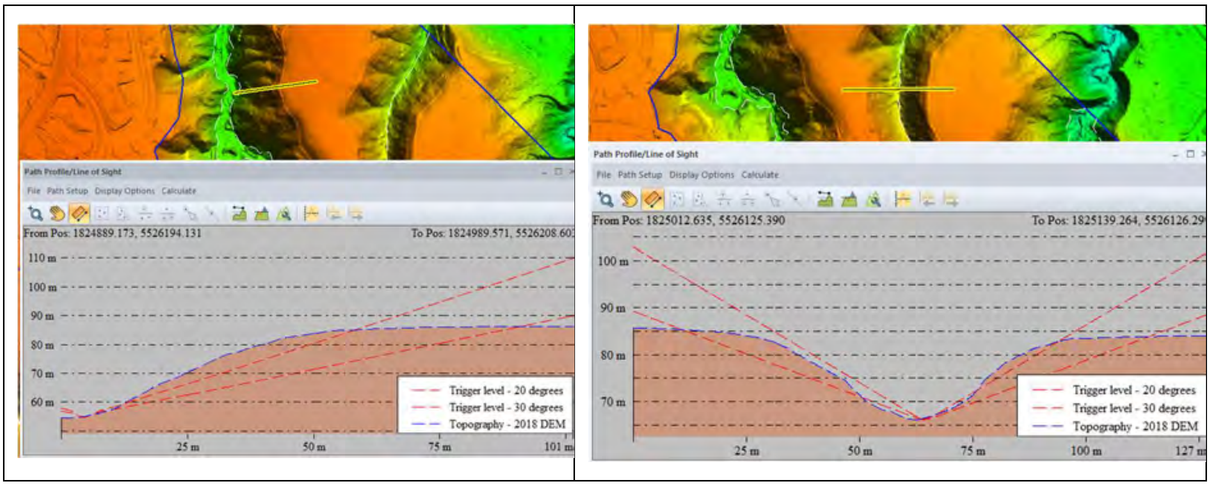


Figure 2: the relationship between the topography and the two threshold slopes. The point at which the false slopes 'daylight' represents the setback point for the profile.

4 Set-back line creation and smoothing

Results of the raster analysis outlined above is used to inform the creation of a set-back line. A first iteration primarily uses the resulting raster to form the line. The positioning of this line is then smoothed and adjusted to align with engineering judgement and empirical knowledge of the site. Some areas of noise in the model output and areas where topography is complex require rationalisation and interpolation.

5 Delineation of down-slope set back

Further analysis was undertaken on one slope to inform the classification of down-slope hazard risk. Results of the analysis demonstrated that the vast majority of the slope was too shallow to produce a result with a 20° or 30° setback. In other words, the slope is found to be flat enough to be classed as Class A, B, C, aside from the small area indicated in Figure 3.

Figure 3: Mid-slope 20° setback analysis results. Areas exceeding threshold indicated in yellow.

6 Analysis Limitations

The identification and accurate positioning of the slope base is fundamental to the accuracy of the output analysis results, because the elevation directly under the feature is used as the baseline point. The 2018 DEM and derived slope was used along with judgement of those who had been to the site to define this positioning.

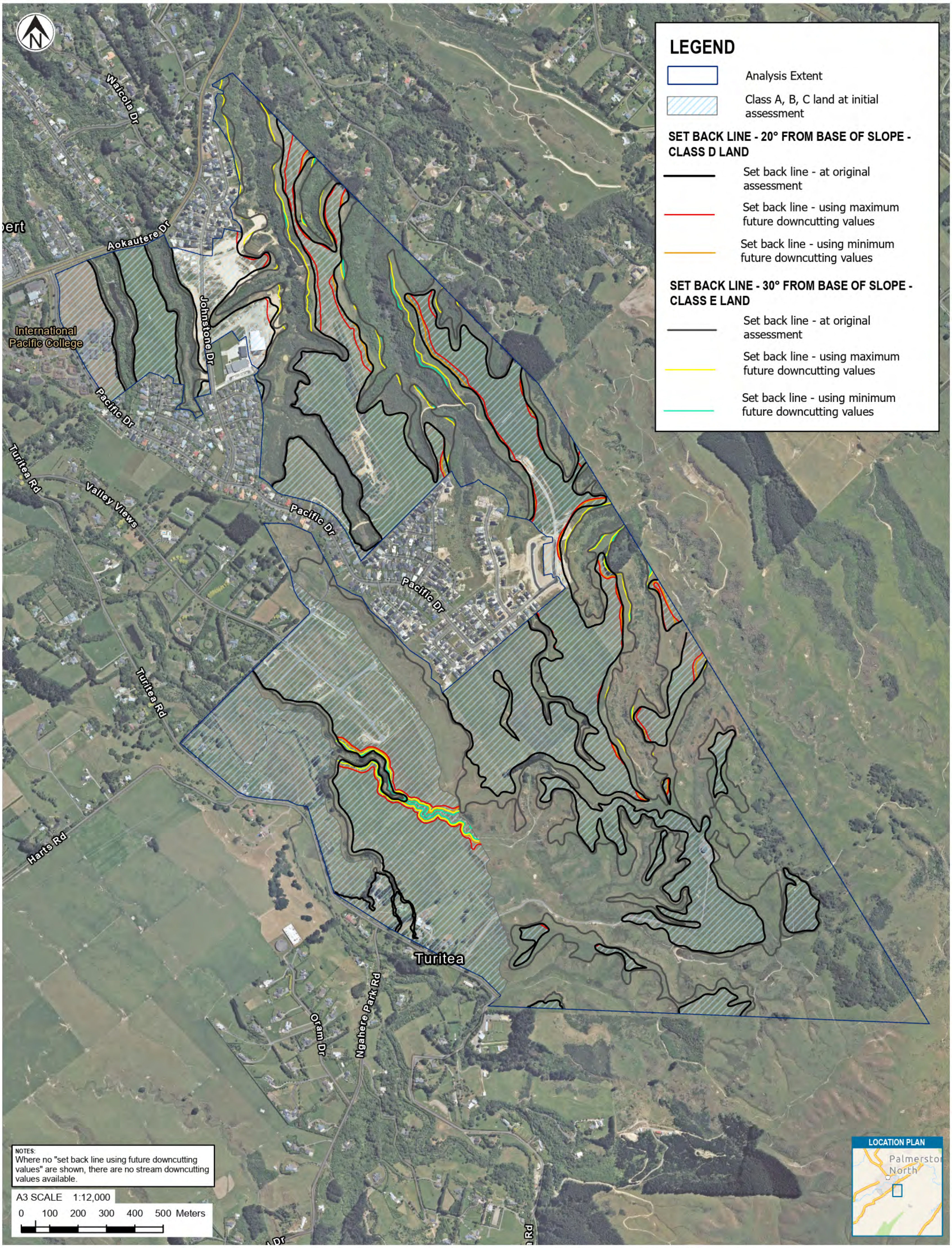
The topography of the analysis area is defined by many complex slopes in close proximity. The automated analysis detailed above assumes that the closest baseline point represents the offset value on which to base the threshold slope calculation. In a few cases, QA reveals that where two slopes are close to one another, particularly where the baseline is complex, the assumption that the closest baseline is the most appropriate causes unrealistic results. To mitigate this effect, slopes that were subject to this effect were run individually to avoid confounding factors.

7 Output

Five figures have been prepared and are presented in Appendix A.

- Figure 1: Shows both 20° and 30° set back lines using both the minimum and maximum downcutting values.
- Figure 2: Shows 20° and 30° setback lines using only the minimum downcutting values.
- Figure 3: Shows 20° and 30° setback lines using only the maximum downcutting values.
- Figure 4: Shows 20° setback lines only, using the minimum and maximum downcutting values.
- Figure 5: Shows 30° setback lines only, using the minimum and maximum downcutting values.

Appendix A - Potential set back from steep slope areas within the Aokautere Land Development Area



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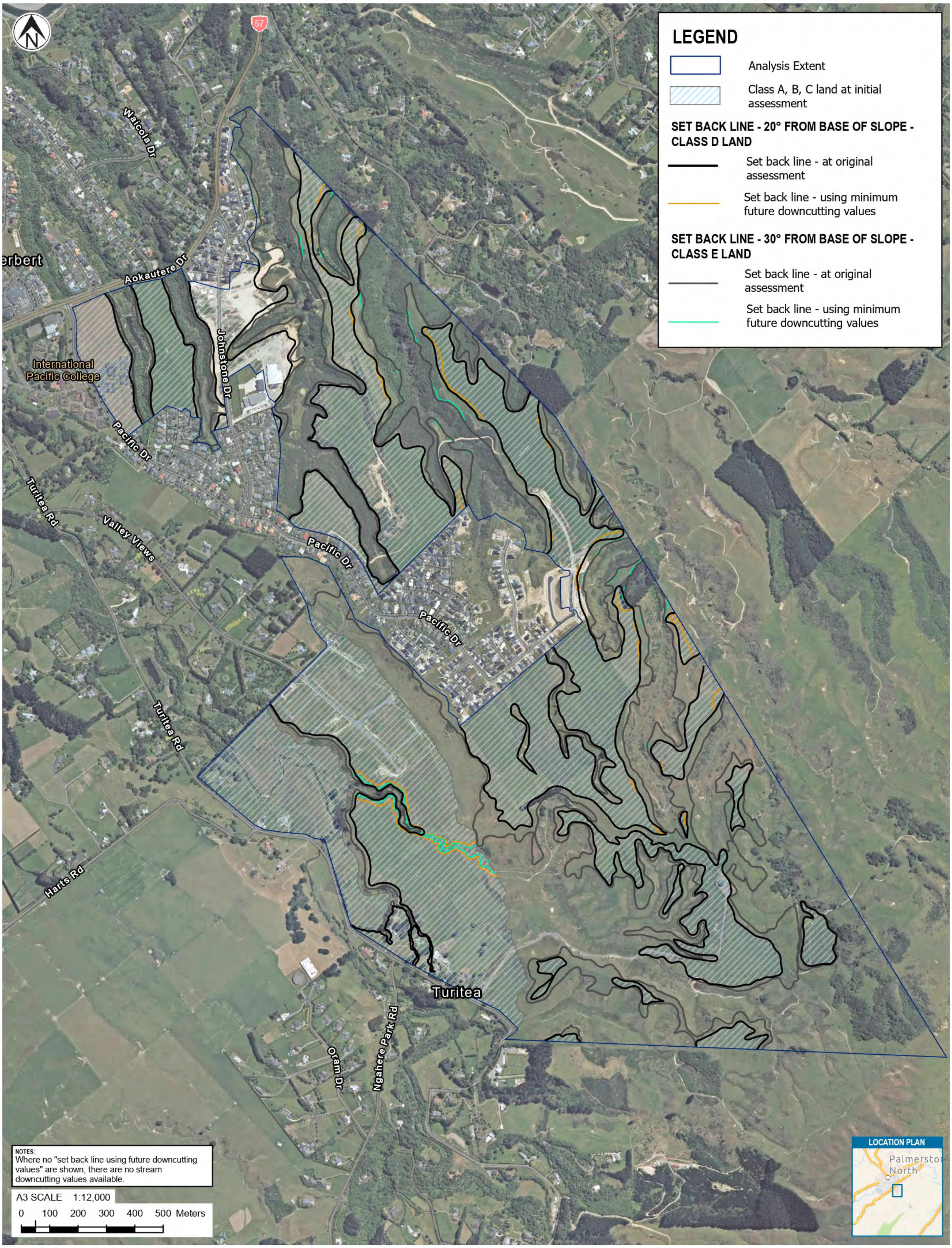
NOTES:
Basemap Hybrid Reference Layer: Esri Community Maps Contributors, LINZ, Stats NZ, Esri, HERE, Garmin, Foursquare, METI/NASA, USGS. World Imagery: Manawatu-Whanganui LASS, Maxar. NZ Navigation Map: Eagle Technology, LINZ, StatsNZ, NIWA, Natural Earth, © OpenStreetMap contributors.

REV	DESCRIPTION	GIS	CHK	DATE
0	First version	RANI	CHSA	27/07/23

PROJECT No.	85442.0300	
DESIGNED	RANI	JUL.23
DRAWN	RANI	JUL.23
CHECKED	CHSA	JUL.23
APPROVED		DATE

CLIENT PALMERSTON NORTH CITY COUNCIL
PROJECT AOKAUTERE GEOTECHNICAL ASSESSMENT
TITLE POTENTIAL SET BACK FROM STEEP SLOPES WITHIN THE AOKAUTERE LAND DEVELOPMENT AREA

SCALE (A3) 1:12,000 | FIG No. FIGURE 1. | REV 0



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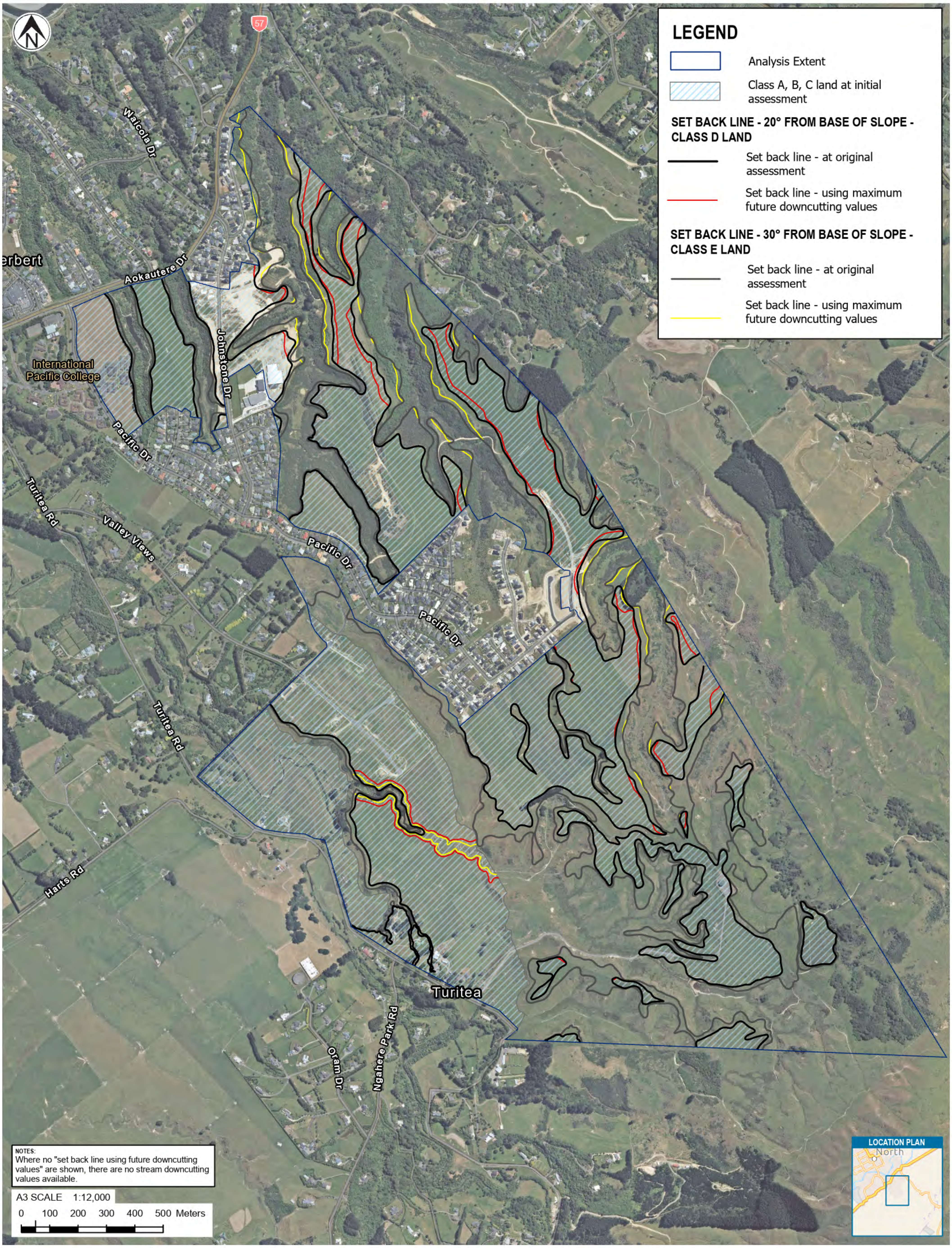
NOTES:
Basemap Hybrid Reference Layer: Esri Community Maps Contributors, LINZ, Stats NZ, Esri, HERE, Garmin, Foursquare, METI/NASA, USGS. World Imagery: Manawatu-Whanganui LASS, Maxar. NZ Navigation Map: Eagle Technology, LINZ, StatsNZ, NIWA, Natural Earth, © OpenStreetMap contributors.

REV	DESCRIPTION	GIS	CHK	DATE	APPROVED	DATE
0	First version	RANI	CHSA	26/07/23		

PROJECT No.	85442.0300	
DESIGNED	RANI	JUL.23
DRAWN	RANI	JUL.23
CHECKED	CHSA	JUL.23

CLIENT: **PALMERSTON NORTH CITY COUNCIL**
PROJECT: **AOKAUTERE GEOTECHNICAL ASSESSMENT**
TITLE: POTENTIAL SET BACK FROM STEEP SLOPES WITHIN THE AOKAUTERE LAND DEVELOPMENT AREA

SCALE (A3) 1:12,000 FIG No. FIGURE 2. REV 0



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NOTES:
Basemap Hybrid Reference Layer: Esri Community Maps Contributors, LINZ, Stats NZ, Esri, HERE, Garmin, Foursquare, METI/NASA, USGS. World Imagery: Manawatu-Whanganui LASS, Maxar. NZ Navigation Map: Eagle Technology, LINZ, StatsNZ, NIWA, Natural Earth, © OpenStreetMap contributors.

REV	DESCRIPTION	GIS	CHK	DATE
0	First version	RANI	CHSA	26/07/23

PROJECT No.	85442.0300	
DESIGNED	RANI	JUL.23
DRAWN	RANI	JUL.23
CHECKED	CHSA	JUL.23
APPROVED		DATE

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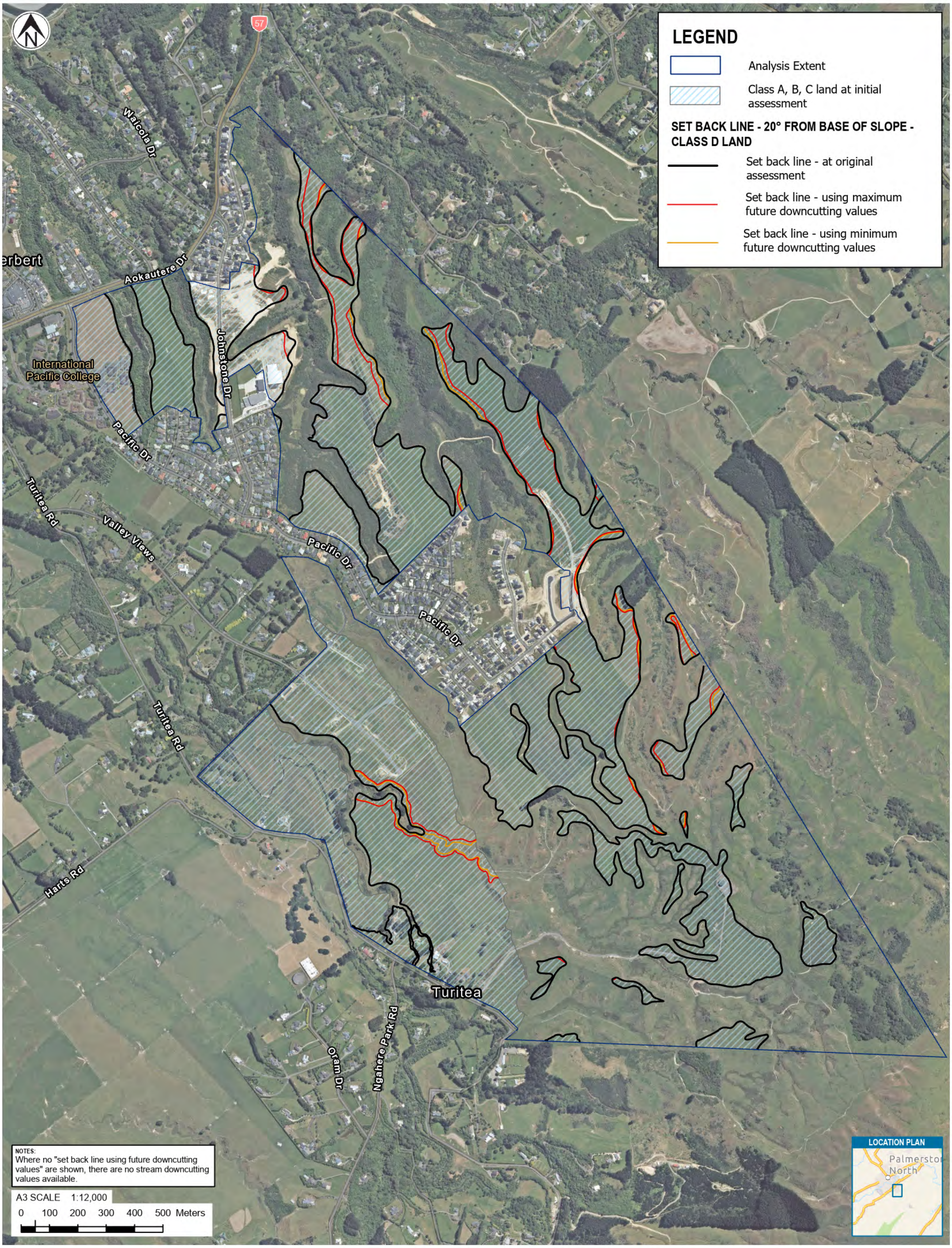
TITLE POTENTIAL SET BACK FROM STEEP SLOPES WITHIN THE AOKAUTERE LAND DEVELOPMENT AREA

SCALE (A3) 1:12,000 FIG No. FIGURE 3. REV 0



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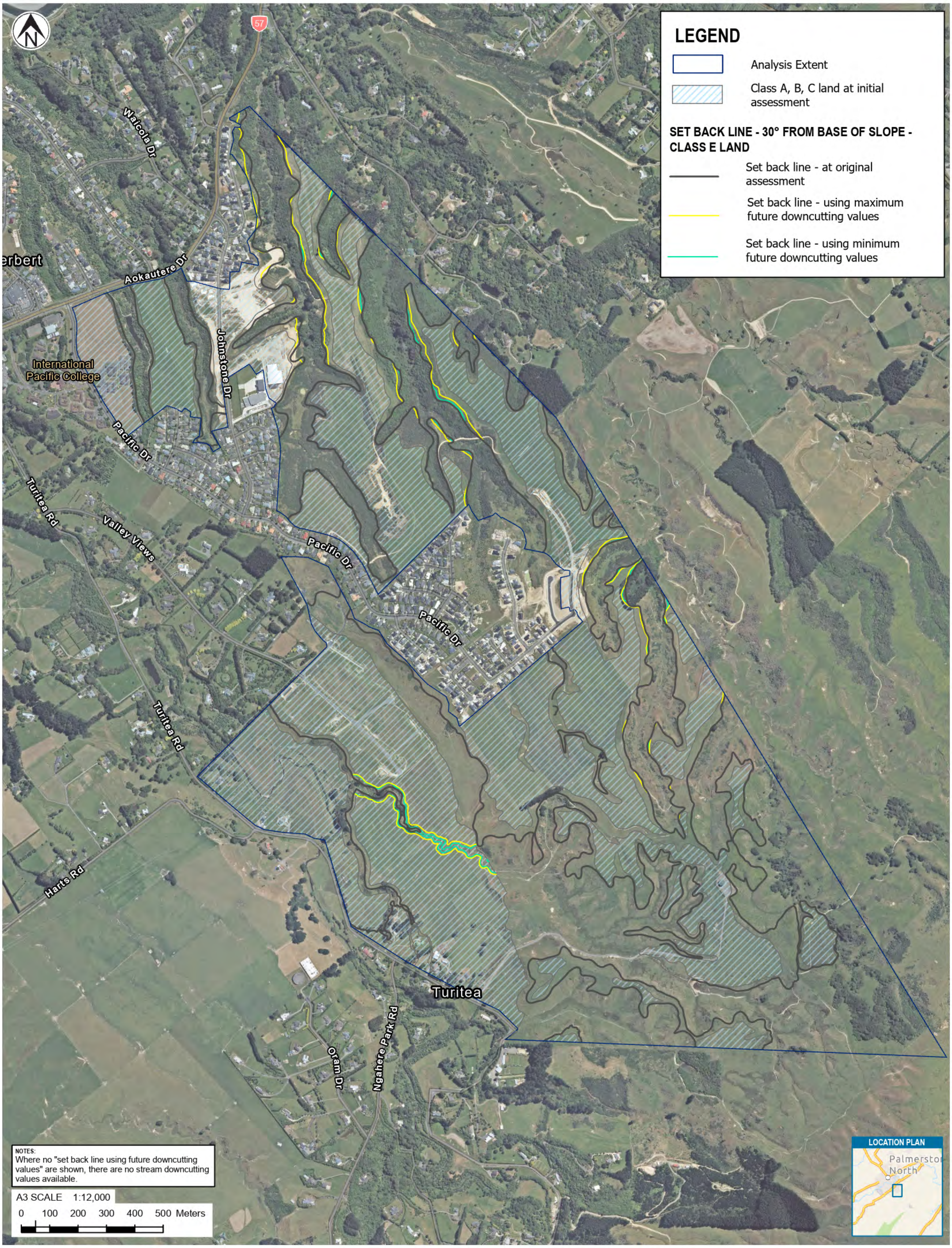
SCALE (A3) 1:12,000 FIG No. FIGURE 4. REV 0



\\ttgroup.local\corporate\Wellington\TT Projects\85442\85442.0300\WorkingMaterial\GIS\MapDocuments\Aokautere_GullyIncising_2406\Aokautere_GullyIncising_2406.aprx Layout: FIG_05 2023-Jul-26 1:55 pm Drawn by RANI

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SCALE (A3) 1:12,000 FIG No. FIGURE 5. REV 0

Appendix B. Summary of future downcutting values used in analysis extracted from GHD's Technical Memorandum.

Chainage 1	Chainage 2	Minimum Downcutting	Maximum Downcutting
Gully 1			
0	200		
200	350	1	2
350	480	0.5	4
480	900		4
900	1020	0.5	0.8
1020	1400		4
Gully 2			
0	250	0	0.8
250	546	0	0.8
Gully 3			
0	25		
25	325	0.8	2.5
325	400	1	2
400	1150	2	6
1150	1250		
1250	1650	1	2
Gully 3a			
0	326		
Gully 3b			
0	300	0	1.8
300	500		
500	969		
Gully 4			
0	200		0.8
200	341		1.2
Gully 5			
0	323		
Gully 6			
0	280	0.5	1.2
280	380		1.2

380	522	0	0
Gully 7			
0	110	1.5	2.5
110	185	0	0
Gully 8			
0	302	1.5	2.5
Gully 9			
0	130	1.5	2
130	990	0.5	1.5
Gully 10			
0	90	0.5	1.5
90	337		
Gully 11			
0	350	3	4
350	650	1.5	5
650	900	3	5
900	1400	0.5	0.7
1400	1800		
Gully 11a			
0	499		1.5
Gully 11b			
0	361		1.5
Gully 12			
0	1750		0
1750	2580	0	1
2620	3150		0.5
3330	3450		
Gully 13			
0	500		
500	1050	1.5	2.5
1600	1850	0.5	3

Attachment F