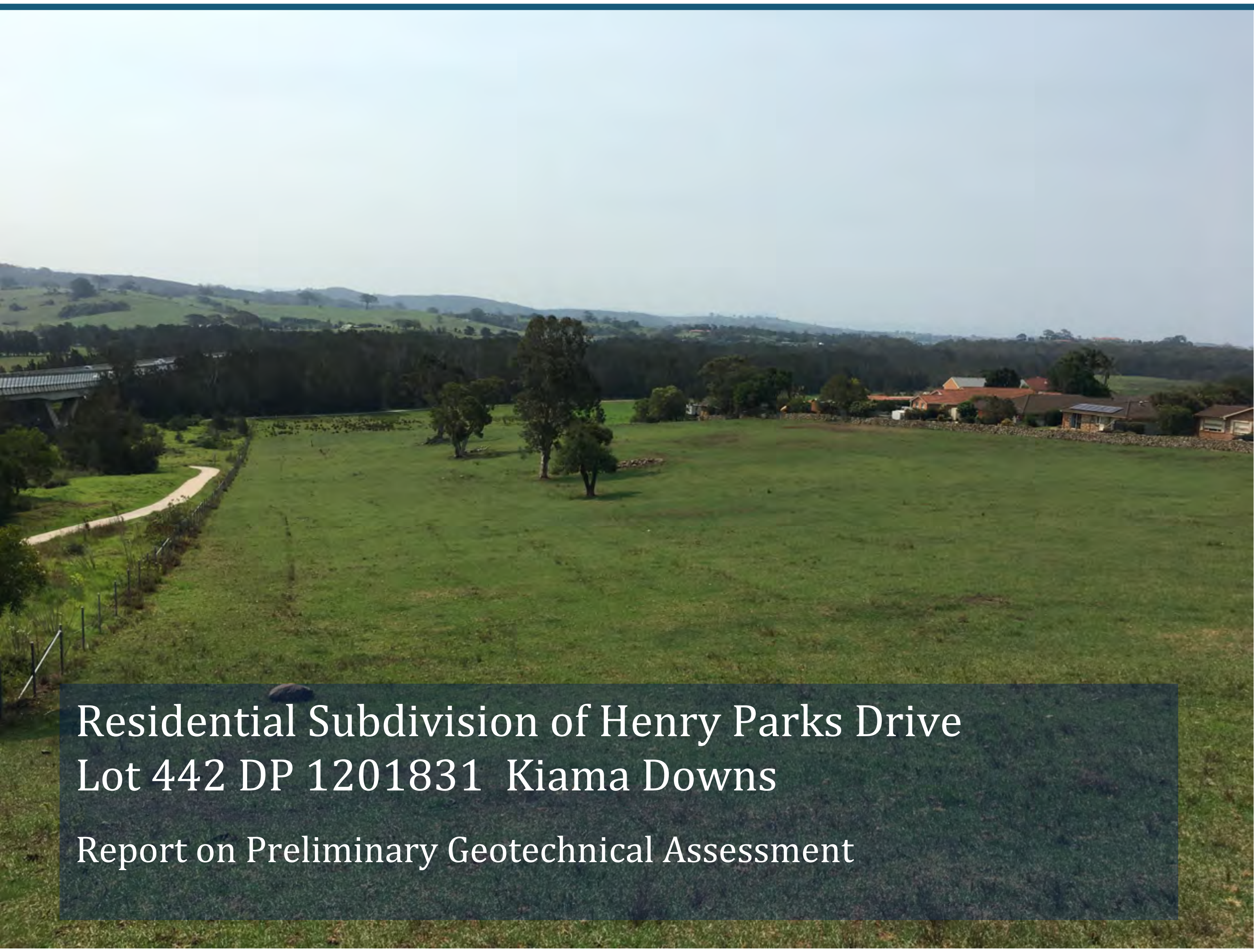

Residential Subdivision of Henry Parks Drive
Lot 442 DP 1201831 Kiama Downs

Report on Preliminary Geotechnical Assessment

Prepared for:

Indesco

Our Ref: TERRA19419.Rep1.Rev2

Prepared for:
Indesco Pty Ltd
No 25 Athison Street
WOLLONGONG NSW 2500

27 August 2020

Attention: Mr K Macdonald

RE: Residential Subdivision of Henry Parks Drive Lot 442 DP 1201831 Kiama Downs
Report on Preliminary Geotechnical Assessment

Dear Kelly,

Please find enclosed our revised geotechnical report for the above site in relation to its proposed residential subdivision. This report should be read in conjunction with the attached document 'About Your Report' in Appendix A. Should you have any questions please contact the undersigned.

For and on behalf of Terra Insight

Karen Gates
Principal Engineer/ Director
CPEng MIEaust BEng MEngSc(Geot) MEnvMgt MBA

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1. Introduction

It is understood that Lot 442 on DP 1201831 Kiama Downs (hereafter referred to as the site) is proposed to be subdivided to facilitate residential development. To support the preliminary planning of the site and to facilitate conceptual civil design, preliminary geotechnical assessment of the site was required. At the request of Indesco Pty Ltd (the Client), TerraInsight Pty Ltd (Terra) has performed this preliminary geotechnical assessment with the following objectives:

- Provide a geotechnical characterisation of the Site based on a desktop review of available information;
- Identify geotechnical constraints and opportunities which may impact the development; and
- Provide advice on the management and mitigation of geotechnical risks.

This report details the results of this preliminary geotechnical assessment, referencing the conceptual plan for the site dated 7 June 2019 (refer Appendix B).

2. Scope of work

The scope of work was divided into three components as detailed in the following sections.

2.1. Geotechnical desktop study

The geotechnical desk study involved the following:

- Review of published information including geology, soil landscape, topography, slope stability (if available), land use, urban capability maps / reports (if available), soil landscape maps, and information held by the NSW Office of Water and the NSW Soil and Landscape Information Systems and through GIS mapping system provided by Broadcrest (refer Appendix C); and
- Review of aerial photographs (refer Appendix D);
- Collation of the broad scale information available above for the site to allow preliminary characterisation of the geomorphological conditions likely to be encountered within the site;

2.2. Site walkover and Site Geotechnical Characterisation

- Truth sensing of the information gathered during the desk study phase by undertaking a walkover of the site, to observe surface conditions (refer appendix E) including mapping of main features, noting slope gradients, slope stability aspects, rock outcrops, evidence of filling, and water logging/seepages; and
- Dividing the site plan into areas of similar geomorphology (eg similar units of terrain/landform in terms of geological formation and slope conditions).

2.3. Reporting

Documentation of the results of the desk studies and site walk over in a report which included geotechnical advice on the following:

- Assess the suitability of the site for residential development, providing advice on
  - Likely subsurface conditions by geomorphological terrain units and how these may impact on earthworks and foundations, such as the depth to rock and the reactivity of the near surface soils respectively;
  - Preliminary assessment of land slide risk and identification of areas where the risk needs further investigation in accordance with the AGS Landslide risk guidelines (Refer Appendix F);
  - Indicative site classifications to AS2870 – 2011 “Residential slabs and footings”;
  - Likely subgrade conditions for pavement design; and
  - Identification of other relevant geotechnical constraints and opportunities;

3. Desk Study Findings

3.1. Site details

The site includes an area of approximately 3.15 ha located on the western edge of the Kiama Downs area south of Minnamurra River as shown in Figure 1 and detailed in Table 3.1. The site is located approximately 3.2 km north-west of Kiama Centre. The site is bounded by several properties in residential use to the north-east and south-east, the Princes Highway to the south west and low-lying flood plains of the Minnamurra River to the north-west. The site is currently in rural use.

Table 3.1: Summary of site identification information

Street Address	Off Henry Parkes Drive Kiama Downs	
Title Identifiers	Lots 442 DP 1201831	
Area (approximate)	3.15 ha	
Local Government Area	Kiama Municipal Council	
Suburb	Kiama Downs	
Current Zoning	E2 Environmental Conservation	
Current Site Use(s)	The site is currently in rural use.	
Proposed Site Use	Residential living.	
Surrounding Land Use	North-East	In use as residential landscape. Currently zoned for low density residential.
	South-East	In use as residential landscape. Currently zoned for low density residential.
	South-West	Princes Highway infrastructure over the Minnamurra River and flood plains. Zoned as rural landscape beyond.
	North-West	Minnamurra River and flood plains.

3.2. Proposed Site development

Plans showing the proposed development of the site are provided in Appendix B. The main access to the residential development will be from the south-western end of the site via the north-western end of Henry Parks Drive (currently a cul-de-sac). The proposed residential development includes a short access road from henry parks drive to an internal road that loops through the site with part of the road located along the western boundary of the Site.

3.3. Aerial Images

Historical aerial photography of the site (refer Appendix C and Figure 2) indicates the following:

- 1963: This image shows the site was cleared, grassed with two trees on the centre of the site and likely in rural use. Fence lines are visible in this imagery along the north-east boundary.
- 1974: Minimal changes are visible on the site.
- 1984: Minimal changes are visible on the site.
- 1993: Residential development has occurred adjacent to the north-eastern boundary of the site and a drainage depression is visible to the south-west of the site. Otherwise minimal changes are visible on the site.
- 2005: The Princes Highway has been recently constructed to the south-west of the site. As part of this work sedimentation/retention ponds have been excavated in the drainage depression to the south-west of the site. Further residential development has occurred outside the north-east boundary of the site and mature trees are now growing along this boundary. Minimal changes are visible on the site.
- 2010: Some water inundation is present on the northern portion of the site. Livestock are visible in the image.
- 2015: Minimal changes are visible on the site.

- 2019: Minimal changes are visible on the site. A pathway has been constructed outside the south-western and north-western boundary of the site and some surficial earth movement has occurred adjacent to the south-west pathway.

3.4. Local and regional geology

The 1:50,000 geology map sheet for Kiama indicates the following:

- The site is mainly underlain by rock formations from the Shoalhaven Group, specifically the Bumbo Latite Member of the Gerringong Volcanics sub-group as shown on Figure 3A. Bumbo Latite consists of aphanatic to porphyritc latite.
- The north-west portion of the site consists of quaternary aged alluvial material, consisting of alluvium, gravel, beach and dune sand.

More recently vailable on line geological mapping sourced from Minview (Figure 3) indicates the following:

- The surface geology on the north-west portion of the site comprises of holoene aged alluvial flood plain deposits (ref: QH_af). These deposits mainly consist of silcrete. This unit is mapped as below the Q100 level;
- The remainder of the site is underlain by Bumbo Latite of the Gerringong Volcanics; and
- Colluvial talus material (Q_ct), is mapped as present to the south-west of the site on the southern side of the freeway/ This material is remote from the site.

3.5. Soil landscapes and soil formation

Soil landscaping mapping accessed using NSW eSPADE v2.0, as shown in Figure 4, indicates that the site is underlain by the following main soil types:

- Bumbo (9028bo): Is mapped on the elevated southern half of the site. This soil landscape is associated with rolling low hills with elevations of 40-100m, slope gradients between 15-25%, long and gently inclined convex ridges, moderately inclined slopes and isolated steep slopes. The soil landscape may have scattered benches and terracettes on the upper slopes. On the mid and foot slopes, narrow incised drainage lines and springs may be present. The soils are underlain by Bumbo Latite. Soils are typically comprised of Krasnozems on the upper and mid slopes and brown and red podzolic soils on the lower slopes. Near surface soils are generally have a moderate to high erodibility, consist of sand and clay loams. Subsurface soils have a low erodibility as they are strongly structured, consisting of sandy clay and light to medium clay.
- Mangrove Creek (9028mc): Is mapped on the lower half of the site. This soil landscape is associated with mangrove open-scrub, saltmarsh herbland, sedgeland, low open forest, with elevations typically < 3m and gently slopes < 3%. Soil consists of siliceous and calcareous sands. Near surface soil is generally silty/sandy loam and sand which have low erodibility. Deeper soils consist of sandy clay and have high erodibility.

The descriptions of the Bumbo and Mangrove Creek Soil landscapes are provided in Appendix E. The main limitations to development associated with these soil landscapes are:

- Bumbo - South eastern half of the site, above elevations approximately 12 to 16m AHD:
  - High organic matter for surface soils
  - Low wet bearing strength for surface soils.
  - High erodaibility potential
  - High sodicity and shrink-swell potential
  - High aluminium toxicity
  - Stoniness
  - Hardsetting
  - Low permeability
  - Strongly acid for deeper soil.
  - Rock outcrops
  - Localise steep slopes and localise mass movement hazard

- Mangrove Creek Soil landscape - lower parts of the site below 12 to 16m AHD:
  - Low wet bearing strength
  - Low permeabililty
  - High organic matter
  - Acid sulphate potential
  - Permanently high water table
  - Strongly sodic and saline

3.6. Hydrogeology and groundwater useage

The surface hydrology (refer Figure 5) shows surface waters will generally flow to the north-west and west into a drainage channel near the south-west boundary of the site (eg near the Princes Highway).

The depth to groundwater on the site is unknown. In areas underlain by bedrock, a perched water table is likely to occur near the surface at the soil rock interface and be observable as springs. In the area underlain by alluvial deposits, a permanent water table will likely be present at an elevation around 0-1m AHD.

A survey of groundwater bores (within a 500m radius of the site) registered with the NSW Office of Water indicates that a registered bore is located about 360m to the south-west of the site as shown in Figure 6. This groundwater bore is known as GW109554. Information about the bore is limited other than its final depth is 4.25m and its use as a monitoring bore.

3.7. Desktop salinity assessment

Based on reference to the NSW National Resources Atlas website (11/05/15), there is no evidence of salting in soil profiles located within 5km from site.

3.8. Acid Sulfate Soils

Review of acid sulfate soil (ASS) using NSW eSPADE v2.0 mapping shows a high potential for ASS material to be naturally present on the site at depths typically about 1-3m below the ground level on the lower north-western portion of the site. These ASS materials are associated with the Holocene aged alluvial soils. The mapping shows the risk of ASS being present as high on the north-western portion of the site with no know occurrence on the south-eastern portion of the site (refer Figure 7). The risk of acid sulfate soil occurrence on the site is mapped as potentially impacting the site up to elevations of approximately 10m AHD. However, it is noted that most ASS materials are typically encountered at elevations below 5m AHD.

3.9. Topography, Slope Heat Mapping and Land Stability

The site is located on the lower foot slopes of a hill which has a crest to the south of the site. The slopes predominantly fall to the north-west and west. The relief of the site is between 1 and 28m AHD. Figure 8 shows the topography of the site which includes the following main topographical features:

- T1: predominant area on the site consisting of slopes falling to the north-west and west with gentle to moderate slopes.
- T2: Far north-western portion of the site, consisting of near level land.
- T3: Small area on the northwest portion of the site, where the slope is slightly concaved shaped and falling to the north with moderate to steep slopes.

Slope heat mapping for the site is shown on Figure 9. This mapping shows:

- The slopes predominantly fall at between 5 to 10 degrees except the transition between sloping land and near level land (T1 and T2 transition) on the northern part of the site near the Minnamurra River. Slopes near this transition are generally between 10 to 15 degrees and locally up to 20 degrees.
- A small area on the southern corner of the site which has slopes between 10 and 20 degrees, which steepen towards the crest of the hill to the south of the site.

The slopes of the Illawarra escarpment have been mapped on several occasions for landslide risk, since the early 1970s. The area for proposed development was mapped by Neville in the early 1970's. No areas within the site were mapped as "Unstable", "moderately unstable" or "less stable" land. Unstable land includes regions with slopes typically greater than 20 degrees where extensive and detailed geotechnical investigation are required prior to development. No recorded landslides were identified on or near the site (refer Figure 10).

3.10. Summary of Desk Study findings:

Based on the above topographical features, the site is developed into four areas as follows:

- Area 1 – Upper and mid slopes: These areas are comprised of the upper and mid gentle to moderate slopes of the Site. The internal access roads are within this area. The average fall on these slopes is about 5 to 10 degrees and moderate to steep near the southern corner of the site. The surface elevation within this part of the site is typically above 2m to 9m AHD m and below 28m AHD. This part of the site is expected to be underlain by Bumbo Latite at relatively shallow depth (eg < 1 to 2m).
- Area 2 – Toe slopes: This area includes the moderate to steep slopes near the transition between sloping land within Area 1 and level land on the north-western portion of the site within Area 3. The average slopes in this area are between 10 and 20 degrees. The surface elevation within this area is typically above 2m AHD and below 6m to 9m AHD. This part of the site is expected to be underlain by Bumbo Latite at slightly deeper depths then within Area 1 (eg within 2 to 4m). On parts of the site with elevations below 5m AHD, there is the potential for ASS to be present.
- Area 3 – Near level alluvial plain: This area is comprised of the near level area on the north-west portion of the site. This area is typically below 2m AHD and has a high risk of ASS being present.
- Area 4 – Access area: This area includes moderate to steep slopes near the access point to the site. The access road from Henry Parks Drive are partially located within this area. The surface elevation within this area is between 23m and 28m AHD. This part of the site is underlain by Bumbo latite.

4. Site Observations

Observations of the site were made at the time of the site inspection. Photographs taken of the general site conditions are provided in Appendix D. Observations of the site are provided based on the four areas identified in Section 3.10 and on Figure 11. Observations within these areas are as follows:

4.1. **Area 1** – Upper and mid slopes

This area is predominantly grassed and contains four mature trees towards the centre of the site (refer photographs 1 – 18). Slopes on the site are gentle to moderately sloping towards the north-west and west into a slight depression near the south-western boundary of the site.

Small areas of outcropping bedrock and small boulders below the surface are found within this area, typically near the upper slopes. Exposed surface soils consisted of a red brown gravelly clayey sand. Piles of latite boulders are present within the area.

A stone wall is present along the north-eastern boundary.

4.2. **Area 2** – Toe Slope (refer photographs 19 – 23):

The area slopes with moderate to steep slopes onto the level land of Area 3. The height and steepness of this slope increases to the east. Slopes are consistent to the east. The extent of the neighbouring residential area stops just above these slopes.

Surface soils consist of a red brown cobbly clayey sand with gravel. Bedrock was not visible in the slope. No signs of surface movement were visible. No signs of seepage were observed. However, it was noted that the climate had been exception dry at the time of the site visit with NSW experiencing drought.

4.3. **Area 3** – Near level alluvial plains (refer photographs 24-28):

This part of the site is level to near level and predominantly grassed. Exposed surface soils consist of a red brown friable clayey sand.

4.4. **Area 4** Near level alluvial plains, (refer photographs 6 – 8):

This part of the site is a small area on the access point of the subdivision. This area has a higher elevation and steeper slopes than the remainder of the site. On the ground surface fill material was observed including small sandstone gravel and boulders, potentially associated with the development of land to the south of the site.

5. Geotechnical Site Characterisation

5.1. Interpreted subsurface conditions by Terrain Units

Geomorphology has been used to divide the Site into Terrain Units. These Terrain units are used to define parts of the Site with similar:

- Topography;
- Landslide risk;
- Subsurface geology; and
- Subsurface soil profiles.

The Site is located on a hill side area with the depth to rock expected to be relatively shallow. The soil profile likely to be encountered across the site will vary within each terrain unit. On lower slopes alluvium and colluvium will be encountered underlain by residual soil and latite at depth. On the upper slopes, colluvium and residual soil which grades into weathered latite will be encountered. Depth of overburden soils will increase to the north. Localised areas of fill may be present, in particular within area 4 where this was observed on the site. Review of the geology and surface observation indicates the site can be divided into the following terrain units:

- **Terrain Unit 1 - Upper and mid slopes within Area 1:**
  Gentle to moderate slopes and terraces underlain by residual soils (medium to high plasticity silty clay with gravel < 2.0m thick) underlain by latite. Latite bedrock can vary in depth locally due to variable weathering as a result of columnar jointing typically associated with latite. A shallow layer of colluvial soil comprised of clayey sand and silty clay with cobbles and gravels may be present on lower slopes. Instability in this area is unlikely.
- **Terrain Unit 2 - Toe Slope within Area 2:**
  Moderate to steep slopes adjacent to alluvial plain. This are is underlain by shallow alluvium (clayey sand to sandy clay of medium to high plasticity) and colluvium (clayey sand and silty clay with cobbles and gravels) possibly interbedded with the alluvium, increasing in thickness to the north on the lower slopes, potentially up to 2.0m thick and then residual soils (< 1.5m thick). Localised instability may be present in this Terrain Unit associated with seepages and instability of colluvial and alluvial soils.
- **Terrain Unit 3 - Near level alluvial plains Area 3:**
  Level alluvial plains. Area likely to be underlain by moderate to deep topsoil and alluvial (clayey sand to sandy clay of medium to high plasticity) material increasing with depth towards the north-west.
- **Terrain Unit 4 – Filled Access Area within Area 4:**
  Fill (Comprised of sandy silty clay with gravel and cobble) has been placed within the moderate to steep slopes on this part of the site. The fill is estimated to be < 2.0m thick and underlain by shallow colluvial soils and residual soils (< 1.0m thick). Bedrock is expected at depths of up to 3.0m. Instability may be present in this terrain Unit associated with the placement of fill and steep slopes.

A summary of the Terrain Units is shown on Figure 12.

6. Preliminary Landslide Risk Assessment

6.1. Introduction

This landslide risk assessment relates to the proposed subdivision of site and was carried out generally in accordance with the risk assessment method described in Appendix C of the journal, Australian Geomechanics, Vol. 42, No. 1, dated March 2007. Important information in relation to the use of this risk assessment method is provided in Appendix E of this report.

Assessment of landslide risk considers the frequency and consequences of particular failure events. The landslide risks considered herein, are those that directly impact on existing and proposed development of the site.

6.2. Potential landslide risks

Terrain Unit 1, 2 and 4 are typically located within regions of inherently stable land with slopes of 10 to 15 degrees with some localised steeper zones. Localised instability may be caused within these localised steeper slopes due to the accumulation of soils at the toes of slopes and/or excavation or emplacement of fill.

6.3. Risk to Property

Risk to property is assessed based on the proposed conditions of the site, including any risk management implemented as part of the proposed additions to the site. As there is no structure currently on this part of the site, the existing risk has not been assessed. Landslide within Area 3/terrain unit 3 has also not been considered as this area is not proposed for development.

Risk assessment for property loss was undertaken using the Risk Matrix according to AGS (2007). The Risk Matrix defines a qualitative terminology for likelihood, consequence and risk. The frequency estimate is expressed as an annualised probability, considering the probability of spatial impact and is expressed qualitatively as likelihood.

The result of this assessment is summarised in Table 5.1. As the structures proposed are mainly residential buildings and residential infrastructure (roads and utilities), an assigned Importance Level of Structure of 'Two' has been adopted in accordance with AGS, 2007 (Appendix D, pg 86). This assessed level of risk post the proposed site works, is based on the advice provided within this report being implemented on the site (refer section 5).

Table 5-1: Landslide event - future likelihood and consequences to property

Case	Event	Likelihood	Consequences to property*	Level of Risk
Terrain Unit 1 – Upper and mid site slopes which cover most of the site.				
Localised soil creep		Unlikely	Insignificant	Very Low
Large scale slope failure (uphill/downhill)		Rare	Major	Low
Terrain Unit 2 – Transitional slope between Area 1 and 3 impacting potential northern lots.				
Localised soil creep		Possible	Minor	Moderate
Local failure of slopes		Possible	Medium	Moderate
Large scale slope failure		Unlikely	Major	Moderate
Terrain Unit 4 – Filled access area impacting potential lots within the area.				
Localised soil creep on filled slopes		Possible	Minor	Moderate
- Soil creep on remediated fill slopes		Unlikely	Minor	Low
Local failure of filled slopes		Possible	Medium	Moderate
- Local failure of remediated filled slopes		unlikely	Medium	Low
Large scale slope failure		Rare	Major	Low

Note to Table: * It is assumed that the recommendations in Section 7 are adopted/implemented.

The risk assessment above has assumed the following:

- Habitable building will not be constructed within Terrain Unit 3 (Areas 3).
- Sub surface investigations will be undertaken within Terrain Unit 2 and 4 to determine the sub surface conditions and establish the suitability of the building envelopes for development.
- The risk of landslide events within Area 4 can be reduced by replacing any uncontrolled fill in a controlled manner.

7. Geotechnical Engineering Assessment

7.1. Geotechnical constraints and opportunities

The key issues to facilitate development of the Site are:

- Management of surface stormwater runoff and surface seepages across the Site; and
- Establishment of building envelopes suitable for development with the steep slopes within Terrain Unit 2;
- Removal of fill placed within Terrain Unit 4 or replacement of this fill in a controlled manner.

Terrain Units 1 is assessed as most suitable for residential development. Most of the proposed lots are located within this terrain unit.

The following geotechnical constraints and opportunities have been identified for the Terrain Units identified on the site:

- Terrain Unit 1:
  - The shallow depth to rock (potentially < 2.0m) provides reasonably shallow foundation depths on these parts of the site;
  - Shallow to moderate depth of bedrock provides a potential source of low reactivity fill, depending on the extent of earthworks in the area.
  - Site classes are likely to range from Class M to Class H1, depending on the depth of soil cover and placement of fill. Existing mature trees will cause swelling of soils in the short term after removal. Lots in proximity to these trees will be Class P sites.
- Terrain Unit 2:
  - The potentially shallow to moderate depth to rock (1.5 to 3m) this terrain unit provides reasonable foundation depths.
  - Site specific investigations are recommended to identify suitable building envelopes within each proposed allotment.
  - Potential ASS on the lower slopes. ASS testing is recommended if excavation is proposed for the lower slopes within this area.
  - The Site Classifications are likely to be in the region of H1 to H2 depending on the depth of overburden. Class P site is likely to be applicable for potential lots within this area.
- Terrain Unit 3:
  - High potential for ASS within this area, site specific ASS testing is recommended if excavation is proposed for this area;
  - Soft alluvial soils are expected to moderate and deeper depths (> 2m); and
  - There is a risk of flooding.
- Terrain Unit 4:
  - Depth of fill up ranging from non-existent to up to 2m deep. Resulting in Class P sites lots within the Terrain Unit.
  - According to the Kiama Development Design Specification D1 Geometric Road Design (Urban and Residential) the maximum desirable grade for residential roads is 17%.

7.2. Landslide Risk Evaluation and Management

The qualitative measure of the consequences to property will depend on the final design and construction methods adopted for the residential development. However, for this assessment, assuming recommendations provided in this report are followed, the implied level of risk to property is assessed as:

- Low for residential dwellings and infrastructure constructed within Terrain Unit 1; and
- Moderate for residential dwellings and infrastructure constructed within the northern portions of Terrain Unit 2 and within Terrain Unit 4 which is impacted by uncontrolled fill.

For residential habitable buildings (Importance level 2 structures), the AGS recommends a 'low' level of risk associated with damage to property. Residential development in Terrain Unit 1 is therefore deemed to be associated with an acceptable level of risk. Suitable building envelopes for Lots within Terrain Unit 2 be located within the northern extent of Terrain Unit 1. Earthworks can be undertaken for Lots within Terrain Unit 4 to reduce the risk to acceptable.

It is common for many councils to accept a low to moderate level of risk. Consequently, residential development within Terrain Unit 1 is deemed within the acceptable level and within Terrain Units 2 and 4 within the tolerable range. Construction of non-habitable structures (roads etc) are classed as Importance level 1 structures and can accept a moderate level of risk. Construction of these structures within Terrain Units 1,2 and 4 is therefore deemed acceptable.

Guidance on the good hill side practice for residential developments on sloping Site is provide in LR08 AGS guide (refer Appendix F) should be followed for Lots 16 to 20.

7.3. Surface Protection, Storm Water and Vegetation

On-site disposal of stormwater by concentrated soakage is not recommended within Terrain Unit 2 based on the increased risk of slope instability and potential for reactive clay movement. Subsoil drainage is recommended on the upslope side of pavements to limit the ingress of seepage into subgrades and pavement materials.

Surface water flows, which could occur downhill toward developed areas, should be diverted around these areas and trained to flow away from proposed areas to be residentially developed.

Exposed soil within Terrain Unit 1, 2 and 4 will need to be protected from erosion, by means of directing surface water to the lower part of the slopes and revegetating the surface with grasses or small to medium sized plants. Sick or dying trees, which may fall, should be removed before they can impact on the slope.

7.4. Footings Design Considerations

7.4.1. Site classification

Site classification, in accordance with AS2780, requires detailed investigation of each proposed residential lot, which at the conceptual stage is not feasible. In addition, the site classification of lots is likely to change because of earthworks undertaken on the site during residential sub-division and development.

At this stage, a preliminary assessment of site classifications likely to be associated with the site has been undertaken. This preliminary assessment has identified the following:

- Terrain Unit 1: This terrain unit consist of gentle to moderate slopes, slope instability is assessed to be low. This unit likely contains sandy silty clays of medium to high plasticity with gravels/cobbles and of thickness typically less than 1.0m. Within these areas, fill is also likely to be placed. Where possible, low plasticity fill should be placed in the upper fill layers towards the final ground surface to optimise the site classifications for this part of the site. Site classifications for lots within this portion of the site will likely range from M to H2 and will be highly dependent on the type and depth of fill placed. Existing trees will cause nearby lots to be classed as P sites.
- Terrain Unit 2: This terrain unit consists of moderate to steep slopes, slope instability is assessed to be moderate. This unit will likely contain colluvial and residual sandy silty clays of medium to high plasticity

with gravel and cobbles to depths to rock potentially up to 1.5 to 3m. As this part of the site is located on sloping ground with some risk of slope instability, a site classification of P is appropriate at this stage.

- Terrain Unit 3: No lots and infrastructure are proposed for this area.
- Terrain Unit 4: This terrain unit consist of moderate to steep slopes (15 to 20 degrees), slope instability is assessed to be moderate due to the steeper slopes and filled areas. Part of the access road is proposed for this area. This unit will likely contain sandy clay fill of medium plasticity to depths of up 2m in the centre of the unit and shallower towards the edges underlain by sandy silty clays of medium to high plasticity likely to depths less than 1.0m. Depending on the depth of fill, this lots within Terrain Unit 4 will be classed as a P site.

7.4.2. Footing design parameters

Shallow footings should be feasible within Terrain Unit 1. Suspended slabs supported on piers should be feasible within parts of Terrain Units 2 and 4. Piers should be able to bear on stiff residual clayey material or weathered rock. **Geotechnical investigation should be undertaken to confirm the strength/consistency and reactivity/plasticity of the soils which underlie the site.**

7.4.3. Footing maintenance

Appendix B of AS 2870-2011 (refer Appendix G) indicates that to reduce but not eliminate the possibility of damage, trees should be restricted to a distance from proposed building of at least their mature height. Where rows or groups of trees are proposed, the distance from the building should be increased. Landscaping should consider the location and type of streetscape vegetation to minimise the impact on the moderate to high plasticity soils which underlie the site.

7.5. Pavement Design considerations

7.5.1. Design subgrade CBR

The proposed design CBR documented herein assume good drainage conditions for the clayey soils and that drainage is maintained throughout the pavement design life. **Based on field observations, a design CBR of 3 to 5% should be achievable for internal roads within Terrain Units 1, 2 and 4.** The design CBR is based on pavement investigations for similar sites to the south where the soils were comprised of medium to high plasticity silty clays of similar geological setting. Laboratory testing on these soils included three (3) CBRs with test results ranging from 2.0% to 6.0%. It is noted that swells were also recorded during this CBR testing, indicating that the high plasticity clay soils are highly sensitive to moisture ingress, and therefore we recommend that these soils should be removed where encountered and be replaced with a select subgrade material or alternatively the subgrade should be stabilised by the use of lime.

It is recommended that a detailed pavement investigation be conducted on the site when the proposed alignment and design subgrade profiles of the roads are confirmed.

A preliminary pavement thickness design based on Austroads (2008) design guidelines using the unimproved design subgrade CBR of 3% over an assumed traffic loading (ESAs) for a *minor* (6×10^4), *local access* (3×10^5) and *collector* (1×10^6), the total minimum thicknesses of unbound subbase and base materials would be >350mm, >450mm, and >550mm, respectively.

We note that the assumed design subgrade CBR is relatively low, other treatment measures such as thicker asphalt, lime stabilisation of the subgrade or over-excavation /subgrade replacement may be required.

This report provides specific guidance on pavement requirements from the geotechnical perspective. This report does not provide a comprehensive overview of all the pavement requirements as per the Kiama Development Design Specification D2 Pavement Design. Pavements for roads and accessways within the site will need to consider projected traffic movements and the subgrade conditions following preliminary earthworks.

7.5.2. Pavement construction requirements

Construction of flexible pavements should comply with the following recommendations:

- In areas where poor subgrade conditions exist, replacement of the upper 300mm to 500mm may be required using coarse well graded crushed rock materials (75mm minus), in combination with geotextile and geogrid. Alternatively, the clay subgrade material will need to be stabilised in situ. Once the subgrade soils are exposed, they may soften and deteriorate rapidly if exposed to rain or experience significant cracking if allowed to dry in warm dry weather;
- Where General Fill is required it should be placed to the required thickness in layers, using either a method specification (if coarse materials are used) or using a testing specification (if finer materials are used). If a testing specification is used, layers should be maximum 200mm thick compacted thickness, and materials should be compacted to the required density ratio at a moisture content of -2% to + 2% of OMC.

For General Fill Zone materials, the use of imported or borrow materials from the site could be considered as follows:

General Fill Zone Option 1 – use of 75mm minus quarry product as General Fill

If during boxing of the subgrade in readiness for pavement construction, the remaining clayey subgrade soils are significantly over-moist or water inflows occur and there is a requirement for significant 'over-excavation' of unsuitable materials, then a 75mm minus quarry product (or other product in liaison with the Geotechnical Engineer) can be considered for use as a replacement material. This product should be well graded, should allow compaction to be readily achieved with a tight surface and very low air voids. This material should be placed to a thickness sufficient to achieve adequate proof rolling performance with a 12-tonne static mass smooth drum roller.

General Fill Zone Option 2 – use of imported or site borrow material achieving CBR of at least 10%

If during stripping of topsoils and box-out to subgrade level in readiness for pavement construction, the exposed clayey subgrade soils are not significantly over-moist, and there is no requirement for significant 'over-excavation' of unsuitable materials, then the use of material having a minimum CBR of 10% could be considered for use as General Fill comprising:

- Well graded crushed rock or natural gravel or weathered rock materials that can be tested for in situ density by the nuclear density gauge, or alternatively be assessed using a method specification such as proof rolling and observation by an experienced geotechnician;
- Materials having a maximum particle size of 75mm, with no greater than 20% of the material larger than the 37.5mm sieve; and
- Materials approved for use by the Geotechnical Testing Authority prior to construction.

7.5.3. Drainage measures and pavement performance

Standard pavement lives of 20 years for flexible pavements and 40 years for rigid pavements are suggested as baseline values for typical pavements in Austroads (2008). However, the council pavement design life typically adopted is 50 years. The practicality of designing a pavement to last for a 50 year design life constructed over clayey subgrades which may occur within Terrain Unit 1 and 4, is heavily dependent on long term control and maintenance of the moisture content of the subgrade materials and maintenance of good drainage at this site.

In order to achieve a 50 year design life, it is important that table drains (where there is no kerb and gutter) or subsoil drains (where kerb and gutter is proposed) are provided along both sides of each road where the road surface is close to or below the surrounding ground levels. Subsoil drains should outlet into the nearest stormwater drainage pit, provided there is sufficient fall. Details of subsurface drainage requirements should be further refined once the extent of groundwater seepages encountered during road and drainage construction has been assessed.

Surface maintenance of any asphalt wearing course and table drains will be periodically required. This would include localised infilling of minor surface cracks in the wearing course with emulsion routinely applied as part of normal pavement maintenance measures. Trees and vegetation should be excluded from pavement verge areas or traffic islands if their roots are assessed as likely to enter subgrade areas beneath the road during the design life of the pavement.

7.6. Earthworks

7.6.1. Waste minimisation

Waste materials are likely to be generated as a result of initial site earthworks and during the construction of roads and service trenches.

Site cut and fill earthworks should be balanced where possible to reduce the amount of waste materials produced which need offsite disposal. Weathered rock exposed during earthworks on the upper hill slopes could provide a suitable source of fill of low reactivity. However, this material is likely to be of limited supply and should be used wisely.

To minimise the costs associated with pavement construction and the installation of services (including off-site disposal of materials), it is preferable to minimise the disturbance of the in situ soils and/or re-use these in situ materials where possible.

The clayey alluvium and colluvium soils underlying the site would generally not be considered suitable for use as general or select fill due to low CBR values and high plasticity. These clayey materials would require further treatment if they are to remain in situ. This treatment may include in lime stabilisation in roads.

7.6.2. Site preparation

Vibratory rollers should not be used within 40 m of any existing residential structures or similar structure, unless a trial is conducted with vibration monitoring occurring at the nearest residence. Static rolling of fill and pavements should be carried out within 40 m of any existing buildings.

The installation of stormwater drains and the sewer will involve some trenching under or close to roads and within residential lots along or close to boundaries. Drainage or sewer trenches deeper than 1 m may need to be benched or may require temporary support (shoring).

Backfilling of trenches should be carried out to Kiama Muncipal Council's subdivision design specification or the pipe manufacturer's specification using suitable select materials around the pipe and fill approved by the geotechnical engineer. Suitable backfill above the pipe would include soils or rock (less than 100 mm maximum particle size) excavated from the trenches subject to separation and discarding of any vegetation, topsoils, saturated soils or large rock fragments before placement.

Any areas where groundwater seepages are discovered during the earthworks may require subsoil drainage or other treatment to allow earthworks to proceed in the area. Clay soils exposed during construction may become soft and wet during and following rain.

Subsoil drainage should be provided at least along the uphill edge of all roads, with additional lines (possibly on both sides) where roads are aligned perpendicular to the contours, or where groundwater seepages occur randomly over the hillside.

7.6.3. Excavation

The ease with which materials can be excavated on site has been assessed in accordance with Kirsten's "Classification for the excavation of natural materials" (1992), as shown in Table 6.1.

We anticipate that excavation depths over the site will be relatively minor, up to approximately 1m below existing surface levels. Some localised deeper excavations may be required for service trenches and other associated infrastructure.

The fill, topsoil, alluvium, colluvium and residual materials encountered on site are expected to be Class 2 to 3 materials and should be readily excavated by backhoe or small excavator, whilst the highly weathered rock below is expected to be Class 4 to 5. Our local experience indicates that a Class 4 or 5 materials can be excavated with a 25 to 30 Tonne excavator with a rock hammer or ripped with a D7 to D8 dozer. Rock strength will increase with depth. **Further investigation should be undertaken to confirm the depth to highly weathered rock.**

Table 6.1: Kirsten's Eight Point Excavation Classification System

Class	Material Type	Description of Excavatability
1	Soil / Detritus	Hand spade (Dozer D3)
2		Hand pick and spade
3		Power tools
4	Rock	Easy ripping (Dozer D7)
5		Hard ripping (Dozer D8)
6		Very hard ripping (Dozer D9)
7		Extremely hard ripping / blasting (Dozer D10)
8		Blasting

7.6.4. Filling

Fill materials to be placed on the site are likely to comprise:

- general fill;
- select or structural fill;
- trench backfill materials; and
- pavement materials.

Fill should be placed in accordance with the following:

- Density and compaction testing should be undertaken on all fill placed in road formations, building lots and stormwater / sewer trenches. Where filling is proposed within building lots and road formations, the proposed fill material should be approved by a geotechnical engineer prior to placement. Density and compaction testing of the fill should be carried out on each 200mm thick layer of the compacted fill. Proof rolling of each layer should also be carried out using a smooth drum or pad foot roller of at least 12 tonne mass, without vibration;
- Density testing of fill should be carried out at the rate of three tests per visit or one test every 2000m^2, whichever is the greater. If full time geotechnical supervision of the fill occurs, then a minimum three tests per day will be sufficient;
- Density testing should be undertaken on pavement subgrades, subbase and base layers;
- Benkelman Beam testing of pavements on completion of pavement base is recommended.
- Where fill is to be placed continuously in lots or roads, geotechnical supervision to 'Level 1' is recommended, as defined in AS3798 – Guidelines on Earthworks for Commercial and Residential Developments. However, where the placement of fill occurs in small stages or placement is slow or delayed due to weather or other restrictions, geotechnical supervision to Level 2 could occur;
- For roadworks (other than general filling) and for storm drain and sewer trench backfills, geotechnical supervision to Level 2 is recommended as defined in AS3798.
- Where the fill material has a grading with more than 20% coarser than 37.5mm, a method specification should apply; and
- Where the fill has less than 20% of particles coarser than 37.5mm they can be tested for in situ density by nuclear gauge.

Fill materials should be placed at the required compaction ratios as outlined in Table 6.2.

Table 6.2: Minimum Compaction Requirements

Description	Compaction Requirements
Pavement - Base	Minimum 98% Modified
Pavement - Sub-base	Minimum 95% Modified
Subgrade (top 300mm) and Select Material Zone	Minimum 100% Standard
General Fill Zone (deeper than 300mm below top of subgrade)	Minimum 98% Standard
General fill placed within residential lots at least 0.3m below final design level	Minimum 95% Standard

7.6.5. Site preparation

Ground preparation should allow for the stripping of topsoil and uncontrolled fill (if deemed required) from structural footprints. Stripped soil would not be suitable for structural fill and must be processed to exclude cobbles and foreign material (where present) and then used for landscape applications if determined to be suitable for this purpose.

Surplus excavated materials may need to be exported or disposed of off the Site. Structural fill should be compacted in layers not exceeding 200mm thick compacted thickness to achieve a minimum density ratio of not less than 98% standard dry density (SDD).

Construction during Site preparation works may impact on the existing trees. This may result in disturbance to the soil and changes to in situ moisture regimes which will need to be considered in the preparation of subgrades for pavements on the western side of the Site.

7.6.6. Temporary and permanent retention of slopes

Temporary and permanent slopes may be required for the development as recommended in Table 6.3. Cut and fill batters in excess of 1.0m in height may require retention by structural retaining walls.

Table 6.3: Design Slopes for Cut/fill Slopes

MATERIAL DESCRIPTION	PERMANENT SLOPES	TEMPORARY SLOPES
Fill	1V:3H	1V:2H
Topsoil	1V:3H	1V:2H
Alluvium/Colluvium	1V:3H	1V:2H
Residual Clay	1V:3H	1V:2H
Extremely Weathered Rock	1V:2H	1V:1.5H
Highly to Moderately Weathered Rock	1V:1H	1V:1.5H

8. Conclusions

The site can be divided into four areas based on topography (refer Figure 8) and the proposed development (refer Figure 12) as follows:

- Area 1 – Upper and mid slopes: These areas are comprised of the upper and mid gentle to moderate slopes of the Site. This are wholly contains the proposed internal access streets and covers most of the site. The average fall on these slopes is about 5 to 10 degrees and moderate to steep near the southern corner of the site. The surface elevation within this part of the site is typically above 2m to 9m AHD m and below 28m AHD.

- Area 2 – Toe slope: This area includes the moderate to steep slopes near the transition of sloping land and near level land on the north-western portion of the site. The average slopes in this area are between 10 and 20 degrees. The surface elevation within this area is typically above 2.0m AHD and below 6m to 9m AHD.
- Area 3 – Near level alluvial plain: This area is comprised of the near level area on the north-west portion of the site. No lots or roads are proposed for this area. This area is typically below 2m AHD.
- Area 4 – Access area and Lot 1: This area includes moderate to steep slopes near the access point to the site. This area may contain lots and the access road from Henry Parks Drive are partially within this area. The surface elevation within this area is between 23m and 28m AHD.

Based on the results of landslide risk, subsurface geology, and site observations, the conditions likely to be encountered on the site have been classified into the following Terrain Units (refer Figure 16):

- **Terrain Unit 1 - Upper and mid site slopes within Area 1:**
  This includes gentle to moderate upper and mid hill site slopes underlain by shallow residual soils consisting of sandy silty clays of medium to high plasticity with gravels/cobbles (typically < 2 m thick) and Latite Rock. Rock may locally outcrop on the upper parts of the slopes and may be deeper in localised spots. This area is assessed as having a low risk for slope movement and is suitable for residential development. Within these areas, fill is also likely to be placed. Where possible, low plasticity fill should be placed in the upper fill layers towards the final ground surface to optimise the site classifications for this part of the site. Site classifications for lots within this portion of the site will likely range from M to H2 and P class for lots near existing mature trees. A design CBR of 3% should be adopted for conceptual pavement design.
- **Terrain Unit 2 – Toe Slopes within Area 2:**
  This area includes moderate to steep slopes adjacent to an alluvial plain. This area is likely to be underlain by shallow colluvial and alluvial material on the lower slopes (<2.0m) and residual soils (< 1.5m thick). These areas typically have a moderate risk of landslide. Where possible, low plasticity fill should be placed in the upper fill layers towards the final ground surface to optimise the site classifications for this part of the site. Based on the location of the building envelope on the slope, the site classification within this portion of the site will likely be P class or range from H1 to H2. Potential for ASS occurrence is possible on the lower slopes.
- **Terrain Unit 3 – Near level alluvial plain within Area 3:**
  Level alluvial plains. Area likely to be underlain by moderate to deep topsoil and alluvial material increasing with depth towards the north-west. Ground conditions potentially consist of medium to high plasticity soft silty sandy clays to depths > 2m and have a high potential for ASS. No lots or infrastructure are proposed for this area due to flood risk.
- **Terrain Unit 4 – Access area within Areas 4:**
  This area includes a filled area with moderate to steep slopes. The area is underlain by fill (< 2.0m thick), and residual soils (< 1.0m thick). Latite bedrock is expected at depths of up to 3.0m. A moderate risk of slope instability is assessed for this area. Part of the access road is proposed for this area. This unit will likely contain sandy clay fill of medium plasticity to depths of up 2m in the centre of the unit and shallower towards the edges underlain by sandy silty clays of medium to high plasticity likely to depths less than 1.0m. Depending on the depth of fill, potential lots in this area will be classed as a P site. A design CBR of 3% should be adopted for conceptual pavement design.

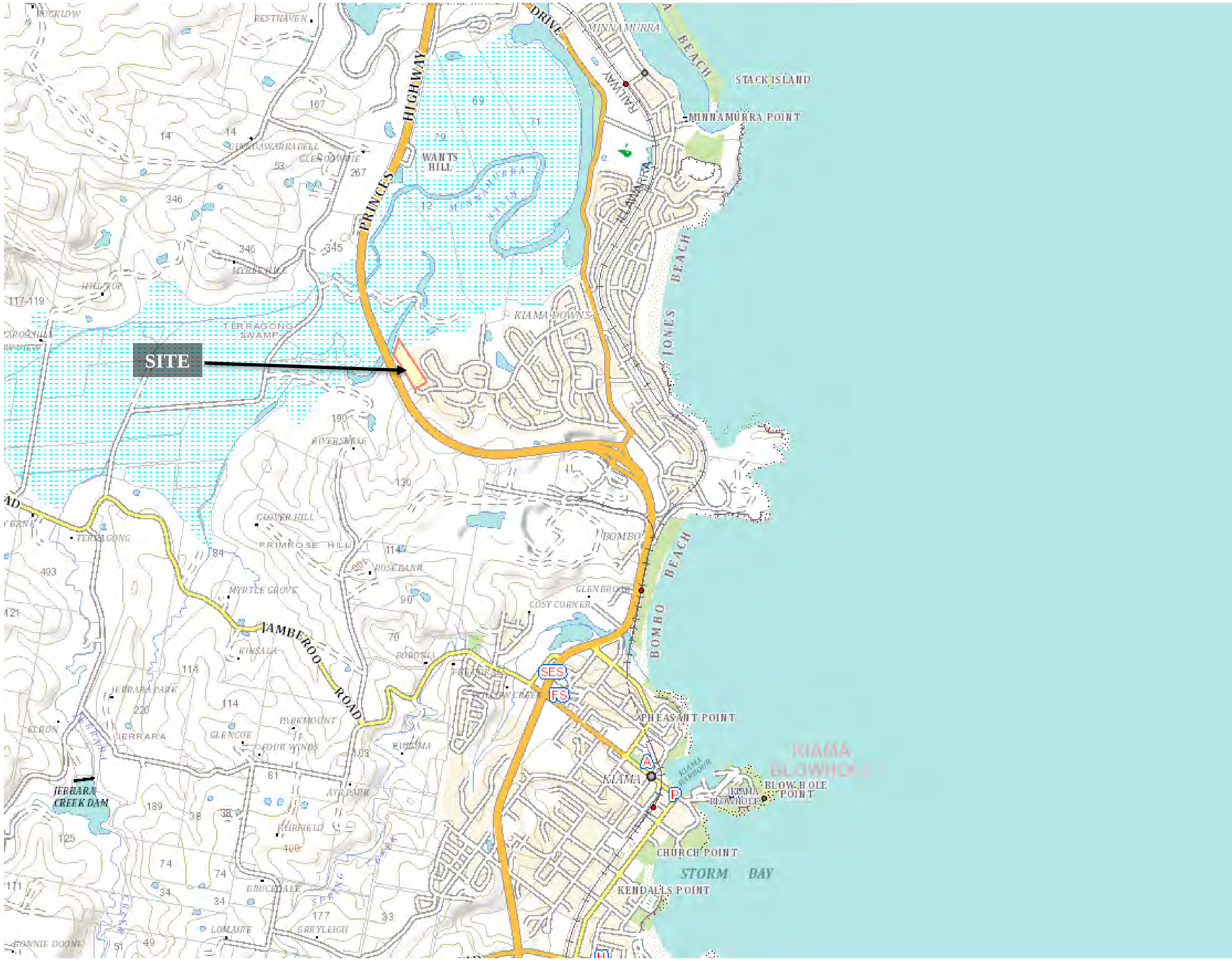
9. Recommendations for further Investigation

The following is recommended for further investigation:

- A subsurface investigation to confirm the subsurface conditions within the Terrain Units should be undertaken including the strength/consistency and plasticity/reactivity of the soils which underlie the site.
- A detailed pavement investigation to confirm subgrade conditions and design CBRs when the proposed alignment and design subgrade profiles of the roads are confirmed.
- ASS sampling and field screening of soils within the lower slopes and alluvial plains (Terrain Unit 2 and 3) if excavation is required in these areas.

- Detailed mapping within Terrain units 2 and 4 to allow identification of suitable building envelopes and/or lots within this area.

Figures



Site Location

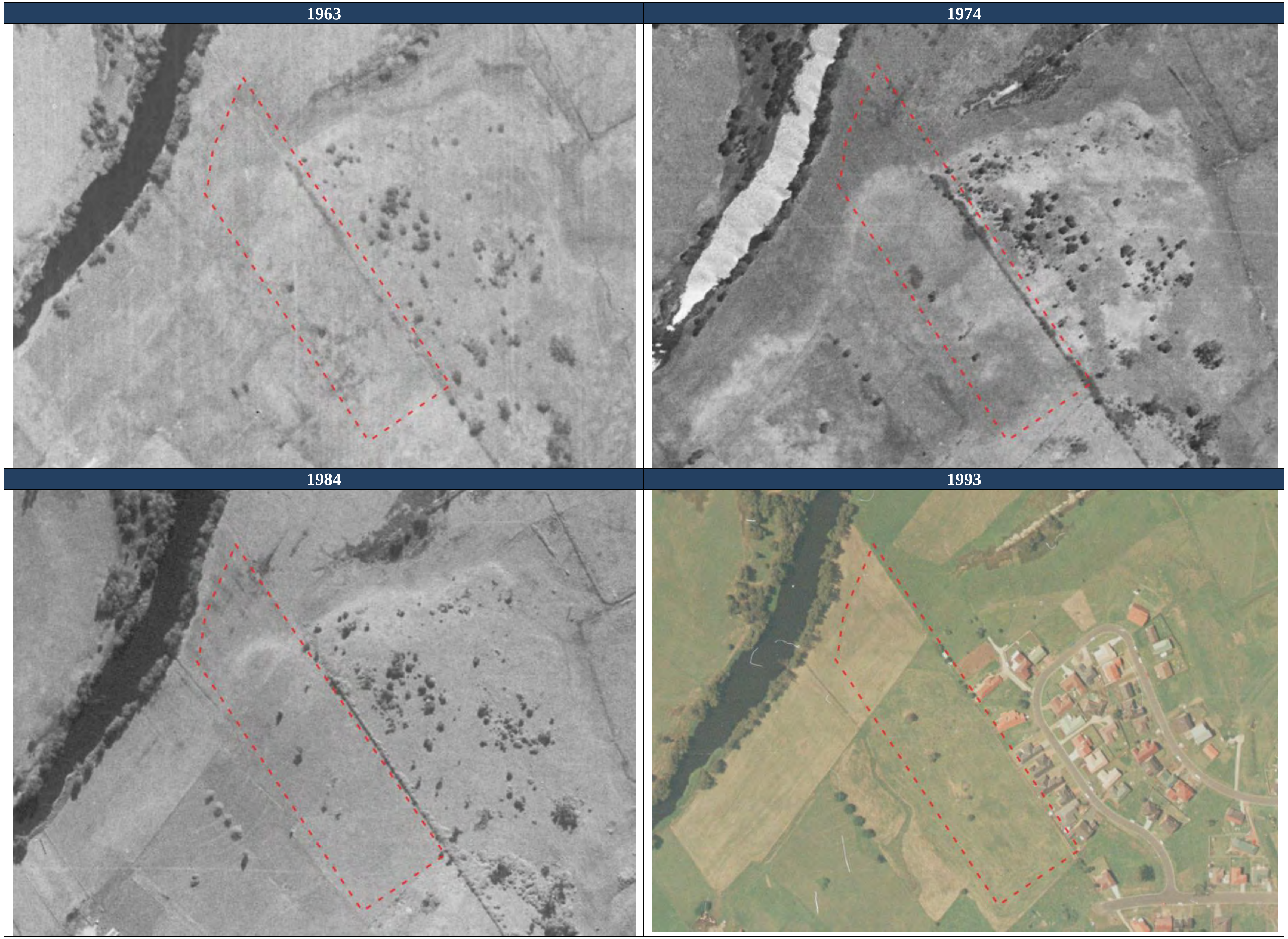
revision	description	drawn	approved	date
	Site location	XJ	KEG	22/01/2020

Data Source:
Six Maps

TERRA INSIGHT

scale	NTS
original size	A3

client:	**Indesco**
project:	**Geotechnical Desk Study Investigation for Proposed Subdivision Lot 442 DP 1201831 Kiama Downs**
title:	**Site Location**
project no: **TERRA19419**	figure no: **FIGURE 1**



description	drawn	approved	date
Aerial images	XJ	KEG	30/01/2020

Data Source: Department of Finance, Services & Information

TERRA INSIGHT

scale	NTS
original size	**A3**

client: **Indesco**

project: **Geotechnical Desk Study Investigation for Proposed Subdivision Lot 442 DP 1201831 Kiama Downs**

title: **Historical Imagery**

project no: **TERRA19419** figure no: **FIGURE 2**

description	drawn	approved	date
Aerial images	XJ	KEG	30/01/2020

Data Source:
- Department of Finance, Services & Information
- Google Earth Imagery (2005, 2015)

TERRA INSIGHT

client:	**Indesco**
project:	**Geotechnical Desk Study Investigation for Proposed Subdivision Lot 442 DP 1201831 Kiama Downs**
title:	**Historical Imagery**
scale	NTS
original size	**A3**
project no: **TERRA19419**	figure no: **FIGURE 2**

SITE

Site Geology

Symbol	Age	Group / sub group	Unit	Lithology
QHaf	Holocene cenozoic	-	Alluvial flood plain deposits	Alluvium (flood plain deposits), gravel, swamp deposits and sand dunes
P gu	Permian	Shoalhaven Group Gerringong Volcanics	Bumbo Latite Member	Aphanitic to porphyritic latite

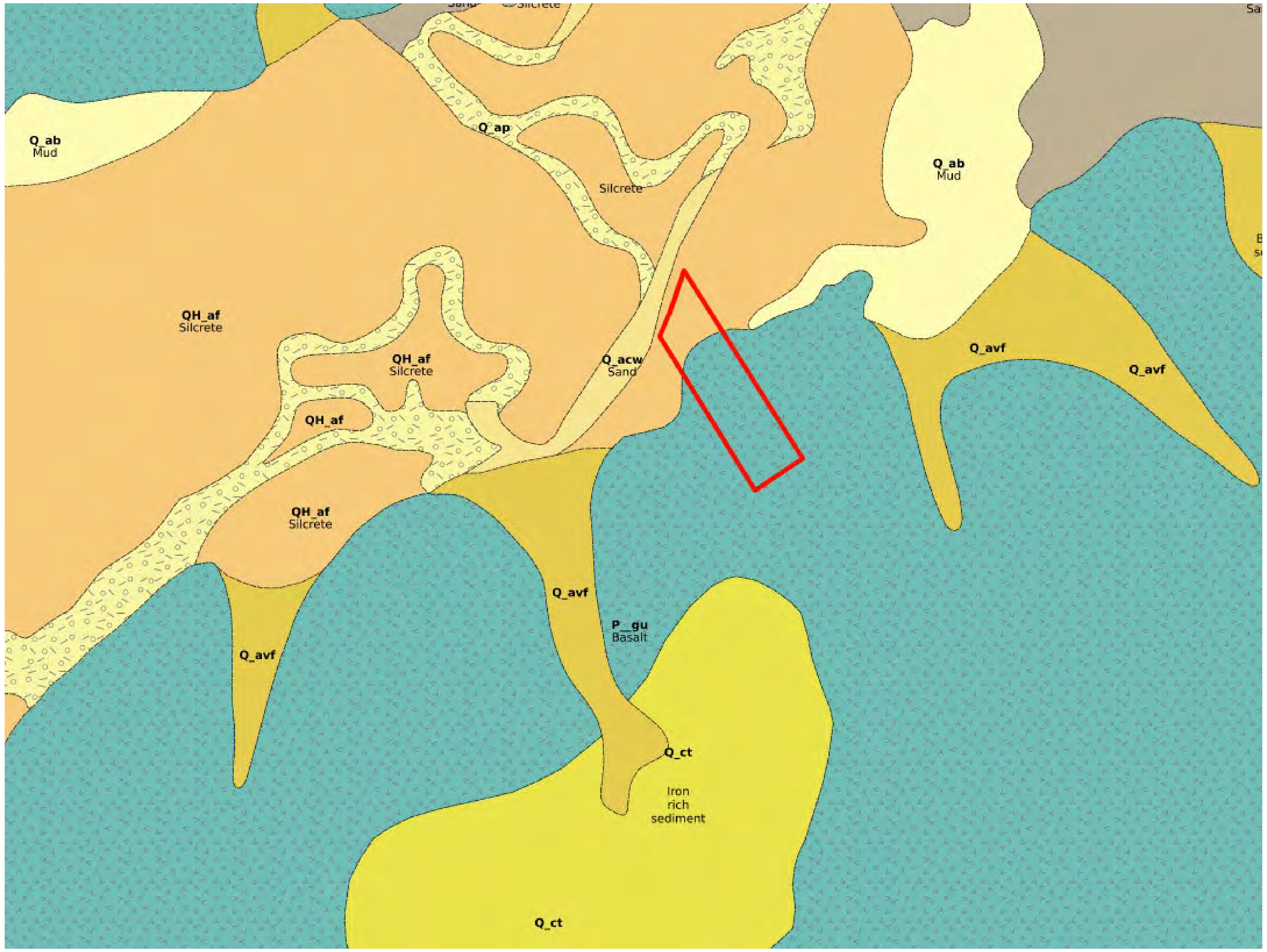
revision	description	drawn	approved	date
	Site Geology	XJ	KEG	23/01/2020

Data Source:
1:50,000 Geology Sheet for Kiama

TERRA INSIGHT

scale: NTS
original size: A3

client: **Indesco**
project: **Geotechnical Desk Study Investigation for Proposed Subdivision Lot 442 DP 1201831 Kiama Downs**
title: **Site Geology**
project no: **TERRA19419**
figure no: **FIGURE 3A**



Site Geology

Symbol	Group	Sub-group	Unit	Dominant Lithology
QH_af	-	-	Alluvial flood plain deposits	Silcrete
Q_ab	-	-	Alluvial backswamp deposits	Mud
Q_avf	-	-	Alluvial fan deposits	Biogenic sediment
Q_acw	-	-	Alluvial channel deposits	Sand
Q_ct	-	-	Colluvial talus deposits	Iron rich sediment
P_gu	Shoalhaven Group	Gerringong Volcanics	Bumbo Latite Member	Basalt

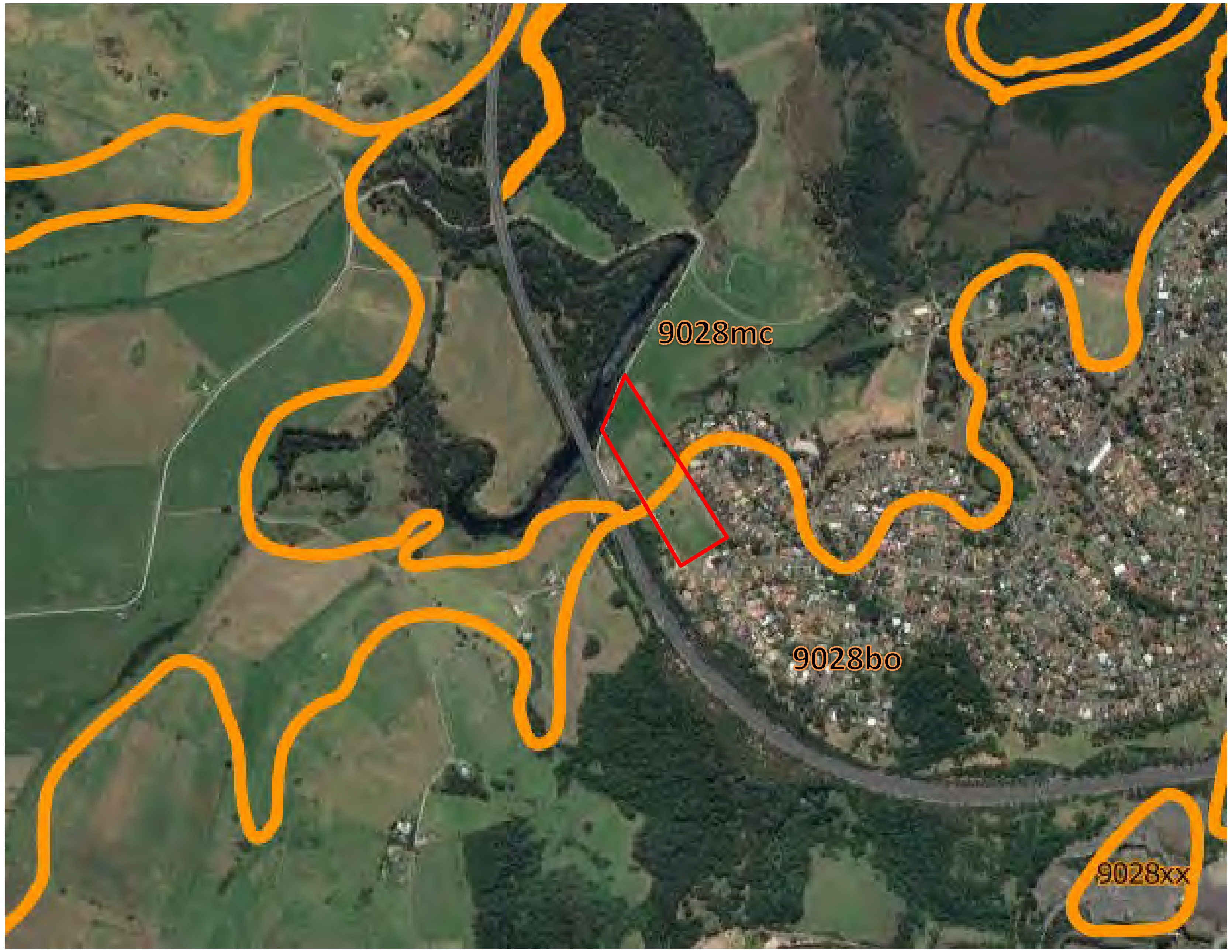
revision	description	drawn	approved	date
	Site Geology	XJ	KEG	23/01/2020

Data Source:
https://minview.geoscience.nsw.gov.au

TERRA INSIGHT

scale: NTS
original size: A3

client: **Indesco**
project: **Geotechnical Desk Study Investigation for Proposed Subdivision Lot 442 DP 1201831 Kiama Downs**
title: **Site Geology**
project no: **TERRA19419**
figure no: **FIGURE 3B**



Soil Landscapes

Symbol	Group
9028bo	Bumbo
9028mc	Mangrove Creek

revision	description	drawn	approved	date
	Soil Landscapes	XJ	KEG	23/01/2020

Data Source:
environment.nsw.gov.au/eSpade2WebApp

TERRA INSIGHT

scale: NTS

original size: **A3**

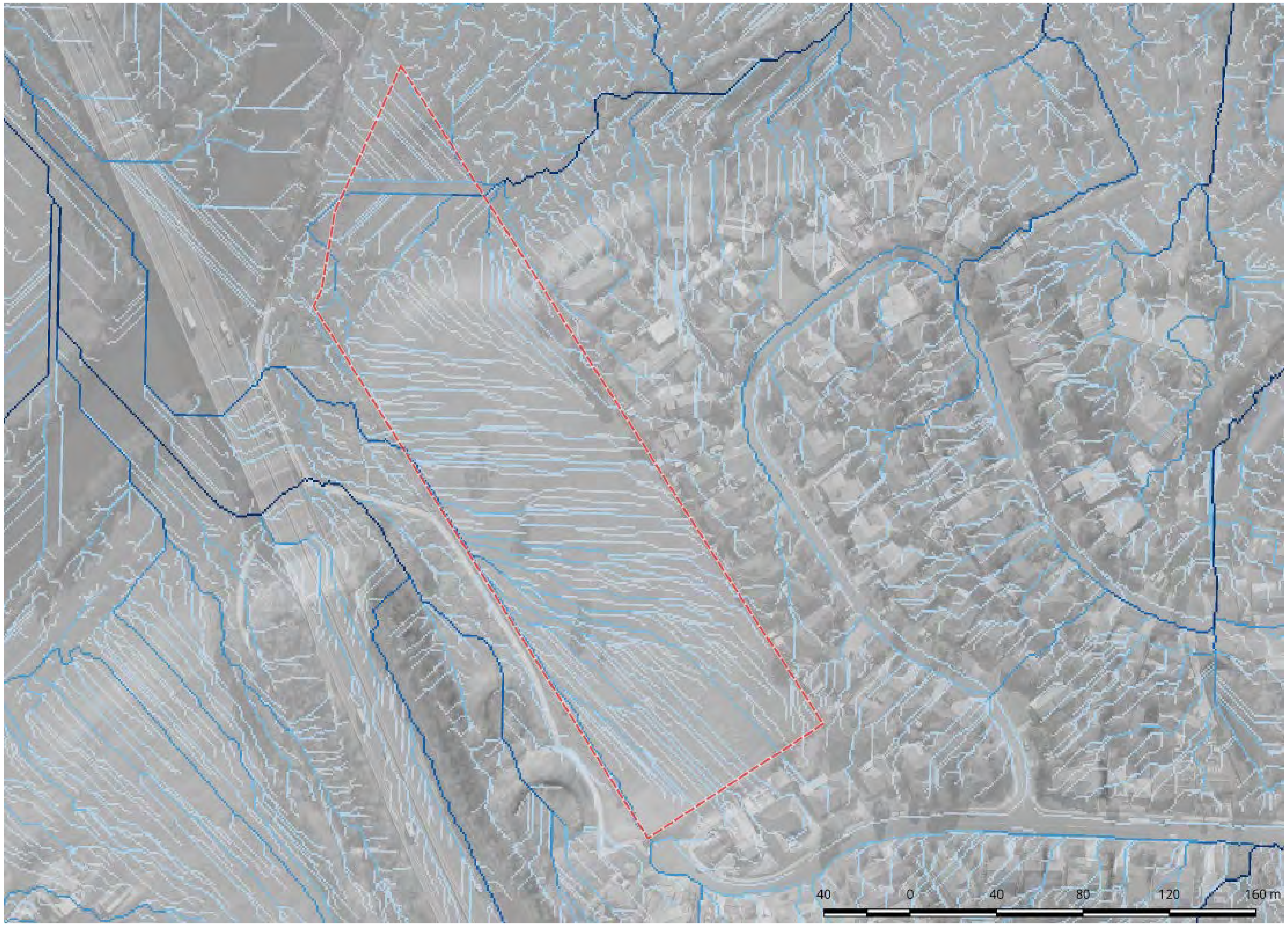
client: **Indesco**

project: **Geotechnical Desk Study Investigation for Proposed Subdivision Lot 442 DP 1201831 Kiama Downs**

title: **Soil Landscapes**

project no: **TERRA19419**

figure no: **FIGURE 4**



revision	description	drawn	approved	date
	Water Courses and Hydrogeology	XJ	KEG	23/01/2020

Data Source
Derived from LIDAR Data | Geoscience Australia | Obtained on 18.07.2018
Creative Commons 3.0 - Commonwealth of Australia

TERRA INSIGHT

scale	NTS
original size	A3

client:	**Indesco**
project:	**Geotechnical Desk Study Investigation for Proposed Subdivision Lot 442 DP 1201831 Kiama Downs**
title:	**Water Courses and Hydrogeology**
project no: **TERRA19419**	figure no: **FIGURE 5**

revision	description	drawn	approved	date
	Groundwater Bores	XJ	KEG	23/01/2020

Data Source:
https://minview.geoscience.nsw.gov.au/

TERRA INSIGHT

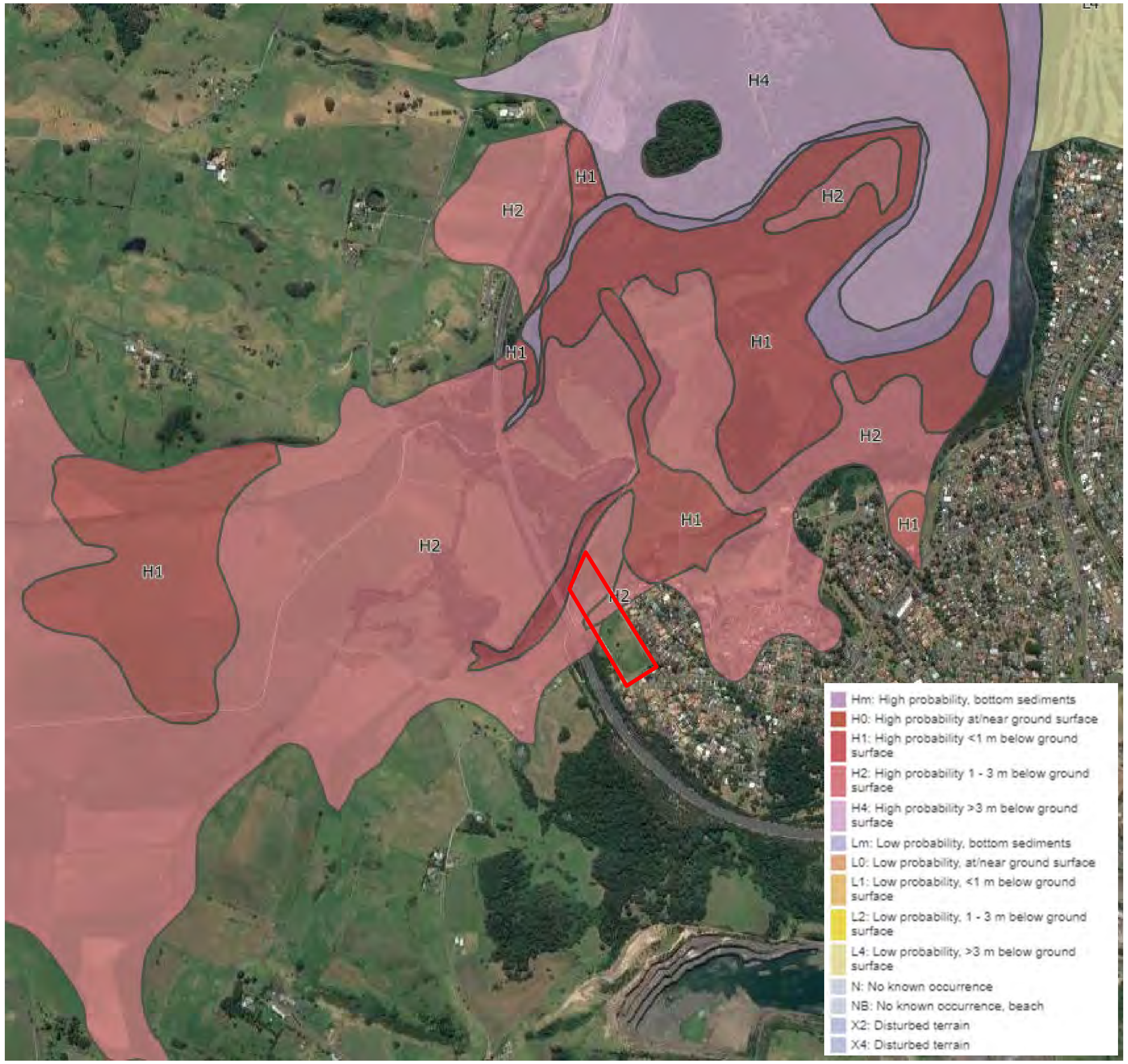
scale	NTS
original size	**A3**

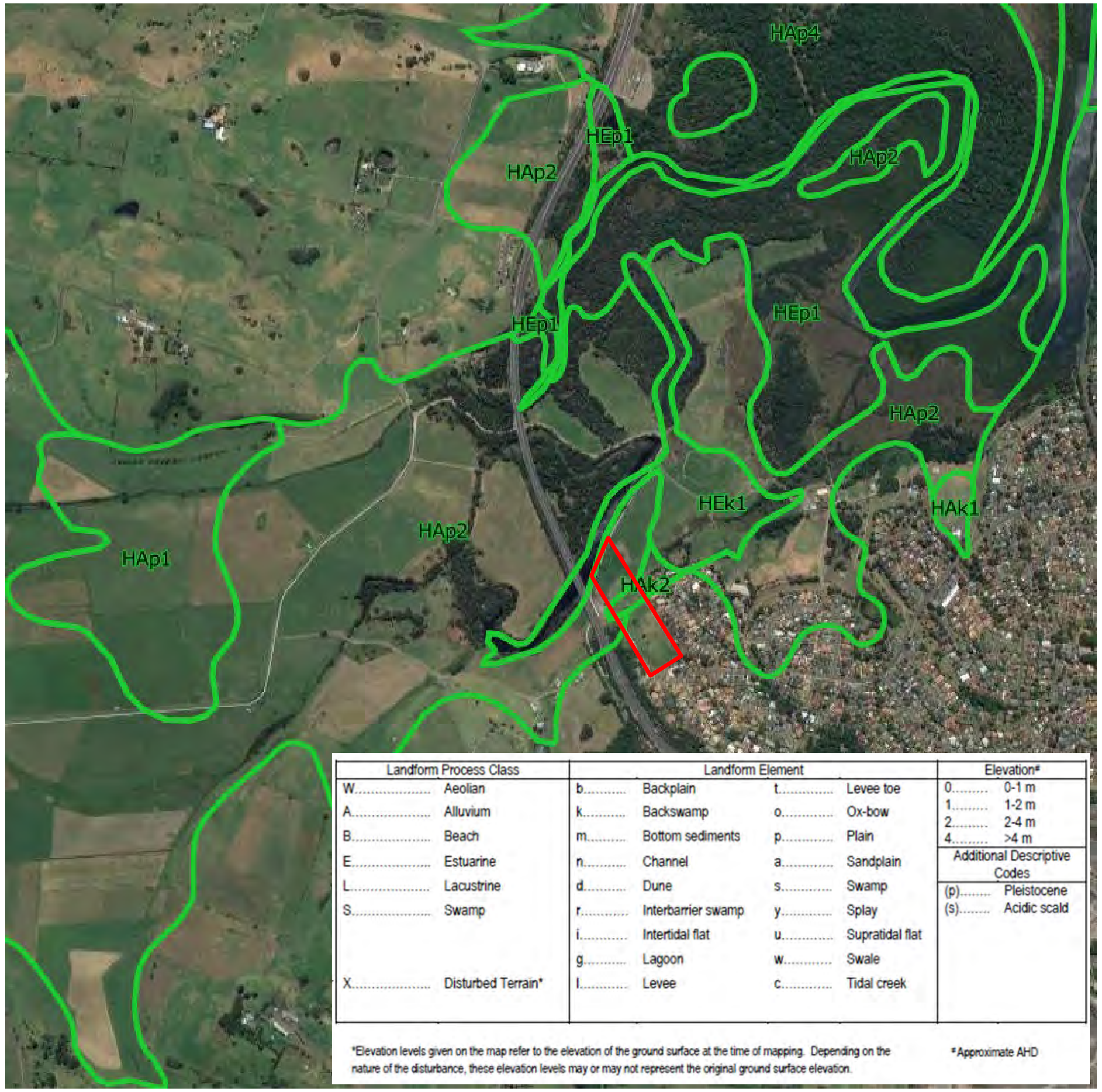
client: **Indesco**

project: **Geotechnical Desk Study Investigation for Proposed Subdivision Lot 442 DP 1201831 Kiama Downs**

title: **Groundwater Bores**

project no: **TERRA19419** figure no: **FIGURE 6**





revision	description	drawn	approved	date
	Acid Sulfate Soils	XJ	KEG	23/01/2020

Data Source:
environment.nsw.gov.au/eSpade2WebApp

TERRA INSIGHT

scale	NTS
original size	A3

client:	**Indesco**
project:	**Geotechnical Desk Study Investigation for Proposed Subdivision Lot 442 DP 1201831 Kiama Downs**
title:	**Acid Sulfate Soils**
project no: **TERRA19419**	figure no: **FIGURE 7**

revision	description	drawn	approved	date
	Acid Sulfate Soils	XJ	KEG	23/01/2020

Data Source
NSW Planning and the Environment | Obtained on 18.07.2018
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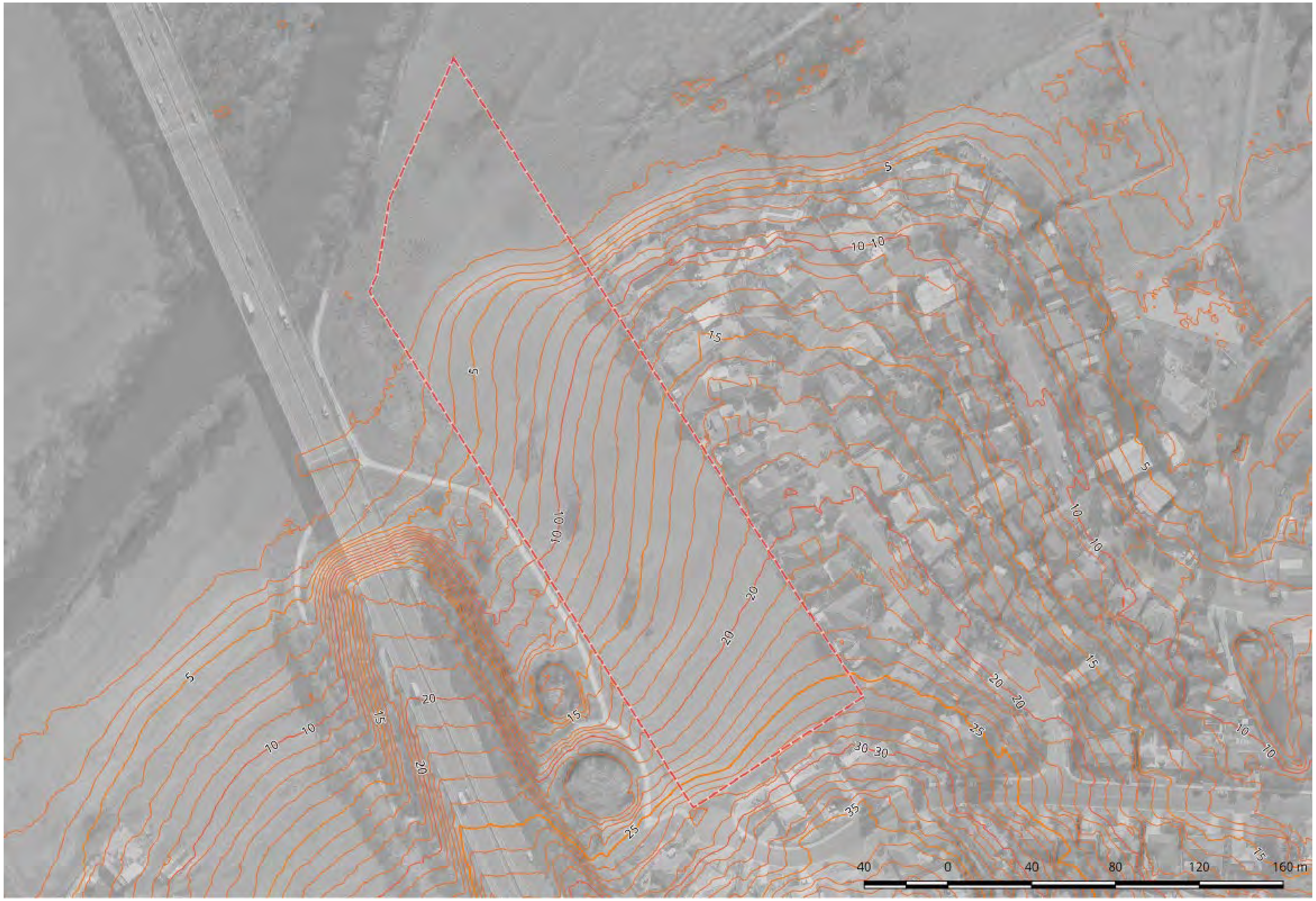
TERRA INSIGHT

client:	Indesco
project:	Geotechnical Desk Study Investigation for Proposed Subdivision Lot 442 DP 1201831 Kiama Downs
scale	NTS
title:	Acid Sulfate Soils
original size	A3
project no:	TERRA19419
figure no:	FIGURE 7



revision	description	drawn	approved	date
	Topography	XJ	KEG	30/01/2020

Data Source
Derived from LIDAR Data | Geoscience Australia | Obtained on 18.07.2018
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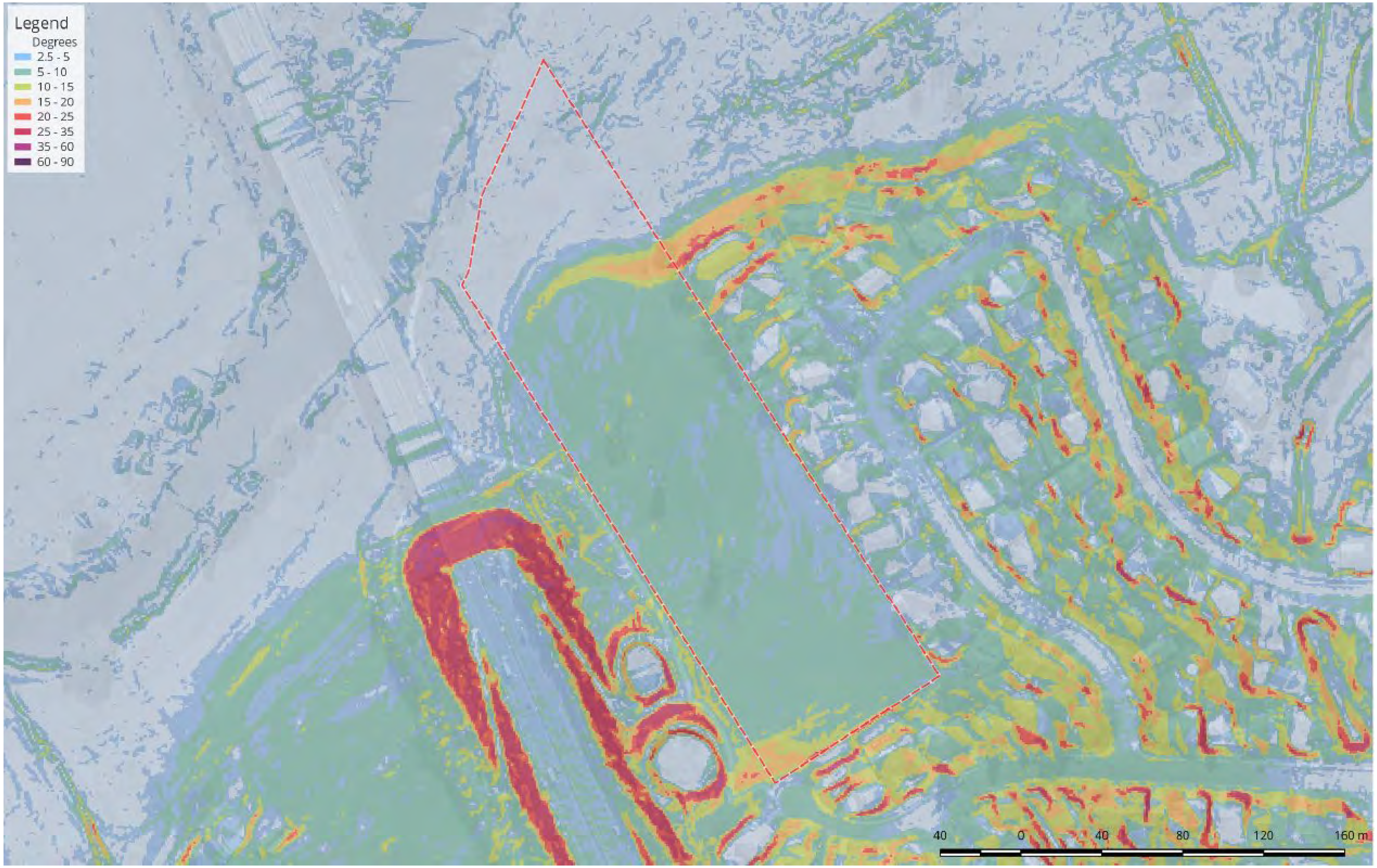
TERRA INSIGHT

client:	**Indesco**
project:	**Geotechnical Desk Study Investigation for Proposed Subdivision Lot 442 DP 1201831 Kiama Downs**
title:	**Topography**
scale	NTS
original size	**A3**
project no:	**TERRA19419**
figure no:	**FIGURE 8**



revision	description	drawn	approved	date
	Slope Heat Mapping	XJ	KEG	23/01/2020

Data Source
Derived from LIDAR Data | Geoscience Australia | Obtained on 18.07.2018
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TERRA INSIGHT

scale	NTS
original size	A3

client:	**Indesco**
project:	**Geotechnical Desk Study Investigation for Proposed Subdivision Lot 442 DP 1201831 Kiama Downs**
title:	**Slope Heat Mapping**
project no: **TERRA19419**	figure no: **FIGURE 9**

ID	Date	Hazard	Synopsis
695	04/04/2004	Landslide	Heavy rainfall triggered landslide a landslide that blocked the northbound lane of the Princes Highway

revision	description	drawn	approved	date
	Recorded Landslides	XJ	KEG	30/01/2020

Data Source
NSW Planning and the Environment | Obtained on 18.07.2018
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TERRA INSIGHT

client:	**Indesco**
project:	**Geotechnical Desk Study Investigation for Proposed Subdivision Lot 442 DP 1201831 Kiama Downs**
scale	NTS
title:	**Recorded Landslides**
original size	**A3**
project no:	**TERRA19419**
figure no:	**FIGURE 10**

revision	description	drawn	approved	date
	Site observations	XJ	KEG	23/01/2020

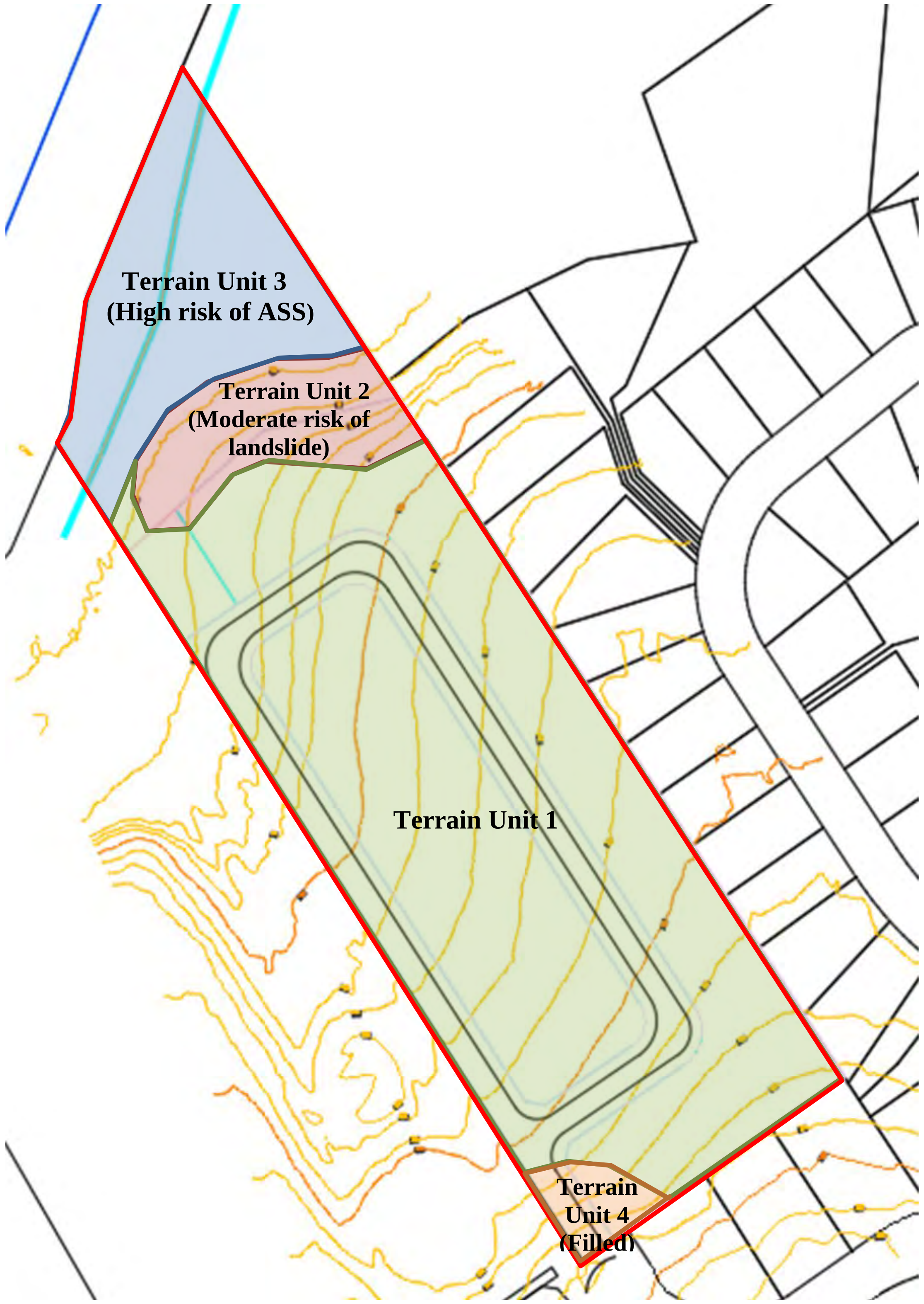
Data Source:
Google Earth Imagery

TERRA INSIGHT

scale	NTS
original size	**A3**

client:	**Indesco**
project:	**Geotechnical Desk Study Investigation for Proposed Subdivision Lot 442 DP 1201831 Kiama Downs**
title:	**Site Observations**
project no: **TERRA19419**	figure no: **FIGURE 11A**

N



revision	description	drawn	approved	date
	Site observations	XJ	KEG	23/01/2020

Data Source:
Indesco

TERRA INSIGHT

scale	NTS
original size	A3

client:	**Indesco**
project:	**Geotechnical Desk Study Investigation for Proposed Subdivision Lot 442 DP 1201831 Kiama Downs**
title:	**Terrain Units**
project no: **TERRA19419**	figure no: **FIGURE 12**

Appendix A: Your Report

TERRA INSIGHT

Your Report

These notes have been prepared to help you understand the advice provided in Your Report and its limitations.

Your Report is based on what you tell us

Your Report has been developed based on the information you have provided such as the scope and size of your project. It applies only to the site investigated. If there are changes to the proposed works, then the advice provided within Your Report may need to be reviewed

Your Report is written with your needs in mind

The advice provided within Your Report is also not relevant to another purpose other than that originally specified at the time the report was issued. Please seek advice from Terra Insight before you share Your Report with another third party – except for the purpose for which the report was written.

Terra Insight assumes no responsibility and will not be liable to any other person or organisation for, or in relation to, any matter dealt with or conclusions expressed in the report, or for any loss or damage suffered by any other person or organisation arising from matters dealt with or conclusions expressed in Your Report.

Your Report is based on what we observed

The advice provided within Your Report assumes that the site conditions, revealed through selective point sampling (undertaken in accordance with normal practices and standards) at a particular point in time, are indicative of the actual conditions on your site. However, the nature of the materials underlying your site is affected by natural processes and the activity of man. Under no circumstances can it be considered that these findings represent the actual state at all points. The subsurface conditions may vary significantly on the other parts of the site, particularly where no nearby sampling and testing work has been carried out.

As a result conditions on your site can change with time; they can also vary spatially. As a result, the actual conditions encountered may differ from those detailed within Your Report. Although nothing can be done to change the actual site conditions which exist, steps can be taken to gain a better understanding of the subsurface conditions underlying your site and reduce the potential for unexpected conditions to be encountered

The advice within Your Report also relies on interpretation of factual information based on judgement and opinion and has a level of uncertainty attached to it. Only Terra Insight is fully familiar with the background information needed to assess whether or not the report's recommendations are valid and whether or not changes should be considered as the project develops. If the details of your project have changed, the site conditions have changed or a significant amount of time as elapsed since our report was written, the advice provided within Your Report may need to be reviewed.

Your Report has been written by a Professional

The report has been prepared using accepted procedures and practices of the consulting profession at the time it was prepared, and the opinions, recommendations and conclusions set out in the report are made in accordance with generally accepted principles and practices of that profession.

Your Report is better when it is kept together

Your Report presents all the findings of the site assessment and should not be copied in part or altered in any way. Keeping Your Report intact reduces the potential for yourself or other design professionals to misinterpret the report.

Your Geo-Environmental Report

If Your Report is for geotechnical purposes only, it will not relate any findings, conclusions, or recommendations about the potential for hazardous materials to exist at the site unless you have specifically asked us to do so. If your report is written for Geo-Environmental purposes the following should be noted in addition to the above:

- Advancements in professional practice regarding contaminated land and changes in applicable statues and/or guidelines may affect the validity of this report. Consequently, the currency of conclusions and recommendations in Your Report should be verified if you propose to use this report more than 6 months after its date of issue;
- Your Report is based on information gained from environmental conditions (including assessment of some or all of soil, groundwater, vapour and surface water) and supplemented by reported data of the local area and professional experience. The assessment has been scoped with consideration to industry standards, regulations, guidelines and your specific requirements, which includes budget and timing;
- The characterisation of site conditions is an interpretation of information collected during assessment, in accordance with industry practice. Any interpretation in Your Report is not a complete description of all material on or in the vicinity of the site, due to the inherent variation in spatial and temporal patterns of contaminant presence and impact in the natural environment.
- We may have relied on data and other information provided by you and other qualified individuals in preparing Your Report. We have not verified the accuracy or completeness of such data or information except as otherwise stated in Your Report. For these reasons Your Report must be regarded as interpretative, in accordance with industry standards and practice, rather than being a definitive record.
- For each purpose, a tailored approach to the assessment of potential soil and groundwater contamination is required. In most cases, a key objective is to identify, and if possible quantify, risks that both recognised and potential contamination posed in the context of the agreed purpose. If the proposed use of the site changes, the assessment may no longer be valid and will need to be reviewed.

* For further information on this aspect reference should be made to "Guidelines for the Provision of Geotechnical information in Construction Contracts" published by the Institution of Engineers Australia, National headquarters, Canberra, 1987.

Appendix B: Proposed Site Development

revision	description	drawn	approved	date
	Site location	XJ	KEG	7/02/2020

Data Source:
Indesco

TERRA INSIGHT

client:	**Indesco**
project:	**Geotechnical Desk Study Investigation for Proposed Subdivision Lot 442 DP 1201831 Kiama Downs**
title:	**Proposed Site Development**
scale	NTS
original size	**A3**
project no:	**TERRA19419**
figure no:	**FIGURE 1**

Appendix D: Historical Aerial Images

Broadcrest Consulting

MAPPING & SPATIAL SERVICES

LOCATION: Henry Parkes Drive, Jambaroo

REPORT

DATE 30.1.2020

SITE AREA 3.1192 ha (approx)

Disclaimer

Broadcrest Consulting has taken all reasonable care in collating and providing the data within this report on the basis that any person given access to this report are responsible for assessing the relevance of the content. The purpose of this report is to provide an overview of the site based on some data collated from various government, public and private sources. You should obtain independent advice before you make any decision based on the information in this report.

Broadcrest Consulting do not make any claim that the data is free from errors, omission, or that it is exhaustive. Furthermore, there is no claim that the data is accurate, authentic, current, complete, reliable, or suitable.

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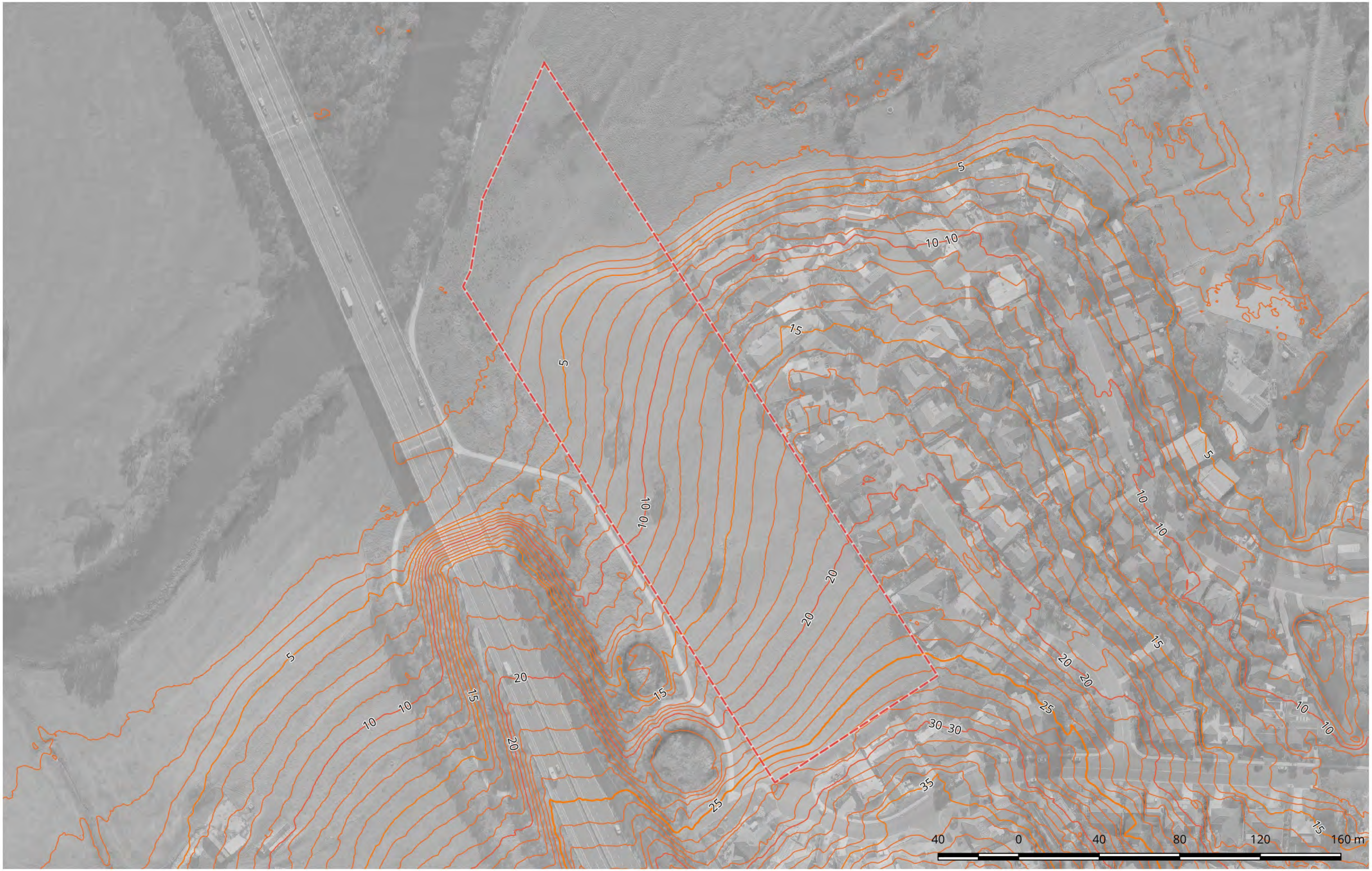
MAPPING & SPATIAL SERVICES
broadcrest.com.au | contact@broadcrest.com.au | 1300 554 945
Broadcrest Consulting Pty Ltd | ABN: 622 508 187

Client TerraInsight	**Map** Site Aerial Photograph	**Data Source**	**Scale** 1:2000
Location Henry Parkes Drive, Jambaroo LOT: 442 DP1201831	**LGA** THE COUNCIL OF THE MUNICIPALITY OF KIAMA	**Base map** atial Services Imagery | © Department of Finance, Services & Innovation 2017 Street Maps | Creative Commons 3.0 - OpenStreetMap Contributors	**Project**

BROADCREST MAPPING & SPATIAL SERVICES broadcrest.com.au | contact@broadcrest.com.au | 1300 554 945 Broadcrest Consulting Pty Ltd | ABN: 622 508 187	**Client** TerraInsight	**Map** Site Location with Terrain	**Data Source** Geoscience Australia | Obtained on 18.07.2018 Creative Commons 3.0 - Commonwealth of Australia	**Scale** 1:2000
	Location Henry Parkes Drive, Jambaroo	**LGA** THE COUNCIL OF THE MUNICIPALITY OF KIAMA	**Base map** atial Services Imagery | © Department of Finance, Services & Innovation 2017 Open Street Maps | Creative Commons 3.0 - OpenStreetMap Contributors	**Project**



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broadcrest.com.au | contact@broadcrest.com.au | 1300 554 945
Broadcrest Consulting Pty Ltd | ABN: 622 508 187

Client	Map
TerraInsight	Topography
Location	**LGA**
Henry Parkes Drive, Jambaroo	THE COUNCIL OF THE MUNICIPALITY OF KIAMA

Data Source
Derived from LiDAR Data | Geoscience Australia | Obtained on 18.07.2018
Creative Commons 3.0 - Commonwealth of Australia

Base map
...treet Maps | Obtained on 30.1.2020
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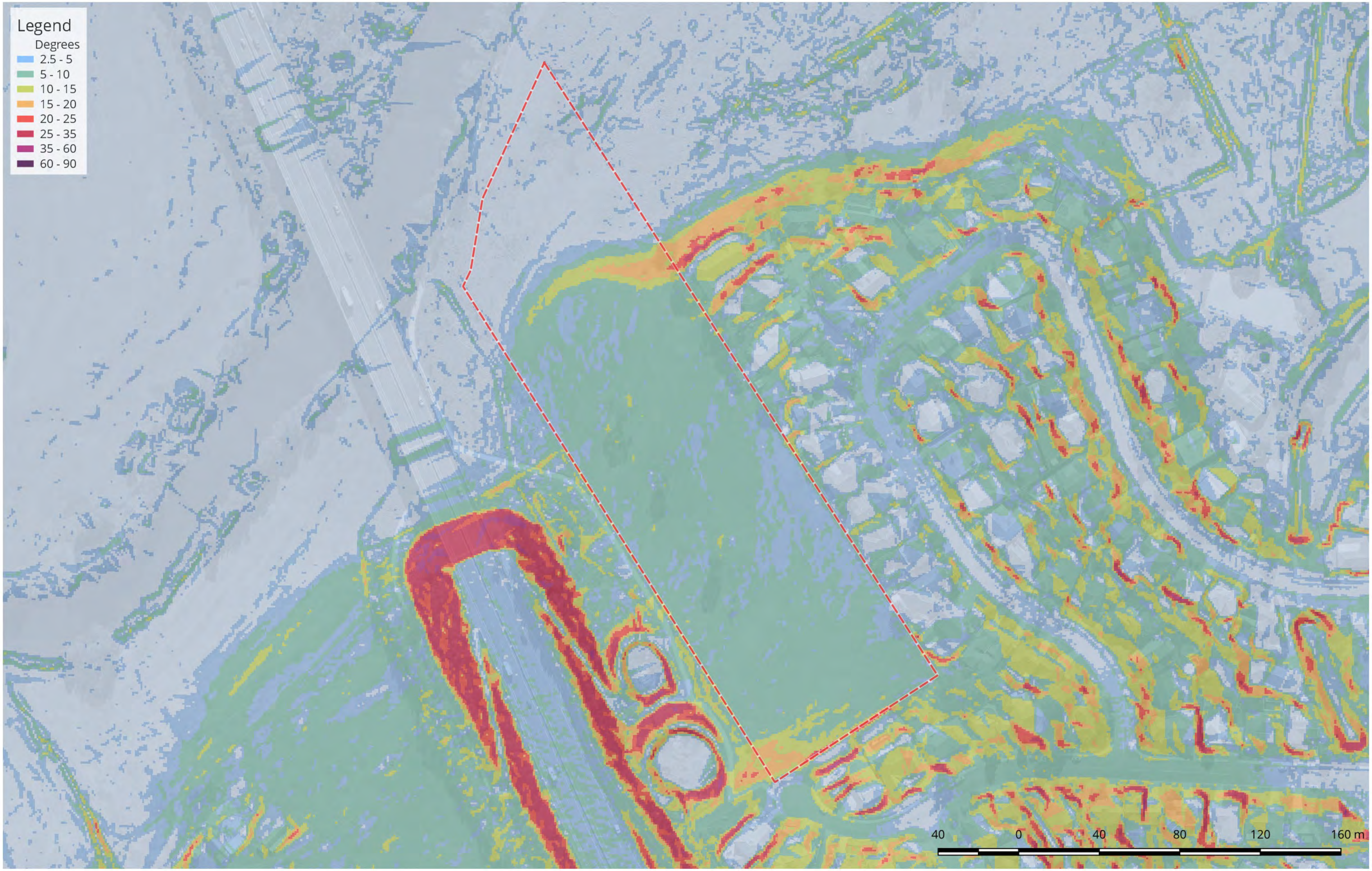
Scale
1:2000

Project



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Broadcrest Consulting Pty Ltd | ABN: 622 508 187

Client	Map
TerraInsight	Slope Heat Map
Location	LGA
Henry Parkes Drive, Jambaroo	THE COUNCIL OF THE MUNICIPALITY OF KIAMA

Data Source
Derived from LiDAR Data | Geoscience Australia | Obtained on 18.07.2018
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Base map
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Scale	1:2000
Project	

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Client TerraInsight	**Map** Land Zone Map
Location Henry Parkes Drive, Jambaroo	**LGA** THE COUNCIL OF THE MUNICIPALITY OF KIAMA

Data Source
NSW Planning and the Environment | Obtained on 18.07.2018
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Base map
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Scale
1:2000

Project

ID	NAME	LEVEL
	No data in mapped area.	

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Client	Map
TerraInsight	Heritage Listed Sites
Location	**LGA**
Henry Parkes Drive, Jambaroo	THE COUNCIL OF THE MUNICIPALITY OF KIAMA

Data Source
NSW Planning and the Environment | Obtained on 18.07.2018
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Base map
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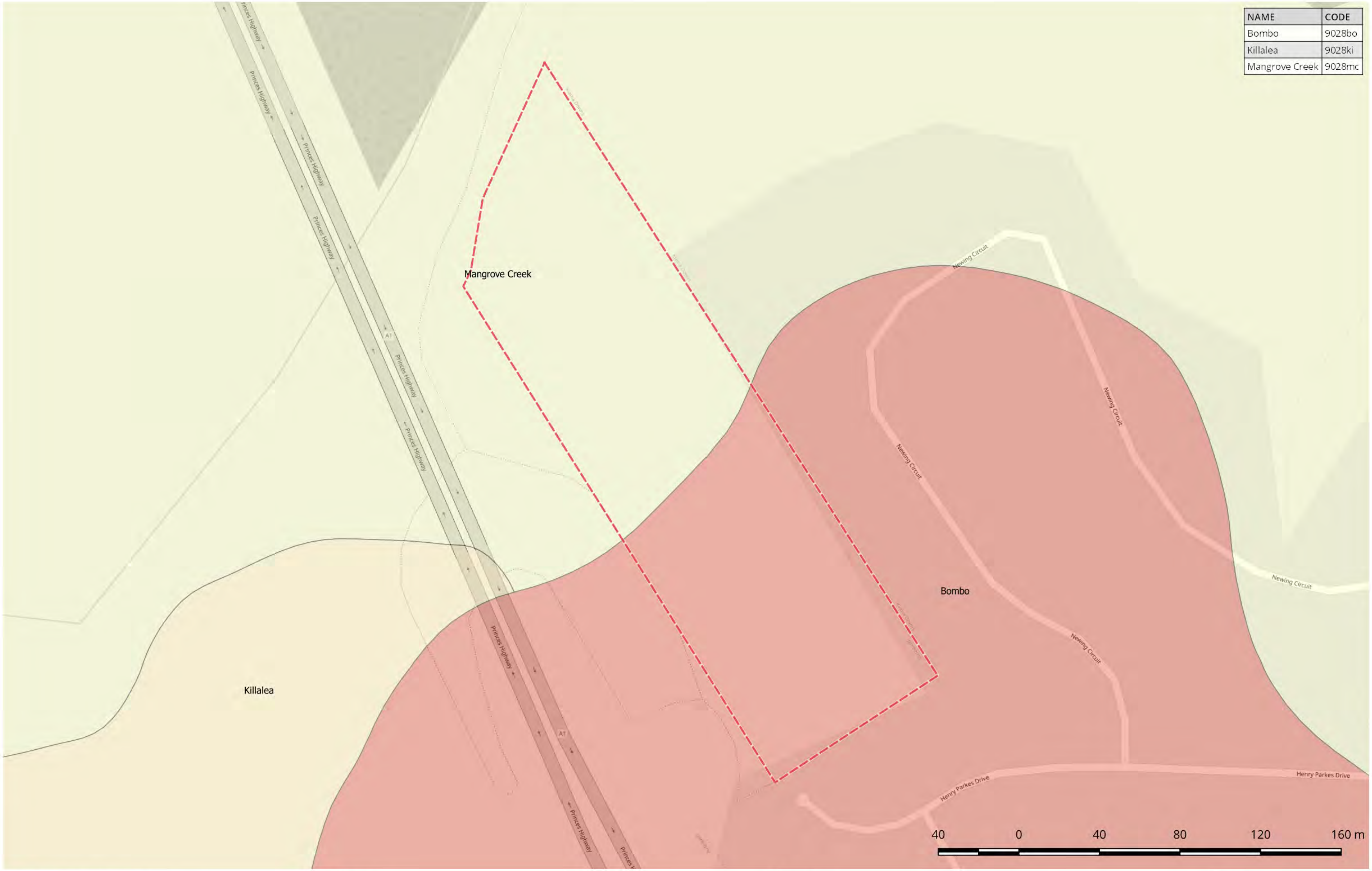
Scale
1:2000

Project

BROADCREST MAPPING & SPATIAL SERVICES broadcrest.com.au | contact@broadcrest.com.au | 1300 554 945 Broadcrest Consulting Pty Ltd | ABN: 622 508 187	Client TerraInsight Location Henry Parkes Drive, Jambaroo	Map Bushfire Prone Land LGA THE COUNCIL OF THE MUNICIPALITY OF KIAMA	Data Source NSW Planning and the Environment | Obtained on 18.07.2018 Creative Commons 3.0 - Commonwealth of Australia Base map treet Maps | Obtained on 30.1.2020 Creative Commons 3.0 - OpenStreetMap Contributors
Scale 1:2000 Project			



NAME	CODE
Bombo	9028bo
Killalea	9028ki
Mangrove Creek	9028mc

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Client	Map
TerraInsight	Soil Landscapes
Location	**LGA**
Henry Parkes Drive, Jamboroo	THE COUNCIL OF THE MUNICIPALITY OF KIAMA

Data Source
Office of Environment and Heritage | Obtained on 18.07.2018
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Base map
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Scale
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Project

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MAPPING & SPATIAL SERVICES
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Client TerraInsight	Map Soil Formation
Location Henry Parkes Drive, Jambaroo	LGA THE COUNCIL OF THE MUNICIPALITY OF KIAMA

Data Source
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Base map
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Scale 1:2000	
Project	

NSW Code	Lithology
P__gu	Dark grey to black, porphyritic basalt (in hand specimen), phenocrysts are plagioclase with minor clinopyroxenes; sporadically veshicular. Columnar jointing and breccia zones common

BROADCREST MAPPING & SPATIAL SERVICES broadcrest.com.au | contact@broadcrest.com.au | 1300 554 945 Broadcrest Consulting Pty Ltd | ABN: 622 508 187	Client TerraInsight Location Henry Parkes Drive, Jambaroo	Map Geology (1:100,000 Mapping) LGA THE COUNCIL OF THE MUNICIPALITY OF KIAMA	Data Source NSW Planning and the Environment | Obtained on 18.07.2018 Creative Commons 3.0 - Commonwealth of Australia Base map OpenStreet Maps | Obtained on 30.1.2020 Creative Commons 3.0 - OpenStreetMap Contributors
Scale 1:2000 Project			

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Client TerraInsight	Map Hydrogeological Landscapes
Location Henry Parkes Drive, Jambaroo	LGA THE COUNCIL OF THE MUNICIPALITY OF KIAMA

Data Source
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Base map
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Scale
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Project

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Client TerraInsight	Map Acid Sulfate Risk map
Location Henry Parkes Drive, Jambaroo	LGA THE COUNCIL OF THE MUNICIPALITY OF KIAMA

Data Source
NSW Planning and the Environment | Obtained on 18.07.2018
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Scale
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Project

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Broadcrest Consulting Pty Ltd | ABN: 622 508 187

Client	Map
TerraInsight	Watercourses and Hydrology
Location	**LGA**
Henry Parkes Drive, Jambaroo	THE COUNCIL OF THE MUNICIPALITY

Data Source
Department of Finance, Services & Innovation | Obtained on 30.1.2020
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Open Street Maps | Obtained on 30.1.2020
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Scale
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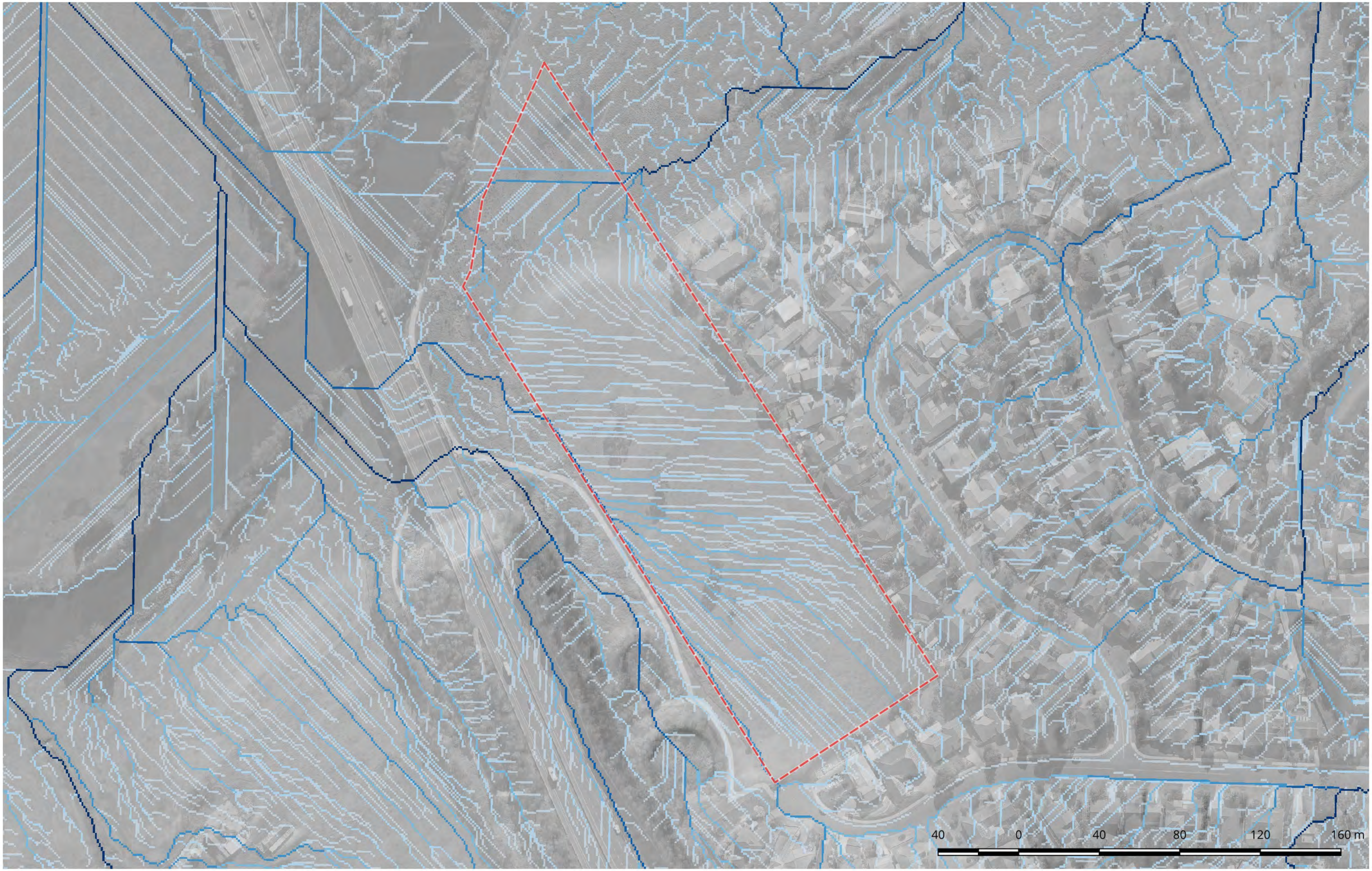
Project



BROADCREST MAPPING & SPATIAL SERVICES broadcrest.com.au | contact@broadcrest.com.au | 1300 554 945 Broadcrest Consulting Pty Ltd | ABN: 622 508 187	Client TerraInsight Location Henry Parkes Drive, Jambaroo	Map Rainfall Overland Flow Paths LGA THE COUNCIL OF THE MUNICIPALITY OF KIAMA	Data Source Derived from LiDAR Data | Geoscience Australia | Obtained on 18.07.2018 Creative Commons 3.0 - Commonwealth of Australia Base map treet Maps | Obtained on 30.1.2020 ative Commons 3.0 - OpenStreetMap Contributors
Scale 1:2000 Project			

HydroCode	Depth	Strata Description	Bore Data
GW023121.1.1	0m - 3.04m	Sand water supply	Date Drilled: 01/02/1965 Ref Elevation: 4.03 AHD Drill Depth: 3m Purpose: Irrigation SWL: 0m
GW109552.1.1			Date Drilled: 30/03/2001 Ref Elevation: 1.55 AHD Drill Depth: 3.2m Purpose: Exploration SWL: m
GW109553.1.1			Date Drilled: 30/03/2001 Ref Elevation: 8.88 AHD Drill Depth: 2.8m Purpose: Exploration SWL: m
GW109554.1.1			Date Drilled: 30/03/2001 Ref Elevation: 3.94 AHD Drill Depth: 4.25m Purpose: Exploration SWL: m

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Client TerraInsight	Map Groundwater Bores
Location Henry Parkes Drive, Jambaroo	LGA THE COUNCIL OF THE MUNICIPALITY OF KIAMA

Data Source
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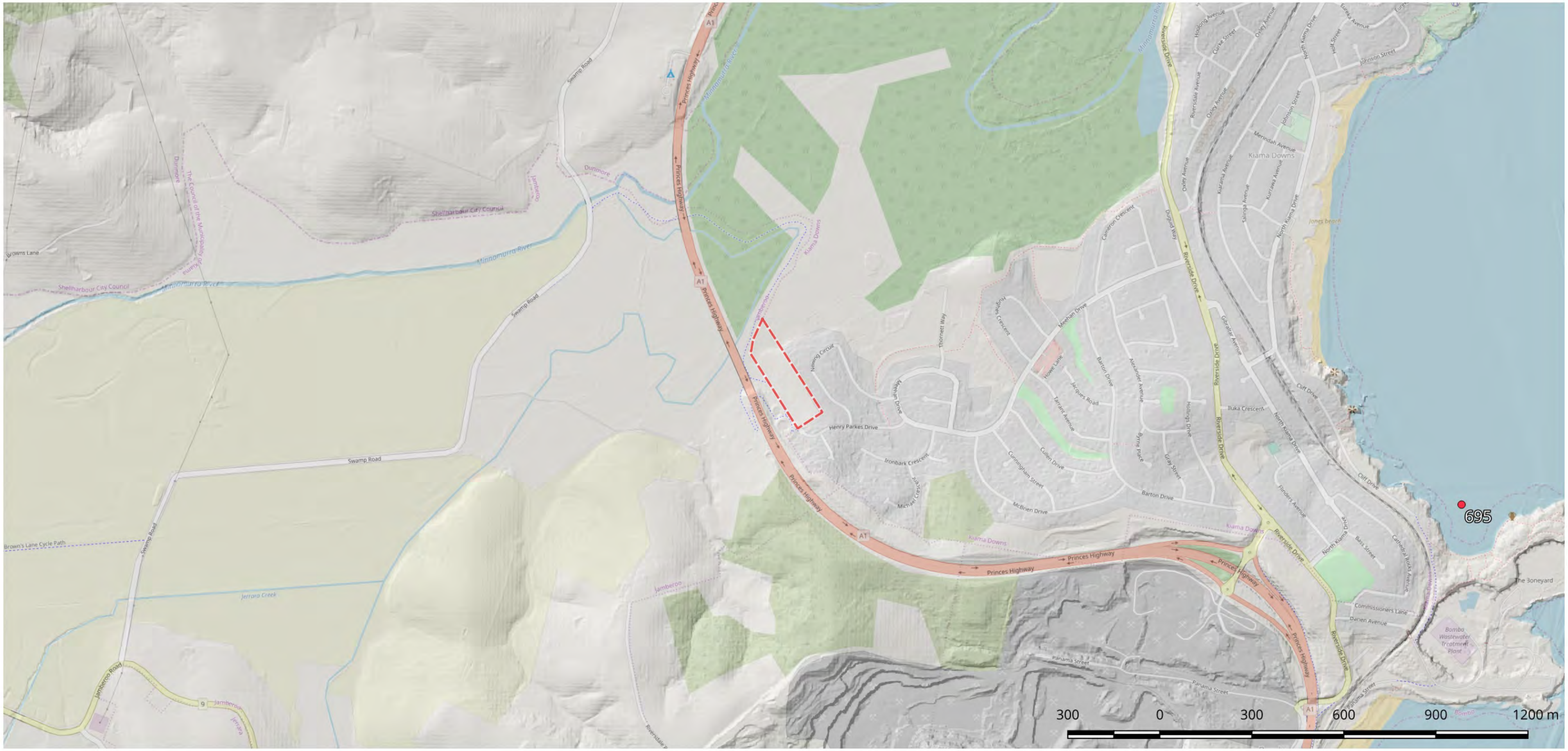
Scale
1:10000

Project



ID	Date	Hazard	Synopsis	Impact Comments
695	04-04-2004	Landslide	Heavy rain triggered a landslide that blocked the northbound land of the Princes Highway.	

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Client TerraInsight	Map Recorded Landslides
Location Henry Parkes Drive, Jamberoo	LGA THE COUNCIL OF THE MUNICIPALITY OF KIAMA

Data Source
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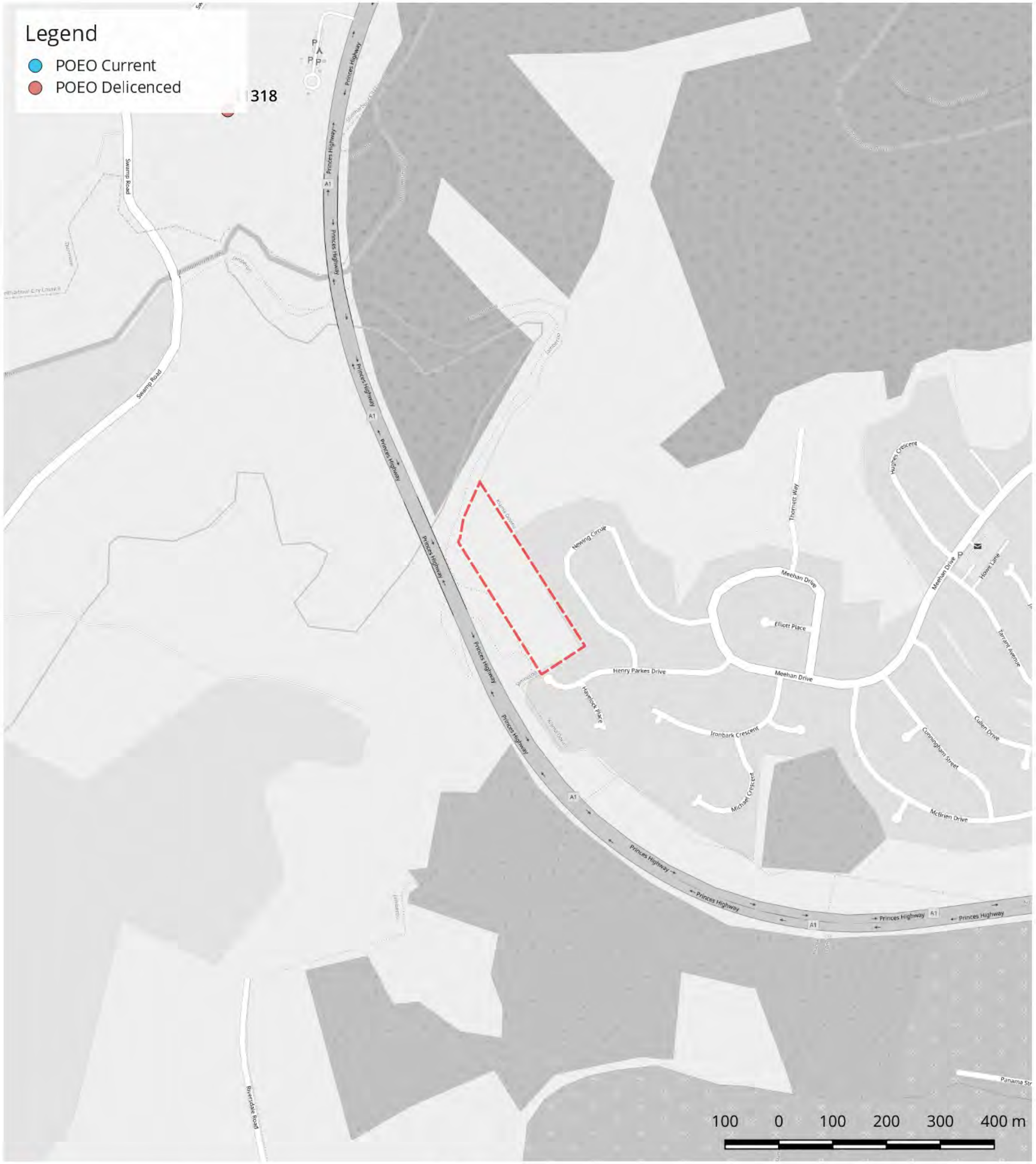
Scale
1:15000

Project



POEO Registered Schedule 1 Sites

EPL	Organisation Name	Fee-Based Activity	Geocode Reference	Quality
No data in mapped area.				

POEO Delicenced Premises

EPL	Organisation Name	Status	Geocode Reference	Quality
11318	BAULDERSTONE PTY LTD	Surrendered	345 SWAMP ROAD, DUNMORE, NSW 2529	Rooftop

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Client	Map
TerraInsight	EPA POEO Licences
Location	**LGA**
Henry Parkes Drive, Jambaroo	THE COUNCIL OF THE MUNICIPALITY OF KIAMA

Data Source
NSW Environment Protection Authority | Obtained on 12.09.2018
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Base map
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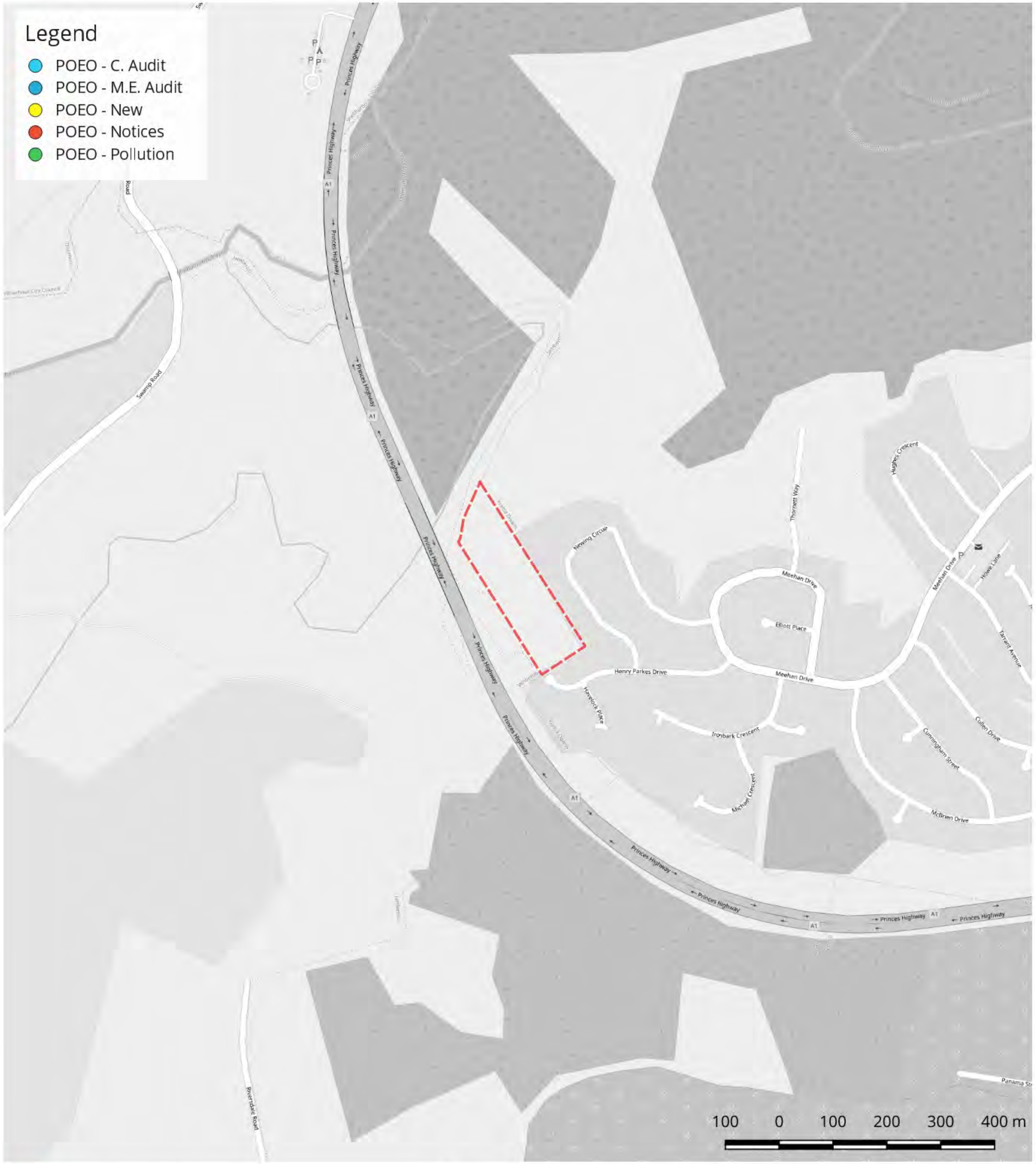
Scale
1:10000

Project



POEO Compliance Audit

EPL	Organisation Name	Status	Geocode Address	Quality
No data in mapped area.				

POEO Mandatory Environmental Audit

EPL	Organisation name	Status	Geocode Address	Quality
No data in mapped area.				

POEO New Licences

EPL	Organisation Name	Type	Status	Geocode Address	Quality
No data in mapped area.					

POEO Notices

EPL	Organisation Name	Type	Status	Geocode Address	Quality
No data in mapped area.					

POEO Pollution

EPL	Organisation Name	Type	Geocoded Address	Quality
No data in mapped area.				

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Client TerraInsight	Map EPA POEO Registers
Location Henry Parkes Drive, Jambaroo	LGA THE COUNCIL OF THE MUNICIPALITY OF KIAMA

Data Source
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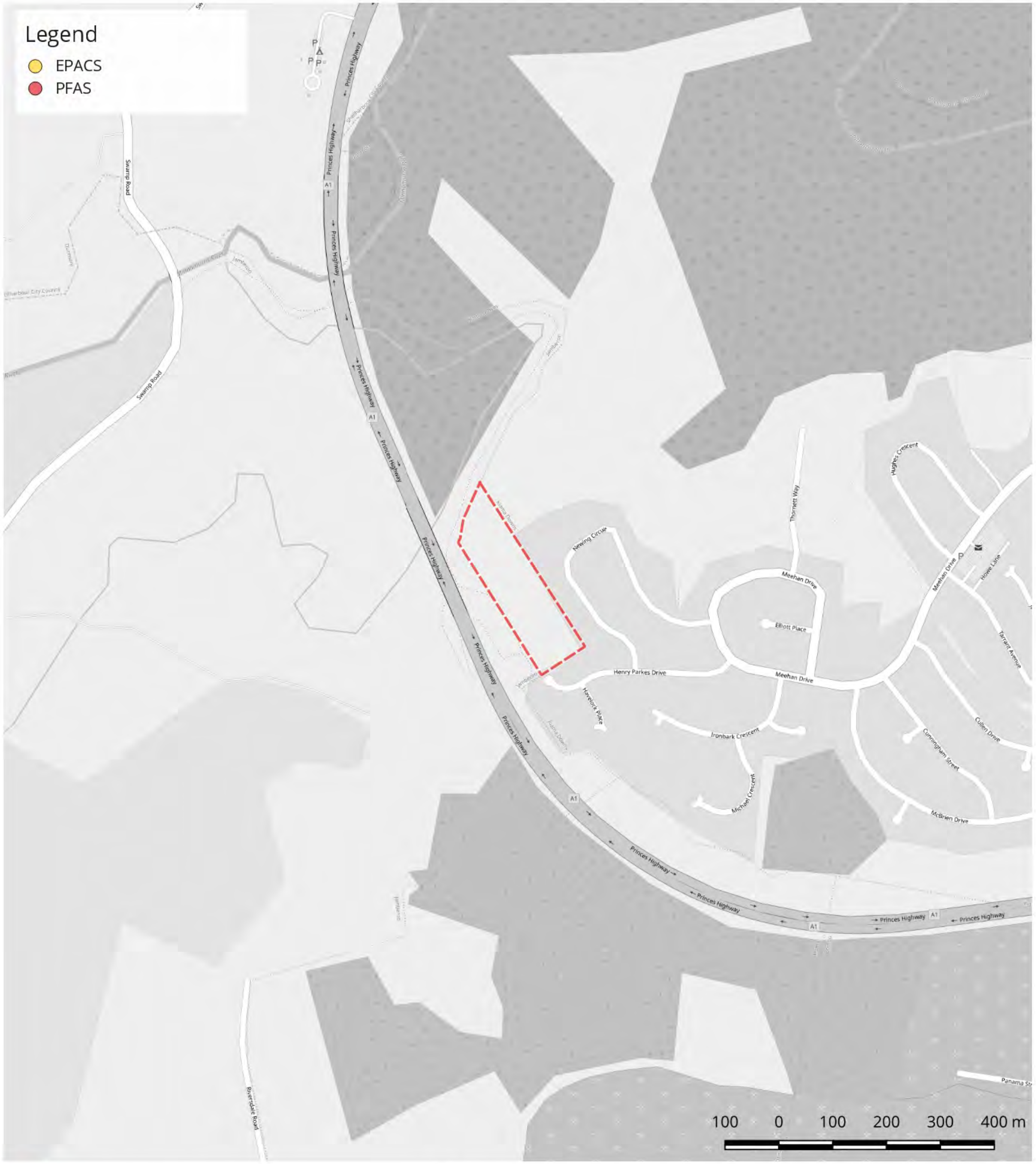
Scale
1:10000

Project



EPACS - Contaminated sites notified to EPA

Organisation Name	Address	Type	EPA Management Class
No data in mapped area.			

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Client
TerraInsight

Map
Other Contaminated Sites

Location
Henry Parkes Drive, Jamberoo

LGA
THE COUNCIL OF THE MUNICIPALITY OF KIAMA

Data Source
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Scale
1:10000

Project

ID	Name	Address
	No data in mapped area.	

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Broadcrest Consulting Pty Ltd | ABN: 622 508 187

Client	Map
TerraInsight	Additional Sites for Consideration
Location	**LGA**
Henry Parkes Drive, Jambaroo	THE COUNCIL OF THE MUNICIPALITY OF KIAMA

Data Source
Google | Obtained on 30.1.2020
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Base map
...treet Maps | Obtained on 30.1.2020
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Scale
1:10000

Project

Appendix D: Historical Aerial Images

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MAPPING AND SPATIAL SERVICES
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Client	Date
TerraInsight	2019
Location	**LOT**
Henry Parkes Drive, Jambaroo	442 DP1201831

Data Source
Department of Finance, Services & Innovation
Copyright: Department of Finance, Services & Innovation

Base map (shown in blue)
Department of Finance, Services & Innovation
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Scale
1:1750

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MAPPING AND SPATIAL SERVICES
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Client	Date
TerraInsight	2010
Location	**LOT**
Henry Parkes Drive, Jambaroo	442 DP1201831

Data Source
Department of Finance, Services & Innovation
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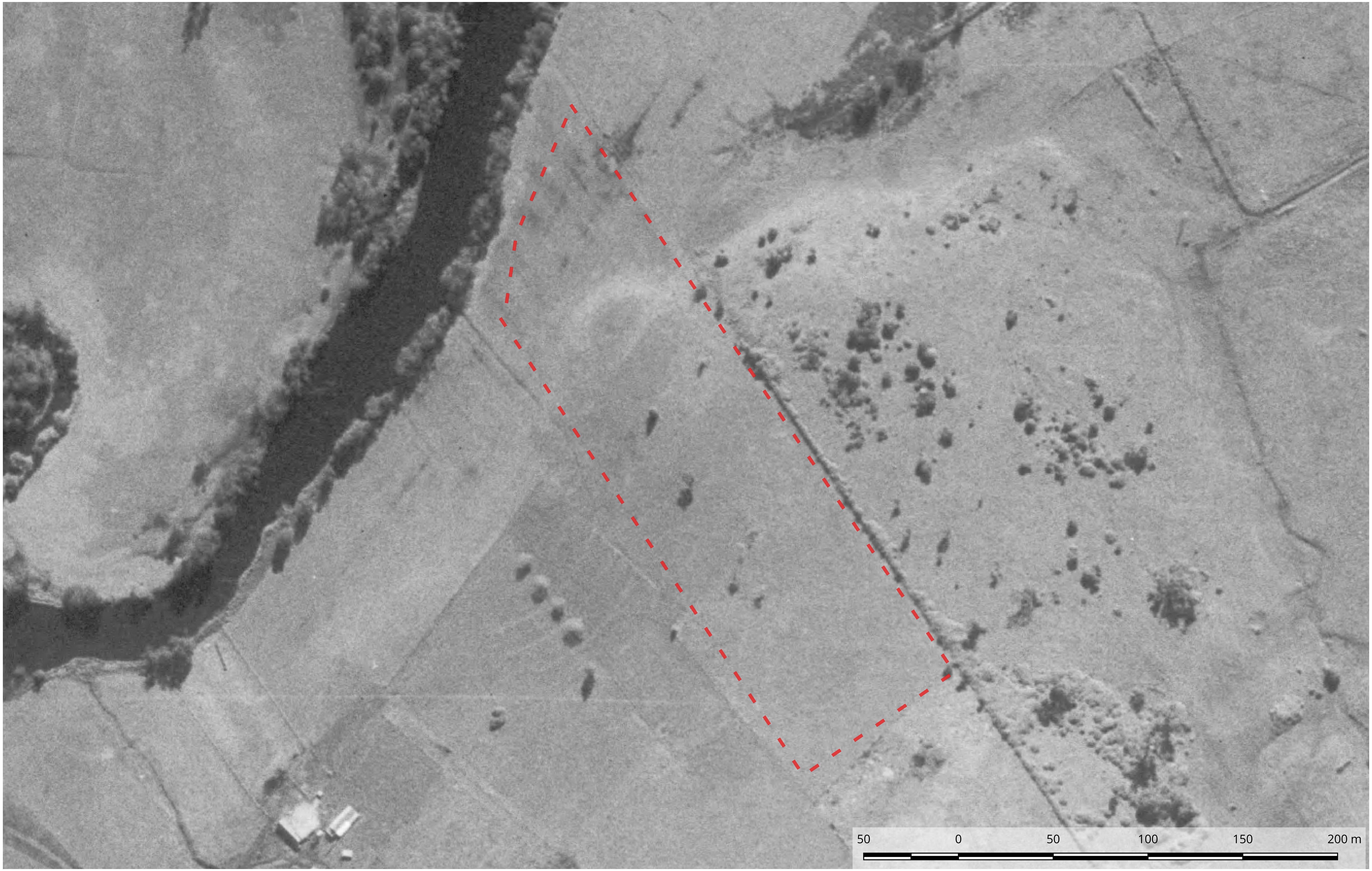
Base map (shown in blue)
Department of Finance, Services & Innovation
Copyright: Department of Finance, Services & Innovation

Scale
1:1750
Page

BROADCREST MAPPING AND SPATIAL SERVICES	Client	Date	Data Source	Scale
broadcrest.com.au | contact@broadcrest.com.au |1300 554 945	TerraInsight	1993	Department of Finance, Services & Innovation Copyright: Department of Finance, Services & Innovation	1:1750
Broadcrest Consulting Pty Ltd | ABN: 622 508 187	**Location**	**LOT**	**Base map (shown in blue)**	**Page**
	Henry Parkes Drive, Jambaroo	442 DP1201831	Department of Finance, Services & Innovation Copyright: Department of Finance, Services & Innovation	



BROADCREST
MAPPING AND SPATIAL SERVICES
broadcrest.com.au | contact@broadcrest.com.au |1300 554 945
Broadcrest Consulting Pty Ltd | ABN: 622 508 187

Client TerraInsight	**Date** 1984
Location Henry Parkes Drive, Jambaroo	**LOT** 442 DP1201831

Data Source
Department of Finance, Services & Innovation

Base map (shown in blue)
Department of Finance, Services & Innovation

Scale
1:1750
Page

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MAPPING AND SPATIAL SERVICES
broadcrest.com.au | contact@broadcrest.com.au |1300 554 945
Broadcrest Consulting Pty Ltd | ABN: 622 508 187

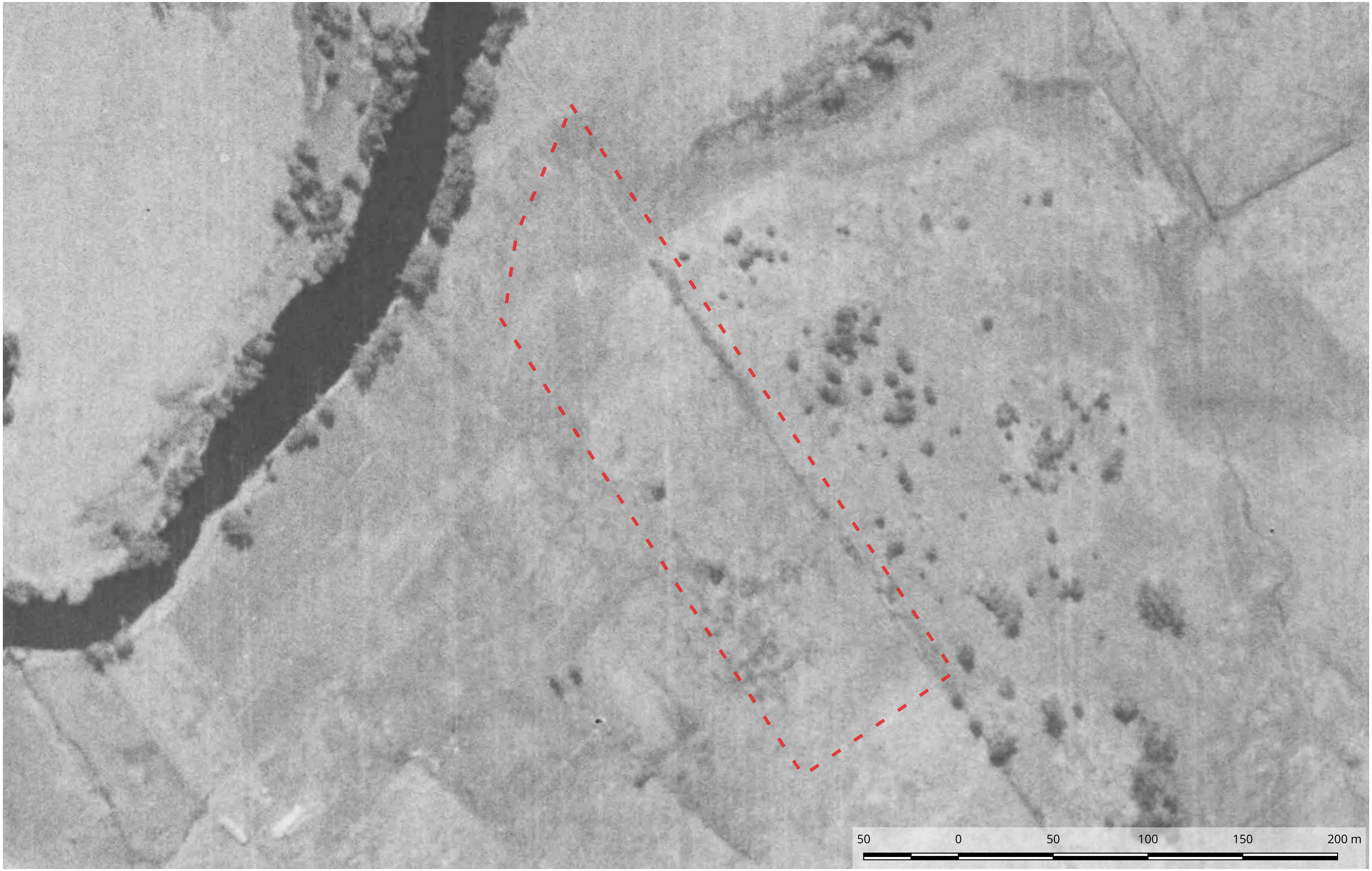
Client Terralnsight	**Date** 1974
Location Henry Parkes Drive, Jambaroo	**LOT** 442 DP1201831

Data Source
Department of Finance, Services & Innovation

Base map (shown in blue)
Department of Finance, Services & Innovation

Scale
1:1750

Page



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MAPPING AND SPATIAL SERVICES
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Broadcrest Consulting Pty Ltd | ABN: 622 508 187

Client TerraInsight	**Date** 1963
Location Henry Parkes Drive, Jambaroo	**LOT** 442 DP1201831

Data Source
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Scale
1:1750

Page

Appendix E: Site Images

Photograph 1: View of the site (area 1) from the Henry Parks Drive access point, looking along south-west boundary from within area 4.

Photograph 2: View of the site (area 1) from the Henry Parks Drive access point, looking along south-east boundary from area 4.

Photograph 3: View of the middle of Area 1, contains four mature trees.

Photograph 4: View of Area 1 looking towards residential development and rock wall along the eastern and southern boundaries.

revision	description	drawn	approved	date
	Plate1	XJ	KEG	31/01/2020

TERRA INSIGHT

client:	**Indesco**
project:	**Geotechnical Desk Study Investigation for Proposed Subdivision Lot 442 DP 1201831 Kiama Downs**
scale	NTS
Title	**Images of the site**
original size	**A3**
project no:	**TERRA19419**
Plate no:	**1**

Photograph 5: Small retaining wall on the southern boundary.

Photograph 6: View of Area 4. Area steeper than surrounding land, contains a sandstone boulder on the slope.

Photograph 7: View of Area 1 showing outcropping bedrock or a large boulder consistent with the site geology in the foreground.

Photograph 8: View of Area 4, centre of photograph.

revision	description	drawn	approved	date
	Plate2	XJ	KEG	31/01/2020

TERRA INSIGHT

client:	Indesco
project:	Geotechnical Desk Study Investigation for Proposed Subdivision Lot 442 DP 1201831 Kiama Downs
scale	NTS
Title	Images of the site
original size	A3
project no: TERRA19419	Plate no:2

Photograph 9: Centre of Area showing mature trees and pile of latite boulders.

Photograph 10: Pile of latite boulders on the centre of the site.

Photograph 11: Slopes on the western half of Area 1, looking north.

Photograph 12: Slopes of on the eastern side of area 1. Outcropping bedrock shown in the foreground, looking south.

revision	description	drawn	approved	date
	Plate3	XJ	KEG	31/01/2020

TERRA INSIGHT

client:	Indesco
project:	Geotechnical Desk Study Investigation for Proposed Subdivision Lot 442 DP 1201831 Kiama Downs
scale	NTS
Title	Images of the site
original size	A3
project no:	TERRA19419
Plate no:	3

Photograph 13: View looking north-west near the foot slopes of Area 1.

Photograph 14: View looking south-east near the foot slopes of Area 1.

Photograph 15: Centre of Area 1 from the north looking south.

Photograph 16: View along south-west boundary. Slight drainage depression in this area.

revision	description	drawn	approved	date
	Plate4	XJ	KEG	31/01/2020

TERRA INSIGHT

client:	Indesco
project:	Geotechnical Desk Study Investigation for Proposed Subdivision Lot 442 DP 1201831 Kiama Downs
scale	NTS
Title	Images of the site
original size	A3
project no:	TERRA19419
Plate no:	4

Photograph 17: View of outcropping boulders near mature trees.

Photograph 18: Exposed ground adjacent to trees containing gravelly clayey sand.

Photograph 19: View of lower lying part of site (Area 3), showing moderate to steep slopes on eastern side.

Photograph 20: View showing slopes of Area 3 are similar towards the east and extent of residential development to the east of the site.

revision	description	drawn	approved	date
	Plate5	XJ	KEG	31/01/2020

TERRA INSIGHT

client:	**Indesco**
project:	**Geotechnical Desk Study Investigation for Proposed Subdivision Lot 442 DP 1201831 Kiama Downs**
scale	NTS
Title	**Images of the site**
original size	**A3**
project no: **TERRA19419**	Plate no:**5**

Photograph 21: View of Area 3.

Photograph 22: View of Area 3 and the site from the north.

Photograph 23: gravelly clayey sand with cobbles visible in the slopes of Area 3.

Photograph 24: Land to the east of Area 2.

revision	description	drawn	approved	date
	Plate6	XJ	KEG	31/01/2020

TERRA INSIGHT

client:	Indesco
project:	Geotechnical Desk Study Investigation for Proposed Subdivision Lot 442 DP 1201831 Kiama Downs
scale	NTS
Title	Images of the site
original size	A3
project no: TERRA19419	Plate no:6

Photograph 25: Level land of Area 2, looking north.

Photograph 26: Level land of Area 2, looking west.

Photograph 27: Land to the north-west of Area 2.

Photograph 28: View looking towards Area 2 from the northern side of Area 1.

revision	description	drawn	approved	date
	Plate7	XJ	KEG	31/01/2020

TERRA INSIGHT

client:	Indesco
project:	Geotechnical Desk Study Investigation for Proposed Subdivision Lot 442 DP 1201831 Kiama Downs
scale	NTS
Title	Images of the site
original size	A3
project no:	TERRA19419
Plate no:	7

Appendix F: Appendix C of the journal, Australian Geomechanics, Vol. 42, No. 1, dated March 2007

APPENDIX C: LANDSLIDE RISK ASSESSMENT

QUALITATIVE TERMINOLOGY FOR USE IN ASSESSING RISK TO PROPERTY

QUALITATIVE MEASURES OF LIKELIHOOD

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

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

QUALITATIVE MEASURES OF CONSEQUENCES TO PROPERTY

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

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

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

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

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

QUALITATIVE RISK ANALYSIS MATRIX – LEVEL OF RISK TO PROPERTY

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

Notes: (5) For Cell A5, may be subdivided such that a consequence of less than 0.1% is Low Risk.

(6) When considering a risk assessment it must be clearly stated whether it is for existing conditions or with risk control measures which may not be implemented at the current time.

RISK LEVEL IMPLICATIONS

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

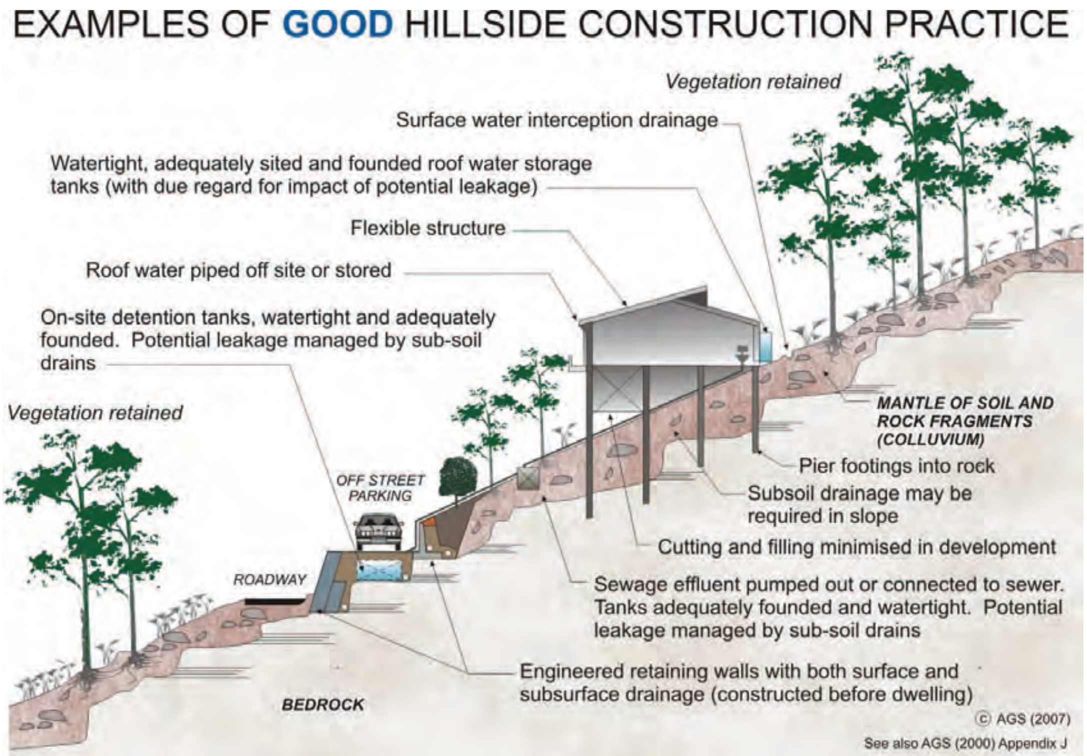
Note: (7) The implications for a particular situation are to be determined by all parties to the risk assessment and may depend on the nature of the property at risk; these are only given as a general guide.

Appendix G: GeoGuide Good Hillside practice guidelines LR08

AUSTRALIAN GEOGUIDE LR8 (CONSTRUCTION PRACTICE)

HILLSIDE CONSTRUCTION PRACTICE

Sensible development practices are required when building on hillsides, particularly if the hillside has more than a low risk of instability (GeoGuide LR7). Only building techniques intended to maintain, or reduce, the overall level of landslide risk should be considered. Examples of good hillside construction practice are illustrated below.



WHY ARE THESE PRACTICES GOOD?

Roadways and parking areas - are paved and incorporate kerbs which prevent water discharging straight into the hillside (GeoGuide LR5).

Cuttings - are supported by retaining walls (GeoGuide LR6).

Retaining walls - are engineer designed to withstand the lateral earth pressures and surcharges expected, and include drains to prevent water pressures developing in the backfill. Where the ground slopes steeply down towards the high side of a retaining wall, the disturbing force (see GeoGuide LR6) can be two or more times that in level ground. Retaining walls must be designed taking these forces into account.

Sewage - whether treated or not is either taken away in pipes or contained in properly founded tanks so it cannot soak into the ground.

Surface water - from roofs and other hard surfaces is piped away to a suitable discharge point rather than being allowed to infiltrate into the ground. Preferably, the discharge point will be in a natural creek where ground water exits, rather than enters, the ground. Shallow, lined, drains on the surface can fulfil the same purpose (GeoGuide LR5).

Surface loads - are minimised. No fill embankments have been built. The house is a lightweight structure. Foundation loads have been taken down below the level at which a landslide is likely to occur and, preferably, to rock. This sort of construction is probably not applicable to soil slopes (GeoGuide LR3). If you are uncertain whether your site has rock near the surface, or is essentially a soil slope, you should engage a geotechnical practitioner to find out.

Flexible structures - have been used because they can tolerate a certain amount of movement with minimal signs of distress and maintain their functionality.

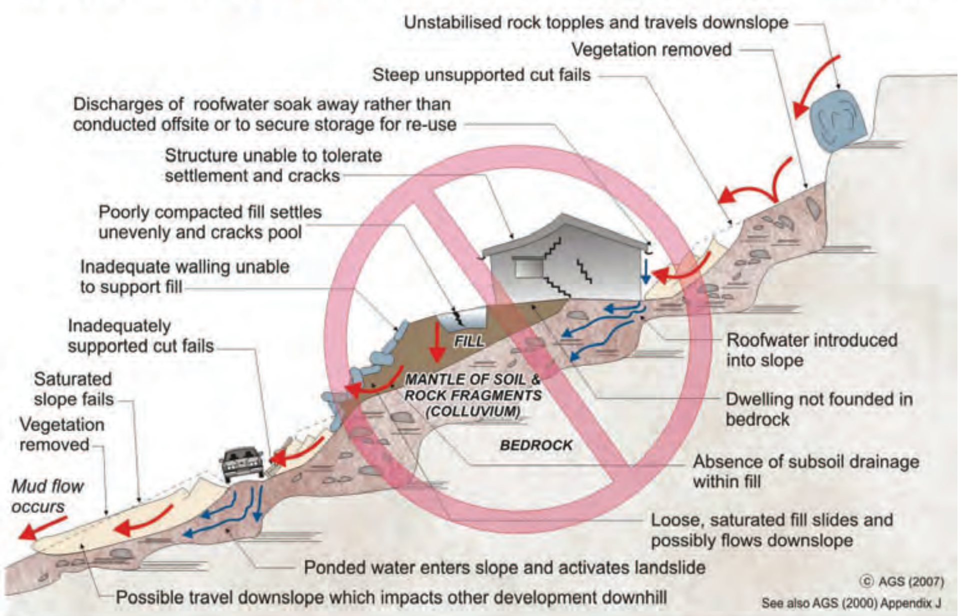
Vegetation clearance - on soil slopes has been kept to a reasonable minimum. Trees, and to a lesser extent smaller vegetation, take large quantities of water out of the ground every day. This lowers the ground water table, which in turn helps to maintain the stability of the slope. Large scale clearing can result in a rise in water table with a consequent increase in the likelihood of a landslide (GeoGuide LR5). An exception may have to be made to this rule on steep rock slopes where trees have little effect on the water table, but their roots pose a landslide hazard by dislodging boulders.

Possible effects of ignoring good construction practices are illustrated on page 2. Unfortunately, these poor construction practices are not as unusual as you might think and are often chosen because, on the face of it, they will save the developer, or owner, money. You should not lose sight of the fact that the cost and anguish associated with any one of the disasters illustrated, is likely to more than wipe out any apparent savings at the outset.

ADOPT GOOD PRACTICE ON HILLSIDE SITES

AUSTRALIAN GEOGUIDE LR8 (CONSTRUCTION PRACTICE)

EXAMPLES OF POOR HILLSIDE CONSTRUCTION PRACTICE



WHY ARE THESE PRACTICES POOR?

Roadways and parking areas - are unsurfaced and lack proper table drains (gutters) causing surface water to pond and soak into the ground.

Cut and fill - has been used to balance earthworks quantities and level the site leaving unstable cut faces and added large surface loads to the ground. Failure to compact the fill properly has led to settlement, which will probably continue for several years after completion. The house and pool have been built on the fill and have settled with it and cracked. Leakage from the cracked pool and the applied surface loads from the fill have combined to cause landslides.

Retaining walls - have been avoided, to minimise cost, and hand placed rock walls used instead. Without applying engineering design principles, the walls have failed to provide the required support to the ground and have failed, creating a very dangerous situation.

A heavy, rigid, house - has been built on shallow, conventional, footings. Not only has the brickwork cracked because of the resulting ground movements, but it has also become involved in a man-made landslide.

Soak-away drainage - has been used for sewage and surface water run-off from roofs and pavements. This water soaks into the ground and raises the water table (GeoGuide LR5). Subsoil drains that run along the contours should be avoided for the same reason. If felt necessary, subsoil drains should run steeply downhill in a chevron, or herring bone, pattern. This may conflict with the requirements for effluent and surface water disposal (GeoGuide LR9) and if so, you will need to seek professional advice.

Rock debris - from landslides higher up on the slope seems likely to pass through the site. Such locations are often referred to by geotechnical practitioners as "debris flow paths". Rock is normally even denser than ordinary fill, so even quite modest boulders are likely to weigh many tonnes and do a lot of damage once they start to roll. Boulders have been known to travel hundreds of metres downhill leaving behind a trail of destruction.

Vegetation - has been completely cleared, leading to a possible rise in the water table and increased landslide risk (GeoGuide LR5).

DON'T CUT CORNERS ON HILLSIDE SITES - OBTAIN ADVICE FROM A GEOTECHNICAL PRACTITIONER

More information relevant to your particular situation may be found in other Australian GeoGuides:

- GeoGuide LR1 - Introduction
- GeoGuide LR2 - Landslides
- GeoGuide LR3 - Landslides in Soil
- GeoGuide LR4 - Landslides in Rock
- GeoGuide LR5 - Water & Drainage
- GeoGuide LR6 - Retaining Walls
- GeoGuide LR7 - Landslide Risk
- GeoGuide LR9 - Effluent & Surface Water Disposal

GeoGuide LR10 - Coastal Landslides

- GeoGuide LR11 - Record Keeping

The Australian GeoGuides (LR series) are a set of publications intended for property owners; local councils; planning authorities; developers; insurers; lawyers and, in fact, anyone who lives with, or has an interest in, a natural or engineered slope, a cutting, or an excavation. They are intended to help you understand why slopes and retaining structures can be a hazard and what can be done with appropriate professional advice and local council approval (if required) to remove, reduce, or minimise the risk they represent. The GeoGuides have been prepared by the Australian Geomechanics Society, a specialist technical society within Engineers Australia, the national peak body for all engineering disciplines in Australia, whose members are professional geotechnical engineers and engineering geologists with a particular interest in ground engineering. The GeoGuides have been funded under the Australian governments' National Disaster Mitigation Program.

Appendix H: CSIRO BTF 18 Guidelines

Foundation Maintenance and Footing Performance: A Homeowner's Guide

CSIRO

BTF 18 replaces Information Sheet 10/91

Buildings can and often do move. This movement can be up, down, lateral or rotational. The fundamental cause of movement in buildings can usually be related to one or more problems in the foundation soil. It is important for the homeowner to identify the soil type in order to ascertain the measures that should be put in place in order to ensure that problems in the foundation soil can be prevented, thus protecting against building movement.

This Building Technology File is designed to identify causes of soil-related building movement, and to suggest methods of prevention of resultant cracking in buildings.

Soil Types

The types of soils usually present under the topsoil in land zoned for residential buildings can be split into two approximate groups – granular and clay. Quite often, foundation soil is a mixture of both types. The general problems associated with soils having granular content are usually caused by erosion. Clay soils are subject to saturation and swell/shrink problems.

Classifications for a given area can generally be obtained by application to the local authority, but these are sometimes unreliable and if there is doubt, a geotechnical report should be commissioned. As most buildings suffering movement problems are founded on clay soils, there is an emphasis on classification of soils according to the amount of swell and shrinkage they experience with variations of water content. The table below is Table 2.1 from AS 2870, the Residential Slab and Footing Code.

Causes of Movement

Settlement due to construction

There are two types of settlement that occur as a result of construction:

- Immediate settlement occurs when a building is first placed on its foundation soil, as a result of compaction of the soil under the weight of the structure. The cohesive quality of clay soil mitigates against this, but granular (particularly sandy) soil is susceptible.
- Consolidation settlement is a feature of clay soil and may take place because of the expulsion of moisture from the soil or because of the soil's lack of resistance to local compressive or shear stresses. This will usually take place during the first few months after construction, but has been known to take many years in exceptional cases.

These problems are the province of the builder and should be taken into consideration as part of the preparation of the site for construction. Building Technology File 19 (BTF 19) deals with these problems.

Erosion

All soils are prone to erosion, but sandy soil is particularly susceptible to being washed away. Even clay with a sand component of say 10% or more can suffer from erosion.

Saturation

This is particularly a problem in clay soils. Saturation creates a bog-like suspension of the soil that causes it to lose virtually all of its bearing capacity. To a lesser degree, sand is affected by saturation because saturated sand may undergo a reduction in volume – particularly imported sand fill for bedding and blinding layers. However, this usually occurs as immediate settlement and should normally be the province of the builder.

Seasonal swelling and shrinkage of soil

All clays react to the presence of water by slowly absorbing it, making the soil increase in volume (see table below). The degree of increase varies considerably between different clays, as does the degree of decrease during the subsequent drying out caused by fair weather periods. Because of the low absorption and expulsion rate, this phenomenon will not usually be noticeable unless there are prolonged rainy or dry periods, usually of weeks or months, depending on the land and soil characteristics.

The swelling of soil creates an upward force on the footings of the building, and shrinkage creates subsidence that takes away the support needed by the footing to retain equilibrium.

Shear failure

This phenomenon occurs when the foundation soil does not have sufficient strength to support the weight of the footing. There are two major post-construction causes:

- Significant load increase.
- Reduction of lateral support of the soil under the footing due to erosion or excavation.
- In clay soil, shear failure can be caused by saturation of the soil adjacent to or under the footing.

GENERAL DEFINITIONS OF SITE CLASSES

Class	Foundation
A	Most sand and rock sites with little or no ground movement from moisture changes
S	Slightly reactive clay sites with only slight ground movement from moisture changes
M	Moderately reactive clay or silt sites, which can experience moderate ground movement from moisture changes
H	Highly reactive clay sites, which can experience high ground movement from moisture changes
E	Extremely reactive sites, which can experience extreme ground movement from moisture changes
A to P	Filled sites
P	Sites which include soft soils, such as soft clay or silt or loose sands; landslip; mine subsidence; collapsing soils; soils subject to erosion; reactive sites subject to abnormal moisture conditions or sites which cannot be classified otherwise

Tree root growth

Trees and shrubs that are allowed to grow in the vicinity of footings can cause foundation soil movement in two ways:

- Roots that grow under footings may increase in cross-sectional size, exerting upward pressure on footings.
- Roots in the vicinity of footings will absorb much of the moisture in the foundation soil, causing shrinkage or subsidence.

Unevenness of Movement

The types of ground movement described above usually occur unevenly throughout the building's foundation soil. Settlement due to construction tends to be uneven because of:

- Differing compaction of foundation soil prior to construction.
- Differing moisture content of foundation soil prior to construction.

Movement due to non-construction causes is usually more uneven still. Erosion can undermine a footing that traverses the flow or can create the conditions for shear failure by eroding soil adjacent to a footing that runs in the same direction as the flow.

Saturation of clay foundation soil may occur where subfloor walls create a dam that makes water pond. It can also occur wherever there is a source of water near footings in clay soil. This leads to a severe reduction in the strength of the soil which may create local shear failure.

Seasonal swelling and shrinkage of clay soil affects the perimeter of the building first, then gradually spreads to the interior. The swelling process will usually begin at the uphill extreme of the building, or on the weather side where the land is flat. Swelling gradually reaches the interior soil as absorption continues. Shrinkage usually begins where the sun's heat is greatest.

Effects of Uneven Soil Movement on Structures

Erosion and saturation

Erosion removes the support from under footings, tending to create subsidence of the part of the structure under which it occurs. Brickwork walls will resist the stress created by this removal of support by bridging the gap or cantilevering until the bricks or the mortar bedding fail. Older masonry has little resistance. Evidence of failure varies according to circumstances and symptoms may include:

- Step cracking in the mortar beds in the body of the wall or above/below openings such as doors or windows.
- Vertical cracking in the bricks (usually but not necessarily in line with the vertical beds or perpends).

Isolated piers affected by erosion or saturation of foundations will eventually lose contact with the bearers they support and may tilt or fall over. The floors that have lost this support will become bouncy, sometimes rattling ornaments etc.

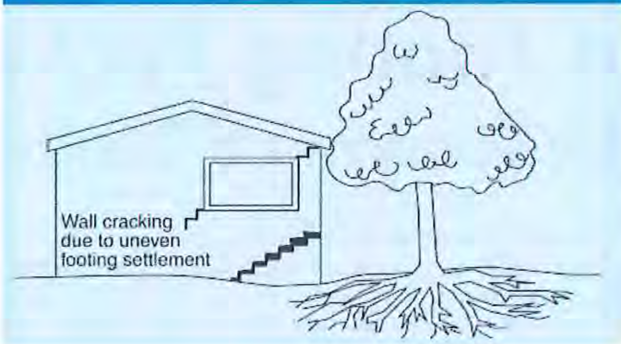
Seasonal swelling/shrinkage in clay

Swelling foundation soil due to rainy periods first lifts the most exposed extremities of the footing system, then the remainder of the perimeter footings while gradually permeating inside the building footprint to lift internal footings. This swelling first tends to create a dish effect, because the external footings are pushed higher than the internal ones.

The first noticeable symptom may be that the floor appears slightly dished. This is often accompanied by some doors binding on the floor or the door head, together with some cracking of cornice mitres. In buildings with timber flooring supported by bearers and joists, the floor can be bouncy. Externally there may be visible dishing of the hip or ridge lines.

As the moisture absorption process completes its journey to the innermost areas of the building, the internal footings will rise. If the spread of moisture is roughly even, it may be that the symptoms will temporarily disappear, but it is more likely that swelling will be uneven, creating a difference rather than a disappearance in symptoms. In buildings with timber flooring supported by bearers and joists, the isolated piers will rise more easily than the strip footings or piers under walls, creating noticeable doming of flooring.

Trees can cause shrinkage and damage



As the weather pattern changes and the soil begins to dry out, the external footings will be first affected, beginning with the locations where the sun's effect is strongest. This has the effect of lowering the external footings. The doming is accentuated and cracking reduces or disappears where it occurred because of dishing, but other cracks open up. The roof lines may become convex.

Doming and dishing are also affected by weather in other ways. In areas where warm, wet summers and cooler dry winters prevail, water migration tends to be toward the interior and doming will be accentuated, whereas where summers are dry and winters are cold and wet, migration tends to be toward the exterior and the underlying propensity is toward dishing.

Movement caused by tree roots

In general, growing roots will exert an upward pressure on footings, whereas soil subject to drying because of tree or shrub roots will tend to remove support from under footings by inducing shrinkage.

Complications caused by the structure itself

Most forces that the soil causes to be exerted on structures are vertical – i.e. either up or down. However, because these forces are seldom spread evenly around the footings, and because the building resists uneven movement because of its rigidity, forces are exerted from one part of the building to another. The net result of all these forces is usually rotational. This resultant force often complicates the diagnosis because the visible symptoms do not simply reflect the original cause. A common symptom is binding of doors on the vertical member of the frame.

Effects on full masonry structures

Brickwork will resist cracking where it can. It will attempt to span areas that lose support because of subsided foundations or raised points. It is therefore usual to see cracking at weak points, such as openings for windows or doors.

In the event of construction settlement, cracking will usually remain unchanged after the process of settlement has ceased.

With local shear or erosion, cracking will usually continue to develop until the original cause has been remedied, or until the subsidence has completely neutralised the affected portion of footing and the structure has stabilised on other footings that remain effective.

In the case of swell/shrink effects, the brickwork will in some cases return to its original position after completion of a cycle, however it is more likely that the rotational effect will not be exactly reversed, and it is also usual that brickwork will settle in its new position and will resist the forces trying to return it to its original position. This means that in a case where swelling takes place after construction and cracking occurs, the cracking is likely to at least partly remain after the shrink segment of the cycle is complete. Thus, each time the cycle is repeated, the likelihood is that the cracking will become wider until the sections of brickwork become virtually independent.

With repeated cycles, once the cracking is established, if there is no other complication, it is normal for the incidence of cracking to stabilise, as the building has the articulation it needs to cope with the problem. This is by no means always the case, however, and monitoring of cracks in walls and floors should always be treated seriously.

Upheaval caused by growth of tree roots under footings is not a simple vertical shear stress. There is a tendency for the root to also exert lateral forces that attempt to separate sections of brickwork after initial cracking has occurred.

The normal structural arrangement is that the inner leaf of brickwork in the external walls and at least some of the internal walls (depending on the roof type) comprise the load-bearing structure on which any upper floors, ceilings and the roof are supported. In these cases, it is internally visible cracking that should be the main focus of attention, however there are a few examples of dwellings whose external leaf of masonry plays some supporting role, so this should be checked if there is any doubt. In any case, externally visible cracking is important as a guide to stresses on the structure generally, and it should also be remembered that the external walls must be capable of supporting themselves.

Effects on framed structures
Timber or steel framed buildings are less likely to exhibit cracking due to swell/shrink than masonry buildings because of their flexibility. Also, the doming/dishing effects tend to be lower because of the lighter weight of walls. The main risks to framed buildings are encountered because of the isolated pier footings used under walls. Where erosion or saturation cause a footing to fall away, this can double the span which a wall must bridge. This additional stress can create cracking in wall linings, particularly where there is a weak point in the structure caused by a door or window opening. It is, however, unlikely that framed structures will be so stressed as to suffer serious damage without first exhibiting some or all of the above symptoms for a considerable period. The same warning period should apply in the case of upheaval. It should be noted, however, that where framed buildings are supported by strip footings there is only one leaf of brickwork and therefore the externally visible walls are the supporting structure for the building. In this case, the subfloor masonry walls can be expected to behave as full brickwork walls.

Effects on brick veneer structures
Because the load-bearing structure of a brick veneer building is the frame that makes up the interior leaf of the external walls plus perhaps the internal walls, depending on the type of roof, the building can be expected to behave as a framed structure, except that the external masonry will behave in a similar way to the external leaf of a full masonry structure.

Water Service and Drainage

Where a water service pipe, a sewer or stormwater drainage pipe is in the vicinity of a building, a water leak can cause erosion, swelling or saturation of susceptible soil. Even a minuscule leak can be enough to saturate a clay foundation. A leaking tap near a building can have the same effect. In addition, trenches containing pipes can become watercourses even though backfilled, particularly where broken rubble is used as fill. Water that runs along these trenches can be responsible for serious erosion, interstrata seepage into subfloor areas and saturation.

Pipe leakage and trench water flows also encourage tree and shrub roots to the source of water, complicating and exacerbating the problem.
Poor roof plumbing can result in large volumes of rainwater being concentrated in a small area of soil:

- Incorrect falls in roof guttering may result in overflows, as may gutters blocked with leaves etc.
- Corroded guttering or downpipes can spill water to ground.
- Downpipes not positively connected to a proper stormwater collection system will direct a concentration of water to soil that is directly adjacent to footings, sometimes causing large-scale problems such as erosion, saturation and migration of water under the building.

Seriousness of Cracking

In general, most cracking found in masonry walls is a cosmetic nuisance only and can be kept in repair or even ignored. The table below is a reproduction of Table C1 of AS 2870.

AS 2870 also publishes figures relating to cracking in concrete floors, however because wall cracking will usually reach the critical point significantly earlier than cracking in slabs, this table is not reproduced here.

Prevention/Cure

Plumbing
Where building movement is caused by water service, roof plumbing, sewer or stormwater failure, the remedy is to repair the problem. It is prudent, however, to consider also rerouting pipes away from the building where possible, and relocating taps to positions where any leakage will not direct water to the building vicinity. Even where gully traps are present, there is sometimes sufficient spill to create erosion or saturation, particularly in modern installations using smaller diameter PVC fixtures. Indeed, some gully traps are not situated directly under the taps that are installed to charge them, with the result that water from the tap may enter the backfilled trench that houses the sewer piping. If the trench has been poorly backfilled, the water will either pond or flow along the bottom of the trench. As these trenches usually run alongside the footings and can be at a similar depth, it is not hard to see how any water that is thus directed into a trench can easily affect the foundation's ability to support footings or even gain entry to the subfloor area.

Ground drainage
In all soils there is the capacity for water to travel on the surface and below it. Surface water flows can be established by inspection during and after heavy or prolonged rain. If necessary, a grated drain system connected to the stormwater collection system is usually an easy solution.

It is, however, sometimes necessary when attempting to prevent water migration that testing be carried out to establish watertable height and subsoil water flows. This subject is referred to in BTF 19 and may properly be regarded as an area for an expert consultant.

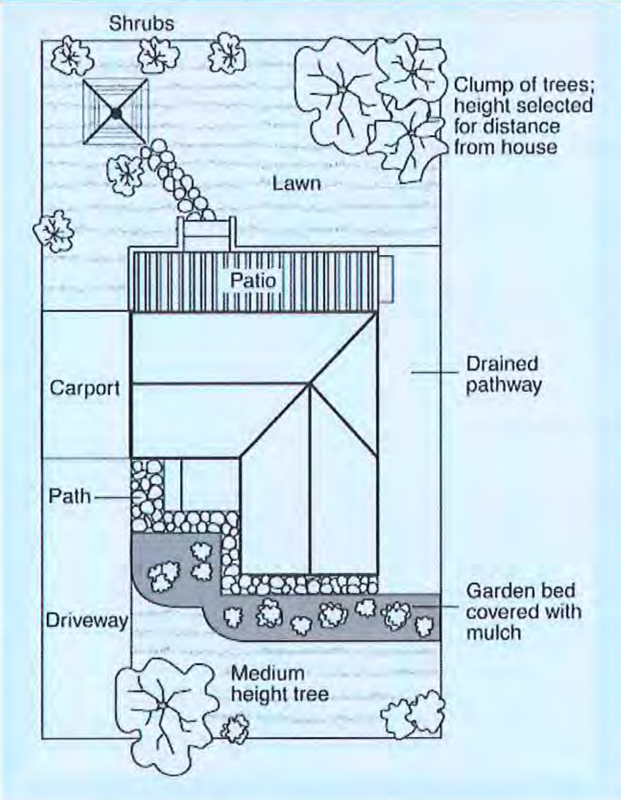
Protection of the building perimeter
It is essential to remember that the soil that affects footings extends well beyond the actual building line. Watering of garden plants, shrubs and trees causes some of the most serious water problems.

For this reason, particularly where problems exist or are likely to occur, it is recommended that an apron of paving be installed around as much of the building perimeter as necessary. This paving

CLASSIFICATION OF DAMAGE WITH REFERENCE TO WALLS

Description of typical damage and required repair	Approximate crack width limit (see Note 3)	Damage category
Hairline cracks	<0.1 mm	0
Fine cracks which do not need repair	<1 mm	1
Cracks noticeable but easily filled. Doors and windows stick slightly	<5 mm	2
Cracks can be repaired and possibly a small amount of wall will need to be replaced. Doors and windows stick. Service pipes can fracture. Weathertightness often impaired	5–15 mm (or a number of cracks 3 mm or more in one group)	3
Extensive repair work involving breaking-out and replacing sections of walls, especially over doors and windows. Window and door frames distort. Walls lean or bulge noticeably, some loss of bearing in beams. Service pipes disrupted	15–25 mm but also depend on number of cracks	4

Gardens for a reactive site



should extend outwards a minimum of 900 mm (more in highly reactive soil) and should have a minimum fall away from the building of 1:60. The finished paving should be no less than 100 mm below brick vent bases.

It is prudent to relocate drainage pipes away from this paving, if possible, to avoid complications from future leakage. If this is not practical, earthenware pipes should be replaced by PVC and backfilling should be of the same soil type as the surrounding soil and compacted to the same density.

Except in areas where freezing of water is an issue, it is wise to remove taps in the building area and relocate them well away from the building – preferably not uphill from it (see BTF 19).

It may be desirable to install a grated drain at the outside edge of the paving on the uphill side of the building. If subsoil drainage is needed this can be installed under the surface drain.

Condensation

In buildings with a subfloor void such as where bearers and joists support flooring, insufficient ventilation creates ideal conditions for condensation, particularly where there is little clearance between the floor and the ground. Condensation adds to the moisture already present in the subfloor and significantly slows the process of drying out. Installation of an adequate subfloor ventilation system, either natural or mechanical, is desirable.

Warning: Although this Building Technology File deals with cracking in buildings, it should be said that subfloor moisture can result in the development of other problems, notably:

- Water that is transmitted into masonry, metal or timber building elements causes damage and/or decay to those elements.
- High subfloor humidity and moisture content create an ideal environment for various pests, including termites and spiders.
- Where high moisture levels are transmitted to the flooring and walls, an increase in the dust mite count can ensue within the living areas. Dust mites, as well as dampness in general, can be a health hazard to inhabitants, particularly those who are abnormally susceptible to respiratory ailments.

The garden

The ideal vegetation layout is to have lawn or plants that require only light watering immediately adjacent to the drainage or paving edge, then more demanding plants, shrubs and trees spread out in that order.

Overwatering due to misuse of automatic watering systems is a common cause of saturation and water migration under footings. If it is necessary to use these systems, it is important to remove garden beds to a completely safe distance from buildings.

Existing trees

Where a tree is causing a problem of soil drying or there is the existence or threat of upheaval of footings, if the offending roots are subsidiary and their removal will not significantly damage the tree, they should be severed and a concrete or metal barrier placed vertically in the soil to prevent future root growth in the direction of the building. If it is not possible to remove the relevant roots without damage to the tree, an application to remove the tree should be made to the local authority. A prudent plan is to transplant likely offenders before they become a problem.

Information on trees, plants and shrubs

State departments overseeing agriculture can give information regarding root patterns, volume of water needed and safe distance from buildings of most species. Botanic gardens are also sources of information. For information on plant roots and drains, see Building Technology File 17.

Excavation

Excavation around footings must be properly engineered. Soil supporting footings can only be safely excavated at an angle that allows the soil under the footing to remain stable. This angle is called the angle of repose (or friction) and varies significantly between soil types and conditions. Removal of soil within the angle of repose will cause subsidence.

Remediation

Where erosion has occurred that has washed away soil adjacent to footings, soil of the same classification should be introduced and compacted to the same density. Where footings have been undermined, augmentation or other specialist work may be required. Remediation of footings and foundations is generally the realm of a specialist consultant.

Where isolated footings rise and fall because of swell/shrink effect, the homeowner may be tempted to alleviate floor bounce by filling the gap that has appeared between the bearer and the pier with blocking. The danger here is that when the next swell segment of the cycle occurs, the extra blocking will push the floor up into an accentuated dome and may also cause local shear failure in the soil. If it is necessary to use blocking, it should be by a pair of fine wedges and monitoring should be carried out fortnightly.

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Distributed by

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