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The paper was published in the proceedings of the 12th Australia New Zealand Conference on Geomechanics and was edited by Graham Ramsey. The conference was held in Wellington, New Zealand, 22-25 February 2015.

Fox Glacier – Geological and geotechnical issues for access

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ABSTRACT

Increasing tourist numbers and demands to access New Zealand's national parks and glaciers means access ways and infrastructure are required to be built and maintained in geologically young and extremely dynamic environments. Fox Glacier is a unique environment where rock fall, flooding and ice melt play a challenge to organisations trying to provide consistent access. This paper describes the access issues and challenges involved in providing roading and car parking in flood prone areas that also sit on deep ice melt, in conjunction with rockfall and flooding hazards to foot paths.

Work has included:

- Ground penetrating radar of car park to provide indication of subsidence causes and presence of any ice moraine; and
- Assessment of best approach to ongoing maintenance and actions.

Keywords: rockfall, glacier, ice, subsidence, moraine.

1 INTRODUCTION

GHD was contracted by Department of Conservation (DOC) as part of the New Zealand Transport Agency (NZTA) -Glacier Roads Professional Contract to undertake works at Fox Glacier, which amongst other tasks include the following scope:

- Assess changes to NZTA funded infrastructure;
- Rockfall assessments;
- Remote sensing study; and
- Assessment of Existing Hazard Database.

This paper describes the work undertaken on assessment of subsidence of the Terminal Car Park and causeway at Fox Glacier Valley.

2 FOX GLACIER LOCATION AND GEOLOGICAL SETTING

2.1 Location

Fox Glacier is located on the West Coast of New Zealand. Access to Fox Glacier Valley is via two access roads known as the northern and southern access roads, both of which extend inland and to the east from State Highway 6. The Northern Access Road provides access to the main walking track to Fox Glacier.

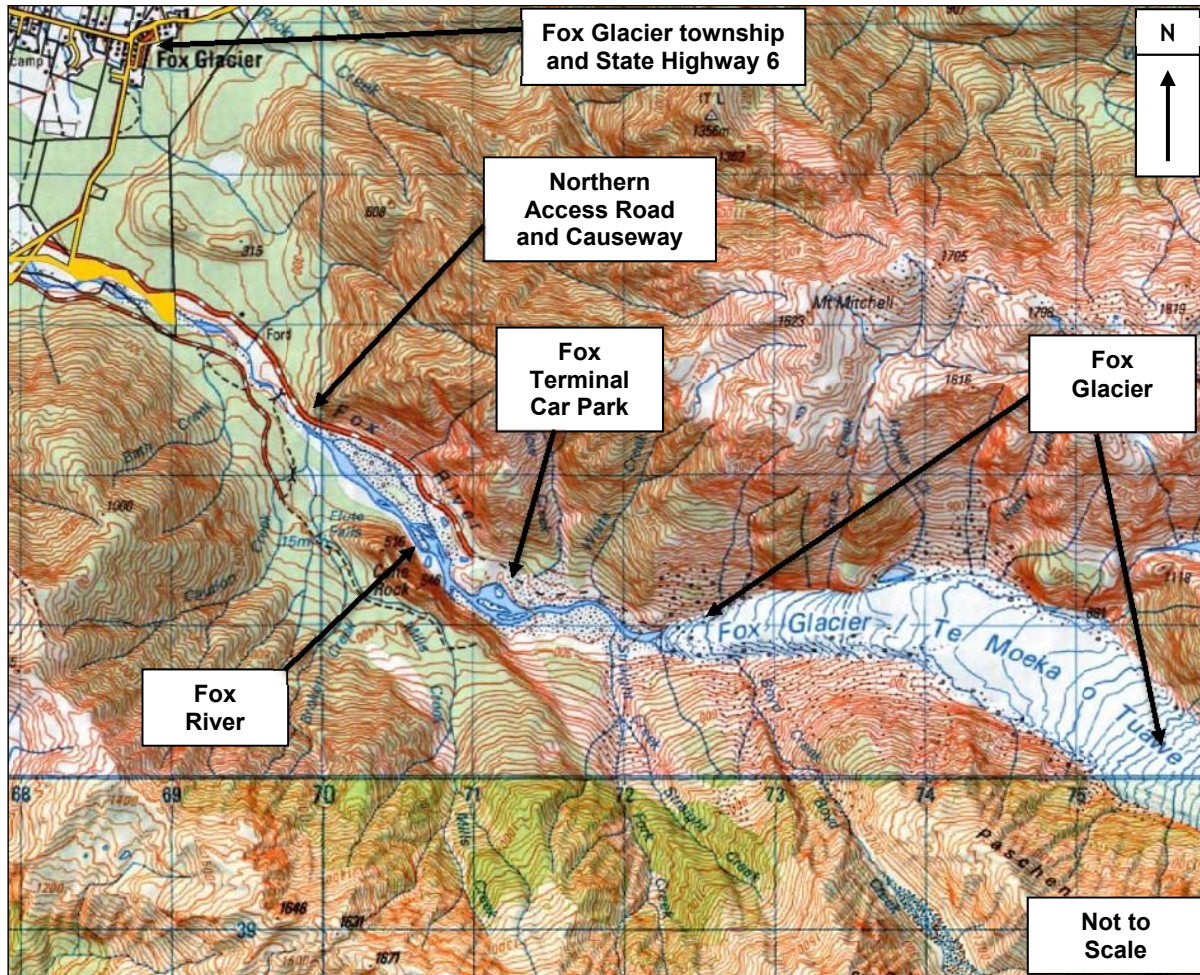


Figure 1. Site Location (Source: Terraview Platinum, 2010)

The Northern Access Road to the glacier leads from State Highway 6, see Figure 1 and Figure 2. The access road runs into the Fox Glacier Valley, a portion of the access road is a gravel causeway running between the slopes of Undercite Creek and the Fox River. The causeway is raised on an annual basis by 0.5 m due to subsidence. The causeway is also affected by river erosion from scouring by the Fox River on the true right of the valley and on the southern edge of the causeway. The causeway has a floodwall comprising rip-rap. The causeway leads to the Terminal Car Park. The car park comprises gravel hard standing with rip-rap construction on the river (southern) side to aid with river scour protection.

The car park is used all year round with daily visitor numbers being in excess of 3000 people a day in summer months with a decrease in the winter months.

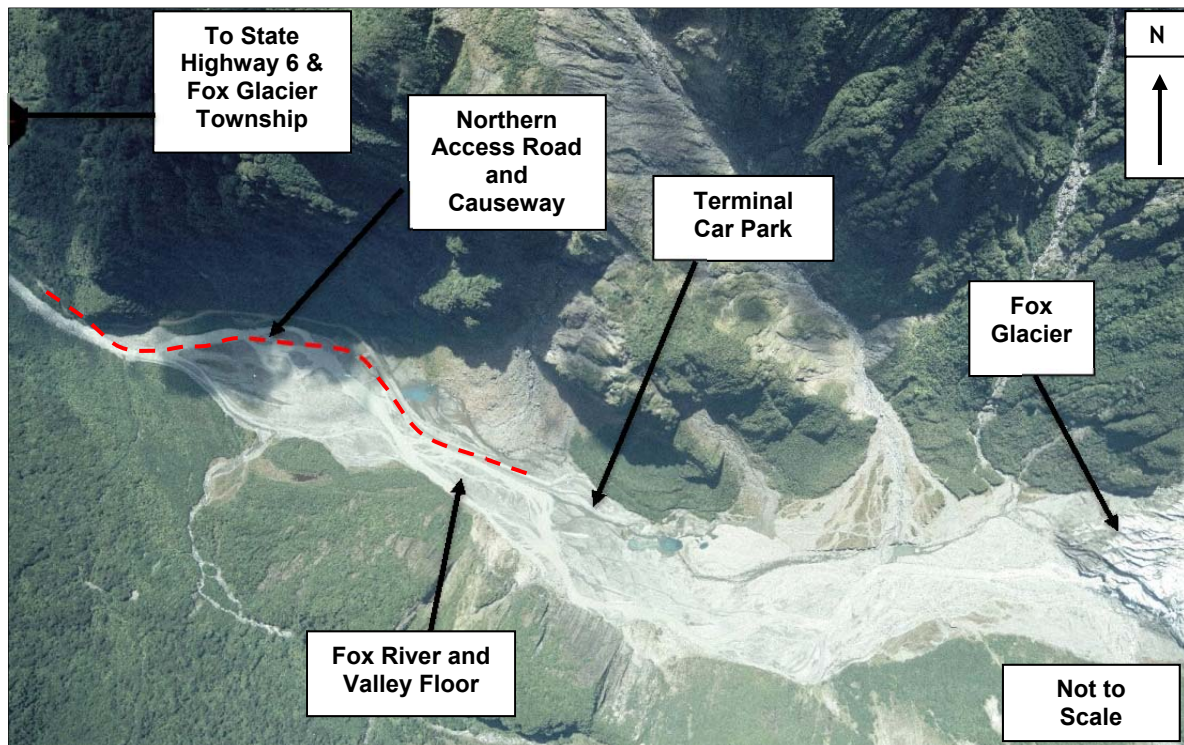


Figure 2. Fox Valley Aerial Map Showing Site Features (courtesy Aerial Surveys Ltd, 2009)

2.2 Geology

The geology in the area is characterised by with solid geology to the East of the Alpine Fault as early Permian to Late Triassic-aged Torlesse Composite Terrane Deposit with Schists and recent Alluvial Deposits to the West of the Alpine Fault.

2.3 Glacial Processes

This section details the historical glacial processes that have occurred in the area around the Terminal Car Park. The valley has undergone a number of glacial fluvial processes, these include:

- Glacio fluvial depositions and redistribution;
- Glacial till deposition in the valley floor and up the valley sides; and
- Melting of remnant in the valley floor and contained within old moraines, resulting in kettle formation and land settlement.

Melting of a large proportion of the 1960's ice cored moraine, which was to the east of the car park, occurred in 2009 and 2010. Cut degradation processes have been reported on the right side of the valley around this area and the moraine ice has reduced in size significantly, leaving only moraine material on the upper slopes.

With the reduced protection offered by the moraine ice, the car park is subject to a more erosional effect from the flow of the river along the southern edge of the floodwall.

3 CARPARK AND ROADING SUBSIDENCE

3.1 Background

The causeway overlies buried ice (as previously mentioned). This is melting over time and this melting causes the development of kettle ponds, settlement of the road terminal and the causeway. Generally this is a maintenance issue, but abrupt discontinuities in the pavement surface may result. This risk is managed as part of maintenance.

The Fox Glacier car park has in the past few years suffered from:

- Increased subsidence;
- Reduced height (or elevation);
- Pot holes; and
- Sudden changes in levels.

The above activities have resulted in:

- Maintenance on a daily and weekly basis;
- Increased need for reinstatement;
- Raising of the car park by 0.5 m every year; and
- Increasing costs of maintenance.

3.2 Historical Information

Historically MWH Ltd undertook a 'Glacier Roads Strategy Study' (MWH 2005) in 2004. This work included a ground penetrating radar (GPR) survey of the car park. This report concluded the following with respect to the car park:

- Ice is unlikely to be present in significant volumes above 4 m depth within the car park.
- Relatively small (1 m³ to 2 m³) blocks of ice could be present below the northwest part of the car park.
- No data is available for the ground below the existing car park lake.

The various car park profiles are characterised by a strong reflector at about 3 m depth. Aerial photographs taken in 1965, 1981 and 1985 show the river flowing around the west of the then present 1960's ice-cored moraine and across what is now the car park area. Figure 3 below compares aerial photographs of the car park as it was in 2004 and 2011. As it can be seen in 2004 the area was a pond and not filled in. The photograph from 2011 shows the car park much as it is today.



Figure 3. Comparison of Terminal Car Park in 2004 and 2011

During ongoing site visits and maintenance observed settlement and subsidence of the car park has been noted. This has occurred on a regular basis over the last few years with a couple of incidents between April 2012 and May 2013 that have seen more substantial changes, illustrated by photographs in Figures 4 below.



Figure 4. Photographs of subsidence

3.3 Investigation

Due to the increase in the discussed processes in 2013 it was decided that the material beneath the car park be further investigated. This was to assess the causes of the subsidence to aid with providing solutions for long term maintenance. Due to the nature and depth of the car park deposits, it was recommended that a GPR survey was best placed to interpret deposits at depth rather than investigation by way of intrusive boreholes.

GPR survey was undertaken by Southern Geophysical in December 2013. The survey found:

- The car park is estimated to be some 5 to 6 m higher than it was in 2004.
- The first 2 to 2.5 m below ground level is gravel fill used in the construction of the car park.
- The fill appears to be unsorted material based on the presence of occasional large boulders. This overlies another set of gravels marked by more frequent boulders and less well stratified layers. The latter could be older fill overlying and mixed into river gravels.
- The water table appears to lie between 4.75 m and 5 m below ground level (bgl).
- Beneath the gravels is a horizon marked by boulders, some of which are greater than 5 m in diameter, which is interpreted to be landslide deposit that predates the car park. The landslide deposits lie at 3.5 m bgl in the south-east corner of the site, but drops off to around 8.5m bgl in the north-west corner of the site. The landslide and engineered fill deposits are subsiding in the western and northern sections of the site, with subsidence features down to 16 m bgl.
- Subgrade layers across the car park were found to have good lateral continuity across the site and have been shown to dip or subside to the north-west corner of the car park. Subsidence of layers to 4 m depth are shown to have occurred in the north-western area, see Figure 5 and 6, older deposits have been shown to have subsided down to 15 m bgl in the south-eastern area of the car park near the toilet block, Figure 7.

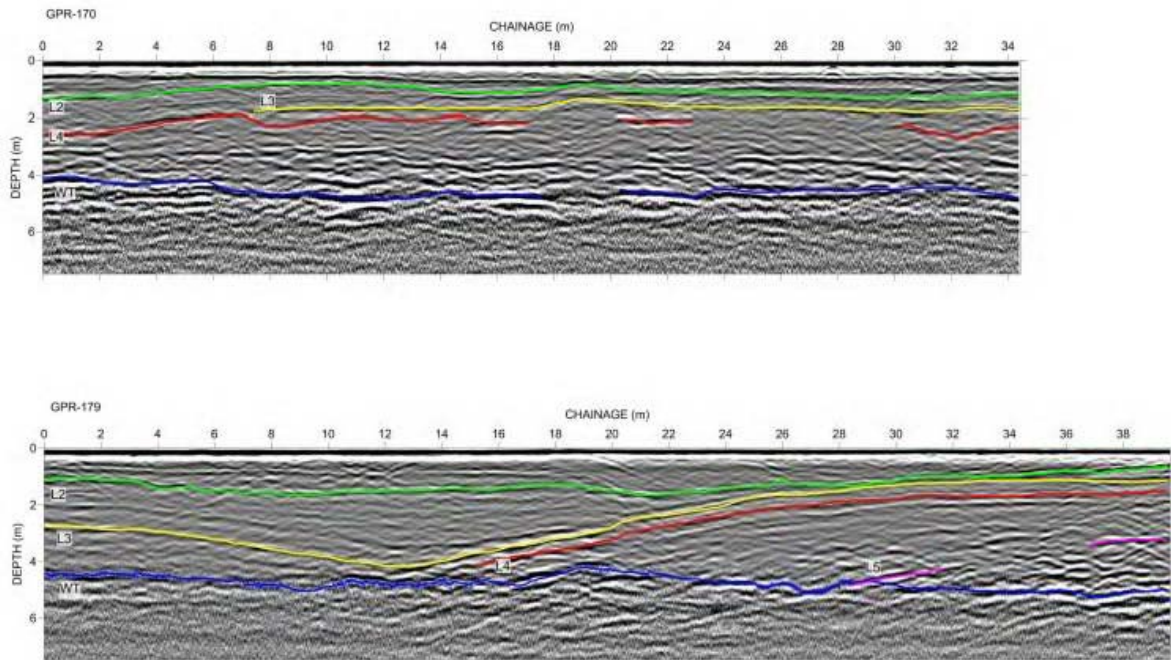


Figure 5. Settlement of car park layers demonstrated by GPR survey.

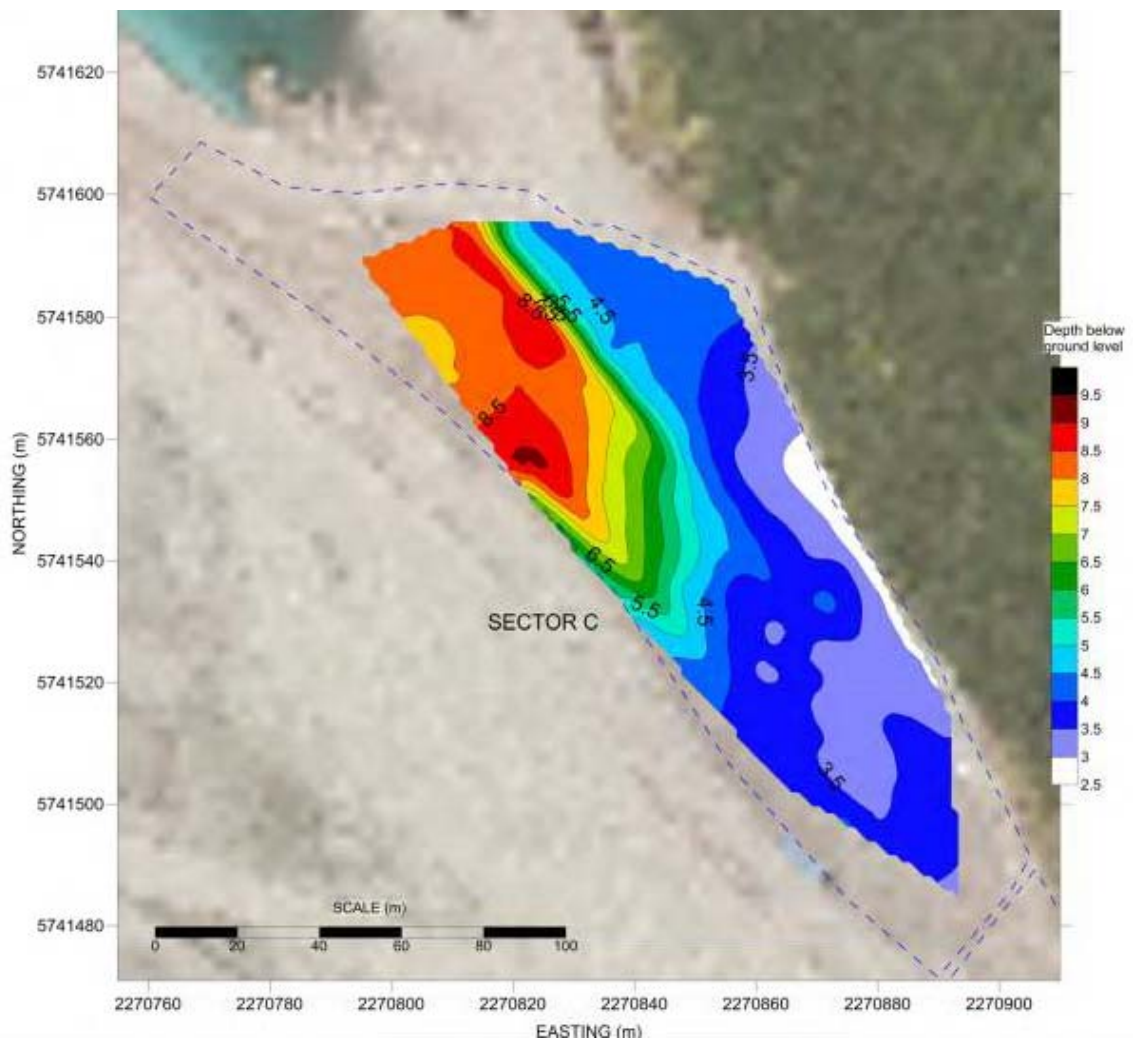


Figure 6. Fill layers showing subsidence depths.

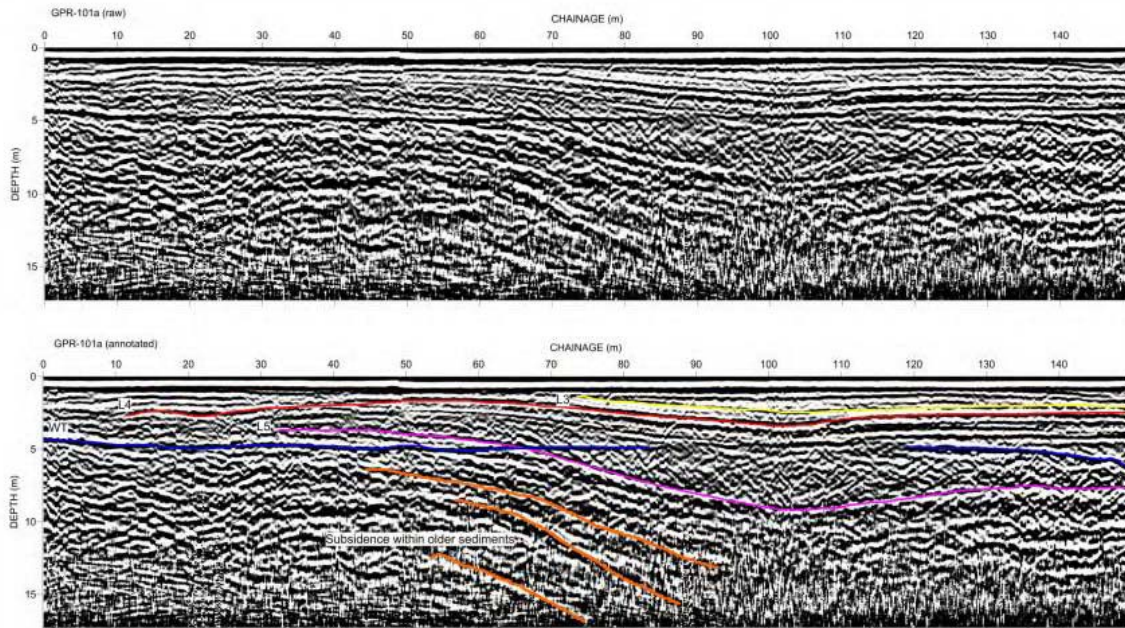


Figure 7. Deep subsidence layers within the Terminal Car Park

3.4 Assessment

3.4.1 River Channels

The historical aerial photographs and anecdotal evidence suggests that river channels once crossed the car park area and also broke into the car park area from the main river channels. These are now buried and may form a pathway for water to pass through the car park to Undercite Creek pond. The GPR survey in 2004 also suggested that water was crossing the floodwall due to the 2 m+ hydraulic difference.

It must also be noted that without protection the river channels which flow against the car park wall / flood wall can penetrate deposits beneath the car park and erode the car park if not enough rip rap material is provided for protection.

3.4.2 Spring

A spring or buried river channel may be feeding water into the north-western area of the site which potentially flows into the Undercite Creek pond area. The Undercite Creek pond area was dry in 2004.

3.4.3 Ice Melt

The 2004 GPR survey found possible small pockets of ice within 2 m of ground level but concluded ice was unlikely within 4 m below ground level. With the increase in levels from 2004 to 2013 being 5 to 6 m it would therefore be unlikely for ice to be present within the top 9 to 10 m of the car park now. No ice was found in the GPR results to depths of 15 m. Also anecdotal evidence from the early 2000's indicates that ice was visually evident in the water of the pond and river channels indicating that ice was still nearby and breaking up. In recent years no ice has been seen in the pond areas. This may indicate that this ice source has now melted.

Deeper dead ice may be present as a remnant feature of a deep valley glacial ice and moraine left by the glacier before it retreated. This may be deep seated, for example the dead ice below the terminus of the Tasman Glacier is reportedly 600 m thick. Mapping of deep valley ice and moraine would require a cross valley seismic refraction or reflection survey, or a close-spaced gravity profile.

3.4.4 Remedial Actions

Ongoing maintenance work and raising of the causeway and car park area has been a regular requirement for a number of years. As the cause of the subsidence is likely to be deep seated,

conventional remedial measures for this type of subsidence such as sheet piling to prevent deep buried water flow and spread of subsidence are unlikely to be either practical (due to the presence of boulders), or economical considering the location of the site and size of works required.

The monitoring of the car park on a daily basis by DOC and infilling of the car park is the current method of management, which has worked fairly effectively to date. As this issue, possibly due to deep dead ice, may continue for some time (years) to come.

The proposed solutions for the site are as follows:

- Ongoing daily monitoring and management;
- Placement of sufficient rip-rap is required on the southern car park / flood wall area to protect it from river channel flow into the car park wall, beneath the car park or over the top of the car park in flood events.
- Stockpiling (surcharging) of the main area of subsidence in the north-western area of the site, which will allow the area;
 - To be loaded.
 - Not driven on.
 - Isolate risks posed by sudden subsidence.

4 CONCLUSION

A GPR survey has been undertaken at the Fox Glacier Terminal Car Park to investigate the causes of ongoing subsidence. This data has been compared to a previous GPR survey undertaken in 2004. The results find that there is now a further 5 to 6 m of fill present over the original 2004 ground conditions. Two areas of subsidence have been found to be evident in the GPR layers:

- In the north western area of the site to 4 m bgl where a pond was once present.
- In the south-eastern area of the site with older subsided sediments down to 14 m bgl.

Both areas are consistent with visual and photographic evidence of subsidence over the last few years. The causes of subsidence could be related to deep seated melting ice or deep water flow through old river channels or springs. No shallow ice deposits were encountered.

Remedial options could include surcharging the area in the north western portion of the car park, and maintaining a strong flood wall to protect the car park from flood events.



Figure 9. Terminal Car Park 2014 after maintenance works.

5 ACKNOWLEDGEMENTS

Tom Hopkins and Wayne Costello – Department of Conservation
Southern Geophysical

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