



## Memorandum

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<b>Date</b>	19 June 2020
<b>File/Ref</b>	6-XO011.00 015GX
<b>Subject</b>	Glenorchy Floodbank Rees River

### Summary

- The Rees main channel has recently shifted from the true right to the true left bank
- It is now impacting the floodbank where the Lagoon stream enters the channel
- The length downstream of the confluence is not armoured, and shows evidence of undercutting and slip circles forming. Reports note armouring on the west end (downstream) of the floodbank, but not observed.
- There is a depression, possible evidence of piping
- Willow trees on the river of the floodbank are possibly providing some protection, but also being undermined
- Larger willow trees on the land side
- 4wd access could do with minor shaping works
- Some standing water upstream of the bridge
- Remediation measures would involve armouring the stopbank, and potentially diverting the flow further upstream of the confluence to take the channel back to the true right.

### Background

- WSP were engaged by ORC to undertake a site visit and walkover of the full floodbank structure to check for any obvious Geotechnical/Structural issues. Specifically and especially, a review of the floodbank adjacent to the Rees River to see if there is any evidence for recent/ongoing erosion at this structure.

- Identification of any locations on the structure where erosion poses a threat to the structure's integrity in the short-term, or at high flows, and which would benefit from remedial works.
- A site inspection was undertaken on Thursday 11<sup>th</sup> June by Paul Jaquin of WSP

## Situation

- The Rees River flows south into Lake Wakatipu at Glenorchy
- The head of Lake Wakatipu is a delta formed around the base of Mount Alfred, where the Rees and Dart Rivers combine.
- The interaction of the Lake, Rees and Dart rivers produce a complex hydrological situation leading to varying river channel patterns
- Aggradation of the river bed has occurred due to mobilisation and deposition of river sediments at the point where the Rees River enters Lake Wakatipu.
- The Glenorchy lagoon is a wetland formed on the true left of the Rees river, upstream of Glenorchy
- The main channel flow of the Rees River runs alongside the lagoons.
- Main river channel is flowing hard up against the Glenorchy Floodbank in the vicinity of Lake Road and Butement Street
- The lagoons have a small outfall channel. This channel meets the Rees River at the northern end of Butement Street.

## Glenorchy – Rees Floodbank

A floodbank was constructed in 2000 to protect the Glenorchy township from inundation from the Rees River. The flood bank runs for approximately 1400m from the car park at the southern end, to the golf course at the northern end, with the southern part adjacent to the Rees River, and the northern part adjacent to the Lagoon stream.

The external face is constructed to a 3:1 batter, and the internal face at a 1.5:1 batter. Information on the construction is minimal, but it is expected that locally sourced or site won material was used for the construction. The founding of the flood bank is expected to be the delta and lake bed sediments (ORC, 2007), and the construction is noted as *Grey, dense, moist silty, sandy gravel* (OPUS, 2004), suggesting that the delta and lake bed schist sediments were used for the construction.

There are trees older than 20 years on the land side of the flood bank, suggesting they were present prior to its construction, but there are numerous young willow trees growing on the bank.

## References

The following documents were referenced as part of this study:

OPUS. (2004). *Wakatipu Flood Bank Stability Survey, Queenstown and Glenorchy*. Opus

This report notes that the flood bank to be in good condition, but noted that the trekking crossing location was experiencing some erosion, and recommended reinstatement of the bank to prevent further erosion.

This report notes that a large quantity of gravel was situated in the Rees River bed above Glenorchy, and that migration of the gravel downstream could result in realignment of the main river channel, consequently placing the Glenorchy Flood Bank under pressure, and Glenorchy township under increased flood risk.

There was considered to be little change to the Rees River flood plain from 1937 – 2001, the river split into two main channels in the vicinity of Precipice Creek, and water flowed in both channels. After 2001 it was noted that the river flow had consolidated to the east, with the main river channel passing closer to Glenorchy.

The report describes rip rap erosion protection at the western end of the embankment, the rip rap consisted of schist boulders of approximately 1m diameter, with potentially poor interlocking properties, placing the rip rap in danger of being dislodged.

## **Evidence of erosion**

The following locations have been identified where erosion poses a threat to integrity in the short term or at high flows, and would benefit from remedial works

### Golf course to Rees

1. Areas of standing water at the head of the slope upstream of the crossing point. There appears to be dumped material on the head of the floodbank. There is some standing water on the path and behind the mounded material. This is not considered a significant issue in terms of stability of the floodbank, although significant standing water could lead to oversaturation of the floodbank, resulting in a reduction in strength. Track maintenance would allow this to drain.
2. Some minor erosion and track damage was noted in the vicinity of the trekking / 4wd crossing point. This is not considered to be a major threat to the stability of the flood bank, but works to locally repair the track could be undertaken to prevent further damage by wheel tracks, and to locally improve the drainage.
3. There are areas where the bank appears significantly over steep compared to other areas. There is little evidence of failure of the slopes in this area, and the Lagoon stream does not generally appear to be eroding the base of the bank. Vegetation maintenance and monitoring of this area is considered to be required.

The stream has scoured a deep channel at the base of the floodbank due to continued flow through low strength sediments of the lagoon.

4. An eddy area has formed immediately upstream of the bridge. While flows from the lagoon are generally low velocity, vegetation maintenance may be required in this area. The site was not inspected from the water, but it is not considered that the floodbank is being undermined.

## Rees to Delta

5. Upriver of the Glenorchy Lagoon Stream confluence, the scouring action of the main flow of the Rees River is causing the existing silt bar to be eroded. Erosion and removal of this floodbank would allow the Rees River to impact further up the Lagoon stream, and further damage the flood bank.

A few boulders of dimension 500mm were noted at the toe of the bank, it was unclear if these were rip rap. Other than these, there was no visible rip rap along the toe of the bank. It is however unclear if rip rap boulders have been covered in vegetation, or have been dislodged.

The Glenorchy Lagoon channel gradient is shallow, and may be to be subject to backflow when the Rees River is in flood.

6. The current path of the main river channel is causing the full volume of the Rees River to flow into the flood bank at an almost perpendicular angle, with some over steepening, and erosion of the toe of the flood bank visible. This is an area of significant concern, and mitigation in the form of armouring should be installed to protect the floodbank.

The comparatively deep channel of the Lagoon stream at the confluence means that main flow of the Rees River will be directed into that channel and against the toe of the bank.

The undermining of some of the trees on the bank could lead to their death and collapse into the river. This has the potential to cause further collapse of the bank, leading to a reduced cross section, which would then rapidly scour.

7. A large depression visible in the centre of the track is possible evidence of piping. There may be flow of water from the land side, through the bank, transporting fine material and leading to a loss of material and a depression at the surface.
8. Headscarps appear to be forming at the river side of the bank where it is overstep and being undermined by the Rees River. The slope is reasonably well bound by the vegetation, specifically the roots of the willows, but undermining of the toe of the slope and erosion of the soil matrix is occurring.
9. At site 9 we understand that fill material was dumped following remediation works to the roading network north of Glenorchy. This area appears to be poorly drained and has the potential to allow the floodbank in this area to become saturated.
10. A minor channel of the Rees River runs against the base of the floodbank. At the time of inspection the channel did not have significant flow, but there is the potential that this could form the main channel following future flood events or sediment mobilisation. If this does become activated as the main channel this would cause significant flow of the Rees against the floodbank.
11. At Site 11 there is evidence of minor slope failure on the water side of the floodbank. This is evidenced by a drop in the ground surface and the formation of a headscarp.

12. Around the length between Butement Road and the car park there are a number of older (than the floodbank) Crack Willow trees on the land side of the floodbank which have the potential to collapse and cause damage to the floodbank.
13. Close to the car park there is evidence of minor slope failure on the water side of the floodbank. This is evidenced by a drop in the ground surface and the formation of a headscarp. The scarps at site 13 are more pronounced than at Site 11.
14. The track between the car park and the floodbank has several large scour depressions. It is assumed that these formed as floodwater from previous events drained across and through this area.

## Prognosis

### Normal flow conditions

- If the main channel of the Rees River is allowed to flow against the toe of the floodbank, it is expected that that the floodbank will become undermined, become over steep and fail.
- The schist gravel that the bank is constructed from is considered to be a relatively erodible material, particularly where direct river flow is sustained against the flood bank (ORC, 2007). While the root systems of the vegetation growing on the flood bank appear to be providing some structural support to the flood bank material, as further erosion occurs there is the risk of trees falling into the river and pulling sections of the floodbank down.
- As the walking trail gets steeper and closer to the water's edge, there is an increased risk to public safety.

### Flood conditions

- Under flood conditions there is an increased hydraulic head on the bank. The founding materials to the floodbank are expected to be the river delta and lake sediments, with the floodbank made from compacted materials transported to site. It is therefore possible that the foundations are more permeable than the flood bank, meaning significant seepage could occur under the floodbank, as outlined in the ORC 2007 report.
- This may already be occurring at the location 7, which is adjacent to the dumped material and could be evidence of piping flow.

## Remedial Works Options

Remedial options would look to:

- Eliminate the erosion occurring at the toe of the flood bank by armouring the affected section to prevent undercutting, and defend against the migration of the river down stream
- Provide river training to encourage the main river channel to return to the older river channel, alteration of river sediment deposition to promote aggradation in the vicinity of the flood bank

- Dredging of the old river channel, to encourage the main channel back to the true right

### Do nothing:

- If no remedial works are completed, and the main channel of the Rees River continues to flow hard against the toe of the floodbank, the already visible undercutting and erosion will continue, placing the flood bank at risk of long term failure.
- This could allow the lagoon and the Rees River to flow into the area south of Butement Street. The area to the north of Butement Street is a raised platform, but area to the South, specifically 14 and 18 Butement Street are lower lying and therefore may be at risk in the event of a failure of the floodbank.

### Do medium – Armouring of flood bank:

Armouring of the northern section of the flood bank would prevent further undercutting and armouring of the south section would defend the floodbank in the event of migration of the river downstream.

This would involve:

- Placement of armouring material at the toe of the flood bank
- Armouring could consist of rip rap, gabion baskets, or Elcorock Shoreline protection system
- If rip rap is employed, the size and shape of material should be considered, to maximise interlocking capacity and stability, as previously placed rip rap does not appear to be present.
- The Glenorchy Lagoon Stream should be armoured upstream to mitigate against flow of the Rees river channel against this bank. Further investigation into the depth of the Glenorchy Lagoon Stream channel, and the extents of armouring are recommended.
- A fence at the top of the floodbank could be installed to provide a pedestrian barrier if necessary.

This works would require closure of the pedestrian access along the affected area of the flood bank for the duration of the works.

### Do maximum – River Training in conjunction with Armouring

In addition to the armouring described above, river training in the form of channel dredging and groyne placement to encourage the main river channel to flow to the west and away from the flood bank could be undertaken.

The installation of groynes in the river, upriver from the affected area of flood bank, would act to create a deposition environment between the groynes. Groynes would be placed on the true left at approximately 20m intervals above the confluence of the Glenorchy Lagoon Stream. Groynes would be designed to have a steeper (1:5:1) upstream face, and a shallow (3:1) downstream face, with a fall of 3:1 from the bank to the river.

The installation of the groynes could be undertaken in conjunction with dredging of the original main river channel on the true right. Removal and redistribution of the river sediment should encourage the main flow away from the flood bank, and the groyne placement would encourage future deposition of mobilised river sediments on the eastern bank of the river. The long term goal of groyne placement and river training is to protect the flood bank from

the continual erosion threat posed by the location of the main Rees River channel against the toe of the flood bank.

## Recommendations

The following measures are recommended in order of preference:

1. Installation of armouring along the northern length of the bank downstream of the Lagoon confluence.
2. Installation of the full length of rock armouring between the lagoon confluence and the delta.
3. Installation of groynes upstream of the confluence
4. Dredging of the original channel on the true right bank.

## Considerations for all options

- Maintenance of large or older trees in the vicinity of the flood bank. While the smaller trees are considered to be younger than the floodbank (ie 20 years), there are several older trees, which may reach the end of their natural life (approximately 100 years) soon, and could require removal.
- Upgrade and reworking of the 4wd crossing point, to mitigate against erosion due to vehicle tracking.

## Photographs



Site 1. Standing water on the floodbank upstream of the bridge.



Site 2 – 4wd crossing point



Site 2 – 4wd crossing point, with drainage channel and culvert.



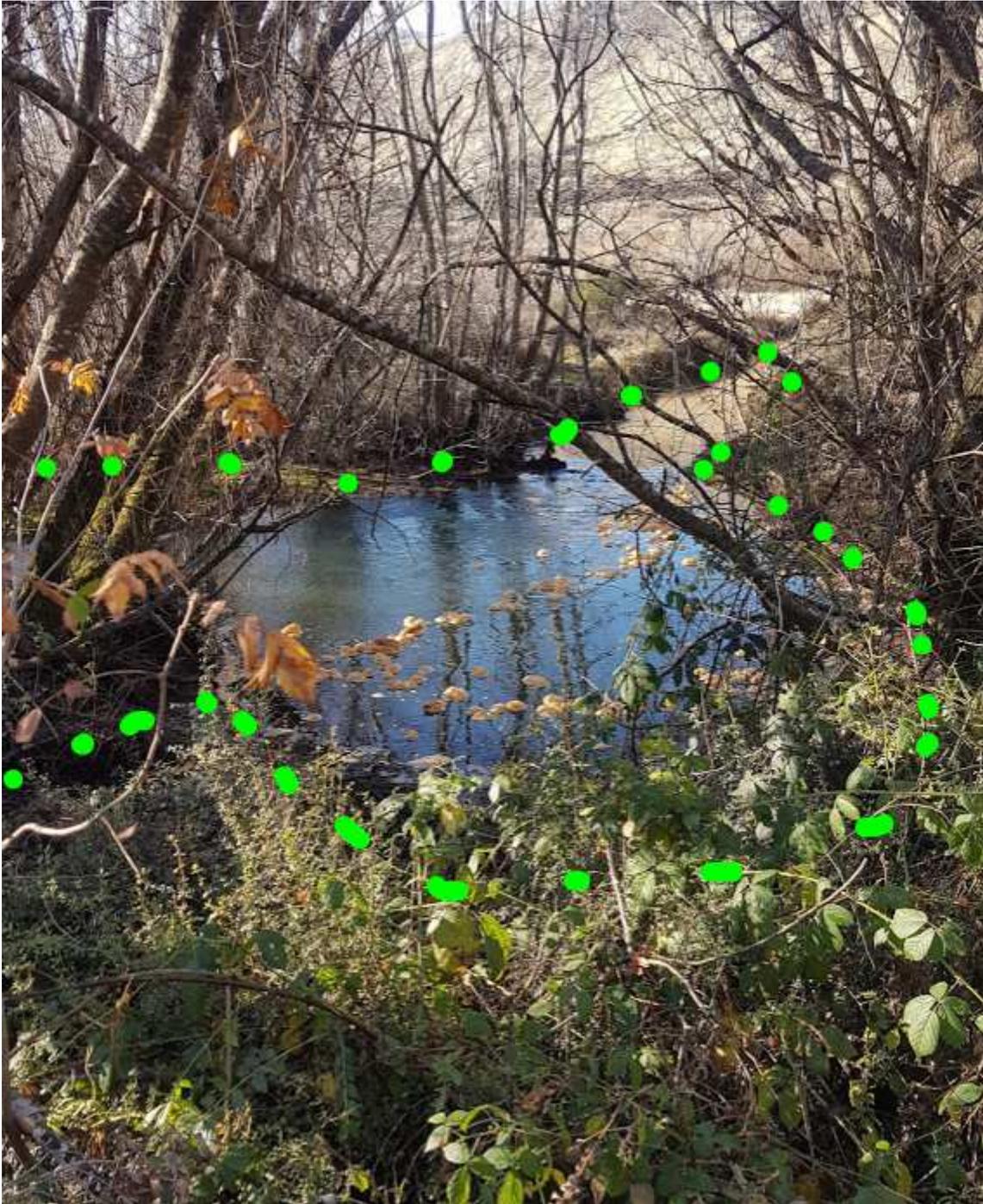
Site 2. 4wd crossing point



Site 3 - Potentially oversteep bank upstream of the bridge



Site 3 - Floodbank at the Lagoon stream



Site 4 – Eddy area upstream of the bridge



Site 5 - Confluence of the lagoon stream and the Rees



Site 5 - Lagoon stream confluence looking downstream, standing on the silt bar



Site 5 - Lagoon stream confluence looking upstream



Site 5 - Lagoon stream confluence looking upstream, showing the silt bar



Site 5 - Floodbank at the Lagoon stream confluence



Site 6 - Rees river running against the base of the flood bank, undermining the bank



Site 7 - Large circular puddle, evidence of piping



Site 8 - Rees River against the base of the slope



Site 8 - Rees river hard up against the bank downstream of the lagoon confluence



Site 8 - Headscarps forming at over steep bank downstream of the Lagoon stream confluence



Site 9 - Area of dumped fill on the right of the photograph



Site 10 - Channel against the base of the floodbank



Site 10 – Minor channel against the base of the floodbank



Site 11 - General section of trail with a drop in trail level and the formation of a headscarp on the water side.



Site 12 - Older cracked willow on the land side



Site 13 - Headscarp forming at the delta end of the track



14 - Scour holes at the path between the car park and the floodbank.