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Dear Dan

HENLEY DOWNS DEVELOPMENT PROPOSAL: REVIEW OF SITE GEOLOGY AND GEOTECHNICAL HAZARDS

As requested, please find below an outline description of the geological conditions present in both the core development region and proposed extensions along the western and north-east sectors. Perceived hazards are addressed, as appropriate, using both pre-existing data (Thomson, February 2006) and present field interpretations.

It is noted that a detailed geotechnical investigation of the proposed development area was undertaken by Tonkin & Taylor Ltd in 2007, and reported on in April 2008. This work included mapping, 36 test pits, 2 cored drilled holes, and 23 cone penetrometer tests. The assessment of the report data in geological terms was outside of my brief but liquefaction implications are being reviewed by geotechnical personnel.

GEOLOGICAL SETTING

Figure 1 presents the fundamental lithologies present at the surface in the area of interest. It is largely as produced from field mapping in early 2006, with local adjustments as a consequence of more recent work in and near the site. Of note:

- Schist outcrops extensively to the west of the central valley but has been eroded (glacially) to significant depths in central and eastern areas.

  Where exposed, the schist is sound (glacially sculptured), and there is a moderate foliation dip to the south-east (Figs. 2, 3). There are no known gravitationally disturbed areas in the schist.

- Glacial till (mostly lodgement type) onlaps the schist to the west of the central valley, and appears further east as patchy mounds with strongly variable surface morphologies. Where visible, there is a well-graded, clastic composition in an overall compact material. Locally, tills have an approximate 18,000 year age.

- Fluvioglacial sediments (proglacial river alluvium) are interpreted as being significant components of the hummocky terrain near State Highway 6. There are no perceived adverse characteristics with respect to construction.

- An interpreted proglacial stream fan mantles intermediate elevation terrace remnants east of the central valley. No adverse characteristics perceived.

- Lake margin erosion features and accumulation deposits (storm beaches) extend north-south at about RL 356 on both sides of the central valley. This equates to the long-duration stillstand of the post-glacial, proto Lake Wakatipu when the outlet fed into the Mataura River system at Kingston.

Apart from the storm beaches, which appear to be largely poorly graded gravel, the relevance of the lake margin is that it provides a temporal datum (present to an estimated 7,000 years BP) and physical boundaries to other processes and deposits (e.g. lake sediments and older fans).

- Fine-grained lake sediments are present along the central valley region. These originated from suspended fines transported by currents from the Shotover Delta during floods, at the time when the lake was at RL 356. Obviously currents being directed to the south. Test pits (Thomson, 2006) indicate horizontally bedded sediments, with a preponderance of silt and sandy silt; generally soft and saturated. In TP 3, a depth of 5.2m was reached without bottoming the formation.

  Additional comments will be provided when addressing "hazards".

- Fan deposits are significant both to the north-east of the site and along the west side of the central valley.

  Two fundamental types:

  — older fans, grading out to the lakeshore when it was at RL 356, approximately. Largely confined to the north-east sector; clearly would have been developing mini deltas out into the lake in front of main streams at this time.

  — younger fans developed subsequent to the drop in lake level. A range in ages over the last 7,000 year (est.) period. Significant along western shorelines.

  It should be noted that during the period of lake sediment accumulation (effectively ceased a nominal 7,000 years BP) there would be minimal sediment entering the lake from the west but significant sediment being introduced from tributaries flowing from the east, i.e. off The Remarkables. This implies that lake sediments generally east of the proto lake arm axis will have interfingering, finer clastic units at irregular depths, whereas the sediments to the west of the axis should be fine over the full depth.

Depicted on Figure 1 are two lines representing outer limits to lake sediment units. They are intuitive, and defined from a range of geological factors. It is reasonable to expect that such bounding limits can be at least locally refined as a consequence of the Tonkin & Taylor investigations in 2007.

WESTERN EXTENSION GEOLOGY

Figures 2 and 3 illustrate lithological variations in relative detail to beyond any envisaged development zone. Pertinent features of note:

- Schist is sound, and in situ. There are several strike ridges, with and without glacial till cappings, in the southern sector (ice-sculptured) but further north the relief increases and the schist tends more bluffy. Wave-cut benches are significant within the Figure 3 map zone.

- Glacial till will have a local presence in prospective development areas. It should be clastic and compact; no adverse characteristics expected.

- Fans are almost ubiquitous along the western slopes at lower levels. Difficult, in part, distinguishing between gully deposits and lake margin sediments, much of which will be reworked beach deposits, distributed widely as the lake level dropped.

  Some investigations, including test pitting, should be undertaken at an opportune time to resolve some uncertainties, such as:

  — primarily, what is the more distal composition, are there underlying lake sediments (probably in part), and where is the water table? And the bearing strength?

— Adjoining the top end of the main water body (Fig. 2) there is a prominent, low relief, fan element. Does it have requisite bearing strengths for buildings or infrastructure?

- Lake sediments are assumed to extend relatively close to the proto lake shoreline but there are no subsurface investigations to establish parameters. While I have constructed a bounding line on Figures 2 and 3, please accept this is provisional only.

- A small dump, for miscellaneous materials, has been formed close to the south boundary and near the golf course. Keep this in mind when defining platforms. (Can easily remove, in total).

NORTH-EASTERN EXTENSION ISSUES

It is proposed to develop an area of clean terrace on the north side of Woolshed Creek (name adopted for convenience purposes). As depicted by Figure 5, much of this terrain is at or slightly above the creek level and it is apparent that there are overflow channels that may have been occupied in the recent past. (Catchment flood history not researched).

Part of the problem appears to be the result of severe aggradation in the creek from about 300m upstream from Woolshed Road. Willow growth may be the dominant factor, but there are a couple of embankments (Fig. 5) which enhance the aggradation. Mitigation of the flood risk (both creek banks) can be achieved to some extent by regrading the channel thalweg up from its gradient close to Woolshed Road; this could result in a deepening of the channel by, say, 2 to 3m close to State Highway 6. However, this has to be done as part of a broader exercise assessing present catchment sizes and stream avulsion potential. Figure 4 depicts the main Woolshed Creek and tributary locations at and above SH 6, but:

- the stream to the north could avulse close to SH 6, and join Woolshed Creek in a flood situation.

- the catchment 1 km south of Remarkables Station could also avulse to the north – the flood channels already exist on the upper fan.

In a worst case scenario, during a rainstorm (unspecified), an approximate 2 km reach of The Remarkables face could drain into Woolshed Creek above the proposed subdivision.

This discussion is of a preliminary nature, only. Perhaps it would be best to definitively plan development close to Woolshed Creek, then again appraise flood hazard and risks, and means of mitigation appropriate to the proposal.

LIQUEFACTION HAZARD

QLDC hazard maps depict the central valley, and fan elements to the east, as being either "susceptible" or "possibly susceptible" to liquefaction. I do not have an updated plan so I'm unable to say what boundaries QLDC specify for a hazardous zone at the present time.

The February 2006 report discussed the issue in some detail and concluded:

- fan deposits were not susceptible to liquefaction, where outside lake sediment terranes.

- "liquefaction is probably a non-issue" in the lake sediment area in the central valley. However, "they will cause engineering complications".

I accept the apparent low risk of liquefaction, given the overall gradings, age, seismic history (inferred) and the likelihood of interfingering of fan debris with lake sediments in the eastern part of the proto lake corridor. However, I remain concerned with a few factors, such as:

- the small cluster of closed depressions just east of the large lake (right side of Figure 2). These clearly post-date at least part of the lake lowering phase.

- the uncertainty of the lake sediment boundaries and sediment thickness variations.

- saturation of the sediments at near surface levels.

- the massive texture and very soft "silt" units in some test pits (e.g. TP's 3, 5 of the Thomson 2006 report). (It is acknowledged that no seismically-induced distress was observed in the five key test pits). Concern largely linked to Christchurch liquefaction phenomena, of which I have no personal experience.

- unknown lake sediment parameters to the west of the original development layout.

Clearly there is a need to closely appraise the Tonkin & Taylor report data and conclusions, prior to development. It would also be appropriate to extend the subsurface investigations to the west to probe any gap between the present pitting layout and the distal margin of the outcropping schist; comforting to know the subsurface geology in association with the subdivision design.

CONCLUSIONS

(a) The accepted site geology is essentially as presented in an appraisal report of February 2006. A subsequent investigation report by Tonkin & Taylor Ltd (April 2008) incorporates substantial subsurface data, which is planned to be scrutinised by an experienced geotechnical engineer..

(b) It is proposed to extend the development onto the west flank of the valley. Schist and glacial till form the foundation lithologies at intermediate elevations while stream fans and beach deposits are significant features below RL 356. Distal fan areas probably overlie the westernmost lake sediment units.

(c) A proposed development extension to the north of Woolshed Creek (new name) will notionally incorporate part of a low relief region that is probably a creek overflow channel. The nearby creek is also severely aggraded due to a number of factors, including the construction of embankments across the channel. Mitigative works, such as channel deepening and bunding, can be undertaken to reduce and eliminate the flood hazard, but this should be designed following a review of the levels of flooding potentially achievable should flanking catchments on The Remarkables face avulse into Woolshed Creek in a rainstorm.

(d) The central valley segment is underlain by fine-grained lake sediments, deemed to have liquefaction potential by reference to QLDC's hazard maps. The sediments are relatively old, and have been affected many times by major seismic events; they are probably not susceptible to future liquefaction as a consequence. However, there are some anomalous surface features in the sediment terrane, and material characteristics, in part, point to soft, saturated conditions. Further studies of existing data should be undertaken to fully categorise the hazard.

(e) Site-specific test pitting may be required along the proposed western extension at lower levels once the development layout has firmed up.

There remain numerous unknowns with respect to the subsurface geology beneath the central valley region in general, and at lower levels along the proposed new western development. A combination of limited and prudent subsurface investigations, and a review of Tonkin & Taylor (2008) data, should substantially reduce the areas of uncertainty.

Regards,