REPORT

Tonkin+Taylor

Lower Tongariro River

Potential breakout management options study

Prepared for
Waikato Regional Council

Prepared by
Tonkin & Taylor Ltd

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1 Introduction

1.1 Description of issue being addressed

The issue being addressed has been concisely summarised in a previous report (Niwa 2005) as follows:

"The Tongariro is a volatile river which undergoes significant channel changes in response to floods and eruptions. The river transports vast amounts of sediment through its upper reaches and deposits the sediment on its delta from Turangi downstream.

Visual inspections of the lower delta show the river is close to breaking out of its present channel to find a new course to Lake Taupo. There is a significant amount of water being lost from the 'normal' river channel, even during moderate freshes. Floodwaters spill from the river upstream of De Latours Pool eastwards to Stump Bay and west towards the Tokaanu Tailrace via Deep Stream. The most likely future breakout route is from Downs Pool to Tokaanu Bay via Deep Stream."

Since the NIWA report was published in 2005, visual observations of the lower river (ie downstream of Turangi township) indicate that this section of the river is slowly aggrading resulting in increased spill from the river during flood events.

In October 2013, bank erosion and overtopping during a flood event resulted in the river cutting through to short-cut the meander that formed De Latours Pool. This short-cut has resulted in significant degradation of the river bed upstream of the short-cut, with accelerated aggradation and erosion evident downstream of the short-cut. This has exacerbated the risk of the river breaking out of its current course into Deep Creek.

Should the river change course into Deep Creek, there will be significant effects on some land owners at the end of Awamate Rd, potential damage or loss of some waahi tapu sites, potential issues with sediment deposition into the Tokaanu hydro powerstation tailrace, and potential risk to the wastewater treatment ponds on Awamate Rd. For these reasons there is strong interest from the community in taking action to prevent the river changing course into Deep Creek.

1.2 Purpose, scope and structure of report

This report provides a range of potential options for river management for the Lower Tongariro River to be presented to the community for discussion. The options range from the status quo (ongoing gravel and riparian vegetation management), through to significant engineering works designed to reduce the risk of breakout to Deep Creek.

Section 2 provides background information including a brief description of the river and a summary of previous work, Section 3 provides a description of the current situation in the Lower River and describes the risks associated with a change in course of the Lower River. A range of options are described in Section 4 together with the expected consequences of the works, and a high level approximate estimate of likely costs.

Section 5 describes the key issues and Section 6 makes recommendations for the next steps.

2 Background

2.1 Brief summary of river history and how it has changed over time

The Tongariro River is a highly dynamic river that originates on the north eastern slopes of Mt Ruapehu and transports high volumes of sediments generated from the recent volcanic geology and occasional eruptions. The river flows into the southern end of Lake Taupo where it is building a "bird's foot" delta.

A flood protection scheme incorporating stopbanks and rock revetments has been constructed on the banks of the river where it passes through Turangi township, with a stopbank extending down the left bank to a point just north of the wastewater treatment ponds on Awamate Rd.

Downstream of Turangi, the river changes to a meander pattern as it crosses the delta to Lake Taupo. The land formed by the delta has historically been farmed. However, over the past 10 – 20 years the land has become wetter with more frequent overtopping from the Lower River and higher groundwater levels. There are a number of factors that may be contributing to the wetter ground including the gradually aggrading river bed in this reach, tectonic subsidence (thought to be around 3mm/year), and the changes to the water level in Lake Taupo.

The morphology of the delta development is such that evulsion of the river will eventually occur, where the river finds a steeper path to the lake. Currently, the river channel has built out the delta to the currently furthest point out into the lake. The shorter pathways are to either Deep Creek or directly north from Downs Pool to the lake.

2.2 Summary of previous studies / reports / papers relevant to this stretch of river

Management of the Lower Tongariro River has been the focus of numerous papers, reports and studies. Some of those focusing on river management within the lower Tongariro River are identified in Table 2-1 below, where excerpts and comments are provided to describe conclusions or recommendation from these documents.

Table 2-1: Reports and papers addressing the lower Tongariro River management

Paper title	Comment
NIWA / G Smart 2005 paper – The higher Lower Tongariro	In this 2005 paper, Mr Smart identifies the risk of a break out and likely routes to the lake with the dominant risk being a potential breakout from Downs Pool into Deep Creek, and potential for a new channel to form from near Tongariro Lodge down the left side of the flood plain to join Deep Creek at the end of Awamate Rd (this overflow channel is known as the Hirangi Arm – See Figure 3-6 on page 9). We note that this paper was written following the 2004 flood event which caused a significant amount of gravel to move down the lower reaches of the Tongariro River. Figure 18 of this paper shows the possible breakout routes and locations for the future mouth of the Tongariro River. This figure is superseded by figure 4 in the 2011 paper (included below as Figure 2-1) showing flow vectors in a 1300 m^3/s flood flow. Recent observations indicate that it appears more likely that the river will breakout at Downs Pool than through the Hirangi Arm.
G Smart Technical Paper "Pre-empting flood avulsion and 2D modelling", 2011 Tsinghua University Press, Beijing.	In this paper, Mr Smart has used a 2D hydrodynamic computer model (Hydro2de) to analyse flood flows, overland flow paths, and bed shear stress. The model has been used to demonstrate where the most likely breakout (avulsion) is likely to occur, and has modelled a number of intervention strategies to see how effective they may be in preventing breakout. Figure 4 of the paper (included below) shows flow vectors in a 1300 m^3/s flood flow. These clearly show the dominant overflow path is out the left bank of the river to Deep Creek with a smaller overflow path to the north from either side of Downs Pool. Note that this modelling was completed in 2011 based on aerial LIDAR survey data. The river channel in this reach has changed considerably since 2010 as described in Section 3 below.
T+T 2014 letter "Tongariro River – information Review Stage 1"	Gravel monitoring and management are identified as priority issues in this 2014 Letter Report – this is discussed in more detail in Section 3 below.
G Smart memo - 27 March 2014	In this memo, Mr Smart describes the changes and potential changes to the lower part of the river as a result of the shortcut at De Latours, this is described in more detail in Section 3 below.

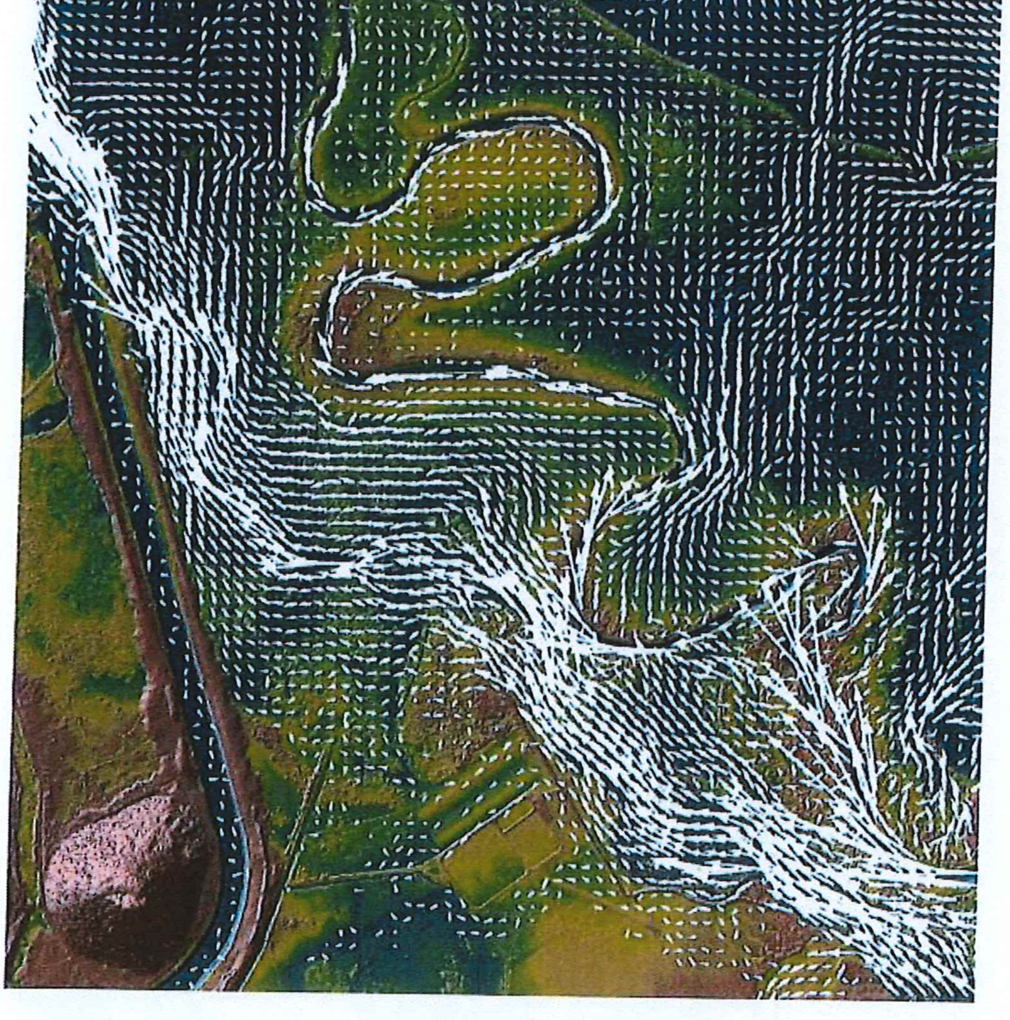

Figure 4 Flow vectors for a 1300 cumec (50 year) flood

Figure 2-1 Extracted figure 4 from G Smart paper "Pre-empting flood avulsion and 2D modelling", 2011

3 Recent developments and associated risks for the lower part of the Tongariro River

In 2013, during two flood events, a breakout occurred in the channel bypassing De Latours Pool, this is shown in Figure 3-1 below.

Figure 3-1: De Latours Pool Breakout

The photograph below taken on 21 February 2016 shows the bank erosion and deposition that has occurred over the last 2 years or so.

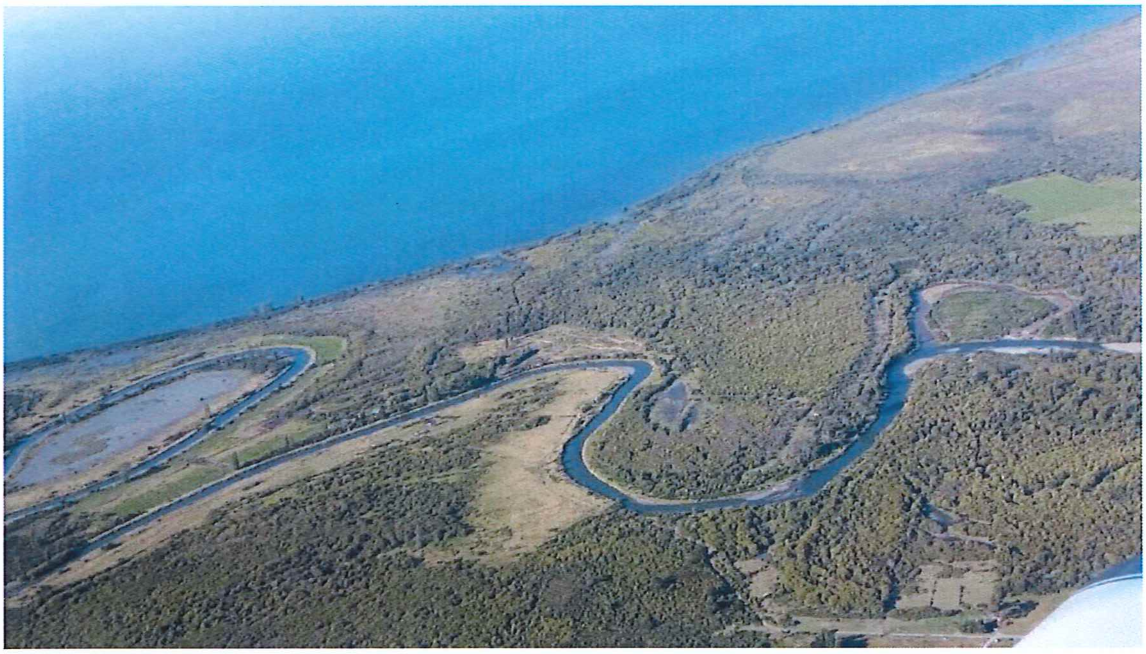

Figure 3-2: February 2016 photograph showing changes downstream of De Latours Pool

Following the short-cut, a T+T letter "Tongariro River - Information Review Stage 1" in March 2014 highlighted again the possibility of a breakout into Deep Creek as a priority issue with a recommendation to further investigate the effect in order to assess the risk of such a breakout. As well as this, the importance of continued monitoring was reiterated (from the 2010 Design Waterway report). The relevant recommendations from the 2014 are included in Appendix A.

The changes and potential changes as a result of the shortcut are also summarised in a memo from G Smart dated 27 March 2014 as follows:

- *"The cut-off at Delatours' bend has increased the river gradient and gravel transport capacity at the cut-off and for a considerable distance upstream of it. Typically, over time, scour and less braiding will appear upstream of a cut-off and deposition and bank attack will occur downstream of a cut-off. At the Delatours cut-off there is clear evidence of river channel lowering, starting with around a 1 metre drop in channel bed level at the upstream end of the cut-off and reducing to about 0.5 metre by 750 m upstream of the cut-off. With time this bed lowering should move progressively further upstream and combine with the bed lowering due to channel berm clearance.*
- *The increase in channel slope and conveyance have allowed the river just upstream of the cut-off to move bars of gravel much further downstream than has occurred over recent decades.*
- *Gravel-bed reaches tend to be straighter than sand-bed reaches and the Tongariro now displays characteristics of a gravel-bed river as far downstream as the exit of the cut-off at De Latours "island".*
- *There is also active bank attack and gravel in the channel downstream of the cut-off exit but bed aggradation downstream of the cut-off was not evident. The deposition zones for gravel produced by degradation upstream of the cut-off was not determined.*
- *While lower bed levels are advantageous in reducing flood risk, there are also potential adverse effects of undermining banks or bridge piers and reduced channel diversity to consider."* (this point refers to degradation upstream of the shortcut)

During a site visit on 28 October 2015, it was clearly evident that there is recent active erosion and overtopping of the river banks downstream of the De Latours shortcut, and this erosion is resulting in lower banks in places, thus increasing the frequency and volume of overtopping during freshes and floods. This is likely exacerbated due to less overflow from the right bank upstream of the shortcut due to bed degradation in this area. Refer to Figures 3-3 and 3-4 below.

Figure 3-3 Active erosion and overtopping of right bank immediately downstream of De Latours shortcut

Figure 3-4 Active erosion and overtopping of left bank at Downs Pool and sediment deposition on inside of bend. Note low areas of bank.

The overflow from the left bank at Downs Pool flows overland to the west and enters Deep Creek. The increased volume and frequency of overtopping events is resulting in head-ward erosion of the upper reaches of deep creek (refer Figure 3-5 below).

Figure 3-5 Head-ward erosion of upper reaches of Deep Creek

The layout and locations of key features of the current situation are shown in Figure 3-6 below.

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LOWER TONGARIRO RIVER
RIVER MANAGEMENT OPTIONS
CURRENT SITUATION

FIG. No. Figure 3-6

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4 River management options and associated consequences

4.1 Option 1 – Status-quo

Description

Continue with the level of river management and maintenance that has been practiced over the last 10 years. This includes some gravel extraction and vegetation control generally concentrated on the reach through Turangi township where the flood control scheme and assets are located. Past work has included filling in of the entrances to some overflow channels into the upstream end of the Hirangi Arm with the aim of preventing the river changing course at this point into the Hirangi Arm. This work appears to have been effective, and it is assumed that these overflow points will continue to be monitored, and filled in as required as part of the ongoing river management regime. Some minor work has been undertaken in the Lower River near the end of Awamate Rd (eg nominal topping up of low spots in river bank).

Likely Consequences

With the current level of funding and river management inputs, the river is likely to change course during a flood event by cutting through from Downs Pool to Deep Creek and/or through the Hirangi Arm down the left side of the flood plain as described in previous reports. Observations over the last 2 years indicate that the most likely breakout point is from Downs Pool, and that this could happen in the next significant flood event. The risks are as described in Section 1.1.

Costs

No up-front capital costs.

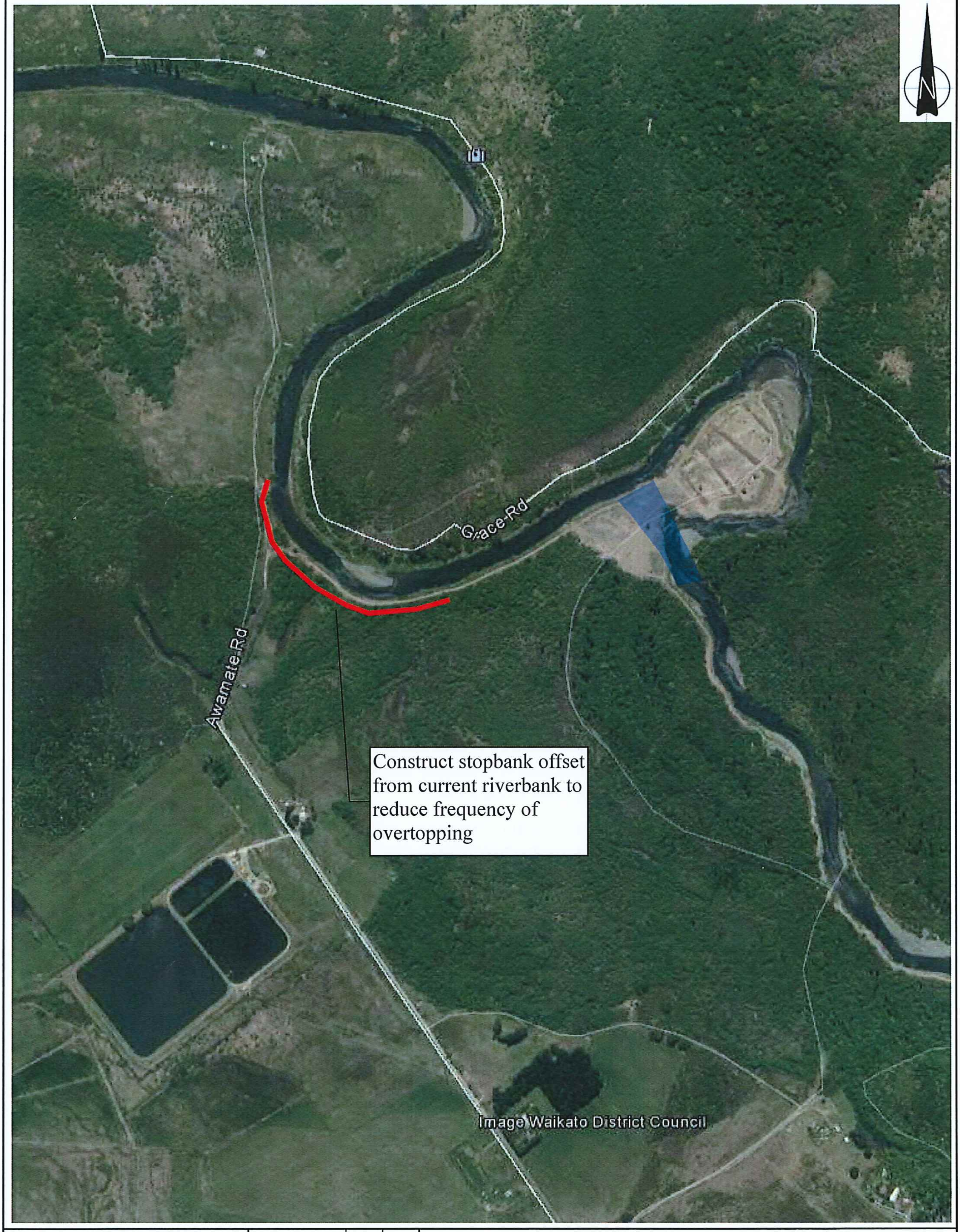
Ongoing river management costs are approximately $120,000/annum with only a small proportion being spent on the Lower River.

4.2 Option 2 - Off-set stopbank to reduce overtopping

Description

Construct a nominal stopbank along the left bank of the river around Downs Pool. This would target the areas where the bank is low and frequent overtopping is occurring. The bank would need to be offset from the existing bank to provide some allowance for the ongoing erosion of the left bank in this location. Refer to Figure 4-1. A reinforced section of stopbank designed to act as a controlled overflow or spillway could be considered as a variation to this option.

As the left bank is expected to continue to erode, this approach is considered a short term measure to reduce the frequency and volume of overtopping at Downs Pool.



Tonkin+Taylor Level 1, 525 Cameron Road, Tauranga www.tonkintaylor.co.nz	DRAWN: CAD ----	WAIKATO REGIONAL COUNCIL LOWER TONGARIRO RIVER RIVER MANAGEMENT OPTIONS OPTION 2 CONCEPT - TOP-UP LEFT BANK AT DOWNS POOL	
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Consequences

- Reduced frequency of overtopping the left bank at Downs Pool.
- Environmental impact of construction works in the river flood plain.
- Ongoing erosion of left bank at Down's Pool that would eventually undermine the stopbank.
- This option does not address the flows that enter the Hirangi Arm during flood events, so there is a risk that the stopbank will get outflanked. The downstream end of the Hirangi Arm bypasses the proposed works. However, with the ongoing river management works filling in the entrances at the upstream end of the Hirangi Arm, and the degradation of the section of river upstream of De Latours pool, it is likely that there will be comparatively less flow in the Hirangi Arm in flood events than there was prior to the De Latours short-cut. The flows in the Hirangi Arm during flood events should be monitored, together with monitoring of the headward erosion of Deep Creek.

Costs

Capital costs for design, consenting, and construction of the stopbank. Estimate $0.5M to $1M

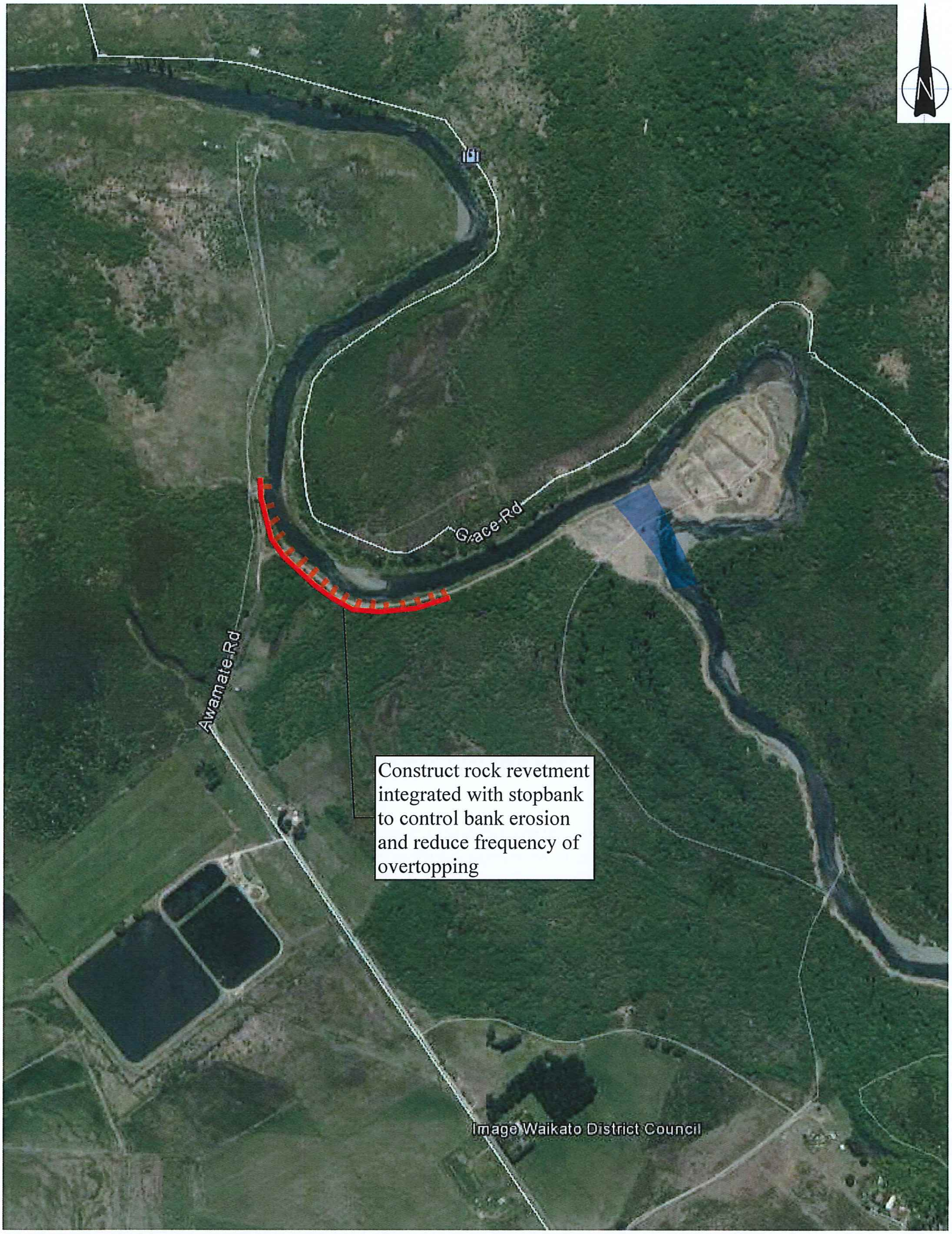
A modest increase in ongoing river management and maintenance to allow for maintaining the stopbank. Estimate $ 20,000/annum increase.

4.3 Option 3 - Stopbank and add rock revetment at Downs Pool

Description

Construct a rock revetment around the left bank at Downs Pool to prevent further erosion of the bank together with a stopbank in the low areas to reduce the frequency and volume of overtopping. For this option, the stopbank could be located immediately beside the bank with the rock revetment continuing up to the design crest level. Refer to Figure 4-2.

This option is considered a medium term solution. Given the volume of sediment being transported into the Lower River and delta areas, it is expected that the river will continue to aggrade in the Downs Pool reach which will eventually reduce the effectiveness of these works.



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LOWER TONGARIRO RIVER
RIVER MANAGEMENT OPTIONS
OPTION 3 CONCEPT - ROCK REVETMENT AND STOPBANK AT DOWNS POOL

FIG. No. Figure 4-2

REV. 0

Consequences

- Reduced frequency of overtopping the left bank at Downs Pool.
- Control of left bank erosion at Downs Pool
- Environmental impact of construction works in the river and its flood plain, which may be more for this option as a rock revetment needs to be constructed in the river.
- This option does not address the flows that enter the Hirangi Arm during flood events, so there is a risk that the rock revetment and stopbank will get outflanked. The downstream end of the Hirangi Arm bypasses the proposed works. However, with the ongoing river management works filling in the entrances at the upstream end of the Hirangi Arm, and the degradation of the section of river upstream of De Latours pool, it is likely that there will be comparatively less flow in the Hirangi Arm in flood events than there was prior to the De Latours short-cut. The flows in the Hirangi Arm during flood events should be monitored, together with monitoring of the headward erosion of Deep Creek.
- Ongoing aggradation at Downs Pool that would eventually reduce the effectiveness of these works.

Costs (initial and ongoing)

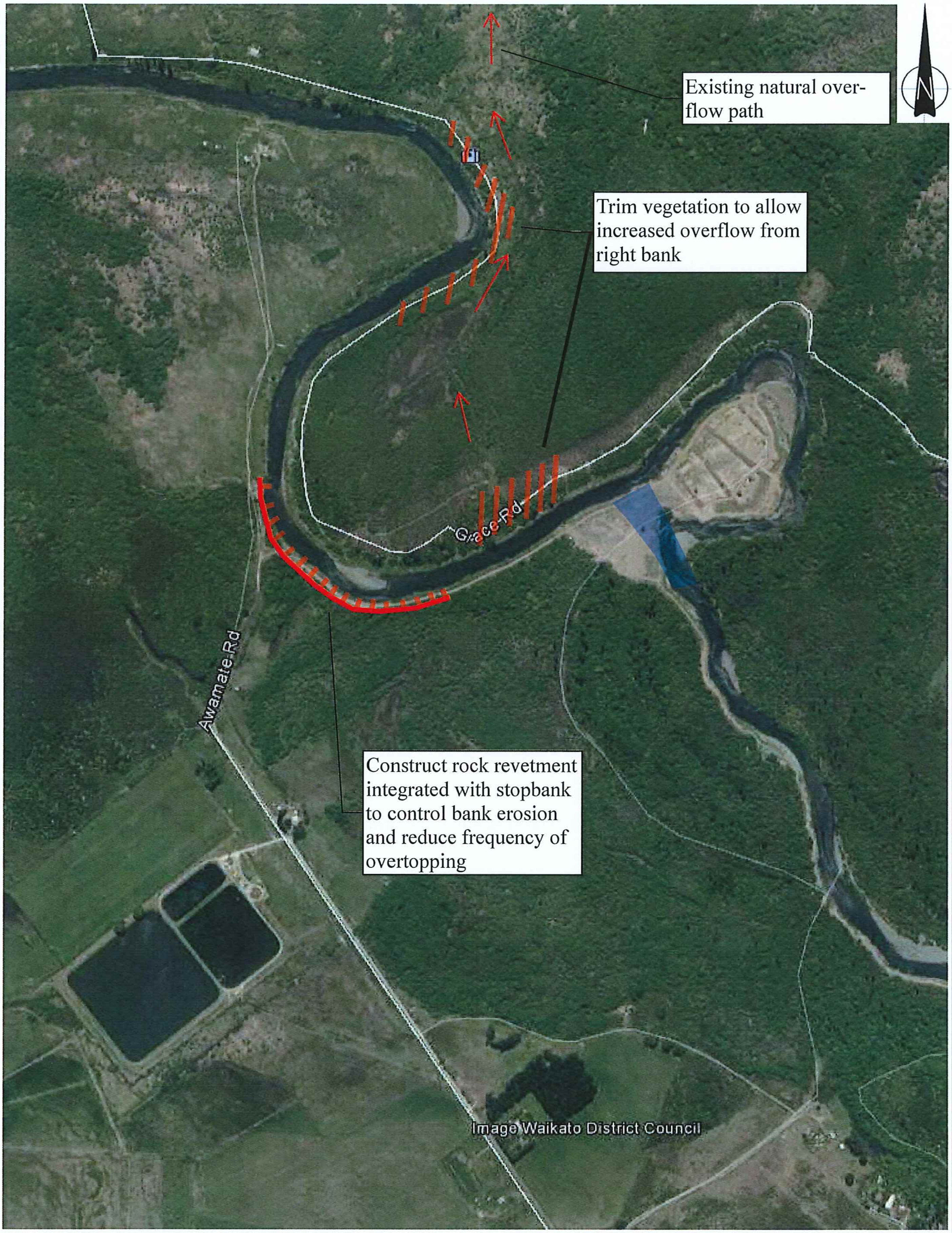
Capital costs for design, consenting, and construction of the revetment and stopbank. Estimate $3.5 to $6.5M.

A modest increase in ongoing river management and maintenance to allow for maintaining the revetment and stopbank. Estimate $ 20,000/annum increase.

4.4 Option 4 – Option 3 works plus encourage overflow to the north

Description

Construct the rock revetment and associated stopbank as described in Option 3 together with vegetation clearance and minor works to encourage overflow from the right bank to the north. The river is actively overflowing the right bank at these points already and the modelling work completed by G Smart in 2011 indicates that the overflow flow path from these areas to the North is the next most active after the Hirangi Arm and Downs Pool overflows. These works are designed to encourage the river to overflow more to the north, and less to the west. Refer to Figure 4-3.



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RIVER MANAGEMENT OPTIONS
OPTION 4 CONCEPT - REVETMENT AND STOPBANK AT DOWNS POOL PLUS MINOR WORKS ON RIGHT BANK

FIG. No. Figure 4-3

REV. 0

Consequences

- Increased overflows to the north will reduce the flow rate and hence water level at Downs Pool.
- Reduced frequency of overtopping the left bank at Downs Pool.
- Control of left bank erosion at Downs Pool
- Increased volume and frequency of overtopping at the existing right bank overflow points upstream and possibly downstream of Downs Pool with consequential effect on the land in this area.
- This option does not address the flows that enter the Hirangi Arm during flood events, so there is a risk that the rock revetment and stopbank will get outflanked. The downstream end of the Hirangi Arm bypasses the proposed works. However, with the ongoing river management works filling in the entrances at the upstream end of the Hirangi Arm, and the degradation of the section of river upstream of De Latours pool, it is likely that there will be comparatively less flow in the Hirangi Arm in flood events than there was prior to the De Latours short-cut. The flows in the Hirangi Arm during flood events should be monitored, together with monitoring of the headward erosion of Deep Creek.
- Increased potential for the river to change course to the North during a major flood event. This would steepen the river gradient and likely result in degradation upstream that could potentially affect bank stability.
- Environmental impact of construction works in the river and its flood plain, which may be more for this option as a rock revetment needs to be constructed in the river.
- Ongoing aggradation at Downs Pool that would eventually increase the overflows to the North and reduce the effectiveness of the Downs Pool left bank assets.

Costs (initial and ongoing)

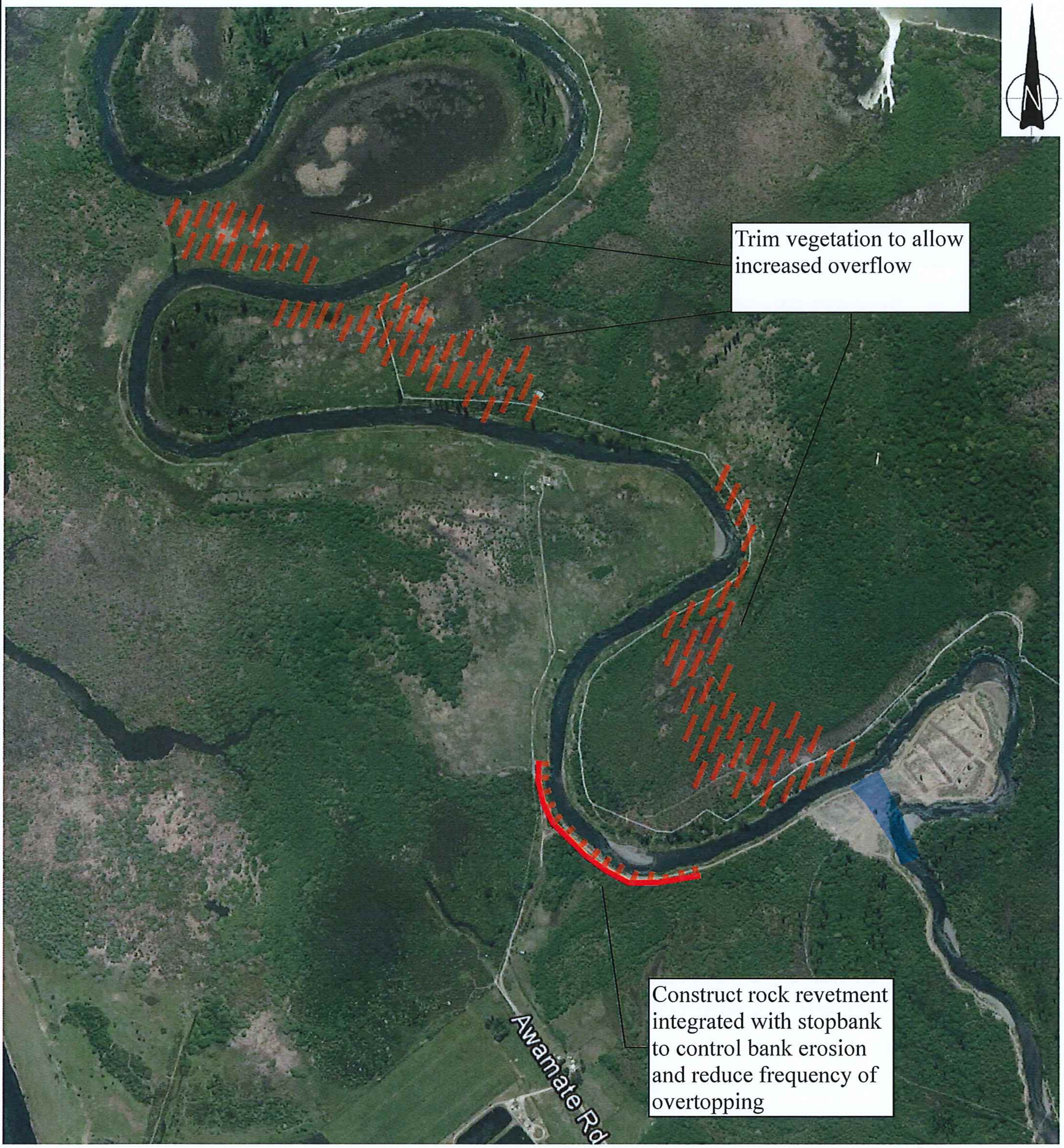
Capital costs for design, consenting, and construction of the revetment and stopbank and vegetation clearance. Estimate \$3.6M to \$6.7M.

A modest increase in ongoing river management and maintenance to allow for maintaining the revetment and stopbank and cleared vegetation areas. Estimate \$ 25,000/annum increase.

4.5 Option 5 – Option 4 works plus further vegetation clearance to encourage overflow to the north

Description

Construct the rock revetment and associated stopbank as described in Option 3 together with more extensive vegetation clearance and minor works to encourage overflow from the right bank to the north thereby reducing flows at Downs Pool. Also provide similar clearance at the two meanders further downstream to encourage overflow at these points. The river is actively overflowing the right bank immediately downstream of the De Latours short-cut already and the modelling work completed by G Smart in 2011 indicates that the overflow flow path from this point to the north is the next most active after the Hirangi Arm and Downs Pool overflows. These works are designed to encourage the river to overflow more to the north, and less to the west. Refer to Figure 4-4.



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LOWER TONGARIRO RIVER
RIVER MANAGEMENT OPTIONS
OPTION 5 CONCEPT - REVETMENT AND STOPBANK AT DOWNS POOL PLUS MORE EXTENSIVE VEGETATION CLEARANCE

FIG. No. Figure 4-4

REV. 0

Consequences

- Increased volume and frequency of overtopping at the existing right bank overflow points upstream and possibly downstream of Downs Pool with consequential effect on the land in this area. With more extensive vegetation clearance than Option 3, more rapid bank erosion may be expected with potential for the river to eventually short-cut Downs Pool.
- Increased overflows to the north will reduce the flow rate and hence water level at Downs Pool.
- Reduced frequency of overtopping the left bank at Downs Pool.
- This option does not address the flows that enter the Hirangi Arm during flood events, so there is a risk that the rock revetment and stopbank will get outflanked. The downstream end of the Hirangi Arm bypasses the proposed works. However, with the ongoing river management works filling in the entrances at the upstream end of the Hirangi Arm, and the degradation of the section of river upstream of De Latours pool, it is likely that there will be comparatively less flow in the Hirangi Arm in flood events than there was prior to the De Latours short-cut. The flows in the Hirangi Arm during flood events should be monitored, together with monitoring of the headward erosion of Deep Creek.
- Control of left bank erosion at Downs Pool
- Increased potential for the river to change course to the North during a major flood event. This would steepen the river gradient and likely result in degradation upstream that could potentially affect bank stability.
- Environmental impact of construction works in the river and its flood plain, which may be more for this option as a rock revetment needs to be constructed in the river.
- Ongoing aggradation at Downs Pool that would eventually increase the overflows to the North and reduce the effectiveness of the Downs Pool left bank assets.

Costs (initial and ongoing)

Capital costs for design, consenting, and construction of the revetment and stopbank and vegetation clearance. Estimate $4.1M to $7.7M.

A modest increase in ongoing river management and maintenance to allow for maintaining the revetment and stopbank and cleared vegetation areas. Estimate $ 30,000/annum increase.

4.6 Option 6 – Off-set stopbank at Downs Pool with vegetation clearance to encourage overflow to the north

Description

Construct the off-set stopbank as described in Option 2 together with the extensive vegetation clearance described in Option 5. This option is a lower cost version of Option 5 (as it does not include the rock revetment). These works are designed to encourage the river to overflow more to the north, and less to the west. Refer to Figure 4-5 (red stopbank).

Consequences

- Increased volume and frequency of overtopping at the existing right bank overflow points upstream and possibly downstream of Downs Pool with consequential effect on the land in this area. With more extensive vegetation clearance than Option 3, more rapid bank erosion may be expected with potential for the river to eventually short-cut Downs Pool.

- Increased overflows to the north will reduce the flow rate and hence water level at Downs Pool.
- Reduced frequency of overtopping the left bank at Downs Pool.
- This option does not address the flows that enter the Hirangi Arm during flood events, so there is a risk that the rock revetment and stopbank will get outflanked. The downstream end of the Hirangi Arm bypasses the proposed works. However, with the ongoing river management works filling in the entrances at the upstream end of the Hirangi Arm, and the degradation of the section of river upstream of De Latours pool, it is likely that there will be comparatively less flow in the Hirangi Arm in flood events than there was prior to the De Latours short-cut. The flows in the Hirangi Arm during flood events should be monitored, together with monitoring of the headward erosion of Deep Creek.
- Continued erosion of the left bank at Downs Pool. This erosion may eventually undermine the offset stopbank unless the river short-cuts Downs Pool.
- Increased potential for the river to change course to the North during a major flood event. This would steepen the river gradient and likely result in degradation upstream that could potentially affect bank stability.
- Environmental impact of construction works in the river and its flood plain.
- Ongoing aggradation at Downs Pool that would eventually increase the overflows to the North and reduce the effectiveness of the Downs Pool left bank assets.

Costs (initial and ongoing)

Capital costs for design, consenting, and construction of the revetment and stopbank and vegetation clearance. Estimate $1.2M to $2.2M.

A modest increase in ongoing river management and maintenance to allow for maintaining the stopbank and cleared vegetation areas. Estimate $ 30,000/annum increase.

4.7 Option 7 – Extend the Awamate Rd stopbank to downstream end of Downs Pool with vegetation clearance to encourage overflow to the north

Description

Construct a new section of stopbank from the end of the existing Awamate Rd stopbank to the higher ground at the downstream end of Downs Pool. Refer to Figure 4-5 (yellow stopbank).

This stopbank could potentially be along the alignment of the paper road, with the road placed on the crest thereby improving access to the land northwest of Downs Pool during flood events. The existing culverts under the existing access track would probably need to be upgraded to allow water flowing down the Hirangi Arm to drain. However these culverts would be sized to limit the peak flow into Deep Creek thereby reducing the risk of ongoing headward erosion. An alternative stopbank alignment further to the west would require less fill volume but would be located on private property. During a flood event, this stopbank could impound a significant volume of water. To alleviate the risk posed by this stored water, design of this stopbank should include a defined spillway to allow greater than design events to overflow west without compromising the stopbank integrity.

The alternative stopbank alignment has the advantage of controlling peak flows from the Hirangi Arm by forcing flows in excess of the culvert capacity back into the river at Downs Pool. Hydraulic modelling would be required to confirm the effectiveness, effects and stopbank levels (necessary for all options).

The extensive vegetation clearance described in Option 5 is included in this option. This option is a variation of Option 6 with a different stopbank alignment. The option 7 stopbank alignment better integrates with the existing flood protection scheme and provides management of flood flows down the Hirangi Arm. These works are designed to encourage the river to overflow more to the north, and less to the west.

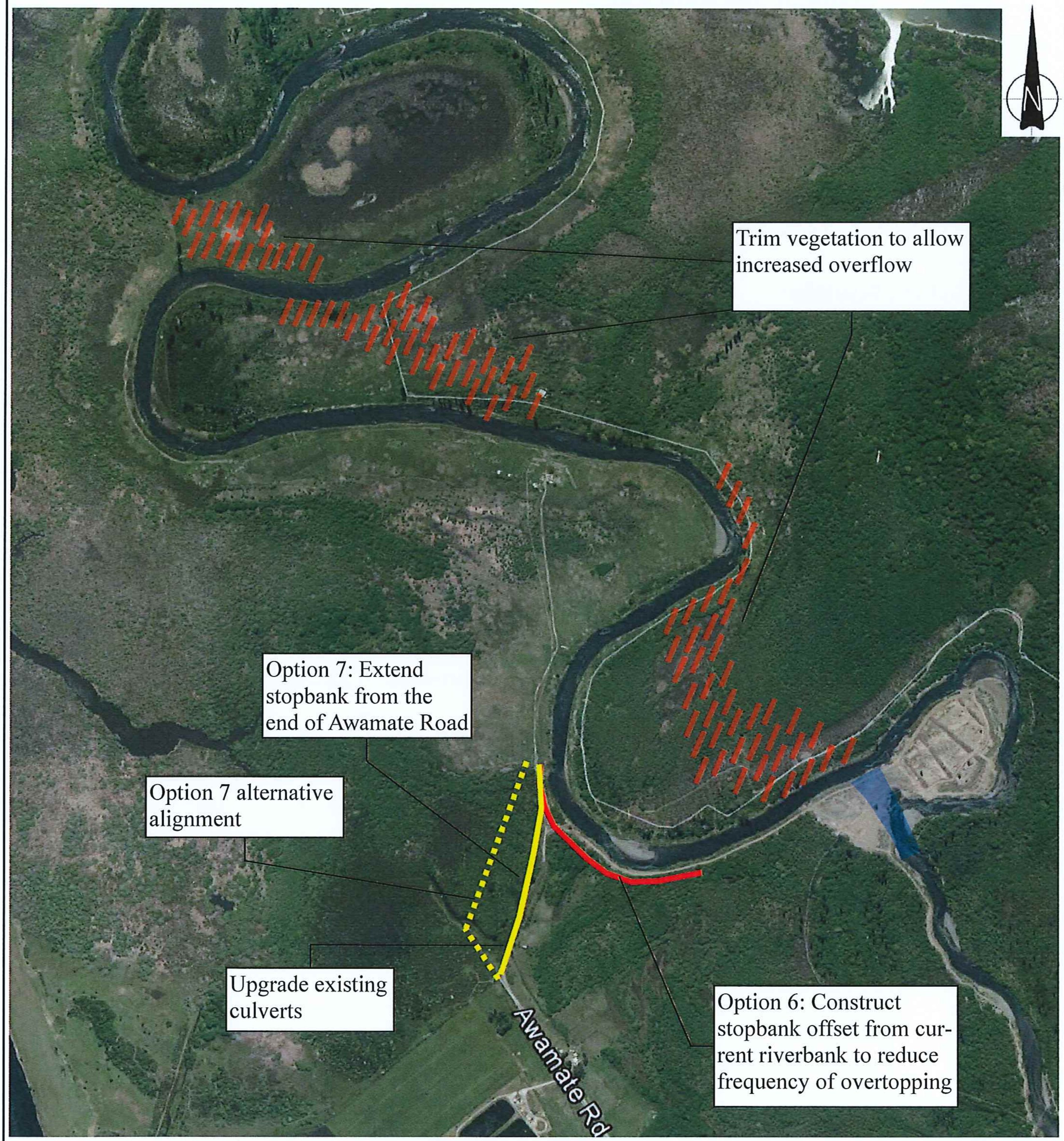
Consequences

- Increased volume and frequency of overtopping at the existing right bank overflow points upstream and possibly downstream of Downs Pool with consequential effect on the land in this area. With more extensive vegetation clearance than Option 3, more rapid bank erosion may be expected with potential for the river to eventually short-cut Downs Pool.
- Increased overflows to the north will reduce the flow rate and hence water level at Downs Pool.
- Reduced frequency of overtopping the left bank at Downs Pool.
- This is the only option that provides some control over the flows that enter the Hirangi Arm during flood events. With the ongoing river management works filling in the entrances at the upstream end of the Hirangi Arm, and the degradation of the section of river upstream of De Latours pool, it is likely that there will be comparatively less flow in the Hirangi Arm in flood events than there was prior to the De Latours short-cut. The flows in the Hirangi Arm during flood events should be monitored.
- Continued erosion of the left bank at Downs Pool.
- Increased potential for the river to change course to the North during a major flood event. This would steepen the river gradient and likely result in degradation upstream that could potentially affect bank stability.
- Environmental impact of construction works in the river and its flood plain.
- Ongoing aggradation at Downs Pool that would eventually increase the overflows to the North and reduce the effectiveness of the Downs Pool left bank assets.

Costs (initial and ongoing)

Capital costs for design, consenting, and construction of the revetment and stopbank and vegetation clearance. Estimate $1.5M to 2.8M.

A modest increase in ongoing river management and maintenance to allow for maintaining the revetment and stopbank and cleared vegetation areas. Estimate $ 30,000/annum increase.



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LOWER TONGARIRO RIVER
RIVER MANAGEMENT OPTIONS
OPTION 6 + 7 CONCEPTS - STOPBANK OPTIONS PLUS MORE EXTENSIVE VEGETATION CLEARANCE

FIG. No. Figure 4-5

REV. 0

5 Summary and conclusions

It is clear that with the current level of river management of the Lower Tongariro, the river will at some time in the not too distant future, break out of its existing channel at Downs Pool (or possibly through the Hirangi Arm) and follow Deep Creek to Lake Taupo.

Six options for some level of intervention works have been presented that are all aimed at reducing the risk of the break-out at Downs Pool. These options are summarised in Table 5-1 below.

Table 5-1 Intervention Options Summary

Option	Description	Key risks	Capital cost $ million	Operational cost $ 000 /annum)
1	Status quo – ongoing river management	River may break out to Deep Creek in next major flood	0	120
2	Off-set stopbank at Downs Pool	Ongoing erosion of left bank will eventually undermine the stopbank Ongoing aggradation will reduce capacity of stopbank No control of Hirangi Arm overflows	0.5 - 1	140
3	Stopbank and rock revetment at Downs Pool	Ongoing aggradation will reduce capacity of stopbank No control of Hirangi Arm overflows	3.5 – 6.5	140
4	Stopbank and rock revetment at Downs Pool Limited vegetation clearance on right bank	Ongoing aggradation will reduce capacity of stopbank No control of Hirangi Arm overflows Small increase in potential for overflow and break out to the North	3.6 – 6.7	145
5	Stopbank and rock revetment at Downs Pool More extensive vegetation clearance on right bank	Ongoing aggradation will reduce capacity of stopbank No control of Hirangi Arm overflows Increased potential for overflow and break out to the North	4.1 – 7.7	150
6	Off-set stopbank at Downs Pool More extensive vegetation clearance on right bank	Ongoing erosion of left bank will eventually undermine the stopbank Ongoing aggradation will reduce capacity of stopbank	1.2 – 2.2	150

		No control of Hirangi Arm overflows Increased potential for overflow and break out to the North		
7	Extension of Awamate Rd stopbank past Downs Pool More extensive vegetation clearance on right bank	Ongoing erosion of left bank may eventually affect downstream end of this stopbank Ongoing aggradation will reduce capacity of stopbank Increased potential for overflow and break out to the North	1.5 – 2.8	150

Apart from Option 7, these options do not address the risk of breakout via the Hirangi Arm as it is assumed that the combination of river management works targeted to reduce inflows at the upstream end of the Arm combined with the degradation of the section of river upstream of De Latours pool, the flows in the Arm are likely to be less than experienced prior to 2013. However this assumption needs to be verified, and the flows in the Hirangi Arm during flood events monitored. Option 7 (extending the Awamate Rd stopbank to downstream of Downs Pool) will provide some control over flows through the Hirangi Arm and reduce the risk of headward erosion of Deep Creek associated with these flows.

The options presented involve a range of increased levels of cost and ongoing maintenance commitment with a various reductions in the risk of break-out. Options 4, 5, 6 and 7 include some vegetation removal that is expected to increase the risk of the river breaking out of the right bank and through an existing overland flow path to the North. If the river did break-out to the North, it is expected to greatly reduce the risk of breakout to Deep Creek.

None of these options will completely eliminate the risk of break-out to Deep Creek.

6 Recommendations

In order to reduce the risk of break-out to Deep Creek, the following steps are recommended:

1. Continue the ongoing monitoring including inspections after freshes and floods.
2. Consult the Tongariro River Forum and Catchment Committee and wider community with the options presented in this report and decide on a preferred option(s).
3. Develop equitable funding arrangements for the works.
4. Complete a survey of the bed and banks downstream of Tongariro Lodge. This could either be a repeat cross section survey, or a scan type survey (above and below water LIDAR/ Scanning).
5. Proceed with further investigations and preliminary design of the preferred option. This is likely to include some geotechnical investigation, and updated hydraulic modelling based on the latest survey data.

7 Applicability

This report has been prepared for the exclusive use of our client Waikato Regional Council, with respect to the particular brief given to us and it may not be relied upon in other contexts or for any other purpose, or by any person other than our client, without our prior written agreement.

Tonkin & Taylor Ltd

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Appendix A: Relevant recommendations from T+T 2014

Recommendation 2: *"A complete (comprehensive) cross section survey and new LiDAR survey. This is to gain better understanding of gravel movement since the 2009 cross section survey and its consequence on flood protection freeboard. We re-iterate the importance of regular complete cross section surveys to gain a better understanding of gravel movement. The 2010 Design Waterway Report included the following gravel monitoring recommendation:*

"A monitoring programme is required that will identify changes to bed levels, and assess the consequences of these changes. The recommended monitoring programme consists of:

1. *Bimonthly visual inspections of the river by EW Taupo Zone Manager or delegate,*
2. *Visual inspection of the river immediately following flood events by EW Zone Manager or delegate,*
3. *Regular cross section survey. Given that there is very little hard data to indicate the volume or locations of gravel accumulation, it is recommended that cross sections surveys are completed as follows:*
    - *In 2010 (12 months after the 2009 survey)*
    - *In 2013 or sooner if the 2010 survey indicates significant aggradation over the last 12 months)*
    - *5 yearly thereafter (or sooner if the 2010 and 2013 surveys indicate that aggradation will exceed the trigger levels earlier than 5 years)*
4. *Cross section survey following flood events where it is evident that there has been significant gravel accumulation."*

Recommendation 4: "A more detailed analysis of the effects of the breakout at De Latours bend. This includes:

- *A risk assessment of the implications on the potential breakout through to Deep Creek.*
- *The effects on channel stability (bed and bank erosion) upstream of De Latours bend."*

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