SHOTOVER COUNTRY

STRUCTURE PLAN AND GEOTECHNICAL ASSESSMENT

REPORT PREPARED FOR: CLARK FORTUNE MACDONALD & ASSOCIATES

09 February 2010

CFMALADIESMILE071227.DOC

CONTENTS

INTRODUCTION

This report has been prepared for the Ladies Mile Partnership (LMP) as part of a technical information requirement for a proposed private plan change request to the Queenstown Lakes District Council. The proposed study area encompasses approximately 130 hectares lying between the Ladies Mile section of SH 6 to the north and the Kawarau River to the south with the lower Shotover River to the west. The scope of this report is to assess the existing landform, soil types, natural hazards (if any) and to provide a summary of the geotechnical suitability of the site for development.

The following work was undertaken to accomplish the above scope of work:

- Desk studies comprising aerial photo interpretation of stereo photo pairs dated 1956, review of the Council hazard register, review of the GrowOtago website and review of a previous report on the lower terraces of this block[i]

- Field work involving a site walkover and excavation of 10 hand-dug pits.

SITE DESCRIPTION

The site is located within the predominantly rural Ladies Mile area of Queenstown and is bounded by the Shotover River to the west and the terrace edges to the east. Further to the east, the recent Lake Hayes Estate and Walnut Grove subdivisions are separated from the area of interest by a higher-standing terrace remnant. The proposed study area boundaries are shown in red on the annotated aerial photo (Figure 1).

Current access is off SH6 via Stalker Road. This road leads down onto the next terrace on which the upper part of the site is located. Several formed roads and farm tracks feed off Stalker Road to give access to the lower terraces. Old School Road leads to the northwestern corner of the structure plan boundary with access to this off Spence and Lower Shotover Roads.

LANDFORMS

The site comprises several river terrace platforms successively cut down by meanders of the Shotover River over the past few thousand years. Six distinct river terraces that decrease successively in elevation from the northeast to the southwest have been identified with several degraded intermediary terraces also visible. For the purpose of this report, each of the main terraces has been labelled from T1 (the highest in elevation) to T6 (the lowest in elevation) as shown on Figure 2.

The terrace slopes rising above each terrace have been labelled with the identifier for the terrace below and the suffix S. Slope heights range from 15 to 20 m for $T1_S$ down to 1 to 2 m for $T6_S$; the general trend is for the terrace slope heights to reduce towards the southwest. Slope angles typically range from 30° to 40° and sometimes up to 50° indicating oversteep slopes not in equilibrium with the geomorphic processes shaping the landforms.

The river terraces grade very gently towards the river with only 1 to 2 m of fall across the surface. Localised humps and depressions representing palaeochannels are more pronounced on the lower terraces but become less distinguished with height. The difference in relief is typically as a result of the lower terraces being younger geologically and therefore having less soil profile formed to "fill in these hollows". Recent farming activities including cultivation, sowing of crops, irrigation and grazing on the upper terraces, has levelled out the platforms further. The lower terraces (T4, T5 & T6) have been subjected to less intensive farming hence the more pronounced palaeochannel visibility, as evidenced on the aerial photo in Figure 1.

No active watercourses were observed on T1 to T5 however several old channels were noted. Some of these would be ancient stream beds that are now cut off from their source of water whilst others only activate in times of persistent or heavy rain fall. Many of these features lead to incised gullies in the terrace slopes with debris fans extending out into the terrace flats.

T6, the lowest terrace adjacent to the Shotover River, has had man-made ponds and ditches excavated into it that are flowing actively as a result of groundwater inflow. A small channel about 1 to 2 m across has been cut across T6 to divert water from the northwest corner and discharge to the Kawarau River. This feature is visible on the aerial photo in Figure 1 as the linear structure in the south corner of the study area.

There are nine larger debris fans present across the study area as shown on Figure 2. The fans extend from incised gullies out on to the terrace platform from a few meters to tens of metres. They are likely to have formed during periods of prolonged or heavy rainfall when ephemeral streams were active. The farming history of the site is not known but it is suspected that flood irrigation practices may also have been partly responsible for their emplacement. The largest debris fan, labelled D1 on Figure 2, has been modified by roading earthworks to create the existing access of Stalker Road. Other debris fans, particularly the larger ones, have been utilized to provide access to the terraces below by recent roading and earlier farm tracks.

The site is bounded to the south by a hill of schist bedrock that comprises the only observed outcrop in the area. Bedrock was not encountered in the course of the subsurface investigations but is estimated to range between a few meters to 10's of meters deep depending on terrace elevation.

SITE INVESTIGATIONS

A site walkover and 10 hand dug pits were conducted as part of this scope to supplement the existing soil information from the previous Geoconsulting Ltd[1] investigations, which comprised 9 test pits to depths of 2.2 m in January 2006 for the purpose of aggregate supply. Locations of the test pits and hand pits are shown on Figure 2.

To complement the site walkover a stereoscopic review of 1959 aerial photos (Queenstown to Lumsden series 2824/11 and 2824/12) was conducted to identify any previous instability within the study area.

The hand pit and test pit logs are summarized in the following table.

Pit No.	Depth (m)	Description	Name
HP1	0.0	Grass roots, ORGANIC Silt minor sand, dark brown, dry, stiff	Topsoil
	0.15	Silty fine SAND, brown, dense	Loess
	0.4	Becoming medium dense to dense	
	0.6	Sandy GRAVEL, fine to medium gravels fine to coarse sand, brown, dense	Alluvium
	0.7	End of pit, difficult to excavate further, no groundwater encountered	
HP2	0.0	Grass roots, ORGANIC Silt minor sand dark brown, moist, stiff	Topsoil
	0.05	Sandy SILT, blue/grey, firm to very loose, micaceous, wet	Alluvium (Flood Deposit)
	0.15	Sandy SILT ORGANIC, dark brown, wet, firm with extensive roots and mild pungent odour	Buried Topsoil
	0.35	Sandy SILT, blue/grey, firm to very loose, micaceous, wet	Alluvium (Flood Deposit)
	0.45	SAND coarse, some silt blue/grey saturated loose to medium dense. Wet	Alluvium (sands)
	0.60	Groundwater encountered	
	0.70	End of pit, becoming gravelly	
HP3	0.0	Grass roots with blue/grey SILT, wet	Alluvium (Flood Deposit)
	0.20	PEAT/roots, no soil mass, saturated	Peat
	0.40	Silt, blue grey with extensive roots and organics, firm, soils oxidize to brown in minutes when exposed to air, saturated	Alluvium (Flood Deposit)
	0.5	End of pit, groundwater infilling hole	
HP4	0.0	Grass roots, ORGANIC Silt minor sand dark brown, moist, stiff	Topsoil

Pit No.	Depth (m)	Description	Name
	0.2	SILT some sand, minor fine gravels, moist light brown, stiff to loose.	Alluvium (silts)
	0.35	GRAVEL medium to coarse some sand and silt, brown, dense dry	Alluvium (gravels)
	0.40	End of pit, difficult to excavate further, no groundwater encountered	
HP5	0.0	Grass roots, ORGANIC Silt minor sand, dark brown, dry, stiff	Topsoil
	0.1	SILT sandy, brown, very stiff to dense, dry	Loess
	0.4	GRAVEL sandy, fine to medium, brown, medium dense to dense, dry	Alluvium (gravels)
	0.6	SAND coarse, some fine gravels, brown, loose, dry	Alluvium (sands)
	0.7	End of pit, no groundwater encountered	
HP6	0.0	Grass roots, SILT dark brown, dry, stiff	Topsoil
	0.05	SILT minor sand, brown, dense, dry	Loess
	0.4	GRAVEL coarse, sandy, brown dense, dry	Alluvium (gravels)
	0.45	End of pit, difficult to excavate further, no groundwater encountered	
HP7	0.0	Grass roots, SILT, dark brown, dry, stiff	Topsoil
	0.05	SILT sandy fine to medium, brown, very stiff to dense, dry	Loess
	0.70	SILT, fine gravelly, brown, dense dry	Alluvium
	0.75	End of pit, difficult to excavate further, no groundwater encountered	
HP8	0.0	Grass roots, SILT, dark brown, dry, stiff	Topsoil
	0.08	SILT fine sandy, brown, very stiff to dense, dry	Loess
	0.90	GRAVEL silty, medium to fine gravels, brown,	Alluvium

Pit No.	Depth (m)	Description	Name
		dense dry	(gravels)
	0.90	End of pit, difficult to excavate further, no groundwater encountered	
HP9	0.0	Grass roots, SILT, dark brown, dry, stiff	Topsoil
	0.08	SILT fine sandy, brown, very stiff to dense, dry	Loess
	0.90	Becoming slightly moist	
	1.00	GRAVEL silty, medium to fine gravels, brown, dense dry	Alluvium (gravels)
	1.00	End of pit, difficult to excavate further, no groundwater encountered	
HP10	0.0	Grass roots, SILT dark brown, dry, stiff	Topsoil
	0.1	SILT fine sandy, brown, very stiff to dense, dry	Loess
	0.95	GRAVEL silty, medium to fine gravels, brown, dense dry	Alluvium (gravels)
	1.00	End of pit, difficult to excavate further, no groundwater encountered	
Test pits from March 2006 Geoconsulting Ltd report			
TP1	0.0	Topsoil/ Loess	Loess
	0.4	Sandy Gravels	Alluvium
	1.5	End of pit	
TP2	0.0	Topsoil/ Loess	Loess
	0.4	Sandy Gravels	Alluvium
	1.25	End of pit	
TP3	0.0	Topsoil/ Loess	Loess
	0.15	Sandy Gravels	Alluviumm
	1.5	End of pit	

Pit No.	Depth (m)	Description	Name
TP4	0.0	Topsoil/ Loess	Loess
	0.36	Sandy Gravels	Alluvium
	1.4	End of pit, wet near base	
TP5	0.0	Topsoil/ Loess	Loess
	0.3	Sandy Gravels with sand beds 0.3m to 0.6m thick	Alluvium
	1.4	End of pit, groundwater at 1.4m	
TP6	0.0	Topsoil/ Loess	Loess
	0.45	Sandy Gravels	Alluvium
	1.4	End of pit	
TP7	0.0	Topsoil/ Loess	Loess
	0.3	Sandy Gravels	Alluvium
	1.1	End of pit, groundwater at 0.8m	
TP8	0.0	Topsoil/ Loess	Loess
	0.4	Sandy Gravels	Alluvium
	2.1	End of pit, groundwater at 2.1m	
TP9	0.0	Topsoil/ Loess	Loess
	0.4	Sandy Gravels	Alluvium
	2.2	End of pit	

GEOLOGY

The geology of the block is mapped by the 1:250,000 Geological Map of New Zealand (QMAP), published by GNS Science as Younger Quaternary deposits comprised of alluvial gravels, loess, lake silts, swamp deposits, peat and aggradation gravels (glacial).

The typical soil profile encountered in the hand pits displayed a sequence of: topsoil, loess and alluvium in order of depth. This sequence is consistent with the mapped geology (QMAP).

Although not encountered during the investigation, there is the possibility for lake sediments and localized pond deposits, particularly on the lower terraces. These deposits are likely to be comprised of blue grey silts and fine sands that may exhibit dilatant and thixotropic properties. If present, their extent is expected to be minor and standard engineering solutions are available to deal with them.

GROUNDWATER

Groundwater was encountered in test pits on the lower terrace platforms T5 and T6 at depths between 0.8 and 2.1 m below the T5 surface. The depth tended to increase with increased elevation across Terrace 5 and indicate a nearly flat groundwater gradient on the lower sections of the site. A borrow pit in Terrace 5 near TP 2 had a static groundwater level 1.2 m below terrace level at the time of the site investigations.

Groundwater was near surface across Terrace 6 or exposed in the ponds and trenches to the west of the terrace.

Groundwater was not found in any of the higher terraces during the site investigations; however it is expected to have a slight upward gradient away from the Shotover River towards the east with a component rising towards the higher ground north of the Ladies Mile.

NATURAL HAZARDS

There are several natural hazards present both regionally and locally that could potentially affect the site as listed and discussed as follows:

- Oversteep, unstable slopes,
- Debris fans,
- Erosion,
- Flooding,
- Low bearing capacity soils,

- Liquefaction,
- Seismic ground shaking.

The river-eroded terrace slopes $T1_S$ to $T6_S$ are considered to have marginal stability as a result of their past oversteepening. Subsequent rain and wind erosion, gravitational creep and small, shallow slips have modified the slopes to a more stable angle and establishment of a good vegetative cover of grass, scrub and trees has further improved stability. The well-drained nature of the terrace edges is conducive to stable slopes although periods of prolonged or heavy rainfall may result in localized failures. No large-scale movements were observed from either the field work or examination of aerial photographs. Farming activities along the terrace slopes has removed whatever evidence may have been present for shallow instability.

Terrace edge erosion and the resultant deposition of debris fans has been an active process in the past and could potentially reactivate under appropriate conditions. The site walkover and aerial photos show the majority of these fans have established a good vegetative cover indicating they have been mostly inactive. The road and track formations help control surface water runoff and it is envisaged that the proposed developments would also utilize these fans. Construction of sealed roads and an engineered stormwater system should greatly mitigate any risks for the larger fans.

Erosion is a natural process occurring with each significant rainfall or wind event sufficient to activate the process. The loess soils present across the site are particularly prone to erosive forces and during intense periods can cause considerable damage. The debris fans present across the site are the result of erosive forces, as are the loess soils covering the site.

Flooding is identified as a hazard on the QLDC Hazard Map and is reproduced as a blue stippled area covering T5 and T6 on Figure 1. Flooding is to be dealt with in more detail by others but is included here as a recognized hazard for the site. Hand-dug pits on T6 showed layers of silt that indicated deposition during a prolonged period of submersion from two distinct flooding events. Similar silt layers were not identified on T5 suggesting that any past flooding across the terrace could have been either of short duration or the water channelled through the area and any such silt layers are localised.

Soils of low bearing capacity are those that contain a high organic content or soft, unconsolidated silts and are susceptible to load-induced consolidation and consequent settlement. The low-lying areas of T6 have elevated groundwater levels or surface ponding and are expected to flood frequently. Most of this area is marshland /swamp and is underlain by well-formed beds of peat and silts. The marshland is shown as a green stippled area on Figure 1.

Liquefaction is an earthquake-induced hazard present in some areas of the Wakatipu Basin. Recently deposited soils with uniform grading can be susceptible to liquefaction when saturated. The lowest lying terraces (T5 & T6) are the only areas likely to be underlain by elevated groundwater levels. The subsurface investigations indicate that well graded sandy gravels predominate suggesting this site is unlikely to be affected by liquefaction. No evidence was found either on the ground or from aerial photograph inspection of past liquefaction damage. Liquefaction is thus not considered a hazard for this site.

Seismic ground shaking (earthquakes) is a common hazard to the area due to close proximity of the tectonic plate boundary (Alpine Fault) on the West Coast and several active fault traces throughout the Wakatipu region. Predictions for a magnitude 7.5 or greater shaking event within the next 50 years for the Wakatipu (NIWA) and the 15,000 seismic events that New Zealand has each year warrant this as a substantial hazard. Though significant, this hazard cannot be eliminated but can be mitigated by the appropriate application of the relevant standards and codes as is currently the practice for any development in the Wakatipu Basin.

GEOTECHNICAL CONSIDERATIONS OF THE NATURAL HAZARDS

This section is concerned with ground-related hazards and it is expected that detailed discussion on flooding will be found in companion reports.

Solutions for terrace slope instability would be determined by the final subdivision layout with specific solutions provided in the Geotechnical Investigation Report (GIR) as required by the QLDC subdivision standards and NZS4404:2004 and could include either or a combination of the following:

- Slope regrading and associated earthworks,
- Specific investigation and design for individual buildings,
- Subsoil drainage,
- Retaining and soil stabilization measures,
- Building restriction, setbacks or zoning.

Of these, the latter option in conjunction with a sensitive subdivision layout are the preferred means of controlling building development on the terrace slopes. Aligning roads near to the crest and toe of terrace slopes, zoning the slopes as reserve or green belt and applying building restrictions on slopes steeper than 25° are possible solutions to avoiding disturbance to the steeper slopes or to restrict building away from potential landslides or their runout zones.

Erosion and debris fan emplacement are considered to be dormant processes giving rise to a relatively minor hazard. Current subdivisional standards and resource management guidelines for development contain adequate stormwater control and disposal requirements. All roading in the vicinity of terrace crests should have kerb and channel to prevent runoff escaping over the edge and disposal into soak pits should not be allowed within 50 m of the terrace edge. The existing vegetative cover on terrace slopes should be retained and enhanced to encourage rainfall infiltration and to mitigate rainwash erosion.

T6 has soils of low bearing capacity and as such does not have "good ground" as defined in NZS 3604. Notwithstanding the flooding hazard of this area, development would require substantial earthworks and drainage operations, specific design of all infrastructure and dwellings and the likelihood of title certificates registering natural hazard susceptibility. The direct and indirect costs of such work are likely to make housing or infrastructure development in this area unattractive. It is considered the best option is to zone the land as reserve or some other use that is not sensitive to the particular hazards that affect the area.

Seismic ground shaking is an inevitable hazard for the area and as such any development works are to be designed according to the relevant standards, with the GIR specifically addressing this issue in more detail..

CONCLUSIONS

The site as defined in red on Figure 1 is considered geotechnically suitable for subdivision and building development provided the identified hazards are taken into consideration and appropriate subdivisional engineering standards and geotechnical mitigation works are adopted.

It must be appreciated that while the site is generally suitable for building development, the costs of mitigating some of the hazards may be considerable. Careful design of the subdivision layout is considered necessary to optimise the hazard controls. It is proposed that the T6 terrace be utilised as a stormwater attenuation area for the development.

---

[i] Jeff Bryant Geoconsulting Ltd report "Lower Shotover Partnership: Assessment of gravel reserves" February 2006