



19 January 2015

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Dear Dan

**MILLBROOK MACAULEY LAND: APPRAISAL OF KNOWN AND INFERRED HAZARDS
AND POTENTIALLY ADVERSE GEOTECHNICAL FEATURES AT SITE**

As requested, please find below a discussion on the geology within the property footprint and my interpretation of the various geotechnical issues which could have some bearing on future utilisation of some site elements. This report is designed to complement the various planning assessments being prepared for plan change consent purposes.

The mapping undertaken was essentially at the reconnaissance level, but modelling in most areas is not difficult as the host lithologies are reasonably well displayed, or can be inferred with a significant degree of confidence. Field work was supplemented by the use of stereopair aerial photos, and hazard features of regional interest were addressed by reference to QLDC-supplied data maps and other known sources.

GEOLOGICAL SETTING

(a) Physiography

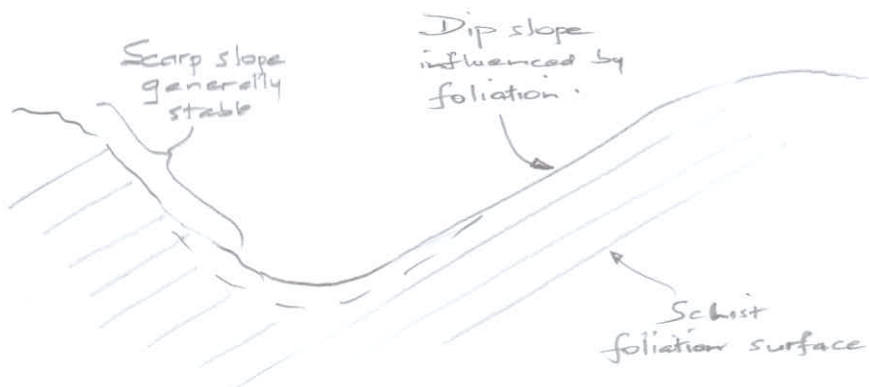
The site occupies part of an east-west-trending, glacially sculptured, valley and ridge complex just west of Arrowtown (Fig. 1). Mill Creek, and its associated floodplain, traverse the northerly lobe of the property as a variable width band (Fig. 2a) that is flanked by low to moderate gradient slopes. These, in part, are mantled by fans constructed by ephemeral, tributary streams. As indicated by Cross Sections AA' to CC' on Figure 2b, the elevated southern half of the property effectively forms an irregular platform approximately 75 – 100m above Mill Creek, this being a region within which there are substantial proposed developments (Attachment 1).

(b) Rock Types and Distribution

- (i) Schist is the basement lithology in the region. At the site it is prominent in outcrop to the south of Mill Creek and there are several small outcrops close to Malaghans Road (Fig. 2a) which suggest schist is close to the surface in the northern sector.

Pertinent characteristics include:

- Greyschist dominates on site.
- Planar, thin foliations dip to the WSW at about 30°.
- Strike ridges are locally prominent landforms in the plateau area.
- Foliation influences terrain morphologies in the vicinity of incised gullies.



- No significant discontinuities, such as faults, were observed in outcrop.
 - Jointing is not well developed. Steeper slopes not prone to rockfall, as a consequence.
 - Generally south of Mill Creek there is a slight component of foliation dip into the slope, inherently increasing overall slope stability.
- (ii) Glacial till is present as an irregular mantle on schist in the plateau area. Outcrops are poor (commonly rabbit holes) but it can be inferred that:
- The till is ablation in type, i.e. essentially fluvial deposits formed on the schist surface during the melting of the intruding glacier. A well-graded, gravel/sand/silt mix generally present.
 - Estimated minimum age for the glacier that intruded into the plateau area is 70,000 years. (Morven Ferry Glacial Advance in local terminology).
 - Where the till has a significant thickness the terrain tends hummocky. Note that in lower relief areas, such as the south-east property sector, there is a tendency towards a boggy condition.
- (iii) River alluvium probably forms the effective terrace occupied by Malaghans Road near the present site entrance. (Could be till; not established in site-related outcrops).
- (iv) Stream fans, of various dimensions, flank the Mill Creek floodplain (Fig. 2a). While not obviously active, each is potentially subject to stream incursions during future rainstorm events.
- (v) Landslide deposits are minor, and limited to the walls of one gully in the central - west region of the plateau area (Fig. 2a). In general, the slopes, at all inclinations, are not affected by mass movement.
- (vi) Floodplain sediments form a variable width (30 – 100m) deposit on the valley floor. The host surface tends flat and is unlikely to project more than about 1m above the stream surface.

The subsurface material characteristics and depth parameters are not known. As depicted on Figure 2b, schist is likely to underlie the sediments at a depth of 10m.

(c) Groundwater and Surface Flows

Mill Creek drains 25 km² of catchment west of the site. It is clearly a permanent stream with a significant flood potential. Left and right bank tributaries intersecting the site are ephemeral but there is also flooding potential, particularly in the catchment to the north, which originates on the steep, valley wall.

Of interest is seepage along the axis of a gully close to the eastern property boundary (Fig. 2a). The seepage can only originate as race leakage from a non-specific but reasonably defined point at the gully head adjoining the race.

Two significant springs are present along the true left side of the floodplain, upstream from the access road (Fig. 2a). It is assumed both are sourced in subcatchments north of Malaghans Road and west of Dennison Way and both notionally drain to the south via gutters in the schist, now overlain by alluvium (or till). Flow volumes are unknown; it is assumed they will be seasonably variable.

GEOTECHNICAL HAZARDS: GENERAL

(a) QLDC/ORC Depictions

Attachments 2a and 2b illustrate the extent of the known hazards directly pertaining to the site. They include:

(i) Liquefaction, categorised as LIC 1 (P), which implies a low risk. Comment:

- For some reason, unknown to QLDC staff, the hazard ceases in an upvalley direction at the position of the present site access road, whereas similar valley floor conditions extend well to the west.

In a pragmatic sense, it would be prudent to accept all of the north embayment at the site is categorised as LIC 1 (P) in the QLDC classification.

- The designated liquefaction risk zone clearly incorporates areas which are known, or inferred to be, in situ schist. A refinement of the zone is clearly warranted.
- It is acknowledged that the valley floor floodplain comprises at least some weak sediments with unknown liquefaction susceptibility. Depending on final development proposals, some subsurface investigations in the fill deposits may be required on the right bank.

(ii) Alluvial fan, an ORC assessment, subclassified as "fan less recently active".

As previously mentioned, all the lower fan elements must be subject to some flows during storm events, which will need addressing in sympathy with the development proposals.

(b) Other Hazard Issues

(i) Flooding

Mill Creek, at site, is the flow path from a large (25 km²) catchment to the west and it is evident that there is some inundation of at least parts of the floodplain during storms of a regular nature. As the flat, 'dry', floodplain on the true right bank downstream of the road bridges lies only 1m (approx.) above creek level, it must be assumed to be inundated by flooding as well; perhaps on a 1 in 200 year basis (speculative estimate).

Given a development proposal includes dwelling platforms on parts of the right bank floodplain (Attachment 1) it would be prudent to approve key areas in terms of flood hazard and risk, and develop mitigating solutions, as appropriate.

(ii) Seismic Events

It is assumed that the greatest risk is posed by an M8, or greater, earthquake on the Alpine Fault. Assessed felt intensities at the Wakatipu Basin have been integrated into statutory

authority requirements for building codes, which have evolved over time as earthquake characteristics become better understood.

At a more local level there is an active, west-side-up, reverse fault trending north-south through the west end of the Gibbston Basin (est. MCE M7.3), and seismic monitoring has established the presence of numerous, shallow crustal events in the Arrowtown region (Fig. 3). The latter earthquakes have small magnitudes (generally <M3.8) and have not been associated with any known faults that rupture the surface, but there is clearly some local, ongoing, crustal strain. Implications for the site:

- Minor earthquakes will continue to be generated near Arrowtown at irregular intervals. Building codes adequate for mitigation purposes.
- Surface ruptures are not likely in the Arrowtown region.
- There is a very low risk of a large earthquake being generated on a nearby fault in the life of any dwelling that exists or will be constructed in the future.

(iii) Mass Movement

Apart from the minor intra-property occurrences, the nearest known landslides to the site lie in schist terranes approximately 0.7 km away from the boundary.

Mass movements are not an issue of consequence in the proposed development area, therefore.

SITE GEOLOGICAL FEATURES OF INTEREST

(a) Malaghans Road – Mill Creek Floodplain

The proposed development in this zone is limited to fairways and greens. Note:

- In general, schist with a variable alluvial cap should dominate, although fan deposits in the central region could have a significant thickness.
- In the eastern sector, the floodplain-proximal slope tends wet. This should be noted in any layout.
- Two springs, and a steep riser, are floodplain-proximal features in the western sector. Perhaps appropriate earthworks should be undertaken to modify the local terrain.
- Flooding on the central fan can be restricted to the axial channel by appropriate earthworks.

(b) Mill Creek Floodplain

Proposed zonal developments include a farm shed, a fairway, and parts of a low elevation dwelling complex. Note:

- The farm shed should be elevated on fill or be bunded, should the current proposed site be occupied.
- Central parts of Fairway 8 will occupy the floodplain. As a low risk area, flooding on sporadic occasions may be acceptable.
- Central parts of the dwelling complex occupy the floodplain footprint, the flood hazard for which will be notionally exacerbated by the formation of adjoining ponds (Attachment 1).

The flood risk to dwellings in this terrain needs to be vigorously appraised.

(c) Right Bank Fans

These are, in part, the proposed locations for low level housing development. Note:

- Appraise each site to minimise flood risk from the superadjacent catchments. Adjust platform locations.
- Develop platform-proximal channelling/bunding, as appropriate.

(d) North Facing Slopes

In the central area both higher and lower density dwelling construction is proposed.

- The terrain is assessed as stable; schist with a probable alluvium mantle.
- A concrete pipe siphon segment rises up through the central section; inherent concern with integrity under major seismic event conditions.

Further to the east dwellings are proposed in lower relief terrain, comprising schist with a patchy till cap. Note:

- The wet gully is being avoided in the proposed layout.
- Review the potential for water race embankment failure at any location between the mini siphon and the eastern property boundary.
- The western platforms are close to the flanking slope of a strongly incised gully. As previously highlighted, the eastern slopes tend to be controlled by foliation and slope regression, by slab failure, is a future possibility.

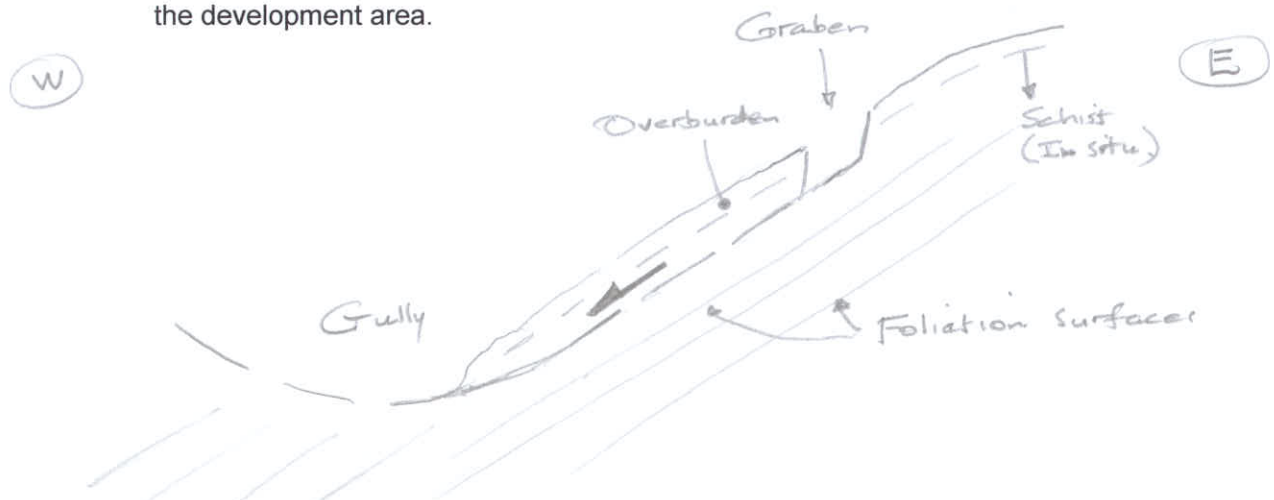
Ensure an adequate setback from the slope crest is implemented for pertinent platforms or design a stable foundation.

(e) Plateau Zone

In effect, the terrain varies markedly, but the highest, and most pinnacle element, lies to the west, and outside of any proposed development.

With reference to Attachment 1 and Figure 2a, it is evident that there are multiple housing areas intermixed with golfing venues, each of which will occupy schist in isolation, and schist with a variable till cap. Both are inherently stable, but note:

- There is a small, recent landslide on the east flank of a deep gully in the western region of the development area.



- The foliation failure is not going to impact on any proposed construction area but is a good example of a dip slope failure in schist in a specific terrain. (Note also the potential for a like failure in any major dwelling excavations).
- On the gully wall opposing the above there is evidence for an old failure in a schist scarp slope. I have annotated the approximate vacated outline, and it is unlikely to regress, but it proves that scarp slopes are not necessarily absolutely stable, in the long term.
- Approximately 100m south-west of the above slide feature there is an assessed area of soil creep; probably a till capping on schist, creeping under wet conditions. Of no significance in a development context.

CONCLUSIONS

- (a) There are several significant terrain elements in the Macauley block, including a floodplain-dominated valley floor to the north, low to moderate relief flanking slopes, and a high, effective plateau to the south.
- (b) Schist is the basement rock in the area and it outcrops extensively to the south of Mill Creek. Glacial till, at least 70,000 years in age, is a prominent cover deposit on schist in the plateau area, while stream fans, and assessed river alluvium, flank the valley fill deposits.
- (c) Schist outcrop areas are largely sound with rare, small landslides being defined in a single gully. Foliation has influenced terrain development in the past and care should be taken in the siting of dwellings in dip slope situations, adjoining deeper gullies, at all elevations. Rockfall is absent.
- (d) Several dwelling clusters are proposed on the north-facing slopes south of the valley axis. Apart from some wet conditions, deemed to be sourced in a leaking race, there are no obvious adverse conditions, providing schist dip slope issues are recognised.
- (e) The lowermost cluster of dwellings is sited variously on fans and a floodplain to the south of Mill Creek. This zone is characterised by QLDC as a low risk area for potential liquefaction, and flooding, and/or erosion, are prospective hazards on both the floodplain and fans during storm events.
- (f) The terrain to the north of Mill Creek is designed as a golfing facility. Issues of flooding on both the floodplain and the central fan are clearly subjective at this stage, although hazard mitigations by earthworks are optional in this area.
- (g) There is some intuitive concern with the long-term integrity of the water race, especially under the influence of strong seismic shaking. For instance, the upper reach of the main siphon is composed of butting concrete pipes, and there is a 450m reach of open race in the property, with unknown construction methodologies being applied along the complete length of the outer embankment.

RECOMMENDATIONS

- (a) Review the flooding risk for proposed platforms extending onto the right bank floodplain. If the hazard is acceptable, undertake appropriate subsurface investigations to:
 - Assess subfoundation material types.
 - Address the QLDC-defined liquefaction issue.
- (b) Where dwellings are to be sited on right bank fans at lower elevations, adjust platform locations in association with engineering solutions to the relevant flooding and erosion hazards.

- (c) Review the integrity of the irrigation pipe and open race complex in relation to the proposed dwellings at lower elevations. Of particular interest is the response to a major seismic event.

This report is fundamentally an assessment of the geological conditions at site, and any consequential adverse features which may impact on development proposals, as highlighted by Attachment 1. I trust the level of mapping and appraisal detail is sufficient to qualify the hazards and risks which clearly apply, in part, to the major development items at lower elevations in particular.

Regards,



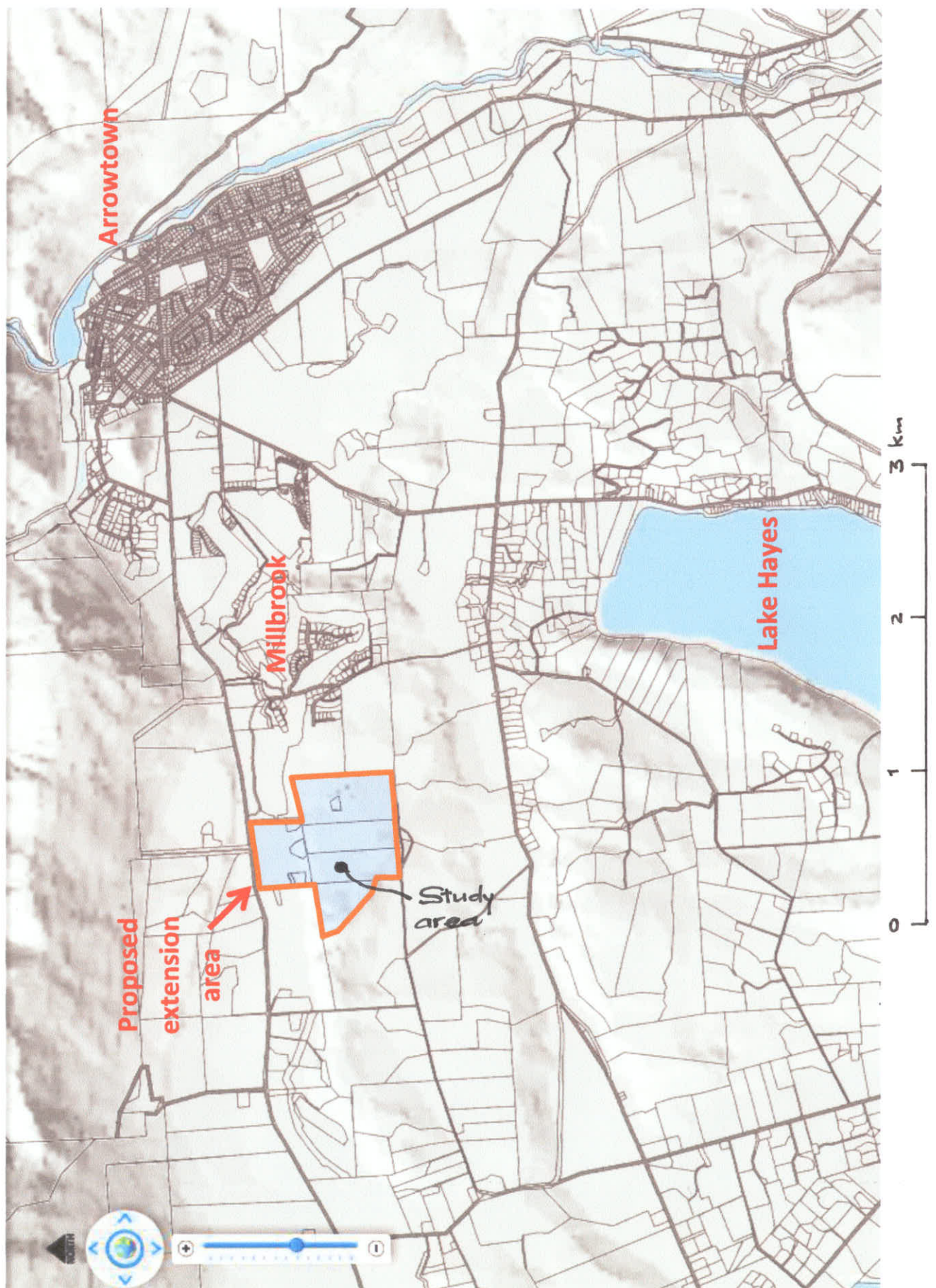


Fig.1 Location of Millbrook site

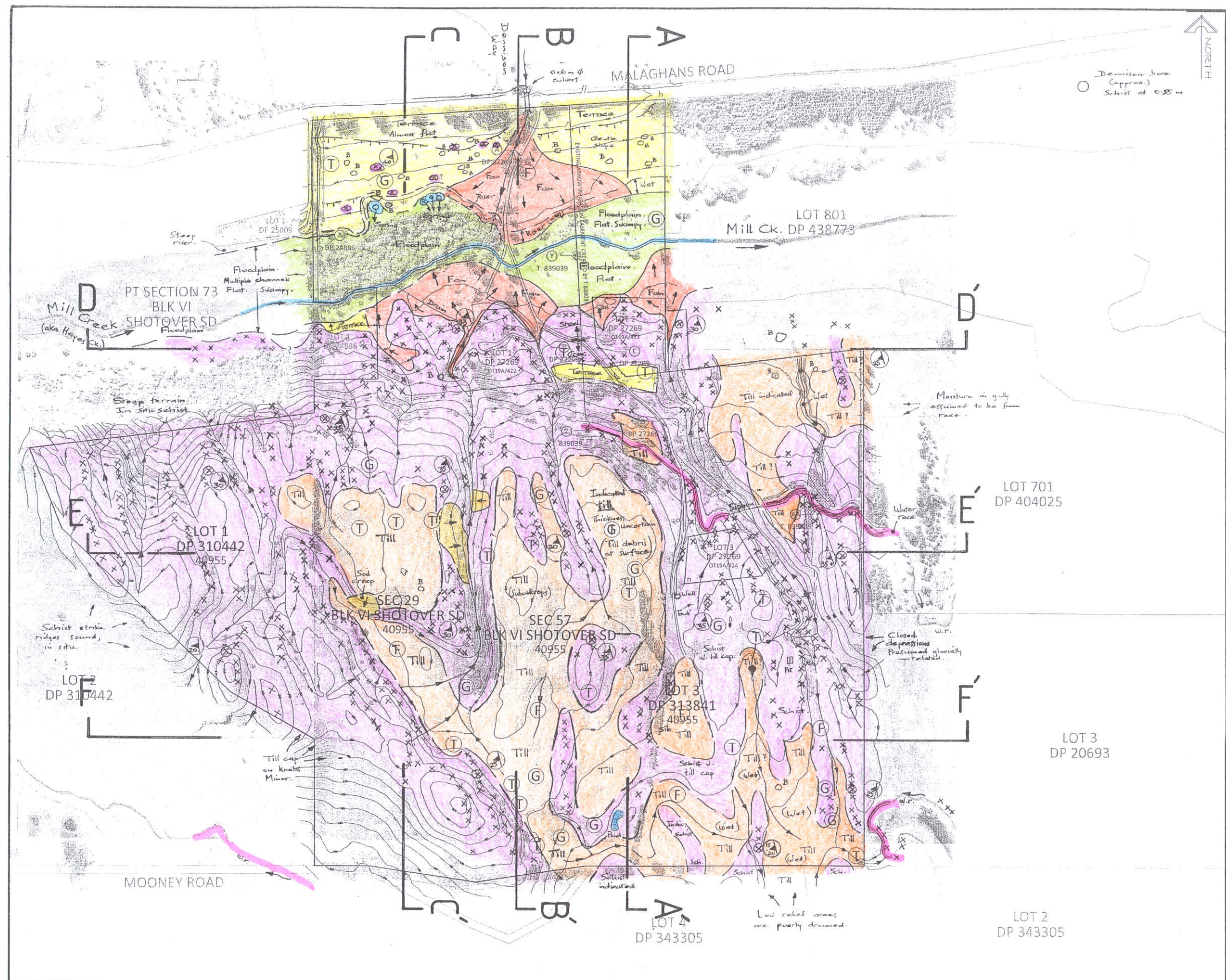


Fig. 2a

Geological Plan of the Millbrook Extension on the Macauley Farm Block

Scale 1:2500

- Schist. An applied cross denotes outcrop visited or remotely observed.
- Glacial till (ablation)
- Stream fan
- Floodplain (Mill Creek)

- Landslide
- River alluvium (assumed)
- Spring
- Water race (open)
- Schist foliation attitude

- Boulder at surface
- Geological cross section

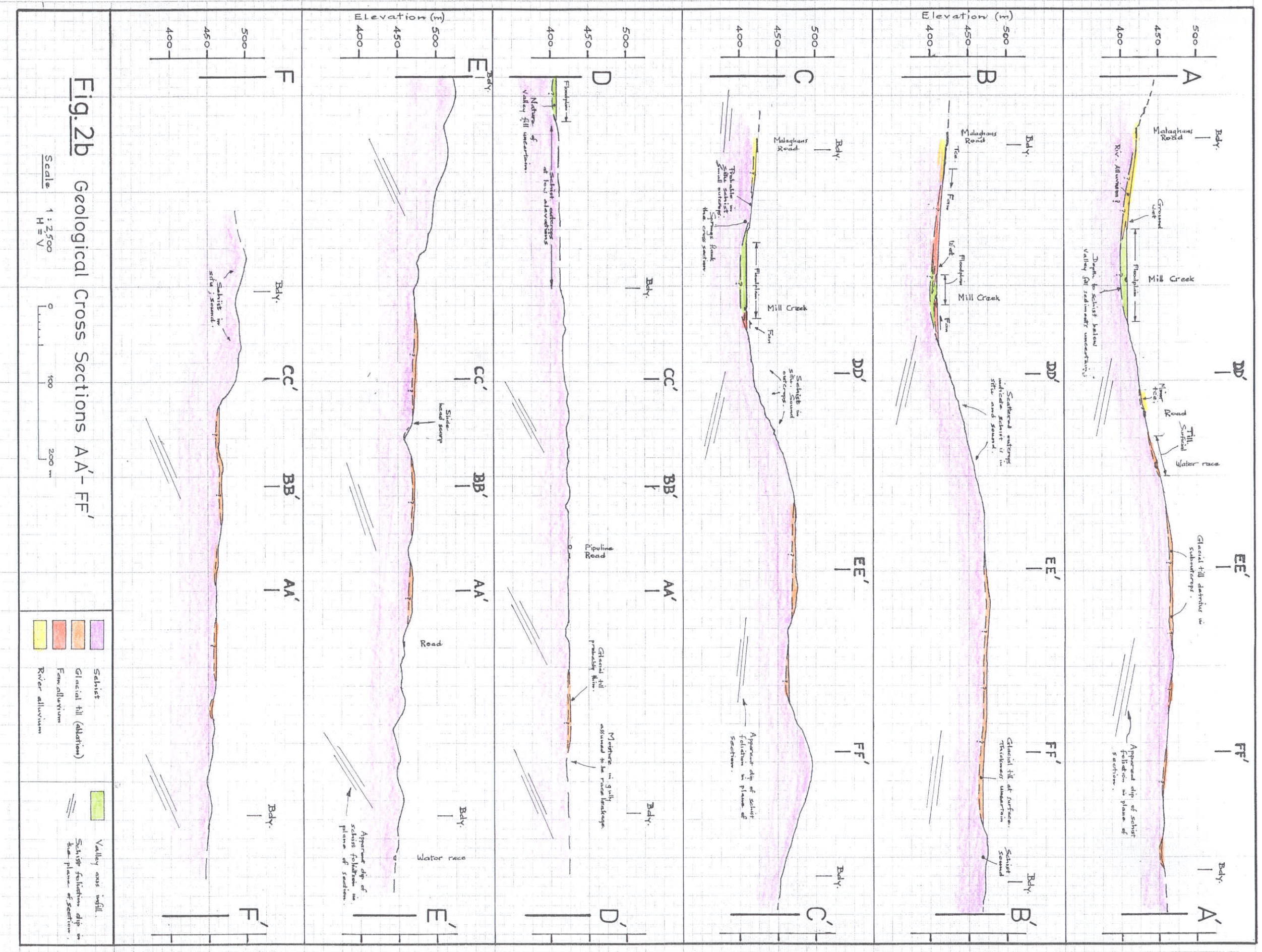


Fig. 3

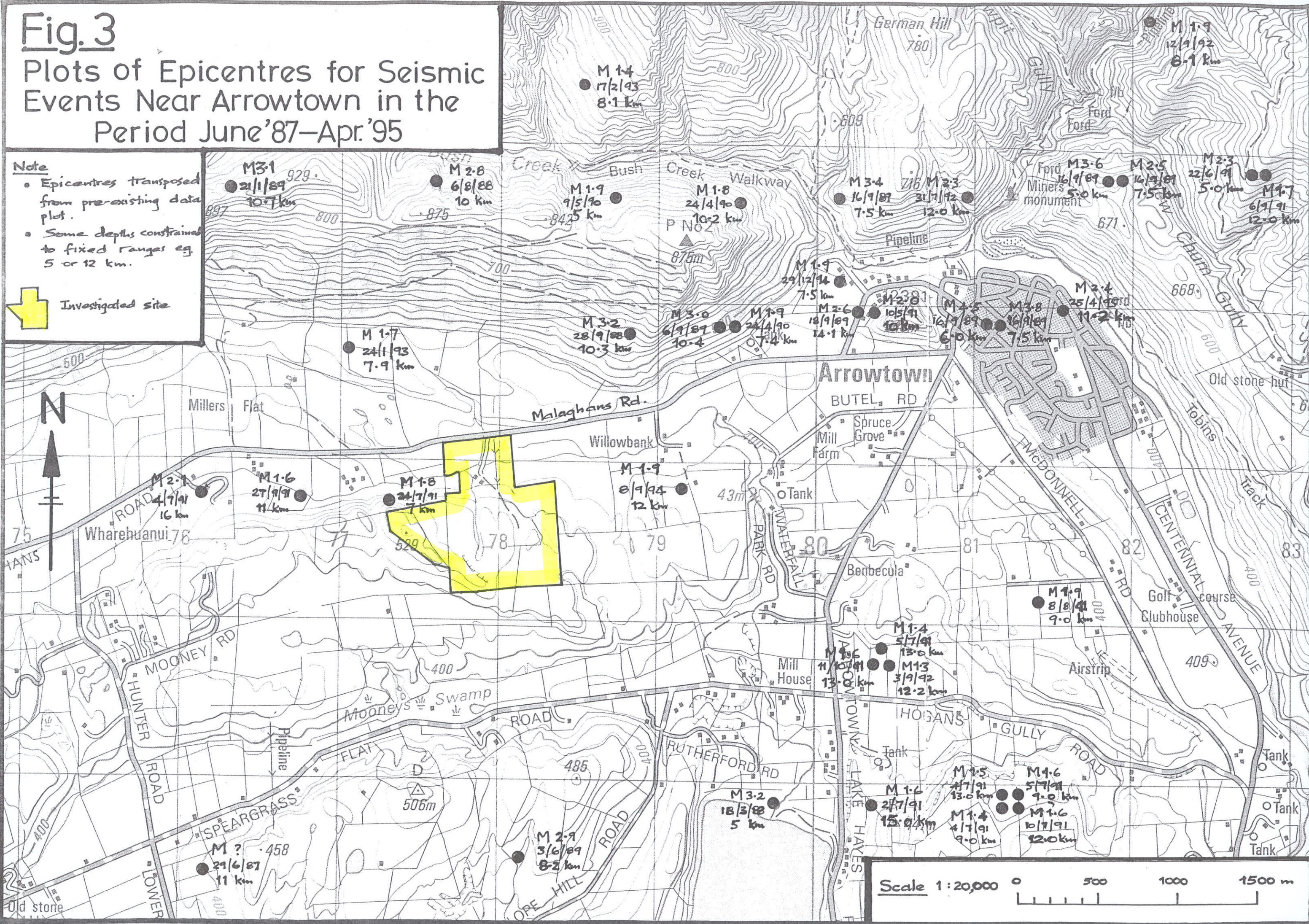
Plots of Epicentres for Seismic Events Near Arrowtown in the Period June '87–Apr. '95

Note

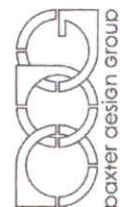
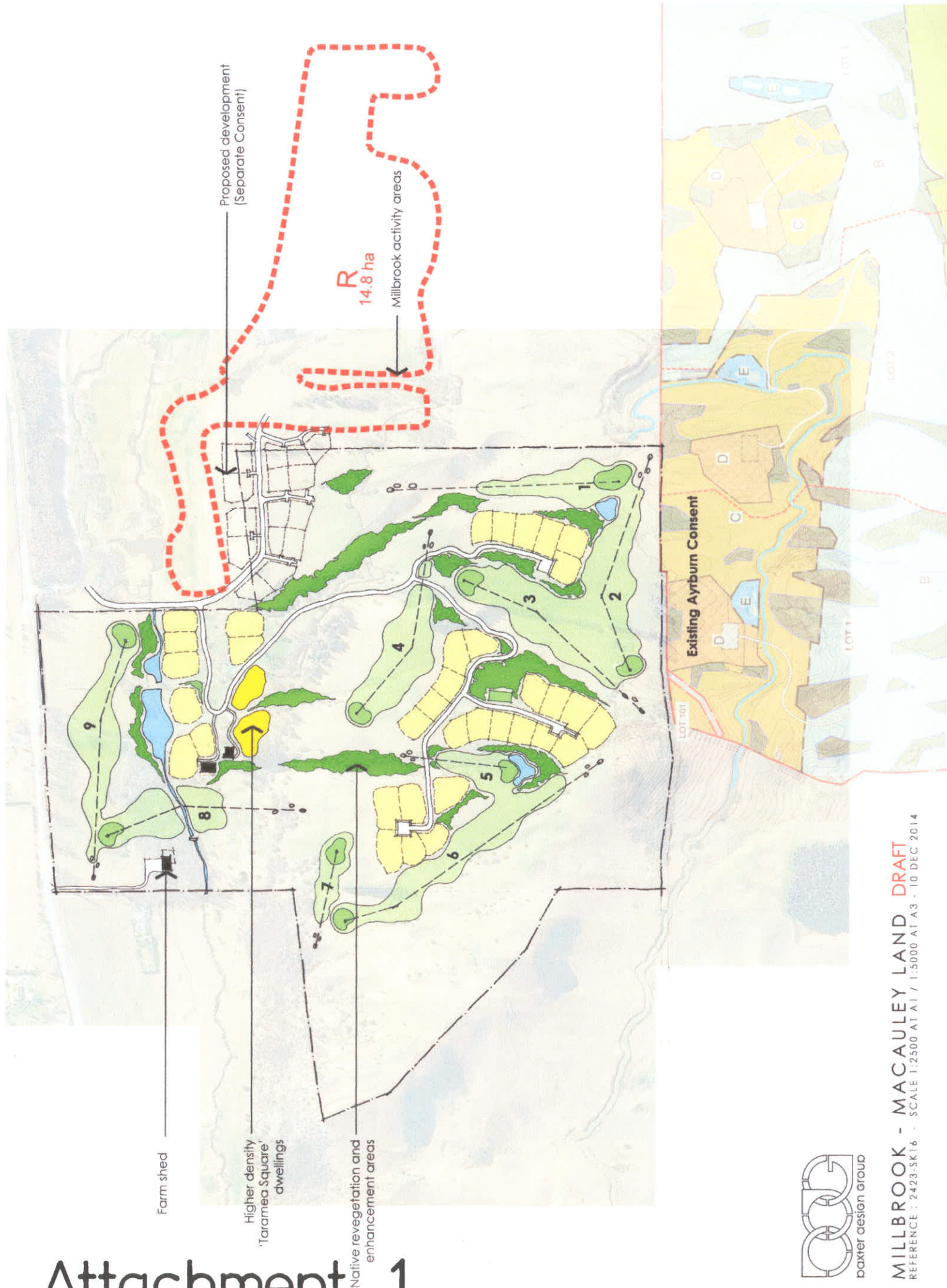
- Epicentres transposed from pre-existing data plot.
- Some depths constrained to fixed ranges eg. 5 or 12 km.



Investigated site



Attachment 1



Malaghans Rd - Hazards



Legend

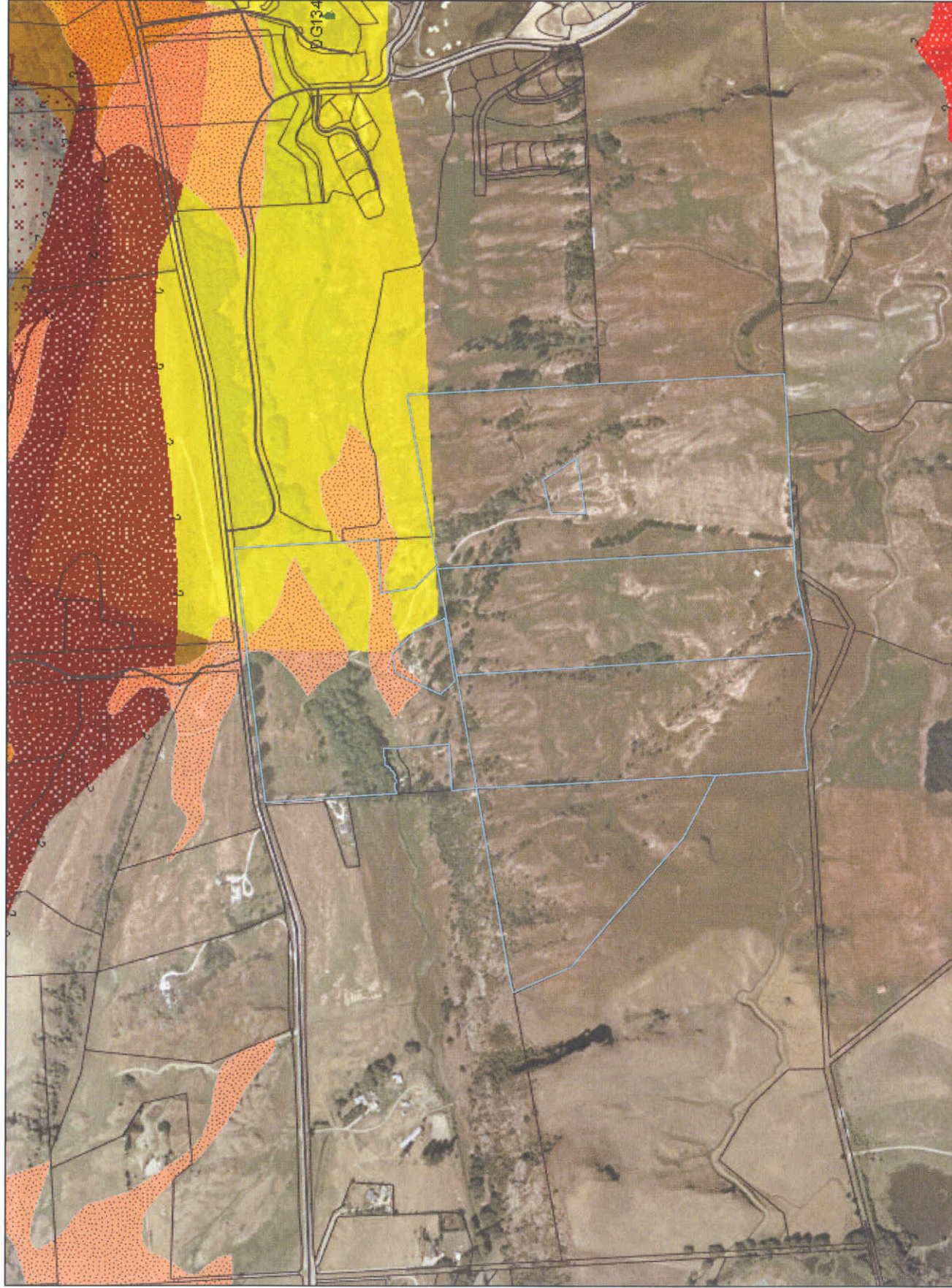
- Dangerous Goods Licence
- LPG CYLINDER
- POTENTIALLY CONTAMINATED SITE
- Flood Return period
 - 150 Year
 - 100 Year
 - 75 Year
 - 50 Year
- Faults
 - Active
 - Inactive
- Potentially Contaminated Sites
 - Contaminated Sites
 - Potentially Contaminated Sites
 - Managed / Remediated
 - Dangerous Goods Licence
 - Landfill
- Landslide Areas
 - Active Pre-existing Schist Debris Landslides
 - Pre-existing Schist Debris Landslides
 - Dormant Pre-existing Schist Debris Landslides
 - Slope Failure Hazard in Superficial Deposits
 - Shallow Slips and Debris Flows in Colluvium
 - Debris Flow Hazards
 - Rockfall
 - Landslide Areas (Outside priority areas)
 - Flooding - rainfall
 - Flooding - damburst
 - Erosion Areas
 - Aluvial Fan High Hazard - Channels
 - Aluvial Fan High Hazard - Incision Line
 - Aluvial Fan High Hazard - Catchment Areas
 - Aluvial Fan High Hazard - Hazard Area
 - Aluvial Fan High Hazard - Source Area
- Alluvial Fan - ORC
 - Aluvial Fan - fan active bed
 - Aluvial Fan - fan recently active
 - Aluvial Fan - fan less recently active
- Alluvial Fans Regional scale
 - Active, Composite
 - Active, Debris-dominated
 - Active, Floodwater-dominated
 - Inactive, Composite
 - Inactive, Debris-dominated
 - Inactive, Floodwater-dominated
- Liquefaction Risk
 - LIC 1 - Nil to Low
 - LIC 1 (P) - Probably Low
 - LIC 2 (P) - Possibly Moderate
 - LIC 3 (P) - Possibly High
 - Possibly Susceptible
 - Susceptible
- Avalanche Areas
 - Avalanche Areas

Lines and areas with approximate locations are shown with "?."



The information provided on Dekho is intended to be general information only. While considerable effort has been made to ensure that the information provided on this site is accurate, current and otherwise adequate in all respects, Queenstown Lakes District Council does not accept any responsibility for content and shall not be responsible for, and excludes all liability, with relation to any claims whatsoever arising from the use of this site and data held within.

Malaghans Rd - Hazards



Legend

- Dangerous Goods Licence
- LPG CYLINDER
- POTENTIALLY CONTAMINATED SITE
- Flood Return period
 - 150 Year
 - 100 Year
 - 75 Year
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- Faults
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- Avalanche Areas
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Attachment 2b

Scale 1:599
Map produced by Queenstown Lakes District Council's Dekho GIS viewer

462.5

925 Metres

Map date:
16/12/2014