BEFORE THE QUEENSTOWN LAKES DISTRICT COUNCIL HEARINGS PANEL

UNDER	the Resource Management Act 1991
IN THE MATTER	of the review of parts of the Queenstown Lakes District Council's District Plan under the First Schedule of the Act
AND	
IN THE MATTER	of submissions and further submissions by **REMARKABLES PARK LIMITED AND QUEENSTOWN PARK LIMITED**

STATEMENT OF EVIDENCE OF ROBERT BOND ON BEHALF OF REMARKABLES PARK LIMITED AND QUEENSTOWN PARK LIMITED

(GEOTECHNICAL ENGINEERING – NATURAL HAZARDS)

STREAM 13 REZONING HEARINGS

9 June 2017

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1. QUALIFICATIONS AND EXPERIENCE

1.1 My name is Robert Bond, I am a Senior Geotechnical Engineer with Opus International Consultants.

1.2 I am a Chartered Professional Engineer of the Institution of Professional Engineers, New Zealand and a Chartered Engineer with the Engineering Council UK with specialist areas in Geotechnical Engineering and Management.

1.3 I have a Bachelor of Engineering degree (1993) from the Camborne School of Mines, Exeter University, UK.

1.4 I was employed by Opus International Consultants in 1998 as a Geotechnical Engineer in the UK and was an office manager and design team manager for two offices responsible for a team of dedicated structural, civil, geotechnical and contaminated land engineers. In 2010 I transferred to the NZ division of Opus and have been based in Central Otago since 2011. Since that time I have worked across the North Island and South Island assessing Geotechnical hazards and acting as Senior Geotechnical Engineer conducting investigations and assessments of natural hazard risks and in assessing design schemes for mitigation and protection measures for infrastructure and development projects. Most recently I was the senior engineer responsible for completing the initial natural hazard risk assessments on behalf of NZTA for the Kaikoura seismic event recovery works on the Inland Road route and SH1 north of Kaikoura, was instrumental in the establishment of the Geotechnical Group of NCTIR (North Canterbury Transport and Infrastructure Rebuild) and in identifying key geotechnical redevelopment constraints and solutions to the redevelopment of SH1.

2. CODE OF CONDUCT

2.1 I have read and am familiar with the Code of Conduct for Expert Witnesses in the current Environment Court Practice Note (2014), have complied with it, and will follow the Code when presenting evidence to the Council. I also confirm that the matters addressed in this statement of evidence are within my area of expertise, except when relying on the opinion or evidence of other witnesses. I have not omitted to consider material facts known to me that might alter or detract from the opinions expressed.

3. SUMMARY

3.1 My main conclusions are as follows:

(a) The report compiled by Opus Consultants titled Geotechnical Hazard Appraisal referenced 6-XZ226.02 dated 10 August 2015 is relevant to the rezoning hearings and the conclusions reached are valid;

(b) There are no natural hazards identified that are of a significant concern that could negate or seriously jeopardise the currently proposed activity areas; and

(c) In terms of Natural Hazard Risk the proposed areas are considered suitable for development and that where present, identified hazards can be appropriately managed.

4. INTRODUCTION

4.1 In 2015 Opus consultants were instructed by Remarkables Park Limited (**RPL**) to complete an appraisal of the potential geotechnical hazards posed to infrastructure, site users and occupiers of Queenstown Country Station (**Site**) given a number of proposed activity areas (namely Rural Residential (**RR**) and Rural Visitor (**RV**)) in selected areas of the Site.

4.2 The scope of works completed in 2015 included:

(a) A detailed geotechnical and geological desk study of currently available information sources;

(b) A walkover of the Site by two experienced Opus geotechnical engineers to note geological and geotechnical features including an assessment of potential development of hazards;

(c) Compilation of a series of hazard maps for the Site; and

(d) Provision of a summary report.

4.3 No further site investigations or detailed assessments were completed.

4.4 In 2017 I was presented with the revised Queenstown Park Activity Areas (RR and RV) plan (**attached** and marked "**A**") and was instructed to review the 2015 Opus report with respect to the proposed activity areas, namely;

(a) RV 2;

(b) RV 3;

(c) RV 4;

(d) RR 2;

(e) RR 3;

(f) RR 4;

(g) RR 5;

(h) RR 6; and

(i) RR 7.

4.5 The findings of my review were then presented to RPL in the form of an email and revised summary table with key natural hazard risks identified and referenced to each of the above RV and RR areas. Where appropriate mitigation measures were proposed. A copy of the table is **attached** and marked "**B**".

5. GEOTECHNICAL HAZARD APPRAISAL, 2015

5.1 The Geotechnical Hazard Appraisal (**Opus 2015 Report**) was compiled by Emily Stevens and reviewed by myself. A copy of the Opus 2015 Report is **attached** and marked "**C**".

5.2 The appraisal considered desk based information sourced from available geotechnical resources including, the QLDC and ORC natural hazard databases, the Opus archives and geological information held by GNS.

5.3 The site walkover was completed in multiple stages between October 2014 and March 2015 by both Emily Stevens and myself.

5.4 On the basis of the collected data, a Site Geotechnical Hazard Assessment was developed and produced a series of Hazard Maps (Appendix A to the Opus 2015 Report, which is attached and marked "**C**").

5.5 Each hazard map identified the proposed activity areas together with the extrapolated extent of potentially affected areas. In terms of rock fall, a qualitative assessment system was designed specifically for the Site to assess the potential risk in terms of a rock fall hazard rating ranging from None or Very Low to High rock fall risk.

5.6 In addition, each activity area was individually assessed in terms of perceived or observed natural hazard occurrence and was described in the report together with a qualitative assessment of perceived risk (low / medium (or moderate) / high) and where deemed appropriate a proposed mitigation measure was proposed.

5.7 In terms of the risk assessment methodology adopted reference was made to the Seismic Risk in the Otago Region report produced by Opus Consultants (Brabhaharan et al 2005) on behalf of the ORC in 2005 with observations relating to geology and topography and the sensitivity of the proposed activity on the Site, (including consideration of the proposed Importance level of structures as noted by NZS 1170.0).

5.8 Where a Low or Non Risk of occurrence was identified for a particular hazard then no mitigation measures were deemed appropriate. Where a Medium Risk was identified for a particular hazard type then further investigation or assessment was proposed together with possible mitigation measures for consideration. Where a High risk was identified then further investigation was deemed necessary and mitigation measures were proposed for inclusion in the specific activity area. Such measures could include avoidance of the hazard and result in a strong recommendation to move the activity beyond the influence of the hazard or re-assess the activity type proposed (sensitivity analysis).

5.9 The 2015 report concluded that on the basis of desk based researches and site inspections completed, multiple natural hazards had been identified that could potentially affect the Site and, in limited cases, the proposed activity areas. The key natural hazards identified in the 2015 study were:

(a) **Rock fall -** Across the entire Site area various erosional rock fall sites were identified. The rock fall hazard rating that applied to the Site varied from None or Very Low to High. For the proposed activity areas however, the rock fall hazard risk was assessed as being None to Low;

(b) **Flooding -** Localised areas of the Site were identified to be at risk of flooding. Only one of the activity areas was considered at risk of flooding, L6 (now referenced as RR4) and this was deemed as being a Low risk;

(c) **Channel Migration** – Limited areas of the Site were assessed as being at potential Low or no risk from channel migration either as river channels associated with alluvial fan deposition or as meandering;

(d) **Scour Hazard** – Certain sections along the Kawarau River, the Rastus Burn and Owens Creek were noted to be at risk of potential scour erosion;

(e) **Deep Seated Landslides** – Four key areas of deep seated large landslides were noted to potentially affect the Site. However, none were noted to impact directly on an activity area. Reference was made to the classification adopted by Brabha et al (Opus 2005) in terms of susceptibility category linked to seismic activity for earthquake induced mass movement and all sites were considered to be of Susceptibility Category Low;

(f) **Shallow Landslide –** Where steep slopes were identified and their heights were generally greater than 4m a shallow landslide or slope instability hazard was identified. These areas were generally in close proximity to the banks of the Kawarau River and along the southern extents of the activity areas. These hazards were identified as localised areas of surficial instability where slope angles were recorded as being steep (>40°). This applied only to RV2, RV3 and RR7 and only to the margins of those areas;

(g) **Liquefaction Potential –** As per the 2005 Opus Report the Site has been assessed in terms of liquefaction potential and assigned a soil Class A, B or C rating. The majority of the low lying areas of the Site in close proximity to the Kawarau River have been assigned as soil Class C, (Possibly Susceptible). The potential for liquefaction is governed by a number of factors including the presence of groundwater and grainsize of the deposited sediments. Liquefaction can result in slope failures, lateral spreading of river

banks and settlement in weak or loose soils under the right seismic loading conditions and soil profiles. Whilst areas are identified as being possibly susceptible the actual effects of liquefaction on the Site are driven by these other factors. The potential for liquefaction effects to occur on the Site or a given activity area have been typically assessed as Low or Low to Medium based on anticipated depths to groundwater and material composition of the Site soils based on observations made during the site inspections;

(h) **Alluvial Fan – Active debris flow –** The topography of the Site is governed by the Remarkables Mountain Range to the south and several large alluvial fans that extend northward off the flanks of the Mountains associated primarily with the two major river courses that cut through the Site, namely the Rastus Burn and Owens Creek. Active debris dominated flow fans are also present together with inactive composite fans (ORC Natural Hazard Database, Opus and GNS 2009). As per the 2009 Opus/GNS report recommendations, awareness of the hazards and processes associated with the fan development is sufficient mitigation. Where appropriate further mitigation of identified associated alluvial fan feature risks has been made; and

(i) **Soft Ground –** In localised areas of the Site soft ground associated with high groundwater tables has been identified as a potential hazard, namely RR6. The associated risk posed to the activity area can be mitigated following further investigation and surface water drainage design. The risks posed by this hazard have been determined as being Low.

5.10 The Opus 2015 Report provided an appraisal of each activity area with respect to the observed or perceived Natural Hazard and where a Medium or higher risk was perceived, provided proposed mitigation measures.

5.11 The proposed measures typically comprised the following:

(a) Avoidance Actions – move the activity area away from the area of impact or concern;

(b) Containment Actions – establish contingencies to deal with the risk if it occurs; and

(c) Mitigation Actions – propose works to be completed to prevent the risk from occurring.

5.12 In terms of the activity areas the majority of recommendations made were typically either avoidance, with the establishment of safe stand off or set back zones for development and mitigation, with the establishment of engineering solutions developed to manage the risk.

5.13 The Opus 2015 Report concluded that the hazards at the Queenstown Station were manageable and that mitigation measures proposed were relatively minor.

5.14 A recommendation was made to assess the soil conditions of the development areas to fully determine the degree of actual liquefaction risk and enable suitable infrastructure and foundation designs to be determined.

6. GEOTECHNICAL REVIEW, 2017

6.1 In 2017 I was issued a revised development plan showing the new RR and RV activity areas. The plan is **attached** and marked "**A**".

6.2 I was asked to review the proposed RR and RV zones in respect of the 2015 Opus Report. In doing so, I compiled the spreadsheet referred to previously and presented in **Attachment B**.

6.3 The conclusions of my review were:

(a) The activity areas were similar to those previously considered in 2015;

(b) The risks appraised to each of the previous activity areas were commensurate with the 2017 proposals;

(c) The natural hazards identified and risk levels assessed were appropriate and relevant to the current proposal;

(d) The levels of risk assessed were typically Low and that these did not require mitigation;

(e) The natural hazard risks could, where necessary, be mitigated without affecting the development proposals;

(f) Further investigation of the activity areas to fully qualify the risks and enable the mitigation measures to be designed would be required, particularly in terms of potential liquefaction risk (all RV and RR areas) and potential soft ground (Area RR6 only), where it occurs; and

(g) Further investigation work would be required to facilitate foundation and infrastructure design.

7. CONCLUSION

7.1 It is my opinion that the Site is potentially affected by several identified natural hazards.

7.2 The identified natural hazards are however similar to the wider Otago region and are well understood and well documented with recognised means of mitigation being commonly adopted for both residential and commercial developments.

7.3 The risks posed by the hazards identified are generally considered to be rated as Low or Low to Medium, and in most cases do not warrant further investigation or mitigation.

7.4 The risks, where identified as being Low to Medium or higher, warrant further investigation and possibly mitigation, dependent upon the form of construction/development proposed and land use proposed.

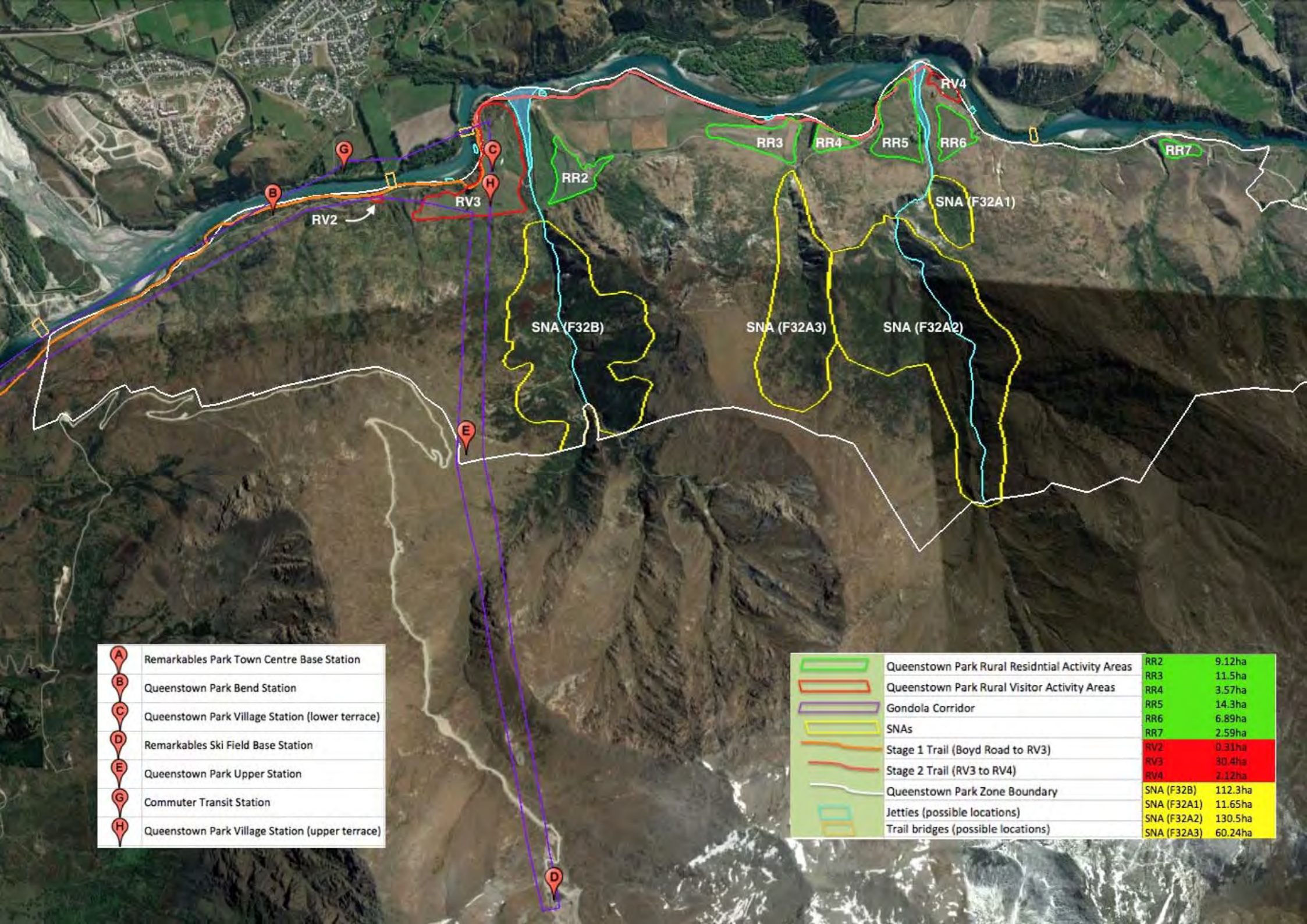
7.5 Further geotechnical site investigations are warranted in order to fully assess the liquefaction potential of some areas of the Site and also to facilitate adequate foundation and infrastructure design.

7.6 Where a natural hazard exists and mitigation measures are to be adopted this should not preclude or unnecessarily restrict development.

Robert Bond

9 June 2017

APPENDIX A: QUEENSTOWN PARK ACTIVITY AREAS PLAN 2017



A	Remarkables Park Town Centre Base Station
B	Queenstown Park Bend Station
C	Queenstown Park Village Station (lower terrace)
D	Remarkables Ski Field Base Station
E	Queenstown Park Upper Station
G	Commuter Transit Station
H	Queenstown Park Village Station (upper terrace)

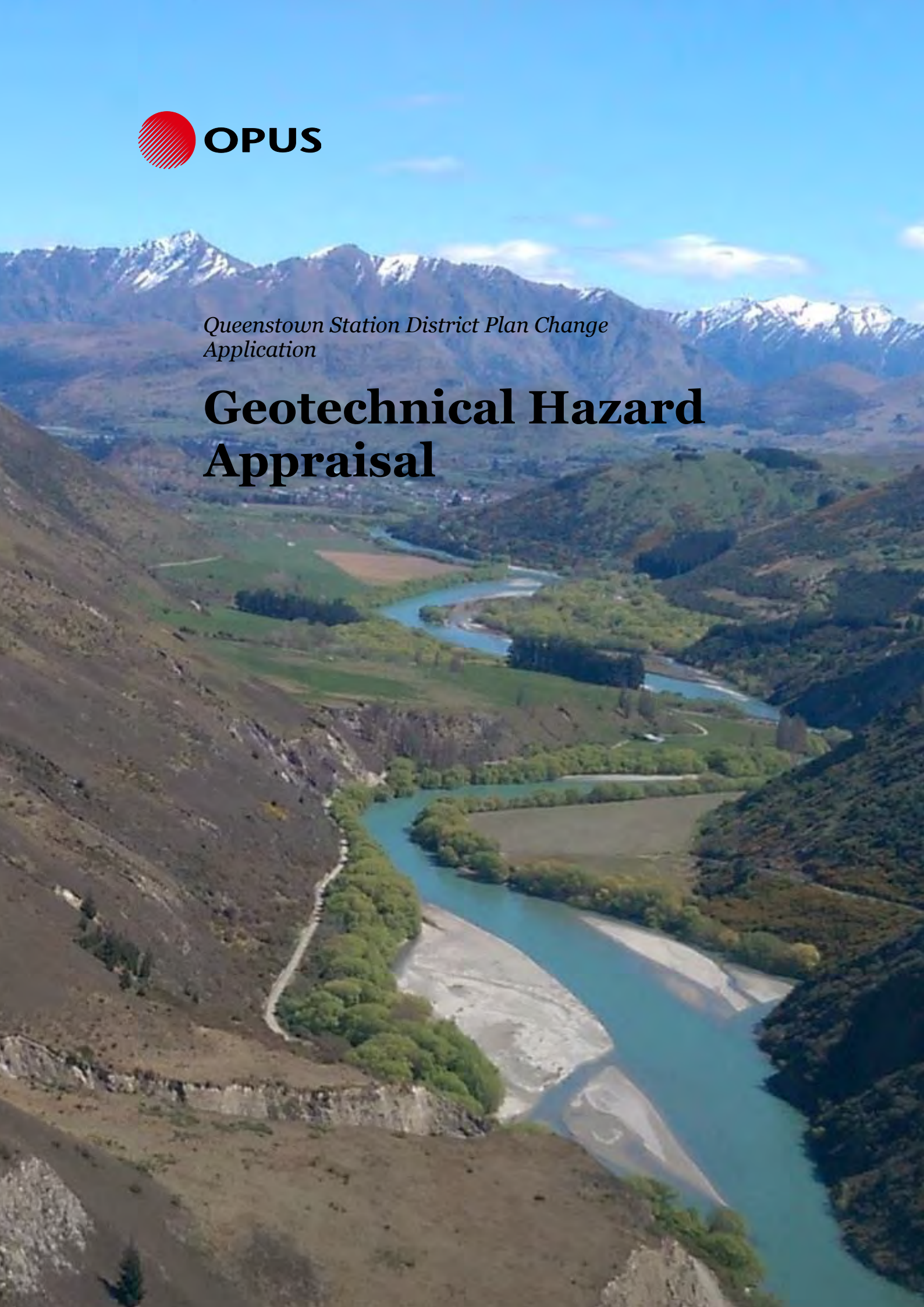
	Queenstown Park Rural Residntial Activity Areas	RR2 9.12ha
	Queenstown Park Rural Visitor Activity Areas	RR3 11.5ha
	Gondola Corridor	RR4 3.57ha
	SNAs	RR5 14.3ha
	Stage 1 Trail (Boyd Road to RV3)	RR6 6.89ha
	Stage 2 Trail (RV3 to RV4)	RR7 2.59ha
	Queenstown Park Zone Boundary	RV2 0.31ha
	Jetties (possible locations)	RV3 30.4ha
	Trail bridges (possible locations)	RV4 2.12ha
		SNA (F32B) 112.3ha
		SNA (F32A1) 11.65ha
		SNA (F32A2) 130.5ha
		SNA (F32A3) 60.24ha

APPENDIX B: NARUAL HAZARD RISK SUMMARY TABLE

Queenstown Park Station Activity Areas Natural Hazard Assessment

Activity Area	Relevent Opus 2015 Ref	Identified Natural Hazard	Risk None/Low/Med/High	Evidence	Mitigation Proposed
RV 1	removed				
RV 2	Not previously investigated	Slope instability	LOW - MED	Steep slopes with high banks down to the Kawarau river, some evidence of surface creep below the access track.	Careful investigation and constriution of development platform
RV 2	Not previously investigated	River Scour	LOW - MED	On the banks of the Kawarau river, scour is active	Installation of rock protection, planting and other river bank protection works
RV 3	L2	Erosional Rockfall on South West corner	LOW	Minor rockfall away from bluffs not extending on to platform area	No Mitigation necessary
RV 3	L2	Erosional Rockfall on South East corner	NONE	No source identified	No Mitigation necessary
RV 3	L2	Possible Liquefaction Risk	LOW	Identified as Possibly Susceptible to liquefaction risk (ORC natural Hazards database) and QLDC natural hazards register. No shallow groundwater.	No Mitigation necessary
RV 3	L2	Alluvial fan - Active debris dominated	LOW	Identified on ORC natural hazards and evident on site.	None - awareness of location and control measures in place with respect to river channels and debris flows.
RV 4	V4	River Scour	LOW - MED	Evidence of river scour and erosional slopes adjacent to kawarau River	20m set back for development possibly consider additional planting to slow erosion of banks
RV 4	V4	Possible Liquefaction Risk	LOW	Identified as Possibly Susceptible to liquefaction risk (ORC natural Hazards database) and QLDC natural hazards register. No shallow groundwater.	No Mitigation necessary
RV 4	V4	Contaminated Land	MED	Former woolshed and landfill site	removal of landfill and complete a DSI
RR 1	removed				
RR 1	L1	Slope erosion	LOW	Minor small shallow slides evident on steeper gully slopes - creep of hillside in localised areas (southern side)	10m set back to edge of slope, possible investigation and re-engineering of platform for development
RR 1	L1	Possible Liquefaction Risk	LOW	Identified as Possibly Susceptible to liquefaction risk (ORC natural Hazards database) and QLDC natural hazards register. No shallow groundwater.	No Mitigation necessary
RR 2	L2	Erosional Rockfall on South West corner	LOW	Minor rockfall away from bluffs not extending on to platform area, no evidence of rocks on area.	No Mitigation necessary
RR 2	L2	Possible Liquefaction Risk	LOW	Identified as Possibly Susceptible to liquefaction risk (ORC natural Hazards database) and QLDC natural hazards register. No shallow groundwater.	No Mitigation necessary
RR 3	L5	River Scour	LOW - MED	Evidence of river scour and erosional slopes adjacent to kawarau River	20m set back for development possibly consider additional planting to slow erosion of banks
RR 3	L5	Possible Liquefaction Risk	LOW	Identified as Possibly Susceptible to liquefaction risk (ORC natural Hazards database) and QLDC natural hazards register. No shallow groundwater.	No Mitigation necessary
RR 4	L6	Flooding	LOW	Identified surface water erosion features on southern central part of site leading to depression on the area - possible swale feature	Possible formation of engineered swale drain through centre of site.
RR 4	L6	Possible Liquefaction Risk	LOW	Identified as Possibly Susceptible to liquefaction risk (ORC natural Hazards database) and QLDC natural hazards register. No shallow groundwater.	No Mitigation necessary
RR 5	L7	River Scour	LOW - MED	Evidence of river scour and erosional slopes adjacent to Owens Creek on eastern side of zone.	20m set back for development possibly consider additional planting to slow erosion of banks. Consider river training and bed load management to keep river channelised.
RR 5	L7	Possible Liquefaction Risk	LOW	Identified as Possibly Susceptible to liquefaction risk (ORC natural Hazards database) and QLDC natural hazards register. No shallow groundwater.	No Mitigation necessary
RR 6	L9	Soft Ground	LOW	shallow groundwater flow off the higher slopes to the south causes saturated near surface soils on southern extents of the site.	Install drainage to intercept surface water run off.
RR 6	L9	Possible Liquefaction Risk	LOW-MED	Identified as Possibly Susceptible to liquefaction risk (ORC natural Hazards database) and QLDC natural hazards register. Shallow groundwater is possible on southern areas of the zone.	Investigation may be required combined with specialist foundation design
RR 7	Not previously Investigated	Slope Instability	LOW	Area of steep slopes close to Kawarau River with minor land instability on slopes	Investigation may be required combined designed set back from slope crests up to 10m set back for structures
RR 7	Not previously investigated	River Scour	LOW - MED	Area of known river scour from Kawarau river	Assessment required and assess extent of potneital threat
RR 7	Not previously investigated	Possible Liquefaction Risk	LOW	Identified as Possibly Susceptible to liquefaction risk (ORC natural Hazards database) and QLDC natural hazards register. No shallow groundwater.	No Mitigation necessary

APPENDIX C: GEOTECHNICAL HAZARD APPRAISAL (OPUS 2015 REPORT)



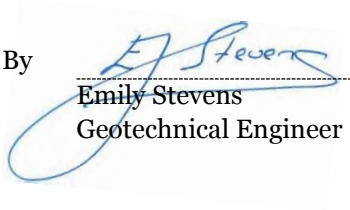
Queenstown Station District Plan Change Application

Geotechnical Hazard Appraisal

Queenstown Station District Plan Change Application

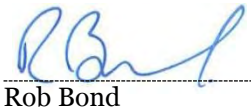
Geotechnical Hazard Appraisal

Prepared By



Emily Stevens
Geotechnical Engineer

Reviewed By



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Date: 10 August 2015
Reference: 6-XZ226.02
Status: Final

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Summary

An appraisal of the potential geotechnical hazards posed to infrastructure and site users/occupiers has been carried out on the property known as Queenstown Station for Remarkables Park Limited by Opus International Consultants Ltd (Opus), for the purpose of applying for a District Plan change for the property.

A preliminary development plan has been provided by Remarkables Park Limited and this plan that has been used as a base plan for the following natural hazard assessment.

The geotechnical hazards considered in this appraisal are:

1. Alluvial fan – split into Debris Flow, Flooding, Channel migration, Scour
2. Rockfall
3. Liquefaction
4. Shallow landslip
5. Deep seated landslide

No hazards of significant concern have been identified that could negate or seriously jeopardise any of the currently proposed development sites at the Queenstown Station and overall the hazard level at the property is considered to be manageable. Note that no site investigations have been completed at this stage to confirm the extent of liquefaction risk and trial pit investigation is recommended prior to any detailed design of structures.

The level of qualitative rockfall risk using criteria specific to the Queenstown Station site, has been assessed for all alluvial fan areas. The only area of High Rockfall Risk is located immediately east of Chard Farm, which is outside the Queenstown Station property boundary however does affect the potential use of the Station and is included for that reason.

This report outlines sites where minor mitigation measures will be required and the options available. Preliminary mitigation recommendations for the development sites are as follows:

L1 – Development setback 5.0m from southern boundary

L2 – No mitigation measures considered necessary

L3 – *In the area identified as having moderate rockfall risk:* Planting of large trees behind structures built within 100m of base of slope or directly below a 'gully' feature.

L5 – No mitigation measures considered necessary

L6 – Observe site during rainfall to determine amount of ponding and water flow. Possible drainage installation or formation of landscaped pond in low lying area.

L7 - *Scour:*

- 20m setback for structures, Importance Level 2 -5 (NZS1170.0)

- Planting of tree species such as willows along the creek bank to help stabilise.
- River training measures such as channel excavation to channelize the stream and lower the bed level. Possible groyne placement upstream to direct flow away from L7 area.

L9 - *Scour:*

- 20m setback for structures, Importance Level 2 -5 (NZS1170.0) (recommendation currently met - shown as approximately 85m on the development plan).
- Planting of large tree species such as willows along the creek bank to help stabilise.
- River training measures such as channel excavation to lower the bed level and possible groyne placement upstream.

Flooding:

Monitor groundwater levels at the site during winter and spring and after high rainfall events. Preliminary development set back of 20m east of the dam structures. Subsoil or gravel drains may be necessary to drain the proposed development area.

Planting of trees and large shrubs on the site will also help to keep the groundwater level low.

Shallow Landslip:

Further planting of large trees and shrubs in the gullies to reduce the impact of surface water erosion.

Development set back of 20m from the base of the slope directly below the gully features.

V2 - 20m setback for structures from the western boundary, Importance Level 2 -5 (NZS1170.0)

- Monitoring of amount of erosion and slope release. Consider the use of erosional control matting if rate of erosion is rapid.

- Planting of trees and shrubs close to slope crest where possible to help mitigate against the effects of erosion and slope release.

V3 - 20m setback for structures, Importance Level 2 -5 (NZS1170.0)

V4 - A Contaminated Land Assessment to be carried out in the area surrounding the woolshed and along the western edge of the terrace.

20m setback for structures, Importance Level 2 -5 (NZS1170.0)

R1 - Further geotechnical investigation needed for situating of structures Importance Level 2-5 (NZS1170.0).

Access Road –

The Queenstown Station access road will require proactive maintenance and clearance of shallow slips and debris flow as they occur. It will be important to maintain good drainage along the uphill drainage channel to prevent blockage and saturation of the uphill slope toe, which could destabilise the slope and cause shallow landslip.

A driveover inspection of the access road immediately following rain events is advised.

If scour erosion and failure is observed, Remarkables Park Limited could look at a programme of rock armouring and other road protection measures to protect against river scour damage (washouts) from the Kawarau River at the Chard Farm end of the site.

Culverting, bridging and fords across either the Rastus Burn or Owen Creek will need to consider for the potential impact of debris flows.

Consideration should be given to working with QLDC to mitigate the high rockfall risk on the Station access road east of Chard Farm.

Contents

1 Appraisal Scope

The following report presents a Preliminary Appraisal of the Geotechnical Hazards identified through desk based research and a detailed site inspection that may affect the proposed development known as Queenstown Station, Queenstown. This study has been carried out for Remarkables Park Limited by Opus International Consultants Ltd as part of the development's feasibility analysis.

A preliminary development plan has been prepared by Landscape Architect Ben Espie (Vivian+Espie Limited) and this plan has been used as a base plan for the following natural hazard assessment (see Appendix A).

The development site is understood to be 1850 hectares in size, as shown on the development plan and is likely to be subdivided over time for the purpose of development as Queenstown Station. Development of the site is anticipated to include a mixture of land uses including low density residential, recreational parks, light commercial/industrial and conversion of existing buildings.

This report considers the following prime geotechnical hazards and their potential effect on the currently proposed development sites:

6. Alluvial fan – split into Debris Flow, Flooding, Channel migration, Scour
7. Rockfall
8. Liquefaction
9. Shallow landslip
10. Deep seated landslide

Each site listed on the development plan has been individually appraised for its proximity and potential susceptibility, to these hazards.

Potential mitigation measures have been suggested where applicable, however it should be noted that any proposed mitigation works shall require confirmation through further detailed engineering assessment of each of the sites as part of the detailed design and consent process.

As this is a geotechnical hazard assessment, this report does not consider non-geotechnical based natural hazards such as avalanche or wildfire, however it is recommended that the risk from all natural hazards is investigated and assessed as part of the site specific detailed design processes.

In addition to the detailed site assessment, site hazard maps have been prepared depicting the initial appraisal of the potential hazard extents. These maps provide a useful tool for Remarkables Park Ltd for future use in planning of any further development changes during the feasibility stage. However it is noted that any development changes will be required to be re-assessed for hazard susceptibility by an experienced geotechnical professional.

2 Appraisal Methodology

This appraisal comprised the following scope of work:

- A desk study of available geotechnical resources.
- A review of public access information held in QLDC's natural hazard GIS database.
- Two site walkovers by two Opus Geotechnical Engineers in October 2014 and March 2015.
- Development of qualitative rockfall risk assessment criteria specific to Queenstown Station
- Geotechnical hazard appraisal of the information gathered.

3 Topography and Proposed Development

Queenstown Station (The Park) is located approximately 2km directly east of the Queenstown Airport. It is bounded to the north by the Kawarau River for approximately 14km and to the south by the Remarkables Mountain Range (Remarkables), which includes (immediately south of the site) the peaks of Ben Cruachan at 1905m and an unnamed peak at 2057m. The Park is around 5km wide at it widest point. An access road runs for around 14km East-West across the length of the Park, approximately following the Kawarau River, which was once the main route into Queenstown from Cromwell.

The Park is around 1850 hectares in size, comprising steep (typically greater than 40°) north facing slopes from the northern end of the Remarkables that slope from the mountain peaks to alluvial river fans and flat land created by both the Kawarau River and multiple watercourses emanating from the adjoining mountains. The two primary watercourses sourcing from the Remarkables are the Rastus Burn (approximately 4km along The Park access road from the western end of site) and Owen Creek (approximately 7.5km along The Park access road from the western end of site).

The western end of the site contains the Remarkables Ski Area Access Road. Current land use of the alluvial derived lower land includes viticulture (the Chard Farm Winery is located at the eastern end of the Park) and agriculture (namely pasture for cows, sheep and deer). There are several existing dwellings and farm buildings on the property.

The proposed development comprises 5 key elements – Visitor, Living, Retreat, Jetty or which are for the most part located on the alluvial land on the northern side of the Park. These elements are described in Section 6 of this report and are shown on the landscape masterplan attached in Appendix A.

4 Regional Geological Setting

4.1 Geology

The 1:250,000 Geological Map of New Zealand (Map 18, published by the Institute of Geological & Nuclear Sciences (GNS) NZ) identifies The Park as being geologically comprised as follows:

- Undifferentiated pelitic and psammitic schist and greenschist sequences (Yw) of Rakaia Terrane. Grade IV metamorphosed, which indicates a high degree of foliation and segregation. This type of rock is generally more susceptible to weakness along the foliation (mass landsliding etc) and weathering processes that can induce rockfall. Foliation typically dips at angles from 10° to 20° to the south-west regionally.

  Remarkables Mountain Range; Bedrock underlying alluvial soils

- Tabular cross-bedded gravel and sand in river deltas (Q1a)

  Primarily near the Shotover/Kawarau confluence at the western end of the site. Flood plain deposition. Holocene Age Deposits.

- Undifferentiated, variably weathered gravels, sands and silts in alluvial fans (uQa)

  Alluvial fans from Remarkables Range watercourses (Owen Creek, Rastus Burn etc).

4.2 Seismicity

The closest active fault system is the Nevis Cardrona Fault System, which runs from north to south and is located approximately 3.5km directly east of the eastern (Chard Farm) end of the site. This is a reverse thrust fault system with an estimated event recurrence interval of 5000-10000 years and the last known event on this fault system has not been established. The trace of this fault can be seen as an approximately 6.0m high step in a field immediately east of the AJ Hackett Bungy carpark (visible from SH6).

Due to the proximity to an active fault, consideration will need to be given to ground shaking induced damage and liquefaction during the detailed structural and foundation design of individual structures.

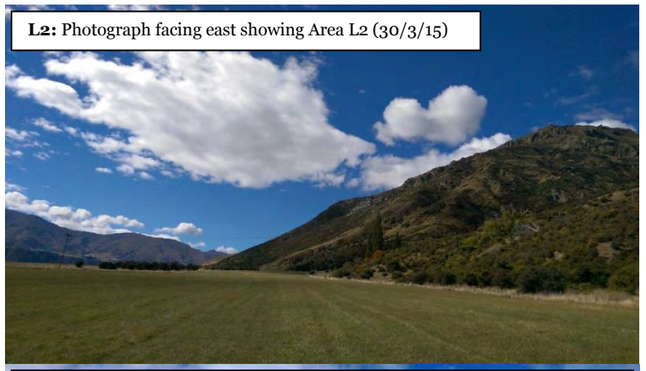
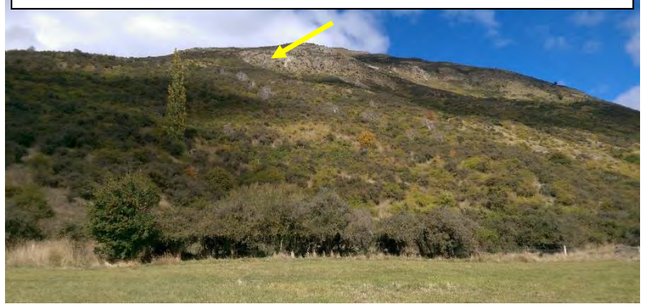
5 Development Site Geotechnical Hazard Assessment

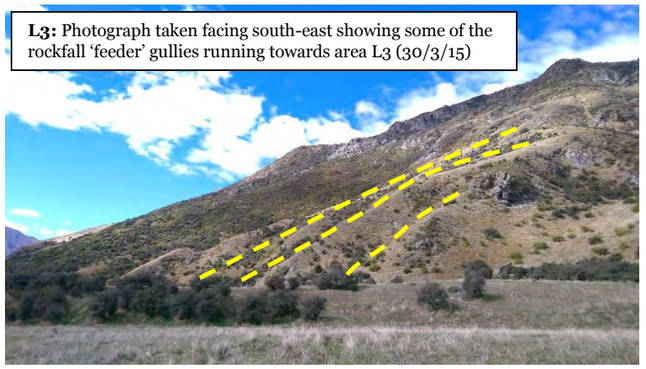
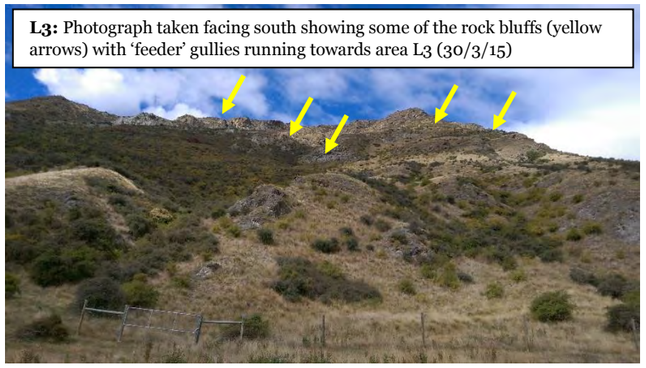
Background information for the specific hazards assessed for Queenstown Station is attached to this report as Appendix C. Please refer also to the Queenstown Station Hazard Maps attached to this report in Appendix A and Rockfall Risk Assessment Criteria in Appendix B.

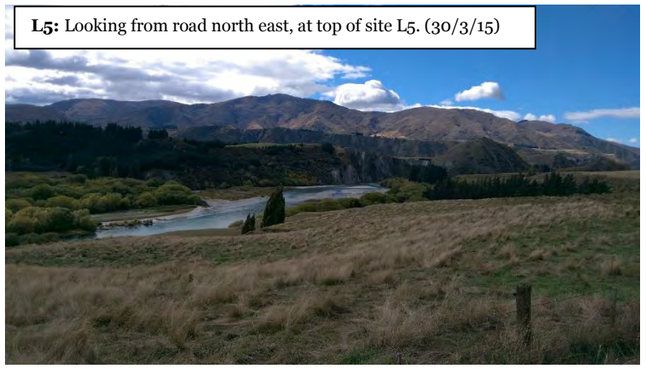
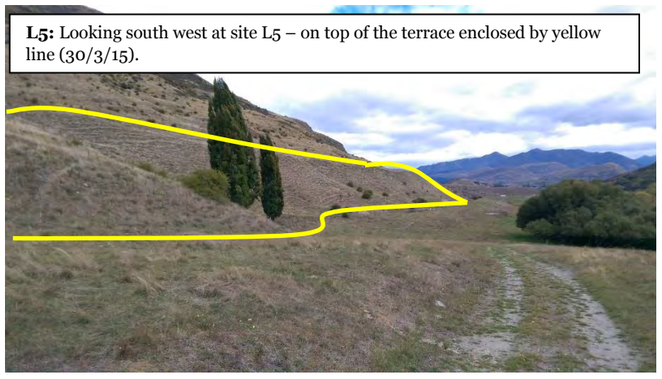
Note that Table 1 contains a preliminary overview assessment of the respective sites on the current preliminary development plan provided by the client, Remarkables Park Ltd. A detailed assessment should be carried out of each site as development proceeds.

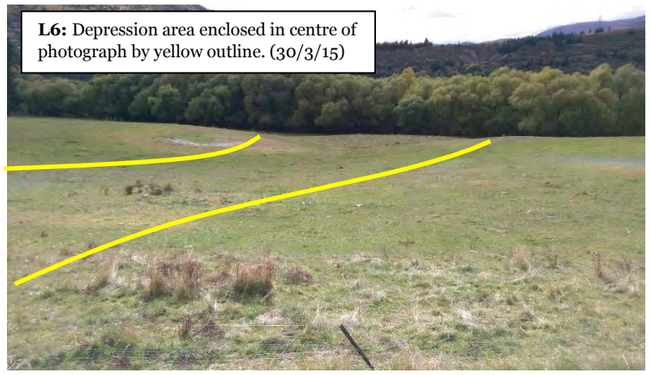
Table 1. Queenstown Station Preliminary Geotechnical Hazard Appraisal

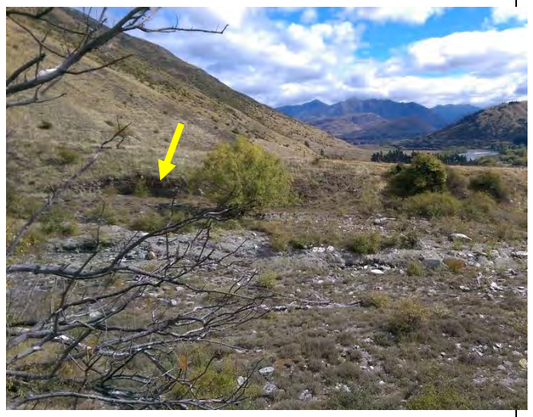
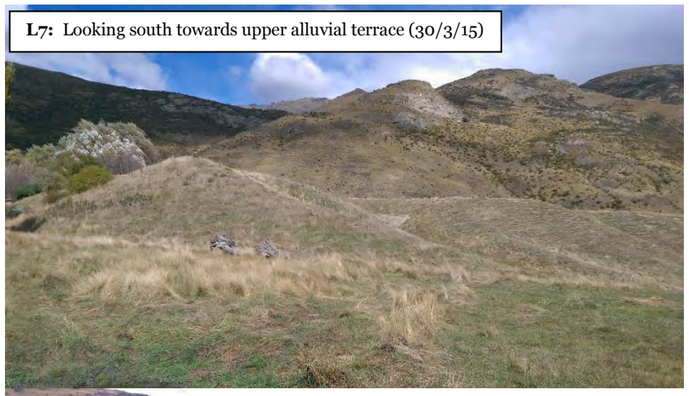
Development Site ID	Description of Site Topography and Planned Development	Geotechnical Hazards	Proposed Site Mitigation (if any)	Photographs
L1	Living. Residential and Visitor Accommodation options. Site is flat on a ridgeline approximately 1.5km up the Remarkables Ski Field Road. 5-10m deep gully forms the southern boundary of development area. Site is currently vegetated with a mixture of tussock, grass and matagouri.	Scour Shallow landslip There is a 5-10m deep gully on southern boundary of development area. It is considered there is a low risk during storm events of minor scour, shallow landslip or slope erosion along this boundary. Minor slope failure scars on gully walls can be seen upstream of site.	Development setback 5.0m from southern boundary.	**L1: G**ully along southern boundary of site, shown by dotted yellow lines (30/3/2015). 

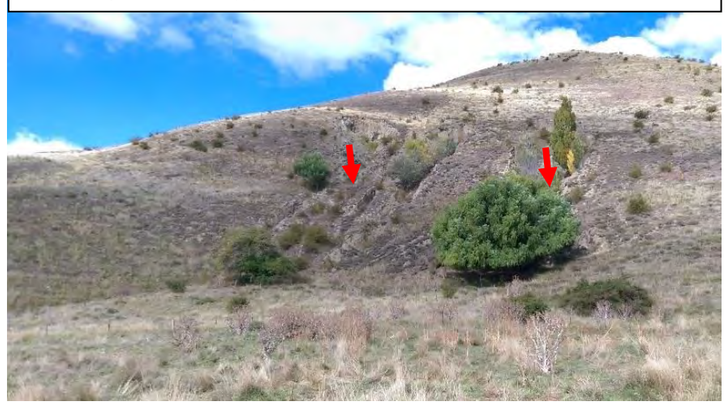
Development Site ID	Description of Site Topography and Planned Development	Geotechnical Hazards	Proposed Site Mitigation (if any)	Photographs
L2	Living. Residential and Visitor Accommodation options. Site is located on top of a flat high alluvial terrace that is approximately 10m above the lower terrace (V2 development area) and approximately 15m above current bed level of the Rastus Burn. Rastus Burn is reasonably well channelized into its alluvial fan at this location. The southern boundary of the site is formed by the Remarkables Mountain Range, sloping towards the site at 25-30 degrees. Site is grassed and used for agricultural grazing/airport runway.	Rock fall –No risk to Low risk An erosional rockfall source area exists at the west end of the site approximately 500m upslope of development site L2. Assessed as no to low rockfall risk to site L2. It is considered most of the rock debris released from this area will run into the gully directly west of L2. There is also mature scrub (Matagouri, Poplar, assorted small trees) covering the slope between the source area and the development site which will act as protection to halt rock debris. Rock run out length from the source area appears to only be around 50m downslope. No rocks were observed in Area L2. Liquefaction Lateral Spreading The area is classified as possibly susceptible to liquefaction (Opus 2002) in the QLDC Natural Hazards Database.	No mitigation measures considered necessary.	**L2:** Photograph facing east showing Area L2 (30/3/15)  **L2:** Photograph facing east showing erosional rockfall source area approximately 500m upslope of Area L2 indicated by yellow arrow (30/3/15) 

Development Site ID	Description of Site Topography and Planned Development	Geotechnical Hazards	Proposed Site Mitigation (if any)	Photographs
L3	Living – rustic. Residential and Visitor Accommodation options. The topography of site is slightly undulating from ancient stream channel paths, with lower and upper (south eastern side of site) alluvial terraces with around 5m height difference. The southern boundary of the site is formed by the Remarkables Mountain Range, with slopes of 25 to 30 degrees. The site is approximately 10m above current bed level of the Rastus Burn. The Rastus Burn is reasonably well channelized into its alluvial fan at this location. Site is vegetated with grass and matagouri and used for agricultural grazing.	Rock fall – Low to Moderate The majority of this site can be classified as no to low rockfall risk. The south eastern corner of the site is considered to have a low to moderate rockfall risk due to the presence of rock bluffs above the site with adversely oriented rock joints. Several 'feeder gullies' lead to development area L3 and a large volume rock failure from one of the bluffs could potentially release rock with enough energy to reach area L3. These rock failures are considered to be a very rare event, likely occurring in a high magnitude seismic or storm event. No evidence of recent rockfall was found in area L3. Liquefaction Lateral Spreading The area is classified as possibly susceptible to liquefaction (Opus 2002) in the QLDC Natural Hazards Database.	*In the area marked as Moderate Rockfall Risk on attached Map 1:* Planting of large trees (non-invasive species similar size to pine) behind structures built within 100m of base of slope or directly below a 'gully' feature. Once structure locations are decided on they should also be assessed for rockfall risk by a suitably experienced geotechnical engineer.	 **L3:** Photograph taken facing south-east showing some of the rockfall 'feeder' gullies running towards area L3 (30/3/15)  **L3:** Photograph taken facing south showing some of the rock bluffs (yellow arrows) with 'feeder' gullies running towards area L3 (30/3/15)

Development Site ID	Description of Site Topography and Planned Development	Geotechnical Hazards	Proposed Site Mitigation (if any)	Photographs
L5	Living. Residential and Visitor Accommodation options. Undulating topography, likely a mix of colluvium or alluvium from the slope located directly south overlying an alluvial terrace of the Kawarau River. Approximately 10m above a lower alluvial terrace (V3 development site). Site is currently grassed and used for agricultural grazing.	Liquefaction Lateral Spreading The area is classified as possibly susceptible to liquefaction (Opus 2002) in the QLDC Natural Hazards Database.	No mitigation measures considered necessary.	**L5:** Looking from road north east, at top of site L5. (30/3/15)  **L5:** Looking south west at site L5 – on top of the terrace enclosed by yellow line (30/3/15). 

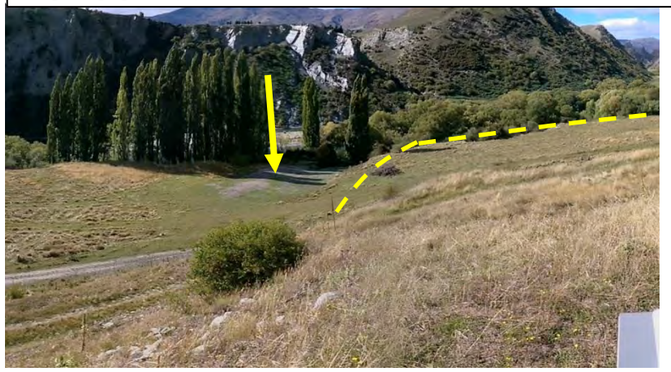
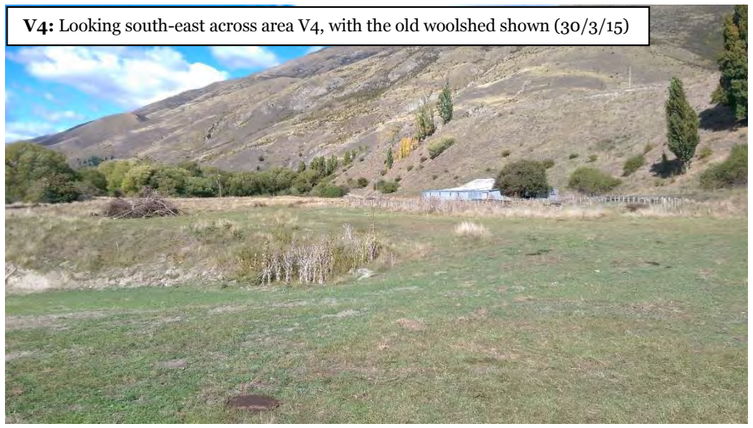
Development Site ID	Description of Site Topography and Planned Development	Geotechnical Hazards	Proposed Site Mitigation (if any)	Photographs
L6	Living - Residential and Visitor Accommodation options. Site is located on a flat to slightly undulating alluvial terrace of the Kawarau River. A depression approximately mid-site, with a small gully leading to it from the south (across road). The site is currently grassed and used for agricultural purposes.	Flooding The depression in the centre of this site could indicate that water flows down the small feeder gully into the site during periods of rainfall – either ponding here or continuing onto the Kawarau River beyond. Liquefaction Lateral Spreading The area is classified as possibly susceptible to liquefaction (Opus 2002) in the QLDC Natural Hazards Database.	Observations of site during rainfall to determine amount of ponding and water flow. Either installation of drainage culverts to carry flow through site or perhaps formation of a landscaped pond at this location.	 **L6:** Depression area enclosed in centre of photograph by yellow outline. (30/3/15)  **L6:** Small gully across road leading towards depression (30/3/15)

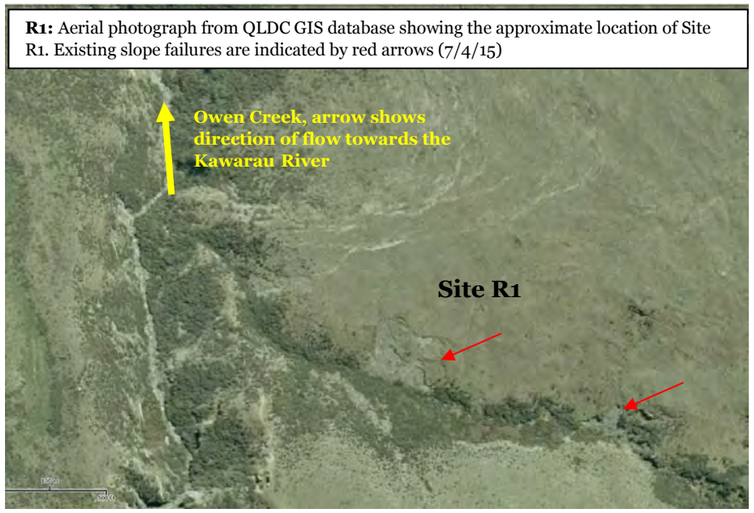
Development Site ID	Description of Site Topography and Planned Development	Geotechnical Hazards	Proposed Site Mitigation (if any)	Photographs
L7	Living - Residential and Visitor Accommodation options. The L7 site comprises two alluvial terraces – an upper terrace approximately 5m (upper reaches) to 10 m above the current bed level of Owen Creek, and a lower terrace approximately 5.0m above the current bed level of Owen Creek. The southern boundary of the upper terrace is formed by the northern slope of the Remarkables Mountain Range (with a gradient of around 25-30 degrees). The L7 site is understood from the development plan provided by the client to not include the current dwelling location, which is at a lower level (approximately 2.0m to 3.0m above current bed level) and considered to have a higher risk of debris flows and flooding.	Scour A minor scour hazard exists along the eastern boundary of the L7 site from the Owen Creek. Although the flow in the Creek is normally small, the catchment area in the Remarkables Mountain Range is large indicating there is potential during a storm event for a rapid increase in flow. This flow will also likely carry rock and gravel due to the rock debris source areas currently visible upstream. The current height of the L7 terrace is considered likely to protect the site from the direct effects of debris flows or channel migration in all but the very extreme of events. However some scour of the banks is considered likely to occur annually, as shown in the photograph below (one recent scour site is indicated by yellow arrow).  There is not considered to be a rockfall risk at this site. Liquefaction Lateral Spreading The area is classified as possibly susceptible to liquefaction (Opus 2002) in the QLDC Natural Hazards Database.	*Scour:* • 20m setback for structures, Importance Level 2 -5 (NZS1170.0) • Planting of tree species such as willows along the creek bank to help stabilise. • River training measures such as channel excavation to channelize the stream and lower the bed level. Possible groyne placement upstream to direct flow away from L7 area.	**L7:** Looking south towards upper alluvial terrace (30/3/15)  **L7:** Looking north across lower alluvial terrace (30/3/15)  **L7:** Looking south towards L7, with yellow dotted lines indicated the two terrace levels that form L7 and the red dotted line the level of the current dwelling (30/3/15) 

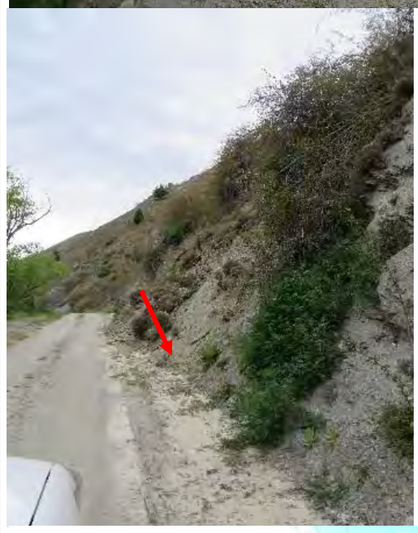
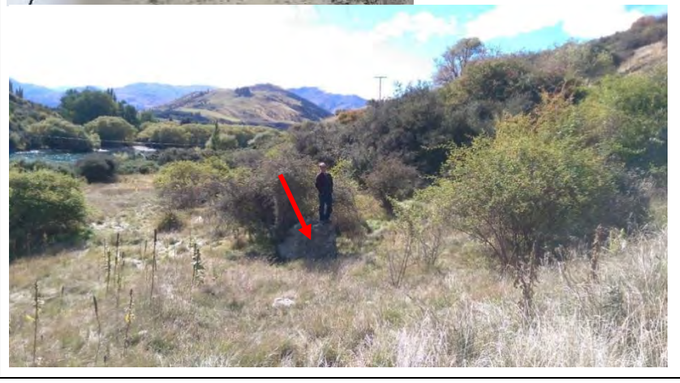
Development Site ID	Description of Site Topography and Planned Development	Geotechnical Hazards	Proposed Site Mitigation (if any)	Photographs
L9	Living - Residential and Visitor Accommodation options. The L9 site is located on an alluvial terrace approximately 3.0-5.0m above the current bed level of Owen Creek. The terrace is generally slightly undulating to flat at the base of an approximately 30 degree slope leading to the Remarkables Mountain Range. Just outside the western edge of the site appears to have been excavated to form three dams approximately in line with each other. These were not full with water at the time of inspection but evidence of recent ponded water could be seen in the lower dam. There are two gullies in the north facing slope that forms the south western boundary of the site. These gullies contain mature trees and vegetation/ The entire paddock is hummocky, suggesting it is water-logged at certain times of year.	Scour Similar to the L7 area, a minor scour hazard from Owen Creek exists along the western boundary of the L9 site. The current height of the L9 terrace combined with the presence of mature trees directly upstream is considered likely to protect the L9 site from the direct effects of debris flows or channel migration except in the very extreme of events. However some minor scour of the banks is considered likely to occur annually. Flooding Aerial imagery from the QLDC GIS Database from July 2014 shows the three dams containing water, suggesting they are full at certain times of year. There was not any evidence of surface water flow to these dams from Owen Creek, which suggests that perhaps the groundwater level can rise to be close to the ground surface in the L9 development area. A high groundwater level at times is also suggested by the hummocky ground. Surface flooding during certain seasons and after high rain events could be likely in the L9 area, particularly on the western side of the site surrounding the dam system. The presence of mature vegetation in the two gullies on the slope on the south-western boundary could indicate that groundwater is close to the surface in the slope. Shallow landslip The two gullies in the southwestern slope have formed in what appears to be loose highly erodible silt and sandy gravel alluvial sediments. The gullies are considered likely to be mainly formed by surface water runoff during rain events. No groundwater was observed running in these gullies at the time of inspection however it is possible the groundwater is present in the slope that rises to the surface in certain seasons or storm events. These gullies have the potential to deposit small to moderate volumes of soil debris at their base. Liquefaction Lateral Spreading The area is classified as possibly susceptible to liquefaction (Opus 2002) in the QLDC Natural Hazards Database.	*Scour:* • 20m setback for structures, Importance Level 2 -5 (NZS1170.0) (recommendation currently met - shown as approximately 85m on the development plan). • Planting of large tree species such as willows along the creek bank to help stabilise. • River training measures such as channel excavation to lower the bed level and possible groyne placement upstream. *Flooding:* Monitor groundwater levels at the site during winter and spring and after high rainfall events. Preliminary development set back of 20m east of the dam structures. Subsoil or gravel drains may be necessary to drain the proposed development area. Planting of trees and large shrubs on the site will also help to keep the groundwater level low. *Shallow Landslip:* Further planting of large trees and shrubs in the gullies to reduce the impact of surface water erosion. Development set back of 20m from the base of the slope directly below the gully features.	**L9:** Western edge of L9, looking upstream at the catchment area for Owen Creek. Large erosional debris source areas can be seen, suggesting that the creek could aggrade relatively quickly. Channel excavation is recommended to prevent scour (30/3/15)  **L9:** South-western slope forming boundary of L9, showing the two erosional gullies – indicated by red arrows (30/3/15)  **L9:** Looking north east across L9 area, showing dam area in the distance (yellow arrow) and gullies (red arrows) (panoramic photograph - 30/3/15) 

Development Site ID	Description of Site Topography and Planned Development	Geotechnical Hazards	Proposed Site Mitigation (if any)	Photographs
V2	Visitor accommodation and commercial activities, specifically at this stage linkage to the mountain via the gondola, river trail, footbridge and jetty. Eastern extent of the potential golf course and site of possible golf club rooms.	Scour The western boundary of area V2 appears to be prone to small landslips and minor surface water erosion. The Kawarau River bends sharply at this point around the Rastus Burn alluvial fan and in times of high flow likely erodes the toe of the slope. However at the time of inspection the amount of erosion and slope failure appeared minimal and surficial only. There is no sign of any deeper seated slope failure such as tension cracking. The alluvium is relatively tightly packed at this point and hence reasonably resistant to erosion. Liquefaction The area is classified as possibly susceptible to liquefaction (Opus 2002) in the QLDC Natural Hazards Database.	- 20m setback for structures from the western boundary, Importance Level 2 -5 (NZS1170.0) - Monitoring of amount of erosion and slope release regularly. Consider the use of erosional control matting if rate of erosion is rapid. - Planting of trees and shrubs close to slope crest where possible to help mitigate against the effects of erosion and slope release.	**V2:** Panoramic photograph showing site V2, approximately enclosed by yellow dotted line. (30/3/15)  **V2:** Erosional slope failure at along the Kawarau River edge of area V2 (30/3/15) 

Development Site ID	Description of Site Topography and Planned Development	Geotechnical Hazards	Proposed Site Mitigation (if any)	Photographs
V3	Commercial and accommodation facilities supporting people using the river trail. It also links a jetty to the river. The site is located on a lower alluvial terrace, approximately 3-5m above the Kawarau River flowing west to east and a small tributary (name unknown) flowing south to north.	Scour This site is around 5.0m above the average flow level of the Kawarau River and around 3.0m above a floodplain of the River. In times of high flow it is likely that this lower floodplain will flood and cause surficial failures and scour erosion along the edge of the V3 terrace. However at the time of inspection the edge of the terrace was reasonably well vegetated with only very minor signs of surficial erosion and no sign of any deeper seated slope failure. Liquefaction The area is classified as possibly susceptible to liquefaction (Opus 2002) in the QLDC Natural Hazards Database.	*Scour* - 20m setback for structures, Importance Level 2 -5 (NZS1170.0)	**V3:** Looking northeast across site V3. The unnamed tributary runs from the gully indicated by the yellow arrow across the back of the photograph (approx. 3.0m below V3 terrace), shown by the yellow dotted line. (30/3/15).  

Development Site ID	Description of Site Topography and Planned Development	Geotechnical Hazards	Proposed Site Mitigation (if any)	Photographs
V4	Commercial recreation activities, possibly including a café and restaurant to support the users of the river and trail. Jetty access. The site is generally flat and located on a lower alluvial terrace around 5-10m above the Kawarau River. There is a refuse tip (recently covered in) on its western boundary on a lower terrace. The station access road forms the southern boundary to the site. A disused woolshed is located just off the access road approximately mid-site.	*Contaminated Land Assessment* - Unknown influence of the recent landfill area and woolshed on surrounding ground condition. Liquefaction Lateral Spreading The area is classified as possibly susceptible to liquefaction (Opus 2002) in the QLDC Natural Hazards Database.	A Contaminated Land Assessment to be carried out in the area surrounding the woolshed and along the western edge of the terrace. 20m setback for structures, Importance Level 2 -5 (NZS1170.0)	**V4:** Looking north across area V4, rubbish area shown by yellow arrow and northern and western extents of the V4 area indicated by yellow line. Access road can be seen on the left of the photograph. (30/3/15)  **V4:** Looking south-east across area V4, with the old woolshed shown (30/3/15) 

Development Site ID	Description of Site Topography and Planned Development	Geotechnical Hazards	Proposed Site Mitigation (if any)	Photographs
R1	Low impact eco-tourism. Accessible only by helicopter. The site is located on a SW facing slope approximately 2.8km upstream of the confluence of Owen Creek with the Kawarau River.	Deep seated landslide SW facing slopes in Central Otago that approximately follow the direction of the regional foliation are prone to deep seated slide failure along this foliation. This is particularly prevalent when the toe of the slope is being actively downcut by a stream or river. From this preliminary overview analysis, it does appear that the R1 site could be prone to a deeper seated landslide failure. There are several slope failures on the same slope and the overall topography is generally hummocky which suggests ground movement. It may be possible to locate a resort building successfully at some point on this slope but it requires further detailed geotechnical investigation.	Further geotechnical investigation needed for situating of structures Importance Level 2-5 (NZS1170.0).	**R1:** Aerial photograph from QLDC GIS database showing the approximate location of Site R1. Existing slope failures are indicated by red arrows (7/4/15) 

Development Site ID	Description of Site Topography and Planned Development	Geotechnical Hazards	Proposed Site Mitigation (if any)	Photographs
Access Road	Not specified in development plan – possible upgrading likely	Rock fall / Scour / Flooding Channel migration / Lateral Spreading Shallow landslip / Debris Flow or Flood As it tracks east-west through the site approximately following the path of the Kawarau River the access road traverses a range of topography along the northern boundary of Queenstown Station, from being cut into slopes to running across alluvial river flats. It is important to the commercial success of the park that this road remains operational. The road is subject to several geotechnical hazards along its route. At times, the road has been cut into the base of the Remarkable Mountain Range, and this cutting has locally created steep 60 to 80 degree bluffs comprising predominantly colluvium and alluvium. The road is sometimes narrow and winds tightly between the Kawarau River and the large uphill slope. River scour from the Kawarau River has caused several washouts at both the Queenstown and Chard Farm end of the site. There are also small shallow landslips along the access road on the uphill side towards the Chard Farm end of The Park, and groundwater was observed emanating from the uphill slope at several locations. It is considered that the Queenstown Station can expect regular shallow land slips on this section of road during rain events and following freeze-thaw cycles, especially during the winter and spring months annually. Rock fall from the upper slopes rolling to road level is considered a very low risk based on the geology and observed existing rockfall debris, however could still be a rare occurrence. Flooding, debris flow and channel migration could affect the access road on both of the major alluvial fans (Owen Creek and Rastus Burn), as well as on several minor alluvial fans throughout the park.	The Queenstown Station access road will require proactive maintenance and clearance of shallow slips and debris flow as they occur. It will be important to maintain good drainage along the uphill drainage channel to prevent blockage and saturation of the uphill slope toe, which could destabilise the slope and cause shallow landslip. A driveover inspection of the access road immediately following rain events is advised. If scour erosion and failure is observed, Remarkables Park Limited could look at a programme of rock armouring and other road protection measures to protect against river scour damage (washouts) from the Kawarau River at the Chard Farm end of the site. Culverting, bridging and fords across either the Rastus Burn or Owen Creek will need to consider for the potential impact of debris flows. The only area of High Rockfall Risk is located immediately east of Chard Farm, which is outside the Queenstown Station property boundary however does affect the potential use of the Station and is included for that reason. It is recommended that QLDC and Remarkables Park Ltd work together to reduce the rockfall risk along this section of road, particularly if traffic volumes are to increase.	   **Above:** Washout /river scour location on road at Chard Farm end of the Station. The road has recently been reformed. **Left:** Surficial slip encroaching into drainage channel and threatening road. **Below:** Boulder from a rockfall event below the access road at the Queenstown end of the Station.

6 Conclusions

Overall the geotechnical hazard level at Queenstown Station is considered to be manageable. No hazards of significance were identified that would negate development of any of the currently proposed development sites at this stage. It is recommended that further investigation into the siting of the proposed Resort site, R1, is carried out.

Several minor mitigation measures have been recommended for the development sites based on the hazards observed and currently proposed nature of the development.

Site investigations are recommended during the details design stage to confirm the degree of the Liquefaction risk across the Station, which is currently broadly classified as 'Possibly Susceptible' according to the Opus 2002 Natural Hazards Study.

Appendix A

Queenstown Station Geotechnical Hazard Maps

Enter your Appendix information here.

Appendix B

Qualitative Risk Assessment Criteria for Queenstown Station

Enter your Appendix information here.

Appendix C

Geotechnical Hazard Background Information

Enter your Appendix information here.

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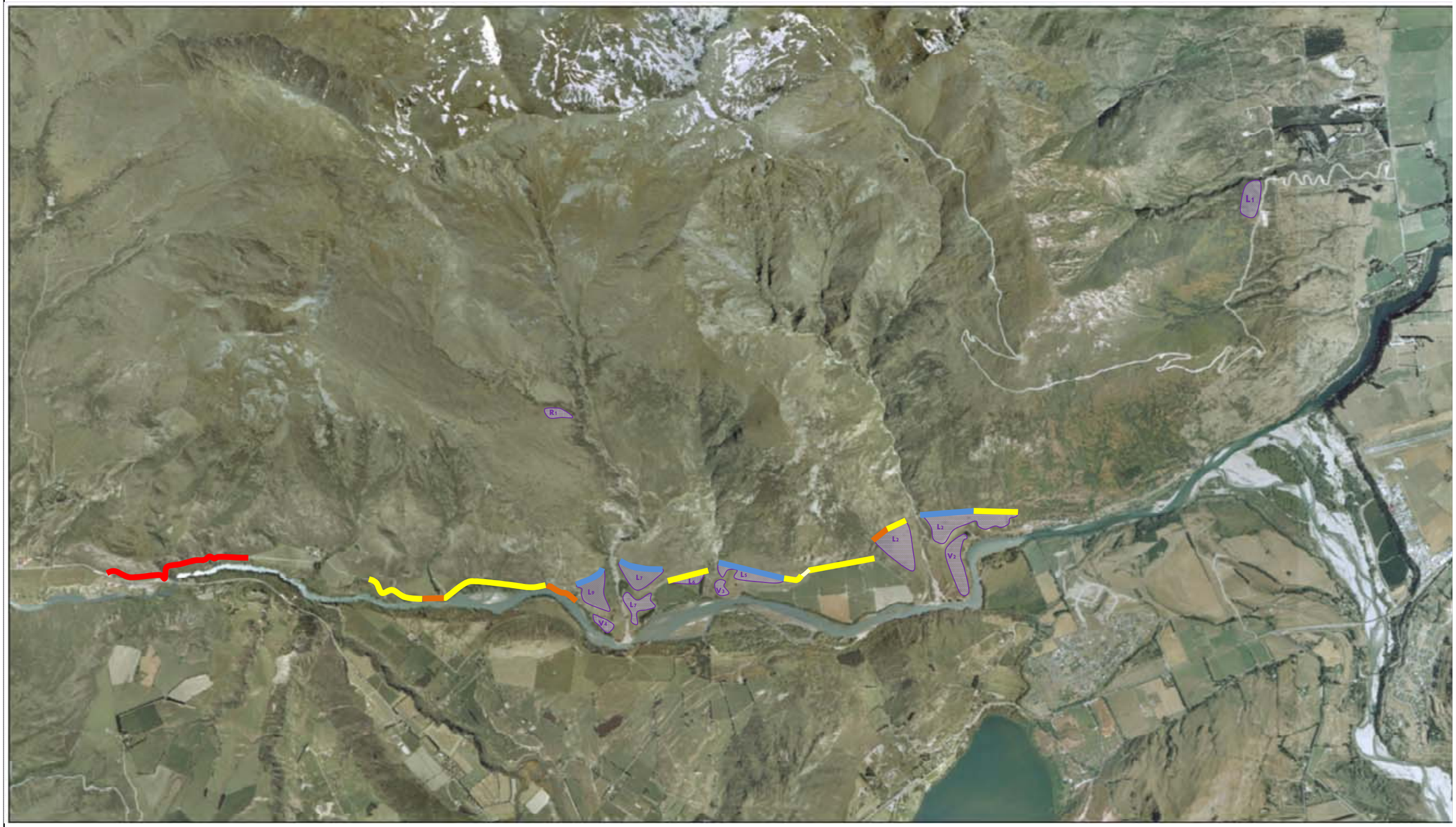

LEGEND - ROCKFALL HAZARD

- No to very low rockfall risk
- Low rockfall risk
- Moderate rockfall risk
- High rockfall risk

QUEENSTOWN LAKES DISTRICT COUNCIL

OPUS

Opus International Consultants Ltd
153 Glenda Dr, Frankton Industrial Estate
PO Box 2323, Wakatipu

Project: Queenstown Station
Geotechnical Hazards Preliminary Appraisal
Project No.: 6-XZ226.02
Client: Remarkables Park Limited

Map 1: Rockfall Hazard

Drawn: Emily Stevens
Geotechnical Engineer, CPEng
Date: 31-Mar-15

LEGEND

Flooding Hazard - Potentially Affected Area

QUEENSTOWN LAKES DISTRICT COUNCIL

OPUS

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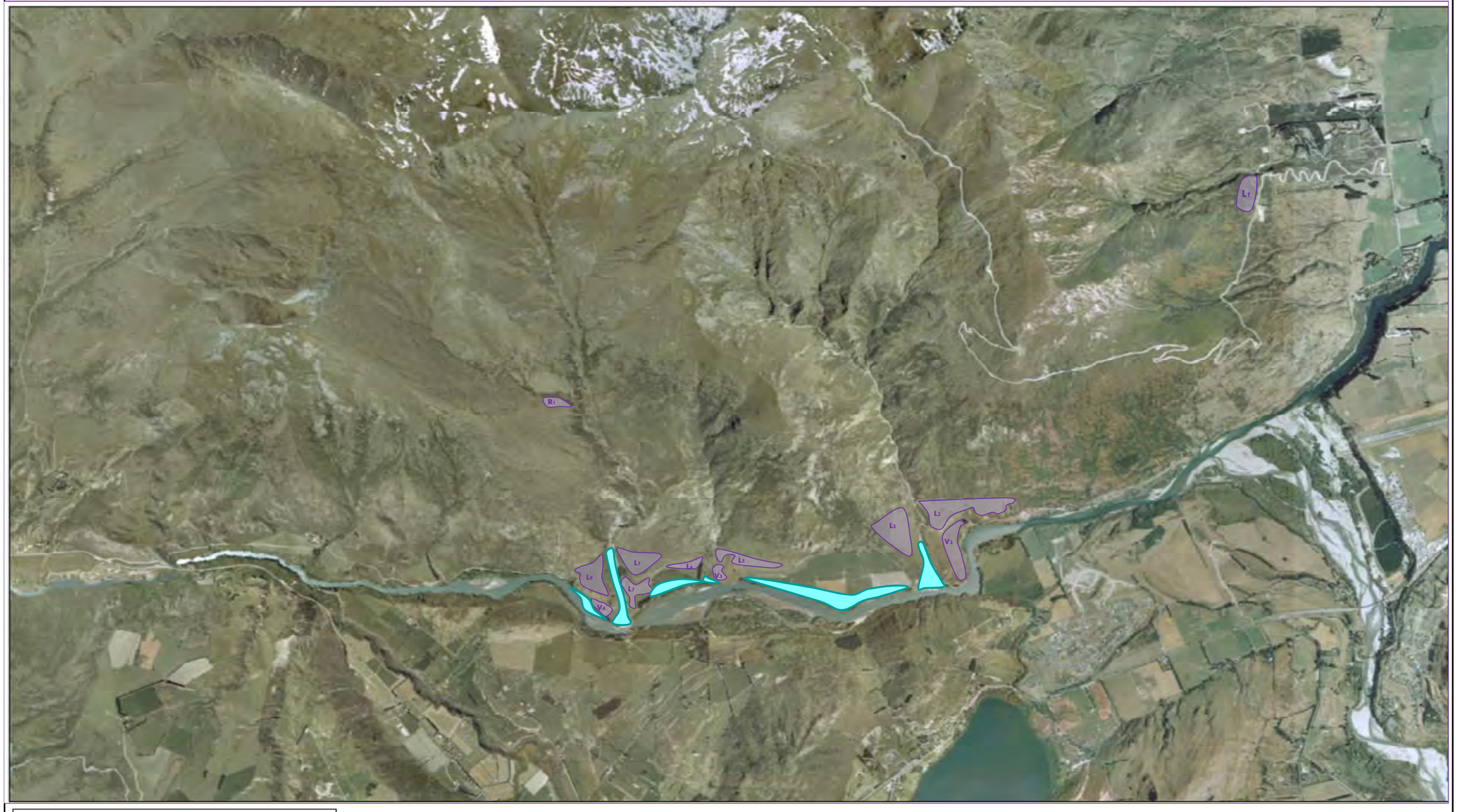
153 Glenda Dr, Frankton Industrial Estate
PO Box 2323, Wakatipu

Project: Queenstown Station
Geotechnical Hazards Preliminary Appraisal
Project No.: 6-XZ226.02
Client: Remarkables Park Limited

Map 2: Flood Hazard

Drawn: Emily Stevens
Geotechnical Engineer, CPEng
Date: 31-Mar-15



LEGEND

Channel Migration Hazard - Potentially Affected Area

QUEENSTOWN LAKES DISTRICT COUNCIL

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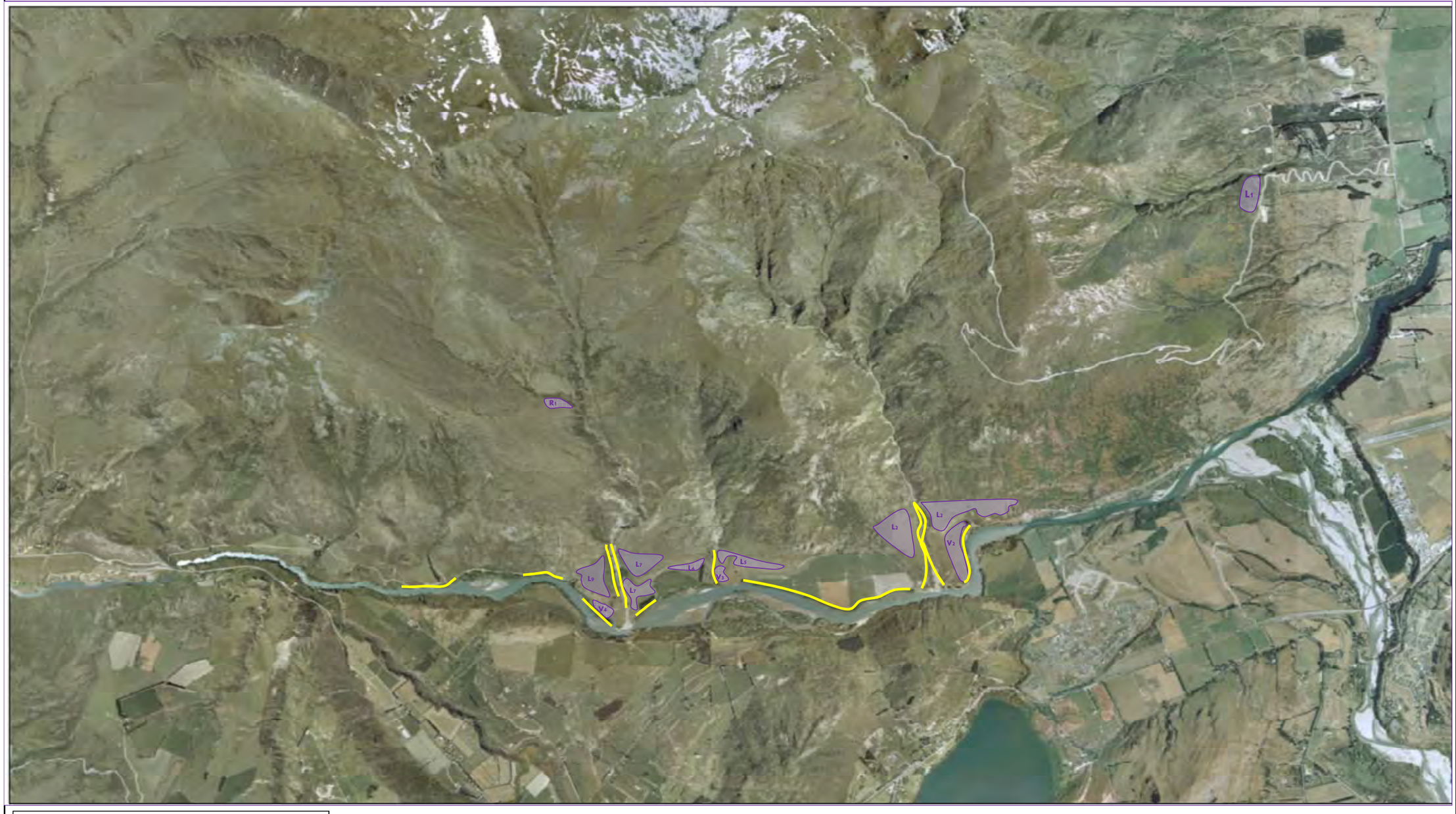
PO Box 2323, Wakatipu

Project: Queenstown Station
Geotechnical Hazards Preliminary Appraisal
Project No.: 6-XZ226.02
Client: Remarkables Park Limited

Map 3: Channel Migration Hazard

Drawn: Emily Stevens
Geotechnical Engineer, CPEng
Date: 31-Mar-15



LEGEND

Scour Hazard - Potentially Affected Area

QUEENSTOWN LAKES DISTRICT COUNCIL

OPUS

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Project: Queenstown Station
Geotechnical Hazards Preliminary Appraisal
Project No.: 6-XZ226.02
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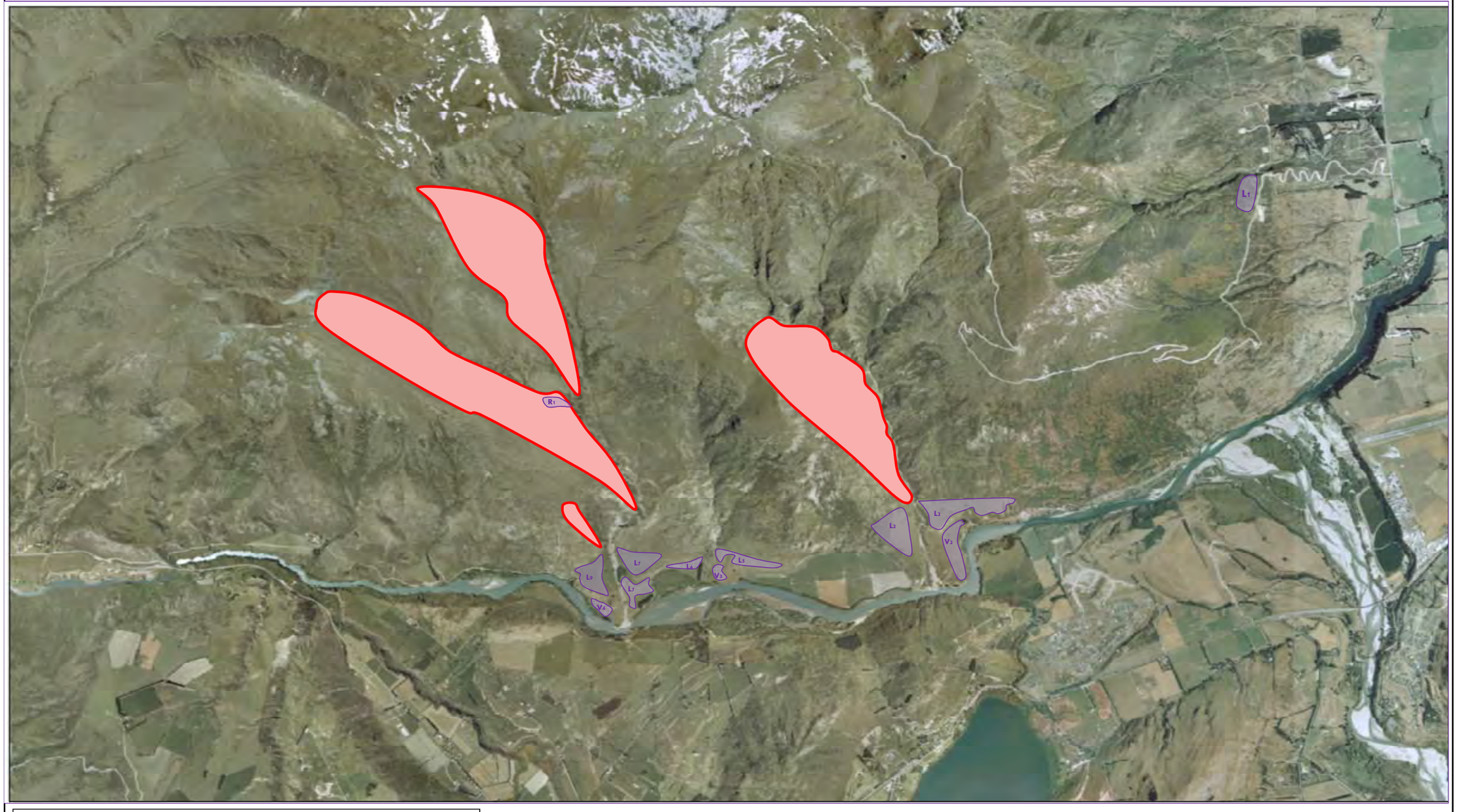
Map 4: Scour Hazard

Drawn: Emily Stevens
Geotechnical Engineer, CPEng
Date: 31-Mar-15



LEGEND

Potential deep seated landslide - foliation controlled

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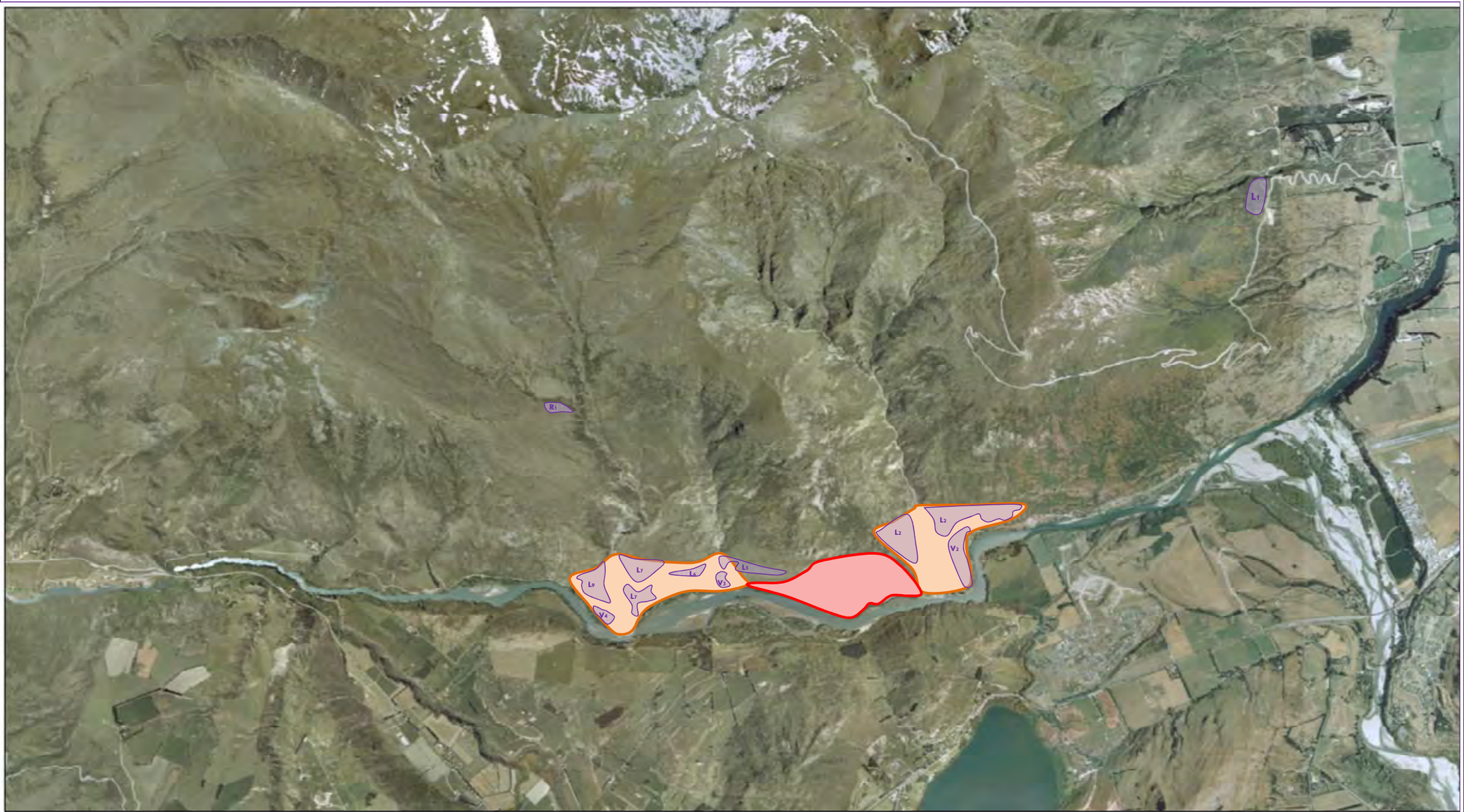
PO Box 2323, Wakatipu

Project: Queenstown Station
Geotechnical Hazards Preliminary Appraisal
Project No.: 6-XZ226.02
Client: Remarkables Park Limited

Map 5: Deep Seated Landslide Hazard

Drawn: Emily Stevens
Geotechnical Engineer, CPEng
Date: 31-Mar-15



LEGEND

Liquefaction Hazard - Possibly Susceptible (Opus, 2002)

Liquefaction Hazard - Susceptible (Opus , 2002)

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Project: Queenstown Station
Geotechnical Hazards Preliminary Appraisal
Project No.: 6-XZ226.02
Client: Remarkables Park Limited

Map 6: Liquefaction & Lateral Spread Hazard

Drawn: Emily Stevens
Geotechnical Engineer, CPEng
Date: 31-Mar-15

LEGEND

Shallow Landslip Hazard - Affected Area

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Project: Queenstown Station
Geotechnical Hazards Preliminary Appraisal
Project No.: 6-XZ226.02
Client: Remarkables Park Limited

Map 7: Shallow Landslip Hazard

Drawn: Emily Stevens
Geotechnical Engineer, CPEng
Date: 31-Mar-15

APPENDIX B

Rockfall Quantitative Risk Assessment Criteria - Queenstown Station

Based on the Oregon State Highway Division's Rockfall Hazard Rating System (Pierson et al 1990). Developed by Emily Stevens (Opus).

NO RISK.

LOW RISK.

No rockfall mitigation measures required.

Has one or several of the following characteristics:

- Good catchment area or adequate natural barrier before development zone.
- DISCONTINUITY CONTROLLED SLOPE: Rock joint orientation is favourable i.e. sloping away from asset. Joints are discontinuous, rough, irregular.
- EROSIONAL CONTROLLED SLOPE: Few or occasional differential erosion features that develop over many years to a few years.
- Anticipated block diameter – ≤300mm.
- Quantity of rockfall event - ≤1.0m^3.
- Few rockfalls – rockfall occurs a few times a year or less.

MODERATE RISK.

Minor rockfall mitigation measures may be required, dependent on final position of development and requiring geotechnical professional to assess requirements. Likely measures include planting of vegetation (trees or large shrubs), minor rock removal or construction of earth bunds.

Has one or several of the following characteristics:

- Moderate catchment or small natural barrier before development zone.
- DISCONTINUITY CONTROLLED SLOPE: Rock joint orientation is random i.e. either towards or away from asset. Joints are discontinuous, undulating or planar.
- EROSIONAL CONTROLLED SLOPE: Many erosion features that develop annually.
- Anticipated block diameter – ≤600mm.
- Quantity of rockfall event - ≤5m^3.
- "Occasional" to "Many" falls. Rockfalls expected several times a year or during certain seasons e.g. winter/spring freeze-thaw.

HIGH RISK.

Rockfall mitigation measures will be required. Likely measures could include benching, rock bolt or mesh stabilisation, significant rock removal.

Has one or several of the following characteristics:

- No or limited catchment or natural barrier before development zone.
- DISCONTINUITY CONTROLLED SLOPE: Rock joint orientation is adverse i.e. sloping towards asset. Joints are continuous (persistency >3m).
- EROSIONAL CONTROLLED SLOPE: Major erosion features that develop rapidly.
- Anticipated block diameter – ≥600mm.
- Quantity of rockfall event - ≥5.0m^3.
- Constant rockfalls – rockfall occurs frequently throughout the year.

APPENDIX C

Queenstown Station Geotechnical Hazard Background Information

This appraisal aims to assess the extents and potential scale of impact/ threat posed by identified geotechnical hazards at the Queenstown Station site. The study does not include any assessment of non-geotechnical hazards such as avalanche or wild fire, but it is recommended that these are considered by the developer during the feasibility stage or future detailed design of any part of the project.

The following paragraphs describe the geotechnical hazards considered for this appraisal and attached to each site in Table 1 of the report.

1.1 Alluvial Fan

Alluvial fans are typically evolving landforms, with the primary controlling factors being topography, climate, catchment characteristics and vegetation changes in the catchment. Change in the alluvial fan can be rapid and aggressive, or occur intermittently over a long period.

There are four main parts to a typical alluvial fan, as described below and shown in Figure 1

A. Catchment area - where precipitation is collected before being carried downstream across the fan

B. Fan head – the area of highest elevation on the fan, where the stream is often incised into the fan surface

C. Braided zone - area of topographic change where the fan gradient decreases and a wider flatter area is encountered. Flow velocity is lost and larger grade sediment is deposited.

D. Fan toe – lower fan section, where finer grained sediment load is deposited, water may infiltrate into the fan deposits and slopes are lower gradient

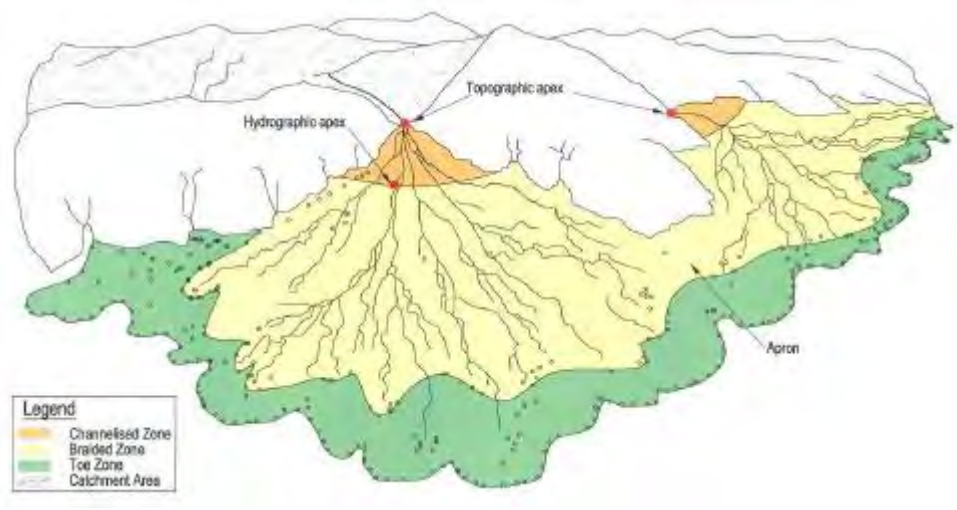


Figure 1. Figure taken from the Otago Alluvial Fans Project Report (ORC, 2009), showing the various areas of an alluvial fan

The alluvial fans in the Queenstown Station have been assessed to be classified as 'young' fans using the Alluvial Fans Project definition. Young fans are defined in the as being 'possibly less than 100 years old up to 10 000 years old, possibly up to 20 000 years old'. Assessing the activity of an alluvial fan is helpful in appraising the hazard presented by an alluvial fan. An *Active* alluvial fan is where there is 'evidence of historically recent (within last 100 years) or ongoing flooding, erosional and/or depositional processes on the fan surface'**Error! Bookmark not defined.**. All of the alluvial fans observed within Queenstown Station can be classified as active, with varying levels of activity.

There are four key hazards that can be associated with alluvial fans:

1. Debris Flow and debris flood. These comprise a dense viscous mix of water, silt, sand, gravel and large boulders. They have high energies and velocities. When the water course bed slope lessens to about 5 or 6°, the debris flow typically becomes a debris flood, which is a flood more viscous than normal sediment-laden floodwater. Debris floods still have the potential to move large boulders and can occur without a debris flow having occurred. For the purpose of this appraisal both debris flow and flood events have been considered to be the same in terms of consequence and termed 'debris flow'.
2. Inundation by flood water (Flooding). Typically occurring in period of high river flow and worse in the braided section of the alluvial fan.
3. Channel migration . Where channels are not deeply incised, such as in the braided section, channel migration across the fan may occur during the course of a flood.
4. River channel Scour may occur in a channelized watercourse, particularly when the channel wall comprises loosely packed (usually young) alluvial material.

The two main watercourses forming alluvial fans within The Park boundary are the Rastus Burn and Owen Creek. The following is a description of their alluvial fans.

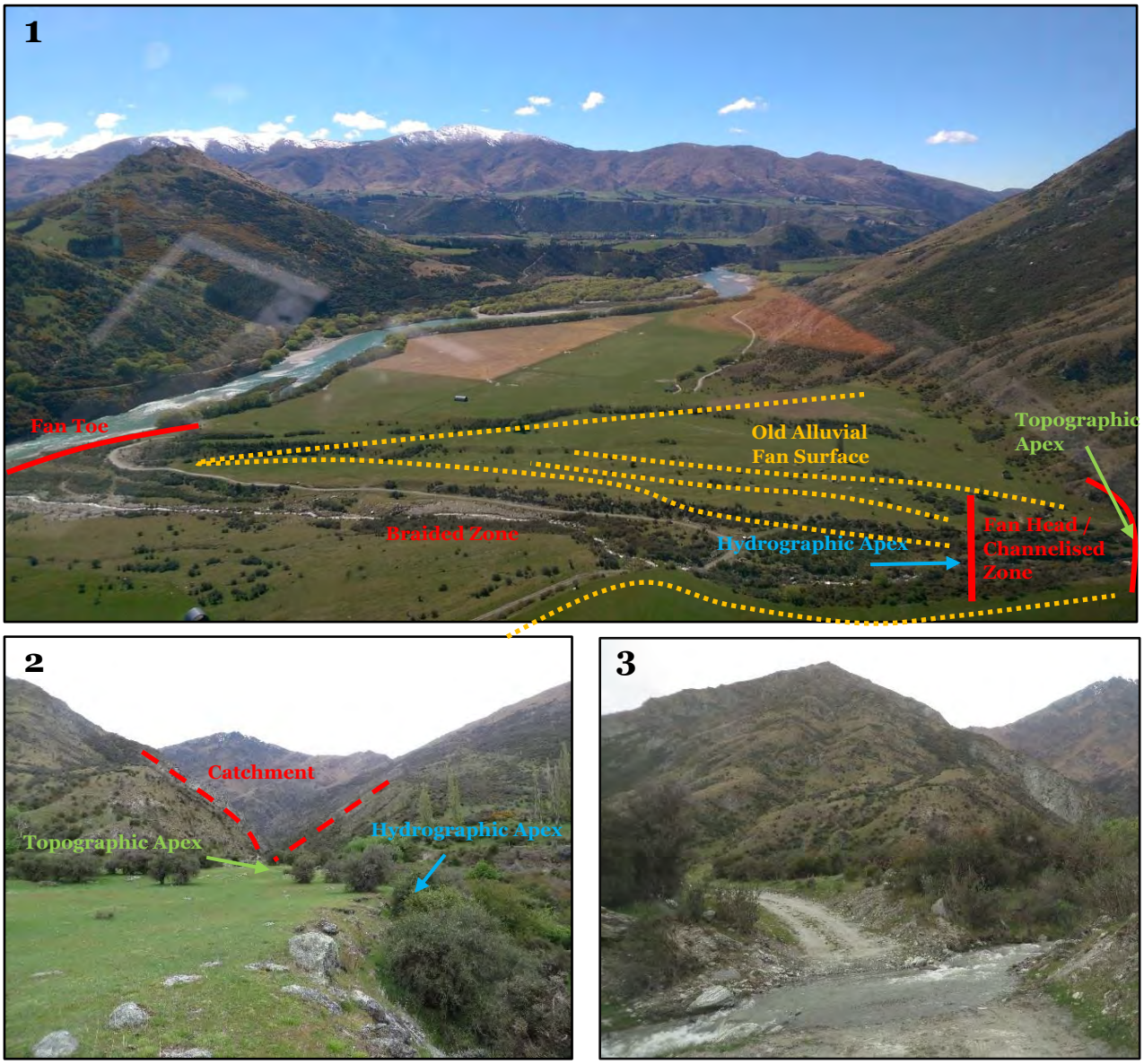
1.1.1 Rastus Burn Alluvial Fan

The Rastus Burn has a relatively large catchment area (approximately around 6 km^2), with its upper reaches just below the Remarkables Skifield. This catchment area has a number of south-west facing slopes that could potentially be prone to landslide and release of schist debris to feed into the river channel. Compared to the catchment area, the fan length is reasonably short at around 0.8km. With a large catchment and short fan, the fan might be expected to be aggradational (that is, aggrading with sediment and steeply sloping), however the powerful clearing force of the Kawarau River at the fan toe keeps the fan in relative sediment equilibrium.

Evidence of debris flow and recent flood events was observed during the site walkover on the Rastus Burn alluvial fan, with boulders up to 1.0 to 1.5m diameter observed to be located chaotically over the landscape. The relatively large size of these boulders indicates a potential high energy event and flow.

When viewing aerial images of the Rastus Burn fan it can be seen that historically overbreak of the stream channel during high flow events typically occurs to the eastern side of the fan. There appears to be at least 3-4 alluvial terraces and old stream channels in this area. Currently however, the stream is reasonably well channelized in the centre of the fan at the fan head with channel walls around 3.0m deep that are becoming well vegetated. Whilst the risk of channel overbreak to the east cannot be completely discounted, it is considered that this would only occur in an extreme rainfall event such as a 1 in 100 year intensity.

Photographs 1 to 3 show typical characteristics of the Rastus Burn Alluvial Fan.



Photograph 1 (Top): Aerial photograph showing the Rastus Burn fan characteristics. Approximate positions of some proposed development sites are shown.
Photograph 2 (Bottom Left): Photograph taken on the Rastus Burn fan at approximately the location of the hydrographic apex, looking towards the topographic apex. One residential platform from development Site 15 indicated by pink rectangle.
Photograph 3 (Bottom Right): Access road crossing the Rastus Burn, on the braided section of the fan

1.1.2 Owen Creek Alluvial Fan

Owen Creek has a larger catchment than the Rastus Burn, approximately double at around 11km^2. The alluvial fan is similar in size, which presents obvious potential aggradation issues. However, the Kawarau River flow again appears to be strong enough to carry the majority of the sediment away. At this point it can be seen that the alluvial fan is constricting the Kawarau River and pushing it into the opposing river bank resulting in erosion and collapse of that opposite bank and bluff (not on Queenstown Station land).

The debris deposited by the flows onto this fan is smaller in size than on the Rastus Burn, up to a size of around 200mm. Aerial photographs indicate there could be a gorge followed by a sharp bend immediately upstream of the fan apex. The gorge may a) block some of the large debris from continuing in the flow or b) act to increase the water velocity, which rapidly decelerates when the flows hits the following sharp bend, causing rapid deposition of the larger fragments at this point upstream of the alluvial fan apex.

Regardless of the reason, it appears that debris flow carrying large boulders is not a major hazard on the Owen Creek alluvial fan. However, debris flow containing material less than 200mm, flooding inundation, scour and channel migration in the lower braided section are likely to still occur.

Photograph 4 (Top): Aerial photograph showing the Owen Creek fan characteristics. Approximate positions of proposed development sites are shown.
Photograph 5 (Bottom Left): Photograph taken on the Owen Creek fan where the access road crosses the current stream bed. Old alluvial fan terraces are shown by dotted yellow line.
Photograph 6 (Bottom Right): Aerial photograph facing east showing the Owen Creek fan, including the narrowness of the constrained Kawarau River at this point.

1.2 Rockfall

Rockfall

A level of qualitative rockfall risk (none/very low, low, moderate and high) has been assessed on all alluvial fan areas (see Appendix A Map 1) using specific criteria developed for the Queenstown Station by Opus. These criteria are based on the Oregon State Highway Division's Rockfall Hazard Rating System (Pierson et al, 1990) (see Appendix B). The only area of High Rockfall Risk is located immediately east of Chard Farm, which is outside the Queenstown Station property boundary however does affect the potential use of the Station and is included for that reason.

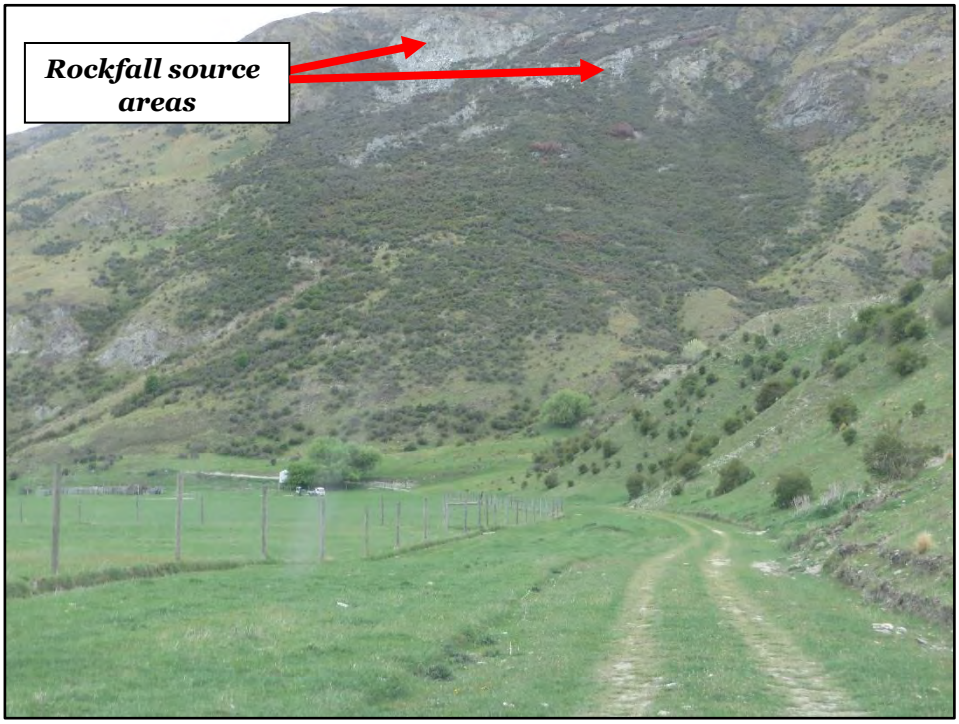
Rockfall at Queenstown Station is considered to originate from 3 key sources:

- Rock failure from schist bedrock outcrops located either directly adjacent to key sites/proposed infrastructure (direct impact) or at some height on a slope above (rock roll then impact). Note that rock roll is considered typically to be a relatively rare event in schist rock due to the foliation weakness that usually creates a slab block that is less likely to roll and more likely to slide.
- Erosion or earthquake induced failure of previously released bedrock boulders that have been deposited on a slope above the asset (re-roll).
- Landslide movement triggering rock release.

Common environmental triggers for rockfall include rainfall, groundwater, wind, general weathering processes and earthquake. Construction activities and human triggers can also be considered such as use of heavy vibrating rolling equipment during road construction or recreational activities such as rock climbing, tramping etc displacing loose rocks.

Photograph 7 (Left): Example of a bedrock outcrop /bluff above the access road that could release rockfall to road level

Photograph 8 (Bottom Left): Example of rockfall source areas high above The Park, which could release rockfall. In this case, The Park is reasonably well protected by vegetation on the slope inbetween.



1.3 Liquefaction & Lateral Spreading

Liquefaction | Lateral Spreading

Liquefaction describes the phenomenon when a saturated or partially saturated, loose, uniformly graded sand, silt or sandy gravel/silty gravel, loses its strength and stiffness during an earthquake event. This can have unfavourable consequences if structures founded on liquefiable soils are not designed appropriately. Liquefaction usually also occurs in relatively young soils (deposited within the last 10 000 years – Holocene period).

During earthquake events, ground shaking induced liquefaction can cause movement of ground towards an unrestrained vertical surface, creating subsidence and cracking in the ground surface. This is commonly observed along river banks, or perhaps the outer edge of an alluvial terrace and is referred to as lateral spread effects.

1.4 Shallow Landslip

Shallow Landslip

This hazard refers to surficial slip failures in soil deposits, up to 5.0m^3 in volume, such as those commonly observed in road cuttings throughout the Queenstown Station. These typically occur in loosely packed alluvium or colluvium (slope debris not carried by water). They are most often triggered by poor cut slope design (i.e. cutting at too steep angle into a slope without considering the friction/cohesion properties of the soil), effect of water, either surface water runoff or groundwater and poor drainage.

Photograph 9 (Left): Shallow landslip along access road (Chard Farm end of The Park)

1.5 Deep Seated Landslide

Deep Seated Landslide

The Central Otago Region is subject to many massive deep seated schist landslides, where movement occurs along the foliation of the bedrock. Foliation is a property of the rock created by the tectonic heat and pressure it has been subject to during its formation. The foliation forms a plane of weakness within the rock mass, undercutting by watercourses or man-made road cuttings can induce deep seated mass movement. Several examples of large deep seated landslides can be observed in the Cromwell and Kawarau Gorges such as the Ripponvale Landslide and Brewery Creek Landslide. These landslide features typically move at a rate of several mm per year and affect large areas of land.

The foliation of the schist bedrock at Queenstown Station can be expected to follow the regional trend and will most likely be generally orientated towards the SW. As the majority of the slopes in the Park are north facing, the overall risk from large global instability is therefore relatively low, and will be limited to localised areas. The greatest risk posed by this identified hazard will be from deep seated movement higher up the slopes in the stream catchment areas which may create dam like structures which could then give rise to the production of a debris flow feeding the alluvial fan below.