Leeston Industrial - Land Constraints Assessment

Selwyn District Council

Flooding, Groundwater and Geotechnical Summary

IZ124100-0005-NP-RPT-0001 | 2

28 February 2020

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Leeston Industrial - Land Constraints Assessment

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2	28.02.20	Updated Final	CR	EM	AH

Contents

Important note about your report

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An assessment or study of on-site conditions investigates the potential for exposure to the presence of inadequate bearing ground. All reports and conclusions that deal with sub-surface conditions are based on interpretation and judgement and as a result have uncertainty attached to them. You should be aware that this report contains interpretations and conclusions which are uncertain, due to the nature of a desktop investigation. No study can investigate every risk, and even a rigorous assessment and/or sampling programme may not detect all problem areas within a site.

This report is based on assumptions that the site conditions as revealed through the desktop study are indicative of conditions throughout the site. The findings are the result of standard assessment techniques used in accordance with normal practices and standards, and (to the best of Jacobs' knowledge) they represent a reasonable interpretation of the current conditions on the site.

Conditions encountered when site work commences may be different from those inferred in this report, for the reasons explained in this limitation statement. If site conditions encountered during site works are different from those anticipated following Jacobs' desktop investigation, Jacobs reserves the right to revise any of the findings, observations and conclusions expressed in this report.

In preparing this report, Jacobs has relied upon, and presumed accurate, any information (or confirmation of the absence thereof) provided by the Client and/or from other sources. Except as otherwise stated in the report, Jacobs has not attempted to verify the accuracy or completeness of any such information. If the information is subsequently determined to be false, inaccurate or incomplete then it is possible that our observations and conclusions as expressed in this report may change.

Jacobs derived the data in this report from information sourced from the Client and/or available in the public domain at the time or times outlined in this report. The passage of time, manifestation of latent conditions or impacts of future events may require further examination of the project and subsequent data analysis, and re-evaluation of the data, findings, observations and conclusions expressed in this report. Jacobs has prepared this report in accordance with the usual care and thoroughness of the consulting profession, for the sole purpose described above and by reference to applicable standards, guidelines, procedures and practices at the date of issue of this report. For the reasons outlined above, however, no other warranty or guarantee, whether expressed or implied, is made as to the data, observations and findings expressed in this report, to the extent permitted by law.

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1. Flooding, Groundwater and Geotechnical Summary

1.1 Introduction

Selwyn District Council (SDC) is considering extending the Business 2 (Industrial) Zone in the east of Leeston Township. The Indicative Site area (SDC reference LEE3) is shown in red in **Figure 1.1**. This report summarises an assessment of the land constraints that apply to the identified site. The constraints considered in this summary report are flooding, shallow groundwater and geotechnical. The full information for flooding and shallow groundwater is provided as Appendix A[1], and for geotechnical as Appendix B[2].

Figure 1.1: Map shows land to the east of Leeston, with the indicative site boundary in red proposed for rezoning to Business 2 (Industrial)

This report identifies whether, and to what extent, these flooding, shallow groundwater and geotechnical land constraints may affect rezoning of this land for industrial purposes. The report also identifies how any constraints on subsequent land use activities could be addressed through existing regulation and/or provides recommendations for how these matters can be addressed. The information in this report could be used to inform an Outline Development Plan and/or a Section 32 report which will be prepared by Selwyn District Council.

[1] Leeston Industrial - Land Constraints Assessment Flooding and Shallow Groundwater Report. IZ124100-0005-NC-RPT-000. 12 April 2019
[2] Jacobs (2019) Leeston Industrial Site Geotechnical Desk Study. IZ124100-0005-CG-RPT-0001. 12 April 2019

1.2 Land Constraints Summary

With respect to the assessments in the vicinity of the Indicative Site, the following key points were noted:

- The site can be considered as two separate portions; the northern portion (north of Volckman Road) having higher existing ground levels than the southern portion (south of Volckman Road) and therefore having a lower exposure to flooding;
- No geotechnical issues have been identified with the site's historical use. There are also no signs of damage historically due to seismic activity. Information for lateral spreading and ground cracking does not show any risk in this area. Liquefaction mapping based on aerial photographs identify the site and surrounding area as being unlikely to be subject to damaging liquefaction. However, due to the low plasticity silts reported in the nearby investigations as well as the high groundwater in the area, it is recommended that liquefaction is considered for future developments on the site. It is recommended that during future development, this material is removed beneath foundations. This material is of low strength when saturated and also may be susceptible to liquefaction should a seismic event impact the site. Any material removed, however, should be built back up with appropriate fill (and, possibly, to a higher level) due to the shallow ground water;
- Based on predictions of depths in the 10 year and 50 year ARI events with climate change, flooding across the Indicative Site is typically shallow, with the southern portion having overland flow routes in a south-easterly direction from Station Street. Access via the surrounding roads (Station Street, Volckman Road and Leeston Road) appears to be largely dry in events up to and including the 50 year ARI event;
- Predictions of flood hazard in 500 year ARI events, including allowance for climate change, have demonstrated that the site does not need to be classified as high hazard (high depth and/or velocity) in accordance with Policy 11.3.1 of the Canterbury Regional Policy Statement;
- However, predictions of flood depths in 200 year ARI events, including allowance for climate change, have demonstrated that the southern portion of the site should have minimum floor levels set above the 200 year flood level, in accordance with Policy 11.3.2 of the Canterbury Regional Policy Statement;
- Average and maximum seasonal groundwater levels across the site are currently shallow, and could be within 1 m of the ground surface. Information is available which indicates that whilst groundwater may not get any shallower with climate change, levels could increase with the Central Plains Irrigation scheme; and
- The proposed Leeston Stormwater Bypass could pass along Volckman Road and therefore could provide some reduction in flood risk at the site if appropriately designed. There is an opportunity to include capture of overland flow routes across the southern portion of the site in the upcoming design.

The information has been used to identify how any constraints on subsequent land use activities from flooding, shallow groundwater and geotechnical perspectives could be addressed through existing regulation. The key outcomes from this review are summarised in Table 1.1.

Table 1.1: Summary of planning provisions considered, and how they could apply to the Indicative Site

Existing Regulation Review Summary	Recommendations for the Indicative Site
Canterbury Regional Policy Statement Policy 11.3.1 seeks to avoid inappropriate development in high hazard areas, defined as the water depth multiplied by the velocity being greater than or equal to 1, or where depths are greater than 1 metre, in a 500 year ARI flood event	Modelling of the 500 year ARI event with an allowance for climate change has demonstrated that the site does not need to be classified as a high hazard area.
Canterbury Regional Policy Statement Policy 11.3.2 seeks to avoid inappropriate development in areas subject to inundation, where new buildings should have floor levels above the 200-year ARI design flood level, and hazardous substances should not be inundated during the event	Modelling of the 200 year ARI event with an allowance for climate change has demonstrated that the southern portion of the site is at risk of flood depths of up to 0.5m. It is recommended that minimum floor levels are set for at least the southern portion of the site, and that hazardous substances should not be inundated in such an event.
Canterbury Regional Policy Statement Policy 11.3.5 seeks a general risk management approach to avoid development where	In addition to the setting of minimum floor levels in the southern portion of the site, the occurrence of shallow ponding and overland

Existing Regulation Review Summary	Recommendations for the Indicative Site
the risk of natural hazards is unacceptable, and to appropriately assess and mitigate the risk elsewhere	flow routes across the site should be appropriately mitigated without increasing the risk of flooding elsewhere. This includes not displacing surface or groundwater elsewhere. Mitigations should be considered alongside the proposed Leeston Stormwater Bypass along Volckman Road.
Selwyn District Plan Chapter 14 only sets floor levels for buildings in residential areas within a flood area or flood plain according to the SDP.	The Indicative Site is at risk of overland flow and shallow groundwater in a 50 year ARI event. However, the Selwyn District Plan does not set floor levels for buildings in a Business Zone, and the Indicative Site is not within a flood area or flood plain according to the SDP. Further, the Building Code does not regulate floor levels for industrial sites and, therefore, the Code cannot be used by SDC to set floor levels above the risk of flooding and shallow groundwater. It is recommended that a mechanism to set floor levels is considered, in addition to filling of land.
Selwyn District Plan Chapter 14 sets limits on earthworks for building foundations, although excludes earthworks in Business Zones	Due to the low plasticity silts reported in investigations near the site, as well as the high groundwater in the area, it is recommended that liquefaction is considered for future developments on the site. It is recommended that during future development, this material is removed beneath foundations. This material is of low strength when saturated and also may be susceptible to liquefaction should a seismic event impact the site. Since earthworks for building foundations in Business Zones are exempt from the rules, there are no limits when constructing a building platform and therefore, under the SDP, the land at the Indicative Site could be filled using a suitable material to raise it above the risk of inundation by overland flowroutes and shallow groundwater. However, it should be demonstrated that filling will not exacerbate flooding on adjacent properties.
Selwyn District Plan rule B3.1.6 requires that any measures to mitigate a potential natural hazard do not lead to or intensify a potential natural hazard elsewhere	In addition to checking that any filling of land at the site does not lead to an increase in flood hazard on adjacent properties, it is recommended that no subsurface infrastructure (e.g. sheet piling) which is likely to alter the natural flow of groundwater – and in particular which could cause it to mound upstream of the site – is constructed. As above, measures should be considered alongside the proposed Leeston Stormwater Bypass along Volckman Road.
Selwyn District Plan rule B4.3.54 requires rezoned land not to cause, or exacerbate, a natural hazard by increasing the rate of stormwater runoff into the Leeston main drain.	Rezoning and subsequent development of the site has the potential to increase the impervious area of the site and therefore increase the discharge into the Leeston Main Drain. Therefore, measures should be considered on the site to minimise this increase in discharge, and design of the proposed Leeston Stormwater Bypass should consider accommodating any residual increase in flows from the site. In particular, the overland flow paths across the southern portion of the site should either be captured and routed into the Leeston Stormwater Bypass, or allowed to pass safely across the site.
Selwyn District Plan Requirement for new developments to provide onsite stormwater retention to mitigate anticipated increase in impervious area as well as the potential increase in contaminated stormwater runoff	There is currently no requirement for industrial buildings to provide onsite stormwater retention, however this must be viewed alongside the above requirement not to increase the rate of stormwater runoff (e.g. flooding effects) into the Leeston main drain. Recommended that the ODP demonstrate how the local stormwater network will be able to accommodate the increased capacity, and what improvements are needed, consideration should be given to how the anticipated increase in impervious area associated with the rezoning, as well as the potential increase in

Existing Regulation Review Summary	Recommendations for the Indicative Site
	contaminated stormwater runoff, could be mitigated through onsite systems, and how the Leeston Stormwater Bypass design can accommodate any increase associated with the development.
Land & Water Regional Plan limits excavations in sites overlying aquifers and/or adjacent to watercourses	The Indicative Site overlies a semi-confined/unconfined aquifer which triggers rules for any excavations. However, with the seasonal water table being so shallow, no permanent excavation (i.e. lowering of ground levels) of the site is recommended.
Land & Water Regional Plan limits discharge of stormwater to land located at least 1 m above the seasonal high water table	Available records show that the seasonal high water table could be within 1 m of the ground surface, and may become shallower in the future. Therefore, as above, it may be necessary for stormwater to be attenuated on site prior to discharge into the Leeston Stormwater Bypass due to increase flood risk, which must be designed to accommodate any additional inflow.

1.3 Recommendations

The whole of the Indicative Site is at risk of shallow groundwater, with the southern portion of the site additionally at risk of overland flow. A combination of the following mitigations is recommended:

1. **Do not *permanently* lower existing ground levels through excavation.** However, during future development of the site, it is recommended that the existing surface layer of material which is susceptible to liquefaction is removed beneath foundations, and the site filled using a suitable material. Since the site overlies a semi-confined/unconfined aquifer, earthworks are subject to standards in the Land & Water Regional Plan. Due to the size of the site, the volume of excavation is likely to exceed 100 m^3 and could be required to a depth within 1 m of the seasonal high water table. Therefore, resource consent will be required from Environment Canterbury, which will allow SDC to demonstrate how the effects of the excavation can be mitigated. This could include reinforcing that the excavation is temporary, and could be undertaken when groundwater levels are at their lowest.
2. **Raise building platforms levels above shallow groundwater and overland flow.** It is recommended that changes to the Selwyn District Plan, sets rules on earthworks for building foundations so there are limits when constructing a building platform. that require demonstration that filling at the site will not exacerbate flooding on adjacent properties. Building platforms at the Indicative Site should be filled using a suitable material to raise them above the risk of inundation by shallow groundwater and overland flow.
3. **Set minimum floor levels above future 200 year ARI flood levels.** The southern portion of the site is subject to overland flow and ponding in the 200 year ARI event, including an allowance for climate change. The Selwyn District Plan does not set floor levels for buildings in a Business Zone, and the Indicative Site is not within a flood area or flood plain according to the Selwyn District Plan. Further, the Building Code does not regulate floor levels for industrial sites. Although there is no existing planning provision by which SDC can set minimum floor levels for future development, changes are proposed through the District Plan Review. The Review is proposing to constrain development in in areas that are subject to inundation during a one in 200 year flood event. The constraint will likely be in the form of site-specific floor level assessments for principal buildings and hazardous substances storage areas, and restrictions on earthworks. This approach is supported by this study.
4. **Manage groundwater and overland flow through the site.** The site is a natural pathway for shallow groundwater and overland flow, approximately from Station Street / Leeston Road to Beethams Road. Therefore, measures to manage the risk to the future development of the site must not lead to or intensify these hazards elsewhere. In addition to ensuring subsurface structures do not impede or alter the natural flow of groundwater, overland flows could either be (i) intercepted before entering the site and routed into the Leeston Main Drain (with the additional inflows accommodated as part of the design of the Leeston Stormwater Bypass) or (ii) routed across the site using the proposed reserve/road layout in the ODP and linking to on site attenuation. It should be ensured that any proposed ODP road design has the capacity to manage the anticipated volume of stormwater.

5. **Discharge attenuated stormwater to Leeston Main Drain.** Since the seasonal high water table could be within 1 m of the ground surface, the Land & Water Regional Plan limits discharge to land. Therefore, discharge to the Leeston Main Drain is suggested. However, the development should not cause, or exacerbate, a natural hazard by increasing the rate of stormwater runoff. Therefore, stormwater discharge must be attenuated to greenfield rates through onsite storage to mitigate the anticipated increase in imperviousness. Neither the Selwyn District Plan, nor the Land & Water Regional Plan, currently require industrial buildings to provide onsite stormwater retention. It is recommended that SDC introduce thresholds of impervious surface areas that, when exceeded, require the provision of onsite stormwater retention. This will assist in managing the rate of stormwater discharge from developed land to the Council system. SDC have commissioned a separate report on servicing that includes stormwater management,

Whilst all implications of Table 1.1 should be carefully considered, the following is recommended for immediate action:

1. Measures should be considered on the site to minimise any increase in discharge due to an increase in impervious land cover. These should be considered together with the design of the proposed Leeston Stormwater Bypass which could potentially accommodate any residual increase in flows from the site. In particular, the overland flow paths across the southern portion of the site should either be captured and routed into the Leeston Stormwater Bypass, or allowed to pass safely across the site without risking inundation of floor levels and any stored hazardous substances.

It is recommended that the above recommendations should be taken into account when preparing the Outline Development Plan to be included in the District Plan Our analysis has suggested a successful plan change is possible by considering the options of filling land following removal of liquefaction-prone material, setting minimum floor levels, attenuation on site and integrating future development with the Leeston Stormwater Bypass.

Appendix A. Flooding and Shallow Groundwater Report

Leeston Industrial - Land Constraints Assessment

Selwyn District Council

Flooding and Shallow Groundwater Report

IZ124100-0005-NC-RPT-0001 | 2

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1. Introduction

1.1 Purpose of this Report

Selwyn District Council (SDC) is considering extending the Business 2 (Industrial) Zone in the south-east of Leeston Township. The Indicative Site area (SDC reference LEE3) is shown in red in Figure 1.1. This report covers an assessment of the land constraints that apply to the identified site. The constraints considered in this report are flooding and shallow groundwater, with geotechnical risks considered in the accompanying report[1].

Figure 1.1: Map shows land to the south east of Leeston, with the indicative site boundary in red proposed for rezoning to Business 2 (Industrial)

[1] Jacobs (2019) Leeston Industrial Site Geotechnical Desk Study. IZ124100-0005-CG-RPT-0001. 12 April 2019

This report identifies whether, and to what extent, these flooding and shallow groundwater land constraints may affect rezoning of this land for industrial purposes. The report also identifies how any constraints on subsequent land use activities could be addressed through existing regulation and/or provides recommendations for how these matters can be addressed. This may include any site-specific rules or notations on an Outline Development Plan and/or a Section 32 report (see Appendix B for descriptions of these) to be included in the District Plan. The information in this report could be used to inform an Outline Development Plan and/or a Section 32 report which will be prepared by Selwyn District Council.

1.2 Description of the Site

The Indicative Site (SDC reference LEE3) occupies four different land parcels as labelled in Figure 1.1. This report will refer to the site area encompassed within Lots 1 DP 35608 and DP 16759 to the north of Volckman Road as the northern portion of the site. The site area encompassed within Part Lot 1 DP 6603 and Lot 2 DP 6603 to the south of Volckman Road will be referred to as the southern portion of the site.

The Indicative Site is located to the south east of Leeston Township and at a distance of approximately 5 km northwest of Lake Ellesmere. The topography of the land is broadly sloped in the southeast direction towards Lake Ellesmere, with an approximate 5 m elevation difference between the north west and south east of Leeston. Reflecting this topography, the general overland flow direction is from northwest to southeast draining to Lake Ellesmere. Elevation data shows that the northern portion of the site is approximately 1 m higher than the southern portion.

There are two waterways in the immediate vicinity of the Indicative Site, which are an open drain that runs adjacent to the southern side of Volckman Road (referred to in the Selwyn District Plan as the Leeston Main Drain), which is fed by Leeston Creek. Leeston Creek conveys floodwater from the largely rural land surrounding the north of Leeston Township through the township and into the Leeston Main Drain. This eventually drains into Lake Ellesmere. There is also a smaller (unnamed) open drain which runs through the middle of the southern portion of the Indicative Site, which also likely receives flow from the Leeston Creek.

There are currently two different uses of the land within the Indicative Site. The northern portion is predominantly occupied by Millars Tractor Spares and several other commercial buildings. The southern portion remains rural, with open pasture and some trees forming shelter belts. Volckman Road effectively separates the already developed and undeveloped portions of the Indicative Site.

1.3 Methodology

This report summarises the findings of a desktop assessment, based on the information made available by SDC and identified elsewhere. Information relating to the following topics was reviewed, with references provided in the footnotes:

- past flooding[2,3];
- current and predicted future groundwater levels;
- modelled flooding for the 50-year ARI[4] event;
- predicted impacts of the proposed Leeston Stormwater Bypass[5,6];
- shallow groundwater levels around the site[7,8]; and

[2] https://www.tvnz.co.nz/one-news/new-zealand/its-coming-right-around-house-leeston-residents-rush-salvage-furniture-latest-floods-fuel-frustration
[3] https://www.newshub.co.nz/nznews/leeston-coping-after-flooding-2013062317
[4] Annual Recurrence Interval
[5] https://www.selwyn.govt.nz/services/water/stormwater/leeston-stormwater-bypass
[6] Aurecon (2017) Leeston Township Stormwater Modelling Report. Revision: 1. Reference: 227110. 23 June 2017
[7] Golder (2017) REVIEW OF INTERNATIONAL CASE STUDIES. Protection Options for Managing Rising Groundwater in South Dunedin. Report Number: 1671023_7410-004-R-Rev2. July 2017
[8] Aqualinc (2017) Memorandum to Murray England from Mark Flintoft. Shallow Groundwater Levels. 10 March 2017

- Selwyn District Plan, the Canterbury Regional Policy Statement and the Canterbury Land and Water Regional Plan.

It is noted that flooding is referred to throughout this report as the inundation of land not usually covered by water. In Leeston, this can arise from rainfall (also potentially snow, hail etc) ponding on the ground surface and flowing overland, open drains and pipe networks exceeding their capacity and groundwater rising to at or near the surface. Groundwater is sometimes referred to explicitly as its mechanisms and management can be significantly different from the more obvious surface water sources.

Further, it is noted that the Indicative Site lies outside of the floodplain of the Selwyn River to the north and Rakaia River to the south, and the Tsunami Evacuation area as defined by Environment Canterbury. Therefore, these sources of flooding have not been considered further.

1.4 Report Structure

To reflect the above methodology, this report is structured as follows, with technical information on flood risk and shallow groundwater being presented ahead of how this could be used to inform planning provisions:

- Section 2: Past Flooding
- Section 3: Flood Modelling and the Leeston Bypass
- Section 4: Shallow Groundwater
- Section 5: Summary and Recommendations

Section 5 consolidates this information to recommend how it could be considered within an Outline Development Plan.

2. Past Flooding in Leeston

In June 2013 and August 2017, Leeston Township experienced significant flood events. Each of these events gained national news coverage and resulted in inundation of the township and surrounding areas. The flooding originates primarily from the Leeston main drain which is fed upstream by Leeston Creek.

Figure 2.1 shows an aerial photograph taken following the June 2013 flooding. The Indicative Site area is outlined in red. It should be noted that this photograph was likely taken after the peak of the flooding had occurred, so does not represent the maximum extent of flooding. Nonetheless, it does indicate that only minimal surface flooding occurred within the Indicative Site, whereas significant pooling of water was observed directly adjacent to the southern portion of the site (near the waste water treatment works), as well as across Leeston Road from the northern portion of the site.

Figure 2.1: June 2013 flooding aerial photograph with the Indicative Area outlined in red.

Several more aerial photographs were captured of this event, which are shown in Appendix A. In these, overland flow paths can be seen flowing across the southern portion of the site, and that other areas in the Leeston Township and surrounding area experienced inundation of flood water.

In response to the June 2013 flooding, a public meeting was held in July 2013[9]. As a result of this the Community asked SDC to investigate options to divert flood waters from the surrounding land around the township and manage localised flooding. These options were then presented back to the Community and resulted in the decision that SDC would implement the Leeston Stormwater Bypass and direct the floodwater captured by Leeston Creek upstream of the township around the town. As summarised in Section 3, the bypass is proposed to improve drainage along Volckman Road which could modify flood risk at the Indicative Site.

[9] https://www.selwyn.govt.nz/services/water/stormwater/leeston-stormwater-bypass

3. Flood Modelling and the Leeston Bypass

3.1 Existing Scenario Flood Modelling

SDC have produced a flood depth map for a 50-year storm event, including 16% rainfall increase for climate change. Figure 3.1 shows the Indicative Site overlaid with the flood depths. This modelling shows that in a 50-year event the study area could experience flood depths of up to 500 mm. The northern portion of the study area, which is higher, has low predicted depths (approximately 10 mm), whereas the lower southern portion has small areas of depths up to approximately 500 mm. These areas of greater depth show a similar pattern of overland flow as in the aerial photograph from the June 2013 flooding (Figure 2.1).

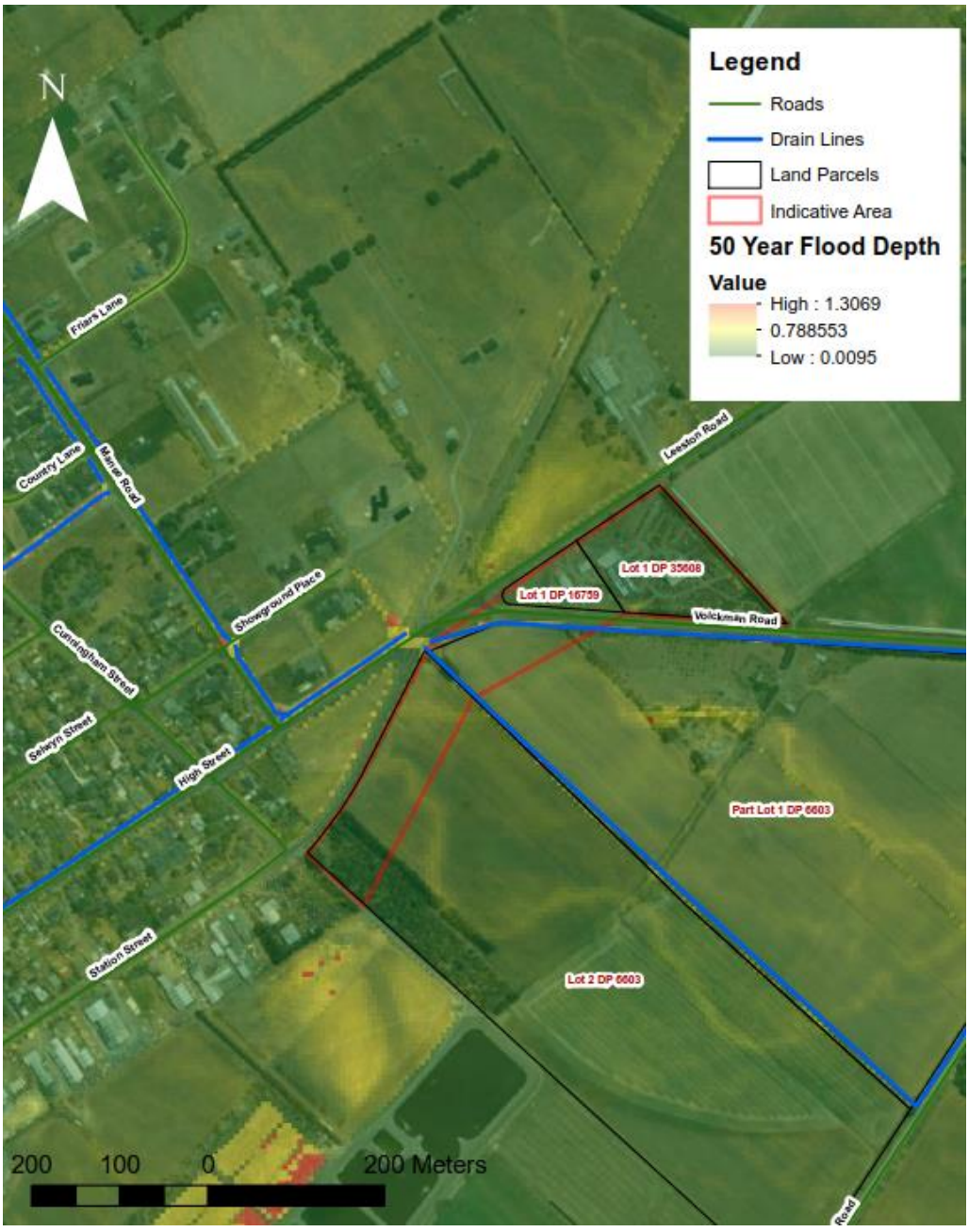

Figure 3.1: Flood depths in the 50-year ARI event, with 16% climate change rainfall increase

As part of the supporting material for the Leeston Stormwater Bypass (see next Section), Aurecon also produced existing scenario flood depth and inundation maps for the 10-year and 50-year ARI flood events, which included an allowance for climate change[10]. This scenario represented peak flows in the Leeston Creek to continue through the Township in the existing channels and pipe network.

The flood maps are shown in Figure 3.2 and Figure 3.3 with the Indicative Site outlined in red. Both the 10-year and the 50-year ARI results show no inundation in the northern portion of the site. Several overland flow paths can be seen for both flood events through the southern portion of the site. The inundation occurring within the southern portion in a 10-year ARI event reaches a maximum depth of between 0.10 – 0.15 m, and in a 50-year ARI event reaches maximum depths of between 0.20 – 0.35 m. However, these maximum depths occur only in a small area of the southern portion of the site and most flood depths are between 0.0 – 0.1 m.

Immediately outside the Indicative Site area, the 10-year event shows little to no flooding occurring around the northern portion of the site, but does indicate some flooding around the southern portion, including across Station Street. For the 50-year ARI event, some concentrated flooding is shown to the north of both the northern and southern portions of the site.

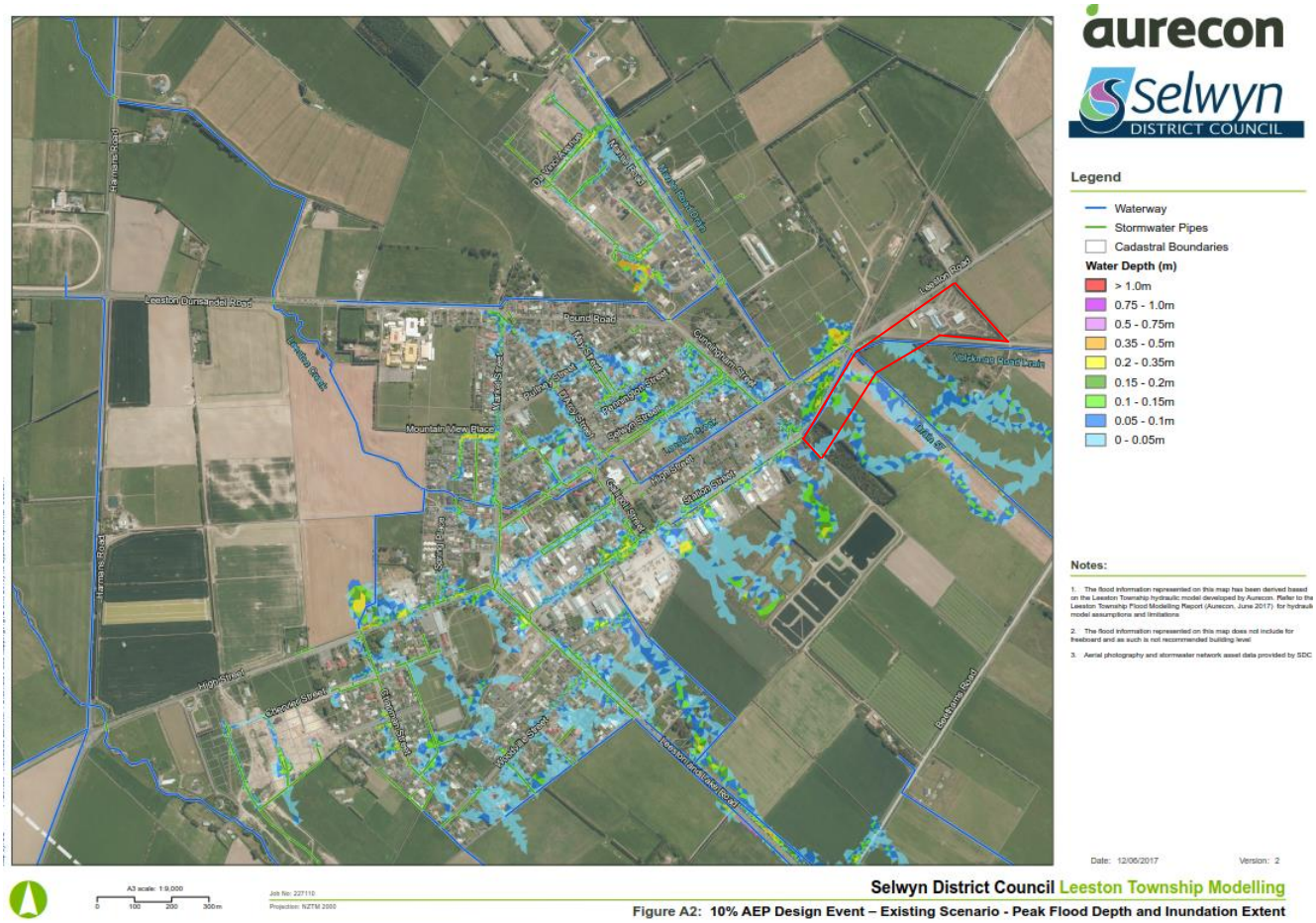

Figure 3.2: Flood depths in the 10-year ARI event (with climate change). Indicative site area is outlined in red. Taken from Aurecon (2017)

[10] Aurecon (2017) Leeston Township Stormwater Modelling Report. Revision: 1. Reference: 227110. 23 June 2017

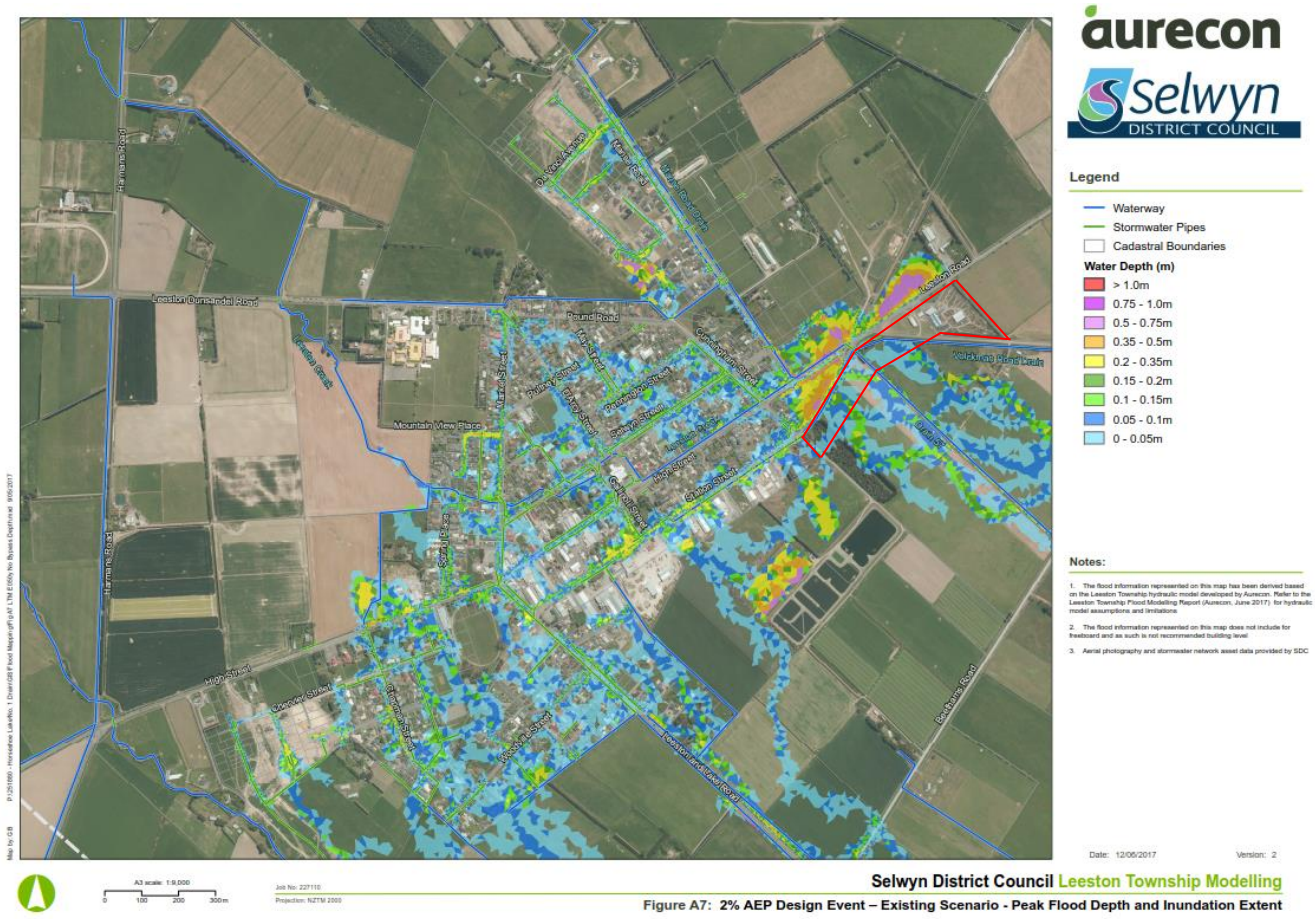

Figure 3.3: Flood depths in the 50-year ARI event (with climate change). Indicative site area is outlined in red. Taken from Aurecon (2017)

SDC has also produced flood maps for 200-year and 500-year ARI events, with climate change, as shown in Figure 3.4 (depth) and Figure 3.5 (hazard). This shows that even when considering a 'high emissions' climate change scenario (RCP8.5):

- Depth across the southern portion of the site does not exceed 0.5m, with no significant depths across the northern portion; and
- Hazard across the site (depth (metres) x velocity (metres per second)) does not exceed 1[11] in either portion. This is the threshold defining High Hazard areas in Policy 11.3.1 of the Regional Policy Statement: "flood hazard areas subject to inundation events where the water depth (metres) x velocity (metres per second) is greater than or equal to 1, or where depths are greater than 1 metre, in a 0.2% AEP flood event".

Figure 3.4 suggests that as the southern site has the potential for flood depths of up to 0.5m, SDC should set minimum floor levels above this 200-year level, as per Policy 11.3.2 of the Regional Policy Statement (RPS). Figure 3.5 shows that neither the site nor the wider area would trigger the planning constraints of a high hazard zone as set out in the Regional Policy Statement (RPS) Policy 11.3.1. Further information on the planning constraints and policies relevant to rezoning of the Indicative Site is provided in Section 5.

Some key observations from this review of these flood maps are:

[11] Flood Hazard is typically calculated as a dimensionless number combining flood depth and velocity, and optionally considering debris which might be transported by the flood water. Defra (2008) Supplementary Note on Flood Hazard Ratings and Thresholds For Development Planning And Control Purpose. Available at: http://randd.defra.gov.uk/Document.aspx?Document=FD2321_3437_TRP.pdf

- the overland flow paths and predicted inundation areas shown in the flood maps align with the areas of inundation and overland flow paths shown in the aerial photograph in Section 2;
- the northern portion of the Indicative Site does not appear to be prone to flooding in events up to 50 year ARI with climate change;
- the southern portion of the Indicative Site has overland flow paths in events greater than a 10-year ARI with climate change, which do present a risk of flooding occurring;
- significant flooding occurs to the north of the site (across Leeston Road) in the 50-year ARI event with climate change, however no significant flooding within the site is shown in either event;
- modelling of a 200-year ARI event with climate change suggests that flood depths of up to 0.5m could occur across the southern portion of the site, such that minimum floor levels should be set; and
- modelling of a 500-year ARI event with climate change has demonstrated that hazard (depth x velocity) does not exceed 1 across the site (or the wider area) so that the site does not need to be classified as high hazard.

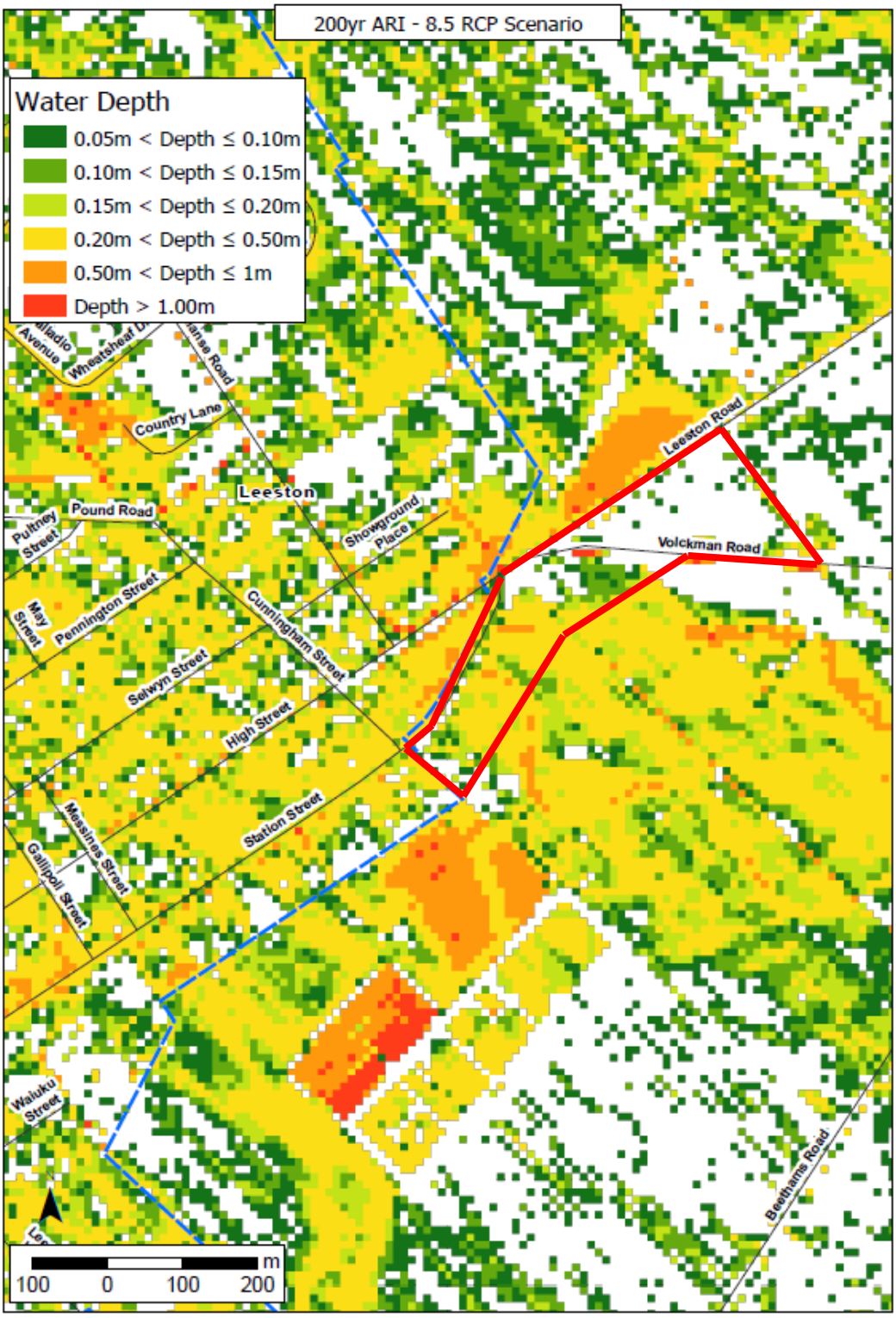

Figure 3.4: Flood depth in the 200-year ARI event with climate change (RCP 8.5 scenario).

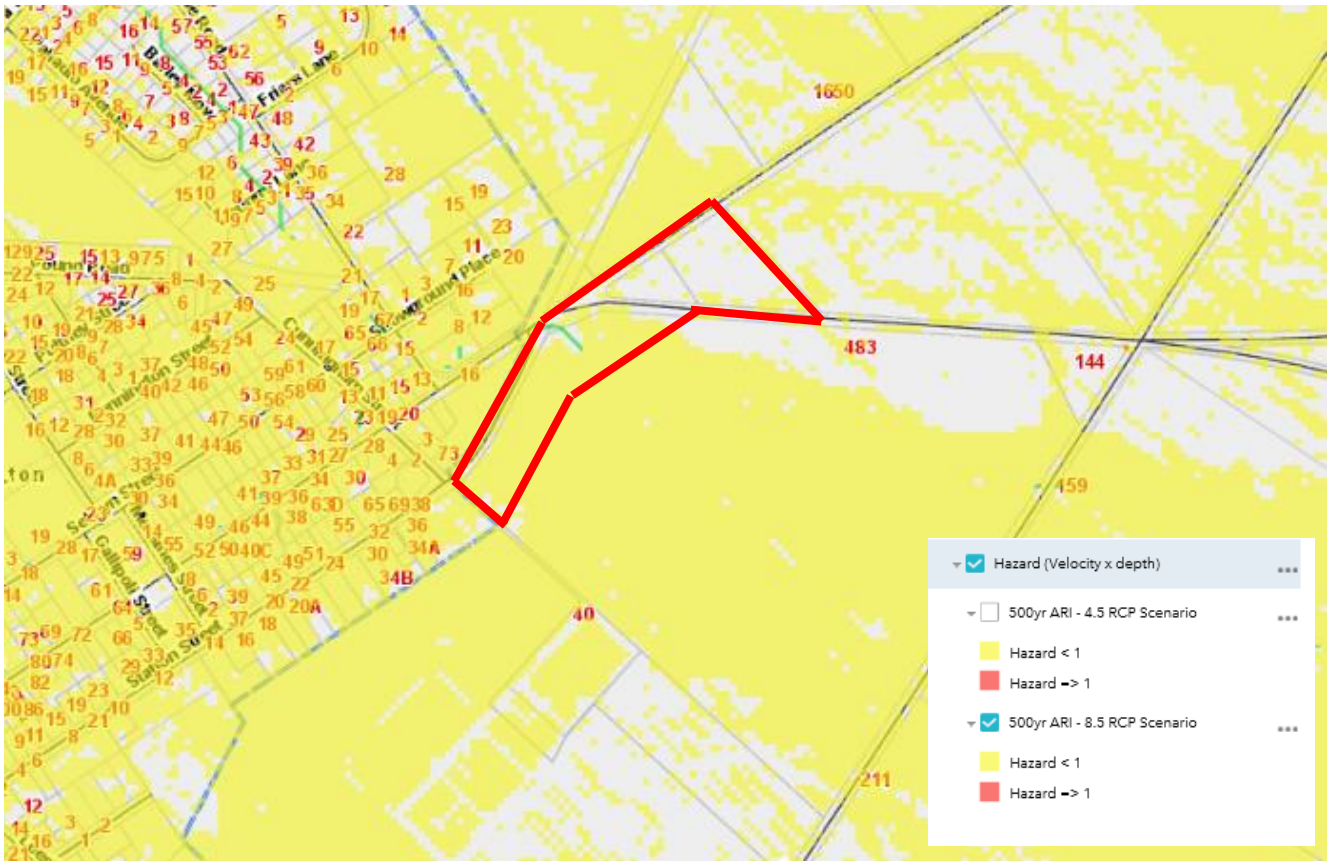

Figure 3.5: Flood hazard (depth x velocity) in the 500-year ARI event with climate change (RCP 8.5 scenario).

3.2 Leeston Stormwater Bypass

Aurecon (2017) has completed a Stormwater Modelling Report for the Leeston Township. A model was developed for the investigation and design of the Leeston Stormwater Bypass, and the above existing scenario events were run as a baseline. The scheme design then allowed for peak flows to be diverted around Leeston Township, within a Leeston Stormwater Bypass. This scenario was used to identify potential capacity constraints and associated localised flooding issues within the existing stormwater network.

A flood map was produced for the 10-year and 50-year ARI events, as well as difference maps. Figure 3.6 and Figure 3.7 show the difference map for the scheme scenario minus the existing scenario for the 10 and 50-year ARI events with the Indicative Site outlined in red. These show that the bypass has either no impact or a minimal positive impact to reduce flood levels (up to 20 mm) in the Indicative Site area.

The Leeston Stormwater Bypass design has been split into two stages; Stage 3 and Stage 4. Stage 4 starts west of the Township at Leeston Creek and finishes at the intersection between Leeston and Volckman Road. We understand that (at the time of writing) construction has not begun as there are some access issues to be resolved. Stage 3 will continue downstream from the Leeston and Volckman Road intersection, and will finish downstream of the Indicative Site. Figure 3.8 shows in red the proposed path of Stage 3.

As the design is yet to begin for Stage 3, there is an opportunity to incorporate capture of the overland flow paths beginning at Station Street within the stormwater bypass design. This could further reduce the observed and predicted flooding in the southern portion of the site.

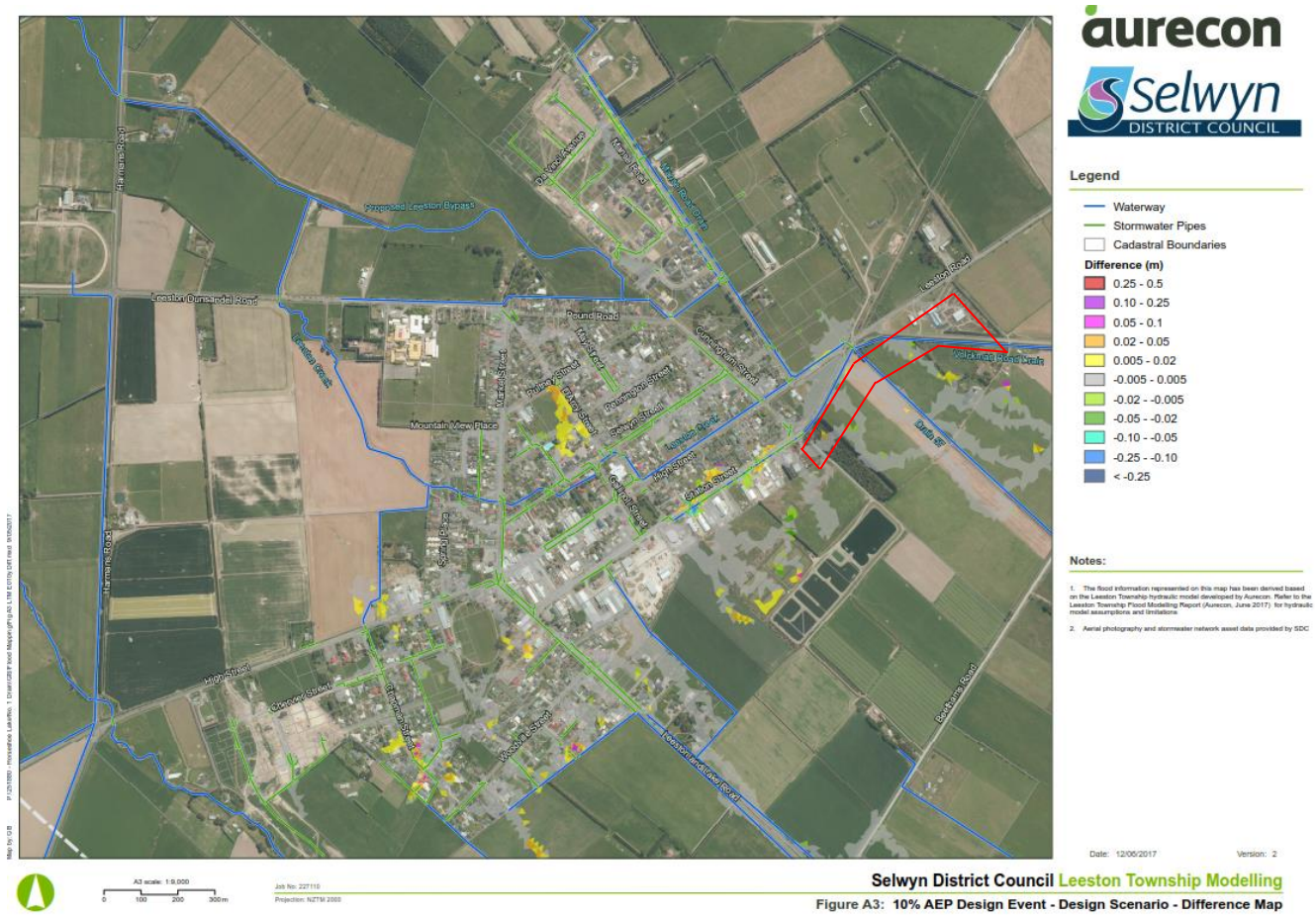

Figure 3.6: Flood depth difference map for the bypass scenario minus the existing scenario in the 50-year ARI event with climate change. Indicative site area is outlined in red. Taken from Aurecon (2017)

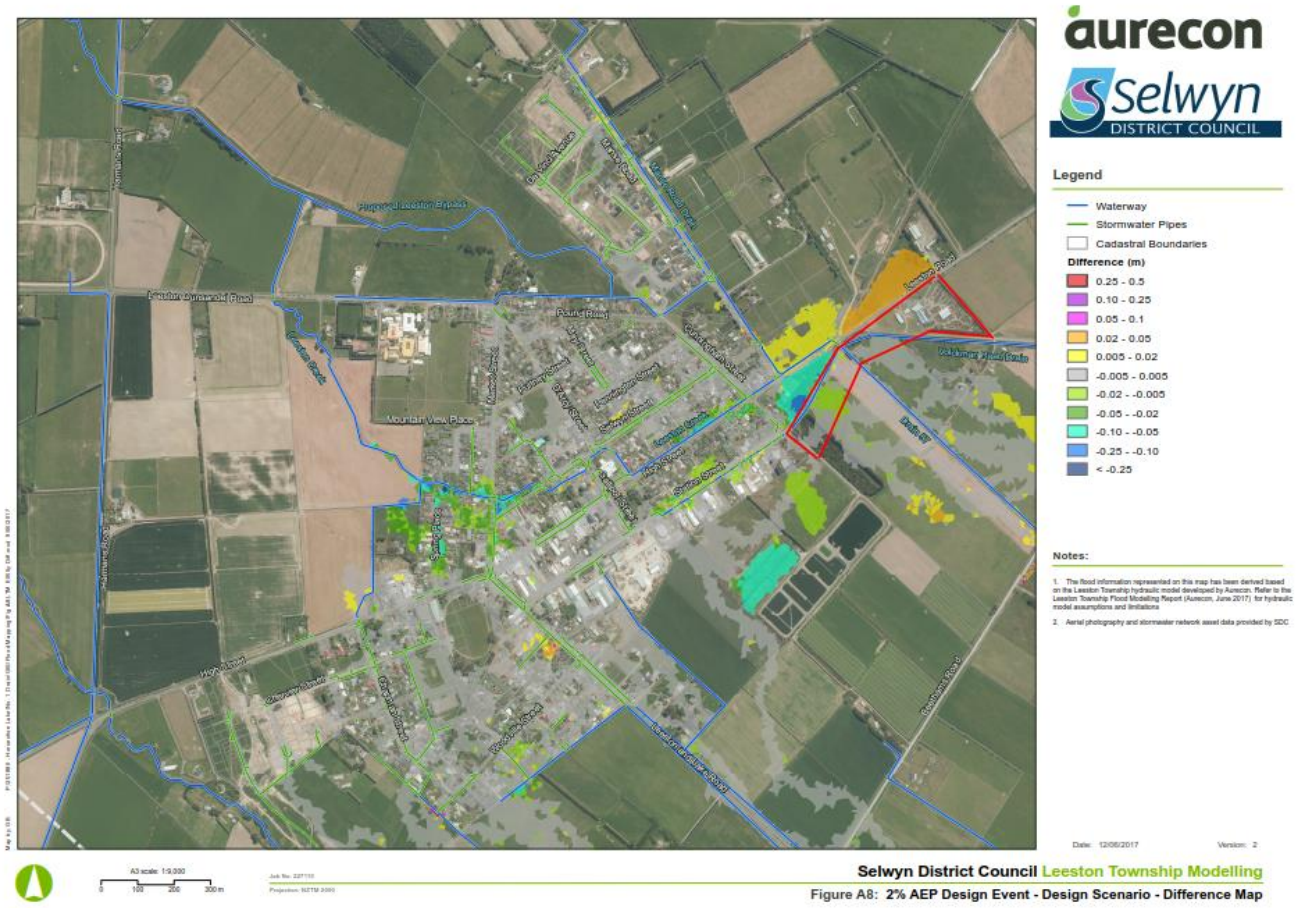

Figure 3.7: Flood depth difference map for the bypass scenario minus the existing scenario 50-year ARI event with climate change. Indicative site area is outlined in red. Taken from Aurecon (2017)

Figure 3.8: Proposed route of Stage 3 of the Leeston Stormwater Bypass, shown in red

4. Shallow Groundwater

4.1 Potential Impacts of Groundwater at or Near the Surface

As listed in Golder (2017)[12], surface water ponding, damage to infrastructure and buildings and increased risks of liquefaction during earthquakes can result from groundwater rising to be at or near the ground surface. Potential issues are:

- high groundwater levels can prolong surface flooding;
- continually damp conditions in buildings are ideal for growth of fungus, affecting building materials such as timber framing and cladding, and causing respiratory diseases;
- fluctuations in groundwater levels can result in differential deformation of structures such as roads and houses due to soil swelling and shrinkage; and
- high groundwater levels contribute to vulnerability of the built environment to damage caused by liquefaction and lateral spreading, affecting buildings, roads, subsurface infrastructure and waterways.

Authorities in The Netherlands use minimum drainage depth guideline values for various urban functions as listed in Table 4.1. The above issues can arise when the required drainage depth cannot be maintained.

Land use type	Drainage depth (depth the groundwater in m below surface level)
Houses, buildings, structures	0.70
Primary roads	1.00
Secondary roads	0.70
Cables and pipes	0.60 – 1.20
Gardens and parks	0.50
Sports fields	0.50
Graveyards	0.30 below coffin

Table 4.1: Minimum drainage depth guideline values in The Netherlands, taken from Golder (2017)

4.2 Existing Leeston Situation

Aqualinc[13] were engaged by SDC to provide a shallow groundwater surface that would enable an assessment of risk to infrastructure in the Selwyn District due to high groundwater levels. An existing situation “maximum” groundwater elevation surface (i.e. no climate change) was produced using groundwater level data from Environment Canterbury (ECan).

The interpolated surface shown in Figure 4.1 was formed using the highest monthly average groundwater levels from data gathered between 2006 and 2014. Depth to groundwater gradually shallows from the northwest towards Lake Ellesmere. Leeston Township is located in an orange to red coloured zone on the map, which indicates that the maximum monthly depth to groundwater can be between 0 – 1 m below ground level. Shallow groundwater levels at the Indicative Site will be similar to those across the existing township and, with reference to Table 4.1, could impact infrastructure at or near to the surface.

[12] Golder (2017) REVIEW OF INTERNATIONAL CASE STUDIES. Protection Options for Managing Rising Groundwater in South Dunedin. Report Number: 1671023_7410-004-R-Rev2. July 2017
[13] Aqualinc (2017) Memorandum to Murray England from Mark Flintoft. Shallow Groundwater Levels. 10 March 2017

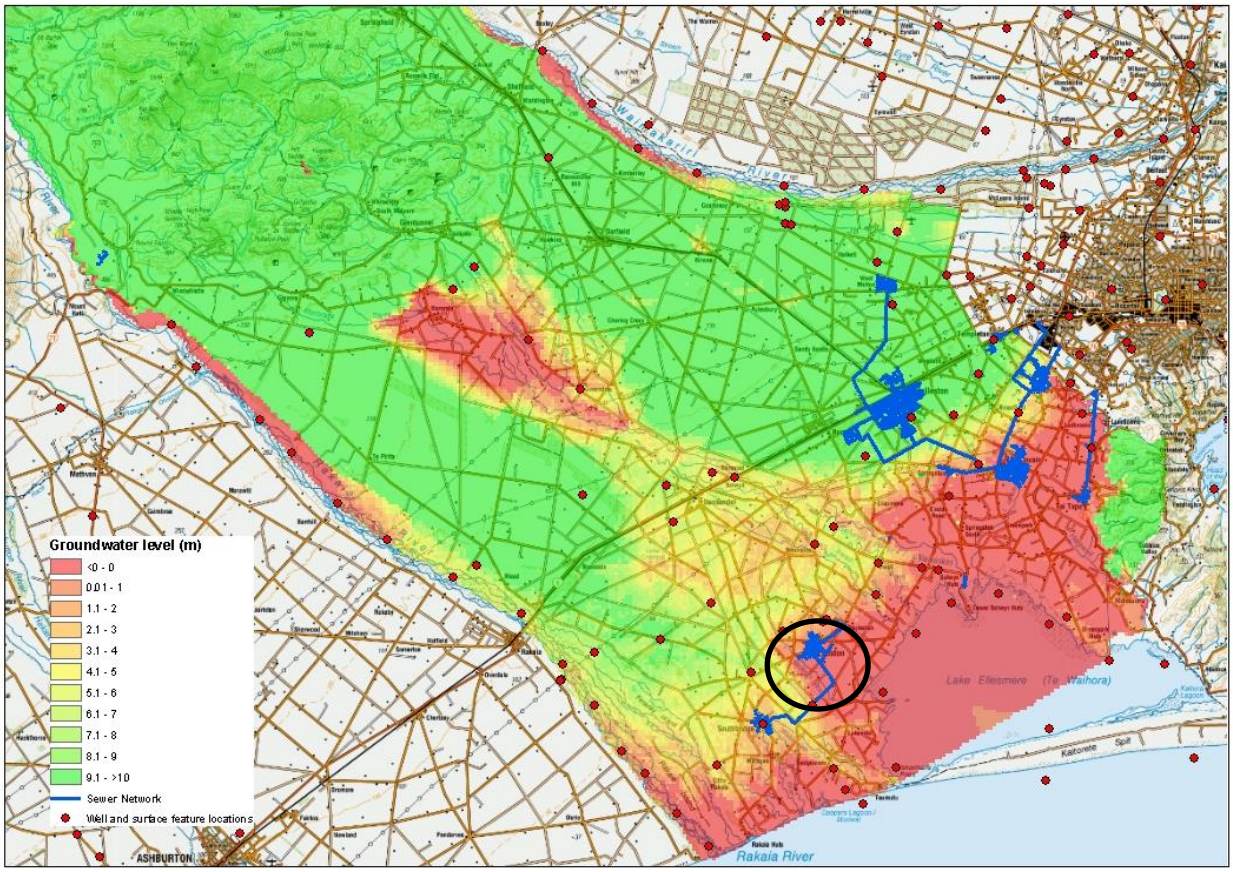

Figure 4.1: Shallow depth to groundwater surface

SDC also provided average depth to groundwater data from a separate study. Figure 4.2 shows these data in the vicinity of the Indicative Site. These data suggest that the average depth to groundwater is fairly consistent across the Indicative Site, and ranges between 0.0 – 0.5 m below ground. As for the above shallow groundwater map, the general pattern indicates that depth to groundwater shallows nearing Lake Ellesmere. Indeed, the average groundwater levels are similar to the maximum groundwater levels and emphasise that shallow groundwater can be at or near to the ground surface. There may, therefore, be a risk to existing assets in Leeston as suggested by Table 4.1, and care should be taken not to expose new assets associated with the proposed development to a similar risk. Therefore, we would not recommend any permanent lowering of ground levels at the site. Instead, raising ground levels through filling should be considered, although SDC should demonstrate that any displaced water does not exacerbate hazards elsewhere. Raising floor levels may also be an appropriate response to shallow groundwater, in a manner that can be integrated with the industrial land use.

4.3 Groundwater and Climate Change

Separately, Aqualinc were engaged by SDC to produce a report on the projected changes in climate, and to assess what impact these changes could have on SDC's water assets through to 2048. With respect to groundwater, this report concludes that through to 2048, climate change will have only a minor impact on groundwater levels. In fact, the report states (see Table 4 2) that Central Plains irrigation will increase groundwater levels to a greater degree than climate change, and that both of these impacts will be less than the existing variation in levels due to seasonal rainfall patterns.

Whereas climate change may not be projected to lead to further shallowing of groundwater, the existing situation of shallow groundwater at the site could be made worse as a result of the Central Plains irrigation scheme, and this constraint should be considered carefully when ground and floor levels are set. This especially relates to the duration at which shallow groundwater is at or above certain levels and may be in proximity to assets.

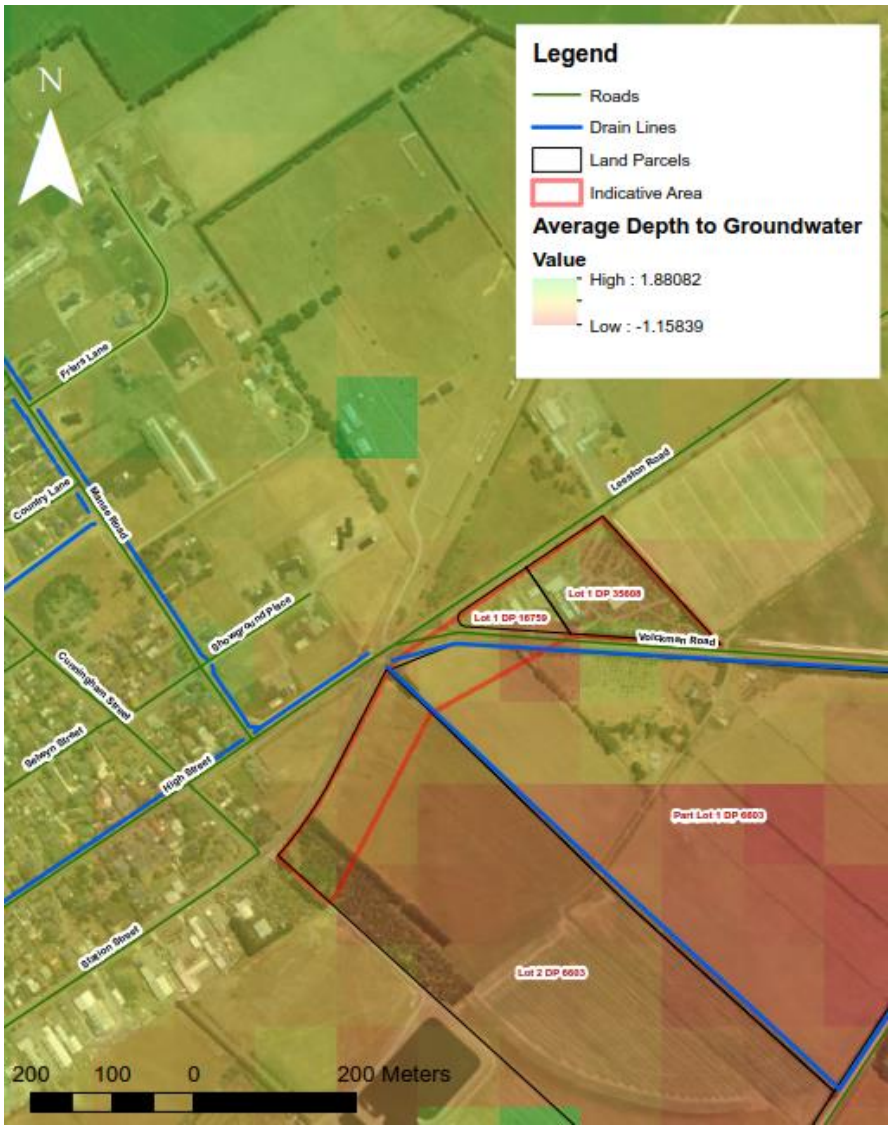

Figure 4.2: Average depth to groundwater, where red shades represent groundwater near the surface and green shades represent deeper groundwater

Factor	Average water level change (% of status quo water level range)
Climate change	-4%
Central Plains Irrigation	+12%
Existing irrigation from groundwater	-17%
Annual rainfall variability	±41%

Table 4 2: Environmental impacts on groundwater levels (taken from Aqualinc, 2016)

5. Summary and Recommendations

This report has assessed the land constraints of flooding and shallow groundwater to the Indicative Site in the south-east of Leeston Township which Selwyn District Council are considering rezoning to Business 2 (Industrial) use. Any constraints to the site from geotechnical risks are considered in a separate accompanying report. It is anticipated that the information in this report will be used to inform an Outline Development Plan which will be subsequently prepared by Selwyn District Council.

With respect to the assessment of flooding and shallow groundwater in the vicinity of the Indicative Site, the following key points were noted:

- The site can be considered as two separate portions; the northern portion (north of Volckman Road) having higher existing ground levels than the southern portion (south of Volckman Road) and therefore having a lower exposure to flooding;
- Based on predictions of depths in the 10 year and 50 year ARI events with climate change, flooding across the Indicative Site is typically shallow, with the southern portion having overland flow routes in a south-easterly direction from Station Street. Access via the surrounding roads (Station Street, Volckman Road and Leeston Road) appears to be largely dry in events up to and including the 50 year ARI event;
- Predictions of flood hazard in 500 year ARI events, including allowance for climate change, have demonstrated that the site does not need to be classified as high hazard (high depth and/or velocity) in accordance with the Canterbury Regional Policy Statement Policy 11.3.1.
- However, predictions of flood depths in 200 year ARI events, including allowance for climate change, have demonstrated that the southern portion of the site should have minimum floor levels set above the 200 year flood level, in accordance with the Canterbury Regional Policy Statement Policy 11.3.2.
- Average and maximum seasonal groundwater levels across the site are currently shallow, and could be within 1 m of the ground surface. Information is available which indicates that whilst groundwater may not get any shallower with climate change, levels could increase with the Central Plains Irrigation scheme;
- The proposed Leeston Stormwater Bypass could pass along Volckman Road and therefore could provide some reduction in flood risk at the site if appropriately designed. There is an opportunity to include capture of overland flow routes across the southern portion of the site in the upcoming design.

The information has been used to inform a review of the planning constraints, Resource Management Act requirements and planning tools that establish constraints on development from a flooding perspective, including the anticipated impacts of shallow groundwater. The key outcomes from this review are summarised in Table 5.1. Whilst all implications in the table should be carefully considered, the following are recommended for immediate action:

1. Measures should be considered on the site to minimise any increase in discharge due to an increase in impervious land cover. These should be considered together with the design of the proposed Leeston Stormwater Bypass which could potentially accommodate any residual increase in flows from the site. In particular, the overland flow paths across the southern portion of the site should either be captured and routed into the Leeston Stormwater Bypass, or allowed to pass safely across the site without risking inundation of floor levels and any stored hazardous substances.

Table 5.1: Summary of planning provisions referred to in this report and how they could apply to the Indicative Site

Existing Regulation Review Summary	Recommendations for the Indicative Site
Canterbury Regional Policy Statement Policy 11.3.1 seeks to avoid inappropriate development in high hazard areas, defined as the water depth multiplied by the velocity being greater than or equal to 1, or where depths are greater than 1 metre, in a 500 year ARI flood event	Modelling of the 500 year ARI event with an allowance for climate change has demonstrated that the site does not need to be classified as high hazard.
Canterbury Regional Policy Statement Policy 11.3.2 seeks to avoid inappropriate development in areas subject to inundation, where new buildings should have floor levels above the 200-year	Modelling of the 200 year ARI event with an allowance for climate change has demonstrated that the southern portion of the site is at risk of flood depths of up to 0.5m. It is recommended that minimum

Existing Regulation Review Summary	Recommendations for the Indicative Site
ARI design flood level, and hazardous substances should not be inundated during the event	floor levels are set for at least the southern portion of the site, and that hazardous substances should not be inundated in such an event.
Canterbury Regional Policy Statement Policy 11.3.5 seeks a general risk management approach to avoid development where the risk of natural hazards is unacceptable, and to appropriately assess and mitigate the risk elsewhere	In addition to the setting of minimum floor levels in the southern portion of the site, the occurrence of shallow ponding and overland flow routes across the site should be appropriately mitigated without increasing the risk of flooding elsewhere. This includes not displacing surface or groundwater elsewhere. Mitigations should be considered alongside the proposed Leeston Stormwater Bypass along Volckman Road.
Selwyn District Plan Chapter 14 only sets floor levels for buildings in residential areas within a flood area or flood plain according to the SDP.	The Indicative Site is at risk of overland flow and shallow groundwater in a 50 year ARI event. However, the Selwyn District Plan does not set floor levels for buildings in a Business Zone, and the Indicative Site is not within a flood area or flood plain according to the SDP. Further, the Building Code does not regulate floor levels for industrial sites and, therefore, the Code cannot be used by SDC to set floor levels above the risk of flooding and shallow groundwater. It is recommended that a mechanism to set floor levels is considered, in addition to filling of land.
Selwyn District Plan Chapter 14 sets limits on earthworks for building foundations, although excludes earthworks in Business Zones	Since earthworks for building foundations in Business Zones are exempt from the rules, there are no limits when constructing a building platform and therefore, under the SDP, the land at the Indicative Site could be filled to raise it above the risk of inundation by overland flow routes and shallow groundwater. However, it should be demonstrated that filling will not exacerbate flooding on adjacent properties.
Selwyn District Plan rule B3.1.6 requires that any measures to mitigate a potential natural hazard do not lead to or intensify a potential natural hazard elsewhere	In addition to checking that any filling of land at the site does not lead to an increase in flood hazard on adjacent properties, it is recommended that no subsurface infrastructure (e.g. sheet piling) which is likely to alter the natural flow of groundwater – and in particular which could cause it to mound upstream of the site – is constructed. As above, measures should be considered alongside the proposed Leeston Stormwater Bypass along Volckman Road.
Selwyn District Plan rule B4.3.54 requires rezoned land not to cause, or exacerbate, a natural hazard by increasing the rate of stormwater runoff into the Leeston main drain.	Rezoning has the potential to increase the impervious area of the site and therefore increase the discharge into the Leeston Main Drain. Therefore, measures should be considered on the site to minimise this increase in discharge, and design of the proposed Leeston Stormwater Bypass should consider accommodating any residual increase in flows from the site. In particular, the overland flow paths across the southern portion of the site should either be captured and routed into the Leeston Stormwater Bypass, or allowed to pass safely across the site.
Selwyn District Plan Requirement for new developments to provide onsite stormwater retention to mitigate anticipated increase in impervious area as well as the potential increase in contaminated stormwater runoff	There is currently no requirement for industrial buildings to provide onsite stormwater retention, however this must be viewed alongside the above requirement not to increase the rate of stormwater runoff (e.g. flooding effects) into the Leeston main drain. Recommended that the ODP demonstrate how the local stormwater network will be able to accommodate the increased capacity, and what improvements are needed, consideration should be given to how the anticipated increase in impervious area associated with the rezoning, as well as the potential increase in contaminated stormwater runoff, could be mitigated through onsite

Existing Regulation Review Summary	Recommendations for the Indicative Site
	systems, and how the Leeston Stormwater Bypass design can accommodate any increase associated with the development.
Land & Water Regional Plan limits excavations in sites overlying aquifers and/or adjacent to watercourses	The Indicative Site overlies a semi-confined/unconfined aquifer which triggers rules for any excavations. However, with the seasonal water table being so shallow, no excavation of the site is recommended.
Land & Water Regional Plan limits discharge of stormwater to land located at least 1 m above the seasonal high water table	Available records show that the seasonal high water table could be within 1 m of the ground surface, and may become shallower in the future. Therefore, as above, it may be necessary for stormwater to be attenuated on site prior to discharge into the Leeston Stormwater Bypass due to increase flood risk, which must be designed to accommodate any additional inflow.

Appendix A. Aerial Flooding Photos

0799 - Looking north-west from the intersection of Beethams Road, Volckman Road and Tramway Reserve Road - 23-06-2013

0798 - Looking north-west across Beethams Road toward Leeston - 23-06-2013


0446 - Leeston. Looking south-west along High Street
- 23-06-2013


0442 - Looking south-west along Beethams Road - 23-06-2013


0395 - Leeston. Looking south-west - 23-06-2013

Appendix B. Geotechnical Desk Study

Leeston Industrial Site

Selwyn District Council

Geotechnical Desk Study

IZ124100-0005-CG-RPT-0001 | A

10 April 2019

BS302

Leeston Industrial Site

Project No:	IZ124100
Document Title:	Geotechnical Desk Study
Document No.:	IZ124100-0005-CG-RPT-0001
Revision:	A
Date:	10 April 2019
Client Name:	Selwyn District Council
Client No:	BS302
Project Manager:	Elaine McLaren
Author:	Kieran Bartram
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Document history and status

Revision	Date	Description	By	Review	Approved
A	10/04/2019	Preliminary Issue	K Bartram	C Watts	H Peacock

Contents

Important note about your report

The sole purpose of this report is to present the findings of a geotechnical investigation carried out by Jacobs for Selwyn District Council ('the Client') for the Leeston Industrial site ("The Site"). This report was produced in accordance with and is limited to the scope of services set out in the contract between Jacobs and the Client. That scope of services, as described in this report, was developed with the Client.

An assessment or study of on-site conditions investigates the potential for exposure to the presence of inadequate bearing ground. All reports and conclusions that deal with sub-surface conditions are based on interpretation and judgement and as a result have uncertainty attached to them. You should be aware that this report contains interpretations and conclusions which are uncertain, due to the nature of a desktop investigation. No study can investigate every risk, and even a rigorous assessment and/or sampling programme may not detect all problem areas within a site.

This report is based on assumptions that the site conditions as revealed through the desktop study are indicative of conditions throughout the site. The findings are the result of standard assessment techniques used in accordance with normal practices and standards, and (to the best of Jacobs' knowledge) they represent a reasonable interpretation of the current conditions on the site.

Conditions encountered when site work commences may be different from those inferred in this report, for the reasons explained in this limitation statement. If site conditions encountered during site works are different from those anticipated following Jacobs' desktop investigation, Jacobs reserves the right to revise any of the findings, observations and conclusions expressed in this report.

The passage of time, manifestation of latent conditions or impacts of future events may require further examination of the project and subsequent data analysis, and re-evaluation of the data, findings, observations and conclusions expressed in this report. In preparing this report, Jacobs has relied upon, and presumed accurate, any information (or confirmation of the absence thereof) provided by the Client and from other sources. Except as otherwise stated in the report, Jacobs has not attempted to verify the accuracy or completeness of any such information. If the information is subsequently determined to be false, inaccurate or incomplete then it is possible that our observations and conclusions as expressed in this report may change.

This report does not address environmental or geo-environmental issues including the presence of any contaminants or hazardous materials at the site unless Jacobs was specifically and expressly retained to do so.

This report should be read in full and no excerpts are to be taken as representative of the findings. No responsibility is accepted by Jacobs for use of any part of this report in any other context.

This report has been prepared on behalf of, and for the exclusive use of, the Client, and is subject to, and issued in accordance with, the provisions of the contract between Jacobs and the Client. Jacobs accepts no liability or responsibility whatsoever for, or in respect of, any use of, or reliance upon, this report by any third party.

1. Introduction

This report has been prepared for Selwyn District Council (SDC) by Jacobs New Zealand Ltd (Jacobs). It presents a Geotechnical Desk Study for an area identified for industrial development by SDC, referenced as LEE 3 (the site), which lies to the South of Leeston Road, on the Eastern edge of the town.

1.1 Objective

This report aims to identify potential sub-surface hazards on the site, an interpretation of the likely geological and geotechnical conditions in the area has also been provided. The aim of which is to assess possible geotechnical impact on the design of future industrial developments at the site and give a sample of the ground conditions in the surrounding area.

1.2 Scope of Work

The scope of work comprised of investigating the following in relation to the site:

- Local geology based on geological maps
- Ground water level from monitoring wells
- Historical use of the site based on aerial photography
- Seismicity, liquefaction and ground cracking
- ground conditions from nearby ground investigation data

2. Site Description

The site runs along the Southern edge of Station Road and into the area between Leeston Road and Volckman Road, as shown below in **Figure 2. 1**. The surrounding area, particularly to the South of the site is to be considered in the report as well to assist with future developments. The site is currently farmland along the edge of Station road, and the area between Leeston Road and Volckman Road is currently occupied by a yard for tractors and construction plant.

Jacobs New Zealand Limited (Jacobs) has been commissioned by SDC to undertake a desktop study of the available geotechnical information within the vicinity of the site.

Figure 2. 1 - Location of the LEE 3 site on the South-East corner of Leeston

3. Available Geotechnical Information

3.1 Regional Geology

The Institute of Geological and Nuclear Sciences' (GNS) 1:250 000 geological map[1] of Christchurch shows the site to be underlain by "Beach gravel and sand of post glacial shorelines, including those of Lake Ellesmere" (Q1b). This is shown in **Figure 3. 1** below, with the location of the site highlighted in orange.

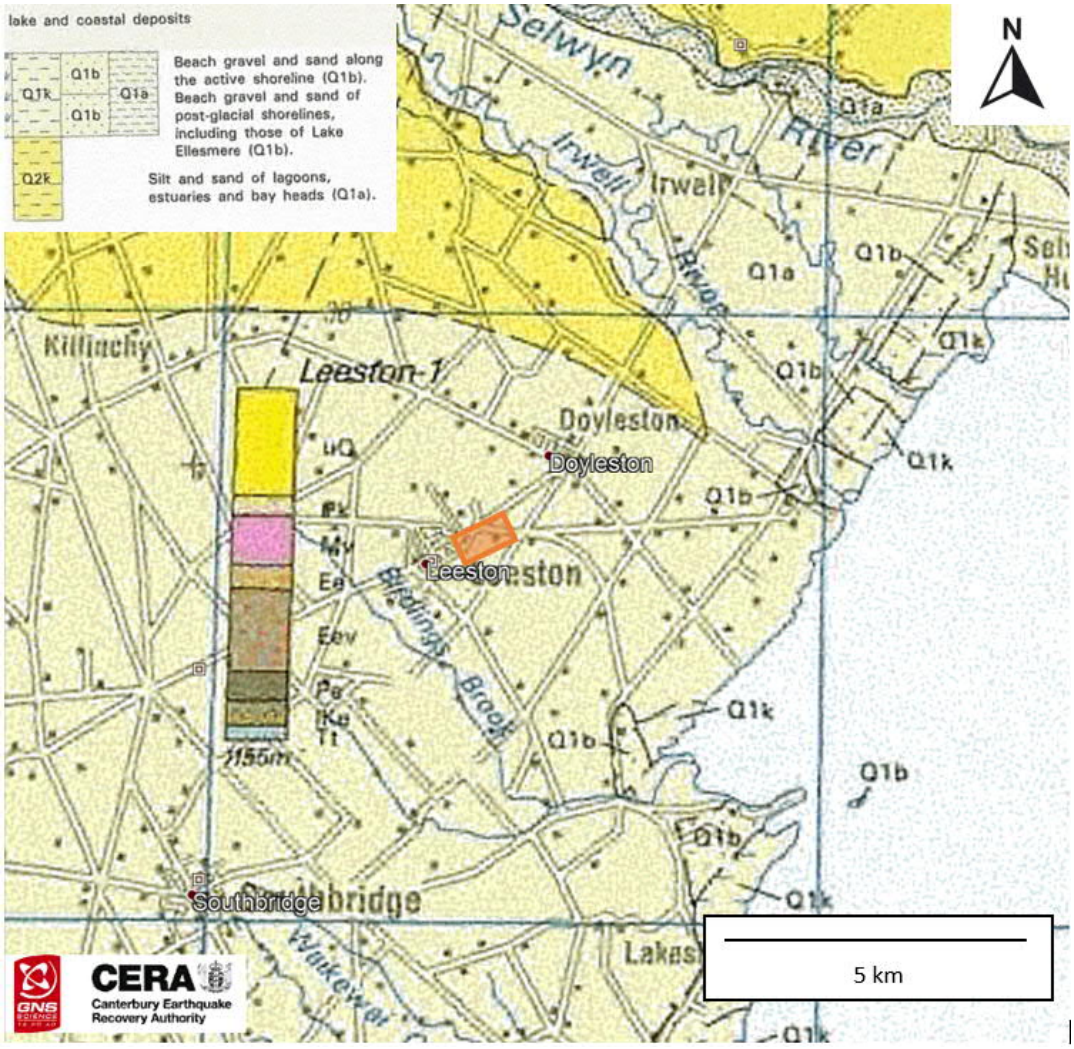


Figure 3. 1 - GNS 1:250,000 geological map 16 - Christchurch – Site extents highlighted in orange

[1] Christchurch – 1:250 000 Geological Map 16, (2008) Institute of Geological and Nuclear Sciences

3.2 Groundwater

Groundwater data is available from various wells near the site via the ECan well database[2]. There are also groundwater readings recorded in the trial pits carried out in the ground investigation carried out in the site to the North of Leeston Road by Geoscience, as provided by SDC, the exploratory locations in this ground investigation are shown in Appendix A Borehole **Logs**. The locations of these sites are shown in **Figure 3. 2** below.

Well M36/3149, which lies to the west of the site, shows a ground water level of 1.25m bgl. This coincides with the levels recorded as part of the Geoscience GI which recorded levels between 0.5 and 1.2m bgl. Another well (M36/2142) to the West of the site gives a similar reading of 1.22m bgl. Well M36/0641, which is on the Northern edge of Leeston Road, adjacent to the centre of the site, records readings between 1953 and 1989. The readings range from 0.01 - 1.65m bgl, the highest reading was recorded in August 1979.

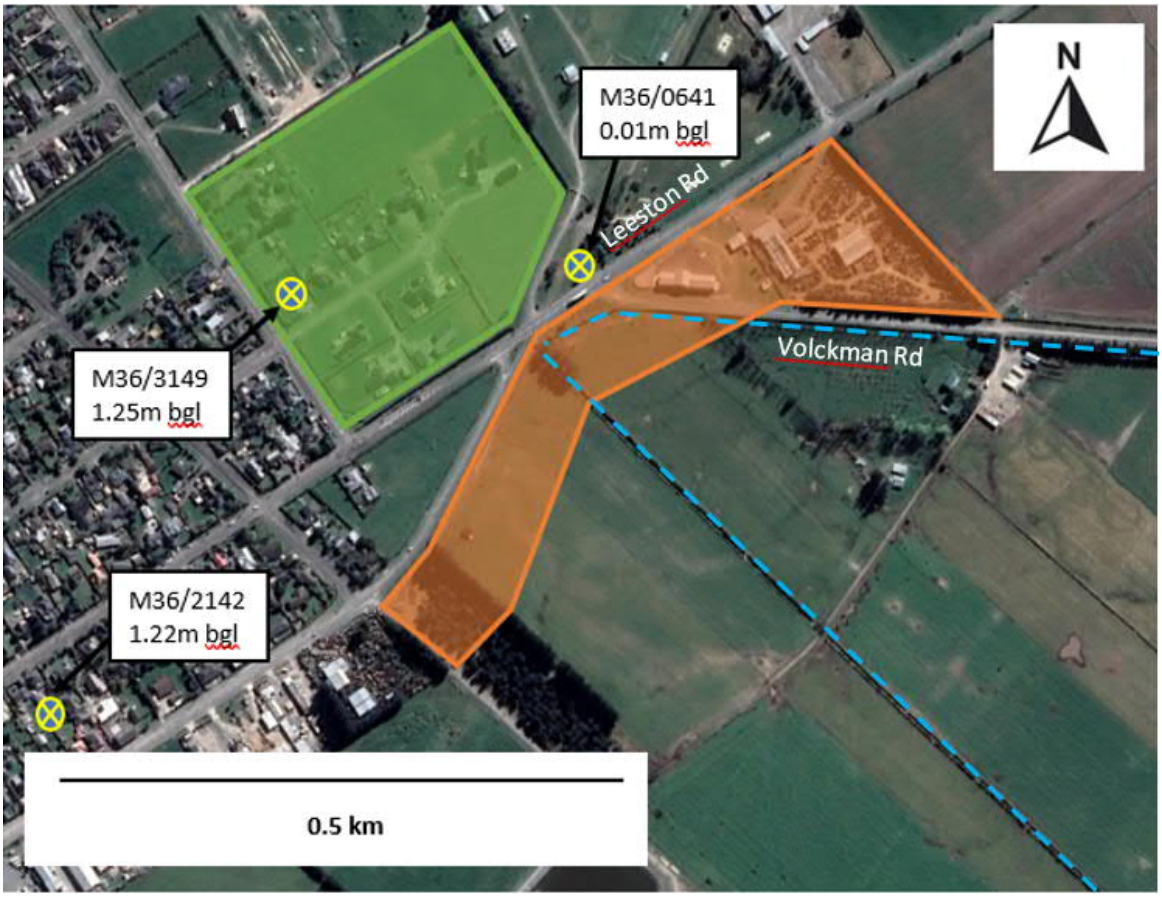


Figure 3. 2 – Groundwater reading locations and highest groundwater level recorded at each well, marked by blue and yellow markers. The site location is marked in orange, the area covered by the Geoscience GI is marked in green. Drainage trenches are marked with the dashed blue line.

There have been historic issues with flooding in the section of the site to the west of Volckman Road, these have been discussed in more depth in the corresponding Flooding & Rising Groundwater Report (IZ124100-0005-NC-RPT-0001).

[2] Environment Canterbury Well Database (2015) Available at: https://www.ecan.govt.nz/data/well-search/

3.3 Historical Aerial Photographs

The historical photographs from 1940-44 show that the site was farm land at that stage, the surrounding roads are all present at this date. The 1965-69 images show a development in the corner where Volckman Road meets Leeston Road, this appears to be some small buildings and entrances from both roads, as sown in **Figure 3. 3** below.

By 1975-79, the previous development has been removed, and a larger development consisting of two large rectangular buildings and a smaller square one, is present. These buildings are present currently, although small extensions have been added. By 1980-84, a large square building is added to the site, to the East of the buildings in place in the 75-79 photographs, this building is also in place currently. The section of the site that runs to the south of Station Road shows no development in the aerial photographs available. This appears to be worked farm land, as it is currently.

Figure 3. 3 - Comparison between 2018 (left) and 1965-69 (right) – The site is outlined in orange in each image (ECan, LINZ & Statistics NZ, n.d.), (Google Earth, 2018).

4. Seismicity and Liquefaction

4.1 Active Fault Lines

The GNS have mapped known active fault lines in the Canterbury region[3]. This shows that the closest known, active fault line to the site is the Greendale fault, which is approximately 18.5 km to the North of the site. The last recorded rupture of this fault occurred on the 4th of September 2010 in the Darfield earthquake. This earthquake struck with a magnitude of 7.1, caused a 5 m horizontal and 1 m vertical offset of the ground surface.

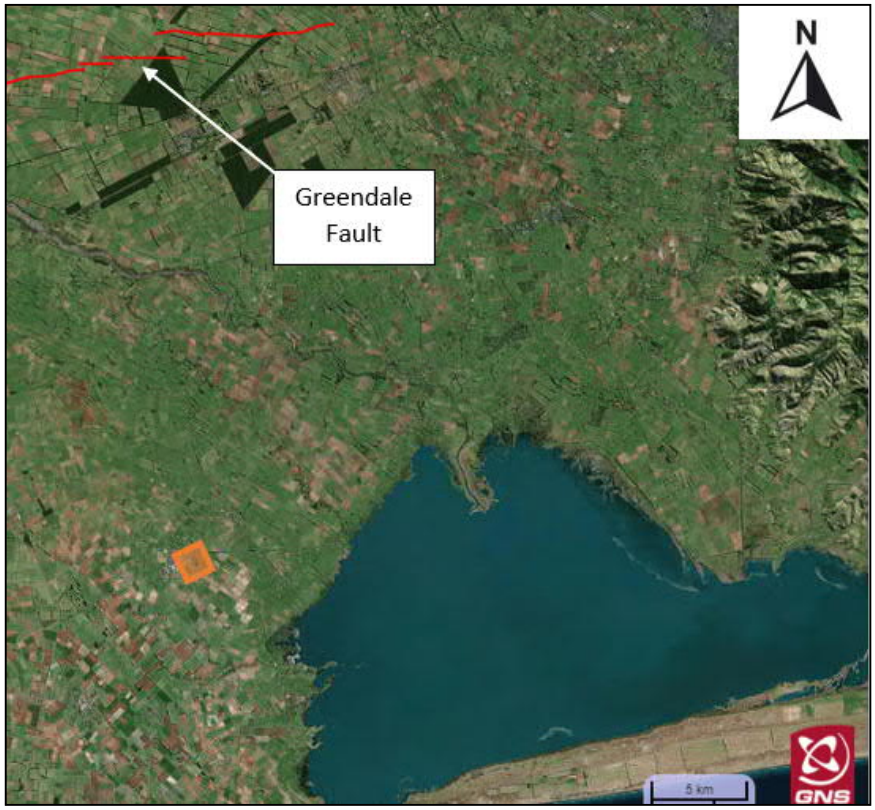


Figure 4. 1 – Closest active fault lines to the site. The site is marked in orange (GNS 2015)

4.2 Regional Liquefaction, Lateral Spreading and Ground Cracking

Canterbury Maps[4] have undertaken liquefaction mapping based on aerial photographs, they have marked the site and surrounding area as being unlikely to be subject to damaging liquefaction. The maps highlighting areas of concern for lateral spreading and ground cracking also don't show anything in this area. Due to the low

[3] Geological & Nuclear Sciences (2015) Available at: http://data.gns.cri.nz/af/
[4] Canterbury Maps (2011) Available at https://mapviewer.canterburymaps.govt.nz/

plasticity silts reported in the nearby investigations as well as the high groundwater in the area, liquefaction should be considered for future developments on the site.

5. Previous Geotechnical Investigations

A previous ground investigation has been carried out to the North of Leeston Road for SDC, the logs from this investigation have been provided by the client. Other than this, no publicly available ground investigation data is available for the area. The ground investigation available consists of six trial pits to depths of 1.2-2.3m bgl, all of which had Scala Penetrometer tests carried out in them. All the trial pits also encountered ground water at levels between 0.5 and 1.2m bgl. The logs provided for this GI are presented in **Appendix A** and a summary of the findings is presented in **Table 5. 1** below, the area covered by the GI is shown in **Figure 3. 2**.

Table 5. 1 - Details of previous geotechnical investigations within vicinity of site. (GeoScience 2012)

Reference	Date	Coordinates		Ground Level (mRL)	Termination Depth (m)
		Easting (mE)	Northing (mN)		
TP01	16/08/2012	-	-	-	1.2
TP02	16/08/2012	-	-	-	1.9
TP03	16/08/2012	-	-	-	1.5
TP04	16/08/2012	-	-	-	2.0
TP05	16/08/2012	-	-	-	2.2
TP06	16/08/2012	-	-	-	2.3

The enginering descriptions from the test pits listed above are consistent across the site. They show a well-graded, sandy gravel, overlain by low plasticity silt. The descriptions and Scala values are given below in **Table 5. 2.**

The ground information available is limited in terms of coverage and depth of investigation, it is however consistent with the information presented on geological maps for the area. The scala results available show the gravel layer to predominantly be classed as dense with one shallow reading categerising the material as medium dense. The readings in the silt layer show this material to be soft at shallow depths, gaining stiffness with depth.

Table 5. 2 – Summary of Scala Results

Depth (mbgl)	TP01 Soil Description	Scala Blows	TP02 Soil Description	Scala Blows	TP03 Soil Description	Scala Blows	TP04 Soil Description	Scala Blows	TP05 Soil Description	Scala Blows	TP06 Soil Description	Scala Blows
0.1	Silt; Dark Brown. Low Plasticity. [TOPSOIL]	1	SILT; dark brown. Low Plasticity [TOPSOIL]	1	SILT; dark brown. Low plasticity. [TOPSOIL]	1	SILT; dark brown. Low plasticity. [TOPSOIL]	2	SILT; dark brown. Low plasticity. [TOPSOIL]	1	SILT; dark Blackish brown. Low plasticity. [TOPSOIL]	2
0.2		0		2		1		2		1		1
0.3		2		2		3		1		1		2
0.4	SILT with trace clay; brown with orange mottles. Low plasticity	9	Silt with trace clay; brown with orange mottles. Low plasticity.	8	Sandy fine to coarse GRAVEL and trace cobbles; grey rounded. Well Graded	4	Silt with trace clay; brown with orange mottles. Low plasticity.	3	Silt with trace clay; brown with orange mottles. Low plasticity.	3		3
0.5		12		14		7		4		8	Silt with trace clay; brown with orange mottles. Low plasticity.	8
0.6						10	Sandy fine to coarse GRAVEL and trace cobbles; grey rounded. Well Graded	7		13		6
0.7						8		13				8
0.8						7					Sandy fine to coarse GRAVEL and trace cobbles; grey rounded. Well Graded	11
0.9						14						
1												

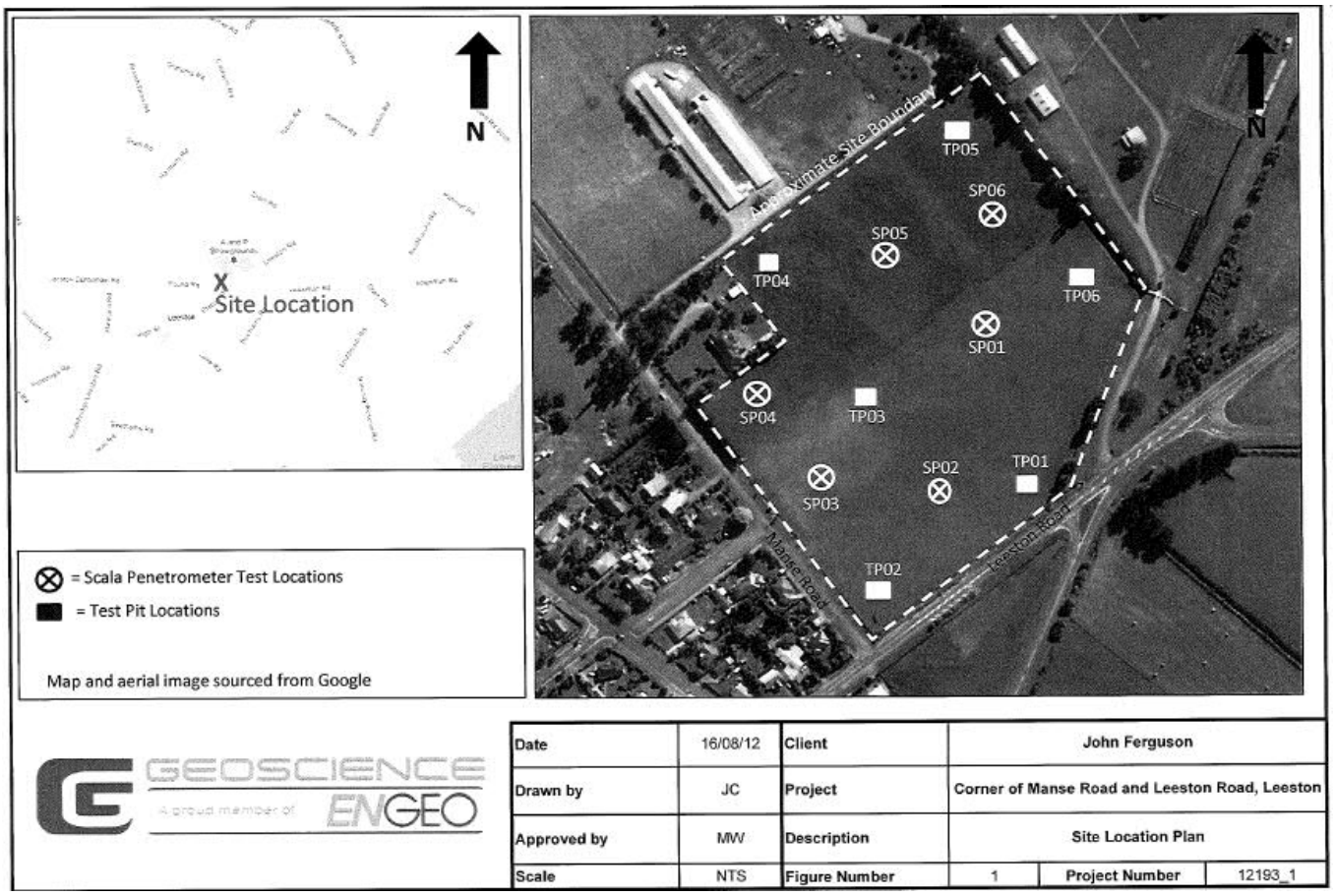
6. Conclusions

The area predominantly consists of sandy gravel as described by the geological maps and corroborated by the available ground investigation logs. The area does however appear to be overlain by a low plasticity silt, this has a maximum depth of 0.7m bgl in the available GI and is shown to be soft in areas. The scala results recorded for the underlying gravel show this to be a dense material.

Groundwater in the area is relatively shallow, with most readings showing a depth of approximately 1.2m bgl, however readings as shallow as 0.1m bgl have been recorded. Aside from previous developments on the land which were removed by 1975, no issues have been identified with the sites historical use. There are also no signs of damage historically due to seismic activity.

Due to the high groundwater in the area and reported low plasticity of the overlying silt, it is recommended that this material be removed beneath foundations for industrial developments on the site. This material is of low strength when saturated and is also may be susceptible to liquefaction should a seismic event impact the site. Any material removed however, should be built back up with appropriate fill due to the high ground water level.

Appendix A. Borehole Logs



Date	16/08/12	Client	John Ferguson		
Drawn by	JC	Project	Corner of Manse Road and Leeston Road, Leeston		
Approved by	MW	Description	Site Location Plan		
Scale	NTS	Figure Number	1	Project Number	12193_1

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TEST PIT - TP01

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Corner of Manse Road & Leeston Road

Leeston

12193

Client	: John Ferguson	**Date Started**	: 16/08/2012
Project	: Cnr Manse & Leeston Road	**Date Completed**	: 16/08/2012
Geoscience Ref.	: 12193	**Hole Depth**	: 1.2 m
Drilling Method	: Excavator	**Logged By**	: JC
Hole Dimensions	: 1 m x 2 m	**Reviewed By**	: MW

Depth (m)	Material	USCS Symbol	DESCRIPTION	Graphic Log	Water Level	Moisture Condition	Shear Vane (kPa) Peak/Remoulded	Consistency / Density	Scala Penetrometer Blows per 100 mm (0 2 4 6 8 10 12 14)
0.0	TOPSOIL	TS	SILT; dark brown. Low plasticity. [TOPSOIL]			W		S	
	ALLUVIUM	ML	SILT with trace clay; brown with orange mottles. Low plasticity.		▼	S		Vst	
0.5	ALLUVIUM	GW	Sandy fine to coarse GRAVEL; grey, rounded. Well graded. Sand is fine to medium.			S		D	
1.0			EOH: Practical Refusal due to pit collapsing.						
1.5									
2.0									
2.5									

Termination: Pit Collapse
Groundwater encountered at 0.5 m.

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TEST PIT - TP02

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Corner of Manse Road & Leeston Road

Leeston

12193

Client	: John Ferguson	**Date Started**	: 16/08/2012
Project	: Cnr Manse & Leeston Road	**Date Completed**	: 16/08/2012
Geoscience Ref.	: 12193	**Hole Depth**	: 1.9 m
Drilling Method	: Excavator	**Logged By**	: JC
Hole Dimensions	: 1 m x 2 m	**Reviewed By**	: MW

Depth (m)	Material	USCS Symbol	DESCRIPTION	Graphic Log	Water Level	Moisture Condition	Shear Vane (kPa) Peak/Remoulded	Consistency / Density	Scala Penetrometer Blows per 100 mm (0 2 4 6 8 10 12 14)
0.0	TOPSOIL	TS	SILT; dark brown. Low plasticity. [TOPSOIL]			M		S	
	ALLUVIUM	ML	SILT with trace clay; brown with orange mottles. Low plasticity.			W		Vst	
0.5		GW	Sandy fine to medium GRAVEL; grey, rounded. Well graded. Sand is fine to medium.			S		D	
1.0		ML	SILT with minor sand; grey with orange mottles. Low plasticity.		▼	S		Vst	
		GW	Sandy fine to coarse GRAVEL with trace cobbles; grey, rounded. Well graded. Sand is fine to medium.			S		D	
1.5									
2.0			EOH: Practical Refusal due to pit collapsing.						
2.5									

Termination: Pit Collapse
Groundwater encountered at 1.2 m.

08-29-2012 J:\PROJECTS\2012\12193 Cnr Manse Road and Leeston Rural, Leeston\Final\12193_Cnr Manse Road and Leeston Rural, Leeston.gpj

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TEST PIT - TP03

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Corner of Manse Road & Leeston Road	**Client**	: John Ferguson	**Date Started** : 16/08/2012
Leeston	**Project**	: Cnr Manse & Leeston Road	**Date Completed** : 16/08/2012
12193	**Geoscience Ref.**	: 12193	**Hole Depth** : 1.5 m
	Drilling Method	: Excavator	**Logged By** : JC
	Hole Dimensions	: 1 m x 2 m	**Reviewed By** : MW

Depth (m)	Material	USCS Symbol	DESCRIPTION	Graphic Log	Water Level	Moisture Condition	Shear Vane (kPa) Peak/Remoulded	Consistency / Density	Scala Penetrometer Blows per 100 mm (0 2 4 6 8 10 12 14)
0.0	TOPSOIL	TS	SILT; dark brown. Low plasticity. [TOPSOIL]			W		S	
0.5	ALLUVIUM	GW	Sandy fine to coarse GRAVEL and trace cobbles; grey rounded. Well graded. Sand is fine to medium.		▼	S		D	
1.0									
1.5			EOH: Practical Refusal due to pit collapsing.						
2.0									
2.5									

Termination: Pit Collapse
Groundwater encountered at 0.8 m.

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TEST PIT - TP04

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Corner of Manse Road & Leeston Road		Client	: John Ferguson	Date Started	: 16/08/2012
		Project	: Cnr Manse & Leeston Road	Date Completed	: 16/08/2012
Leeston		Geoscience Ref.	: 12193	Hole Depth	: 2 m
		Drilling Method	: Excavator	Logged By	: JC
12193		Hole Dimensions	: 1 m x 2 m	Reviewed By	: MW

Depth (m)	Material	USCS Symbol	DESCRIPTION	Graphic Log	Water Level	Moisture Condition	Shear Vane (kPa) Peak/Remoulded	Consistency / Density	Scala Penetrometer Blows per 100 mm (0 2 4 6 8 10 12 14)
0.0	TOPSOIL	TS	SILT; dark brown. Low plasticity. [TOPSOIL]			M		S	
	ALLUVIUM	ML	SILT with trace clay; brown with orange mottles. Low plasticity.			W		St	
0.5		GW	Sandy fine to coarse GRAVEL and trace cobbles; grey rounded. Well graded. Sand is fine to medium.		▼	S		D	
1.0									
1.5									
2.0			EOH: Practical Refusal due to pit collapsing.						
2.5									

Termination: Pit Collapse
Groundwater encountered at 1.2 m.

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TEST PIT - TP05

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Corner of Manse Road & Leeston Road

Leeston

12193

Client	: John Ferguson	**Date Started**	: 16/08/2012
Project	: Cnr Manse & Leeston Road	**Date Completed**	: 16/08/2012
Geoscience Ref.	: 12193	**Hole Depth**	: 2.2 m
Drilling Method	: Excavator	**Logged By**	: JC
Hole Dimensions	: 1 m x 2 m	**Reviewed By**	: MW

Depth (m)	Material	USCS Symbol	DESCRIPTION	Graphic Log	Water Level	Moisture Condition	Shear Vane (kPa) Peak/Remoulded	Consistency / Density	Scala Penetrometer Blows per 100 mm
0.0	TOPSOIL	TS	SILT; dark brown. Low plasticity. [TOPSOIL]			M		S	
0.5	ALLUVIUM	ML	SILT with trace clay; brown with orange mottles. Low plasticity.			W		Vst	
1.0		GW	Sandy fine to coarse GRAVEL and trace cobbles; grey rounded. Well graded. Sand is fine to medium.		▼	S		D	
1.5									
2.0									
			EOH: Practical Refusal due to pit collapsing.						
2.5									

Scala Penetrometer Blows per 100 mm: 0 2 4 6 8 10 12 14

Termination: Pit Collapse
Groundwater encountered at 1.2 m.

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TEST PIT - TP06

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Corner of Manse Road & Leeston Road	Client	: John Ferguson	Date Started : 16/08/2012
Leeston	Project	: Cnr Manse & Leeston Road	Date Completed : 16/08/2012
12193	Geoscience Ref.	: 12193	Hole Depth : 2.3 m
	Drilling Method	: Excavator	Logged By : JC
	Hole Dimensions	: 1 m x 2 m	Reviewed By : MW

Depth (m)	Material	USCS Symbol	DESCRIPTION	Graphic Log	Water Level	Moisture Condition	Shear Vane (kPa) Peak/Remoulded	Consistency / Density	Scala Penetrometer Blows per 100 mm
0.0	TOPSOIL	TS	SILT; dark blackish brown. Low plasticity. [TOPSOIL]			M		S	
0.5	ALLUVIUM	ML	SILT with trace clay; brown with orange mottles. Low plasticity.			W		Vst	
1.0	ALLUVIUM	GW	Sandy fine to coarse GRAVEL and trace cobbles; grey rounded. Well graded. Sand is fine to medium.		▼	S		D	
1.5									
2.0									
			EOH: Practical Refusal due to pit collapsing.						
2.5									

Termination: Pit Collapse
Groundwater encountered at 1.2 m.