Prepared for
NZ TRANSPORT AGENCY

PSW 198 – SH3 Manawatu Gorge Alternative Route Assessment

Final Report

NOVEMBER 2012

REPORT

MWH
BUILDING A BETTER WORLD

QUALITY STATEMENT

PROJECT MANAGER	**PROJECT TECHNICAL LEAD**
Roger Hulme	Craig Pitchford

PREPARED BY		
Project Team	……………………………………………	……/……/……
CHECKED BY		
Project Review Team		
Craig Pitchford	……………………………………………	……/……/……
REVIEWED BY		
Mike Skelton	……………………………………………	……/……/……
APPROVED FOR ISSUE BY		
Craig Pitchford	……………………………………………	……/……/……

WELLINGTON
Level 1, 123 Taranaki Street, Wellington 6011
PO Box 9624, Te Aro, Wellington 6141
TEL +64 4 381 6700, FAX +64 4 381 6739

Revision Schedule

Rev No	Date	Description	Signature or Typed Name (documentation on file).			
			Prepared by	Checked by	Reviewed by	Approved by
1	31/10/12	Final Draft Report	Project Team	Craig Pitchford	Mike Skelton	Craig Pitchford
2	14/11/12	Final Report November	Project Team	Craig Pitchford	Mike Skelton	Craig Pitchford

Executive Summary

SH3 Manawatu Gorge Risk Assessment

The Manawatu Gorge has a significant risk of closure from large scale slope instability. The geology of the Gorge makes it susceptible to seismic events and natural weathering processes.

Based on the current situation, the likelihood of small scale events in the order of 5000m3 to 20,000m3, resulting in closures of one to two weeks, appear to be every 3 to 5 years. The 2011 review of landsliding in the Manawatu Gorge suggested that larger landslides (~20,000–100,000 m^3) could occur every 5–10 years.

The presence of several un-stabilised landslide scars caused by the 2004 rainstorm compared to conditions prior to that event, especially in the centre of the gorge, suggest that estimate is realistic.

Twenty five potential landslide areas have been identified along SH3 in the gorge.

Areas were mapped and ranked according to their estimated size (area and volume) and potential for future slope failures that could damage or close SH3, especially during heavy rainfall and strong earthquake shaking. The raking scale is as follows:

- R1: 10,000 m3;
- R2: 10,000–25,000 m3;
- R3: 25,000–50,000 m3; and
- R4: >50,000 m3.

Eight (32%) of the potential landslide areas are in the western section of the gorge (Gorge Monument to Bluff 10, RP488/1.05–491/0.10);

Thirteen (52%) are in the central section (Bluff 10 to Barney’s Point, RP491/0.10–2.45); and only

Four (16%) are in the eastern section (Barney’s Point to Upper Gorge Bridge, RP491/2.45–4.10).

The 2004 landslide, overslip 2 in Area 14, is currently believed to present the greatest potential landslide risk to SH3 in the Manawatu Gorge. A large failure similar to the 2011 landslide could occur especially during heavy rainfall or strong earthquake shaking.

A number of additional areas where potential localised rock fall, similar to that which occurred during mid-September 2012, are also identifiable through over steepened batter slopes down to road level and a significant change in grade directly above the carriageway section.

In order to manage the risks identified through the Manawatu Gorge and to more effectively manage the potential of slope failures in the future, the following actions and strategies are recommended for implementation:

(a) Very High Threat (Risk) Areas:

- Preparation of a detailed engineering geological/ geotechnical report, including a slope stability analysis and risk assessment using the NZTA’s Advanced Approach;
- Terrestrial laser scanning (TLS) of the landslide sites;
- Monitor future slope failures (rock falls, debris falls, slides) and performance of existing controls (mesh, catch fence etc.) at each potential landslide area.

(b) High Threat (Risk) Areas:

- Prepare a basic engineering geological on each site and monitor slope behaviour and future slope failures in each potential landslide area.

(c) Moderate Threat (Risk) Areas:

- Standard maintenance measures should apply, including signage, traffic control, clearance of slip debris to reopen the road, with minimal cutting back of the slope, and repairs to underslips and road edge failures;
- Monitor future slope failures and performance of existing controls.

(d) Local rock fall sites (Bluffs and rock slopes):

- Review and repair existing slope controls (mesh, catch fences);
- Monitor future slope failures and condition of existing controls to help mitigate damage or loss as result of errant or isolated rock fall;
- Further assessment of locations and implement additional measures such as catch fences, or additional rock netting to prevent further damage from errant rocks falling directly onto the carriageway structures.

It is also recommended that a number changes will be required to how this corridor is managed particularly methods in managing future landslides to SH3 in the Manawatu Gorge, including the development of an overarching landslide management strategy.

A number of key considerations for this strategy may include;

- An engineering geologist/geotechnical engineer should be part of the emergency response to assess the landslide and decide on actions to reopen the road.
- A geological model of the landslide site should be considered before any earthworks are begun that could adversely affect or further decrease the stability of the slope.
- Monitor active or very high risk landslide areas (decided on a site-by-site basis).
- Review and repair existing slope control measures.
- Site-specific engineering geological and geotechnical assessments of potential landslides sites with very high risk ratings identified in this report.
- Limit earthworks that undercut and oversteepen colluvial and regolith slopes along SH3, and use support measures where possible to stabilise future failures. An engineering geologist or geotechnical engineer should be consulted before earthworks are begun.
- Scaling of loose blocks and additional rock bolting is probably required at some locations considered to be at risk of local rock falls (e.g. Bluffs 9 and 12).

For a comprehensive list please see section 2 of this report.

Route Options Considered

Four new route options including the construction of a new alignment bypassing the gorge (Worley Option C)[1], Tunnelling, Bridging, and the construction of a new green fields realignment located directly to the south of the current Gorge alignment were considered. These are outlined in the table below and are shown in Appendix C, Sheet D010.

Realignment Option	TOTAL $ million	BCR	Landslide	Social	Design and Environmental	Impact of Closure probability	Construction Program
(A) GREENFIELDS Route Length – 5910m 🟩	**309**	1.4	Significantly reduced	Medium Social Impact on industry, and High Aesthetic Impact.	3-5 years' timeframe for compliance	Significantly Reduced	3-4 Years
(B) BRIDGING Route Length – 6670m 🟦	**415**	0.9	Similar or Greater to Current Alignment	Low Impact	3-5 years' timeframe for compliance.	Reduced against total length However risk increased slightly through isolated cut section.	3-5 Years
(C) WORLEY option C Route Length – 10600m 🟧	**120**	1.5	Significantly reduced	Medium Social impact on industry	3-5 years' timeframe for compliance.	Significantly Reduced.	4-7 Years
(D) TUNNEL Route Length – 5380m 🟥	**1,800**	0.2	Significantly reduced	low Impact	3-5 years' timeframe for compliance.	Significantly Reduced	5 -7 years

Based on the information gathered and the level of assessment undertaken for each of the above proposals, each option has a residual risk of further closures and will require extensive further investigation to assess the geotechnical risks, environmental impacts, and design parameters.

Each of the options will still require the need for a safe and viable alternative route for detour traffic in case of future closures through the gorge to provide adequate route security.

All options return a positive BCR at this stage; however it must be noted that only modest figures have been provided for earthworks, geological risk, environmental aspects, the wider economic impact of each option and the need to relocate wind turbines. It is likely that project costs could increase considerably, and that timeframes may also extend depending on initial findings.

Based on the economic assessment and sensitivity analysis provided in Appendix F and the available information assessed in the development of the four key options outlined above, the provision of a new route is not justified and that the current strategy of using the SH3 Manawatu Gorge alignment, in conjunction with the upgrade of the current Saddle Road Route is the best strategy.

---

[1] First identified as Route C by the Ministry of Works 1977, and later updated by Worley 1997.

Alternative Route Upgrades

Funding has been made available for the procurement of short to medium term upgrades over the next three years for the Alternative Road Routes.

In terms of alternative route importance this report focussed principally on the Saddle Road based on the following:

a. The Saddle Road is the major use route for road users when the gorge is closed.

b. Tararua District Council have a documented strategic plan for upgrades to the Pahiatua Track Route and have been working to implement works through their normal roading programme.

c. The Saddle Road has higher accident costs when compared to either Pahiatua Track or SH3 and provides more opportunity to deliver potential improvements.

The Saddle route was separated into five individual sections, named A-E, based on geography and current alignment. It consists of three distinct topographies which include two steeply graded sections separated with a moderately flat graded section across the crest of the range.

The portion being considered for improvement is 8160m in length measured from the start of Realignment section A to the finish of Realignment section E.

To provide an improved level of service in the short to medium term in the event of closures and to derive a programme of works over the next three years cost reduction measures through pavement strengthening and seal widening have been investigated.

These were initially assessed through deriving Net Present Value (NPV), in accordance with the NZTA's Economic Evaluation Manual procedures (EEM).

For NPV analysis sheets please see Appendix G.

The immediate benefits obtained through the delivery of full route seal widening particularly in terms of spreading the axle loads, the improved safety benefits through realigning vehicles away from unconstrained road edges, the decongestion of Heavy vehicles around hair pin bends and the de stressing of road users through providing a wider corridor, are easily achievable through this period.

For the medium to long term (4-6 years), an assessment of the benefits for full geometric realignment through each of the five sections in terms of travel time savings and a reduction in driver stresses. A summary is provided below in the following tables.

OPTION	Property Purchase	MSQA & Construct $(000)	TOTAL $ million	Length (km)	Cost million per km $ million
SADDLE ROAD					
realignment A1	83	2,439	3.08	2.60	1.2
realignment B	1	472	0.57	0.90	0.6
realignment C	1	749	0.90	1.29	0.7
realignment D1	26	1,401	1.73	2.02	0.9
realignment E1	2	923	1.13	0.88	1.3
			7.40	7.69	

OPTION (Gorge is open)	*TTC benefits*	VOC+CO_2 benefits	Accident benefits	Total benefits	Net costs	BCR	Comment
SADDLE ROAD 1	1.0	1.9	1.5	4.4	4.6	1.0	Increasing roughness costs for existing Man. Gorge and Saddle Rd from 5 to 7 IRI
SADDLE ROAD 1	1.0	1.1	1.9	4.0	4.6	0.9	Reducing the accident unit rate by $100,000
SADDLE ROAD 1	1.7	2.1	2.8	6.6	4.6	1.4	Increasing the diversion from Pahiatua Track north from 0% to 20 %
SADDLE ROAD 1	1.3	1.4	2.0	4.6	4.6	1.0	Fast tracking the project timing to 2 + 2 years

The sensitivity testing scenarios outlined above indicate a current BCR range of 0.9 to 1.4. In consideration of these and other factors it is recommended to adopt a BCR for the partial (sections A and E) realignment of Saddle Road of 1.1.

For the medium to long term, collectively the realignments provide a positive return and our initial investigations indicate that more substantial realignment works may be justifiable.

However there are still a number of unknowns which would require substantiation prior to finalising a detailed alignment and approach.

If the option to proceed with realignments was taken now, there would still be a need to update and maintain the alternative route in the short to medium term to remediate any potential impacts of future heavy maintenance in case of slip related closures during this period.

As such it is principally recommended that the NZTA proceed with planned rehabilitation and the full route widening programme to obtain the best short term value.

Prior to committing to pavement construction, a robust assessment should be completed of the subgrade layer and a thorough assessment of quantities be delivered to get some surety around quantities and rates.

A prioritised programme of works is provided below.

Section	Maintenance Improvement Cost $(000)	Priority	Year
Lead in section	$ 485	1	13/14
Section A	$1,485	6	15/16
Section B	$ 435	2	13/14
Section C	$ 620	3	13/14
Section D	$1,020	4	14/15
Section E	$ 435	5	14/15
Total	$4,480		

NZ Transport Agency

PSW 198 Alternative Route Assessment Final Draft Report

CONTENTS

LIST OF TABLES

LIST OF FIGURES

Appendices

1 Introduction

The major slip in the Manawatu Gorge (State Highway 3) which occurred in November 2011 resulted in the closure of SH3 between Ashhurst and Woodville. The extent of the closure negatively impacted on the economic wellbeing of the people and communities not only in the Manawatu, Palmerston North and Tararua regions but also had a much wider impact, given the routes national strategic classification, on the national economy.

Given these impacts, and in line with the New Zealand Transport Agencies (NZTA) customer first initiative, further work was required to quantify the risks and scale of risks in the Gorge and development of a management plan for minimising the impact of such events in the future.

The objective of this report is to address the development of such a management plan, in line with the recommendations as outlined in the 2012 project feasibility report[2].

To achieve this, the report details the following;

- The completion of a risk assessment on the probability and potential magnitude of future slips that might block SH3 within the Gorge, including identification and ranking of those slip sites and the development of a high level strategy to manage the identified risks.
- Undertake a review of the New Zealand Transport Agency's current strategy to confirm the most viable route for SH3 between Palmerston North and Woodville, in terms of its economic benefits compared to the alternative or new routes.
- The identification of possible upgrades to the alternative routes to the Manawatu Gorge, principally the Saddle Road Route, to provide an improved level of service (nearer state highway standards) during the times that the Gorge is closed, particularly during long-term closures; and
- Undertake the economic analysis (Strategic Fit, Effectiveness and Efficiency) for proposed construction works and the development of a programme for commissioning improvements over the next three year funding block.

1.1 Consultation / Liaison with LA's

The Key parties which have been consulted as part of this scheme particularly in reference to the upgrading of Saddle Road are Tararua District Council (TDC), Manawatu District Council (MDC), Palmerston North City Council (PNCC), MWH (Network Team), NZTA, Heavy Haulage.

Throughout the review process all those consulted provided very positive feedback which has been used to help assess the viability and priority of upgrades proposed as part of this scheme.

MDC have been in discussion with both the NZTA and with TDC throughout the development of this scheme and are satisfied with the approach to date, provided the treatments selected are consistent along the route length.

Significant consultation has been had with TDC over the current upgrades proposed through the Saddle Road corridor. This was critical as it has also been important to assess the value of any improvements when the diversion is NOT in use.

---

[2] NZTA Project Feasibility Study for Business Continuity and Route Security for the National Strategic Route SH3 Manawatu Gorge, MWH 2012

One of the major concerns highlighted by both TDC and PNCC was to ensure that a robust collaborative, incident response plan is put in place to help the delivery and management of future events in the case of a detour.

Much of this work has already been completed however more work will be required to help develop this plan and an appropriate programme of works particularly through Ashhurst given the impact of the increased traffic volumes through this urban environment.

Once the preferred options for each section have been agreed. Additional assessment and discussion will be required with all Territorial Authorities, to define the Level of Service (LOS) and if an increase in maintenance is required for some areas i.e drainage maintenance and vegetation removal and possible contributions to meet the proposed increases as required.

Future consultation will also be required with all relevant Local Authorities and Regional Councils to finalise any consenting activities for the proposed upgrades, to continually assess the performance of the route diversion protocol and management procedures and to assess future LOS and maintenance activates over the Saddle Road route once the upgrades have commenced.

1.2 Description of Problem

The Manawatu Gorge has a significant risk of closure from large scale slope instability. The geology of the Gorge makes it susceptible to seismic events and natural weathering processes. Although sections at risk of significant instability can be identified and monitored, small scale events can be mitigated with rock netting, retaining walls and small scale slope stabilisation techniques, the prevention of large scale events such as in 2004 and 2011 is not considered viable.

Based on the current situation, the likelihood of small scale events in the order of 5 - 20,000m^3, resulting in closures of one to two weeks, appear to be every three to five years.

Analysis suggests that the larger scale events 20 - 100,000m^3 could occur as frequently as every five years. These events result in longer closures of 60 to 70+ days.

There were also gaps in knowledge regarding the historical mechanics of landslides and the link between the current maintenance and management strategy and the scaled progression of small isolated movement towards large scale slips through this route. Aggregating recent experience and documented information from historical events, an attempt has been made to close this knowledge gap.

The development and implementation of improved management procedures is a key future outcome. This includes the improvement of maintenance and intervention strategies at an operational level to help manage the impact of large scale future landslides in the gorge.

During times of Gorge closure, traffic uses one of two local road alternate routes. Namely Saddle Road to the North of SH3 and Pahiatua Track located to the South of SH3. Approximately 60% of diverted traffic uses the Saddle Road route, with the remaining 40% traveling via the Pahiatua Track Road.

The LOS provided by these local roads is not in context for highway users in that they are very narrow, have little delineation, poor geometry, restricted visibility and are not built for high traffic volumes. This results in significant unplanned repair costs, reduced route availability / security, increased stress on road users and safety issues, at the times when being used for diverted State Highway traffic.

1.3 Site Description

1.3.1 SH3 Manawatu Gorge Route Description

The Manawatu Gorge contains major road and rail links between the west and east coasts of the southern North Island. Excavations for the establishment and widening of SH3 on the south side of the gorge have cut back and over steepened the toes of slopes, contributing towards rock falls and landslides that have affected or closed the road in many places since it was first completed in 1872.

Since the Gorge Road was widened in the 1940s, 1960s, 1970s and 1980s it has been closed by slips, especially following heavy rainfall. Most of these failures can be correlated to the road-widening works completed during these periods.

The route has a typical carriageway width of 7.0m with two 3.5m lanes and no shoulder. This combined with the poor curve geometry provides for vehicle speeds between 50km/hr to 70km/hr for small vehicles.

The winding 8km long section along the Manawatu River allows no overtaking, with double yellow lines installed in 2003 as a result of a joint NZTA / police survey which identified a large number of vehicles crossed the road centreline increasing the risk of head on crashes.

The grade is flat making it the preferred route for heavy commercial vehicles (HCV). The current traffic volume is 6868 vehicles per day with 12% of these classed as HCVs.

No over-weight or over-dimension loads are permitted to travel through the gorge and the route is not suitable for High Performance Motor Vehicles (HPMV) due to under strength bridges, restricted width and the horizontal geometry requiring large vehicles to track across the centreline.

During times of closure, the Manawatu Gorge has two alternate local road routes that are used to divert traffic.

Route descriptions are detailed in the following sections.

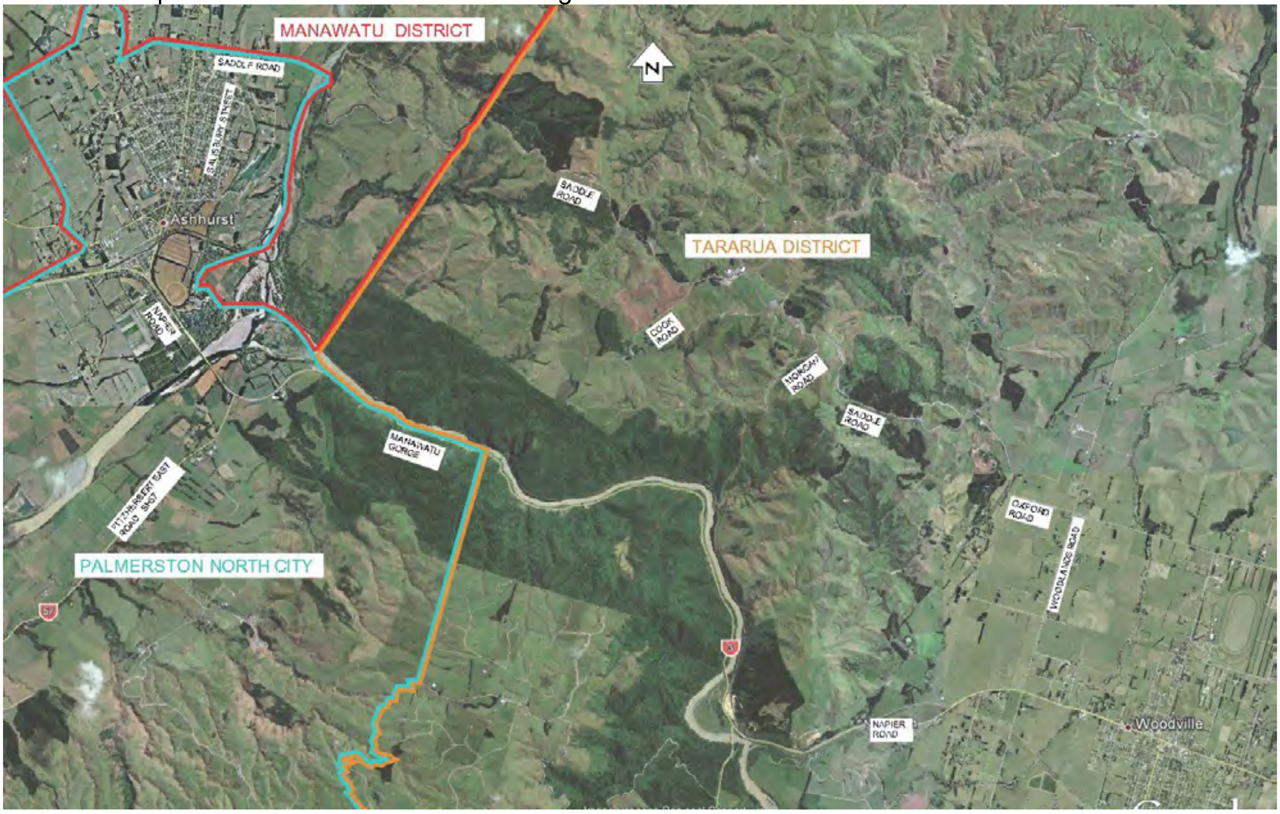


Figure 1-1 : Territorial Authority Boundaries.

(For a larger scale see Appendix A, Sheet D019)

1.3.2 Saddle Road Route Description

The Saddle Road route is the principal bypass for SH3 traffic during closure of the Manawatu Gorge taking 60% of the flow, swelling the traffic on the route from its usual 313 vehicles per day to over 4000 vehicles per day.

The Saddle Road Route currently runs through the boundaries of three Territorial Local Authorities (TLA's).

PNCC has ownership through Ashhurst terminating just east of the recently reconstructed Pohangina Bridge, MDC has accountability for the route from the bridge through to approximately 700m east of Cook Road and TDC has responsibility for the remainder of the detour route terminating at the intersection of Woodlands Road and SH3.

The diversion route commences under PNCC control and takes the detoured Gorge traffic through the urban 50km/hr area of Ashhurst, leading northeast from SH3 onto Cambridge Road, through to Mulgrave Street, onto Salisbury Street before entering the Saddle Road and Pohangina Bridge.

The route then runs through the short MDC section, climbing the Ruahine Ranges with grades as high as 10% through to approximately 700m east of Cook Road.

The remainder of the route falls under the control of TDC, where vehicles continue eastbound with grades in excess of 13% in places, through to Oxford Road, Woodlands Road and then rejoins SH3.

The total diversion route length, commencing at Cambridge Street running through to the intersection of Woodlands Road and SH3 is 16kms with a total estimated travel time of 25 minutes.

The steep grades combined with the tight horizontal geometry force trucks to travel at very low speeds, as a consequence vehicles spend approximately 54% of time in platoons.[3]

The route is also a popular recreational cycle route. However whilst the Gorge is closed, cyclists have been warned to avoid the route due to increased traffic volume and safety concerns.

The Saddle Road has been identified as a potential HPMV route for providing access through the Manawatu region from Hawkes Bay. At present it is unlikely that any planned upgrade based on HPMV access alone will be completed within the next three years however consideration of localised widening and strategic realignment will help significantly improve HPMV access to the Manawatu region from the East Coast.

1.3.3 Pahiatua Track Route Description

This route is located to the south of SH3 and the Manawatu Gorge and during closure takes approximately 40% of the State Highway traffic. The route climbs the Tararua Ranges, has steep grades and tight geometry, particularly through the western section.

The Pahiatua Track route runs through the boundaries of two TLA's.

PNCC has ownership from (SH57) Aokautere, terminating at the intersection of North Range Road, TDC then maintains the remainder of the route heading North East up Ballance Road, through the Gorge Road to Woodville or continuing along Makomako Road towards Pahiatua and SH2.

The diversion route commences under PNCC control, leading southeast from Fitzherbert East road and then continuing along Pahiatua Aokautere Road, to its intersection with North Range Road.

The route then switches to TDC control, continuing along Pahiatua Aokautere Road to its intersection with Ballance Valley Road where vehicles may choose to either continue North East towards SH3 and Woodville or South East towards Pahiatua and SH2.

For SH3 traffic, this provides for a total diversion route length commencing at Fitzherbert East Road, running through to Ballance Valley Road and the intersection of Woodlands Road and SH3 of 50.1 kms, with a total estimated travel time of 36 minutes.

---

[3] Transit New Zealand Saddle Road Ashhurst to Woodville Investigation Report, 1998

This is not considered the best strategic alternative route for traffic traveling west due to the additional detour distance when compared to the Saddle Road route. It is however preferred for Palmerston North traffic and southbound traffic on SH2 but is not as well known for most traffic

As with the Saddle Road route, this is an important route in providing safe and reliable access for the majority of commuters in the event of potential closures of the gorge but also during periods of normal operation.

TDC have developed a strategic plan, as outlined in the Pahiatua Track Route study,[4] and are implementing aspects as funding becomes available.

Significant investigation work has already been completed for future development of the Pahiatua Track route by TDC. This includes three local significant projects for future development.

- Beeches culvert realignment.
- Burney's Hill 35k curve on steep grade.
- Realignment at the bottom of the Pahiatua Track Rd and Balance Rd Intersection.

PNCC has also progressed a number of upgrade schemes through the Pahiatua Track route to improve safety and has identified a hairpin bend which is currently under consideration for upgrade.

1.4 Crash Rates

A review of crashes in the ten years prior to the September 2011 to August 2012 closure of the Manawatu Gorge from the NZTA's Crash Analysis System (CAS) is discussed below:

Most severe crashes from 1 July 2007 to 30 June 2011 resulted in only one DSI (Death or Seriously Injured) casualty.

There were two people seriously injured in the crash at the SH3/57 intersection and also for one of the serious injury crashes along Pahiatua Aokautere Road.

For the same five year period, the greatest number of multiple severe injuries occurred on crashes along Mako Mako Road, with one death and ten seriously injured in the four severe crashes.

From the SH57 intersection to Woodlands Road, for the latest five year period there were 1 fatal, 8 serious, 18 minor and 46 non-injury crashes along this 10.4 km of SH3 through the Manawatu Gorge. Applying an average of 6800 vehicles per day (vpd) results in a reported 10.7 injury crashes per 100 million vehicle kilometres; the severe crash rate is one third of this or 3.6 fatal or serious injury crashes per 100 million vehicle kilometres. These crash rates are comparatively low for a rural two lane highway.

From the outskirts of Ashhurst to its intersection with Woodlands Road and Oxford Street, along the approximately 10.9 km length of Saddle Road (including 0.65 km of Oxford Road) in the past ten years there were nil fatal, 2 serious, 5 minor and 11 non-injury crashes reported.

Adopting an average 140 vehicles per day, results in a reported 126 injury crashes per 100 million vehicle kilometres; the severe crash rate is 36 fatal or serious injury crashes per 100 million vehicle kilometres. These crash rates are high.

By comparison assuming an average of 250 vpd, the injury crash rate for the 1.8 km section of Woodlands Road between Oxford Rd and SH3 is approximately 60 injury crashes per 100 million vehicle kilometres, but this is based on only one (serious) injury crash in ten years.

A factor of 0.60 was applied to the accident data, which resulted in the Saddle Road accidents being 25% of the directly proportionate accident costs; the respective values for the Pahiatua northern and eastern routes were 41% and 60%.

The current annual cost of crashes for each route was derived and divided by the annual vehicle kilometres of travel to get the normalised crash cost. For the existing routes these were (per million veh-km):

---

[4] Pahiatua Track Route Study MWH 2008

Manawatu Gorge	
• SH3 route: west end	$ 70,900
• SH3 route: gorge	$ 187,300
• SH3 route: east end	$ 141,800
Saddle Road	
• Saddle Road west end	$3,361,700
• Saddle Road hilly portion	$1,365,600
• Oxford Rd & Woodlands Rd	$1,660,600
Pahiatua Track	
• Pahiatua Track north route	$ 644,800
• Pahiatua Track east route	$ 383,400

Closure of the gorge results in a substantial increase in traffic, amounting to an increase in typical flows over Saddle Road of more than 30 times the base flow.

The outcome of our assessment was that for the closure of the gorge without any upgrade options, the accident disbenefits from traffic being detoured to less safe existing routes were more than 25% of the total disbenefits.

This provides support that the SH3 Gorge route is the safest, followed by the Pahiatua Track route(s) and the Saddle Road route.

This also indicates that greater safety benefits should be obtained through targeted safety upgrades to the Saddle Road particularly through the western and eastern sections of the route given that these have the highest personal crash costs.

The options considered have therefore also included larger scale realignments to assess the potential benefits across the entire Saddle Route, with this in mind.

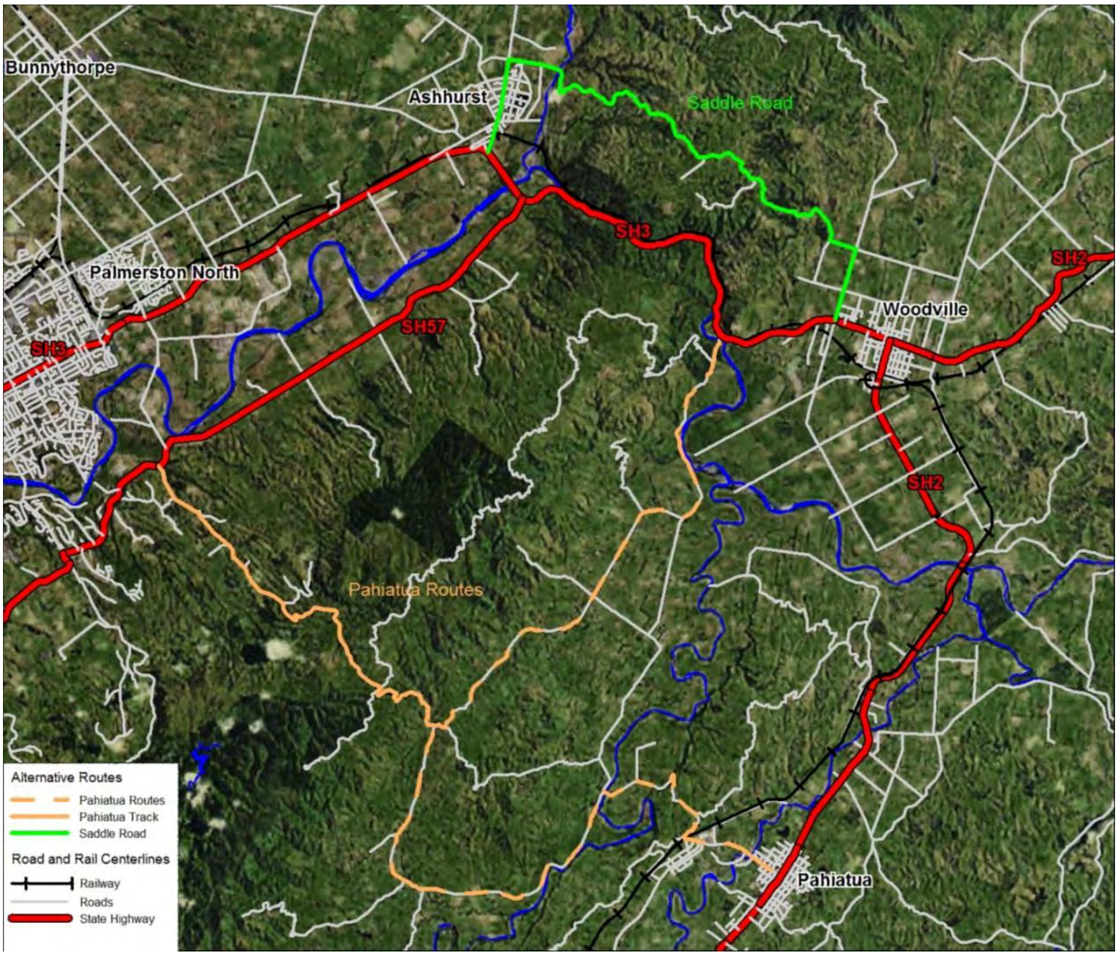


Figure 1-2 : Site map

(For a larger scale see Appendix A)

1.5 Conclusions

In terms of alternative route importance this report focussed principally on Saddle Road based on the following:

- The Saddle Road is the major use route for road users when the gorge is closed.
- TDC have a documented strategic plan for upgrades to the Pahiatua Track Route and have been working to implement works through their normal roading programme.
- The Saddle Road has higher accident costs when compared to either Pahiatua Track, or SH3 and provides more opportunity to deliver potential improvements.

2 Risk Assessment

2.1 Methodology

The assessment of risk from future landslides in the Manawatu Gorge focussed initially on local geology and geomorphology, old (prehistoric) landslides in the area, and information provided by past landslides that significantly affected SH3 in 1995, 1998, 2004, and 2011. The locations and extent of potential landslide areas that could affect SH3 through the gorge were initially identified on oblique and vertical aerial photos with the aid of GIS maps of bedrock, colluvium and prehistoric landslide scars, historical landslide data, and slope angles based on 1m LiDAR contours.

The potential landslide areas identified along SH3 and existing slope controls were later ground-checked and assessed.

Appendix B contains a copy of the GNS Science Consultancy Report 2012/254[5], for supporting details around the Geotechnical and Geological Risk Assessment.

2.2 Site Assessment

Twenty five potential landslide areas have been identified along SH3 in the Gorge based on:

(a) Past landslide history;

(b) Rock types and surficial deposits;

(c) Geomorphic features (prehistoric landslides scarps, bluffs);

(d) Slope angles and heights, and;

(e) Road cuts and slope support measures.

These areas were mapped in GIS and ranked according to their estimated size (area and volume) and potential for future slope failures that could damage or close SH3, especially during heavy rainfall and strong earthquake shaking. The areas have been ranked according to their size and potential to close SH3 as follows:

- R1: 10,000m3;
- R2: 10,000–25,000m3;
- R3: 25,000–50,000m3;
- R4: >50,000m3.

Eight (32%) of the potential landslide areas are in the Western Section of the gorge (Gorge Monument to Bluff 10, RP488/1.05–491/0.10);

Thirteen (52%) are in the Central Section (Bluff 10 to Barney's Point, RP491/0.10–2.45); and

Four (16%) are in the Eastern Section (Barney's Point to Upper Gorge Bridge, RP491/2.45–4.10).

This is similar to the historical distribution of landslides (West - 55 (40%), Centre - 61 (44%), East - 22 (16%).

See Fig 2-1 for the site location plan.

The higher percentage of potential landslide areas in the centre of the gorge is attributed to the number of unstable scars from landslides that occurred during the February 2004 rainstorm.

The risk that the identified landslide areas present to SH3 in the Manawatu Gorge has been assessed using the General Approach outlined in the NZTA's 2004 Risk Assessment Process Manual. This method provides a qualitative technique for analysing landslide risks based on the consideration of

---

[5] Engineering geological assessment of the risk and potential magnitude of future landslides that might close SH3 within the Manawatu Gorge, 11 October 2012.

existing slope controls, and the likelihood and consequences of future slope failures. Three categories of future landslide threat (risk) have been identified in the Manawatu Gorge. The identified sites with assigned risk are tabled below.

Table 2-1: Manawatu Gorge Identified Risk Sites

Area No.	Section of Gorge[4]	Rank[2]	Likelihood Rating	Consequence Rating	Risk Assessment Category[1, 3] (Score)
1	Western	R1	Unlikely (3)	Minor (10)	Moderate Threat (30)
2		R2	Unlikely (3)	Medium (40)	High Threat(120)
3		R2	Unlikely (3)	Medium (40)	High Threat (120)
4		R1	Unlikely (3)	Minor (10)	Moderate Threat (30)
5		R3	Unlikely (3)	Major (70)	VERY HIGH THREAT (210)
6		R3	Unlikely (3)	Major (70)	VERY HIGH THREAT (210)
7		R3	Quite Common (4)	Major (70)	VERY HIGH THREAT (280)
8		R2	Unlikely (3)	Medium (40)	High Threat (120)
9	Central	R2	Unlikely (3)	Medium (40)	High Threat (120)
10		R2	Unlikely (3)	Medium (40)	High Threat (120)
11		R1	Unlikely (3)	Minor (10)	Moderate Threat(30)
12		R3	Unlikely (3)	Major (70)	VERY HIGH THREAT (210)
13		R2	Unlikely (3)	Medium (40)	High Threat (120)
14		R4	Unlikely (3)	Substantial (100)	VERY HIGH THREAT (300)
15		R3	Quite Common (4)	Medium (40)	VERY HIGH THREAT (160)
16		R1	Unusual (2)	Medium (40)	High Threat (80)
17		R2	Unlikely (3)	Medium (40)	High Threat (120)
18		R2	Unlikely (3)	Medium (40)	High Threat (120)
19		R2	Unlikely (3)	Medium (40)	High Threat (120)
20		R2	Unlikely (3)	Medium (40)	High Threat (120)
21		R1	Unlikely (3)	Minor (10)	Moderate Threat (30)
22	Eastern	R1	Unlikely (3)	Minor (10)	Moderate Threat (30)
23		R1	Unlikely (3)	Minor (10)	Moderate Threat (30)
24		R1	Unlikely (3)	Minor (10)	Moderate Threat (30)
25		R1	Unlikely (3)	Minor (10)	Moderate Threat (30)

NOTES:

(1) Risk Assessment carried out according to the procedures of the Risk Management Process Manual, September 2004, Transit New Zealand (NZTA) using the "general approach" (see Appendix B, Appendix 3).

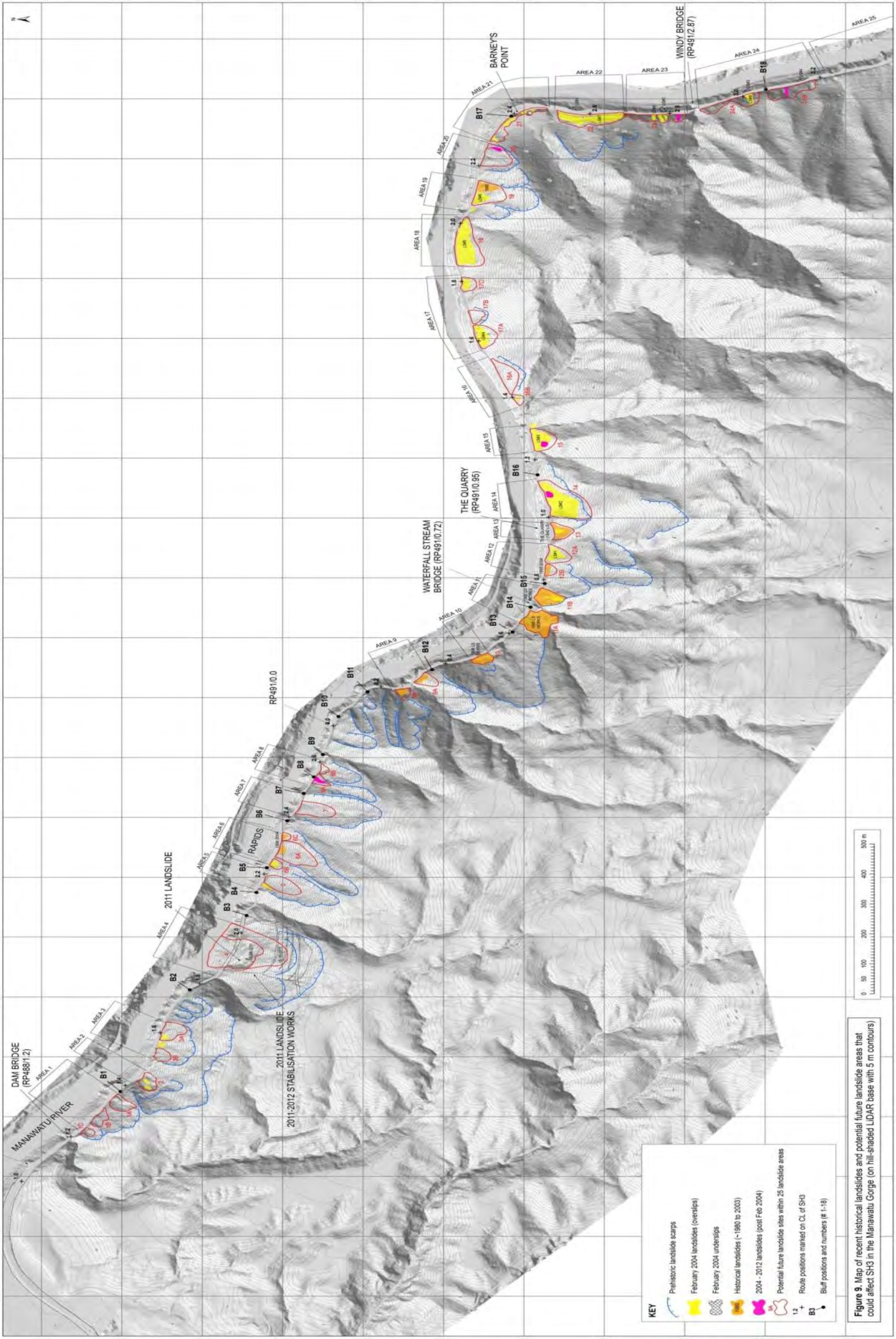


Figure 2-1 : Site Map (Map of recent historical landslides and potential future landslide areas)

The High and Very High Threat (Risk) areas are located in the Western and Central sections of the Gorge and have strong geological and geomorphic similarities to the 2011 landslide area, and have been destabilised to some degree by cutting back the toe of colluvial deposits along SH3, generally without support measures.

Landslides caused by the February 2004 rainstorm had a significant influence on the risk assessments and the larger landslides from the 2004 event, overslips 1 – 5 are the main reason for high risk ratings. The scarps of the 2004 landslide scarps in Areas 12, 14, 15, 17 and 18 are oversteepened and at risk of large regressive failures, especially in Areas 14 and 15 where small failures have already occurred.

The 2004 landslide, overslip 2 in Area 14, is currently believed to present the greatest potential landslide risk to SH3 in the Manawatu Gorge. A large failure similar to the 2011 landslide could occur especially during heavy rainfall or strong earthquake shaking.

The 2011 review of landsliding in the Manawatu Gorge suggested that larger landslides (~20,000–100,000 m^3) could occur every 5–10 years.

The presence of several un-stabilised landslide scars caused by the 2004 rainstorm compared to conditions prior to that event, especially in the centre of the gorge, suggest that estimate is realistic, and is used as the basis for some likelihood ratings (once per 5–10 years) in the landslide risk assessment.

A number of areas where potential localised rock fall, similar to that which occurred during mid-September 2012, are also identifiable through over steepened batter slopes down to road level and a significant change in grade directly above the carriageway section. Due to the change in grade, once errant rocks become loosened and mobilise, these sites provide little natural resistance or protection to the pavement and other structures located within the road corridor and should be considered for further review and the implementation of preventative maintenance measures to catch and / or significantly reduce the impact and velocity of errant rocks through these sections.

2.3 Recommendations

The recommended future actions for better definition and management of at risk potential landslide areas in the three risk categories and local rock fall sites in the gorge include:

(a) Very High Threat (Risk) Areas:

- Preparation of a detailed engineering geological / geotechnical report, including a slope stability analysis and risk assessment using the NZTA's Advanced Approach;
- Terrestrial laser scanning (TLS) of the landslide sites;
- Monitor future slope failures (rock falls, debris falls, slides) and performance of existing controls (mesh, catch fence etc.) at each potential landslide area.

(b) High Threat (Risk) Areas:

- Prepare a basic engineering geological assessment on each site and monitor slope behaviour and future slope failures in each potential landslide area.

(c) Moderate Threat (Risk) Areas:

- Standard maintenance measures should apply, including signage, traffic control, clearance of slip debris to reopen the road, with minimal cutting back of the slope, and repairs to underslips and road edge failures;
- Monitor future slope failures and performance of existing controls.

(d) Local rock fall sites (Bluffs and rock slopes):

- Review and repair existing slope controls (mesh, catch fences);
- Monitor future slope failures and condition of existing controls to help mitigate damage or loss as result of errant of isolated rock fall;
- Further assessment of locations and implement additional measures such as catch fences, or additional rock netting to prevent further damage from errant rocks falling directly onto the carriageway structures.

2.4 Strategy Development

Taking into consideration the results of this study, the recommended methods and strategies that could be used to manage and reduce the consequence of future landslides to SH3 in the Manawatu Gorge are as follows:

- An engineering geologist /geotechnical engineer should be part of the emergency response to assess the landslide and decide on actions to reopen the road.
- A geological model of the landslide site should be considered before any earthworks are begun that could adversely affect or further decrease the stability of the slope.
- Establish an inventory of slope failures in the gorge to provide improved knowledge of the locations, size and events that trigger debris slides and falls, rock falls and falls of individual boulders and effects, and the actions taken to deal with them.
- Monitor active or very high risk landslide areas (decided on a site-by-site basis).
- Review and repair existing slope control measures.
- Site-specific engineering geological and geotechnical assessments of potential landslides sites with very high risk ratings identified in this report.
- Limit earthworks that undercut and oversteepen colluvial and regolith[6] slopes along SH3, and use support measures where possible to stabilise future failures. An engineering geologist or geotechnical engineer should be consulted before earthworks are begun.
- Scaling of loose blocks and additional rock bolting is probably required at some locations considered to be at risk of local rock falls (e.g., Bluffs 9 and 12).
- Prepare an engineering geology / geotechnical completion report on the 2011 landslide area that describes the history, geology and geomorphology of the landslide, the slope stabilisation works, and the stability of the site before and after these measures.
- Detailed documentation and reporting on the engineering, geotechnical, and geological aspects of future large landslides within the Manawatu Gorge is essential to improve the management and minimise the risk that slope failures present to SH3.

---

[6] Regolith - The layer of rock and mineral fragments that rests on bedrock and is produced by the weathering of rocks.

3 Route Options

3.1 Introduction

From time to time, and usually when the SH3 Manawatu Gorge is closed for an extended period of time due to slips, the benefits of a new less at risk route is raised.

In 1977, the Ministry of Works[7], proposed a number of new routes. The economics of the routes was subsequently updated by Worley consultants in 1997[8].

The option of a bridge, located away from the bank has been promulgated through the Gorge as another potential way to reduce the risk of closure due to slips.

To these options, a tunnel and a shortest length route over the ranges to the south of the existing route have been added. These are collectively shown on fig 3-1 below.

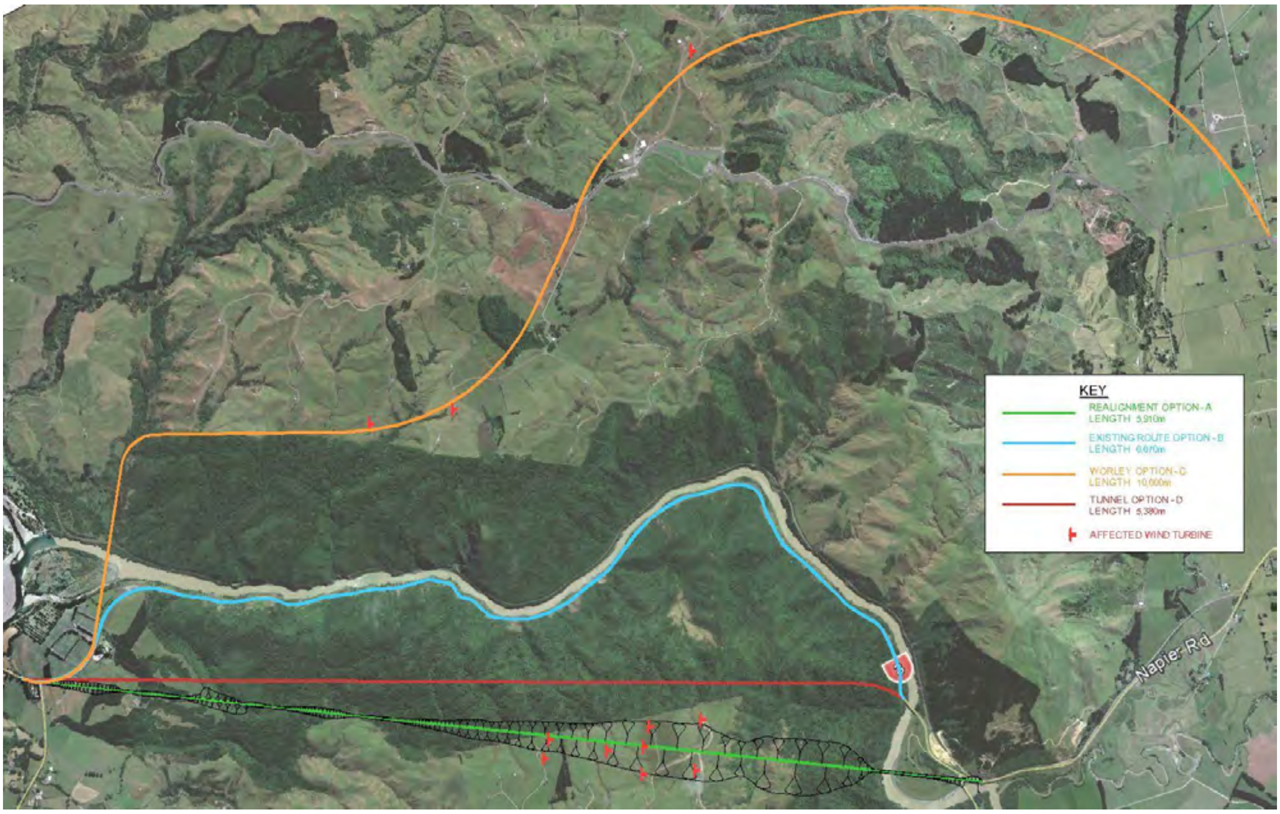


Figure 3-1 : Alternate Route Map

(For larger scale See Appendix C, Sheet D010)

For the purpose of this study, the works investigated by Worley has largely remained unchanged and the data updated to reflect todays rates, current maintenance costs and statistics.

For the Greenfield alignments, Tunnelling and Bridging options, a high level review has been completed to identify those schemes that meet basic funding criteria.

Each of the options considered was assessed from an economic, geotechnical, environmental, social, and construction perspective with consideration on the impact on those businesses directly affected through the development of a sensitivity testing tool.

---

[7] First identified as Route C under the Ministry of Works 1977

[8] Manawatu Gorge Strategic Transportation Study Worley Consultants 1997

All new route options are likely to have long gestation periods due to complexity of design, environmental compliance, social and business continuity considerations and the funding approval process.

The impact of these is different for each option. To this must be added construction periods for each. As a consequence, until routes are operational the status quo remains with existing risks and mitigation / remediation costs to be considered.

Based on the gorge risk assessment (section 2 of this report) a 3-5 year and a 10 year event could be expected for most options with the longest time frames having to accommodate a second 3-5 year event. In addition to clearing SH3, the NZTA will be required to maintain the alternate TLA routes.

This will effectively result in further heavy maintenance activities and stabilisation works to the alternative routes to provide route security in the event of closures until the route options are completed.

3.2 Economic Evaluation

Each route was assessed for economic evaluation purposes for which the length, average absolute grade (for both directions), assumed roughness and the estimated number of isolated speed change cycles were input. The assumed cost of each speed change was input based on the Economic Evaluation Manual procedures (EEM) values for rural roads; a basic value of 25 cents per speed change was assumed in all cases.

To provide a sound comparison between routes, the intersection of SH3 with Cambridge Avenue, Ashhurst, and the intersection of SH3 with Woodlands and Troup Roads west of Woodville was selected as common start and end points.

The average travel speed for each section was input for light, medium and heavy vehicles to take into account the road geometry and to facilitate taking into account the effect of passing lanes (and slow vehicle bays).

The EEM defined 30 year analysis period, was assumed to coincide with the start of construction.

A base level of traffic growth of 1.5 percent per annum has been applied for all vehicles. This is less than the EEM default value for Rural Strategic highways in the Manawatu – Wanganui region of 2.0 percent but is consistent with the historical growth for the SH3 Manawatu Gorge continuous telemetry site.

The adopted AADT for the Manawatu Gorge is 6935, consistent with recent AADT's.

Any potential benefits are assumed from project completion, for the next 27 years with a standard 8 percent discount rate applied.

The current annual cost of crashes for each route was derived and divided by the annual vehicle kilometres of travel to get the normalised crash cost. For the existing routes these were (per million veh-km). For the options being considered, the assumed road safety costs are:

• Greenfields route	$ 250,000
• Bridge route: bridging sections	$ 100,000
• Tunnel route: tunnel section	$ 50,000
• Worley option C	$ 400,000

The table below provides details of the economic assessment.

Table 3-1: Route Option BCR Assessment

OPTION (Gorge is closed)	TTC benefits	VOC+CO_2 benefits	Accident benefits	Project Cost	Total benefits	Rough net costs	BCR
GREENFIELDS	121.6	108.9	71.4	309.0	301.8	**222.3**	1.4
BRIDGING	95.2	101.3	77.1	412.8	273.6	**296.0**	0.9
WORLEY option C	79.9	54.6	-23.7	117.6	106.3	**69.1**	1.5
TUNNEL	102.8	95.5	77.1	1,795	275.4	**1191.7**	0.2

See Appendix F, for full details of sensitivity testing and economic analysis completed.

3.3 Design Assumptions

The assumed base construction period for each option is 3.5, 4.0, 5.5 and 6.0 years for the Greenfields, Bridging, and Worley option C and Tunnel respectively (with base pre-construction period of 4.0 years for each).

Designs costs (set at 6% of construction costs) have been attributed to the first two years.

Consenting costs have been applied to the remaining pre-construction periods. Assumed costs (including Scheme Appraisal Report) have been arbitrarily set as two million dollars for the alternative routes, and nominally $0.15 million dollars for the Saddle Road realignment option.

Given the large scale of the Greenfields, Bridging and Worley Option C alignments they have significant impact on the local environment. These projects will be subject to stringent environmental compliance. It is likely that this process could take in excess of 3-5 years to complete.

No detailed geological assessment has been undertaken as part of the assessment. For the purposes of estimating, it has been assumed that the stability of the material to be excavated will be similar to that understood on the current SH3 route.

For the Greenfields, Bridging and Worley C options, there is still a potential for landslide related closure given the height of the batters. This can be managed through the implementation of robust slip mitigation measures. Without further geotechnical assessment of these slopes it is difficult to assess the costs for these measures.

Given the time frames for Environmental compliance, Private and public consultation, land purchase, investigation, design and construction it is likely that the Current Manawatu Gorge route will need to stay in operation during implementation.

3.5 Route Option A – Greenfields

Realignment Option	TOTAL $ million	Landslide	Social	Design and Environmental	Impact of Closure probability	Construction Program
(A) GREENFIELDS Route Length – 5910m 🟩	**309**	Significantly reduced	Medium Social Impact on industry, and High Aesthetic Impact.	3-5 years' timeframe for compliance	Significantly Reduced	3-4 Years

Route Option A provides for a direct (Shortest Route) alignment with a maximum grade of 8%. It provides three full width lanes for passing on the uphill sections with one lane provided for the down grade section. To meet design, a cut depth of 200m is required.

To minimise loss of land and impact on the wind farm, side slopes (nominally 40^{O}) similar to that of the current stabilised 2011 Gorge slip face have been provided.

The design speed environment for cars is assumed at 85-90 km/hr, with an estimated travelling speed for HCV's of 40-50 km/hr given the steepness of the grade.

Costs including construction, professional service fees, environmental compliance and some contingency are $309M. This generates a BCR of 1.4 on a net cost of $225M.

The route requires the relocation of a number of wind turbines, assumed eight at this stage. No consultation has been undertaken with the wind farm owner or its engineers as part of this assessment.

If relocation is not possible for all turbines, there could be a reduction in energy production, impacting both economically and socially if revenue generation reduces. These benefits are difficult to assess and assign a monetary under the EEM. Instead these factors must be assessed under section 5 of the Resource Management Act (RMA). A detailed review of the wider economic impact has not been completed as part of this assessment.

3.6 Route Option B – Bridging

Realignment Option	TOTAL $ million	Landslide	Social	Design and Environmental	Impact of Closure probability	Construction Program
(B) BRIDGING Route Length – 6670m 🟦	**415**	Low impact	Low Impact	3-5 years' timeframe for compliance	Reduced against total length However risk increased slightly through isolated cut section.	3-5 Years

Route Option B provides for bridged carriageway sections running the length of the current Manawatu Gorge route providing two full width lanes and shoulders suitable for cycle access.

The alignment has similar vertical grades to the current route of 2-3%.

The design speed environment for cars and trucks is assumed at 85-90 km/hr.

Costs including construction, professional service fees, environmental compliance and some contingency are $415M. This generates a BCR of 0.9 on a net cost of $300M.

To achieve the desired horizontal geometry for the design speed and to remove a number of low speed hairpin bends, some bridge sections have been cut back into the southern hillside. This will require extensive battering back and stabilising of the batters through these sections to minimise risk of slip failure. As no Geological assessment has been undertaken it has been assumed that these sections will need to benched back to a grade similar to that of the 2011 Gorge Slip.

As a consequence the bridge option does not fully remove the risk of future landslide at the cut back points nor does it remove the possibility of a very large collapse engulfing a section of the structure. This will result in future maintenance and stabilisation works of the Gorge batters to manage this risk.

3.7 Route Option C – (Worley report Option C)

Realignment Option	TOTAL $ million	Landslide	Social	Design and Environmental	Impact of Closure probability	Construction Program
(C) WORLEY option C Route Length – 10600m ▬	**120**	Significantly reduced	Medium Social impact on industry	3-5 years' timeframe for compliance	Significantly Reduced.	4-7 Years

In addition to a data update, as outlined previously, LiDAR survey data was captured for Saddle Road to obtain more robust information on grades and quantities.

Route Option C provides for a curved alignment with grades between 2-6%. It provides two full width lanes.

This option also includes for the construction of a new bridged section crossing to the west of the Manawatu Gorge, providing the link back onto SH3.

The design speed environment for cars is assumed at 85-90 km/hr, with an estimated travelling speed for HCV's of 40-50 km/hr given the estimated grades.

Costs including construction, professional service fees, land purchase, environmental compliance and some contingency are $120M. This generates a BCR of 1.5 on a net cost of $70M.

The need to relocate two wind turbines, in the middle section of this alignment will incur a high potential cost of relocation given the large size of the turbines in this locality.

Consultation has yet to be undertaken with the power provision authority or its engineers as part of this assessment to clarify the viability of relocation.

If not found possible it is also likely that there will be a reduction in energy production, impacting both economically and socially if revenue generation reduces similar to the assessment provided for Route Option A. Benefits are difficult to assess under the EEM and are difficult to assign a monetary value to. Instead these factors must be assessed under section 5 of the RMA.

For the duration of this period, the remaining risks therefore will remain, with no suitable alternative route in place.

3.8 Route Option D – Tunnelling

Realignment Option	TOTAL $ million	Landslide	Social	Design and Environmental	Impact of Closure probability	Construction Program
(D) TUNNEL Route Length – 5380m	**1,800**	Significantly reduced	low Impact	3-5 years' timeframe for compliance	Significantly Reduced	5 -7 years

Route Option D provides a straight (Shortest Route) tunnel alignment under the Tararua Ranges with flat grades of between 2-3% similar to the current route and the bridge option. The option provides two full width lanes and one service lane provided for incident management.

The design speed environment for cars and trucks is assumed at 85-90 km/hr

Costs including construction, professional service fees, environmental compliance and some contingency are $1.8B. This generates a BCR of 0.2 on a net cost of $1.2B.

Given overall length of the tunnel option, in the event any material or events that could compromise the integrity of the tunnel, consideration must be given to safe exit, assessment, and emergency procedures.

The risks to this project regarding structural complexity and the unknowns around ground stability will also have significant impact on the levels of design and investigation phases and will be subject to stringent design compliance. It is likely that this process could take in excess of 3-5 years to complete incurring a significant impact on programme and costs.

3.9 Recommendations

Based on the information gathered and the level of assessment undertaken for each of the above proposals, each option has a residual risk for further closures and will require extensive further investigation to fully assess the geotechnical risks, environmental impacts, and design parameters.

In addition, each of the options will still require the need for a safe and viable alternative route for detour traffic in case of future closures through the Gorge to provide adequate route security.

From a purely economic perspective, all options return a small positive BCR, at this stage of assessment. However it must be noted that only modest figures have been provided for earthworks, geological risk, environmental aspects, the wider economic impact of each option and the need to relocate wind turbines. It is likely that project costs could increase considerably, and that timeframes may also extend depending on initial findings.

Based on the detailed economic assessment and sensitivity analysis provided in Appendix F and the available information assessed in the development of the four key options outlined above, the provision of a new route is not justified confirming that the current strategy of using the SH3 Manawatu Gorge alignment, in conjunction with the upgrade of the Saddle Road Route is the best strategy.

4 Alternative Route Upgrades – Saddle Road

4.1 Existing Alignment

The Saddle Road commences on the western side of the Ruahine range at the north-eastern corner of the town of Ashhurst before crossing the Pohangina River at the Pohangina River Bridge. The road then climbs approximately 305m for 6kms through various grades, twists and turns to its summit at approximately 370m above sea level. There is another peak 38m lower at 9kms, before the road then descends over 6kms terminating on the eastern side at the Oxford / Hope Road intersection. The road is currently restricted to 70km/hr following a spate of crashes and concerns raised by the police.

The Saddle detour could be considered torturous, with steep grades and tight radius curves leading to increased travel time, higher vehicle operating costs and increased maintenance from the high stresses imparted to the pavement and surface.

The detour can be split into 3 main sections being the ascents on either side of the range and the relatively level but curvilinear section along the top.

The issue with travel time is exasperated by laden heavy commercial vehicles as their low average speed further increases travel time with few opportunities to pass on the hills or through the top of the Saddle. Slow vehicle bays have been provided at locations where construction was easy during the recent closures. These are not ideal and as trucks accelerate (off incline) the number of vehicles that can pass is limited.

The priority alignments feature extended slow vehicle bays which allow faster vehicles to pass the trucks quickly and safely through the hill sections. It was a concern that increased traffic speed would create safety issues through the top of the saddle so improvements have been identified to mitigate this however the 70km/hr speed restriction and general speed achievable by trucks would make the section largely self-policing.

See Appendix D, Sheet D002 for existing route plan.

See Appendix D Sheets D004 - D008 for Realignment Options and Sheets D012 – D016 for Upgrade Options.

4.2 Site Description

The portion of the Saddle road being considered for improvement is 8160m in length measured from the start of Realignment section A to the finish of Realignment section E and covers the three distinct topographies described above.

The graded section at the Ashhurst (western) end of the Saddle Road has an average grade of 8% with a maximum grade of approximately 10%. The length of this section is 2,870m. The existing alignment has 33 curves ranging in radius from a tight 20m up to 300m. Existing seal widths are approximately 7m allowing for two standard lanes without shoulders.

The combination of steep grades, narrow seal width and tight curves has the effect of slowing traffic, especially trucks, which struggle to maintain a constant and steady speed.

The speed environment is in the order of 50-60 km/hr although some curves have a posting as low as 35km/hr.

Eastbound passing opportunity is limited to one short slow vehicle bay (SVB).

Sight stopping distances are constantly compromised by the tight curve geometry and existing topography. The road surface is in poor condition which, when combined with the issues outlined above, contribute to reduced driver confidence in the roads ability to keep them safe.

Maintenance improvement works could be compromised by the high pressure gas main and Telecom fibre optic cable laid in close proximity to the existing road alignment.

The middle 'flat section' is graded between 0 – 8% and is undulating. Although there is the occasional tight curve, generally the alignment is geometrically more forgiving and the speed environment in this section is estimated at 80 km/hr.

It includes two SVB's, one eastbound and the other westbound. Sight stopping sight distance and passing opportunities are better in this section with existing topography being more rolling than mountainous. There are no Gas or Telecom services located through this section, but the road passes through the Te Apiti wind farm which has turbines located on both sides of the road.

The graded eastern section (Woodville end) has an average grade of 9% over 2km with a maximum grade of 13.5%. There are 20 curves on this steep graded section which possess similar characteristics to the western graded section, except that the speed environment is slightly higher at 60-70 km/hr.

There are two westbound SVB's in the section both of which are fairly short in length. Stopping sight distances are compromised in places and existing topography is steep. There are few services in this section with only a few power poles and pylons present.

4.3 Existing Maintenance Costs

The cost of repairs on the Saddle Road has shown to be proportional to the length of the closure. Very short closures have not in the past caused significant damage and repairs have been effectively completed once the gorge was reopened. This provides an adequate LOS for the small number of local road users (AADT of 313 VPD).

However in the event of long term closures, there is limited ability to close the road to make repairs. Repairs can only be patched to a minimum standard requiring more substantial works (permanent repair) once the Gorge route is reopened.

For the period October 2011 through to September 2012, the resulting damage through extended increased traffic volumes has led to severe pavement distress leading to failure and extensive costly maintenance repairs.

The reactive maintenance expenditure bill for the completion of dig out repairs, grader lay asphalt (to repair uneven surfaces), edge break and pot hole repairs, vegetation control, signage, drainage control and incident response of local road alternate routes for the period of the current closure is in the order of $1.8M with an additional $3.56M incurred to provide improvements such as seal widening, additional passing opportunities, pavement rehabilitation and strengthening to the Saddle Road. These improvements were deemed essential to maintaining route viability.

These costs are not sustainable and to be effectively managed a number of options have been considered.

- Pavement strengthening within the existing alignment;
- Pavement strengthening with improvements including Drainage, Subsoil's , and Shoulder Widening;
- Realignment of tight curves and the provision of more passing opportunities and the redundancy of some sections to improve efficiencies.

4.4 Maintenance Strategies

An assessment has been carried out to define possible maintenance strategy's and future costs.

The cheapest option to return the Saddle road to a condition comparable to pre-Gorge closure would be to stabilise the potholed, cracked and deformed sections followed by full length resealing.

A rough measure has identified approximately 10,000m^2 of patching with just over 70,000m^2 of reseal, costs totalling in the region of $850,000. This would be satisfactory for normal Saddle traffic but should the Gorge close again for any length of time then the pavement would rapidly deteriorate leading to high reactive maintenance costs as seen on the last closure and ongoing delays for road users over and above the inconvenience of normal Saddle travel times.

To improve route security and ensure minimal disruption to customers using the Saddle Road during future closures, the pavement requires strengthening through its entire length. The Saddle would also require a higher level of maintenance service to ensure drains were kept clear to avoid premature pavement failure due to water ingress. Pavement strengthening should be augmented with sub soil drainage and where necessary kerb and channel to further improve pavement resilience. Options for pavement rehabilitation range from $2.33M to $3.6M, with drainage upgrades estimated at up to $1M.

Widening should also be considered. A wider sealed surface will stop trucks running along the edge of seal, cutting corners leading to low shoulders and edge break. Widening by 1.0m (0.5m each side) as part of the rehabilitation and drainage works is estimated to cost $1.25M.

4.5 Safety Considerations

The safety of road users travelling along the saddle detour has always been of the utmost concern. A curve speed assessment has been carried out and measures implemented, including the installation of additional curve advisory signage and the use of a 70km/hr speed restriction to lower the speed between the curved sections. Ongoing maintenance of potholes and drainage has also been a high priority to minimise road user exposure to other issues which could further impact safety.

Choice of detour improvement options will have a further impact on road user safety with the possibility of inadvertently making sections of road unsafe causing crash migration and creating black spots. As a result, following discussion on the preferred alignment, further work will be required to assess the possible safety implications and recommend works to mitigate effects. Independent safety audits will also need to be carried out at various stages.

4.6 Design Approach

Sections not covered by realignment were assessed to provide an improved level of service in the short to medium term to derive a programme of works over the next three years. Cost reduction measures such as pavement strengthening and seal widening have been investigated.

Initially a pavement depth of 300mm, including 150mm of M4 AP40, and 150mm AP65, in-situ stabilised to 300mm from the proposed finished surface level was considered, however, as this provided little return initially and limited the ability to procure any widening options to help ease traffic stresses due to additional costs, a modest pavement design depth consisting of a 200mm overlay of M4 AP40 Base course, with in-situ stabilisation to 50mm below the existing finished surface level has been used.

At this stage no detailed investigation or design has been undertaken to determine subgrade quality as part of this scheme.

Improved drainage and widening will reduce maintenance costs; however the availability to fund localised widening will need to be addressed during subsequent design stages following a decision on the most appropriate treatment, further site investigation required, pavement construction details and quantities and rates to be used.

For the purposes of this study an indicative 0.5m shoulder widening has been provided for, with a proposed construction depth of 400mm, including 150-200mm M4 AP40 Base course over 200-250mm AP65 Subbase, giving a finished carriageway surface width of 8.0m.

4.7 Economic Model

The value of cost reduction measures was derived through Net Present Value (NPV), in accordance with the NZTA's Economic Evaluation Manual procedures (EEM).

For (NPV) analysis sheets please see Appendix G.

For the medium to long term (4-6 years), we have also provided an assessment of the potential benefits for full geometric realignment through each of the five sections in terms of travel time savings and a reduction in driver stresses.

For the realignment options, additional maintenance costs for the non-realigned sections of approximately $2.01M, $0.68M and $0.55M for rehabilitation, widening and drainage respectively (total of $3.24M) has been attributed to the third and fourth years of construction.

The Economics was then completed based on the length, average absolute grade (for both directions), assumed roughness and the estimated number of isolated speed change cycles. The assumed cost of each speed change was input based on the EEM values for rural roads; a basic value of 25 cents per speed change was assumed in all cases. The average travel speed for each section was input for light, medium and heavy vehicles to take into account the road geometry and to facilitate taking into account the effect of passing lanes and slow vehicle bays.

4.8 Section A

4.8.1 Existing Alignment Upgrade:

See Appendix D, Sheet D012.

Section A commences under MDC control, at approximate chainage 450m and extends for some 3100m. This section has grades up to 10% with some 33 tight horizontal curves.

The pavement construction through Section A, allows for a 200mm overlay of M4 AP40 Base course, with in-situ stabilisation to 50mm below the existing finished surface level.

This option also provides for an additional 0.5m shoulder either side of the carriageway, the installation of subsoil drainage and improved surface water drainage channels.

The cost for the existing alignment upgrade option, including drainage and widening improvements is estimated at $1.485M.

4.8.2 Realignment:

See Appendix D, Sheet D004.

The realignment option replaces the existing 33 curves with seven higher speed curves at a minimum radius of 120m and design speeds of at least 75km/hr. This is a major realignment which would shift the first half of the realignment well away from the existing route. The improved alignment would allow trucks, in particular, to maintain a higher speed. The grades average around 10% with a range being between 8-14%. The 14% section is a short section (200m) needed to remove a “u bend”. A passing lane is incorporated in the design allowing the majority of vehicles in the traffic stream (cars), safe passing opportunity further reducing travel times on the detour. Sight distance is improved and seal width increased to 8.5m which should enhance safety and reduced maintenance costs.

The realignment length at 2600m is some 500m shorter than the current section length of 3100m. A variation, Option 2 that straightens the last half of the realignment was also investigated, but the volume of earthworks ,some 500,000m^3 and an average grade of 14% over 1100m length makes this option prohibitive even though a further 280m of route shortening can be achieved.

Two crossings of the gas line are required and will require detailed discussions with the utility provider.

The proposed realignment will reduce pressure on the Ashhurst urban section of the detour with regards to vehicle speed and safety. Speed and rat running through Ashhurst has been a problem as road users familiar with the detour are aware that once they cross the Pohangina River there are few safe opportunity’s for passing. The result has been speeding along Cambridge and Salisbury roads making unsafe overtaking manoeuvres by detour users in an attempt to avoid being stuck behind slower moving HCV’s. Following complaints from residents, traffic calming measures were installed and the police stepped up speed enforcement in an attempt to counter.

The cost of the preferred realignment option (including professional service fees, land acquisition and some contingency) is estimated at $3M.

4.8.3 Pre Alignment Section

The section of the Saddle prior to the commencement of alignment A, approximately length 1 kilometre will also require an upgrade to reduce increased maintenance costs.

Costs assumed for the lead in section are as follows:

See Appendix D, sheet D12.

Rehabilitation	- $385K
Drainage	- $105K

4.9 Section B

4.9.1 Existing Alignment Upgrade:

See Appendix D, Sheet D013.

Section B commences at approximate chainage 2720, still under MDC control, running through a predominantly flat section with grades ranging from 0-8%, with sound horizontal geometry. This section terminates at chainage 4400m, close to the eastern most wind turbine. The section is some 910m in length.

The pavement construction through Section B, allows for a 200mm overlay of M4 AP40 Base course, with in-situ stabilisation to 50mm below the existing finished surface level.

This option also provides for the additional 0.5m shoulder either side of the carriageway, the installation of subsoil drainage improved surface water drainage channels.

The cost for the existing alignment upgrades option, including drainage and widening improvements is estimated at $435K.

4.9.2 Realignment:

See Appendix D, Sheet D005.

The realignment section is located on the middle flat section and is graded between 0-8% which will match the existing grades. It allows for minor curve improvements and seal widening. The speed environment may increase slightly due to these improvements and be closer to 85-90 km/hr.

There are no proposed SVB’s, passing opportunities won’t increase significantly but sight stopping distances would improve. Only minor service relocations may be required. Route shortening of only 10m over the current route is expected

The cost of the realignment option (including professional service fees, land acquisition and some contingency) is estimated at $575K.

4.10 Section C

4.10.1 Existing Alignment Upgrade:

See Appendix D, Sheet D014.

This section commences at approximate chainage 4400m under TDC control, continuing through with grades averaging 8%. This section terminates at chainage 5700m, in the vicinity of the second wind farm look out directly adjacent to 414 Saddle Road.

The pavement construction through Section C, includes for a 200mm overlay of M4 AP40 Base course, with in-situ stabilisation to 50mm below the existing finished surface level.

This option also provides for the additional 0.5m shoulder either side of the carriageway, the installation of subsoil drainage and improved surface water drainage channels.

The cost for the existing alignment upgrades option, including drainage and widening improvements is estimated at $620K.

4.10.2 Realignment:

See Appendix D, Sheet D006.

Although this section is located in the middle section, it has an average grade of 8% rising to the east for a significant portion of the realignment. Once again minor curve improvements and seal widening will be required through this section to bring it up to the required standard, and speed environment improvements.

An eastbound SVB will be included through this section. Once again, sight distance will be improved along with seal widths. There are no significant services to be relocated except one fibre cable crossing. This project is 1290m long compared to the existing 1310m, a minor route shortening of 20m.

The cost of the realignment option (including professional service fees, land acquisition and some contingency) is estimated at $900K.

4.11 Section D

4.11.1 Existing Alignment Upgrade:

See Appendix D, Sheet D015.

This section commences at approximate chainage 5700m under TDC control, continuing through the flattest section with grades between 0-5% and incorporates approx. 600m of the steep graded, 7-11%, Woodville end. There are 13 existing curves on this section which terminates at chainage 7420m.

The pavement construction through Section D includes for a 200mm overlay of M4 AP40 Base course, with in-situ stabilisation to 50mm below the existing finished surface level.

This option also provides for the additional 0.5m shoulder either side of the carriageway, the installation of subsoil drainage and improved surface water drainage channels.

The cost for the existing alignment upgrades option, including drainage and widening improvements is estimated at $1.02M.

4.11.2 Realignment Options:

See Appendix D, Sheet D007.

This section incorporates the flattest section at the top and also 600m of the Woodville end steeply graded section. Grades vary between 0- 5% at the top, to 7-11% on the graded section. The 13 existing curves will be reduced, depending on which of the three options is selected.

Option 1 has seven curves with design speeds 75 km/hr or over, grades as stated above with route shortening of 110m. This project overlaps realignment C, by 200m. This is minor realignment with widened seal and improved curves and is the preferred option (of the three) being least cost.

Option 2 has five curves with a minimum design speed of 85 km/hr, grades are as stated above with a route shortening of 215m.

Option 3 is a major alignment, essentially straight, which overlaps into realignment C by 680m, but provides route shortening of 560m. Construction costs are significantly higher with more earthworks required.

There are no SVB’s proposed in this realignment section or any expected issues with services.

All options improve sight distance.

The cost of the realignment option (including professional service fees, land acquisition and some contingency) is estimated at $1.73M.

4.12 Section E

4.12.1 Existing Alignment Upgrade:

See Appendix D, Sheet D016.

This 910m section commences at approximate chainage 7520m with an average grade of 9%. The maximum grade of 13.5% occurs near the eastern end, chainage 8520m.

The pavement construction option provides for a 200mm overlay of M4 AP40 Base course, with in-situ stabilisation to 50mm below the existing finished surface level.

This option also provides for the additional 0.5m shoulder either side of the carriageway, the installation of subsoil drainage and improved surface water drainage channels.

The cost for the existing alignment upgrades option, including drainage and widening improvements is estimated at $435K.

4.12.2 Realignment:

See Appendix D, Sheet D008.

This section has two options designed to achieve similar results. Small improvements in speed environment are achieved with a new value of 75-85km/hr. Grade range on both options is between 8-11% with a realigned section at the beginning being steeper at 14%.

Option 1 involves lowering the existing road alignment to achieve extra road width for seal widening and SVB’s along an existing ridgeline consistent with the existing road. The alignment and curves will be “sweetened”. A retaining wall will be required at one location (smaller than that required on option 2 below). The revised route will be 880m long some 30m less than the existing length of 910m.

Option 2 will also keep the road at existing levels, with two significant retaining walls being required at two narrow points on the ridge. The horizontal alignment will closely match the existing alignment resulting in a lower speed than Option 1 and near the current alignment. A SVB will still be incorporated on this option. 30m route shortening is attained.

Sight distance will be improved and only minor service conflicts (power poles) are expected.

The cost of the preferred realignment option (including professional service fees, land acquisition and some contingency) is estimated at $1.125M.

4.13 PNCC Ashhurst Detour Alternatives

See Appendix D Sheet D003

Initial investigation into possible alternative routes through Ashhurst, was also completed in conjunction with PNCC.

The additional traffic and noise particularly at night for the extended period of the gorge closure became problematic through the urban area and there were a number of complaints. The intention therefore was to identify a route that lowered or avoided these impacts on the community.

The plan below shows the current route and three new routes that were raised with PNCC to test viability

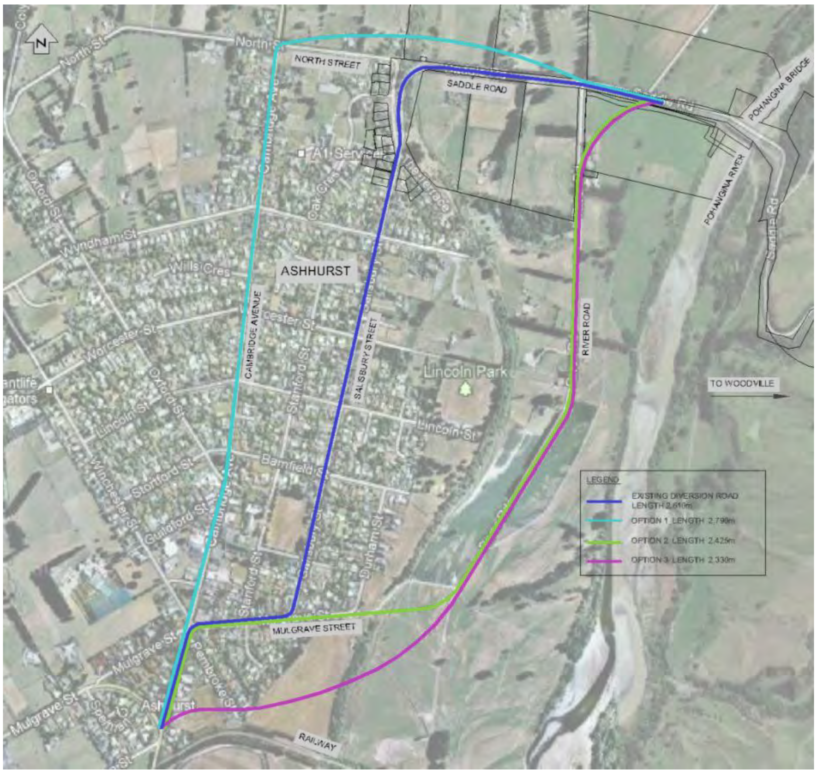


Figure 4-1 : Ashhurst Detour Alternatives

The review with PNCC effectively discounted the new routes due to land purchase (PNCC is currently addressing river access problems with landowners and interest groups regarding the Mulgrave extension), potential high costs as most of the new routes (pink & green) would require full construction. For the same options there is flood risk, as a consequence the BCR is likely to be low making project justification difficult.

The blue route offers no more than the current route as it simply shifts the problem from one section of the community to another.

PNCC confirmed that the current diversion Route through Mulgrave and Salisbury Streets is the preferred option as the road has been improved over time to give a good pavement structure and that it is more appropriate to investigate mitigation measures.

Further investigation into permanent traffic calming measures, amenity screen planting and quieter sealing treatments through Mulgrave Road and Salisbury Road where the impact is greatest is required.

These will need to be assessed by PNCC and provided for in future renewal programmes as part of the Annual Planning Process.

4.14 Economic Assessment

The value of each section was tested within our sensitivity model in accordance with the NZTA's Funding Manual to derive an optimised Benefit Cost Ratio for the entire route.

See Appendix F for details of the economic analysis.

Using the advantage of the developed model to facilitate changing the values of assumptions, selective sensitivity testing was also undertaken.

Through Sensitivity testing, we have been able to assess possible total benefits, by increasing the factors and multipliers for each of the categories as outlined in Fig 4-1 below.

Table 4-1: Saddle Road Sensitivity Analysis

OPTION (Gorge is open)	TTC benefits	VOC+CO_2 benefits	Accident benefits	Total benefits	Net costs	BCR	Comment
SADDLE ROAD 1	1.0	1.9	1.5	4.4	4.6	1.0	Increasing roughness costs for existing Man. Gorge and Saddle Rd from 5 to 7 IRI
SADDLE ROAD 1	1.0	1.1	1.9	4.0	4.6	0.9	Reducing the accident unit rate by $100,000
SADDLE ROAD 1	1.7	2.1	2.8	6.6	4.6	1.4	Increasing the diversion from Pahiatua Track north from 0% to 20 %
SADDLE ROAD 1	1.3	1.4	2.0	4.6	4.6	1.0	Fast tracking the project timing to 2 + 2 years

Using the output from the table above, the BCR's for the Saddle Road realignments for existing traffic remain at or just below 1.0 except for the unlikely case that the upgrade attract some traffic from the Pahiatua Track route. A conservative BCR of 1.4 may be achievable assuming that there will be a 20% increase in traffic from the northern section of the Pahiatua Track route.

The sensitivity testing scenarios outlined above indicate a current BCR range of 0.9 to 1.4. In consideration of these and other factors it is recommended to adopt a BCR for the partial (sections A and E) realignment of Saddle Road of 1.1.

The range of BCR's achievable through sensitivity testing, indicates that there is little merit in undertaking the section A and E realignments of Saddle Road, given the risks outlined for each proposed realignment in this section.

4.15 Recommendations

Funding has been made available for the procurement of short to medium term upgrades over the next three years for the Saddle Road Route. The immediate benefits obtained through the delivery of full route seal widening particularly in terms of spreading the axle loads, the improved safety benefits through realigning vehicles away from unconstrained road edges, the decongestion of heavy vehicles around hair pin bends and the de stressing of road users through providing a wider corridor, are easily achievable through this period.

For the medium to long term (four - six years), our assessment of the benefits for full geometric realignment through each of the five sections in terms of travel time savings and a reduction in driver stresses is provided below.

Table 4-2: Realignment A-E Summary

OPTION	Property Purchase	MSQA & Construct	TOTAL $ million	Length (km)	$ million per km
realignment A1	83	2,439	3.08	2.60	1.2
realignment B	1	472	0.57	0.90	0.6
realignment C	1	749	0.90	1.29	0.7
realignment D1	26	1,401	1.73	2.02	0.9
realignment E1	2	923	1.13	0.88	1.3
			7.40	7.69	

For the medium to long term, collectively the realignments provide a positive return. Our initial research indicates that more substantial realignment works may be justifiable but there are still a number of unknowns which would require substantiation in the next two to three years prior finalising a detailed approach.

If the option to proceed with realignments was taken now, there would still be a need to update and maintain the alternative route in the short term to remediate any potential impacts of future heavy maintenance in case of slip related closures during this period.

As such it is recommended that the NZTA proceed with planned rehabilitation and the full route widening programme to obtain the best short term value.

Table 4-3: Saddle Road Short to Medium Term Upgrade Programme and Priority

Section	Maintenance Improvement Cost $(000)	Priority	Year
Lead in section	$485	1	13/14
Section A	$1,485	6	15/16
Section B	$435	2	13/14
Section C	$620	3	13/14
Section D	$1,020	4	14/15
Section E	$435	5	14/15
Total	$4,480		

Prior to committing to pavement construction, it is important that a robust assessment be completed of the subgrade layer and a thorough assessment of quantities be delivered to get some surety around quantities and rates.

5 Conclusions / Recommendations

Alternative Route Assessment: (From section 3)

Based on the assessment completed in section 3 of this report, and the sensitivity analysis provided, the provision of a new route is not justified.

The current strategy of retaining SH3 Manawatu Gorge with alternate routes when the gorge is closed to slips is appropriate.

Risk Assessment: (From section 2)

25 at risk areas have been identified. It is not considered economically viable to treat these sites.

This review of landsliding in the Manawatu Gorge confirms that larger landslides (~20,000–100,000 m^3) could occur every 5–10 years.

Further work is recommended to better define the management of risk at potential landslide areas in the three risk main categories and local rock fall sites.

The NZTA should adopt the methods and strategies outlined in this report for managing landslide events when they occur in the Manawatu Gorge.

Alternative Route Upgrades: (From section 4)

The Saddle Road remains the priority alternate route.

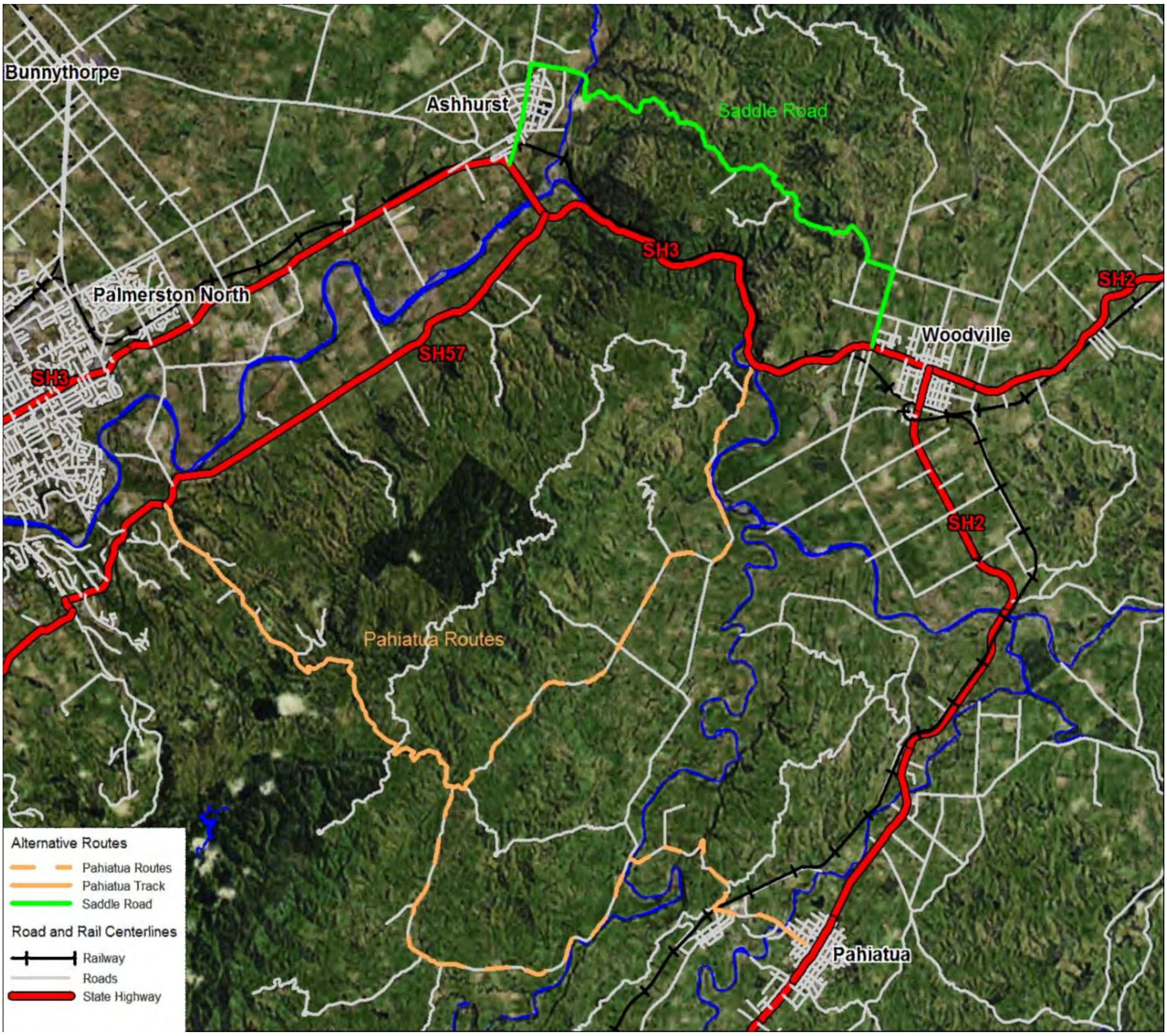
Maintenance upgrade works provide the best short to medium term solution through the Saddle Road. A priority programme has been provided.

The report identifies that there are potential economic benefits for larger scale improvements through this route. Further investigation will be required to assess these benefits.

The current route through Ashhurst Township has been confirmed by PNCC as the preferred route. Traffic calming measures, amenity screen planting and quieter sealing treatments through Mulgrave and Salisbury Streets are recommended to mitigate detrimental traffic impacts.

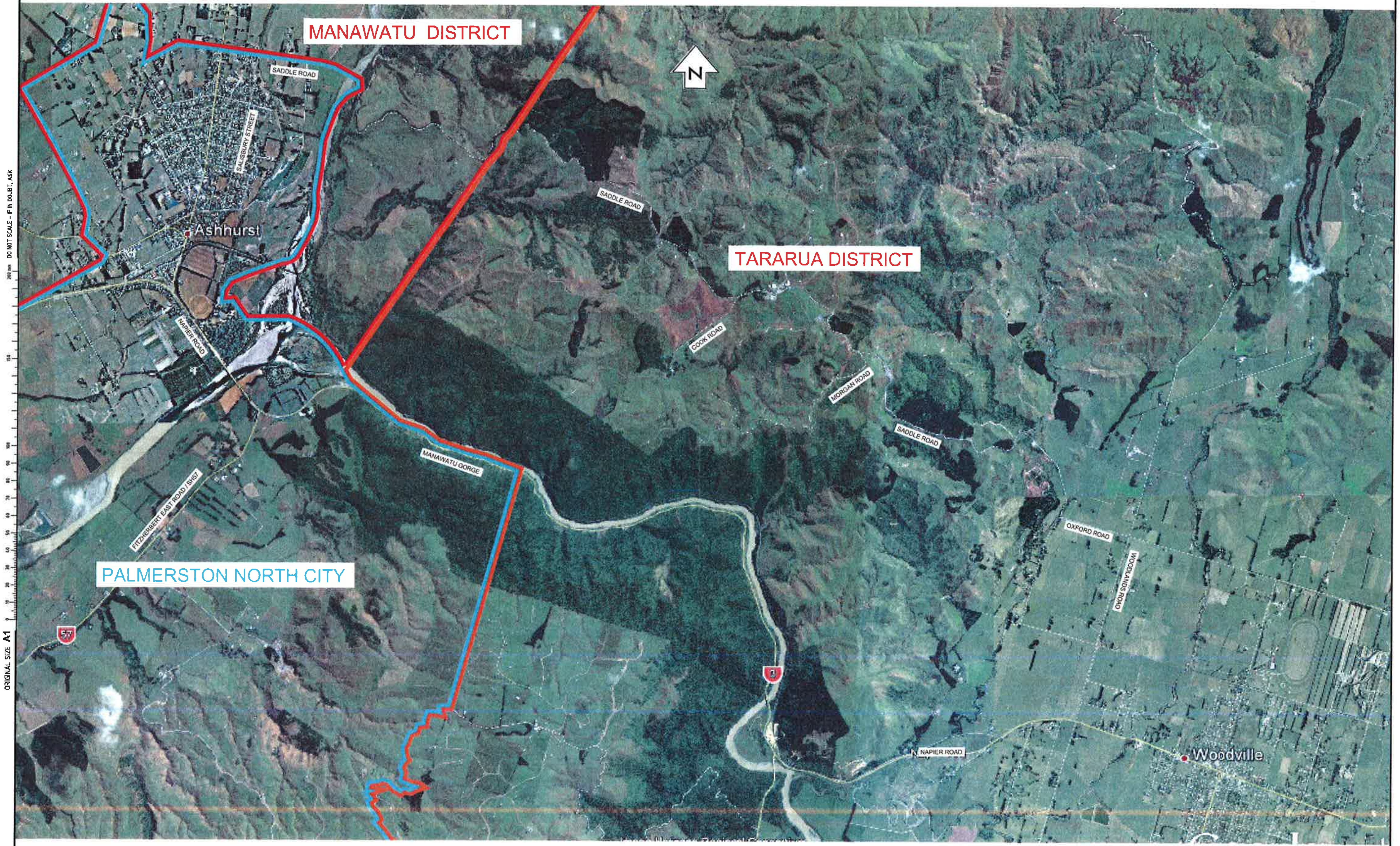
Appendix A Site Location Plans

Site Map showing Alternative Routes



DO NOT SCALE - IF IN DOUBT, ASK

ORIGINAL SIZE A1



NOT FOR CONSTRUCTION

REV	REVISIONS	DRAWN	CHECKED	APPROVED	DATE
A	FOR INFORMATION	CPA	PAC	CDP	30/10/12

	Name	Date
SURVEYED	LIDAR	
DESIGNED	SW BRENNAN	10/12
DESIGN CHECK	AC DROVER	10/12
DRAWN	CP AJOC	10/12
DRAWING CHECK	PA CHILTON	10/12
APPROVED	CD PITCHFORD	30/10/12

XREFS : contour5m_3d

MWH

NZ TRANSPORT AGENCY
WAKA KOTAHI

NZTA NEW ZEALAND
SH 3 MANAWATU GORGE ALTERNATIVE ROUTE

SADDLE ROAD REALIGNMENT OPTIONS
DISTRICT BOUNDARY

Status Stamp: **FOR INFORMATION**

Date Stamp: 30/10/2012

SCALES (A1) NTS

Drawing No.	Sheet No.	Rev.
80500655	D 019	A

\\nzwan1s01\projects_2012 Onwards\NZ Transport Agency\SH3 Manwatu Gorge Alt Route 80000655\80500655 SH3 Manawatu Gorge Alternative Route\CAD\D019 Territorial boundary.dwg

Appendix B Risk Assessment

Engineering geological assessment of the risk and potential magnitude of future landslides that might close SH3 within the Manawatu Gorge

G.T. Hancox, C.D. Robson, and B. Lukovic

GNS Science Consultancy Report 2012/254 (DRAFT)

11 October 2012

DISCLAIMER

This report has been prepared by the Institute of Geological and Nuclear Sciences Limited (GNS Science) exclusively for and under contract to the New Zealand Transport Agency (NZTA). Unless otherwise agreed in writing by GNS Science, GNS Science accepts no responsibility for any use of, or reliance on any contents of this Report by any person other than NZTA and shall not be liable to any person other than NZTA on any ground, for any loss, damage or expense arising from such use or reliance.

The data presented in this Report are available to GNS Science for other use from July 2013.

BIBLIOGRAPHIC REFERENCE

[1]Hancox, G.T., [2]Robson, C.D., [1]Lukovic, B., 2012. Assessment of the risk and potential magnitude of future landslides that might close SH3 within the Manawatu Gorge. *GNS Science Consultancy Report 2012/254*. 82 p.

[1] *GNS Science, PO Box 30368, Lower Hutt.*

[2] *MWH New Zealand Ltd., PO Box 9624, Wellington*

Project Number: 430W1460

CONTENTS

TABLES

FIGURES

APPENDICES

EXECUTIVE SUMMARY

The Manawatu Gorge is an antecedent gorge which has been formed by the west-flowing Manawatu River gradually cutting down through the low point in the Tararua–Ruahine range over the last ~1.5 million years. Bedrock in the ~6 km long gorge typically comprises interbedded, indurated greywacke sandstone, siltstone, and red volcanic argillite. The steep (~35–>60°) slopes on either side of the gorge are overlain by surficial colluvium and old (prehistoric) landslide deposits, and remnants of old alluvial deposits on the upper slopes.

The Manawatu Gorge contains a major road (State Highway 3) and rail link between the west and east coasts of the southern North Island. Excavations for the establishment and widening of SH3 on the south side of the gorge have cut back and oversteepened the toes of slopes, resulting in rock falls and landslides that have affected or closed the road in many places since it was first completed 1872. Since the gorge road was widened in the 1940s, 1960s, 1970s and 1980s it has frequently been closed by slips, especially during heavy rainfall. Most of these failures have been related to the road-widening works. The railway line on the north side of the gorge has been much less affected by landsliding, mainly because of the lower cuts, and the use of tunnels to bypass steeper sections of the gorge.

The first significant landslide closure (more than 1-2 days) of SH3 in the Manawatu Gorge occurred in 1990 when a ~5000 m^3 debris slide blocked the road for 8 days near Barney‟s Point. Other large failures that required major stabilisation works occurred in the centre of the gorge in 1995 and 1998. All of these failures were clearly related to the cutting back of the toe of the slope in the 1980s. Rock falls also occurred on the many rock bluffs present occur throughout of the gorge which had been cut back, requiring rock bolting, scaling, and meshing in a number of places. The most severe episode of multiple landslides in the Manawatu Gorge occurred during the February 2004 rainstorm, which was probably the worst storm to hit the area in the last 50 years. The prolonged high intensity rainfall spread over 2–3 days resulted in extensive landsliding through the gorge, causing 9 large overslips and at least 30 minor overslips and underslips in the ~3 km section of the gorge between Waterfall Stream (~RP 491/0.70) and Upper Gorge Bridge (RP491/4.10). The largest of the overslip landslides was a ~100,000 m^3 failure at ~RP491/1.05, which closed SH3 for 70 days.

On 18 August 2011 the first in a series of debris (colluvium) and rock falls and slides occurred, ultimately involving a total of about 160,000 m^3 occurred between Bluffs 2 and 3 (RP488/1.86–2.10), about 1 km from the Ashhurst end of the gorge. The landslide closed SH3 until 19 September 2012 while investigations and extensive stabilisation works were carried out. The long closure of this strategic highway prompted the New Zealand Transport Agency (NZTA) to commission a risk assessment of the probability and potential magnitude of future „slips‟ (landslides, rockfalls, debris falls) that might block SH3 within the gorge. This report presents the results of that assessment, which identifies and estimates the risk at potential future landslide sites in the gorge, and provides recommendations for a strategy to manage the threat at those sites and future landslide problems in the Manawatu Gorge.

In this study our approach to assessing the risk from future landslides in the Manawatu Gorge focussed initially on local geology and geomorphology, old (prehistoric) landslides in the area, and information provided by past landslides that significantly affected SH3 in 1995, 1998, 2004, and 2011. The locations and extent of potential landslide areas that could affect SH3 through the gorge were initially identified on oblique and vertical aerial photos with the aid of GIS maps of bedrock, colluvium and prehistoric landslide scars, historical landslide data, and slope angles based on 1 m LiDAR contours. The potential landslide areas identified along SH3 and existing slope controls were later ground-checked and assessed.

Twenty five potential landslide areas were identified along SH3 in the gorge based on: (a) past landslide history, (b) rock types and surficial deposits, (c) geomorphic features (prehistoric landslides scarps, bluffs), (d) slope angles and heights, and (e) road cuts and slope support measures. These areas were mapped in GIS and ranked according to their estimated size (area and volume) and potential for future slope failures that could damage or close SH3, especially during heavy rainfall and strong earthquake shaking. The areas have been ranked according to their size and potential to close SH3 as follows: R1: 10,000 m^3 R2: 10,000–25,000 m^3; R3: 25,000–50,000 m^3; and R4: >50,000 m^3.

Eight (32%) of the potential landslide areas are in the Western Section of the gorge (Gorge Monument to Bluff 10, RP488/1.05–491/0.10); thirteen (52%) are in the Central Section (Bluff 10 to Barney"s Point, RP491/0.10–2.45); and only four (16%) are in the Eastern Section (Barney"s Point to Upper Gorge Bridge, RP491/2.45–4.10). This is similar to the historical distribution of landslides (West - 55 (40%), Centre - 61 (44%), East - 22 (16%). The higher percentage of potential landslide areas in the centre of the gorge is attributed to the number of existing unstable scars of landslides caused by the February 2004 rainstorm.

The risk that potential landslide areas present to SH3 in the Manawatu Gorge was assessed using the General Approach outlined in the NZTA"s 2004 Risk Assessment Process Manual. This method provides a qualitative technique for analysing landslide risks based on the consideration of existing slope controls, and the likelihood and consequences of future slope failures. Three categories of future landslide threat (risk) in the Manawatu Gorge, as follows:

(a) Moderate Threat: – 8 Areas (Areas 1, 4, 11, 21, 22, 23, 24, 25). *(Rank 1)*

(b) High Threat: – 11 Areas (Areas 2, 3, 8, 9, 10, 13, 16, 17, 18, 19, 20). *(Rank 2)*

(c) Very High Threat: – 6 Areas (Areas 5, 6, 7, 12, 14, 15). *(Rank 3 and 4)*

The High and Very High Threat (Risk) areas are located in the Western and Central sections of the gorge and have strong geological and geomorphic similarities to the 2011 landslide area, and have been destabilised to some degree by cutting back the toe of colluvial deposits along SH3, generally without support measures.

Landslides caused by the February 2004 rainstorm had a significant influence on the risk assessments, and the larger 2004 landslides (numbers #1 to #5) are the main reason for high risk ratings. The scarps of the 2004 landslide scarps in Areas 12, 14, 15, 17 and 18 are oversteepened and at risk of large regressive failures, especially in Areas 14 and 15 where small failures have already occurred. The 2004 landslide #2 in Area 14 is currently believed to present the greatest potential landslide risk to SH3 in the Manawatu Gorge. A large failure similar to the 2011 landslide could occur at that site at any time, but especially during heavy rainfall or strong earthquake shaking.

The 2011 review of landsliding in the Manawatu Gorge suggested that larger landslides (~20,000–100,000 m^3) could occur every 5–10 years. The presence of several un-stabilised scars of landslides caused by the 2004 rainstorm compared to conditions prior to that event, especially in the centre of the gorge, suggest that estimate is realistic, and is used as the basis for some likelihood ratings (once per 5–10 years) in our landslide risk assessment.

The recommended future actions for better definition and management of risk at potential landslide areas in the three risk categories and local rock fall sites in the gorge include:

(1) *Very High Threat (Risk) Areas:* (a) preparation of a detailed engineering geological/ geotechnical report, including a slope stability analysis and risk assessment using NZTA‟s Advanced Approach; (b) terrestrial laser scanning (TLS) of the landslide sites; (c) monitor future slope failures (rock falls, debris falls, slides) and performance of existing controls (mesh, catch fence etc.) at each potential landslide area.

(2) *High Threat (Risk) Areas:* (a) prepare basic engineering geological on each site; (b) monitor slope behaviour and future slope failures in each potential landslide area.

(3) *Moderate Threat (Risk) Areas:* (a) standard maintenance measures should apply, including signage, traffic control, clearance of slip debris to reopen the road, with minimal cutting back of the slope, and repairs to underslips and road edge failures; (b) monitor future slope failures and performance of existing controls.

(4) *Local rock fall sites (Bluffs and rock slopes):* (a) review and repair existing slope controls (mesh, catch fences); (b) monitor future slope failures and condition of existing controls.

Taking into consideration the results of this study, the recommended methods and strategies that could be used to manage and reduce the consequences of future landslides to SH3 in the Manawatu Gorge are as follows:

- An engineering geologist/geotechnical engineer should be involved in the emergency response to assess landslides that block SH3 and decide on actions to reopen the road.
- A geological model of the landslide site should be considered before any earthworks are begun that could adversely affect or further decrease the stability of the slope.
- Establish an inventory of slope failures in the gorge to provide improved knowledge of the locations, size and events that trigger debris slides and falls, rock falls and falls of individual boulders and effects, and the actions taken to deal with them.
- Monitor active or very high risk landslide areas (decided on a site-by-site basis).
- Review and repair existing slope control measures.
- Site-specific engineering geological and geotechnical assessments should be carried out at potential landslides sites that are assigned very high risk ratings.
- Limit earthworks that undercut and oversteepen colluvial and regolith slopes along SH3, and use support measures where possible to stabilise future failures. An engineering geologist or geotechnical engineer should be consulted before earthworks are begun.
- Scaling of loose blocks and additional rock bolting is probably required at some locations considered to be at risk of local rock falls (e.g., Bluffs 9 and 12).
- Prepare an engineering geology/geotechnical completion report on the 2011 landslide area that describes the history, geology and geomorphology of the landslide, the slope stabilisation works, and the stability of the site before and after these measures.
- Detailed documentation and reporting on the engineering, geotechnical, and geological aspects of future large landslides within the Manawatu Gorge is essential to improve the management and minimise the risk that slope failures present to SH3.

1.0 INTRODUCTION

1.1 Background

State Highway 3 (SH3) through the Manawatu Gorge was closed for more than 365 days since the first in a series of slips about 1km from the Ashhurst end of the road in August 2011 until 19 September 2012. Closure of this Nationally Strategic State highway has meant that traffic has been diverted onto two Local Authority roads namely Saddle Road and Pahiatua Track. In late 2011, the New Zealand Transport Agency (NZTA) commissioned MWH New Zealand Ltd (MWH) to produce a Project Feasibility Report (PFR) to look at "Business Continuity and Route Security" for this route. The PFR was considered by NZTA in February 2012.

This report relates to the next phase of the Manawatu Gorge investigation, for which the outcomes required by NZTA are:

A. Review of previous reports and NZTA‟s Strategies and Policies and confirm (or otherwise) that the most viable route for SH3 between Palmerston North and Woodville, in terms of economic benefits compared to alternative routes, is through the Manawatu Gorge.

B. A risk assessment of the probability and potential magnitude of future „slips‟ (landslides, rockfalls, debris falls etc. - see Appendix 1) that might block SH3 within the Gorge. The risk assessment shall also identify and rank any potential landslide sites in the future and provide a strategy to manage those identified risks. In undertaking this assessment, it will also be necessary to collate all (relevant) geological and geotechnical reports, maps and photos of previous landslides in the Manawatu Gorge and present them to NZTA in Palmerston North.

C. Identification of possible upgrades to alternative routes to the Manawatu Gorge that can be constructed within the next three years, so that they can provide an improved level of service during the times that the gorge is closed, particularly for long periods. For any construction works that are proposed a BCR and profile (Strategic Fit, Effectiveness and Efficiency) will also be provided (referred to as outcome (d)).

1.2 Purpose of study and tasks undertaken

This report presents an engineering geological assessment of the risk and potential magnitude of future landslides that might close SH3 within the Manawatu Gorge and fulfils the requirements of Outcome (B) of the proposed investigation outlined above. The report includes and expands the information presented in the 2011 review by GNS Science (GNS) of the geology and landsliding along SH3 in the Manawatu Gorge (Hancox 2011), which was included in the PFR Report by MWH and provided with the Request for Tender (RFT) for the Manawatu Gorge Alternative Route investigation (Contract Number: PSW198).

The February 2012 PFR report by MWH referred to 15 potential future landslide sites which were identified along SH3 within the Manawatu Gorge by Hancox (2011). The main purpose of this study is to investigate those landslide sites and also any other potential landslide sites identified during the search of historical data, aerial and ground geological inspections (as outlined below), assess the risk of future slope failures at those sites, and deliver a strategic plan to identify measures that would limit future landsliding problems in the gorge.

Our approach to understanding the development of past landslides and assessing the risk of future landsides in the Manawatu Gorge focusses initially on geological and geotechnical information on historical landslides that have affected SH3 through the gorge since the 1930s, and the relationships of those landslides to older (prehistoric) landslides in the area.

As outlined in MWH"s proposal to NZTA for this part (Outcome B) of the SH3 Manawatu Gorge Alternative Route investigation, the tasks that we have undertaken to assess the future landslide potential and risk to SH3 in the Manawatu Gorge have included:

(1) Collation and review of geology and geotechnical material (reports, plans, photos etc.) held by NZTA relating to landslide issues in the Manawatu Gorge.

(2) Helicopter inspection and high resolution oblique photography of Manawatu Gorge, particularly the historical landslide sites and 15 potential landslide sites identified in the PFR report. However, because of persistent bad weather this was not possible until 24 August 2012 in near-perfect conditions. In addition, we arranged for 14 new vertical aerial photos (with 60% overlap) of the gorge to be taken on the same day. Those photos were later ortho-rectified and used in GIS for the landslide assessment.

(3) Ground inspections along SH3 in the gorge from the Gorge Monument (RP488/1.05) to the Upper Gorge Bridge (RP491/4.10) to observe rock and soil types, old and recent landslide areas and stabilisation works, and potential future landslide areas.

(4) Preparation of GIS (Geographic Information System) maps of bedrock geology, areas of thick colluvium and old landslide deposits, prehistoric landslide scarps, slope angle and landslide susceptibility using 1 m ground contours processed from LiDAR flown on 29 September 2011.

(5) The geological data, old landslide records, recent aerial photography, and GIS maps were used to locate historical landslides in the Manawatu Gorge, and identify and map potential future landslide areas that could affect SH3 (done in GIS using LiDAR with overlays of geology, historical landslides, and slope angle and landslide susceptibility).

(6) The potential future landslide areas were then ranked according to their geological and geomorphic characteristics, and probable size and potential to close SH3 for periods ranging from a few hours or days to several months as occurred in 2004 and 2011-12.

(7) This information was then used to carry out a qualitative assessment of risk to SH3 from potential future landslide sites in the Manawatu Gorge using methods used for roads controlled by NZTA in New Zealand. The type, size, and likely triggering events for future failures at those sites are assessed and discussed.

(8) Our assessment will also considers indicative engineering methods and strategies to manage and reduce the consequences of future landslides in the gorge. This will involve consideration of the methods used to manage previous landslide that have closed SH3 and their effectiveness for today"s conditions.

Along with the recent knowledge obtained through stabilising the 2011 landslide, MWH have also gained valuable knowledge of the impact of landslides on both the pavements and supporting structures. Previously, the SH3 carriageway has been subject to widening schemes which have contributed towards slope and cut batter instability, a key contributing factor towards the issues we are trying to resolve today. Our report therefore also provides guidance on how to manage and minimise the impacts and consequences of landslides on this regionally strategic route in the future.

2.0 CHARACTERISTICS OF THE MANAWATU GORGE

2.1 Origin and geology of the gorge

The Manawatu Gorge which separates the Tararua Range from the Ruahine Range contains major road and rail links between the west and east coasts of the southern North Island. Figure 1 shows the regional geology and location of the gorge, and Figures 2 and 3 show the topography, geographic features and vegetation patterns in the area. Geomorphically the Manawatu Gorge is what is known as an antecedent gorge, having been formed by the west-flowing Manawatu River gradually cutting through the low point in the Tararua–Ruahine range as it rose slowly from the sea over the last ~1.5 million years (Stevens 1974).

The rock types exposed in the Manawatu Gorge are generally the same as those which form the adjacent Tararua and Ruahine Ranges (Figure 1). Typically these rocks comprise interbedded, indurated greywacke sandstone and argillite (mudstone) belonging to the Esk Head Belt of the Torlesse Supergroup (Triassic age, ~140–200 million years). The greywacke sequence through the gorge also contains thick bands and lenses of chert, limestone, submarine volcanics, red argillite, and limestone, within disrupted and highly deformed mélange zones (Lee and Begg 2002, Marden 1984).

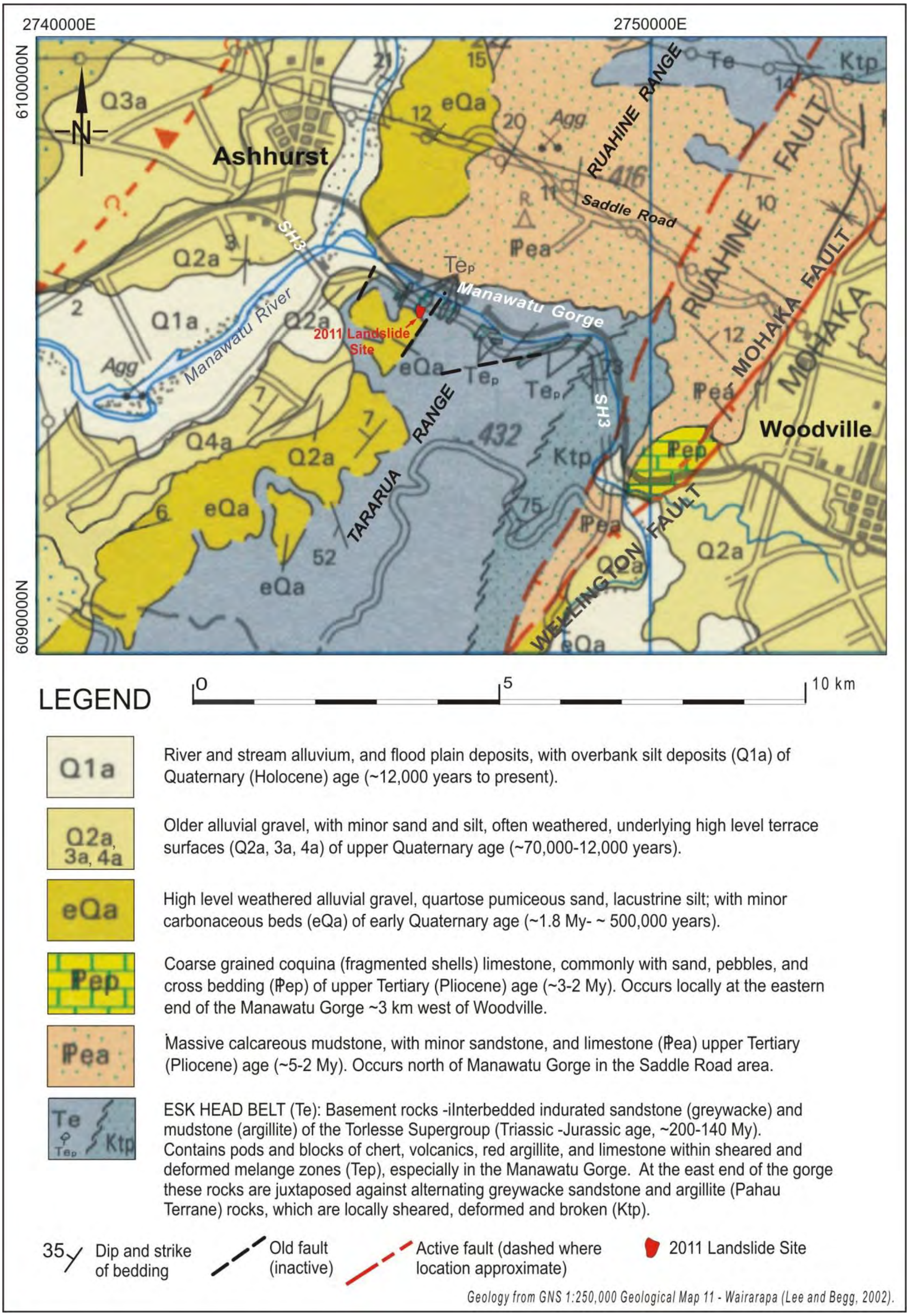
Figure 4 shows the distribution and bedding orientations of the main Torlesse rock types (lithozones) based on Marden‟s (1984) geological mapping through the Manawatu Gorge from the Gorge Monument to Balance Bridge. Bedding and foliation in the gorge generally strikes north to northeast and dips steeply (~55°–80°) to the east and southeast. In many places thick bands of sandstone that strike across the river form steep bluffs on both the sides of the gorge. Adjacent lithozones of weaker argillite have been more eroded by side streams (Figure 5). The active northeast-striking Wellington-Mohaka Fault and the Ruahine Fault (Figure 1) are located at the east end of the gorge, ~5 km west of Woodville (Lee and Begg 2002). Several inactive old faults are mapped within the gorge, which locally causes shattering of the rock mass, making it more susceptible to landsliding (Figure 4).

The smooth top of the Ruahine Range north of the gorge and the Tararua Range to the south represent an old erosion surface on which thick marine sediments and alluvial gravels of Pliocene and early Quaternary age (2.5–0.5 My) occur in the Saddle Road area. Colluvium and old landslide deposits mantle the sides of the gorge, and remnants of early Quaternary alluvial deposits are present on upper slopes at the western end (see Figures 1 and 5).

2.2 Topography

Rising to an elevation of around 350 m north and south of the Manawatu Gorge the Ruahine and Tararua ranges have broad flat-topped crests, on which wind farms have recently been established. The cleft of the gorge is roughly 1 km wide and 6 km long, within which the Manawatu River follows a winding westerly course through the range between Woodville and Ashhurst. Slopes on either side of the gorge rise to 250–300 m above river level (Figure 2).

The lower slopes of the gorge are generally steep (35°–45°) to very steep (45°–60° or greater), particularly in the central and western sections, with near-vertical sandstone bluffs and faces present in many places. The slopes along SH3 are generally very steep (>°–60°) mainly due to the cutting back the toe of the slope along SH3, as shown by the slope angle map prepared in GIS using 1 m contour data in the LiDAR digital elevation model (Figure 6). Towards the eastern end of the gorge the slopes are underlain by thick colluvial deposits and are generally less steep (moderate, 20°–35°) as shown in Figures 5 and 6.



LEGEND

Q1a	River and stream alluvium, and flood plain deposits, with overbank silt deposits (Q1a) of Quaternary (Holocene) age (~12,000 years to present).
Q2a, 3a, 4a	Older alluvial gravel, with minor sand and silt, often weathered, underlying high level terrace surfaces (Q2a, 3a, 4a) of upper Quaternary age (~70,000-12,000 years).
eQa	High level weathered alluvial gravel, quartose pumiceous sand, lacustrine silt; with minor carbonaceous beds (eQa) of early Quaternary age (~1.8 My- ~ 500,000 years).
Ᵽep	Coarse grained coquina (fragmented shells) limestone, commonly with sand, pebbles, and cross bedding (Ᵽep) of upper Tertiary (Pliocene) age (~3-2 My). Occurs locally at the eastern end of the Manawatu Gorge ~3 km west of Woodville.
Ᵽea	Massive calcareous mudstone, with minor sandstone, and limestone (Ᵽea) upper Tertiary (Pliocene) age (~5-2 My). Occurs north of Manawatu Gorge in the Saddle Road area.
Te Tep Ktp	ESK HEAD BELT (Te): Basement rocks -iInterbedded indurated sandstone (greywacke) and mudstone (argillite) of the Torlesse Supergroup (Triassic -Jurassic age, ~200-140 My). Contains pods and blocks of chert, volcanics, red argillite, and limestone within sheared and deformed melange zones (Tep), especially in the Manawatu Gorge. At the east end of the gorge these rocks are juxtaposed against alternating greywacke sandstone and argillite (Pahau Terrane) rocks, which are locally sheared, deformed and broken (Ktp).

35 Dip and strike of bedding

Old fault (inactive)

Active fault (dashed where location approximate)

2011 Landslide Site

Geology from GNS 1:250,000 Geological Map 11 - Wairarapa (Lee and Begg, 2002).

Figure 1. Geological map of the Manawatu Gorge area showing the 2011 landslide blocking SH3 at the western end of the gorge and other features discussed in the report (*after Lee and Begg 2002*

Most of the slopes of the gorge are covered in mature native forest comprising mainly tawa and podocarp species, intermixed with large nikau palms. Areas of lighter coloured younger forest and scrub are evident on many lower slopes of the gorge which have probably been affected by past landslide activity (Figure 3). The relative age and maturity of these trees gives a broad indication of the minimum age of last activity of these landslides.

State Highway 3 is located on a cut bench on the left bank of the gorge (as viewed facing downstream) about 20 m above river level. Numerous steep road cuttings and „half-bridges" have been used to establish the road, particularly where the gorge slopes are very steep. West of Barney‟s Point (~2.5 km from the eastern end of the gorge, where the north-flowing Manawatu River takes a right-angle bend to the west, Figure 2) the north-facing slopes along SH3 generally have cut batters 2 to 10 m high, with typical batter angles ranging from about 65° (½ to 1) to 75° (¼ to 1) in rock, to 40-45° (~1 to 1) in colluvium.

East of Barney‟s Point the colluvium-dominated slopes are generally less steep with fewer high cuttings. Cut slopes immediately adjacent to SH3 generally slope at about 40°, flattening off to around 25–30° about 15 to 20 m above road level (Figure 6).

3.0 LANDSLIDING IN THE MANAWATU GORGE

3.1 Prehistoric landslides

Geomorphic studies of aerial photos, 1:5000 scale topographic maps, and recent LiDAR imagery has enabled evidence of many large prehistoric landslides to be identified on the upper slopes and sides of the Manawatu Gorge. Many of these features were originally shown on Figure 4a and 4b of Appendix I (Perrin and Hancox 2000) in the SH3 Manawatu Gorge Scoping Study in 2001 (Beca 2001). The 2011 LiDAR has enabled them to be mapped more accurately. In this report the scars and scarps of prehistoric landslides on the southern and (upstream of Barney‟s Point) western sides of the Manawatu Gorge are shown on a hill-shaded LiDAR image in Figure 5, together with areas of thick colluvium and old landslide deposits, bluffs, and other key features along SH3 in the gorge.

Most of the prehistoric scarps are subtle bush-covered geomorphic features, which are inferred to have been formed during the cutting of the gorge over the last ~500,000 years. Although none of these landslides has active scarps, they are clearly distinguishable on the LiDAR imagery by their rounded arcuate head scarps and deflated areas filled with old slide debris and colluvium. Areas of colluvium are exposed in many of the road cuts along SH3 on the south side of the gorge, in places forming a mantle more than 10 m thick overlying bedrock. Several prehistoric landslides are present in the area of the 2011 landslide.

The prehistoric landslide on the slope above the 2011 landslide is clearly evident on the LiDAR image (Figure 7) and an oblique aerial photo of the 2011 landslide (Figure 8). Our studies of the 2011 landslide have shown that the prehistoric landslides and areas of thick colluvium have played a major role in the development of the recent slope failure. This relationship between prehistoric and historical landslides in the gorge is also evident at other recent landslide sites along SH3, especially at several large failures which occurred during the February 2004 rainstorm (Figure 9). As will be discussed later, that was one of the main factors used in this study for the identification of potential future landslide areas in the gorge.

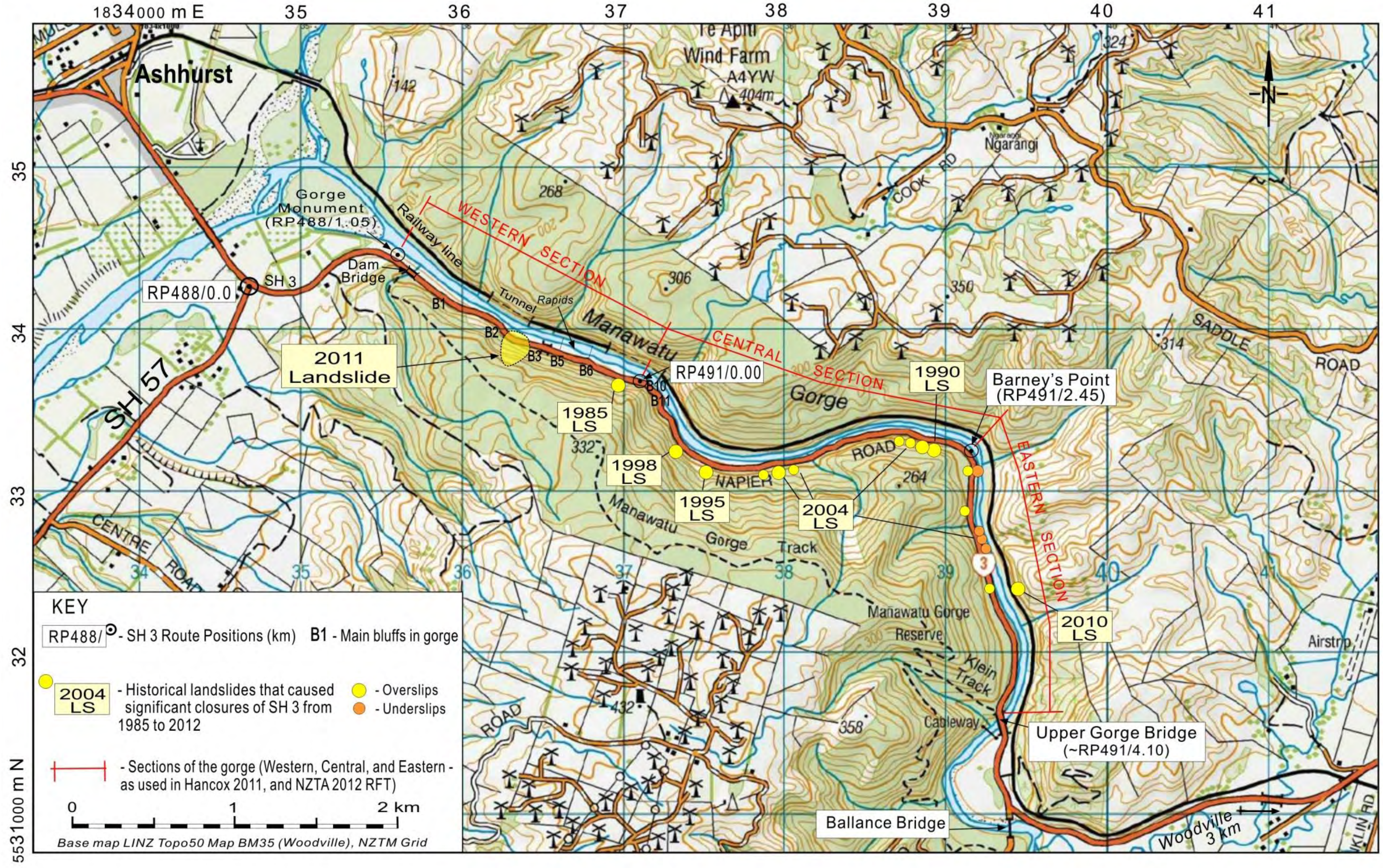


Figure 2. Topographic map of the Manawatu Gorge showing key SH3 Route Positions (RP), sections of the gorge (as used in this report), and the locations of historical landslides that have closed SH3 for significant periods (more than 1–2 days) since 1985.

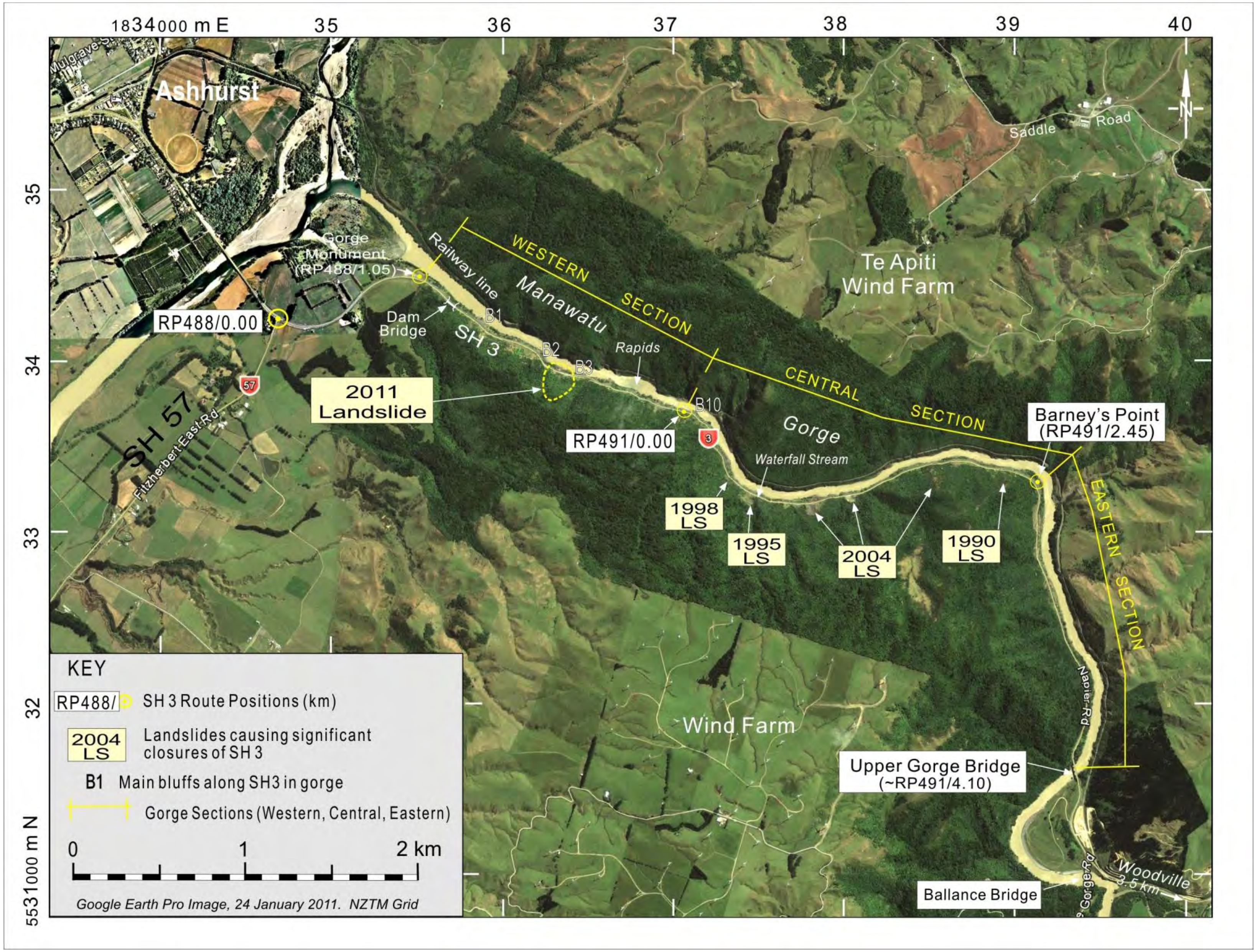
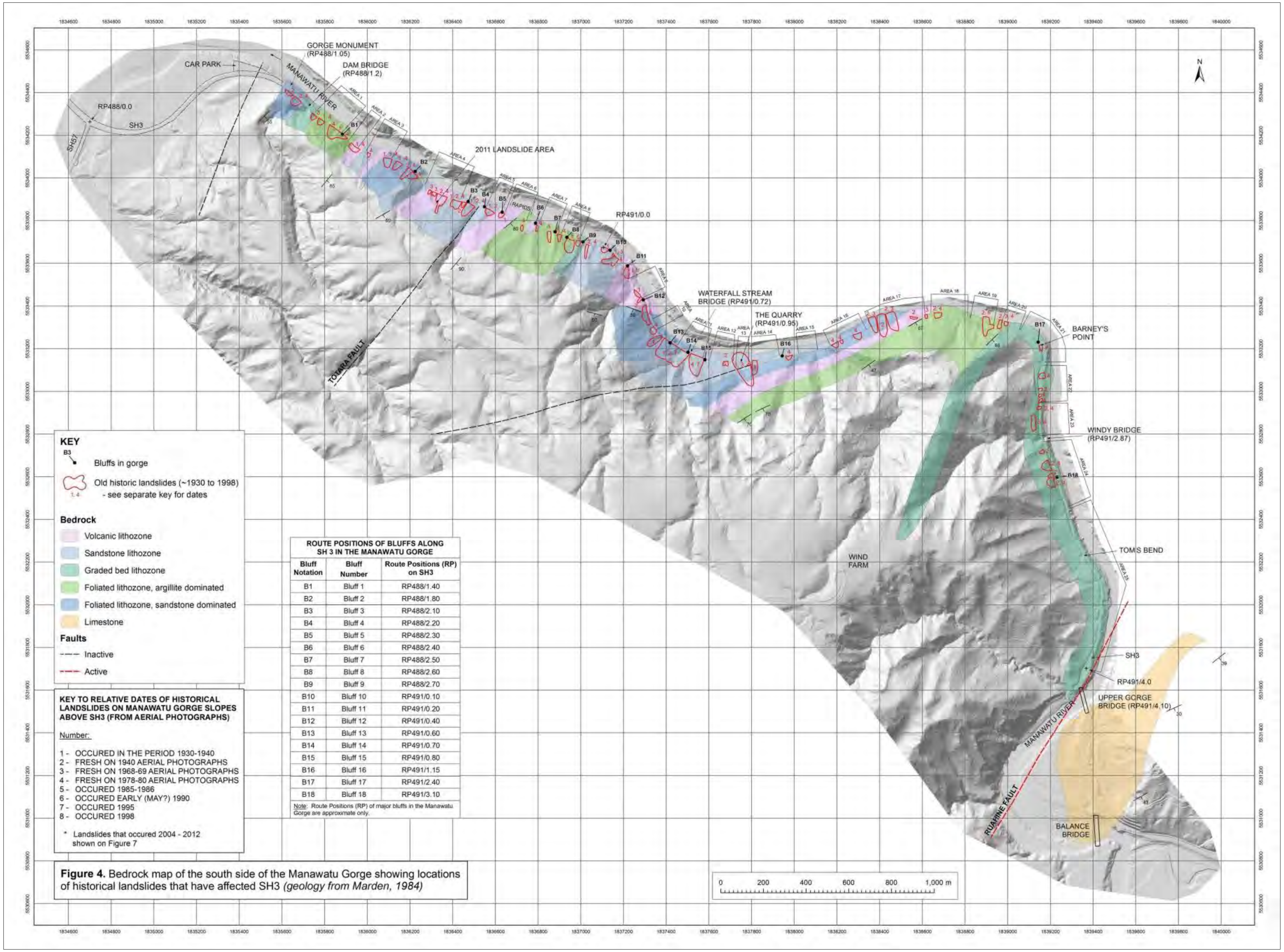


Figure 3. Annotated Google Earth Pro image of the Manawatu Gorge showing vegetation, landslides, and other geomorphic features discussed in the report.



KEY

B3 Bluffs in gorge

Old historic landslides (~1930 to 1998) - see separate key for dates

Bedrock

Volcanic lithozone
Sandstone lithozone
Graded bed lithozone
Foliated lithozone, argillite dominated
Foliated lithozone, sandstone dominated
Limestone

Faults

Inactive
Active

KEY TO RELATIVE DATES OF HISTORICAL LANDSLIDES ON MANAWATU GORGE SLOPES ABOVE SH3 (FROM AERIAL PHOTOGRAPHS)

Number:

1 - OCCURED IN THE PERIOD 1930-1940
2 - FRESH ON 1940 AERIAL PHOTOGRAPHS
3 - FRESH ON 1968-69 AERIAL PHOTOGRAPHS
4 - FRESH ON 1978-80 AERIAL PHOTOGRAPHS
5 - OCCURED 1985-1986
6 - OCCURED EARLY (MAY?) 1990
7 - OCCURED 1995
8 - OCCURED 1998

* Landslides that occured 2004 - 2012 shown on Figure 7

ROUTE POSITIONS OF BLUFFS ALONG SH 3 IN THE MANAWATU GORGE

Bluff Notation	Bluff Number	Route Positions (RP) on SH3
B1	Bluff 1	RP488/1.40
B2	Bluff 2	RP488/1.80
B3	Bluff 3	RP488/2.10
B4	Bluff 4	RP488/2.20
B5	Bluff 5	RP488/2.30
B6	Bluff 6	RP488/2.40
B7	Bluff 7	RP488/2.50
B8	Bluff 8	RP488/2.60
B9	Bluff 9	RP488/2.70
B10	Bluff 10	RP491/0.10
B11	Bluff 11	RP491/0.20
B12	Bluff 12	RP491/0.40
B13	Bluff 13	RP491/0.60
B14	Bluff 14	RP491/0.70
B15	Bluff 15	RP491/0.80
B16	Bluff 16	RP491/1.15
B17	Bluff 17	RP491/2.40
B18	Bluff 18	RP491/3.10

Note: Route Positions (RP) of major bluffs in the Manawatu Gorge are approximate only.

Figure 4. Bedrock map of the south side of the Manawatu Gorge showing locations of historical landslides that have affected SH3 *(geology from Marden, 1984) [A1- in pocket at back of report]*

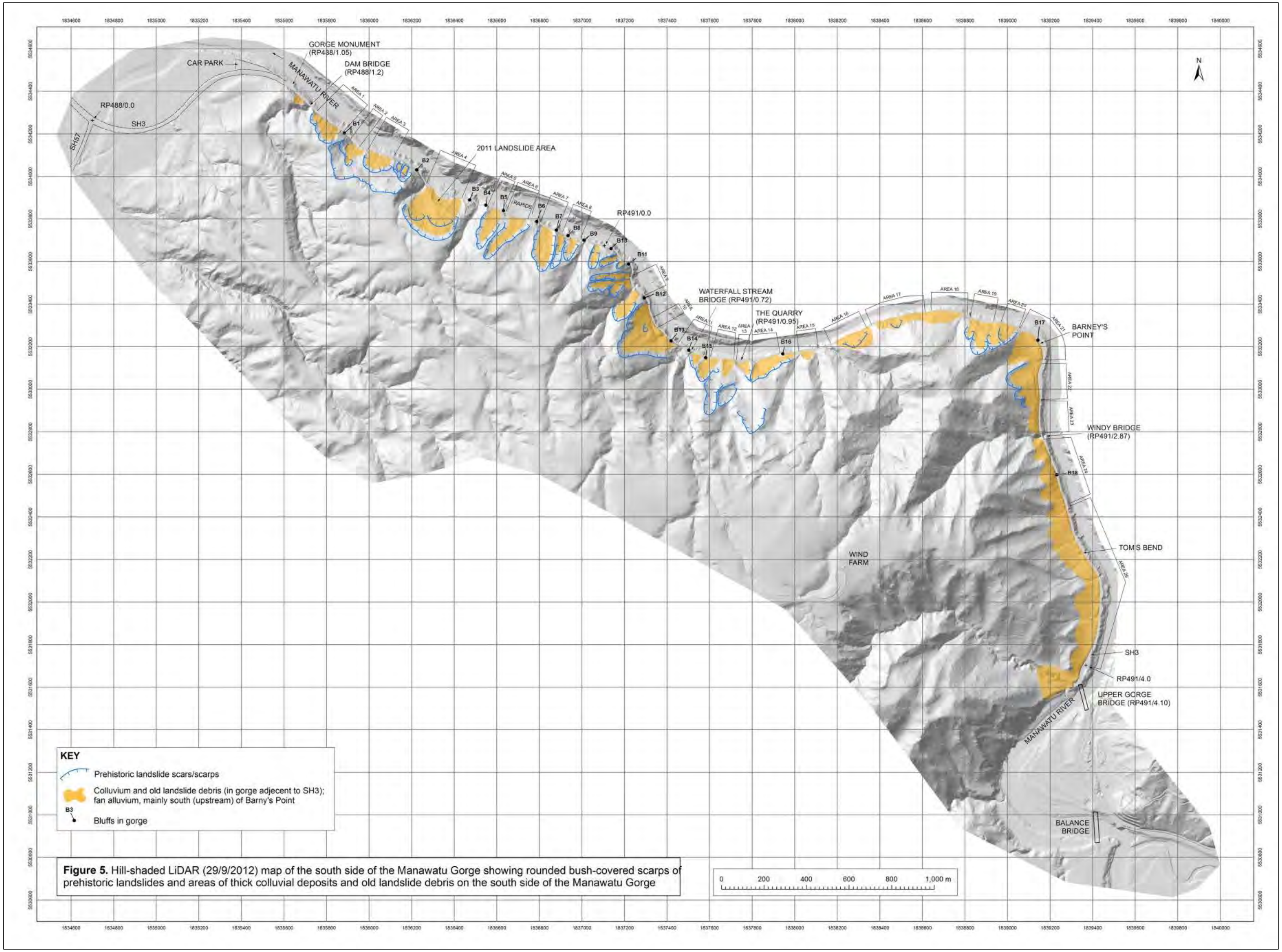


Figure 5. Hill-shaded LiDAR (29/9/2011) map of the south side of the Manawatu Gorge showing rounded bush-covered scarps of prehistoric landsides and areas of thick colluvial deposits and old landslide debris on the south side of the Manawatu Gorge. *[A1- in pocket at back of report]*

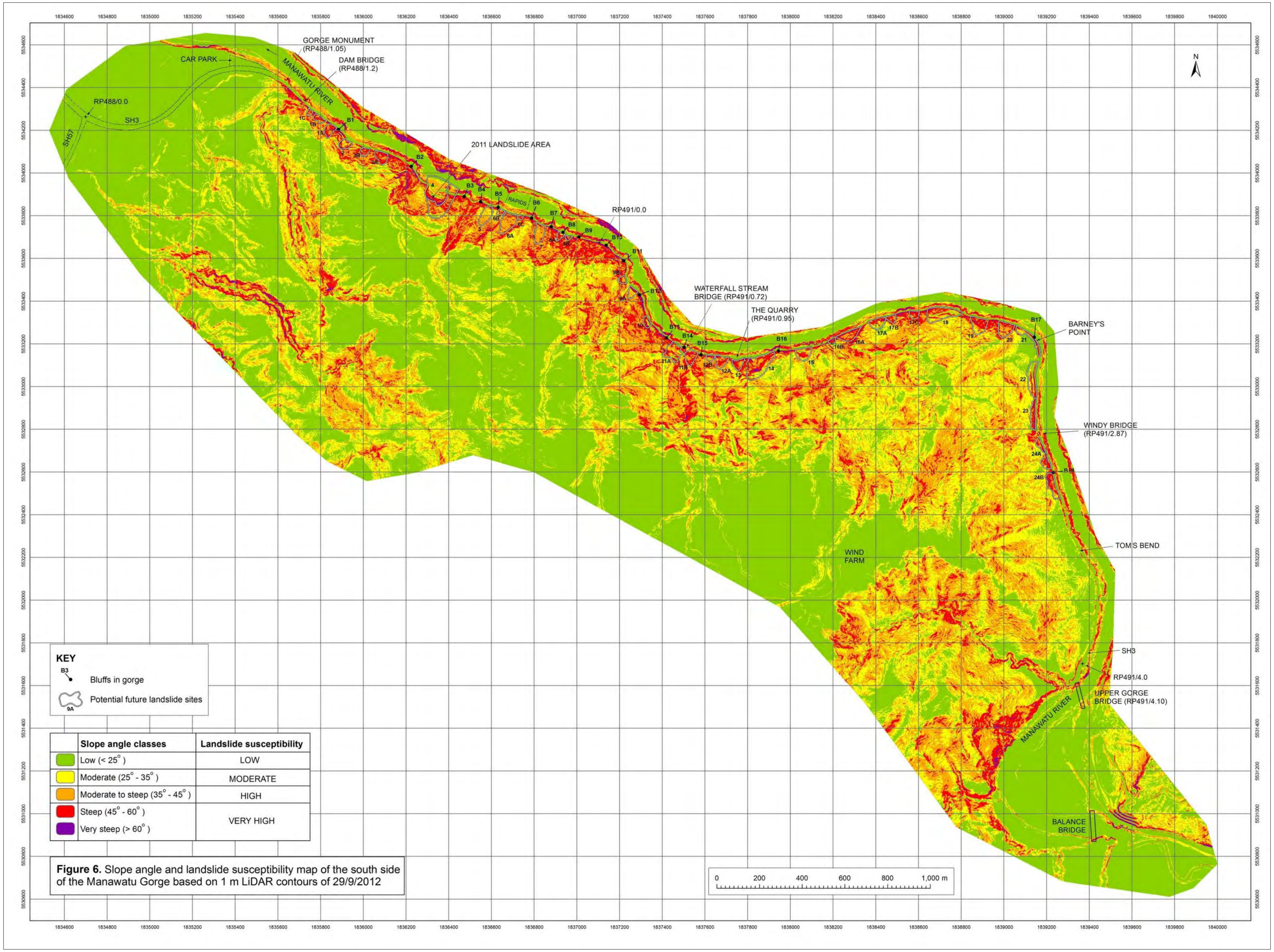


Figure 6. Slope angle and landslide susceptibility map of the south side of the Manawatu Gorge based on 1 m LiDAR contours of 29/9/2011.
[A1- in pocket at back of report]

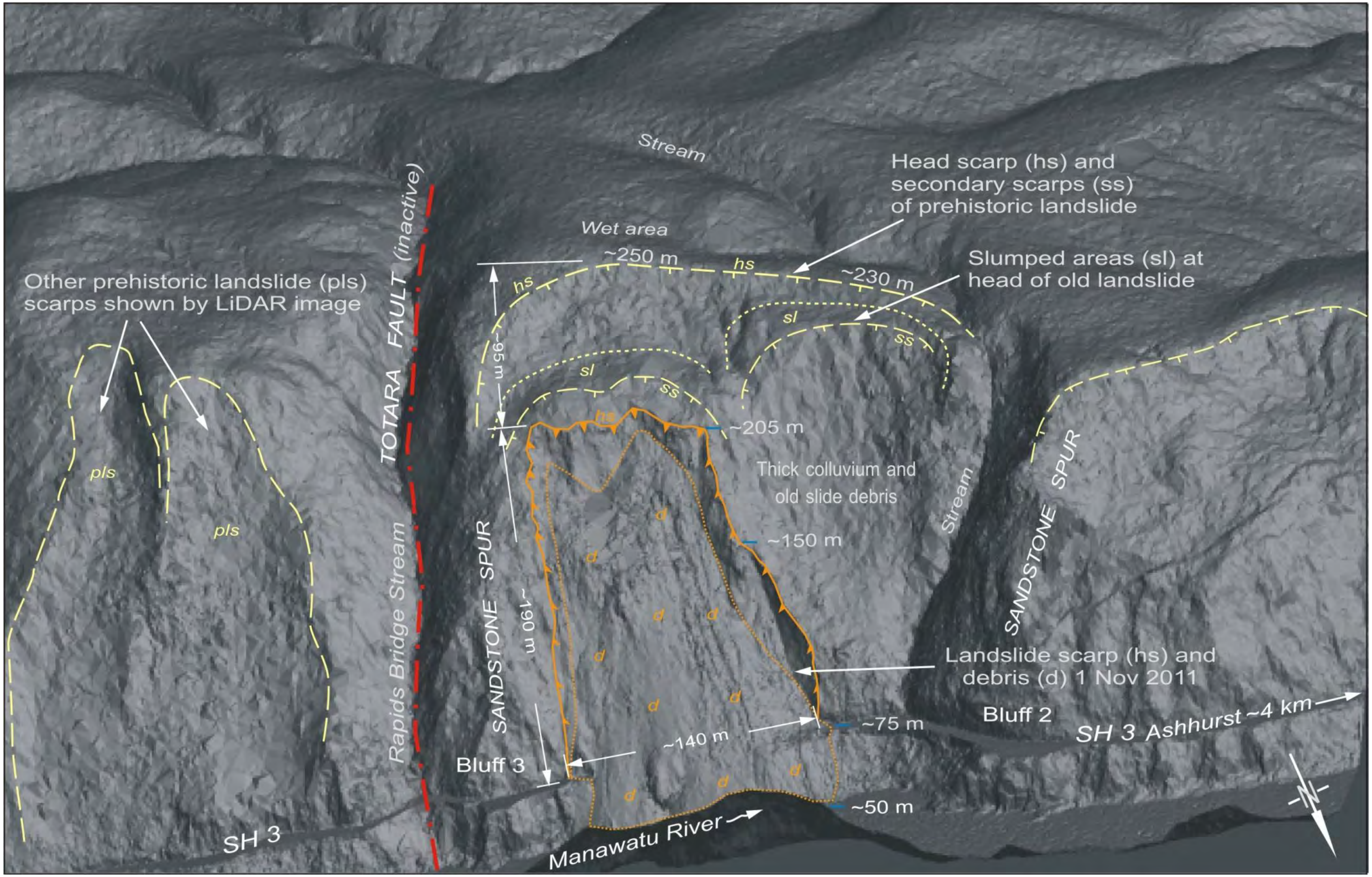


Figure 7. Annotated oblique aerial photo of the 2011 landslide in the Manawatu Gorge showing the headscarp *(hs)*, debris *(d)*, and dimensions of the 18 October 2011 failure, which is located between two sandstone spurs *(Bluffs 2 and 3)* on the lower slopes of a large prehistoric landslide.

Figure 8. Oblique aerial photo of the 2011 landslide in the Manawatu Gorge showing the headscarp *(hs)*, slide debris *(d)*, and extent of the 18 October 2011 failure located between two sandstone spurs *(Bluffs 2 and 3)* on the lower slopes of a large prehistoric landslide *(compare with 2000 photo of site, Figure 12)*.

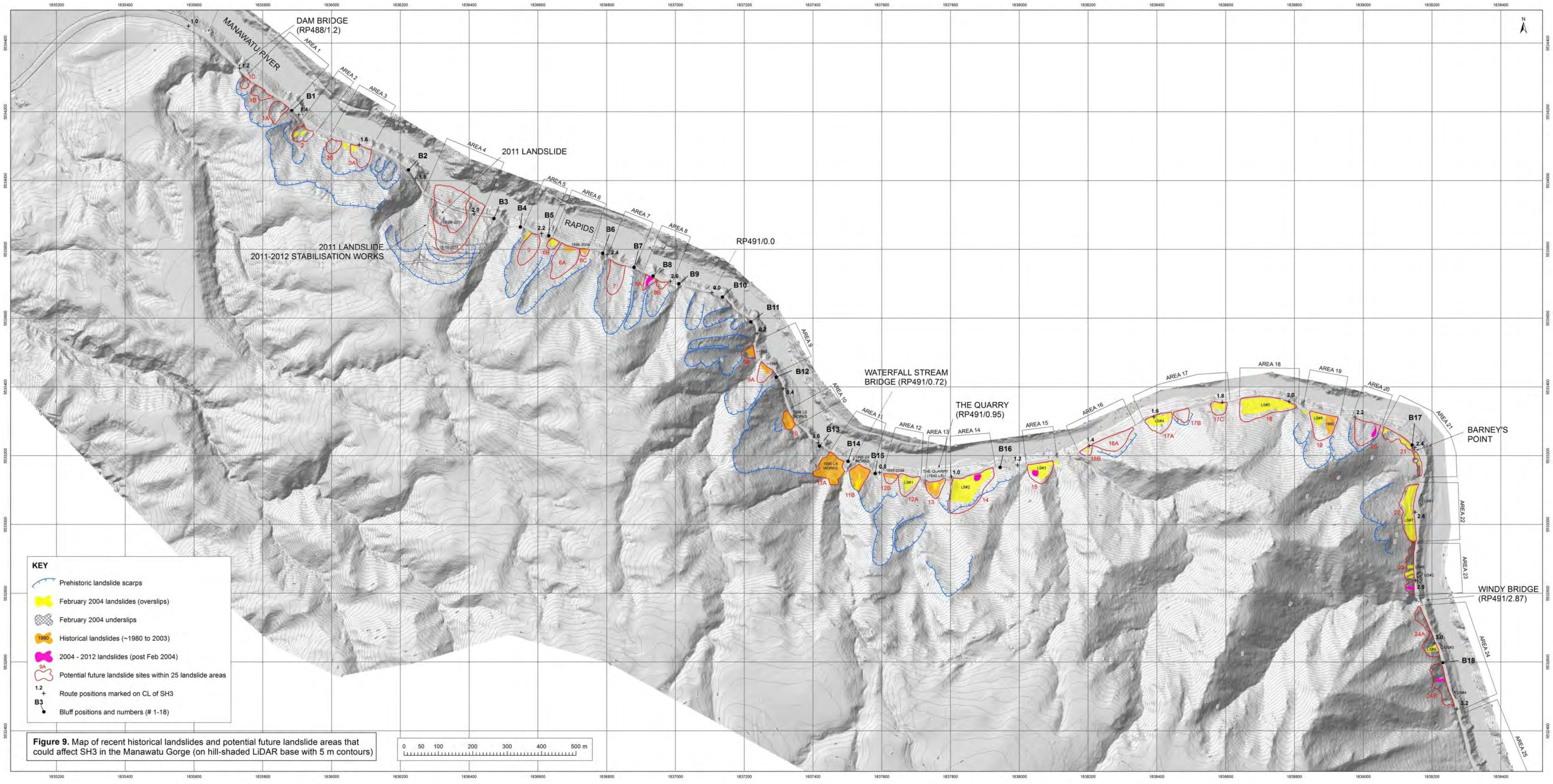


Figure 9. Map of recent historical landslides and potential future landslide areas that could affect SH3 in the Manawatu Gorge *(plotted on hill-shaded LiDAR base with 5 m contours)*.

Figure 9a. Map of recent historical landslides and potential future landslide areas that could affect SH3 in the Manawatu Gorge *(plotted on base of vertical aerial photos taken on 24 August 2012, with 5 m LiDAR contours)*.

Areas of lighter-coloured younger forest on the lower slopes of some of these features on the south side of the gorge (see Figures 3 and 8) suggest that some of these old landslides might have been active as recently as ~150 years ago, perhaps during the 1855 earthquake (Grapes and Downes 1997, Hancox et al 1997, Hancox 2005). The rapids and change in river gradient near the western end of the gorge (between Bluff 5 and Bluff 6, Figure 5) are believed to have been formed by large boulders from an old historic landslide from the south side of the gorge, possibly during the 1855 earthquake.

The toes of several of these ancient landslides have been cut back by the establishment and widening of SH3 through the gorge in the 1960s and 1980s, and hence as at the site of the present failure they are likely to have contributed to the development of other significant historical landslides that have closed the gorge road in the past.

3.2 Historical landslides in the gorge

Excavations for the establishment and widening of SH3 on the southern side of the Manawatu Gorge have cut back and oversteepened the toes of slopes, resulting in rock falls and landslides that have affected or closed the road in many places over the last 50 years. The road through the gorge was first completed as a narrow track in 1872. The road was widened in the 1920s to the 1940s, and again in the 1960s and 1980s.

Since the widening of the gorge road began it has frequently been closed by slips, especially during or following heavy rainfall. Most of the slope failures in the gorge appear to have been related to the road-widening works. By contrast, the railway line on the northern side of the gorge, which was completed in 1891, has been much less affected by landslide problems, probably because of the lower cuts required for the railway, and the use of tunnels to bypass some steeper sections of the gorge on the north side of the river.

Between 1924 and 1929 major works were carried out to upgrade and widen the gorge road to highway standard. Further major excavations were later carried out in the late 1960s and between 1977 and 1981 at two sandstone bluffs near the western exit of the gorge, namely: Bluff No 1 at (Route Position) RP488/1.40 (km), and Bluff No 2 at RP488/1.80 (Figure 4). The rock types forming the bluffs comprise slightly weathered blocky-jointed sandstone. The areas between the bluffs are generally composed of weaker foliated and sheared and volcanic lithozone rocks (red argillite), overlain by thick deposits of potentially unstable colluvium (Figures 4 and 5). This relationship was most recently illustrated by the 2011 landslide that closed the gorge road closed from 18 August 2011 to 19 September 2012. The 2011 landslide occurred in colluvium and old slide debris at the toe of a large prehistoric landslide between Bluff 2 (RP488/1.80) and Bluff 3 (RP488/2.10) 60 m downstream from the Rapids Bridge (Figure 8). Small shallow slips occurred in this area following road widening in the 1930s, 1940s and late 1960s (Figure 4). The initial small debris fall that evolved into a major failure extending 130 m above road level occurred in September 2010 (Figure 12).

Widening of SH 3 in the Manawatu Gorge continued during the 1980s with the trimming back of 15 strong jointed sandstone bluffs located between Bluff 1 at western end (RP 488/1.40) and Bluff 15 (RP 491/0.80) in the centre of the gorge near Waterfall Stream (Figure 4). These works caused small to moderate sized rock falls and colluvial debris falls in a number of places, often requiring rock bolting, mesh, and drainage drilling stabilisation measures (Perrin 1985). The first significant (road-closing) slope failure reported in the gorge occurred in January 1990 near Barney"s Point (RP491/2.45, Figures 4 and 9) when a ~5,000 m^3 landslide occurred at ~RP491/2.15, closing the gorge road for 8 days (Worley 1998).

Significant large slope failures occurred in the central section of the gorge in 1995 and 1998. These involved mainly colluvium and weathered bedrock in areas adjacent to rock bluffs where the toe of steep (45°–60°) marginally stable slopes were destabilised by works to widen the gorge road in the 1960s and 1980s. In most cases the slope failures began as small rainfall-induced falls of colluvium and weathered rock following toe cutting, followed by lateral and upslope regression of the initial scarps.

During an exceptionally wet winter in 1995 three separate landslides (involving a total of ~100,000 m^3) occurred on slopes up to 100 m high in the centre of the gorge between RP491/0.60 and 491/0.80 (Figure 9 and 9a), closing SH 3 for 67 days between July and November 1995 while extensive stabilisation works were carried out (Worley 1996). These failures were clearly related to the cutting back of the toe of the slope in the 1980s. Remedial works subsequently carried out at this site included sluicing, benching and removal of failure debris, drainage drilling, and installation of mesh on the upper slopes.

A smaller (4,500 m^3) landslide occurred in July 1998 between RP491/0.46–0.52, ~120 m downstream of the 1995 failure (Figure 9), closing SH3 for 7 days while stabilisation works were carried out. These remedial measures involved sluicing of loose debris, benching, drainage drilling, and construction of a 10 m high gabion wall at the toe of the unstable slope above SH3 (Worley 1998).

3.2.1 Landslides caused by the February 2004 Rainstorm

The most recent episode of multiple landslides in the Manawatu Gorge occurred during the February 2004 rainstorm, which caused flooding and landsliding over about 16,000 km^2 of the southern North Island (Hancox and Wright 2004, Horizons Regional Council 2004). During the peak of the storm about 200 mm of rain fell in the Manawatu Gorge area over the 24 hours to 9 am on 16 February 2004 (New Zealand Metrological Service 2004). It was arguably the worst storm to hit the area in the last 50 years, causing record flood levels in many rivers. Within the gorge the peak flood scour level of the river was 13 m above normal, about 7 m below road level.

The prolonged high intensity rainfall spread over 2–3 days caused extensive landsliding through most of the Manawatu Gorge, with 9 large overslips and at least 30 smaller (minor) overslips in the ~3 km section of the gorge between Waterfall Stream (~RP 491/0.70) and Upper Gorge Bridge (RP491/4.10, see Figures 4, 9, and 10). The largest of the overslip landslides was a ~70,000–100,000 m^3 failure of colluvium and weathered red argillite at ~RP491/1.05, which closed the gorge road for 70 days (MWH 2004). Three of the largest 2004 landslides (#1, #2, and #3) were in the central section of the gorge that was affected by landsliding in the 1990s. Figure 11 shows the same area in January 2000, highlighting the significant damage caused by the 2004 rainstorm, which has left the area more vulnerable to future slope failures. However, no failures occurred at the 2011 landslide site in February 2004, and only minor instability was evident in January 2000 (see Figures 8 and 12).

On the Woodville side of Barney"s Point a number of significant underslips requiring remedial works occurred between RP492/2.55 to RP492/3.90 (Figure 9). Most of the underslip failures can be attributed to the collapse of soils and road-edge fills saturated by the heavy rainfall, as well as erosional undercutting by the river at near record high flood level.

Figure 10. Oblique aerial photo of the central section of the Manawatu Gorge from ~RP491/0.60–1.30 showing the area of the 1995 landslide works, the „Quarry" where small landslides occurred in 1940 and the 1960s, and three of the largest landslides (#1, #2, and #3) which occurred during the February 2004 rainstorm. The largest failure (#2) closed SH3 for over two months. Small failures *(sf)* have occurred on the scars of landslides #2 and #3 in the last 12 months.

Figure 11. January 2000 photo of the 1995-1998 landslide works and „Quarry" in the Manawatu Gorge showing the areas *(1a, 2a, 3a)* where landslides #1, #2, and #3 occurred in February 2004. A shallow debris slide occurred at the landslide #2 site during the 1960s (note the young vegetation*****).

Figure 12. January 2000 photo of the 2011 landslide area, which developed on a slope underlain by thick colluvium deposits between bluffs of strong sandstone (B2, B3) in the Manawatu Gorge. The lower part of 2011 landslide area is sparsely vegetated because of shallow failures 1930-1940 and 1968-69 *(compare with Figures 8 and 23)*.

3.2.2 Distribution and frequency of historical landsliding in the gorge

Following the landslide problems in the Manawatu Gorge in the 1990s, an assessment in 1998 by Worley Consultants Limited for Transit New Zealand concluded that *"large scale slope failure events are common in the gorge"…, and "estimated that a 5,000 m^3 to 20,000 m^3 event is likely to occur on average once every 3 to 5 years.* The frequency of larger landslides (20,000–500,000 m^3) was found to be uncertain, but a conservative estimate of once every 50 years was suggested based on the history of large slope failures in the gorge through the 1990s (Worley Consultants 1998).

Although Worley Consultants (1998) estimated that the risk of a large scale landslide in the gorge was „generally low‟ based on the limited information available at that time, they pointed out that a comprehensive inspection of the gorge at road level and from the air was required if the level of landslide risk in the gorge was to be better defined.

The records of historical landslides in the Manawatu Gorge from the 1940s to the present day and especially since 1980 (Table 1) suggest, however, that large-scale landsliding in the gorge may occur more frequently than once every 50 years. The potential for larger landslides that cause closures of SH3 is clearly greatest in the western and central sections of the gorge (RP488/1.0 to RP491/2.45), mainly because of the steeper slopes above SH3 (Figure 6) and cutting back of the slope to widen the road during the 1960s and 1980s.

Table 1. Historical landslides that have affected or closed SH 3 in the Manawatu Gorge.

Historical Landslide Occurrence[2]	**Significant Historical Landslides in the Manawatu Gorge[1]**		
	Gorge Monument (RP488/1.05)[3]	**Bluff 10 (RP491/0.10)**	**Barney's Point (RP491/2.45)** **Upper Gorge Bridge (RP491/.4.10)**
	Western Section[3] (1.8 km)	**Central Section** (2.35 km)	**Eastern Section** (1.65 km)
1. Pre ~1930-1940 (on 1940 aerial photos)	13	9	-
2. Fresh on 1940 aerial photos	9	12	6
3. Fresh on 1968-1969 aerial photos	4	7	1
4. Fresh on 1978-1980 aerial photos	19	11	6
5. 1985-86	1 (closed 2 days)	-	-
6. 1990	-	1 (closed 8 days)	-
7. 1995	-	3 (closed 67 days)	
8. 1998	-	1 (closed 7days)	
9. February 2004	7	14 (closed 70 days)	7 (closed ~1-3 days)
10. Aug 2011-Sep 2012	1 (closed ~360 days)	-	-
11. others 2004–2012	1	3	2
Total landslides (slides/km)	55 (30/km)	61 (26/km)	22 (13/km)

Notes:
1. Landslide locations based on mapping by Perrin and Hancox 2000 and this study (Figures 4 and 9).
2. Route Positions (RP, km) of landslides and Sections of the gorge used in this report.
3. Sections of the gorge are shown on Figures 2 and 3.

The historical landslide data presented in Table 1 and Figures 4 and 9 shows that there have been more landslides in the steeper western and central sections of the gorge than there have been upstream of Barney"s Point. All of the larger overslip landslides that have caused long-term closures of SH3 are located in the central and western sections of the gorge. The five underslips that occurred in the eastern section of the gorge during the 2004 storm also had the potential to close the road for a several days.

3.3 Earthquake-induced landsliding in the gorge

Although there is limited historical evidence of earthquake-induced landsliding in the Manawatu Gorge, strong earthquake shaking (intensity MM8 or greater) associated with a potential magnitude 7.5 earthquake on the nearby Wellington-Mohaka Fault could potentially trigger large landslides in the gorge and severely damage the road. Recent studies of earthquake-induced landslides in New Zealand (Hancox et al. 1997, 2002) have shown that shaking of Modified Mercalli (MM) intensity MM 6 generally causes very small ($\leq 10^3$ m^3) soil (earth/debris) and rock falls on steep slopes and cuts. At intensity MM7 (peak ground acceleration (PGA) ~0.1–0.3 g) small rock falls from steep slopes and cuts are common, with a few small to moderately large landslides (10^3–10^5 m^3). Larger landslides (10^5–10^6 m^3 or greater) generally occur at MM8 or greater (PGA ~0.2 –0.5 g or >, see Appendix 2).

Over the last 170 years the Manawatu Gorge area has been affected by ~MM7 or greater shaking on three occasions. The most reliable reports of earthquakes causing landslides in the gorge are of small isolated rock falls in the Manawatu Gorge (at MM7) during the Ms 7.6 Pahiatua earthquake in 1934, and isolated boulders falling on the gorge road (at MM6-7) during the Mw 7.2 Masterton earthquake in June 1942 (Hancox et al. 1997, Downes et al. 2001).

Historically, the strongest earthquake shaking that has affected the Manawatu Gorge occurred during the 1855 magnitude 8.2 Wairarapa earthquake which is believed to have caused MM8 shaking in the Woodville to Palmerston North area (Grapes and Downes 1997, Hancox et al.1997). Shaking of that intensity would have triggered landslides on both sides of the gorge. The large boulders which form rapids in the gorge between Bluffs 5 and 6 (Figures 9 and 11) are thought to be the remains of a large landslide from the south side of the gorge, which may have occurred during the 1855 earthquake.

3.3.1 Modelled recurrence of strong ground shaking

Using the NZ probabilistic seismic hazard model (Stirling *et al.* 2002), recurrence intervals of strong ground shaking of MM intensities can be calculated. The model predicts that MM7 shaking, the threshold to trigger significant landslides, will occur in the Palmerston North to Manawatu Gorge area on average every 30 years (Table 2). The return time for MM8 shaking (equivalent to the 1855 earthquake), the intensity at which large to very large landslides can be expected, is about 125 years (annual probability ~0.008 or 8 x 10^{-3}).

Table 2. Recurrence intervals of MM intensities in the Palmerston North–Manawatu Gorge area.

Modelled MM Intensity Recurrence Intervals						
MM Intensity	5	6	7	8	9	10
Return Period (yrs)	3	10	30	125	700	14,000

Note: MMI return periods calculated by N. Pondard (GNS Science, Lower Hutt using a model developed by W. Smith from the probabilistic seismic hazard model of Stirling et al. 2002.

3.3.2 Potential for future earthquake-induced landslides

A future ~M 7.5 earthquake on the Wellington-Mohaka Fault at the eastern end of the Manawatu Gorge (Figure 1) or another nearby active fault (see Figure 13) is likely to generate very strong shaking (MM8-10) in the Manawatu Gorge. Shaking of intensity MM8 or greater is likely to trigger large and very large (1 Mm^3 or >) landslides on both sides of the gorge. Very large landslides could potentially dam the Manawatu River and have catastrophic effects on SH3, possibly causing closure of the road for up to 1 year or longer.

Typically, landslides and rock falls triggered by strong earthquake shaking (Appendix 2) are larger and more numerous than the rather shallow earth and debris falls (Appendix 1) of colluvium and regolith triggered by rainstorms, such as those which occurred in the gorge during the 2004 rainstorm. Earthquake shaking is likely to be amplified on steep slopes and bluffs within the gorge, possibly by at least 1–1½ intensity units. This could cause large slope failures, not only of oversteepened (cut-back) toes of colluvial slopes, but also from steep rock bluffs along SH3. As was demonstrated during the February 2004 storm, steep rock slopes in the gorge are less affected by heavy rainfall. The potential sites of future rainfall and earthquake-induced landslides in the gorge are discussed in more detail in Section 4.

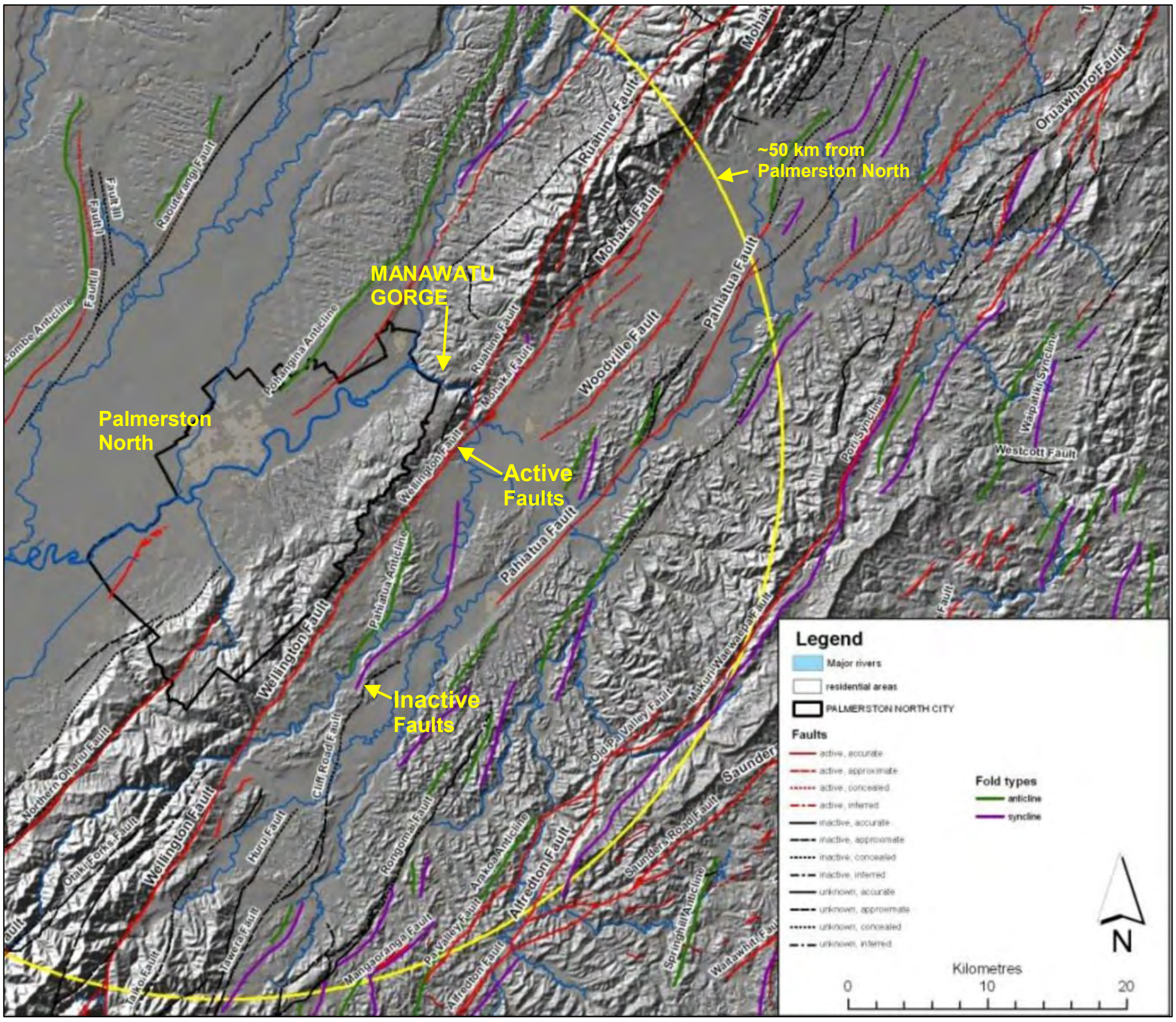


Figure 13. Active faults (red lines) in the Manawatu Gorge area which could generate large earthquakes that could trigger landslides in the gorge. The most significant faults are the Wellington-Mohaka Fault and the Ruahine Fault at the east end of the gorge *(from GNS Active Fault Database)*.

4.0 POTENTIAL FUTURE LANDSLIDES IN THE MANAWATU GORGE

Following the earlier review of the geology, geomorphology, and historical landsliding in the Manawatu Gorge (Hancox 2011), and the expanded appraisal presented above based on recent work on the 2011 landslide and other parts of the gorge, we believe it is possible to identify specific areas and sites where future landslides could occur. From the 2011 review it was concluded that future landslides that could close SH3 will be located where thick colluvial deposits have been destabilised by steep (~50°–60° or >) unsupported road cuts. Most of these slopes are located between bluffs of relatively strong, jointed sandstone and argillite, as is the case with the 2011 landslide.

In the 2011 review (Hancox 2011) fifteen areas were tentatively identified in the western and central sections of the gorge where large landslides could potentially occur in the future. The more detailed aerial photo studies, 2011 LiDAR-data, GIS analysis, and field mapping carried out during this 2012 study have enabled the potential future landslide areas and sites in the Manawatu Gorge to be more accurately located, characterised, and ranked according to their extent and capacity to significantly damage or close SH3. The methodology used to identify the potential future landslide sites and results of the assessment are discussed below.

4.1 Methodology

Areas where potential future landslides could occur in the Manawatu Gorge were identified from several types of information including:

(a) Precedent evidence from historical landslides and remedial works in the gorge.
(b) Rock types and surficial deposits (especially areas of thick colluvium).
(c) Geomorphic features (prehistoric landslides scarps, bluffs, rapids).
(d) Slope angles and heights (from 1 m LiDAR contours).
(e) Man-made modifications to the natural slopes (e.g. road cuts).

Most of this information is discussed in detail above and illustrated by several figures. In assessing landslide susceptibility it is widely accepted that the most important factors are slope angle, slope height, rock and soil types, groundwater conditions, and natural (erosion and landsliding) or man-made modifications to the long-term stable angles of slopes.

Assessment of landslide susceptibility involves both knowledge of the spatial distribution of terrain types, geological materials and properties, and their propensity to produce landslides based on past performance, and a degree of interpretation (Fell et al. 2008). It is important to know about the behaviour of past landslides in any area being considered, and to consider all types of landslides that could occur. An area may be susceptible to different types of landslides (e.g. rock fall, debris fall, debris slide, and earth/soil fall etc., Appendix 1) depending on the terrain and soil and rock types present.

In this study landslide susceptibility has been assessed from a slope angle model based on historical earthquake-induced landslide data and relationships to historical landsliding in greywacke terrain. The susceptibility/slope angle model used in this study of the Manawatu Gorge is defined in Table 3. This model was used in ArcGIS to prepare the slope angle/landslide susceptibility map shown in Figure 6. This map is based on a digital terrain model derived from 1 m LiDAR contours. The landslide susceptibility model used is similar to others used for other landslide hazard assessments in greywacke terrain in the Wellington region (e.g. Brabaharan et al. 1994, Kingsbury 1995), but has been updated to take into account the geology, terrain, and local site conditions in the Manawatu Gorge.

Table 3. Slope angle and landslide susceptibility classes used for landslide risk assessment along SH3 in the Manawatu Gorge.

Slope Class	Slope Angle	Landslide Susceptibility	Slope types and characteristics
Low	< 25°	LOW	Very low to gentle (0–25°) slopes on broad ridge crests and the upper slopes of the gorge, and also on alluvial fans and terraces upstream of Barney‟ s Point, at least 10 m above cut batters along SH3. Very few landslides.
Moderate	25–35°	MODERATE	Moderate (25–35°) slopes on upper levels of the gorge, underlain by thick colluvium and old alluvium, especially upstream of Barney‟s Point. Few small landslides (earth slides and flows) which have little effect on SH3.
Moderate to Steep	35–45°	HIGH	Moderate to steep (35–45°) slopes on mid-level slopes of gorge, side streams, and upper slopes of old landslides. Generally underlain by thick colluvium and old landslide deposits. Landslides relatively common, many affect SH3.
Steep	45–60°	VERY HIGH	Steep to very steep (45–>60°) slopes, mainly on the lower slopes of the gorge, head scarps of existing landslides, on strong sandstone bluffs, and in road cuts along SH3. Larger landslides are most common in this slope range, many of which affect SH3. On steep rock bluffs mainly small local rock falls and isolated boulder falls.
Very Steep	>60°		

The slope angle and landslide susceptibility model defined in Table 3 has been used to prepare Figure 6, which shows the spatial distributions of the five slope angle classes. Areas of red and purple on that map have very high landslide susceptibility, as demonstrated by the distribution of historical and more recent (post 2003) landslides shown in Figures 4 and 9.

Areas with high and very high landslide susceptibility in the Manawatu Gorge are believed to have significant potential for future landsliding that could affect SH3. As proposed in the guidelines of Fell et al. 2008, these areas include:

(a) Sites where there has been a history of landsliding and retrogression of the head scarps or lateral scarps of landslides is likely. Most of these areas were identified in previous reports on landslide works in the gorge (e.g. Worley 1996 and 1998, Perrin and Hancox 2000, Beca 2001, MHW 2004, Hancox 2011), and are shown in Figures 4 and 9.

(b) Sites where there is no history of landsliding but topography (slope angle and height) indicates that landsliding may occur. If slopes are steep enough (either naturally or due to anthropogenic factors) they may be susceptible to landsliding for a wide range of geological conditions. These areas were identified in the gorge on historical and recent oblique and vertical aerial photos with the aid of contoured, hill-shaded, and slope angle maps generated in GIS from 2011 LiDAR, followed by ground inspections along SH3.

(c) Sites where there is no history of landsliding but geological and geomorphological conditions are such that landsliding is possible under appropriate triggering conditions. These areas were identified from geological and geomorphic data (Figures 4 and 5), aerial photos, and ground inspections along SH3.

The positions and characteristics of potential future landslide areas that could affect SH3 within the Manawatu Gorge are discussed next.

4.2 Characteristics of potential landslide areas

The locations and extent of potential future landslides within the Manawatu Gorge that were identified in this study using the methods outlined above are shown in Figure 9 and 9a. The RP positions of these areas along SH3, their characteristics (slope failure history, approximate slope angle, height, area, and volume), rock types and surficial deposits, and potential for future landslides that could affect SH3 are presented in Table 4. Historical landslides that have caused long closures of SH3 in the gorge requiring major remedial works are also included in this table, mainly for comparative purposes. The main landslide areas are illustrated by annotated aerial photos taken on 24 August 2012 (Figures 14 to 19).

The large historical failure and potential future landslide areas have been ranked according to their estimated size and potential to close SH3 using a simple four-fold scale, as follows: R1 -10,000 m^3; R2 - 10,000–25,000 m^3; R3 - 25,000–50,000 m^3; R4 - >50,000 m^3. In this scale the areas ranked R1 and R2 are thought to be less hazardous than those ranked R3 and R4. The 2011 and 1995 landslides areas are ranked as R1 because major slope stabilisation works have been carried out in those areas to reduce the risk of slope failures (Figures 14 and 15). However, the 1998 landslide, which has also been stabilised, is ranked R2 because the gabion wall at the toe of the stabilisation works is bulging and there are fresh cracks in the concrete base (Figure 15). It is possible therefore that the gabion wall could fail during strong earthquake shaking, and may not survive a rainstorm similar to that of February 2004. This will be discussed further in the risk assessment below (Section 5.0).

Twenty five existing or potential landslide areas have been identified in this study (Table 4). Eight (32%) of these areas are in the Western Section of the gorge (Gorge Monument to Bluff 10, RP488/1.05 – 491/0.10); thirteen (52%) are in the Central Section (Bluff 10 to Barney‟s Point, RP491/0.10 – 491/2.45); and only four (16%) in the Eastern Section (Barney‟s Point to Upper Gorge Bridge, RP491/2.45 – 491/4.10, see Figures 2 and 9). This dispersal is similar to the distribution of historical landslides in the Manawatu Gorge shown in Table 1 (West - 55 (40%), Centre – 61 (44%), East - 22 (16%). The greater percentage of potential landslide areas identified in the Central Section compared to the historical landslide pattern is attributed to the greater number of potentially unstable February 2004 landslide scars in that part of the gorge (Figure 9).

Significant potential for future landsliding exists in the Western Section of the gorge in the vicinity of the 2011 landslide, particularly between Bluffs 4 and Bluff 7 (~RP488/2.16–2.50, Figure 9). Three large potential landslide areas (Areas 5, 6 and 7) with similarities to the 2011 landslide have been identified in this part of the gorge. All of these areas are located below prehistoric landslide scarps in „deflated‟ zones filled with thick colluvial deposits between the spurs and bluffs of more resistant sandstone (Figure 14). Small shallow debris slides occurred on cut slopes in these areas in 1930–1940, 1968–69, and two small failures occurred in February 2004 (Figure 9). An old rock fall scar in Area 6 appears to be the source of large boulders which form the rapids in the river channel between Bluffs 5 and 6 (Figure 14). These boulders appear to be the remains of a landslide dam which possibly dates back to the 1855 earthquake.

There is clearly potential in Areas 5, 6, and 7 for future failures of colluvium and regolith similar to the 2011 landslide, especially during heavy rainfall or strong earthquake shaking. As at the 2011 landslide site, these slopes are more vulnerable to slope failures if small failures occur at the toe, or is cut back and oversteepened in any way without the restoration support at the base of the slope. Any future slope failures in these areas need to be approached with caution to ensure that the slope is not destabilised to a greater extent.

Table 4. Locations and characteristics of major historical landslides and potential future landslides areas that could affect SH3 in the Manawatu Gorge.

Area No.	Route Position (RP) on SH3 (km)[1]	Type of Landslide Feature and Previous Slope Failure History[2]	Approx. Height[3] (m)	Approx. Area[4] (m^2)	Approx. Volume[5] (m^3)	Average Slope[3] Angle (°)	Geology – Main Rock Types and Surficial Deposits[6]	Potential for future landsliding that could affect SH 3 and other comments[7]	Rank[8]
1	RP488/1.22 – 1.38	Three potential landslide sites (A, B, C) downstream of Bluff 1. Small shallow landslides in 1930-40, 1968-69, 1978-80, Feb. 2004 (from ~60 m above SH3 at Bluff 1).	1A – 60 1B – 40 1C – 35	1800 1500 800	9000 8000 4000	45–60 35–60 35–60	Foliated lithozone, argillite dominated, with sandstone at Bluff 1. Thin (~1- 3 m) surficial angular colluvium and loess.	Potential for further regressive failures (debris falls) at these sites, especially the very steep top of Site 1A during strong earthquake shaking.	R1
2	RP488/1.42 – 1.47	Potential landslide site in area of small landslides 1930-1940, 1978-80, and two in Feb. 2004,	50	2500	15,000	60	Volcanic lithozone (red argillite), with ~1- 3 m surficial angular colluvium and thin loess.	Potential for debris falls of colluvium from steep scarps of the 2004 failures, especially during heavy rainfall and strong earthquake shaking.	R2
3	RP488/1.51 – 1.64	Two potential landslide sites (A, B) in area of previous small slope failures in 1930-40,1968-69, 1978-80, and three small failures in Feb. 2004	3A – 70 3B – 50	3000 1500	15,000 8000	> 60 (H) 35–60 (T)	Sandstone and Volcanic lithozone (red argillite), with thin (~1- 3 m) angular surficial colluvium and thin loess.	Potential for moderate to large debris falls from scarps of previous failures, especially during heavy rainfall and strong earthquake shaking.	R2
4	RP488/1.86 – 2.10	2011 Landslide area and stabilisation works between Bluffs 2 and 3. The 2011 landslide developed from a small failure in Sep 2010. Small, shallow failures in this section of the gorge in 1930-1940 and 1968-69.	130	16,000	160,000[5a]	45–60 (H) 45–35 (above head)	Sandstone and (minor) Volcanic lithozone (red argillite), with 1- 5 m and in places 10 or more surficial colluvium, alluvium, and thin loess deposits (on the upper slope).	Extensive stabilisation works undertaken in this area during 2012. Future slope failures are considered to be unlikely in this area. This is the largest landslide that has occurred in the Manawatu Gorge landslide in the last 100 years.	R1
5	RP488/2.16 – 2.20	Potential landslide area below a large prehistoric landslide scarp between Bluffs 4 and 5. Small shallow colluvial debris slides occurred in this area from 1930 to 1960s, and in Feb. 2004 on cut slopes along SH3.	90	5000	25,000 – 30,000	45–60 (H) 25–45 (T)	Sandstone and Volcanic lithozone (red argillite) in the upper slope, with ~thick (2-5 m or more) surficial colluvium and thin loess (mainly between bluffs).	Potential for large colluvium/regolith fall during heavy rainfall and/or strong earthquake shaking, especially if the toe of the slope fails again or is cut back. Slope needs to be handled with care.	R3
6	RP488/2.23 – 2.35	Two potential landslide areas (A, B) below large old (prehistoric) scarp between Bluffs 5 and 6. A more recent scar and rapids formed by boulders in the river channel were possibly caused by the 1855 earthquake. Small shallow debris slides occurred in this area between 1930 and 1940, 1998-2003 and Feb. 2004.	6A – 90 6B – 40	5500 800	40,000 1500	45–60 (H) 35–45 (T) 6B - 45–60	Foliated lithozone, argillite-dominated, and Volcanic lithozone (red argillite). Sandstone exposed in bluffs mid slope, with ~1-5 m or more surficial colluvium and thin loess. The rapids are formed by large sandstone boulders inferred to have been derived from this slope.	Potential for large colluvium/regolith fall during heavy rainfall and/or strong earthquake shaking, especially if the toe of the slope fails again or is cut back. This slope needs to be maintained handled with care.	R3
7	RP488/2.42 – 2.47	Large potential landslide area between Bluffs 6 and 7, below a prominent elongate prehistoric landslide scarp. Small historical landslides at toe of slope 1930-40. Small rock falls from Bluff 6 Sep 1985.	80	3600	25,000	45–60 (H) 35–45 (T)	Volcanic lithozone and foliated, argillite-dominated. Thin (~1- 3 m) surficial angular colluvium on slope between Bluffs 6 and 7.	Potential for a large colluvium/regolith fall during heavy rainfall and/or strong earthquake shaking, especially if the toe of the slope is cut back. Slope needs to be handled with care.	R3
8	RP488/2.52 – 2.6	Two potential failure areas between Bluffs 7 and 9 in areas where small road cut failures occurred in 1930-40, 1978-80, and a larger failure occurred at the top of Bluff 8 (8A) between 2004 and 2011. Tied-back wall built in 1985 on the west side of Bluff 9 to stabilise a rock wedge failure.	8A – 50 8B – 30	1000 500	5000 1500	45–>60 (H) 35–45 (T)	Foliated lithozone, argillite-dominated bedrock, with 1-3 m surficial colluvium between Bluffs 7-8. Graded-bedded (sandstone/argillite) at Bluff 9.	Potential for retrogressive upslope failures at these sites during strong earthquake shaking or heavy rainfall, especially at Site 8A where recent failures have occurred. Toe of colluvial slope at Site 8B potentially more vulnerable if cut back.	R2 *p1/4*

Area No.	Route Position (RP) on SH3 (km)[1]	Type of Landslide Feature and Previous Slope Failure History[2]	Approx. Height[3] (m)	Approx. Area[4] (m^2)	Approx. Volume[5] (m^3)	Average Slope[3] Angle (°)	Geology – Main Rock Types and Surficial Deposits[6]	Potential for future landsliding that could affect SH 3 and other comments[7]	Rank[8]
9	RP491/0.23 – 0.34	Two potential landslide sites between Bluffs 11 and 12 at sites where previous failures have occurred. At 9A minor colluvial failures occurred in the 1960s, again in 1996. Extensive failure of colluvium at Site 9B in 1985 after the toe of the slope was cut back.	9A – 40 9B – 35	1700 1100	9000 5000	35–45 (H) 45– >60(T)	Volcanic lithozone rocks (red argillite, sandstone), overlain by thick colluvial deposits.	Potential for retrogressive upslope failures (debris falls/ slides) at both sites especially during heavy rainfall where recent failures have occurred. The toe of these slopes will be more vulnerable to failures if they are cut back and they need to be maintained with care.	R2
10	RP491/0.46 – 0.52	A major landslide occurred here in July 1998, requiring extensive stabilisation works, including sluicing of loose material, benching, drainage drilling, and a 10 m high gabion wall at the toe of the slope above SH3.	50	2000	10,000[5a]	45–60 (H) > 60 (T)	Foliated lithozone, sandstone dominated; closely jointed and shattered due to proximity of major, old ENE-striking fault (Figure 4). Extensive, thick colluvial deposits overlie bedrock in this area.	The benching stabilisation works are effective. However, the MSE wall and gabion facing wall is bulging, and the ~1 m high concrete wall base has fresh cracks spaced ~ 3 m apart. Remedial works are needed here to repair this damage.	R2
11	RP491/0.64 – 0.78	Three large failures occurred on slopes up to 100 m high in this area in sites A (2) and B during a wet winter in 1995. These failures were related to cutting back of the toe of the slope, not the shallow failures that occurred from 1930 to 1940. Extensive remedial works carried included sluicing, benching and removal of ~100,000 m^3 of failure debris, drainage drilling, and installation of mesh on the upper slopes. A small soil slide and flow occurred at the top of Site B during the 2004 rainstorm.	11A – 100 11B – 100	7000 3000	100,000[5a] (A & B)	45–> 60 (H & T)	Foliated lithozone, sandstone dominated; closely jointed and shattered weak rock due to proximity of major, old ENE-striking fault. Thick colluvium also overlies bedrock in this area.	The stabilisation works at site 11A appear to be working well, and few problems are anticipated in this area. Recent landsliding at the top of site 11B in 2004 suggest that future problems could occur in this area. The mesh on this steep slope is loose and is probably ineffective.	R1
12	RP491/0.81 – 0.91	Potential landslide area at 12A, the site of a moderately large colluvial debris fall during the Feb.2004 rainstorm (#1), and a smaller colluvial failure at road level (12B) which occurred sometime between 1998 and 2003.	12A – 60 11B – 30	3000 900	15,000 5000	A35–60 (OS) B45–>60(OS	Sandstone lithozone bedrock, shattered due to fault proximity, with thick (~3-5 m) angular colluvium.	Potential for significant regressive failures (debris falls of colluvium/regolith) from oversteepened head scarps at 2A and 12B, especially during heavy rainfall and strong earthquake shaking.	R3
13	RP491/0.92 – 0.98	This area (aka the "Quarry") was the site of small slip pre 1940, a larger failure during the 1960s, and another small debris fall in Feb. 2004.	50	2000	5000 – 10,000	45–>60	Volcanic lithozone (red argillite), shattered and/or closely jointed, overlain by thick colluvium.	Potential for a large regressive failure (debris fall) from the steep face near SH3, especially during heavy rainfall and strong earthquake shaking.	R2
14	RP491/1.00 – 1.13	This area is the site of the largest landslide (#2) that occurred during the February 2004 rainstorm, although there is no history of previous failures at this site. A small failure occurred on the steep failure scar in July/ August 2012, making it vulnerable to future collapses.	70	10,000	70,000	45 –>60 (H) 35–45 (T)	Volcanic lithozone (red argillite), closely jointed, shattered, and weathered. This weak bedrock is overlain by thick colluvial deposits. Open tension cracks in bush ~20 upslope of head scarp- pins placed for monitoring (pers. comm. P. Wopereis).	There is potential for large upslope failures (rock/ colluvium/ regolith falls) from the over-steepened head scarp, especially during heavy rainfall and strong earthquake shaking. Any further earthworks at this site would need to be carefully designed and implemented.	R4
15	RP491/1.23 – 1.32	Potential landslide area at the head of a large colluvial debris fall during the February 2004 rainstorm (#3). No slope failures previously noted in this area until February 2004. Rock fall from scarp in 2005 destroyed guard rail and blocked SH3 temporarily (pers. comm. P. Wopereis). A small section of the steep head scarp failed again in last 12 months (post 30/9/2011 LiDAR).	45	3500	20,000	45–>60 (H) 35–45 (T)	Thick colluvium overlying sandstone and foliated sandstone lithozones.	At this site there is potential for moderate to large regressive upslope failures of colluvium and weathered rock from the over-steepened head scarp, especially during heavy rainfall and strong earthquake shaking.	R3 *p2/4*

Area No.	Route Position (RP) on SH3 (km)[1]	Type of Landslide Feature and Previous Slope Failure History[2]	Approx. Height[3] (m)	Approx. Area[4] (m^2)	Approx. Volume[5] (m^3)	Average Slope[3] Angle (°)	Geology – Main Rock Types and Surficial Deposits[6]	Potential for future landsliding that could affect SH 3 and other comments[7]	Rank[8]
16	RP491/1.37 – 1.54	Two potential landslide sites noted in this area (16A, B). A very small debris fall occurred at 16B in Feb.2004. Three small failures occurred here in ~1978-80, caused mainly by minor cutting back and over-steepening the toe of the colluvial slope along this section of SH3.	16A – 40 16B – 20	3700 700	10,000 2000	45–>60 (H) 35–60 (T) (A and B)	Thick (~3-5 m) colluvium overlying sandstone and foliated sandstone lithozone bedrock.	Potential for moderate to large colluvial failures (debris falls and slides) at sites 16A and 16B from the steep slope above SH3, especially during heavy rainfall and strong earthquake shaking.	R1
17	RP491/1.57 – 1.81	Three potential landslide sites were noted in this area (17A, B, C). In Feb. 2004 a moderate to large debris fall occurred at 17A (#4), with a smaller failure at 17C. Several failures moderate to large landslides occurred along this section of SH3 in the late 1940s and 1968-69, caused by minor cutting back and oversteepening the toe of the colluvial slope along this section of SH3.	17A – 40 17B – 35 17C – 40	3300 1300 1500	10,000 4000 5000	45–60 (OS) 35–60 (OS) 45–>60 (OS)	Thick (~3-5 m) colluvium overlying sandstone and foliated sandstone lithozone bedrock	Potential for moderate to large colluvial failures (debris falls and slides) at sites 17A, 17B and 17C from the steep slope above SH3, especially during heavy rainfall and strong earthquake shaking. Sites 17A and 17C are more vulnerable because of oversteepening of the toe by the 2004 failures.	R2
18	RP491/1.85 – 2.03	Potential landslide area on slope above a large colluvial debris fall caused by the February 2004 rainstorm (#5). Small debris fall occurred in this area in ~1940, 1968-69, and 1978-80 due to minor toe cutting to widen SH3.	70	8000	20,000	25–35 (AH) 35–>60 (OS)	Volcanic lithozone (red argillite) and argillite-dominated foliated lithozone overlain by thick (~3-5 m) colluvium.	Potential for future moderate to large regressive colluvial failures (debris slides and falls) from the steep headscarp at this site, especially during heavy rainfall and strong earthquake shaking.	R2
19	RP491/2.04 – 2.16	Potential failure area above a moderately large colluvial debris fall which occurred during the February 2004 rainstorm (#6), and a large debris slide just upstream which occurred in 1990, blocking SH3 for several days.	70	5000	15,000	25–35 (AH) 35–>60 (OS)	Argillite-dominated foliated lithozone overlain by thick (~3-5 m) colluvium.	Potential for future moderate to large regressive colluvial failures (debris slides and falls) from the steep headscarp at this site, especially during heavy rainfall and strong earthquake shaking.	R2
20	RP491/2..20 – 2.33	Potential failure site in area of thick colluvium. Several small failures occurred on this section of SH3 in ~1940, 1968-69, and 1978-80; small debris slide/flow occurred high on the slope between 2004 and 2012.	90	7000	20,000	35–45 (H) 45–60 (T)	Foliated argillite-dominated and graded bedded lithozones overlain by thick (~3-5 m) colluvium.	Potential for future small to large debris slides and falls at this site, especially during heavy rainfall and strong earthquake shaking.	R2
21	RP491/2.33 – 2.49	Potential landslide area on the steep cut slopes above at the toe of an old alluvial/debris fan built by the Barney‟s Point stream. A minor road cut failure occurred here in 1978-80, and four very small soil (earth) and debris falls occurred during the February 2004 storm.	5–10	1500 (total area)	3000	45–60 (OS) and > 60 (T)	Thick (~5-10 m) alluvial fan deposits with thin (<0.5 m) surficial loess, overlying graded bedded lithozone bedrock (moderately weathered and closely jointed sandstone and fissile argillite).	Potential for further small earth and debris slides and falls on the steep ~10 m high road cuts in this area, especially during heavy rainfall and strong earthquake shaking.	R1
22	RP491/2.52 – 2.69	Potential landslide area on steep road cuts along SH3, where the colluvial wedge at the toe of the slope east of Barney‟s Point was cut back in the 1960s and 1980s. A small failure occurred here in 1978-80, and a larger debris fall/flow and underslip occurred in February 2004 (#7; U/S#1). The 2004 slip area was benched, but there is still failure potential at the upstream (south) end.	15–25	6000 (total area)	10,000	35–45 (H) 45–60 (T)	Thick (~5-10 m) colluvial wedge/ fan deposits with thin surficial loess, overlying graded bedded lithozone bedrock (moderately weathered and closely jointed sandstone and fissile argillite). Mainly colluvium (with sparse bedrock outcrops) at road level, and bedrock at river level.	Potential exists for further small to moderate-sized debris falls and flows in this area, especially during heavy rainfall and strong earthquake shaking.	R1 *p3/4*

Area No.	**Route Position (RP) on SH3 (km)**[1]	**Type of Landslide Feature and Previous Slope Failure History**[2]	**Approx. Height**[3] **(m)**	**Approx. Area**[4] **(m^2)**	**Approx. Volume**[5] **(m^3)**	**Average Slope**[3] **Angle (°)**	**Geology – Main Rock Types and Surficial Deposits**[6]	**Potential for future landsliding that could affect SH 3 and other comments**[7]	**Rank**[8]
23	RP491/2.70 – 2.83	Potential landslide area (similar to Area 22) where three small debris falls and flows (#8 and U/S#2, Figure 7) occurred during the February 2004 rainstorm. The overslips were meshed, and a similar failure occurred close to Windy Bridge between 2004 and 2011 just south of where the mesh ends.	15–25	3000 (total area)	6,000	35–45 (H) 45–>60 (T) (upper slope 35–25 or<)	Bedrock in the section of the gorge upstream of Barney‟s Point is relatively weak, closely jointed, and in places shattered due to the proximity of the active Ruahine Fault, which is mapped running northeast across the gorge close to the western abutment of the Upper Gorge Bridge (Figure 1). The topography and geology upstream of Barney‟s Point to Upper Gorge Bridge is also very different to the section of gorge (downstream) to the west. Upstream of Barney‟s Point the rock is graded bedded lithozone overlain by thick colluvium, alluvial fan deposits. This is in marked contrast to the repeated sequence of hard sandstone spurs and intervening areas of colluvium in the Central and Western Sections downstream of Barneys‟ Point.	Potential exists for further small to moderate-sized debris falls and flows in this area, especially during heavy rainfall and strong earthquake shaking. The existing area of mesh protects SH3 from small debris falls and flows, but the mesh needs to be extended ~15 m across the recent failure area to the Windy Bridge Stream. Underslips are also expected to occur along this section of the gorge.	R1
24	RP491/2.89 – 3.20	Two potential landslide areas where small debris falls and flows (#9 and U/S #3 and #4, Figure 7) occurred during the February 2004 rainstorm. The underslip damage to the road edge has also been repaired.	25–40	A –3500 B –3900 (totals for A and B)	6000 7000	35–45 (H) 45–>60 (T) (upper slope 35–25 or<)		Potential exists for further small to moderate-sized debris falls and flows and underslips in this area, especially during heavy rainfall and strong earthquake shaking.	R1
25	RP491/3.20 – 4.00	Mainly small underslip failures in this section of the gorge, and small to very small debris falls on the 3-5 m high road cuts into the toe of the thick colluvial slope	2–5	NA	Minor	35–60 (cuts) <25–35 (above cuts)	Thick colluvium, fan and terrace alluvium with thin loess at road level, overlying (at river level) graded bedded lithozone bedrock (moderately weathered and closely jointed sandstone and fissile argillite).	Potential exists for small to very small road cut failures (soil and debris falls) and future underslips in this area, especially during heavy rainfall and strong earthquake shaking.	R1

NOTES:

(1) Route positions (km) on SH 3 are measured from the junction of SH3 and SH57 (RP488/0.00) shown on Figure 2. Locations and RPs of specific landslide areas are shown on Figure 9 and 9a.

(2) Historical landslides are shown on Figures 4 and 9.

(3) Maximum slope heights (above SH3) and slope angles were determined from Figure 6 using 1 m LiDAR contours (29/9/2011). Average slope angles are given for the head scarp (H) and toe (T), areas above the head scarp (AH), or the overall slope (OS) at each site.

(4) Areas of potential landslide sites determined in GIS from Figure 9 polygons.

(5) Volumes of potential future landslide areas were estimated from area of the site and depth of a possible slope failure, based on the depth of surficial colluvium and/or regolith (soils and weathered bedrock).

(5a) Approximate volumes of past landslides that have been stabilised or regraded (1995, 1998, 2011) from works records. These values are included for comparative purposes.

(6) Geology based on Figure 4 (bedrock and structures from Marden 1984), surficial deposits from Figure 5, and field observations.

(7) Assessment of future landslide potential are based on: (a) slope angle and height; (b) rock types and surficial deposits; (c) previous slope failures at sites; and (d) triggering events (heavy rainfall, earthquake shaking) that have affected the slopes and are expected in the future.

(8) Historical and potential landslide areas that could affect SH3 in the gorge are roughly ranked according to their size and potential to close the highway and need for remedial measures, as follows: R1 - ,10,000 m^3; R2 - 10,000–25,000 m^3; R3 - 25,000–50,000 m^3; R4 - >50,000 m^3.

p4/4

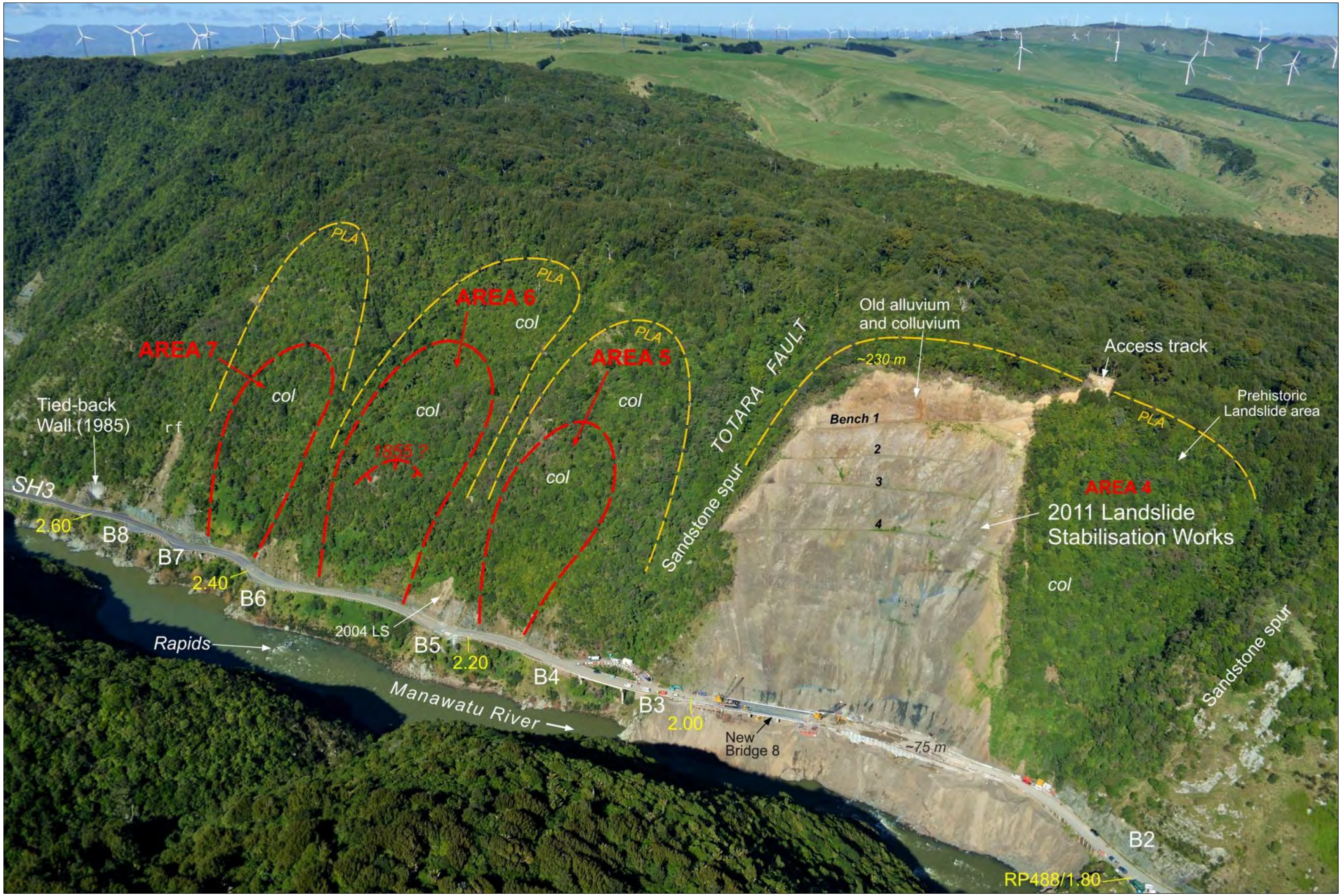


Figure 14. Aerial view of the 2011 landslide stabilisation works (Area 4) and potential landslide Areas 5, 6 and 7 between RP488/1.8 and ~488/2.50. Those areas are located in areas of thick colluvium *(col)* below subtle scarps of prehistoric landslide areas *(PLA)* between bluffs *(B2-B8)* of resistant sandstone. Area 6 is the likely source area of a large rock fall (possibly during the 1855 earthquake) responsible for a boulder deposit which forms rapids in the river channel.

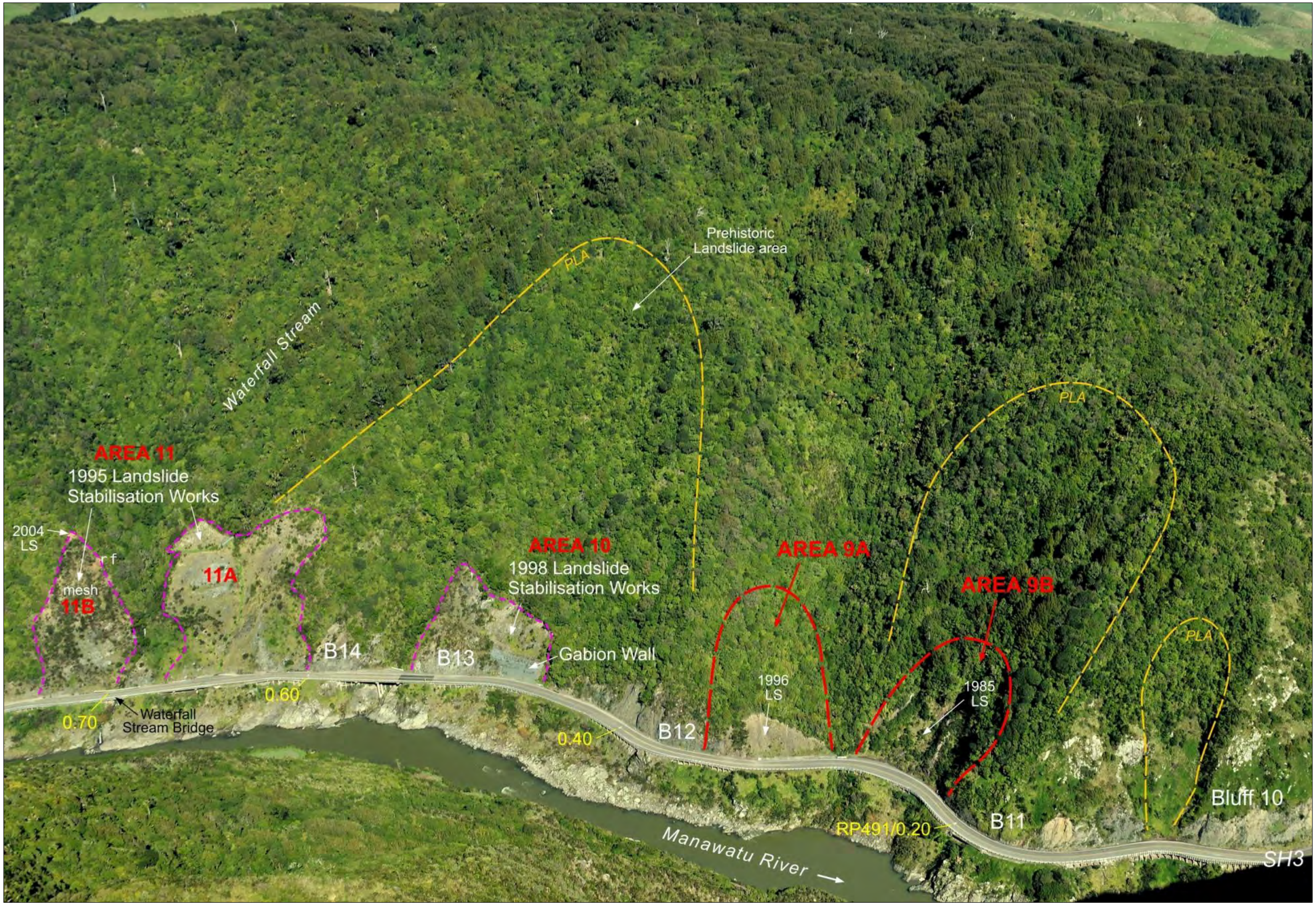


Figure 15. Aerial photo of the 1995 and 1998 landslide stabilisation areas and potential landslide Area 9 near Waterfall Stream in the centre of the gorge. Most of these are located in areas of thick colluvium *(col)* below scarps of prehistoric landslide areas *(PLA)* between bluffs *(B10-14)* of resistant sandstone.

Figure 16. Aerial photo of potential landslide areas 12 to 15 in the Manawatu Gorge from RP491/0.80 to 491/1.25 on 24 August 2012. Regressive failures of the over-steepened (~45–>60°) scarps of the 2004 landslides *(LS#1-3)* are likely to occur in all these areas, especially at landslide #2, which could potentially extend ~25 m upslope from its present position. Small new failures *(nf)* have occurred on two of the 2004 scars in the last 12 months and more are expected in the future. Few slope failures have occurred on bluffs of harder rock (B15, B16), which show little change since January 2000 (compare with Figure 11).

Figure 17. Closer view of the 2004 landslide #2, the largest potential landslide site (Area 14). A small failure *(sf)* on the lower slip face in July/August 2012 removed part of the rock fall mesh. Bedrock at this site is weak, closely jointed, weathered red argillite overlain by thick colluvial deposits. The steep (45–>60°) head scarp now extends ~70 m above SH3 and is likely to retreat further upslope in the future. Open tension cracks are present ~20 m above the head scarp.

Figure 18. Aerial view of potential landslide Areas 18 and 19 and the sites of landslides which closed SH3 in1990 and 2004 (#5 and #6) between RP491/1.80 and 491/2.20, about 200 m downstream of Barney‟s Point. The small recent failure *(rf)* on the head scarp of the 2004 landslide #5 suggests that Area 18 in perhaps more vulnerable to future failures than Area 19. The potential for failures at these sites is slightly less than those in the centre of the gorge.

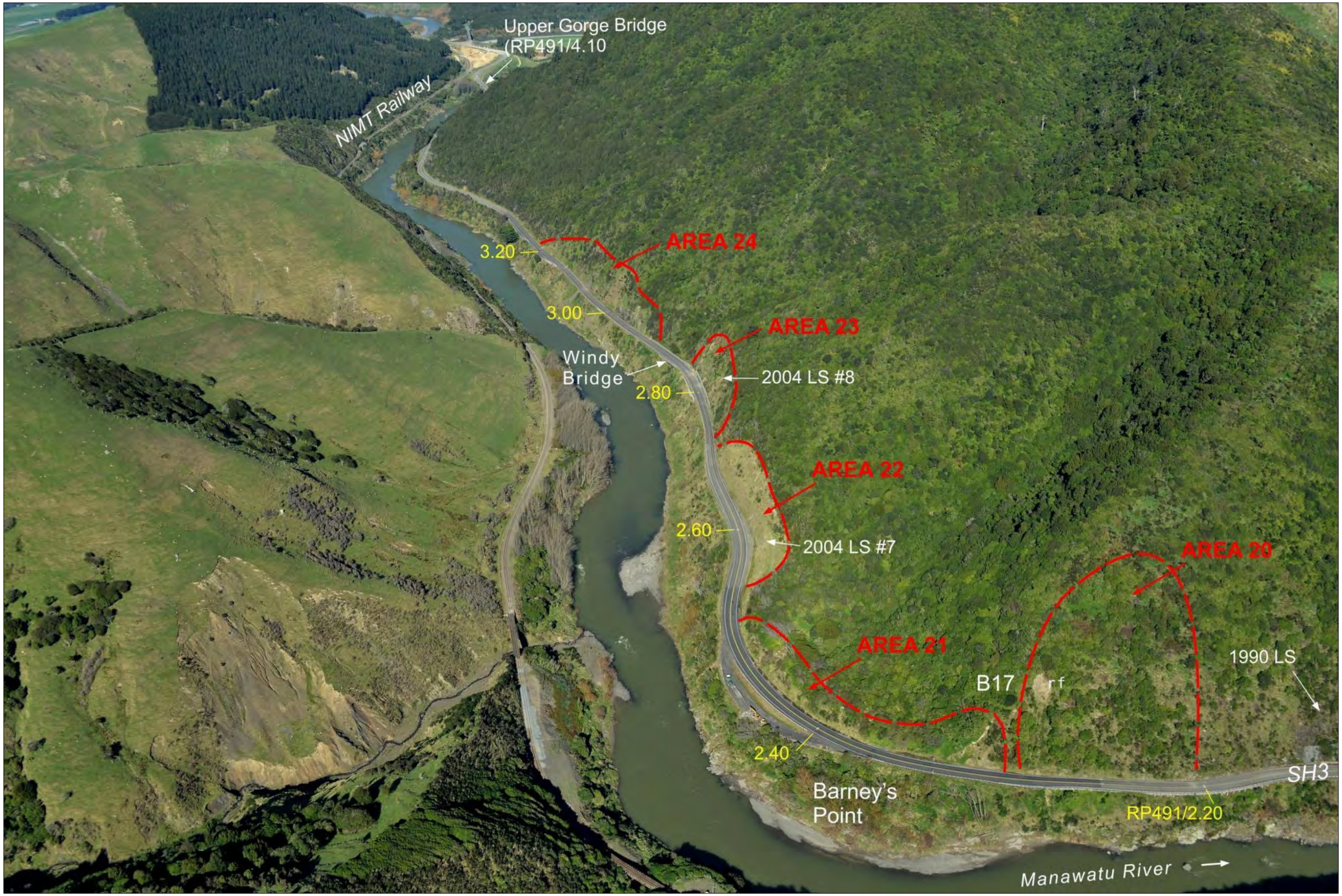


Figure 19. Aerial view of potential landslide Areas 20 to 24 from RP491/2.20 to 491/3.20 in the vicinity of Barney‟s Point and Windy Point Bridge in the Eastern Section of the Manawatu Gorge. The slopes in this area are lower and less steep. There is significant landslide potential in Area 20 (note recent failure, *rf*), but generally only moderate hazard potential (from overslips and underslips similar to those in February 2004) in Areas 21 to 25.

There are several areas with significant landslide potential in the Central Section of the gorge (Areas 12-15, Table 4). As can be seen by comparing Figures 10 and 11, there has been a significant increase in landslide density in this area since January 2000. The February 2004 rainstorm caused several moderate to large landslides (#1 to #5) in the centre of the gorge between Bluff 15 and Barney"s Point (Figure 9). Area 14 at the site of 2004 landslide #2 is the largest and most significant of the areas where future landsliding is expected to occur in the future. A small failure occurred on the steep (45–>60°) failure scarp in July/August 2012, making it more vulnerable to future collapses (Figures 15, 16 and 17).

The bedrock at Area 14 is weak, closely jointed, shattered, and weathered red argillite (Volcanic Lithozone) overlain by thick colluvial deposits (Figure 17). The steep (45–>60°) head scarp in this material now extends ~70 m above SH3 and is likely to retreat further upslope in the future. There is clearly potential at Area 14 for large regressive upslope failures (rock/colluvium/regolith falls and slides) from the over-steepened head scarp, especially during heavy rainfall and strong earthquake shaking. There is an open tension crack in the bush ~20 m upslope of the head scarp. Monitoring pins have been set up on either side of this crack (pers. comm. P. Wopereis), but the results to date are not known.

A high level of landslide hazard exists at both Area 12 and Area 15. The centre of the gorge is more prone to landsliding because of the steep slopes and thick colluvium in that area (Figures 5 and 6), and bedrock is more jointed and shattered due to the presence of an old (inactive) fault that runs east-northeast through that part of the gorge (Figure 4). Similar steep slopes and adverse geological conditions are also present at Areas 18 and 19 (Figure 18).where large overslips occurred in 1990 and again 2004 (#5, #6).

The topography and geology in the Eastern Section of the gorge from Barney"s Point to Upper Gorge Bridge is different to Central and Western sections downstream. Upstream of Barney"s Point the rock is graded-bedded rocks overlain by thick colluvium and alluvial fan deposits which have moderate to gentle slopes (35–25° or <) above the very steep ~3-10 m high cuts along SH3 (Figure 19). This is in marked contrast to the very steep (45–60° or <) slopes and the repeated sequence of sandstone spurs and intervening colluvium areas downstream in the Western and Central Sections of the gorge.

These geological and geomorphic differences in the gorge upstream of Barney"s Point are reflected in the reduced landslide potential identified in Areas 21 to 25 (Figure 19). Historically there have been a number of small slope failures on road cuts (overslips) in these areas and several significant underslips that have necessitated remedial works (Table 4).

The potential exists therefore for further small earth and debris slides, falls, and flows on the steep ~10 m high road cuts in Areas 21 to 23, especially during heavy rainfall and strong earthquake shaking. The area of mesh that protects SH3 from small debris falls and flows in Area 23 needs to be extended ~15 m across the recent failure area to the Windy Bridge Stream. Minor to moderate sized underslips are also expected to occur along this section of the gorge during future heavy rainfall and flooding events similar to that of February 2004. Collapses and lateral spreading of road edge fills are also likely to occur during strong earthquake shaking.

5.0 LANDSLIDE RISK ASSESSMENT

The hazard presented by landslides to SH 3 in the Manawatu Gorge has been identified in this study and several previous studies (e.g., Worley 1998 and Beca 2001) as a significant and on-going problem that presents significant risk. This risk has been assessed in this study according to guidelines specified in the Risk Management Process Manual, September 2004, Transit New Zealand, extracts from which are included here as Appendix 3.

In this study the risk assessment has been completed for each of the 25 potential landslide areas that have been identified (Table 4) using the qualitative General Approach, which is based upon the risk management process and definitions presented in AS/NZS 4360:2004 (Appendix 3). The assessment presented does not specify site-specific treatment options, and there is no discussion of residual risk as that is beyond the scope of this study.

The *General Approach* to risk management specified by NZTA is a qualitative approach. This approach is targeted at achieving the appropriate management of opportunities and threats, through the systematic application of generalised risk management processes and qualitative tools. This approach is believed to be appropriate for this study given the time frame and budget available to undertake the landslide assessments.

The results of the landslide risk assessment in this study may indicate, however, that a more rigorous risk assessment is justified using the *Advanced Approach* outlined in the NZTA guidelines (NZTA 2004). The Advanced Approach to risk management is quantitative, and is based on the modelling of individual risks (landslide events). For the Manawatu Gorge study this would probably involve modelling different types and sizes of landslides and triggering events to provide greater certainty and confidence in the levels of risk assessed.

The Advanced Approach may be used where: (a) professional judgement suggests a more robust approach is required; (b) the General Approach reports a significant risk (e.g. one “extreme” risk or five “very high” risks); (c) there may be a prolonged service disruption (road closure); or (d) expenditure in excess of $5m is likely. Given these criteria and the long history of landslide problems and recent year-long closure of SH3 in the Manawatu Gorge it would be appropriate to use the Advanced Approach to assess future landslide risk in gorge, but that is beyond the scope of the present study.

5.1 Risk assessment process

The factual information on geological conditions, historical slope failures, and location details already presented in relation to the potential landslides areas assessed is vital in applying and guiding the General Approach risk assessment process we have used. This information is critical to understanding the nature of landslide hazard in the Manawatu Gorge, and determining the conditions and trigger events under which future slope failures may occur.

The first step in the risk assessment process was to identify and create a register of the „risks‟. In this case the risks are the potential landslide areas discussed previously (Table 4). Events that may trigger a landslide, such as a rainstorm, strong earthquake shaking, anthropogenic activities (cutting back of slope), or spontaneous failures caused by gradual weakening of slopes over time due to weathering and natural erosional processes, are factors that influence the likelihood of a landslide occurring.

The General Approach provides a qualitative technique for analysing the identified landslide risks. This technique is useful for considering diverse types of risk exposure, which would not otherwise be readily comparable. The analysis includes consideration of: (a) existing controls (b) likelihood, and (c) consequences. These parameters and their ratings are described in Appendix 3 and are discussed below.

5.1.1 Existing controls

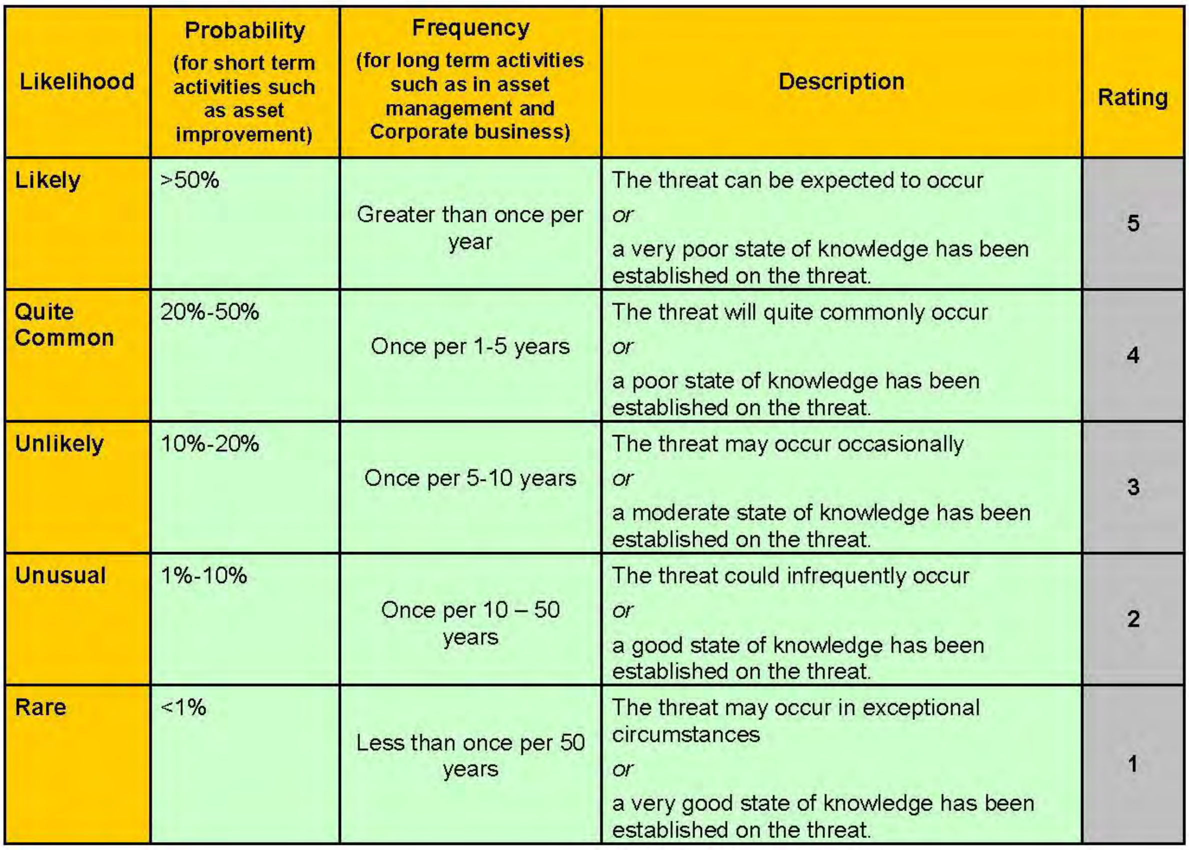
This step in the analysis involves detailing the existing processes, devices, practices, and control systems (e.g., catch fences, benches, slope drainage, toe supports) that act to minimise landslide threats and reduce the opportunities of slope failures, including an indication of how they might reduce the level of risk. The slope failure control measures that are used in different parts of the gorge are discussed in Appendix 4, and listed in Table 5 along with other risk assessment criteria.

5.1.2 Likelihood rating

Evaluation of the likelihood rating for each site provides a qualitative (descriptive) estimate of the probability of landslide events, as defined in Figure 20. This requires consideration of the following inputs:

(1) Historical landslide data (inferred landslide activity and frequency of landsliding). This allows the approximate annual probability of landslide events to be estimated.

(2) Slope failure scenarios and unfavourable geological conditions.



Likelihood	Probability (for short term activities such as asset improvement)	Frequency (for long term activities such as in asset management and Corporate business)	Description	Rating
Likely	>50%	Greater than once per year	The threat can be expected to occur *or* a very poor state of knowledge has been established on the threat.	5
Quite Common	20%-50%	Once per 1-5 years	The threat will quite commonly occur *or* a poor state of knowledge has been established on the threat.	4
Unlikely	10%-20%	Once per 5-10 years	The threat may occur occasionally *or* a moderate state of knowledge has been established on the threat.	3
Unusual	1%-10%	Once per 10 – 50 years	The threat could infrequently occur *or* a good state of knowledge has been established on the threat.	2
Rare	<1%	Less than once per 50 years	The threat may occur in exceptional circumstances *or* a very good state of knowledge has been established on the threat.	1

Figure 20. Rating the Likelihood of a Threat *(Table 1a from NZTA General Approach, 2004)*.

5.1.3 Consequence rating

Evaluation of the consequence rating for each site using the criteria set out in the NZTA General Approach, as defined in Figure 21. Evaluation of the consequence rating for each site requires consideration of the following inputs:

(1) Potential to cause harm to public.

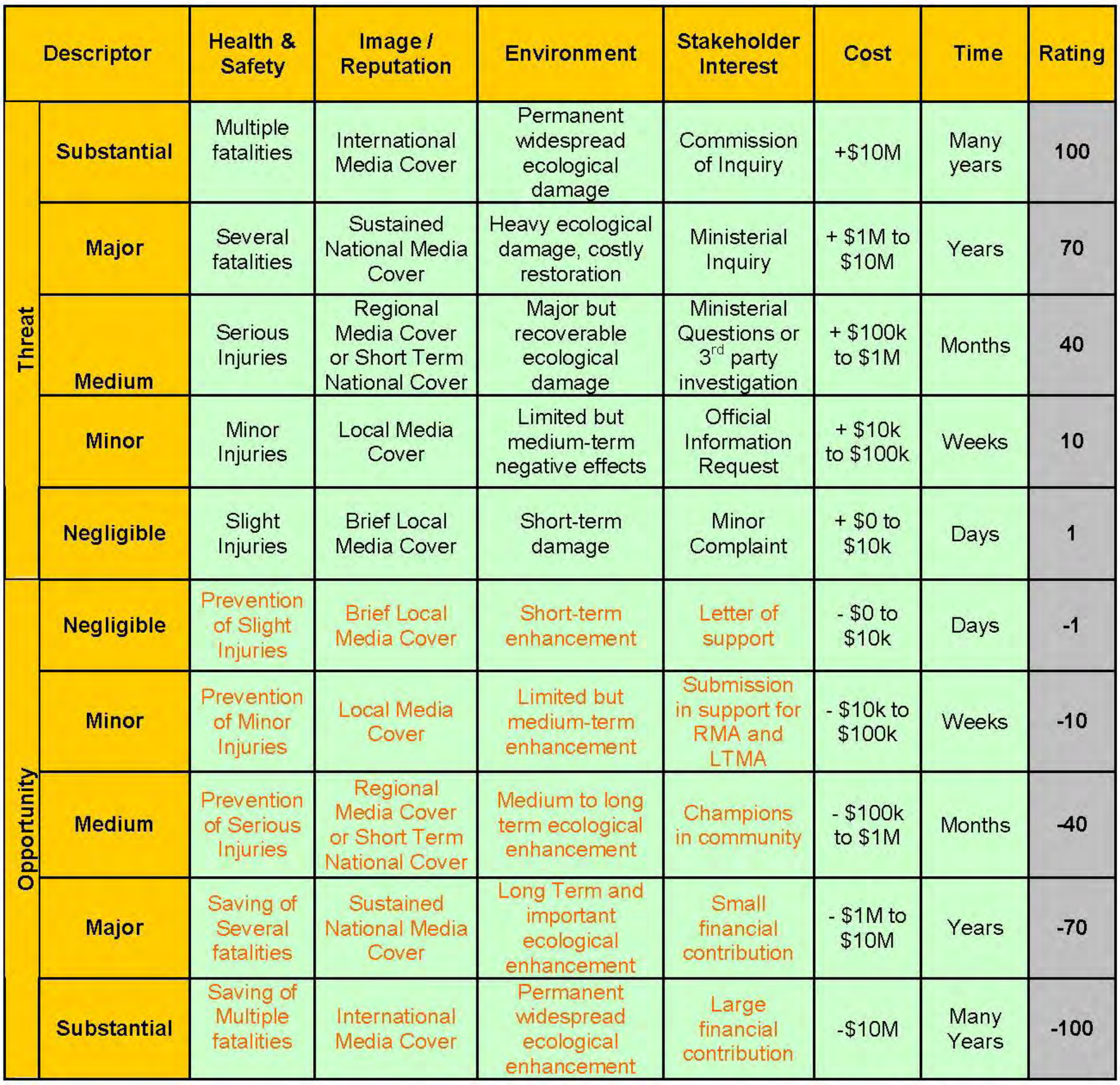
(2) Potential to damage road assets.

(3) Potential „cost" associated with repair.

(4) Potential „time" incurred with closure.

(5) Potential „ecological damage".

(6) Potential „media" coverage.



Descriptor		Health & Safety	Image / Reputation	Environment	Stakeholder Interest	Cost	Time	Rating
Threat	**Substantial**	Multiple fatalities	International Media Cover	Permanent widespread ecological damage	Commission of Inquiry	+$10M	Many years	100
	Major	Several fatalities	Sustained National Media Cover	Heavy ecological damage, costly restoration	Ministerial Inquiry	+ $1M to $10M	Years	70
	Medium	Serious Injuries	Regional Media Cover or Short Term National Cover	Major but recoverable ecological damage	Ministerial Questions or 3rd party investigation	+ $100k to $1M	Months	40
	Minor	Minor Injuries	Local Media Cover	Limited but medium-term negative effects	Official Information Request	+ $10k to $100k	Weeks	10
	Negligible	Slight Injuries	Brief Local Media Cover	Short-term damage	Minor Complaint	+ $0 to $10k	Days	1
Opportunity	**Negligible**	Prevention of Slight Injuries	Brief Local Media Cover	Short-term enhancement	Letter of support	- $0 to $10k	Days	-1
	Minor	Prevention of Minor Injuries	Local Media Cover	Limited but medium-term enhancement	Submission in support for RMA and LTMA	- $10k to $100k	Weeks	-10
	Medium	Prevention of Serious Injuries	Regional Media Cover or Short Term National Cover	Medium to long term ecological enhancement	Champions in community	- $100k to $1M	Months	-40
	Major	Saving of Several fatalities	Sustained National Media Cover	Long Term and important ecological enhancement	Small financial contribution	- $1M to $10M	Years	-70
	Substantial	Saving of Multiple fatalities	International Media Cover	Permanent widespread ecological enhancement	Large financial contribution	-$10M	Many Years	-100

Figure 21. Rating the Consequences of a Threat *(Table 2 from NZTA General Approach, 2004)*.

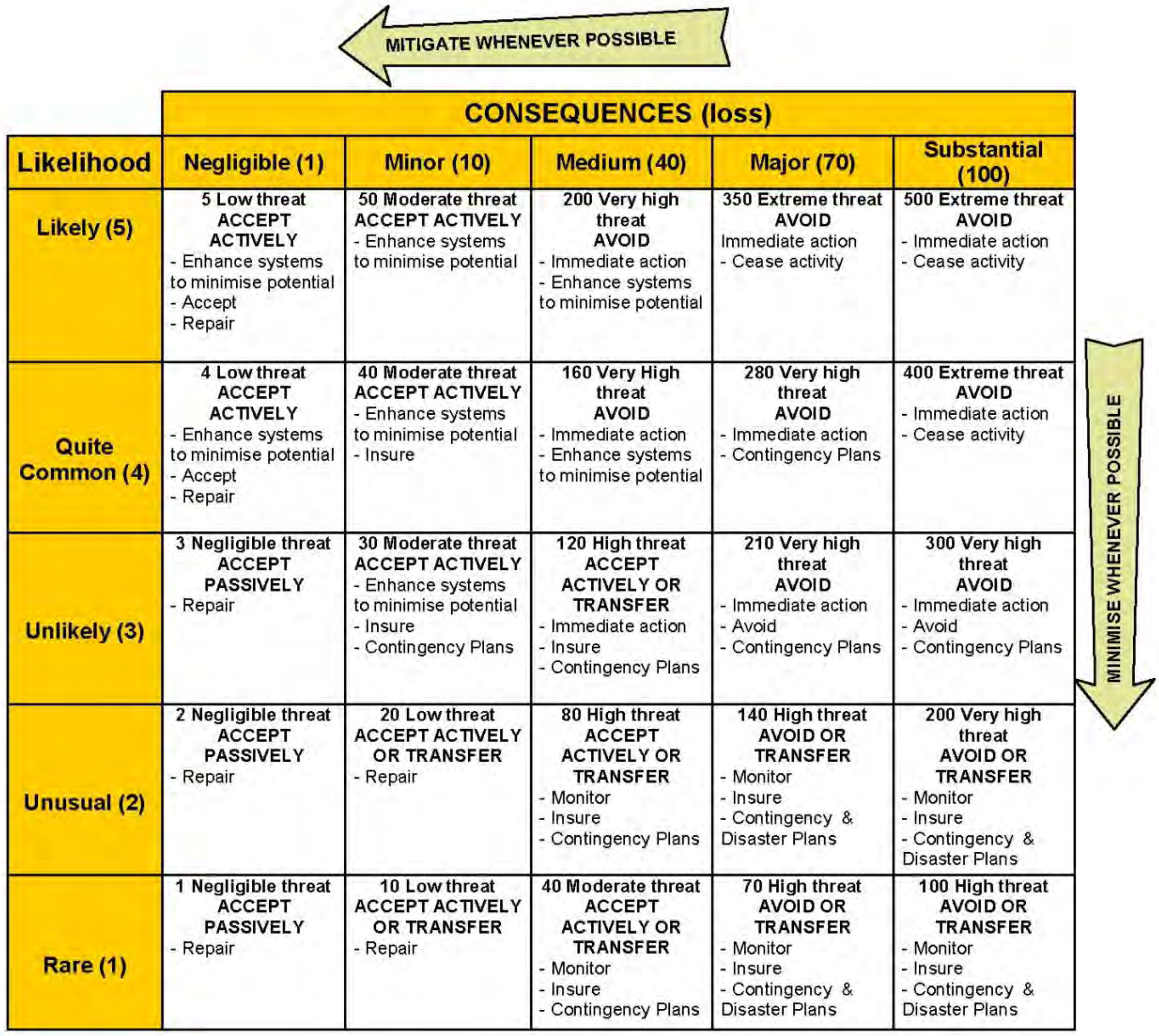
5.2 Results of landslide risk evaluation

The risk from potential landslide areas has been assessed in the General Approach by integrating the Likelihood and Consequences ratings in a matrix, as defined in Figure 22. In this approach the risk for each risk type (landslide area) was evaluated by establishing:

(a) A risk score – the multiple of the likelihood and consequences ratings for each specific risk.

(b) A risk (or threat) category – a description of the risk score in words (i.e. “negligible”, “low”, moderate”, “high”, “very high”, and “extreme”).

(c) A risk (threat) ranking – established by listing all the risks associated with the activity or business level, in order of decreasing risk score.



	CONSEQUENCES (loss)				
Likelihood	**Negligible (1)**	**Minor (10)**	**Medium (40)**	**Major (70)**	**Substantial (100)**
Likely (5)	**5 Low threat ACCEPT ACTIVELY** - Enhance systems to minimise potential - Accept - Repair	**50 Moderate threat ACCEPT ACTIVELY** - Enhance systems to minimise potential	**200 Very high threat AVOID** - Immediate action - Enhance systems to minimise potential	**350 Extreme threat AVOID** Immediate action - Cease activity	**500 Extreme threat AVOID** - Immediate action - Cease activity
Quite Common (4)	**4 Low threat ACCEPT ACTIVELY** - Enhance systems to minimise potential - Accept - Repair	**40 Moderate threat ACCEPT ACTIVELY** - Enhance systems to minimise potential - Insure	**160 Very High threat AVOID** - Immediate action - Enhance systems to minimise potential	**280 Very high threat AVOID** - Immediate action - Contingency Plans	**400 Extreme threat AVOID** - Immediate action - Cease activity
Unlikely (3)	**3 Negligible threat ACCEPT PASSIVELY** - Repair	**30 Moderate threat ACCEPT ACTIVELY** - Enhance systems to minimise potential - Insure - Contingency Plans	**120 High threat ACCEPT ACTIVELY OR TRANSFER** - Immediate action - Insure - Contingency Plans	**210 Very high threat AVOID** - Immediate action - Avoid - Contingency Plans	**300 Very high threat AVOID** - Immediate action - Avoid - Contingency Plans
Unusual (2)	**2 Negligible threat ACCEPT PASSIVELY** - Repair	**20 Low threat ACCEPT ACTIVELY OR TRANSFER** - Repair	**80 High threat ACCEPT ACTIVELY OR TRANSFER** - Monitor - Insure - Contingency Plans	**140 High threat AVOID OR TRANSFER** - Monitor - Insure - Contingency & Disaster Plans	**200 Very high threat AVOID OR TRANSFER** - Monitor - Insure - Contingency & Disaster Plans
Rare (1)	**1 Negligible threat ACCEPT PASSIVELY** - Repair	**10 Low threat ACCEPT ACTIVELY OR TRANSFER** - Repair	**40 Moderate threat ACCEPT ACTIVELY OR TRANSFER** - Monitor - Insure - Contingency Plans	**70 High threat AVOID OR TRANSFER** - Monitor - Insure - Contingency & Disaster Plans	**100 High threat AVOID OR TRANSFER** - Monitor - Insure - Contingency & Disaster Plans

Figure 22. Risk ratings and threat categories *(Table 3a from NZTA General Approach, 2004)*.

The risk of potential landslide areas in the Manawatu Gorge was assessed using the General Approach described above. The results of these assessments for each area are presented in detail in Table 5, summarised in Table 6, and discussed in Section 6.

Table 5. Risk assessment of existing landslides and potential future landslides areas that could affect SH3 in the Manawatu Gorge.

Area No.	Route Position (RP)[1]	Approx. Height[2] (m)	Approx. Area[3] (m^2)	Approx. Volume[4] (m^3)	Average Slope[2] Angle (°)	History of slope failures and remedial works	Potential for future landsliding that could affect SH 3[5]	RISK ASSESSMENT (Based on NZTA Risk Management Process)[6]			
								Existing stability controls	Likelihood Rating	Consequence Rating	Risk Assessment (Score)
1	488/1.22–1.38	1A – 60 1B – 40 1C – 35	1800 1500 800	9000 8000 4000	45–60 35–60 35–60	Small shallow landslides 1930-40, 1968-69, 1978-80, Feb2004.	Potential for further regressive failures (debris falls) at these sites, especially the very steep top of Site 1A during strong earthquake shaking. [7]*Ranking – R1*	None	Unlikely (3)	Minor (10)	**Moderate Threat** **(30)**
2	488/1.42–1.47	50	2500	15,000	60	Small landslides 1930-1940, 1978-80, and two Feb. 2004.	Potential for debris falls of colluvium from steep scarps of the 2004 failures, especially during heavy rainfall and strong earthquake shaking. *Ranking – R2*	None	Unlikely (3)	Medium (40)	**High Threat** **(120)**
3	488/1.51–1.64	3A – 70 3B – 50	3000 1500	15,000 8000	> 60 (H) 35–60 (T)	Small failures 1930-40, 1968-69, 1978-80; 3 (small) Feb. 2004.	Potential for moderate to large debris falls from scarps of previous failures, especially during heavy rainfall and strong earthquake shaking. *Ranking – R2*	Rock fall drape mesh (50% toe coverage)	Unlikely (3)	Medium (40)	**High Threat** **(120)**
4	488/1.86–2.10	130	16,000	160,000[4a]	45–60 (H) 45–35 (above HS)	2011 Landslide/stabilisation works between Bluffs 2 and 3. Small, shallow failures here 1930-1940 and 1968-69.	Extensive stabilisation works were undertaken in this area during 2012. Future slope failures are considered to be unlikely in this area. Largest landslide in the Manawatu Gorge landslide in last 100 years. *Ranking – R1*	Benches / High energy catch fences. Wide verge.	Unlikely (3)	Minor (10)	**Moderate Threat** **(30)**
5	RP488/2.16 – 2.20	90	5000	25,000 – 30,000	45–60 (H) 25–45 (T)	Small shallow colluvial debris slides 1930 to 1960s, and Feb. 2004 on cut slopes along SH3.	Potential for large colluvium/regolith fall during heavy rainfall and/or strong earthquake shaking, especially if the toe of the slope fails again or is cut back. Slope needs to be handled with care. *Ranking – R3*	Rock fall drape mesh (50% toe coverage)	Unlikely (3)	Major (70)	**VERY HIGH THREAT** **(210)**
6	488/2.23–2.35	6A – 90 6B – 40	5500 800	40,000 1500	45–60 (H) 35–45 (T) 6B - 45–60	Small shallow debris slides 1930 to 1940, 1998-2003, Feb. 2004.	Potential for large colluvium/regolith fall during heavy rainfall and/or strong earthquake shaking, especially if the toe of the slope fails again or is cut back. Slope needs to be maintained with care. *Ranking – R3*	None	Unlikely (3)	Major (70)	**VERY HIGH THREAT** **(210)**
7	488/2.42–2.47	80	3600	25,000	45–60 (H) 35–45 (T)	Small slides at toe 1930-40. Small rock falls from Bluff 6 Sep 1985.	Potential for a large colluvium/regolith fall during heavy rainfall and/or strong earthquake shaking, especially if the toe of the slope is cut back. This slope needs to be handled with care. *Ranking – R3*	Rock fall drape mesh (50% toe coverage)	Quite Common (4)	Major (70)	**VERY HIGH THREAT** **(280)**
8	488/2.52–2.6	8A – 50 8B – 30	1000 500	5000 1500	45–>60 (H) 35–45 (T)	Small road cut failures 1930-40, 1978-80 and larger failure top of Bluff 8 (8A) 2004-2011. Tied-back wall built 1985 on west side Bluff 9 to stabilise rock wedge failure.	Potential for retrogressive upslope failures at these sites during strong earthquake shaking or heavy rainfall, especially at Site 8A where recent failures have occurred. Toe of colluvial slope at Site 8B potentially more vulnerable if cut back. *Ranking – R2*	None	Unlikely (3)	Medium (40)	**High Threat** **(120)**
9	491/0.23–0.34	9A – 40 9B – 35	1700 1100	9000 5000	35–45 (H) 45– >60(T)	Minor colluvial failures at site 9A in 1960 and 1996. Larger colluvial failure at 9B in 1985 after toe of the slope was cut back.	Potential for retrogressive upslope failures (debris falls/ slides) at both sites especially during heavy rainfall where recent failures have occurred. The toe of these slopes will be more vulnerable to failures if they are cut back and they need to be maintained with care. *Ranking – R2*	Concrete barrier. Excavated drop zone.	Unlikely (3)	Medium (40)	**High Threat** **(120)** *p1/3*

Area No.	Route Position (RP)[1]	Approx. Height[2] (m)	Approx. Area[3] (m^2)	Approx. Volume[4] (m^3)	Average Slope[2] Angle (°)	History of slope failures and remedial works	Potential for future landsliding that could affect SH 3[5]	RISK ASSESSMENT (Based on NZTA Risk Management Process)[6]			
								Existing stability controls	Likelihood Rating	Consequence Rating	Risk Assessment (Score)
10	491/0.46–0.52	50	2000	10,000[4b]	45–60 (H) > 60 (T)	Failure July 1998 required major remedial works, including sluicing, benching, drainage drilling, and 10m gabion wall at toe of slope.	The benching stabilisation works are effective, but the MSE wall and gabion facing wall is bulging, and ~1 m high concrete wall base has fresh cracks ~3 m apart. Remedial works needed to repair damage. *Ranking – R2*	Gabion wall (failing)	Unlikely (3)	Medium (40)	**High Threat** **(120)**
11	491/0.64–0.78	11A – 100 11B – 100	7000 3000	100,000[4b] (A & B)	45–> 60 (H & T)	Three large failures 1995 at sites A (2) and B. Remedial works included sluicing, benching and removal of failure debris, drainage drilling, and meshing of upper slopes. Small soil slide/flow at top of Site B during 2004 rainstorm.	The stabilisation works at site 11A appear to be effective; few problems anticipated in this area. Recent soil flow at top of site 11B in 2004 suggests future minor problems could occur in this area. The mesh on this steep slope is loose and probably ineffective. *Ranking – R1*	Rock fall drape mesh (50% toe coverage)	Unlikely (3)	Minor (10)	**Moderate Threat** **(30)**
12	RP491/0.81 – 0.91	12A – 60 11B – 30	3000 900	15,000 5000	A35–60 B45–>60 (both OS)	Site of moderately large debris fall February 2004 (#1); small colluvial failure at road level (12B) between 1998 and 2003.	Potential for significant regressive failures (debris falls of colluvium/regolith) from oversteepened head scarps at 2A and 12B, especially during heavy rainfall and strong earthquake shaking. *Ranking – R3*	Concrete barrier. Excavated drop zone.	Unlikely (3)	Major (70)	**VERY HIGH THREAT** **(210)**
13	491/0.92–0.98	50	2000	5000 – 10,000	45–>60	The "Quarry" - site of small slip pre 1940, larger failure in 1960s; and small debris fall in Feb. 2004.	Potential for a large regressive failure (debris fall) from the steep face near SH3, especially during heavy rainfall and strong earthquake shaking. *Ranking – R2*	Excavated drop zone	Unlikely (3)	Medium (40)	**High Threat** **(120)**
14	491/1.00–1.13	70	10,000	70,000	45 –>60 (H) 35–45 (T)	Largest landslide (#2) caused by the February 2004 rainstorm. A shallow debris slide at this site during the 1960s. Small failure on failure scar July/ August 2012.	Potential for large upslope failures (rock/ colluvium/ regolith falls) from over-steepened head scarp, especially during heavy rainfall and strong earthquake shaking, as indicated by small failure of failure scar July/August 2012. Any further earthworks at this site would need to be carefully designed and implemented. *Ranking – R4*	Concrete barrier. Excavated drop zone. Rock fall drape mesh (50% toe coverage)	Unlikely (3)	SUBSTANTIAL (100)	**VERY HIGH THREAT** **(300)**
15	491/1.23–1.32	45	3500	20,000	45–>60 (H) 35–45 (T)	Large debris fall (#3) at this site in February 2004. Small failure on headscarp in the last 12 months.	Potential for moderate to large regressive upslope failures of colluvium and weathered rock from the over-steepened head scarp, especially during heavy rainfall and strong earthquake shaking. *Ranking – R3*	Bench	Quite Common (4)	Medium (40)	**VERY HIGH THREAT** **(160)**
16	491/1.37–1.54	16A – 40 16B – 20	3700 700	10,000 2000	45–>60 (H) 35–60 (T) (A and B)	A very small debris fall at 16B in Feb.2004. Three small failures occurred at this site in ~1978-80.	Potential for moderate to large colluvial failures (debris falls and slides) at sites 16A and 16B from the steep slope above SH3, especially during heavy rainfall and strong earthquake shaking. *Ranking – R1*	None	Unusual (2)	Medium (40)	**High Threat** **(80)**
17	491/1.57–1.81	17A – 40 17B – 35 17C – 40	3300 1300 1500	10,000 4000 5000	45–60 (OS) 35–60 (OS) 45–>60 (OS)	Moderate to large debris fall at 17A (#4); smaller failure at 17C Feb. 2004. Several failures here late 1940s and 1968-69, caused by cutting back of colluvial slope.	Potential for moderate to large colluvial failures (debris falls/slides) at sites 17A, B and C from slope above SH3, especially during heavy rainfall and strong earthquake shaking. Sites 17A and C more vulnerable because of oversteepening of toe by 2004 failures. *Ranking – R2*	None	Unlikely (3)	Medium (40)	**High Threat** **(120)**
18	491/1.85–2.03	70	8000	20,000	25–35 (AH) 35–>60 (OS)	Large colluvial debris fall caused by February 2004 rainstorm (#5). Small debris falls in this area in ~1940, 1968-69, and 1978-80 due to minor toe cutting to widen SH3.	Potential for future moderate to large regressive colluvial failures (debris slides and falls) from the steep headscarp at this site, especially during heavy rainfall and strong earthquake shaking. *Ranking – R2*	Rock fall drape mesh (50% toe coverage)	Unlikely (3)	Medium (40)	**High Threat** **(120)** *P2/3*

Area No.	Route Position (RP)[1]	Approx. Height[2] (m)	Approx. Area[3] (m^2)	Approx. Volume[4] (m^3)	Average Slope[2] Angle (°)	History of slope failures and remedial works	Potential for future landsliding that could affect SH 3[5]	RISK ASSESSMENT (Based on NZTA Risk Management Process)[6]			
								Existing stability controls	Likelihood Rating	Consequence Rating	Risk Assessment (Score)
19	491/2.04–2.16	70	5000	15,000	25–35 (AH) 35–>60 (OS)	Moderately large colluvial debris fall Feb. 2004 (#6); large debris slide just upstream in 1990, blocked SH3 for several days.	Potential for future moderate to large regressive colluvial failures (debris slides and falls) from the steep headscarp at this site, especially during heavy rainfall and strong earthquake shaking. *Ranking – R2*	Rock fall drape mesh (20% toe coverage)	Unlikely (3)	Medium (40)	**High Threat** **(120)**
20	491/2.20–2.33	90	7000	20,000	35–45 (H) 45–60 (T)	Several small failures in this area ~1940, 1968-69, 1978-80; small debris slide/flow 2004-2012.	Potential for future small to large debris slides and falls at this site, especially during heavy rainfall and strong earthquake shaking. *Ranking – R2*	None	Unlikely (3)	Medium (40)	**High Threat** **(120)**
21	491/2.33–2.49	5–10	1500 (total area)	3000	45–60 (OS) and > 60 (T)	A road cut failure here 1978-80; four very small soil (earth)/debris falls February 2004.	Potential for small earth/debris slides and falls on steep ~10 m high road cuts in this area, especially during heavy rainfall and strong earthquake shaking. *Ranking – R1*	None	Unlikely (3)	Minor (10)	**Moderate Threat** **(30)**
22	491/2.52–2.69	15–25	6000 (total area)	10,000	35–45 (H) 45–60 (T)	Small failure here in 1978-80; large debris fall/flow and underslip in February 2004 (#7; U/S#1).	Potential exists for further small to moderate-sized debris falls and flows in this area, especially during heavy rainfall and strong earthquake shaking. *Ranking – R1*	Bench for 50% of exposure length	Unlikely (3)	Minor (10)	**Moderate Threat** **(30)**
23	491/2.70–2.83	15–25	3000 (total area)	6,000	35–45 (H) 45–>60 (T) (upper slope 35–25 or<)	Three small debris falls and flows (#8 and U/S#2) February 2004.	Potential for further small to moderate-sized debris falls and flows in this area, especially during heavy rainfall and strong earthquake shaking. The mesh protects SH3 from small debris falls and flows, but needs to be extended ~15 m across the recent failure area to the Windy Bridge Stream. Underslips are also expected occur along this section of the gorge. *Ranking – R1*	Rock fall drape mesh (50% toe coverage)	Unlikely (3)	Minor (10)	**Moderate Threat** **(30)**
24	491/2.89–3.20	25–40	A –3500 B –3900 (totals for A and B)	6000 7000	35–45 (H) 45–>60 (T) (upper slope 35–25 or<)	Small debris falls and flows (#9 and U/S #3 and #4 Feb. 2004.	Potential exists for small to moderate debris falls/flows and underslips in this area, especially during heavy rainfall and strong earthquake shaking. *Ranking – R1*	None	Unlikely (3)	Minor (10)	**Moderate Threat** **(30)**
25	491/3.20–4.00	2–5	NA	Minor	35–60 (cuts) <25–35 (above cuts)	Mainly small underslip in this area; small to very small debris falls on 3-5 m high road cuts into the toe of the thick colluvial slope.	Potential exists for small to very small road cut failures (soil and debris falls) and future underslips in this area, especially during heavy rainfall and strong earthquake shaking. *Ranking – R1*	None	Unlikely (3)	Minor (10)	**Moderate Threat** **(30)**

NOTES:

(**1**) Route positions (km) on SH 3 are measured from the junction of SH3 and SH57 (RP488/0.00) shown on Figure 2. Locations and RPs of specific landslide areas are shown on Figure 9 and 9a.

(2) Maximum slope heights (above SH3) and slope angles determined from Figure 6 using 1 m LiDAR contours (29/9/2011). Average slope angles given for head scarp (H), toe (T), areas above head scarp (AH), or overall slope (OS) at sites.

(3) Areas of potential landslide sites determined in GIS from Figure 9 polygons.

(4) 4a – Volumes of past landslides (1995, 1998; 2011) from works records. 4b – Potential landslide volumes estimated from area and depth of colluvium or regolith (soils and weathered bedrock).

(5) Assessment of future landslide potential based on: (a) slope angle and height; (b) rock types and surficial deposits; (c) previous slope failures; and (d) triggering events (heavy rainfall, earthquake shaking) that are expected in the future.

(6) The Risk Assessment was carried out according to the procedures of the Risk Management Process Manual, September 2004, Transit New Zealand (NZTA) using the "general approach" (see Appendix 3).

(7) Ranking classes (R1, R2, R3, and R4) are defined in Table 4. *P3/3*

Table 6. Summary of risk assessments and rankings of potential future landslides areas that could affect SH3 in the Manawatu Gorge.

Area No.	Section of Gorge[4]	Rank[2]	Likelihood Rating	Consequence Rating	Risk Assessment Category[1, 3] (Score)
1	Western	R1	Unlikely (3)	Minor (10)	Moderate Threat (30)
2		R2	Unlikely (3)	Medium (40)	High Threat(120)
3		R2	Unlikely (3)	Medium (40)	High Threat (120)
4		R1	Unlikely (3)	Minor (10)	Moderate Threat (30)
5		R3	Unlikely (3)	Major (70)	VERY HIGH THREAT (210)
6		R3	Unlikely (3)	Major (70)	VERY HIGH THREAT (210)
7		R3	Quite Common (4)	Major (70)	VERY HIGH THREAT (280)
8		R2	Unlikely (3)	Medium (40)	High Threat (120)
9	Central	R2	Unlikely (3)	Medium (40)	High Threat (120)
10		R2	Unlikely (3)	Medium (40)	High Threat (120)
11		R1	Unlikely (3)	Minor (10)	Moderate Threat(30)
12		R3	Unlikely (3)	Major (70)	VERY HIGH THREAT (210)
13		R2	Unlikely (3)	Medium (40)	High Threat (120)
14		R4	Unlikely (3)	Substantial (100)	VERY HIGH THREAT (300)
15		R3	Quite Common (4)	Medium (40)	VERY HIGH THREAT (160)
16		R1	Unusual (2)	Medium (40)	High Threat (80)
17		R2	Unlikely (3)	Medium (40)	High Threat (120)
18		R2	Unlikely (3)	Medium (40)	High Threat (120)
19		R2	Unlikely (3)	Medium (40)	High Threat (120)
20		R2	Unlikely (3)	Medium (40)	High Threat (120)
21		R1	Unlikely (3)	Minor (10)	Moderate Threat (30)
22	Eastern	R1	Unlikely (3)	Minor (10)	Moderate Threat (30)
23		R1	Unlikely (3)	Minor (10)	Moderate Threat (30)
24		R1	Unlikely (3)	Minor (10)	Moderate Threat (30)
25		R1	Unlikely (3)	Minor (10)	Moderate Threat (30)

NOTES:

(1) Risk Assessment carried out according to the procedures of the Risk Management Process Manual, September 2004, Transit New Zealand (NZTA) using the "general approach" (see Appendix 3).

(2) Ranking classes (R1, R2, R3, and R4) are defined in Table 4.

(3) Number of potential landslide areas in Risk Assessment Categories/Ranking
- Moderate Threat (30) / R1 = 8 areas (1, 4, 11, 21, 22, 23, 24, 25).
- High Threat (120) /R2 = 11 areas (2, 3, 8, 9, 10, 13, 16, 17, 18, 19, 20).
- Very High Threat (160 or >) / R3 and R4 = 6 areas (5, 6, 7, 12, 14, 15).

(4) Number (and %) of potential landslide areas in Sections of Gorge compared to historical landslides:
- Western = 8 (32%) / Hist. LS - 55 (40%)
- Central = 13 (52%) / Hist. LS - 61 (44%)
- Eastern = 4 (16%) / Hist. LS - 22 (16%)

6.0 DISCUSSION OF RISK ASSESMENTS

The risk assessments were completed for each of the 25 identified potential landslide areas using information from historical landsliding, and especially the 2011 landslide which, being the largest landslide in the gorge in the last 100 years, represents a worst-case scenario. An important part of the assessment process involved the identification of areas with similar geology, slope morphology, slope failure potential, and slope failure controls. This allowed us to provide a balanced assessment of the differences in slope hazard and the risk presented by each of the potential future landslide areas.

Historical landsliding in the gorge provided us with the basis for our estimates of the likelihood and approximate annual probabilities (Figure 20) of landslides at the 25 identified landslide areas. In doing this we also took account of the existing control measures at the various sites, especially where extensive stabilisation measures were completed, such as the 1995, 1998, and 2011 landslides. The performance of these measures over time, for example the bulging and cracking deformation of the gabion wall at the 1998 landslide works, was also considered and factored into the risk assessment.

The summary of the landslide risk assessments presented in Table 6 indicates three categories of future landslide threat (risk) in the Manawatu Gorge, as follows:

(a) Moderate Threat: – 8 Areas (1, 4, 11, 21, 22, 23, 24, 25). *[Rank 1]*

(b) High Threat: – 11 Areas (2, 3, 8, 9, 10, 13, 16, 17, 18, 19, 20). *[Rank 2]*

(c) Very High Threat: – 6 Areas (5, 6, 7, 12, 14, 15). *[Rank 3/4]*

As shown above the High and Very High Threat (Risk) areas are located in the Western and Central sections of the gorge. All of the higher threat areas have strong geological, geomorphic similarities to the 2011 landslide area, and all have been destabilised to some degree over many years by cutting back and oversteepening the toe of thick colluvial deposits without putting support measures in place.

Because of the marked geological and geomorphic differences, particularly the lower and less steep slopes (Figure 19), there is considerably reduced landslide potential in Areas 21 to 25 upstream of Barney"s Point (Section 4.2). This is reflected by the lower (Moderate) risk ratings for these areas in the Eastern Section of the gorge. As previously discussed, the potential exists in Areas 21 to 25 for continued small to moderate earth and debris slides, falls, and flows on the steep road cuts along SH3, especially during heavy rainfall as occurred in 2004, and also during strong earthquake shaking. Underslips are also expected occur along this section of the gorge.

The study has shown that the landslides caused by the February 2004 rainstorm had a significant influence on the risk assessments, especially in the Central Section of the gorge. Several of the larger 2004 landslides (numbers #1 to #5, Figure 9) are the main reason for the high to very high risk ratings of Areas 12, 14, 15, 17 and 18 (Table 4 and 5). As shown in Figures 16, 17, and 18, the 2004 landslide scarps are significantly oversteepened and at risk of regressive failures, especially in Areas 14 and 15 where small failures have already occurred. Future slope failures at these sites should be geotechnically assessed to ensure that appropriate controls and stabilisation measures are used to minimise the size and upslope growth of failures. The 2004 landslide #2 in Area 14 is thought to pose the greatest landslide risk in the gorge. A large failure similar to the 2011 landslide could occur at this site at any time, but especially during heavy rainfall or strong earthquake shaking.

6.1 Recommended actions

It has not been possible in this report to consider in detail the specific actions or procedures that are required to provide a more robust assessment of the future risk at each of the potential landslide areas identified in the gorge. However, some general recommendations are provided as a guide to what would be appropriate for potential landslide areas in the three main risk categories. These recommendations mainly involve the collection of more site-specific information in each potential landslide area, especially in the higher risk areas. Collection of additional data is invariably the basis for preparing a geological/geotechnical model of a landslide site, slope stability analysis, and a more robust risk assessment using the quantitative „Advanced Approach" described in the NZTA risk management process manual (NZTA 2004). The „Advanced Approach" should result in detailed recommendations for specific landslide management and remedial options that are appropriate for each site.

General recommendations for future actions for better definition and management of the risk at potential landslide areas in each of the risk categories, as well as local rock fall sites within the gorge, are discussed below.

6.1.1 Very High Threat (Risk) Areas

For those areas assessed to have the highest landslide risk ratings (Score 210–300: Areas 5, 6, 7, 12, 14, and 15) the following actions are recommended:

(a) Engineering geology report: An engineering geological report on the landslide site(s) should be prepared. This should include: geological and geomorphic mapping of the landslide face and areas upslope and adjacent to active scarps; geological cross sections; documentation of past slope failure history; limit equilibrium slope stability analysis; landslide risk assessment using the Advanced Approach; recommendations for future sites investigations; and suggestions for potential remedial measures.

(b) Terrestrial Laser Scanning (TLS): TLS scans of the landslide site will provide a highly accurate digital elevation model of the current landslide faces and scarps, similar to what was completed at the 2011 landslide site. The TLS slope model would be integrated with the 29 September 2011 LiDAR slope model for the Manawatu Gorge. This will allow topographic changes in the landslide scars over the last 12 months to be detected. Follow-up TLS surveys after any future slope failures at the sites will allow the positions and landslide volumes to be accurately determined.

(c) Detailed assessment: If the initial engineering geological report (a) suggests it is warranted, or new slope failures occur, more detailed geological mapping of the slip face and adjacent areas may be required, possibly using roped access. Investigation drilling may also be required across and above the site. This may be essential to accurately determine the depth of the overburden (colluvium, regolith) and the volume of potentially unstable material on the slope, which is critical in preparing an accurate geological model of the landslide. These methods were used effectively adjacent to the 2011 landslide site, where it resulted in the design and construction of an anchored and tied back wall to reduce the risk of further slope failures above SH3.

(d) Monitor slope behaviour: An accurate record should be kept of future slope failures (rock falls, debris falls and slides) and performance of existing controls (mesh, catch fence etc.) at each potential landslide area. Information on the location, size, type, and cause (trigger) of small-scale slope failures at each site will give an indication of the behaviour of the slope and the likelihood of larger failures that could close SH3.

(e) Instrumental monitoring: More sophisticated monitoring methods may be required if small slope failures occur more frequently, or another large failure occurs. Such methods may include the installation of survey control points, down-hole inclinometer monitoring, and local rain fall recording. This should be considered on a site-by-site basis if and when it is deemed to be necessary.

6.1.2 High Threat (Risk) Areas

For potential landslide areas assessed to have a High Risk rating (Score 120–210, Areas 2, 3, 8, 9, 10,13, 16, 17, 18, 19 and 20), the following actions are recommended:

(a) Engineering geology report: A basic engineering geological report on each landslide area should be prepared which includes: a description of landslide site, geological and geomorphic maps, cross sections, and an appraisal of slope stability and the potential for future retrogressive failures (in-depth stability analysis may not be needed).

(b) Monitor slope behaviour: An accurate record should be kept of future slope failures (rock falls, debris falls and slides) and performance of existing controls (mesh, catch fence etc.) at each potential landslide area. Information on the location, size, type and cause of small-scale slope failures at each site will provide valuable information on the behaviour of the slope and the likelihood of larger failures that could close SH3. If such a failure does occur the actions and methods recommended above for the Very High risk areas should be adopted.

6.1.3 Moderate Threat (Risk) Areas

For potential landslide areas assessed as having a Moderate Risk rating (Score 0–30, Areas 1, 4, 11, 21, 22, 23, 24, and 25), the following actions are recommended:

(a) Standard maintenance measures. These should include signage and traffic control, clearance of slip debris to reopen the road, preferably with minimal cutting back of the slope, and repairs to any underslips and road edge failures (mainly in Areas 21 to 25).

(b) In addition, the slope behaviour in these areas should be carefully monitored by keeping a record of future slope failures (rock falls, debris falls and slides) and performance of any existing controls, as outlined in 2 (b) above.

6.1.4 Local rock fall sites (bluffs and rocky slopes)

In addition to the risk from identified potential landslide areas discussed above, there is also a risk of small rock falls and falls of individual boulders in the gorge, not only from rock bluffs (many of which have control measures), but also from isolated boulders on other slopes. Recording data on future rock fall activity (see 2 (b) above) could be used effectively to determine which slopes and bluffs have the highest failure activity, and also develop a spatial magnitude/frequency probability model for rock falls in the gorge.

Control measures for isolated, local rock falls in the Manawatu Gorge are in a state of disrepair in some places (Appendix 4). Although many of the control systems have worked effectively, multiple small rock falls have damaged the control structures in a number of places. It is no known, however, how much repair and replacement is required to mitigate the hazard from local rock falls in the gorge. It is therefore recommended that the condition of meshed areas and catch fences is reviewed to determine what repairs are needed, and what new control structures are required in areas where none currently exist.

6.2 Future landslide frequency in the gorge

The 2011 review of historical landsliding in the Manawatu Gorge (Hancox 2011) suggested that larger landslides (~20,000–100,000 m^3) could possibly occur every 5 to 10 years. The scars of landslides caused by the 2004 rainstorm compared to conditions prior to that event, especially in the centre of the gorge (Figures 10 and 11), suggests that estimate is realistic. We have used that estimate for many of our likelihood ratings (unlikely/once per 5–10 years) in the landslide risk assessments (Tables 5 and 6).

Based on the information presented in this report the risk of future large landslides that could significantly affect or close SH3 in the Manawatu Gorge in the next 20 years is therefore considered to be high to very high, especially during future high intensity rainstorms or an average wet winter, and also strong earthquake shaking.

The most hazardous areas of the gorge where future large landslides could occur are located at the toes of colluvial slopes that have been destabilised by steep (>45–60°) unsupported road cuts. In most cases these slopes are located between bluffs of resistant sandstone and argillite, as is the case with the 1995, 1998, and 2011 landslides (Figures 14 and 15).

There have been occasional rock falls from some rock bluffs in the past, but in general the existing controls (rock bolting and mesh mainly) have effectively minimised stability problems at these sites. A few areas were noted in this study where rock bolting should be carried out, for example adjacent to Bluffs 9 and12 (Appendix 4). These and other areas of the gorge should be reviewed to determine what additional bolting and slope scaling is needed to reduce the risk of local rock falls and isolated boulders falls in the gorge.

7.0 MANAGEMENT OF FUTURE LANDSLIDES

7.1 Introduction

In this section we will look briefly at the effectiveness of methods used to manage previous landslides that have closed SH3 in the Manawatu gorge, and then consider some indicative engineering methods and strategies that could be used to manage and reduce the consequences of landslides in the future.

One of the most obvious lessons from the 2004 landslides (Figures 16 and 18) and the 2011 landslides (Figures 8) was the significant increase in the size of all of these landslides, both up slope and laterally, compared to the initial failures that occurred. This resulted in much more extensive slope stabilisation works and longer road closures at all these sites.

No slope failures occurred at the 2011 landslide site in February 2004, and only minor instability was evident in January 2000 (Figure 12). The first of the more recent failures at the 2011 landslide site occurred in September 2010 with a small debris fall midway between Bluffs 2 and 3. This was followed on 18 August 2011 by a larger failure about 10 m upstream during a prolonged wet period (~50 mm of rain fell over 7 days in Palmerston North, and probably more fell in the Manawatu Gorge).

The 18 August 2011 debris slide closed SH 3 and it remained closed for more than 360 days as further slope failures and extensive stabilisation works were eventually carried out. The failure sequence that followed at the 2011 landslide site is illustrated in Figures 23 and 24. Over the next two months the failure scar grew considerably, extending both upslope and laterally downstream (to the west) as efforts were made with diggers and bulldozers to remove slide debris from the road and stabilise the slip face. The cutting back the toe to create a debris „catch area‟ was one of the main adverse factors in this process (Figure 24c). Because of the weak nature of the surficial colluvium and regolith within an old (prehistoric) landslide area, these efforts had the effect of further over-steepening the slip face and headscarp, making it more vulnerable to regressive failures (Figure 25). The road through the gorge was about to be reopened to road traffic when the final (apart from minor collapses around the head scarp) and largest failure (debris slide) at the site occurred, sending at least 50,000 m^3 cascading across the road into the river in the early hours of 18 October 2011. The failure scar extended ~80 m upslope and ~50 m west towards the sandstone spur above Bluff 3, and increased the area affected by the landslide by ~150% (Figures 24c and 24d).

From the failure processes observed at the 2011 landslide site it was clear that the methods used to clear the slide debris away at the site, which significantly oversteepened the toe of the slope, were probably responsible for the size of the 18 October failure. Despite the planned reopening of the road that day, we had expected that further slope failures would occur at the site, possibly falls of up to about 5,000-10,000 m^3, but we were surprised by the extent and size of the final en masse failure, which would not have been contained by any of the rock fall protection measures that were being considered to protect traffic on SH3.

One reason that the behaviour of the 2011 landslide site came as a surprise was that several of the 2004 landslide sites (e.g. #2 and #3 in the centre of the gorge, Figures 15 and 16) had been treated in a similar manner (clearing the slide material and cutting back the toe of the slope to create a debris „catch‟ area) but that had not led to a massive regressive failure. However, as shown by the risk ratings discussed earlier, the potential risk of future landsliding at all those sites is rated as very high (Tables 5 and 6).

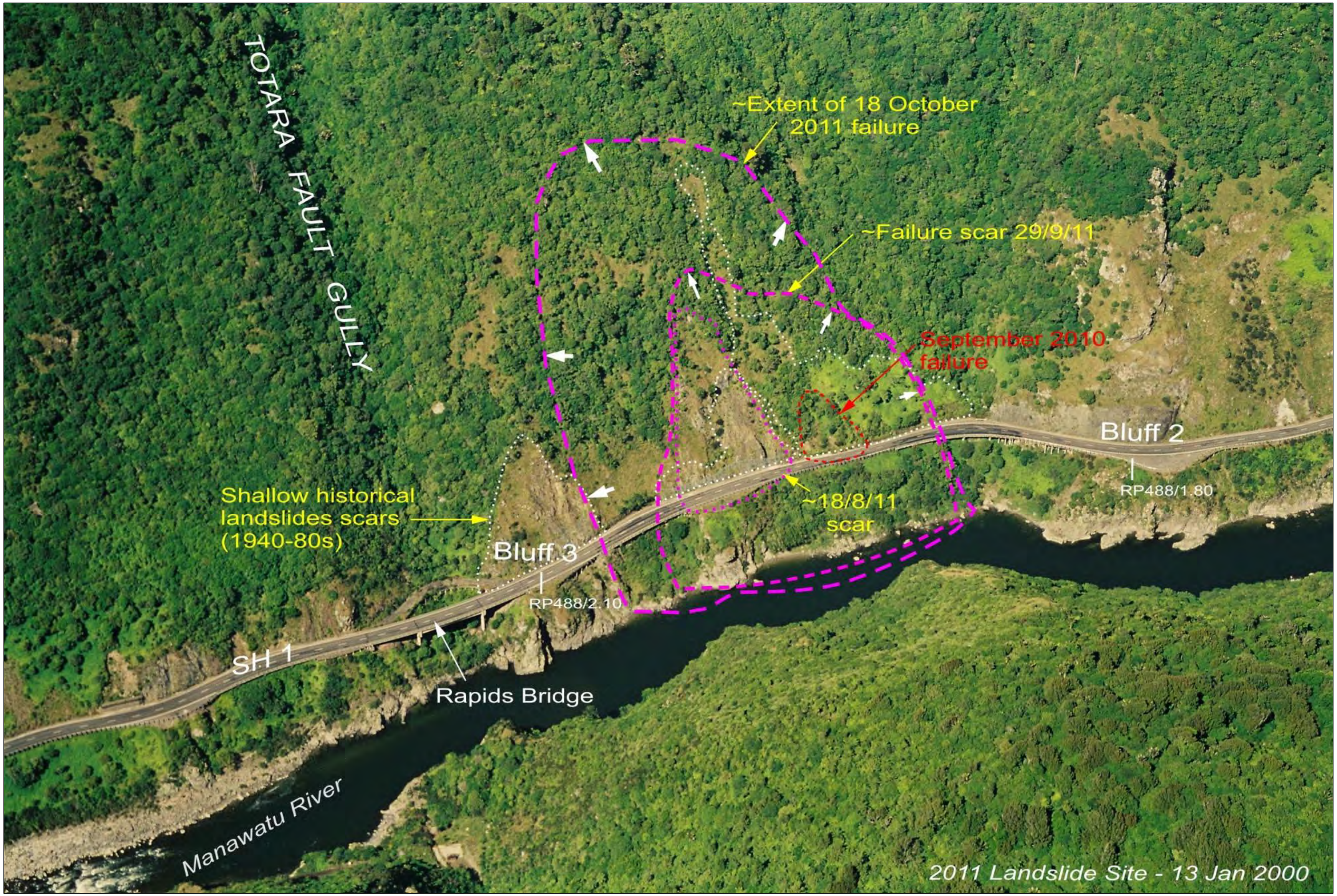
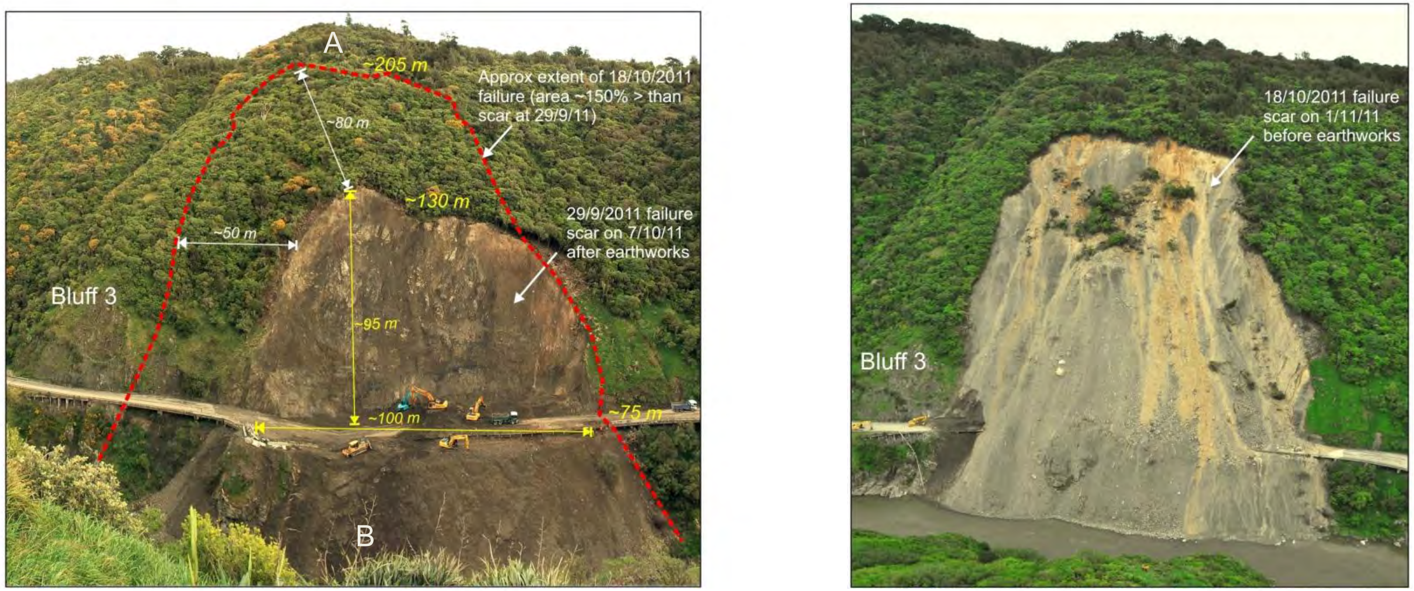


Figure 23. January 2000 photo of the 2011 landslide area showing the original slope between Bluffs 2 and 3, and the sequence and approximate locations and extent of the failure scars that developed from September 2010 to 18 October 2011.

(a) 2011 Landslide a scar on 19/8/2011.

(b) 2011 Landslide a scar on 29/9/2011.



(c) 2011 Landslide a scar on 7/10/2011.

(d) 2011 Landslide scar on 1/11/2011.

Figure 24. Sequence of photos showing the upslope and lateral growth of the 2011 landslide area on: 19 August 2011 (a); 29 September 2011 (b); 7 October 2011 (c); and 1 November 2011. A and B (in c) indicate the location of the cross section shown in Figure 25.

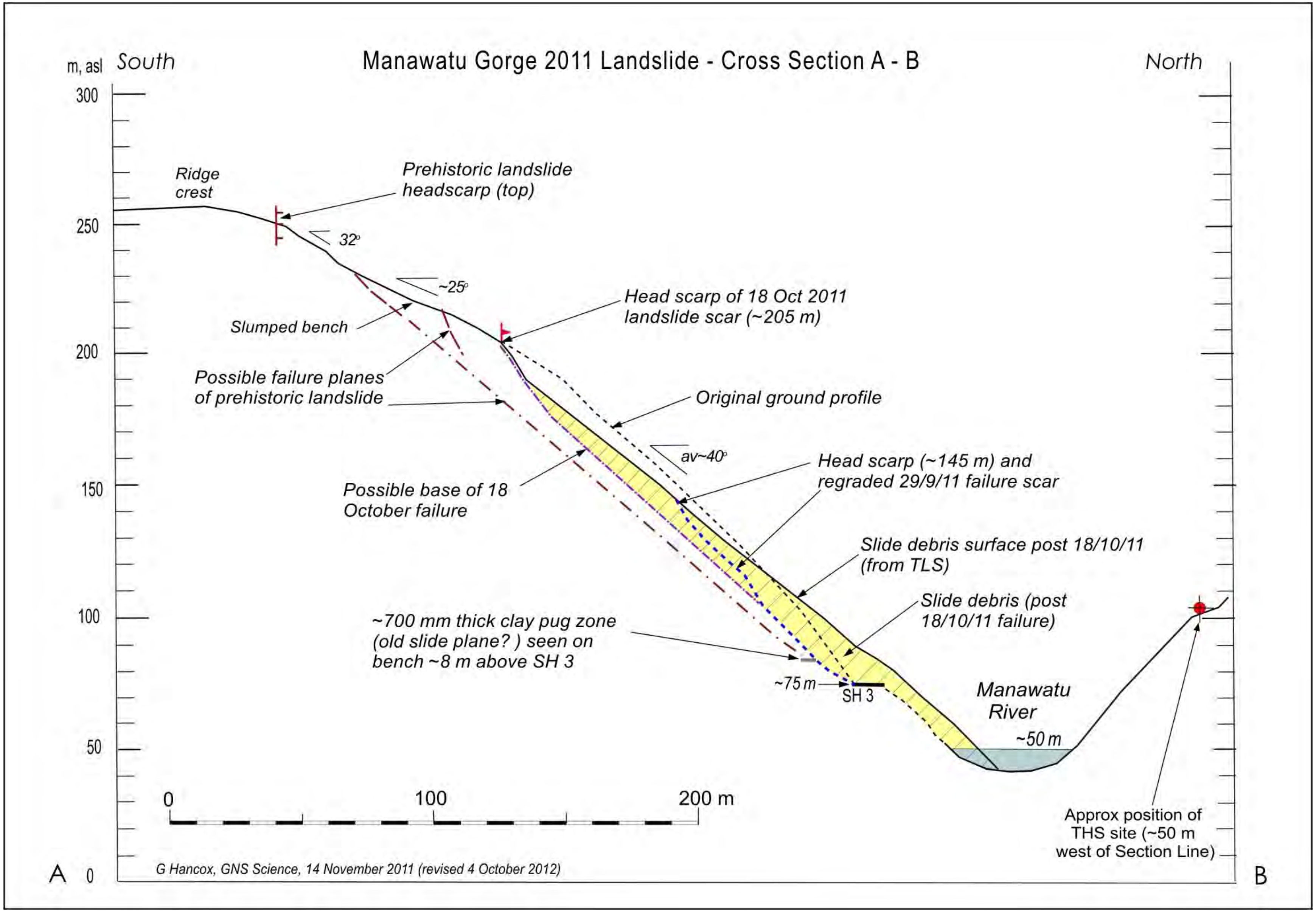


Figure 25. Cross section through the 2011 landslide showing sequence of failure profiles and original ground surface profile (location on Fig. 24c).

7.2 Suggestions for future landslide management strategy

Prior to the 18 October failure the risk of future failures at the 2011 landslide site was also considered to be „very high", although at the time a formal risk assessment had not been undertaken. It was because of this knowledge that the 2011 review of landsliding in the Manawatu Gorge (Hancox 2011) recommended that a review should be undertaken of how past landslide problems in the gorge have been managed and resolved, as a first step in developing an appropriate engineering strategy for managing future landslides in the gorge.

It has not been possible within the scope of this study to undertake a thorough review of previous landslides in the gorge, or develop a detailed landslide management strategy. It has, however, enabled some general concepts to be established, which should be considered in the development of more detailed management strategy guidelines in the near future. The recommended methods and strategies that could be used to manage and reduce the consequences of future landslides in the Manawatu Gorge are as follows:

(1) Emergency response: It is recommended that when a landslide event large enough to close both lanes of SH3 occurs, an experienced engineering geologist or a geotechnical engineer familiar with slope failures in greywacke terrain is involved in the emergency response and decision-making process to assess the landslide and reopen the road.

(2) Geological model: A geological model of the landslide site should be considered before any earthworks are begun that could adversely affect or further decrease the stability of the slope. This should involve looking at the local and site geology, and previous slope failure history of slopes above and below the landslide site, and adjacent areas.

(3) Slope failure inventory: To provide better knowledge of slope failures in the gorge a simple inventory or register of landslide events (rock falls, falls of individual boulders, debris falls and slides etc.) in the gorge should be maintained by the road maintenance contractor. Basic event information to be recorded on a Landslide Report Form should include: the date and time, SH3 location (RP), type and size of slope failure, and remedial actions taken. Copies of these forms should be provided to the engineering consultant responsible for the highway. This is one of the actions recommended to provide further data on the High Risk and Very High Risk potential landslide areas identified in this study (Section 6.1). A basic rock fall and slip inventory will make it possible to determine the frequency and location of these events in the gorge, and this will provide a basis for assessing the annual probability and locations of future events.

(4) Monitoring of slope failures: The landslide inventory suggested above (3) would provide basic monitoring of slope failures at existing or potential landslide sites or areas in the gorge. If future failures occur in the very high risk areas more sophisticated slope monitoring should be considered, possibly using the installation of survey monitoring points, or Terrestrial Laser Scanning, and may require warning signage and traffic control systems. This would be decided on a site-by-site basis.

(5) Review slope controls: Review and repair of the existing draping mesh and catch fence systems is suggested. Observations from our field work (Appendix 4) indicate that several areas require immediate repairs to sections of steel mesh, and other areas need scaling or rock bolting of loose blocks on rock faces (mainly bluffs). Mesh and catch fences are considered suitable for small boulders and small local failures, but are generally not suitable for falls involving several cubic metres (as at Site 15, Figure 17) or larger mass failures as occurred at the 2011 landslide site.

(6) *Site specific assessments*: Engineering geological and geotechnical assessments should be carried out at potential landslide sites that are assigned very high risk ratings (e.g. Areas 5, 6, 7, 12, 14, and 15) to establish a geological and geotechnical slope model, analyse slope stability, and reassess the landslide risk at each site in more depth using the Advanced Method.

(7) *Remedial methods – limit steepening toe of slope*: In clearing a landslide site every efforts should be made to limit earthworks that undercut and oversteepen the toe of the slope adjacent to SH3, especially slopes formed in thick colluvium and regolith. As at the 2011 landslide site and 2004 landslide #2 site, this is often done to form a debris catch area, which may be suitable for small debris falls but not for larger failures. Where possible, support measures should be the preferred method of stabilising the toe of a failing colluvial and regolith slope. If the toe of such a slope is cut back and oversteepened (50-60° or >) without support it may have short-term stability at that angle (as it has at Area 14), but eventually the slope will fail back to the long-term stable angle of ~40-45°. It is strongly recommended that before any earthworks are begun an appropriate Engineering Geologist or Geotechnical Engineer is consulted.

(8) *Performance of Bluffs*: The bluffs within the gorge are generally performing well with the existing controls (mainly mesh and rock bolts). However, our walk-over inspection (Appendix 4) suggested that scaling of loose blocks and rock bolting is required at some locations considered to have a high risk of local rock falls (Bluffs 9 and 12).

(9) *Reporting on 2011 landslide*: In carrying out this study it was again apparent that the lack of good engineering works records and geological completion reports on past landslide problems and stabilisation works in the gorge may be a significant constraint in assessing and dealing with future landslide problems. It is therefore recommended that a detailed completion report be prepared on the 2011 landslide area. This should describe the nature and history of the landslide, the geology and geomorphology of the site, and the stabilisation works that were undertaken. It should also include a limit equilibrium stability analysis of the 2011 landslide slope before and after the stabilisation measures. Such a report will be extremely valuable in managing similar large colluvial and regolith failures in the gorge when they occur.

(10) *Documentation of future landslides problems*: Full documentation and reporting on the engineering, geotechnical, and geological aspects of significant future landslides in the gorge is recommended. This is considered to be an essential component of the strategy that is needed to improve the management and minimise the risk from future landslides to SH3 within the Manawatu Gorge.

8.0 CONCLUSIONS

(1) In this study we have identified estimated the risk at potential future landslide sites in the gorge, and provided recommendations for a strategy to manage the threat at those sites, and future landslide problems in the Manawatu Gorge. Our assessment focussed initially on the geology and geomorphology, old (prehistoric) landslides in the area, and information provided by past landslides that significantly affected SH3 in 1995, 1998, 2004, and 2011.

(2) The locations and extent of potential landslide areas that could affect SH3 through the gorge were initially identified on oblique and vertical aerial photos with the aid of GIS maps of bedrock and colluvium, prehistoric landslide scars, historical landslide data, and slope angles based on 1 m LiDAR contours. The potential landslide areas along SH3 and existing slope controls were later ground-checked and assessed.

(3) Twenty five potential landslide areas were identified along SH3 in the gorge based on: (a) past landslide history, (b) rock types and surficial deposits, (c) geomorphic features (prehistoric landslides scarps, bluffs), (d) slope angles and heights, and (e) road cuts and slope support measures. These areas were mapped in GIS and ranked according to their estimated size (area and volume) and potential for future slope failures that could damage or close SH3, especially during heavy rainfall and strong earthquake shaking. The areas have been ranked according to their size and potential to close SH3 as follows: R1: 10,000 m^3; R2: 10,000–25,000 m^3; R3: 25,000–50,000 m^3; and R4: >50,000 m^3.

(4) Eight (32%) of the potential landslide areas are in the Western Section of the gorge (Gorge Monument to Bluff 10, RP488/1.05–491/0.10); thirteen (52%) are in the Central Section (Bluff 10 to Barney‟s Point, RP491/0.10–2.45); and only four (16%) are in the Eastern Section (Barney‟s Point to Upper Gorge Bridge, RP491/2.45–4.10). This is similar to the historical distribution of landslides (West - 55 (40%), Centre - 61 (44%), East - 22 (16%). The higher percentage of potential landslide areas in the centre of the gorge is attributed to the number of unstable scars of landslides caused by the February 2004 rainstorm.

(5) The risk that potential landslide areas present to SH3 in the Manawatu Gorge was assessed using the General Approach outlined in the NZTA‟s 2004 Risk Assessment Process Manual. This method provides a qualitative technique for analysing landslide risks based on the existing slope controls, and the likelihood and consequences of future slope failures. Three categories of future landslide threat (risk) in the Manawatu Gorge, as follows:

(a) Moderate Threat: – 8 Areas (Areas 1, 4, 11, 21, 22, 23, 24, 25). *(Rank 1)*

(b) High Threat: – 11 Areas (Areas 2, 3, 8, 9, 10, 13, 16, 17, 18, 19, 20). *(Rank 2)*

(c) Very High Threat: – 6 Areas (Areas 5, 6, 7, 12, 14, 15). *(Rank 3 & 4)*

(6) The High and Very High Threat (Risk) areas are located in the Western and Central sections of the gorge and have strong geological and geomorphic similarities to the 2011 landslide area, and have been destabilised to some degree by cutting back the toe of colluvial deposits along SH3, generally without support measures.

(7) Landslides caused by the February 2004 rainstorm had a significant influence on the risk assessments, and the larger 2004 landslides (numbers #1 to #5) are the main reason for high risk ratings. The scarps of the 2004 landslide scarps in Areas 12, 14, 15, 17 and 18 are oversteepened and at risk of large regressive failures, especially in Areas 14 and 15 where small failures have already occurred. The 2004 landslide #2 in Area 14 is currently believed to present the greatest potential landslide risk to SH3 in the Manawatu Gorge. A large failure similar to the 2011 landslide could occur at that site at any time, but especially during heavy rainfall or strong earthquake shaking.

(8) The 2011 review of landsliding in the Manawatu Gorge suggested that larger landslides (~20,000–100,000 m^3) could occur every 5–10 years. The presence of several un-stabilised scars of landslides caused by the 2004 rainstorm compared to conditions prior to that event, especially in the centre of the gorge, suggest that estimate is realistic, and is used as the basis for some likelihood ratings (once per 5–10 years) in our landslide risk assessment.

(9) The recommended future actions for better definition and management of risk at potential landslide areas in the three risk categories and local rock fall sites in the gorge include:

(a) *Very High Threat (Risk) Areas:* (a) preparation of a detailed engineering geological/ geotechnical report, including a slope stability analysis and risk assessment using NZTA"s Advanced Approach; (b) terrestrial laser scanning (TLS) of the landslide sites; (c) monitor future slope failures (rock falls, debris falls, slides) and performance of existing controls (mesh, catch fence etc.) at each potential landslide area.

(b) *High Threat (Risk) Areas:* (a) prepare basic engineering geological on each site; (b) monitor slope behaviour and future slope failures in each potential landslide area.

(c) *Moderate Threat (Risk) Areas:* (a) standard maintenance measures should apply, including signage, traffic control, clearance of slip debris to reopen the road, with minimal cutting back of the slope, and repairs to underslips and road edge failures; (b) monitor future slope failures and performance of existing controls.

(d) *Local rock fall sites (Bluffs and rock slopes):* (a) review and repair existing slope controls (mesh, catch fences); (b) monitor future slope failures and condition of existing controls.

(10) Taking into consideration the results of this study, the recommended methods and strategies that could be used to manage and reduce the consequences of future landslides to SH3 in the Manawatu Gorge are as follows:

- An engineering geologist/geotechnical engineer should be involved in the emergency response to assess landslides that block SH3 and decide on actions to reopen the road.

- A geological model of the landslide site should be considered before any earthworks are begun that could adversely affect or further decrease the stability of the slope.

- Establish an inventory of slope failures in the gorge to provide improved knowledge of the locations, size and events that trigger debris slides and falls, rock falls and falls of individual boulders and effects, and the actions taken to deal with them.

- Monitor active or very high risk landslide areas (decided on a site-by-site basis).
- Review and repair existing slope control measures.
- Site-specific engineering geological and geotechnical assessments should be carried out at potential landslides sites that are assigned very high risk ratings.
- Limit earthworks that undercut and oversteepen colluvial and regolith slopes along SH3, and use support measures where possible to stabilise future failures. An engineering geologist or geotechnical engineer should be consulted before earthworks are begun.
- Scaling of loose blocks and additional rock bolting is probably required at some locations considered to be at risk of local rock falls (e.g., Bluffs 9 and 12).
- Prepare an engineering geology/geotechnical completion report on the 2011 landslide area that describes the history, geology and geomorphology of the landslide, the slope stabilisation works, and the stability of the site before and after these measures.
- Detailed documentation and reporting on the engineering, geotechnical, and geological aspects of future large landslides within the Manawatu Gorge is essential to improve the management and minimise the risk that slope failures present to SH3.

9.0 REFERENCES

Beca 2001. SH3 Manawatu Gorge Study-Scoping Report. *Report Reference 3401693/13 by Beca Carter Holliings and Ferner Ltd. prepared for Transit New Zealand January 2001.*

Brabhaharan, P, Hancox, G.T., Perrin, N.D., and Dellow, G.D. 1994: Earthquake-induced slope failure hazard study, Wellington Region: Reports and maps covering six study areas. *Prepared for Wellington Regional Council by Works Consultancy Services Ltd and Institute of Geological & Nuclear Sciences, May 1994*.

Cruden, D.M. and Varnes, D.J., 1996. Landslide Types and Processes: Chapter 3 in Turner A.K. and Schuster R.L. (Eds.). Landslides - Investigation and mitigation. *Special Report 247, Transportation Research Board, National Research Council. Washington DC, National Academy Press, 36–75.*

Downes, G.L., Dowrick, D.J., Van Dissen, R.J., Taber, J.J., Hancox, G.T., and Smith. E.G.C., 2001. The 1942 Wairarapa, New Zealand, earthquakes: Analysis of observational and instrumental data. *Bulletin of the NZ Society for Earthquake Engineering 34: (2) 125-157.*

Dowrick, D.J., Hancox, G.T., Perrin, N.D., Dellow, G.D. 2008. The Modified Mercalli Intensity Scale – Revisions arising from New Zealand experience. *Bulletin of the New Zealand Society for Earthquake Engineering, Vol. 41 No. 3, September 2008, pp. 193–205.*

Fell, R., Corominas, J., Bonnard, C., Cascini, L., Leroi, E., Savage, W.S., 2008. Guidelines for landslide susceptibility, hazard and risk zoning for land-use planning (paper prepared on behalf of the JTC-1 Joint Technical Committee on Landslides and Engineered Slopes). *Engineering Geology 102 (2008), 99–111*

Grapes R.H., Downes G., 1997. The 1855 Wairarapa earthquake: analysis of historic data. *Bulletin of the N Z National Society for Earthquake Engineering 30(4): 273-368.*

Hancox, G.T., 2005. Landslides and liquefaction effects caused by the 1855 Wairarapa earthquake: Then and now. *Proceedings of 1855 Wairarapa Earthquake Symposium September 2005, pp. 84–94 (Greater Wellington Regional Council: GW/RINV-T05/205).*

Hancox, G.T., 2011. Review of geology and landsliding in the Manawatu Gorge, and implications for future landslide closures of SH3. *GNS Science Letter Report 2011/334LR. 16 December 2011(Prepared for MWH and NZTA, Job No 430W1460).*

Hancox, G.T., and Wright, K, 2005. Landslides caused by the February 2004 rainstorms and floods in southern North Island, New Zealand. *Institute of Geological & Nuclear Sciences science report 2005/10. 32p.*

Hancox, G.T., Perrin, N.D., and Dellow, G.D., 1997. Earthquake-induced landslides in New Zealand and implications for MM intensity and seismic hazard assessment. *GNS Client Report 43601B, 10 Dec 1997.*

Hancox, G.T., Perrin, N.D., and Dellow, G.D., 2002 Recent studies of historical earthquake-induced landsliding, ground damage, and MM intensity in New Zealand. *Bulletin of the New Zealand Society for Earthquake Engineering, 35(2)59-95, June 2002.*

Horizons Regional Council, 2004: Storm: Civil Emergency - Storm and Flood Report. *Horizons Regional Council Report Number 2004/EXT/591, September 2004.*

Kingsbury, P.A., 1995: Sheet 1 Wellington (1st Ed.) Earthquake Induced Slope Failure Hazard Map 1:40,000, with Notes. *Wellington Regional Council, Wellington New Zealand.*

Lee, J.M., Begg, J.G., (compilers) 2002. Geology of the Wairarapa area. *Institute of Geological and Nuclear Sciences 1:250,000 geological map 11. 1 sheet + 66p. Lower Hutt New Zealand: Institute of Geological & Nuclear Sciences Limited.*

Marden, M., 1984. Geology and its relationship to erosion in the southern Ruahine Range, North Island, New Zealand. *PhD thesis, Massey University, Palmerston North.*

Ministry of Works & Development, 1981. SH 3 Manawatu Gorge upgrading, Sections 4 and 5, Feasibility Study (prepared by A Bracegirdle 29/7/1981). *Report SP73, File 72/3/9A/1.*

MWH New Zealand Limited, 2004. Manawatu Gorge February 2004 Flood Event SH3 RP488/0.89 to RP491/4.10: *Preliminary Geotechnical Appraisal Report (prepared for Transit New Zealand, June 2004).*

New Zealand Metrological Service, 2004: Notable weather events – Report on a very stormy period, with severe flooding and gales over southern North Island 14-17 February 2004. *NIWA website (http://www.niwa.co.nz) 2005.*

NZTA 2004. Risk Management Process Manual. *NZTA AC/Man/1, ISBN 0-478-10560-6, Version3, September 2004. p49.*

Perrin, N.D., 1985. State Highway 3, Manawatu Gorge: Engineering geological report on Sections 7 and 8, Bluffs 91/04 to 91/08. *New Zealand Geological Survey EG Immediate Report 85/002.*

Perrin, N.D., Hancox G.T., 2000. SH3 Manawatu Gorge - Interim Report on Slope Stability Study: *Institute of Geological and Nuclear Sciences File Report Job No. 43008B, August 2000 (Appendix I in Beca Carter Hollings and Ferner Ltd Report, Reference 3401693/13 for Transit New Zealand, January 2001).*

Stevens, G.R., 1974. Rugged Landscape: The geology of central New Zealand, including Wellington, Wairarapa, Manawatu, and Marlborough Sounds. *AH & AW Reed, Wellington.*

Stirling, M.W., McVerry, G.H., Berryman, K.R. 2002 A new seismic hazard model for New Zealand. *Bulletin of the Seismological Society of America, 92(5): 1878-1903*

Worley Consultants Limited, 1996. Post construction Completion Report on the 1995 SH3 Section 8 Slip area, RP491/0.6. *Worley Reference 68 817 15 (prepared for Transit New Zealand, March 1996).*

Worley Consultants Limited, 1998. Manawatu Gorge: Progress report on 1998 slip at RP491/0.48, and larger scale instability features. *Reference 68 817 C58 (prepared for Transit New Zealand 31 July 1998).*

10.0 ACKNOWLEDGEMENTS

The author wishes to thank Nick Perrin and Grant Dellow (GNS Science), and Paul Russell and Paul Wopereis (MWH) for helpful reviews of this report, and Craig Pitchford (MWH) for assistance with project management.

APPENDIX 1. CLASSIFICATION OF LANDSLIDES

1. Definition of landslides and related terminology

Landslide is a general term for gravitational movements of rock or soil down a slope. In this context, „soil" includes both earth (material smaller than 2 mm) and debris (material larger than 2 mm); rock is a hard or firm intact mass and in its natural place before movement occurs (Cruden and Varnes 1996).

Landslides are usually classified or described in terms of: (a) the type of material involved (rock, earth, debris, or sometimes sand, mud etc.), and (b) the type of movement – fall, topple, slide, flow, spread, which are kinematically-distinct modes of movement. Combining these two terms gives a range of landslide types such as: *rock fall, rock slide, rock topple, debris slide, debris flow, and earth flow*.

The characteristics of the main types of landslides based on the Cruden and Varnes (1996) classification are summarised in Table A1.1 and illustrated in Figure A1.1.

Table A1.1 Characteristics of the main types of landslides *(after Cruden and Varnes 1996*).

Landslide Type *(Based on movement)*	**General Characteristics**
Landslides (generic term)	Downslope gravitational movements of rocks and „soils" (top soil, colluvium etc.) by falling, sliding, or flowing. Slope failures occur when the destabilising forces (slope steepness, weight, and ground water) exceed the resisting forces (shear strength of rock and soil materials).
Falls	**Falls** are masses of rock, soil, or debris that move rapidly down very steep slopes (>40°) by free fall, bounding or rolling. Disrupted soil and debris falls most common.
Slides	**Slides** are masses of rock, soil, or debris that slide down planes of weakness (bedding, joints, and faults) and other surfaces. Rotational slides (or slumps) in soft rocks and soils move on curved failure surfaces. Disrupted soil and debris slides are most common. Landslides are also referred to (non-specifically) as slips, landslips, or slippages.
Avalanches	**Rock and debris avalanches** are very rapid, long run-out failures on steep slopes (>35-40°) more than 150-200 m high. They may start as falls or slides, and transform into flows (wet or dry) as they travel downslope. Such landslides occur mainly in hill country and on high mountain slopes.
Debris Flows and Debris Floods	**Debris flows** are a type of landslide: they have much higher sediment concentrations (like wet concrete) than debris floods, and are potentially much more hazardous and destructive. Objects impacted by debris floods are surrounded or buried by gravel, but are often largely undamaged. **Debris floods** are rapid hyper-concentrated flows of water loaded with sediment, often mainly coarse gravel and sand. Debris flows and debris floods are mainly responsible for building alluvial (debris) fans.

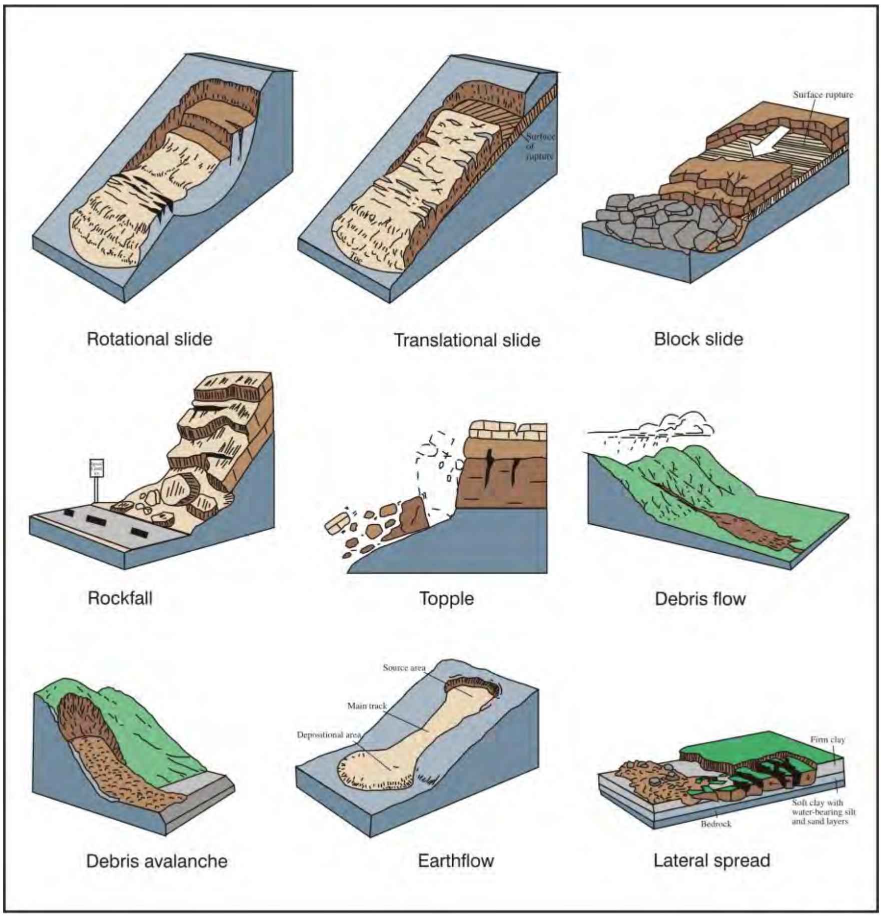


Figure 4.1 Examples of landslide types (after Cruden and Varnes 1996).

Landslides involving soil and rock are often called *„slips‟* or *„landslips‟*, while small failures with rotational slide surfaces are widely referred to as *„slumps‟*. Small landslides often do little damage, but large failures involving thousands or millions of cubic metres moving rapidly (say ~1–50 m/min or >) can damage or bury roads, buildings, and other structures. Effects of landslides can range from minor deformation of foundations and structural failures to total destruction of sites and all buildings, lifelines and infrastructure above or below slopes.

Landslides can occur without an obvious trigger („spontaneous‟ slope failures), or they can be triggered by toe undercutting (natural or man-made), but are most often initiated by heavy rainfall (e.g. ~100 mm or > in 24 hours), or strong earthquake shaking. Shaking of Modified Mercalli (MM) intensity MM7 can cause small failures ($\leq 10^3$–10^4 m^3), but MM8 or greater is generally required for larger landslides ($\geq 10^4$–10^6 m^3). Detailed descriptions of landslides and environmental effects that occur at different shaking intensities are described in Appendix 1 (based on Hancox et al. 1997, 2002; and Dowrick et al. 2008).

The terms used in Appendix 1 and throughout this report to describe landslide size are: V*ery small* (< 10^3 m^3)*; Small* (10^3 –10^4 m^3)*; Moderate* (10^4–10^5 m^3)*; Large* (10^5–10^6 m^3)*; and Very large* ($\geq 10^6$ m^3)*.* These terms were introduced by Hancox et al. (1997, 2002) in their studies of earthquake-induced landslides in New Zealand, and have now been adopted internationally (Guerrieri and Vittori 2007). More recently the term *„giant landslide‟* was introduced for less common, extremely large landslides with volumes of 100 million m^3 or greater, of which there are two historical examples in New Zealand (Hancox et al 2002), and at least twelve prehistoric examples in Fiordland.

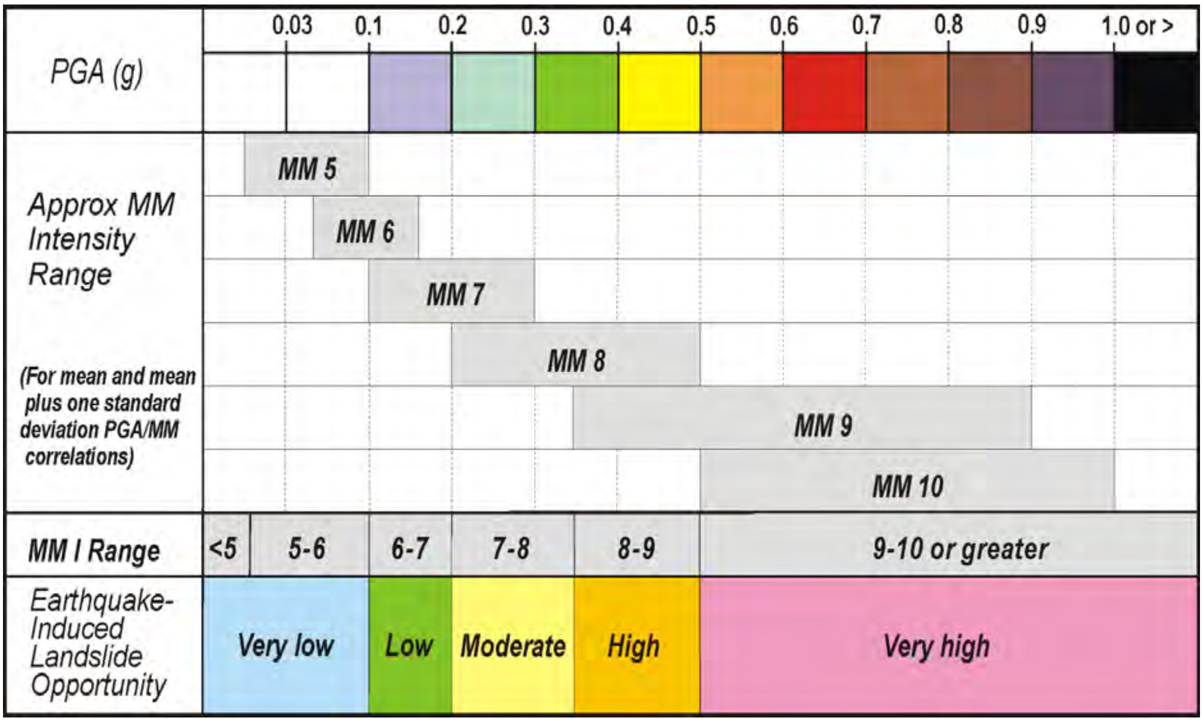
APPENDIX 2. MODIFIED MERCALLI INTENSITY SCALE

A2a Landslide and Environmental Criteria for the Modified Mercalli (MM) Intensity Scale – NZ 2007

MM5	▪ Loose boulders may occasionally be dislodged from steep slopes.
MM6	▪ Trees and bushes shake, or are heard to rustle. ▪ Loose material may be dislodged from sloping ground, e.g. existing slides, talus and scree slopes. ▪ A few very small ($\leq 10^3$ m^3) soil and regolith slides and rock falls from steep banks and cuts. ▪ A few minor cases of liquefaction (sand boil) in highly susceptible alluvial and estuarine deposits.
MM7	▪ Water made turbid by stirred up mud. ▪ Small slides such as falls of sand and gravel banks, and small rock-falls from steep slopes and cuttings common. ▪ Instances of settlement of unconsolidated, or wet, or weak soils. ▪ A few instances of liquefaction (i.e. small water and sand ejections). ▪ Very small ($\leq 10^3$ m^3) disrupted soil slides and falls of sand and gravel banks, and small rock falls from steep slopes and cuttings are common. ▪ Fine cracking on some slopes and ridge crests. ▪ A few small to moderate landslides (10^3 –10^5 m^3), mainly rock falls on steeper slopes (>30˚) such as gorges, coastal cliffs, road cuts and excavations. ▪ Small discontinuous areas of minor shallow sliding and mobilisation of scree slopes in places. ▪ Minor to widespread small failures in road cuts in more susceptible materials. ▪ A few instances of non-damaging liquefaction (small water and sand ejections) in alluvium.
MM8	▪ Cracks appear on steep slopes and in wet ground. ▪ Significant landsliding likely in susceptible areas. ▪ Small to moderate (10^3-10^5 m^3) slides widespread; many rock and disrupted soil falls on steeper slopes (steep banks, terrace edges, gorges, cliffs, cuts etc.). ▪ Significant areas of shallow regolith landsliding, and some reactivation of scree slopes. ▪ A few large (10^5-10^6 m^3) landslides from coastal cliffs, and possibly large to very large ($\geq 10^6$ m^3) rock slides and avalanches from steep mountain slopes. ▪ Larger landslides in narrow valleys may form small temporary landslide-dammed lakes. ▪ Roads damaged and blocked by small to moderate failures of cuts and slumping of road-edge fills. ▪ Evidence of soil liquefaction common, with small sand boils and water ejections in alluvium, and localised lateral spreading (fissuring, sand and water ejections) and settlements along banks of rivers, lakes, and canals etc. ▪ Increased instances of settlement of unconsolidated, or wet, or weak soils.
MM9	▪ Cracking of ground conspicuous. ▪ Landsliding widespread and damaging in susceptible terrain, particularly on slopes steeper than 20˚. ▪ Extensive areas of shallow regolith failures and many rock falls and disrupted rock and soil slides on moderate and steep slopes (20˚-35˚ or greater), cliffs, escarpments, gorges, and man-made cuts. ▪ Many small to large (10^3-10^6 m^3) failures of regolith and bedrock, and some very large landslides (10^6 m^3 or greater) on steep susceptible slopes. ▪ Very large failures on coastal cliffs and low-angle bedding planes in Tertiary rocks. Large rock/debris avalanches on steep mountain slopes in well-jointed greywacke and granitic rocks. Landslide-dammed lakes formed by large landslides in narrow valleys. Damage to road and rail infrastructure widespread with moderate to large failures of road cuts and slumping of road-edge fills. Small to large cut slope failures and rock falls in open mines and quarries. ▪ Liquefaction effects widespread, with numerous sand boils and water ejections on alluvial plains, and extensive, potentially damaging lateral spreading (fissuring and sand ejections) along banks of rivers, lakes, canals etc.). Spreading and settlements of river stop-banks likely.
MM10	▪ Landsliding very widespread in susceptible terrain. ▪ Similar effects to MM9, but more intensive and severe, with very large rock masses displaced on steep mountain slopes and coastal cliffs. Landslide-dammed lakes formed. Many moderate to large failures of road and rail cuts and slumping of road-edge fills and embankments may cause great damage and closure of roads and railway lines. ▪ Liquefaction effects (as for MM9) widespread and severe. Lateral spreading and slumping may cause rents over large areas, causing extensive damage, particularly along river banks, and affecting bridges, wharfs, port facilities, and road and rail embankments on swampy, alluvial or estuarine areas.

Notes: *(1) "Some or 'a few' indicates that threshold for response has just been reached at that intensity. (2) Environmental damage (response criteria) occurs mainly on susceptible slopes and in certain materials, hence the effects described above may not occur in all places, but can be used to reflect the average or predominant level of damage or MM intensity in an area. (3) Environmental criteria not defined for MM11 and 12, as those intensities have not been reported in New Zealand. Earlier versions of the MM intensity scale suggest that environmental effects at MM11-12 are similar to MM9- 10, but are more widespread and severe. (4) This appendix is based on Hancox et al. 1997, 2002, and Dowrick et al., 2008. A summary of the full MM Intensity Scale is given below (A1c).*

A2b Relationship of MM Intensity to Peak Ground Acceleration (PGA) and earthquake-induced landslide opportunity *(after Hancox et al. 2002)*.



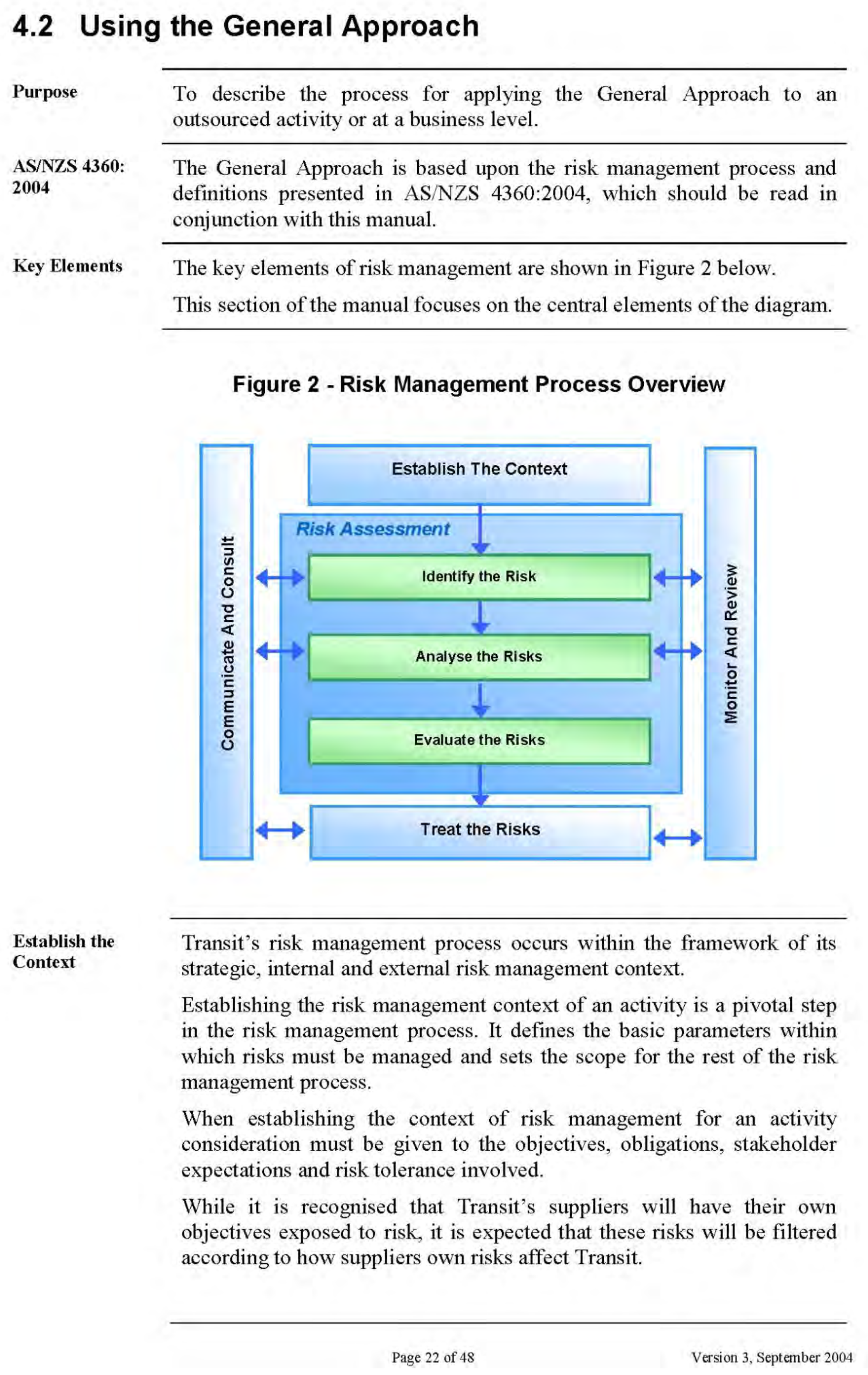
The graph above shows the relationship of MM Intensity to peak ground acceleration (PGA) range based on the mean and mean plus one standard deviation correlations of Murphy and O'Brien (1977) landslide opportunity on New Zealand (from Hancox et al. 2002). The overlap in the PGA values for different MM intensities reflects the considerable scatter in PGA/MM data.

The EIL Opportunity classes define the relative likelihood of earthquake-induced landslides occurring in areas of different shaking (PGA/MM Intensity) based on ground damage effects established for New Zealand. Five classes of relative EIL opportunity are recognised, as follows:

1. *Very Low*	*(≤ MM5-6):*	*Very small rock and soil falls on the most susceptible slopes.*
2. *Low*	*(MM6-7):*	*Small landslides, soil and rock falls may occur on more susceptible slopes (particularly road cuts and other excavations), along with minor liquefaction effects (sand boils) in susceptible soils.*
3. *Moderate*	*(MM7-8):*	*Significant small to moderate landslides are likely, and liquefaction effects (sand boils) expected in susceptible areas. Noticeable damage to roads.*
4. *High*	*(MM8-9):*	*Widespread small-scale landsliding expected, with a few moderate to very large slides, and some small landslide-dammed lakes; many sand boils and localised lateral spreads likely. Severe damage to roads, with many failures of steep high cuts and road-edge fills.*
5. *Very high*	*(≥MM9):*	*Widespread landslide damage expected. Many large to extremely large landslides; sand boils are widespread on alluvium, and lateral spreading common along river banks; landslide-dammed lakes are often formed in susceptible terrain. Extensive very severe damage to roads - failures of steep high cuts and road-edge fills.*

APPENDIX 3. NZTA RISK MANAGEMENT PROCESS MANUAL

(Pages 22-29 illustrating the Risk Assessment Method used in this report)



4.2 Using the General Approach

Purpose	To describe the process for applying the General Approach to an outsourced activity or at a business level.
AS/NZS 4360: 2004	The General Approach is based upon the risk management process and definitions presented in AS/NZS 4360:2004, which should be read in conjunction with this manual.
Key Elements	The key elements of risk management are shown in Figure 2 below. This section of the manual focuses on the central elements of the diagram.

Figure 2 - Risk Management Process Overview

Establish the Context	Transit's risk management process occurs within the framework of its strategic, internal and external risk management context. Establishing the risk management context of an activity is a pivotal step in the risk management process. It defines the basic parameters within which risks must be managed and sets the scope for the rest of the risk management process. When establishing the context of risk management for an activity consideration must be given to the objectives, obligations, stakeholder expectations and risk tolerance involved. While it is recognised that Transit's suppliers will have their own objectives exposed to risk, it is expected that these risks will be filtered according to how suppliers own risks affect Transit.

Identify Risks

All risks (threats and opportunities) must be identified. Refer Appendix 1 for a prompt list to assist the identification of risks.

The risk must be one that ultimately affects Transit – in terms of both tangible and intangible exposure. Such exposure may cover health & safety, image/ reputation, environment, stakeholders interest, cost or time.

In general, risks are to be recorded as discrete risk "events" that may be experienced at some point.

Knowledge of future risk exposure will be incomplete, so an allowance should be made for "unknown" risks. This allowance is a reflection of the current state of knowledge associated with the activity or business level.

To complete the risk identification, each risk must be recorded in a ***risk register*** for that activity or business level. The recorded risk must:

- be given a unique identifying ***number***
- be given a ***name*** – a short descriptive title
- be clearly ***described*** in the words, detailing the specific event that is leading to uncertainty in activity outcome
- be assigned a ***status*** from the following:

  emerging – the risk is still emerging and the full extent of its impact is still undefined. Plans for the management of the risk are required

  live – the risk has emerged and its full extent defined. It is being actively or passively managed

  parked – the risk has been excluded from current management processes. (i.e. has been excluded from treatment at this level of activity management)

  closed – is no longer a risk to the activity eg work has progressed beyond the point where the risk could have occurred. When a risk is closed, the actual outcome should be recorded in the risk register referring to the degree to which the risk was actually experienced or whether some other event was experienced.

Status is particularly important in communicating risk (eg between project phases, or from asset improvement to asset management). Even risks that are closed in terms of the current activity (eg. asset improvement project) or phase may have latent connotations for a future owner (eg. asset manager).

Analyse Risks

The General Approach provides a qualitative technique for analysing the identified risks. This technique is useful for considering diverse types of risk exposure, which would not otherwise be readily comparable.

The analysis consists of:

- ***Existing controls*** – detailing existing processes, devices, practices or controls that act to minimise threats or enhance opportunities, including an indication of how they might be of influence.

- ***Consequence*** – a description and a rating of the consequence of a risk, in terms of the loss or gain that may be experienced if the risk event occurs (refer table 2 for consequence ratings).
- ***Likelihood*** – a description and a rating of the likelihood of the risk for the full range of risk event consequences (refer table 1 for likelihood ratings). In particular for opportunities it is the likelihood of the stated gain being realised if the opportunity is pursued.

It is expected that the ratings given will be based on professional judgement and by consensus (to remove aberrant results).

The analysed consequences and likelihoods of each risk are those that apply after the application of existing control measures, but before the implementation of further risk treatment actions.

Best-case and worst-case scenarios for any risk are to be considered in the analysis. Any one risk may be analysed as having: both an opportunity and a threat component; an opportunity component only; or a threat component only.

Table 1a: Rating the Likelihood (L) of a Threat

(Generally applicable to a passive process)

Likelihood	Probability (for short term activities such as asset improvement)	Frequency (for long term activities such as in asset management and Corporate business)	Description	Rating
Likely	>50%	Greater than once per year	The threat can be expected to occur *or* a very poor state of knowledge has been established on the threat.	5
Quite Common	20%-50%	Once per 1-5 years	The threat will quite commonly occur *or* a poor state of knowledge has been established on the threat.	4
Unlikely	10%-20%	Once per 5-10 years	The threat may occur occasionally *or* a moderate state of knowledge has been established on the threat.	3
Unusual	1%-10%	Once per 10 – 50 years	The threat could infrequently occur *or* a good state of knowledge has been established on the threat.	2
Rare	<1%	Less than once per 50 years	The threat may occur in exceptional circumstances *or* a very good state of knowledge has been established on the threat.	1

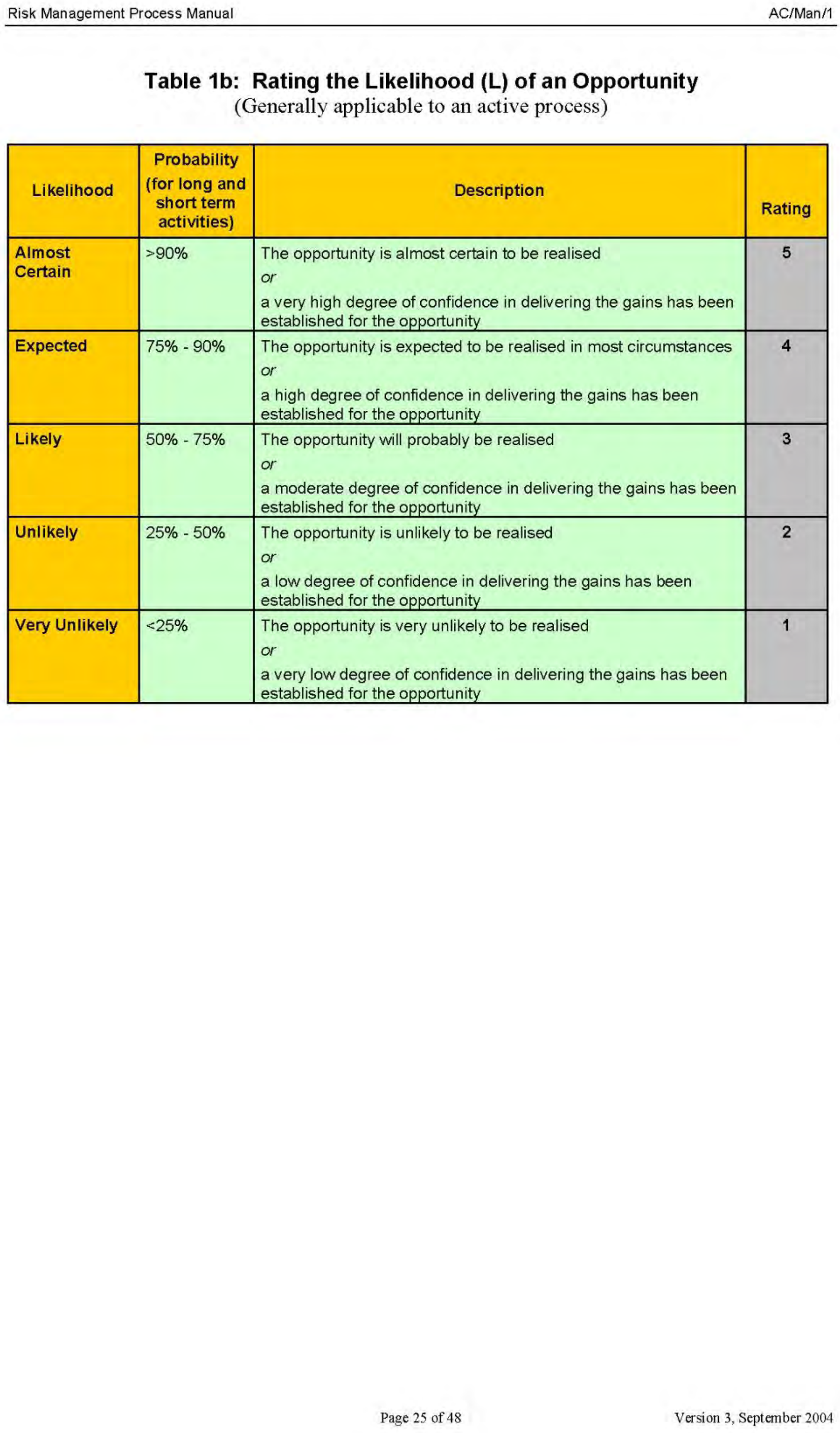


Table 1b: Rating the Likelihood (L) of an Opportunity

(Generally applicable to an active process)

Likelihood	Probability (for long and short term activities)	Description	Rating
Almost Certain	>90%	The opportunity is almost certain to be realised *or* a very high degree of confidence in delivering the gains has been established for the opportunity	**5**
Expected	75% - 90%	The opportunity is expected to be realised in most circumstances *or* a high degree of confidence in delivering the gains has been established for the opportunity	**4**
Likely	50% - 75%	The opportunity will probably be realised *or* a moderate degree of confidence in delivering the gains has been established for the opportunity	**3**
Unlikely	25% - 50%	The opportunity is unlikely to be realised *or* a low degree of confidence in delivering the gains has been established for the opportunity	**2**
Very Unlikely	<25%	The opportunity is very unlikely to be realised *or* a very low degree of confidence in delivering the gains has been established for the opportunity	**1**

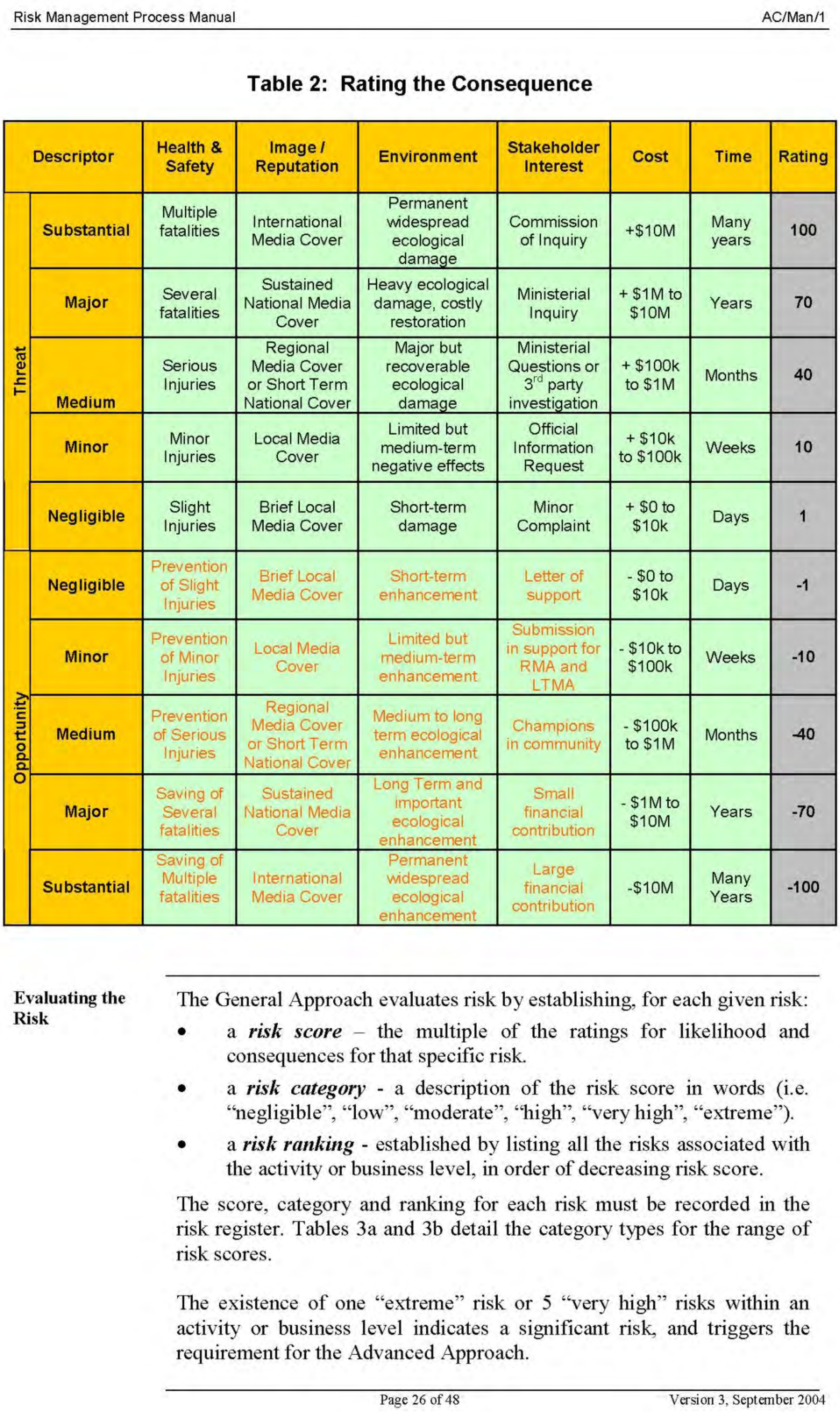


Table 2: Rating the Consequence

Descriptor		Health & Safety	Image / Reputation	Environment	Stakeholder Interest	Cost	Time	Rating
Threat	Substantial	Multiple fatalities	International Media Cover	Permanent widespread ecological damage	Commission of Inquiry	+$10M	Many years	100
	Major	Several fatalities	Sustained National Media Cover	Heavy ecological damage, costly restoration	Ministerial Inquiry	+ $1M to $10M	Years	70
	Medium	Serious Injuries	Regional Media Cover or Short Term National Cover	Major but recoverable ecological damage	Ministerial Questions or 3rd party investigation	+ $100k to $1M	Months	40
	Minor	Minor Injuries	Local Media Cover	Limited but medium-term negative effects	Official Information Request	+ $10k to $100k	Weeks	10
	Negligible	Slight Injuries	Brief Local Media Cover	Short-term damage	Minor Complaint	+ $0 to $10k	Days	1
Opportunity	Negligible	Prevention of Slight Injuries	Brief Local Media Cover	Short-term enhancement	Letter of support	- $0 to $10k	Days	-1
	Minor	Prevention of Minor Injuries	Local Media Cover	Limited but medium-term enhancement	Submission in support for RMA and LTMA	- $10k to $100k	Weeks	-10
	Medium	Prevention of Serious Injuries	Regional Media Cover or Short Term National Cover	Medium to long term ecological enhancement	Champions in community	- $100k to $1M	Months	-40
	Major	Saving of Several fatalities	Sustained National Media Cover	Long Term and important ecological enhancement	Small financial contribution	- $1M to $10M	Years	-70
	Substantial	Saving of Multiple fatalities	International Media Cover	Permanent widespread ecological enhancement	Large financial contribution	-$10M	Many Years	-100

Evaluating the Risk

The General Approach evaluates risk by establishing, for each given risk:

- a ***risk score*** – the multiple of the ratings for likelihood and consequences for that specific risk.
- a ***risk category*** - a description of the risk score in words (i.e. "negligible", "low", "moderate", "high", "very high", "extreme").
- a ***risk ranking*** - established by listing all the risks associated with the activity or business level, in order of decreasing risk score.

The score, category and ranking for each risk must be recorded in the risk register. Tables 3a and 3b detail the category types for the range of risk scores.

The existence of one "extreme" risk or 5 "very high" risks within an activity or business level indicates a significant risk, and triggers the requirement for the Advanced Approach.

Evaluation as to whether the risk requires specific treatment requires judgement, and the judgement exercised shall be documented clearly in the register. Each assessed risk must be considered on its merits, with particular consideration of the adequacy of existing controls. The risk score is intended to provide a clear indication of the need for specific treatment, although the likelihood rating may also provide a useful indication.

Treatment Plans

The development of a risk treatment plan involves the selection of a ***treatment type*** and the identification of ***treatment actions***.

For all emerging and live risks it is required that a treatment plan be developed.

Treatment Type

The decision of a treatment type is the first step in risk treatment planning.

The treatment type may consist of one or more of the following:

- For opportunities or threats:

  Actively Accept – accept the risk and consider options for the treatment of the risk as elaborated below.

  Passively Accept – accept the risk as it is, i.e. no further treatment is appropriate or possible at this time.

  Transfer/Share – pass the risk in whole or in part to others e.g. through contractual agreements or insurance. Appropriate where others are best able to manage the risk.

  Avoid (threats) or Reject (opportunities) – change parts of the activity so that there is no longer any exposure.

- Active treatment strategies for opportunities:

  Maximise – increasing the likelihood of realising the opportunity.

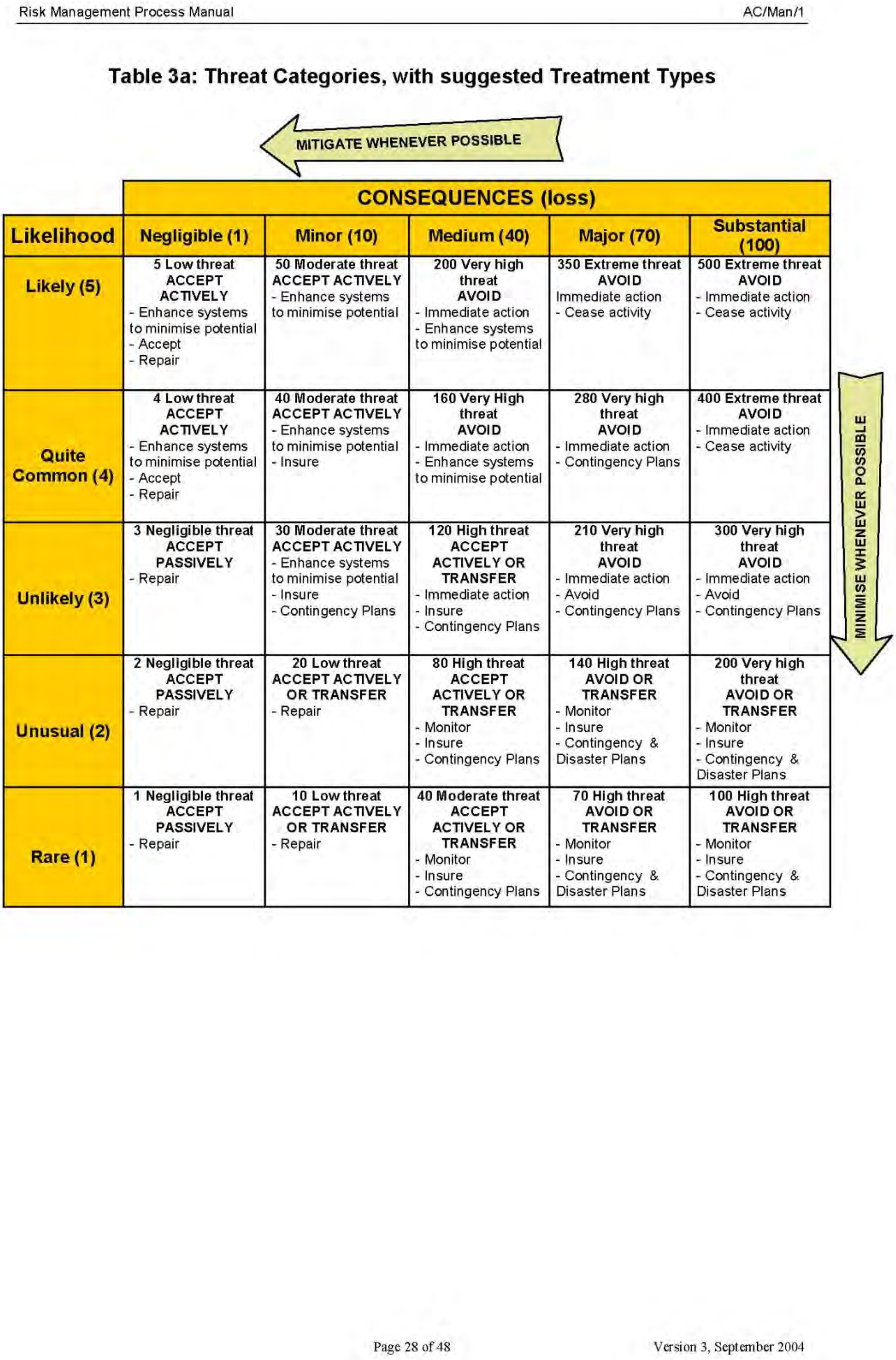
  Enhance – increasing the gains that may be realised from the opportunity.

- Active treatment strategies for threats:

  Minimise – reducing the likelihood of experiencing the threat.

  Mitigate – reduce the consequence of experiencing the threat by means such as establishing "post-occurrence" contingency and disaster plans to reduce the consequence of experiencing the risk.

The decision of treatment type should be made in consideration of the ***risk score***. Tables 3a and 3b suggest a possible treatment type for the range of risk scores. However, the treatment strategy for each risk should be considered on its merits, with particular consideration of the adequacy of existing controls.



Risk Management Process Manual AC/Man/1

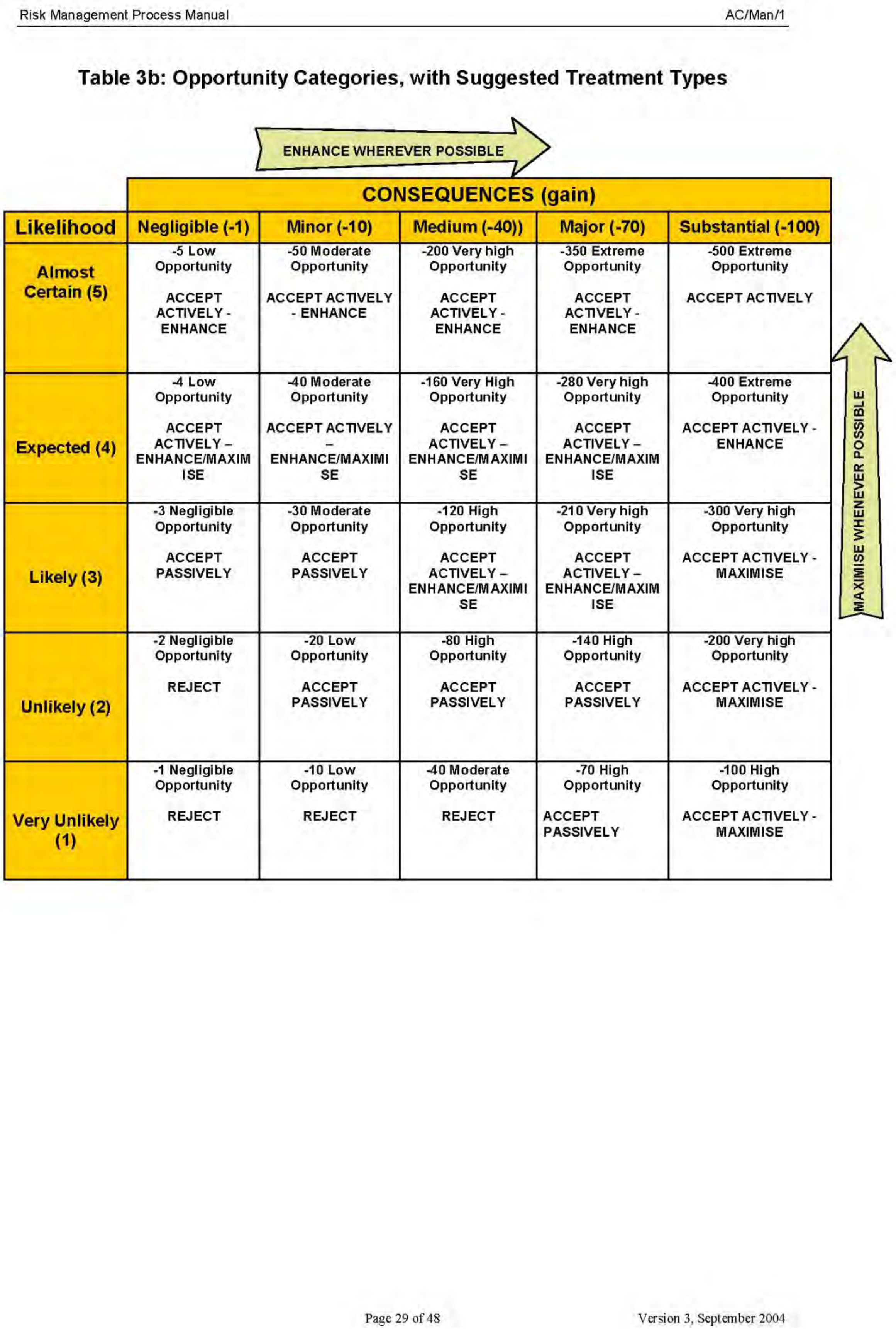
Table 3a: Threat Categories, with suggested Treatment Types

MITIGATE WHENEVER POSSIBLE

	CONSEQUENCES (loss)				
Likelihood	**Negligible (1)**	**Minor (10)**	**Medium (40)**	**Major (70)**	**Substantial (100)**
Likely (5)	5 Low threat ACCEPT ACTIVELY - Enhance systems to minimise potential - Accept - Repair	50 Moderate threat ACCEPT ACTIVELY - Enhance systems to minimise potential	200 Very high threat AVOID - Immediate action - Enhance systems to minimise potential	350 Extreme threat AVOID Immediate action - Cease activity	500 Extreme threat AVOID - Immediate action - Cease activity
Quite Common (4)	4 Low threat ACCEPT ACTIVELY - Enhance systems to minimise potential - Accept - Repair	40 Moderate threat ACCEPT ACTIVELY - Enhance systems to minimise potential - Insure	160 Very High threat AVOID - Immediate action - Enhance systems to minimise potential	280 Very high threat AVOID - Immediate action - Contingency Plans	400 Extreme threat AVOID - Immediate action - Cease activity
Unlikely (3)	3 Negligible threat ACCEPT PASSIVELY - Repair	30 Moderate threat ACCEPT ACTIVELY - Enhance systems to minimise potential - Insure - Contingency Plans	120 High threat ACCEPT ACTIVELY OR TRANSFER - Immediate action - Insure - Contingency Plans	210 Very high threat AVOID - Immediate action - Avoid - Contingency Plans	300 Very high threat AVOID - Immediate action - Avoid - Contingency Plans
Unusual (2)	2 Negligible threat ACCEPT PASSIVELY - Repair	20 Low threat ACCEPT ACTIVELY OR TRANSFER - Repair	80 High threat ACCEPT ACTIVELY OR TRANSFER - Monitor - Insure - Contingency Plans	140 High threat AVOID OR TRANSFER - Monitor - Insure - Contingency & Disaster Plans	200 Very high threat AVOID OR TRANSFER - Monitor - Insure - Contingency & Disaster Plans
Rare (1)	1 Negligible threat ACCEPT PASSIVELY - Repair	10 Low threat ACCEPT ACTIVELY OR TRANSFER - Repair	40 Moderate threat ACCEPT ACTIVELY OR TRANSFER - Monitor - Insure - Contingency Plans	70 High threat AVOID OR TRANSFER - Monitor - Insure - Contingency & Disaster Plans	100 High threat AVOID OR TRANSFER - Monitor - Insure - Contingency & Disaster Plans

MINIMISE WHENEVER POSSIBLE

Page 28 of 48 Version 3, September 2004



Risk Management Process Manual AC/Man/1

Table 3b: Opportunity Categories, with Suggested Treatment Types

ENHANCE WHEREVER POSSIBLE

	CONSEQUENCES (gain)				
Likelihood	**Negligible (-1)**	**Minor (-10)**	**Medium (-40))**	**Major (-70)**	**Substantial (-100)**
Almost Certain (5)	-5 Low Opportunity ACCEPT ACTIVELY - ENHANCE	-50 Moderate Opportunity ACCEPT ACTIVELY - ENHANCE	-200 Very high Opportunity ACCEPT ACTIVELY - ENHANCE	-350 Extreme Opportunity ACCEPT ACTIVELY - ENHANCE	-500 Extreme Opportunity ACCEPT ACTIVELY
Expected (4)	-4 Low Opportunity ACCEPT ACTIVELY – ENHANCE/MAXIMISE	-40 Moderate Opportunity ACCEPT ACTIVELY – ENHANCE/MAXIMISE	-160 Very High Opportunity ACCEPT ACTIVELY – ENHANCE/MAXIMISE	-280 Very high Opportunity ACCEPT ACTIVELY – ENHANCE/MAXIMISE	-400 Extreme Opportunity ACCEPT ACTIVELY - ENHANCE
Likely (3)	-3 Negligible Opportunity ACCEPT PASSIVELY	-30 Moderate Opportunity ACCEPT PASSIVELY	-120 High Opportunity ACCEPT ACTIVELY – ENHANCE/MAXIMISE	-210 Very high Opportunity ACCEPT ACTIVELY – ENHANCE/MAXIMISE	-300 Very high Opportunity ACCEPT ACTIVELY - MAXIMISE
Unlikely (2)	-2 Negligible Opportunity REJECT	-20 Low Opportunity ACCEPT PASSIVELY	-80 High Opportunity ACCEPT PASSIVELY	-140 High Opportunity ACCEPT PASSIVELY	-200 Very high Opportunity ACCEPT ACTIVELY - MAXIMISE
Very Unlikely (1)	-1 Negligible Opportunity REJECT	-10 Low Opportunity REJECT	-40 Moderate Opportunity REJECT	-70 High Opportunity ACCEPT PASSIVELY	-100 High Opportunity ACCEPT ACTIVELY - MAXIMISE

MAXIMISE WHENEVER POSSIBLE

Page 29 of 48 Version 3, September 2004

Reference:

NZTA 2004. Risk Management Process Manual. *NZTA AC/Man/1,ISBN 0-478-10560-6, Version3, September 2004.* p49.

APPENDIX 4. NOTES FROM GORGE WALKOVER INSPECTION

Notes from geological ground inspections along SH3 in the Manawatu Gorge
by GT Hancox and CD Robson, 5 and 6 September 2012.

SH3 Route Position (RP)	Notes	Photos
488/1.00	Gorge Memorial car park. LS hazard decrease as slopes reduce in height. Bedding tighter and more defined contacts, boundinage. High EIL potential at Area 2. Area of mass EIL (?) from Bluff 1 - 2.	
488/1.50	SDST benched Bluff 1. LS release feature ~40m above shotcreted "shoot". High potential for further LS.	
488/1.4 –1.75	Historical feature with high potential for further mass movement in debris and ARG/Soil between bluffs 1 and 2. Large massive sandstone blocks perched up high. EIL risk. Check aerial photography for debris in river.	
488/1.38	BLUFF 1.	
488/1.80	BLUFF 2.	
488/1.85	No 3 creek adjacent to colluvium/debris slope currently under toe reinforcing construction.	
488/1.85–2.02	2011 landslide site.	
488/2.02-2.15	Rapids bridge, Totara Fault creek. Bluffs 3 and 4.	
488/2.2–2.6	Area of multiple high risk slopes inferred to be responsible for failure during 1855 EIL (blocks/boulders of landslide debris in river channel and on north bank). Long slopes, similar geomorphology to 2011 LS site. Steep toe cuts in colluvium/debris slopes bounded by sandstone at Bluffs 5, 6, and 7.	
488/2.61	Large engineered, tied back anchored wall adjacent to Bluff 9. Local rock fall potential from Bluff. May require further investigation for rock bolting and meshing (?)	
TDC – PNCC boundary	Small gulley development in soft completely weathered argillite between sandstone of Bluffs 10 and 11. Minor LS potential.	

SH3 Route Position (RP)	Notes	Photos
499/0.30	Gully in soft completely weathered argillite bedrock. Adjacent to colluvium/weathered sandstone slope. Moderate-high potential for upslope regression ~25m. Chaotic slip debris (Area 9a). Requires toe support system similar to 488/1.85.	
499/0.41	Sandstone at Bluff 12. Open moderate spaced jointed rock mass. Some sheared interbedded argillite bands. May require rock bolting. Local and EIL potential stability issues.	
499/0.50	1998 Gabion wall stabilisation works (Area 10). Gabion wall requires detailed structure/geotechnical assessment. Appears on first inspection to be cracking from frontal heave. Scarp behind dates to ~1998.	
499/0.60	Bluff 13	
499/0.70	Waterfall Stream bridge and creek. Area of mass landsliding 1995. Meshing and rock fence (Area 11B) in poor condition. Some moderate potential above Waterfall Stream ~25 m above highway. Large g/wacke boulders under mesh. Small 2004 slip.	
499/1.00	Area 14 (next to „Quarry"). Site of large 2004 slip (#2). Meshed toe. Recent rock fall requiring rebuild of catch fence. Very High potential for further LS. Immediate local rock fall issue. Argillite and weathered volcanics. Request maintenance records?	 
499/1.20	Area 15. Site of 2004 LS #3. Slip scarp continues to grow via joint-joint controlled rock fall in weathered dilated siltstone and sandstone. Bench only just wide enough for debris "catching". High potential for additional growth/regression. Highway requires better protection system.	 
499/1.80	2004 Slip. Argillites. Toe "controlled" by concrete road barriers. Catch fence in poor state. Area of multiple failures. SDST bedding difficult to determine. Joint-joint controlled rock fall failure on sandstone bluff. Large pieces at risk of further failure from 10m above highway. High potential for further EIL growth/regression.	

SH3 Route Position (RP)	Notes	Photos
499/1.8-2.10	Areas 17-18. High Potential for movement in Colluvium. Check low level photos. Regression both laterally and upwards.	
491/2.0	Bedding dips 84^0 @ 220^0 - block loose (confirm with historical mapping)	
491/2.20	Schistose" argilitic fine sediments + chlorite. Bedding dips 85^0 @244^0 (confirm with historical mapping).	
491/2.45	Barneys Point Rest area. Area of small land sliding 2004. Bluff 17 area .	
491/2.60	Area of 2004 LS#7. Also site of underslip #1. Moderate potential for up slope growth.	
491/2.80	High potential for EIL. Check X-section.	
491/3.05	South of windy bridge. 2004 Slip #9. Dipping folded sandstone and argillite. No significant colluvium deposits at risk. Check rock outcrop in low level photography above slip plane. Funnel/shoot scarp, shallow failures. Catch fence lacking U-bolt on side cables – requires immediate attention.	
491/3.2-3.3	10m High former scarp, now grassed over, adjacent to debris deposit in cut bank. Debris deposits show some rounded cobbles and large coarse boulders in sandy coarse flow deposit.	
Notes: Landslide (LS) Potential = High, Moderate, Minor, EIL, Local rock fall		

www.gns.cri.nz

Principal Location

1 Fairway Drive
Avalon
PO Box 30368
Lower Hutt
New Zealand
T +64-4-570 1444
F +64-4-570 4600

Other Locations

Dunedin Research Centre
764 Cumberland Street
Private Bag 1930
Dunedin
New Zealand
T +64-3-477 4050
F +64-3-477 5232

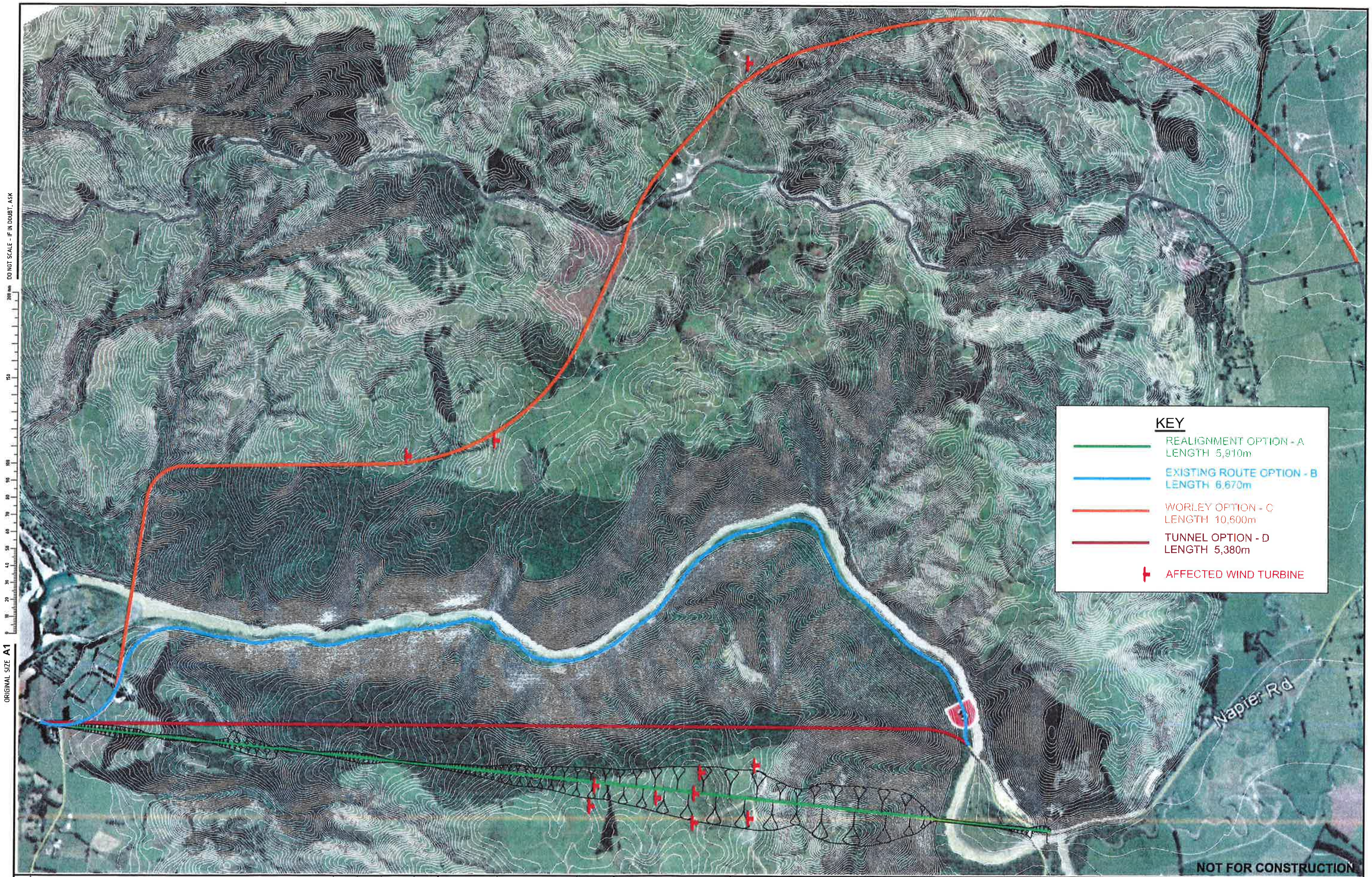
Wairakei Research Centre
114 Karetoto Road
Wairakei
Private Bag 2000, Taupo
New Zealand
T +64-7-374 8211
F +64-7-374 8199

National Isotope Centre
30 Gracefield Road
PO Box 31312
Lower Hutt
New Zealand
T +64-4-570 1444
F +64-4-570 4657

Appendix C SH3 Gorge Bypass Options

DO NOT SCALE - IF IN DOUBT, ASK

ORIGINAL SIZE A1



REV	REVISIONS	DRAWN	CHECKED	APPROVED	DATE
C	KEY PLAN AMENDED	CPA	SWB	CDP	30/10/12
B	FOR INFORMATION	CPA	PAC	CDP	19/10/12

	Name	Date
SURVEYED	LIDAR	
DESIGNED	SW BRENNAN	10/12
DESIGN CHECK	AC DROVER	10/12
DRAWN	CP AJOC	10/12
DRAWING CHECK	PA CHILTON	10/12
APPROVED	CD PITCHFORD	19/10/12

XREFS . contour5m_3d

MWH

NZ TRANSPORT AGENCY
WAKA KOTAHI

NZTA NEW ZEALAND
SH 3 MANAWATU GORGE ALTERNATIVE ROUTE

SADDLE ROAD REALIGNMENT OPTIONS
BYPASS OPTIONS WITH CONTOURS

Status Stamp **FOR INFORMATION**

Date Stamp 30/10/2012

SCALES (A1) 10000 1:20000 A3

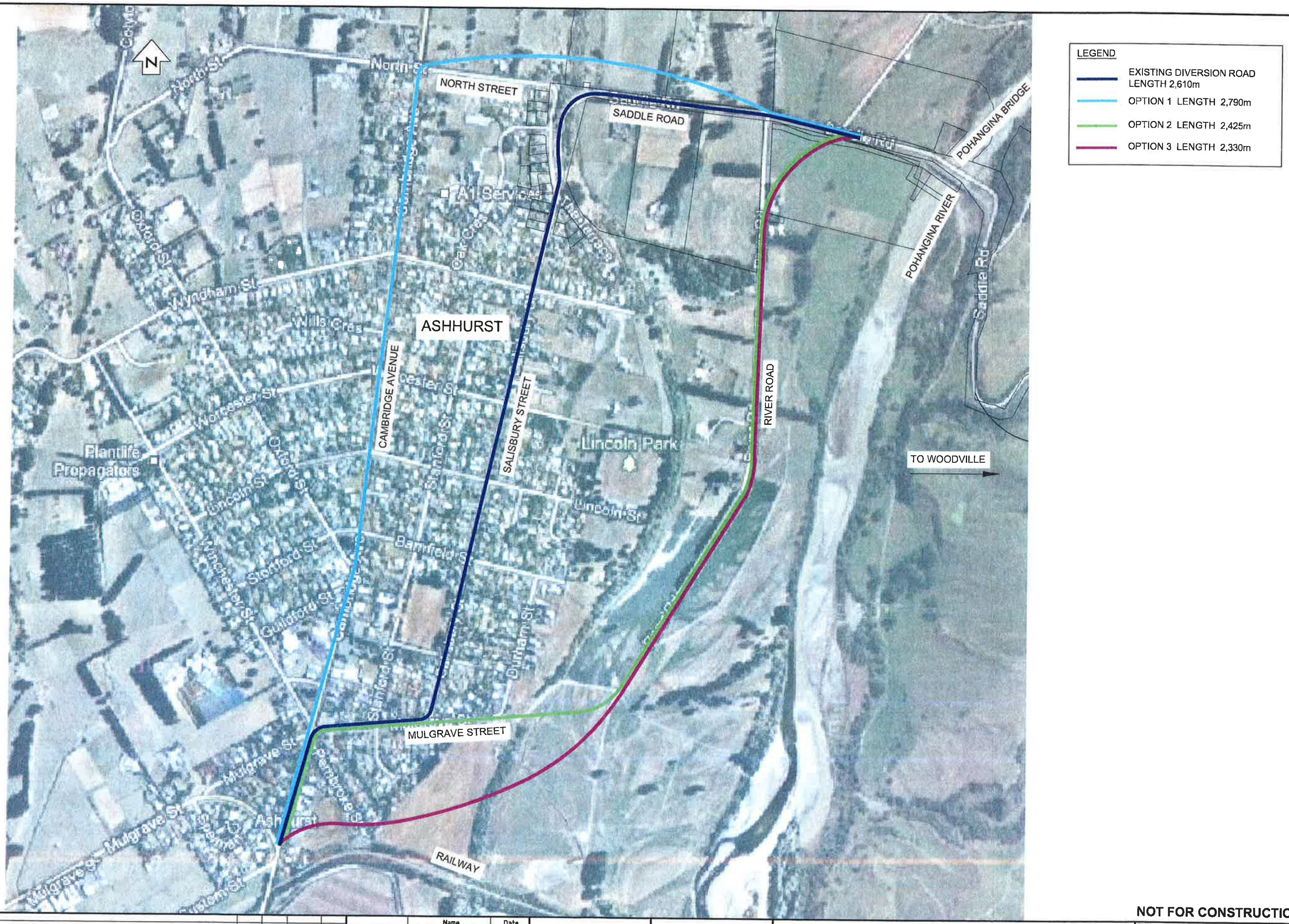
Drawing No.	Sheet No.	Rev.
80500655	D 010	C

\\nzwanls01\projects_2012 Onwards\NZ Transport Agency\SH3 Manwatu Gorge Alt Route 80000655\80500655 SH3 Manawatu Gorge Alternative Route\CAD\D010 Bypass Options.dwg

Appendix D Saddle Road Upgrade Options

DO NOT SCALE - IF IN DOUBT, ASK

ORIGINAL SIZE A1



REV	REVISIONS	DRAWN	CHECKED	APPROVED	DATE
C	EXISTING DIVERSION ROAD ADDED	CPA	SWB	CDP	30/10/12
B	FOR INFORMATION	CPA	PAC	CDP	19/10/12

	Name	Date
SURVEYED	LIDAR	
DESIGNED	SW BRENNAN	10/12
DESIGN CHECK	AC DROVER	10/12
DRAWN	CP AJOC	10/12
DRAWING CHECK	PA CHILTON	10/12
APPROVED	CD PITCHFORD	19/10/12

XREFS : x_aerial, x_contour, x_survey, x_services

MWH

NZ TRANSPORT AGENCY
WAKA KOTAHI

NZTA NEW ZEALAND
SH 3 MANAWATU GORGE ALTERNATIVE ROUTE

MANAWATU GORGE SLIP
ASHHURST DETOUR ALTERNATIVES

NOT FOR CONSTRUCTION

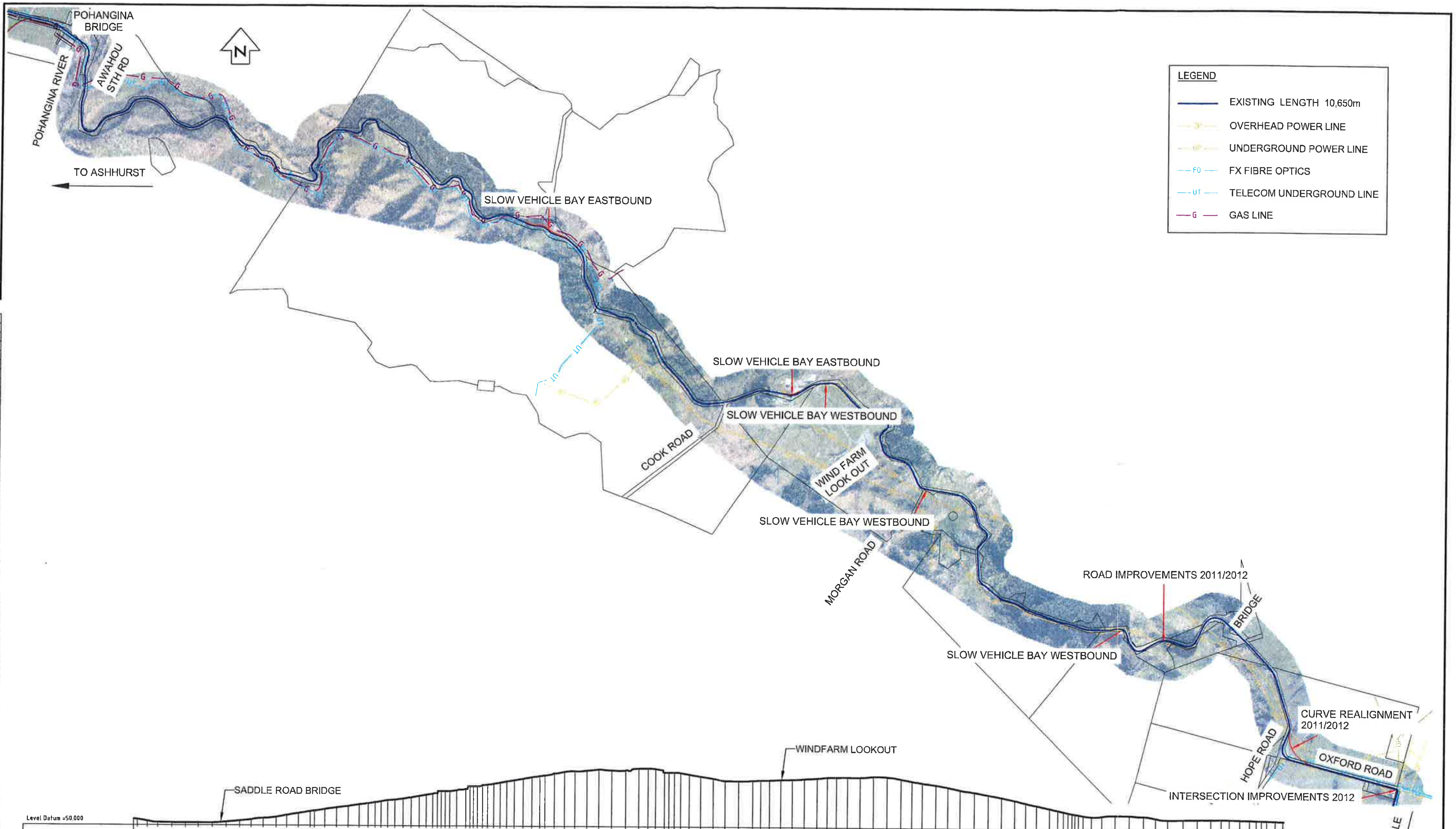
Status Stamp **FOR INFORMATION**

Date Stamp 30/10/2012

SCALES (A1) 1:4,000 1:8,000 A3

Drawing No.	Sheet No.	Rev.
80500655	D003	C

\\nzwan1s01\projects_2012 Onwards\NZ Transport Agency\SH3 Manwatu Gorge Alt Route 80000655\80500655 SH3 Manawatu Gorge Alternative Route\CAD\D003 Ashhurst Detour Alternatives plan.dwg



EXISTING LEVELS	EXISTING GRADE
81.349	-2.858
72.046	-8.817
65.048	-6.671
64.067	-0.647
63.294	-0.528
63.187	-0.077
63.518	0.218
68.093	3.072
74.677	4.501
81.602	6.085
89.049	5.592
95.779	4.768
106.347	10.544
116.826	8.535
127.020	8.100
130.524	7.699
139.126	8.055
148.208	7.150
156.735	6.899
165.637	7.739
172.060	7.054
177.919	7.630
183.509	8.763
189.266	8.175
192.420	4.169
197.685	6.274
205.025	8.965
212.606	8.920
219.035	9.136
224.540	8.519
235.800	26.405
235.800	0.000
235.800	0.000
244.407	6.025
252.013	7.732
266.894	0.000
266.894	0.000
272.907	11.438
275.295	4.460
281.025	8.706
287.161	8.897
293.528	9.333
300.557	9.029
309.170	8.987
317.657	10.031
323.783	7.816
327.037	6.128
338.910	12.887
347.543	8.063
351.836	3.848
355.240	2.650
360.927	4.458
356.729	-2.988
357.671	0.651
367.638	7.198
368.209	0.572
365.241	-3.706
345.761	-20.579
345.761	0.000
345.761	0.000
343.607	-3.173
335.624	-8.598
325.688	-8.023
313.706	-8.786
302.139	-9.022
300.578	-1.059
303.541	1.946
305.903	2.720
306.698	0.825
309.169	2.014
310.603	1.155
314.231	2.754
317.924	2.695
323.121	5.170
324.138	1.102
324.779	0.583
324.055	-0.551
330.450	4.764
328.581	-1.244
316.428	-8.437
305.676	-9.273
295.915	-9.453
285.308	-7.188
273.077	-9.595
259.092	-10.585
246.918	-7.897
233.621	-8.938
219.733	-9.756
204.512	-10.538
190.400	-12.794
177.084	-13.182
162.128	-11.359
151.411	-11.847
144.599	-11.576
134.722	-9.671
128.204	-9.630
123.105	-10.221
118.234	-5.357
120.955	2.433
125.808	3.391
124.689	-0.724
120.096	-2.931
110.657	-7.379
102.632	-7.623
103.431	0.494
104.327	0.567
103.798	-0.354
105.146	1.189
104.268	-1.044
102.863	-1.253
101.627	-1.168
100.256	-1.861
99.533	-1.355
98.712	-1.420
97.238	-1.624
95.865	-1.618

DISTANCE
-1150.000 -1100.000 -1000.000 -900.000 -800.000 -700.000 -600.000 -500.000 -400.000 -300.000 -200.000 -100.000 0.000 100.000 200.000 300.000 400.000 500.000 600.000 700.000 800.000 900.000 1000.000 1100.000 1200.000 1300.000 1400.000 1500.000 1600.000 1700.000 1800.000 1900.000 2000.000 2100.000 2200.000 2300.000 2400.000 2500.000 2600.000 2700.000 2800.000 2900.000 3000.000 3100.000 3200.000 3300.000 3400.000 3500.000 3600.000 3700.000 3800.000 3900.000 4000.000 4100.000 4200.000 4300.000 4400.000 4500.000 4600.000 4700.000 4800.000 4900.000 5000.000 5100.000 5200.000 5300.000 5400.000 5500.000 5600.000 5700.000 5800.000 5900.000 6000.000 6100.000 6200.000 6300.000 6400.000 6500.000 6600.000 6700.000 6800.000 6900.000 7000.000 7100.000 7200.000 7300.000 7400.000 7500.000 7600.000 7700.000 7800.000 7900.000 8000.000 8100.000 8200.000 8300.000 8400.000 8500.000 8600.000 8700.000 8800.000 8900.000 9000.000 9100.000 9200.000 9300.000 9400.000 9500.000 9600.000 9700.000 9800.000 9900.000 10000.000 10100.000 10200.000 10300.000 10400.000 10500.000 10600.000 10700.000 10800.000 10900.000 11000.000 11100.000 11200.000 [illegible]

LONGSECTION OF EXISTING ALIGNMENT

SCALE 1 : 20000 HORIZONTAL 1:10000 VERTICAL

DO NOT SCALE - IF IN DOUBT, ASK

ORIGINAL SIZE A1

REV	REVISIONS	DRAWN	CHECKED	APPROVED	DATE
B	FOR INFORMATION	CPA	PAC	CDP	19/10/12

	Name	Date
SURVEYED	LIDAR	
DESIGNED	SW BRENNAN	10/12
DESIGN CHECK	AC DROVER	10/12
DRAWN	CP AJOC	10/12
DRAWING CHECK	PA CHILTON	10/12
APPROVED	CD PITCHFORD	19/10/12

MWH

NZ TRANSPORT AGENCY
WAKA KOTAHI

NZTA NEW ZEALAND
SH 3 MANAWATU GORGE ALTERNATIVE ROUTE

MANAWATU GORGE SLIP
EXISTING LAYOUT PLAN

NOT FOR CONSTRUCTION

Status Stamp: **FOR INFORMATION**

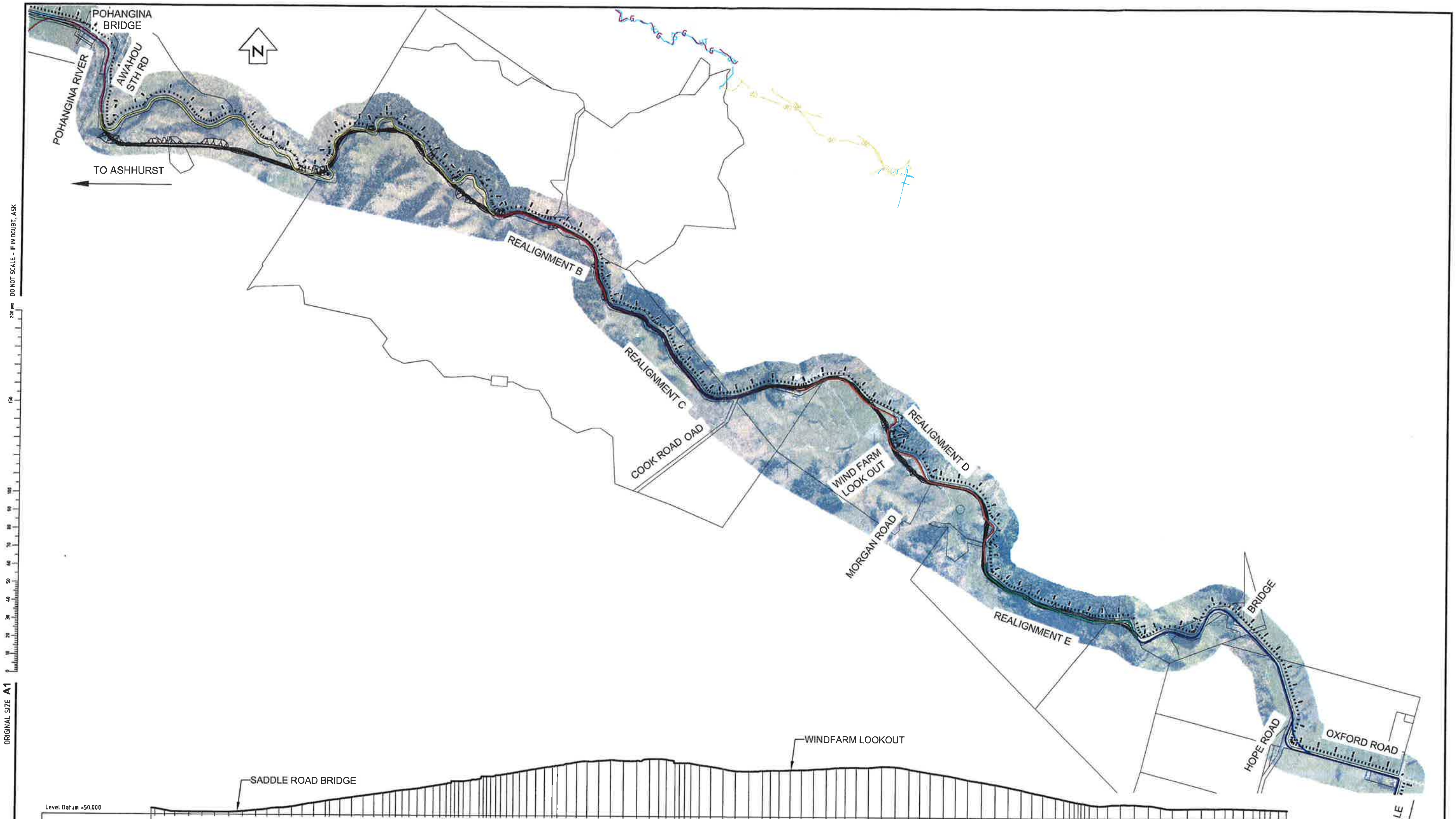
Date Stamp: 19/10/2012

SCALES (A1) 1:10,000 1:20,000 A3

Drawing No. 80500655
Sheet No. D002
Rev. B

XREFS : x_aerial, x_contour, x_survey, x_services

\\nzwants01\projects_2012 Onwards\NZ Transport Agency\SH3 Manwatu Gorge Alt Route 80000655\80500655 SH3 Manawatu Gorge Alternative Route\CAD\D002 Existing layout plan.dwg



EXISTING LEVELS	EXISTING GRADE
81.349	-2.858
72.046	-8.817
65.048	-6.671
64.067	-0.647
63.294	-0.528
63.187	-0.077
63.518	0.218
68.093	3.072
74.677	4.501
81.602	6.085
89.049	5.592
95.779	4.768
106.347	10.544
116.826	8.535
127.020	8.100
130.544	7.699
139.126	8.055
148.208	7.150
156.735	6.899
165.637	7.739
172.060	7.054
177.919	7.630
183.509	8.763
189.266	8.175
192.420	4.169
197.685	6.274
205.025	8.965
212.606	8.920
219.035	9.136
224.540	8.519
239.800	26.405
239.800	0.000
239.800	0.000
244.407	6.025
252.013	7.732
266.894	0.000
266.894	0.000
272.907	11.438
275.295	4.460
281.025	8.706
287.141	8.897
293.528	9.333
300.557	9.029
309.170	8.987
317.657	10.031
323.783	7.816
327.037	6.128
338.910	12.887
347.543	8.063
351.836	3.848
355.240	2.650
360.927	4.458
356.729	-2.988
357.671	0.651
367.638	7.198
368.209	0.572
365.241	-3.706
345.761	-20.579
345.761	0.000
345.761	0.000
343.607	-3.113
335.624	-8.598
325.688	-8.023
313.706	-8.786
302.139	-9.022
300.578	-1.059
303.541	1.946
305.903	2.720
306.698	0.825
309.169	2.014
310.603	1.155
314.231	2.754
317.924	2.695
323.121	5.170
324.138	1.102
324.779	0.583
324.055	-0.551
330.450	4.764
328.581	-1.244
316.428	-8.437
305.676	-9.273
295.915	-9.453
285.308	-7.188
273.077	-9.595
259.092	-10.585
246.918	-7.897
233.621	-8.938
219.733	-9.756
204.512	-10.538
190.400	-12.794
177.084	-13.182
162.128	-11.359
151.411	-11.847
144.599	-11.576
134.722	-9.671
128.204	-9.630
123.105	-10.221
118.234	-5.357
120.955	2.433
125.808	3.391
124.689	-0.724
120.096	-2.931
110.657	-7.379
102.632	-7.623
103.431	0.494
104.327	0.567
103.798	-0.354
105.146	1.189
104.268	-1.044
102.863	-1.253
101.627	-1.168
100.256	-1.867
99.533	-1.355
98.712	-1.420
97.238	-1.624
95.865	-1.618

DISTANCE
-1150.000
-1100.000
-1000.000
-900.000
-800.000
-700.000
-600.000
-500.000
-400.000
-300.000
-200.000
-100.000
0.000
100.000
200.000
300.000
400.000
500.000
600.000
700.000
800.000
900.000
1000.000
1100.000
1200.000
1300.000
1400.000
1500.000
1600.000
1700.000
1800.000
1900.000
2000.000
2100.000
2200.000
2300.000
2400.000
2500.000
2600.000
2700.000
2800.000
2900.000
3000.000
3100.000
3200.000
3300.000
3400.000
3500.000
3600.000
3700.000
3800.000
3900.000
4000.000
4100.000
4200.000
4300.000
4400.000
4500.000
4600.000
4700.000
4800.000
4900.000
5000.000
5100.000
5200.000
5300.000
5400.000
5500.000
5600.000
5700.000
5800.000
5900.000
6000.000
6100.000
6200.000
6300.000
6400.000
6500.000
6600.000
6700.000
6800.000
6900.000
7000.000
7100.000
7200.000
7300.000
7400.000
7500.000
7600.000
7700.000
7800.000
7900.000
8000.000
8100.000
8200.000
8300.000
8400.000
8500.000
8600.000
8700.000
8800.000
8900.000
9000.000
9100.000
9200.000
9300.000
9400.000
9500.000
9600.000
9700.000
9800.000
9900.000
10000.000
10100.000
10200.000
10300.000
10400.000
10500.000
10600.000
10700.000
10800.000
10900.000
11000.000
11100.000
11200.000
11300.000
[illegible]

LONGSECTION OF EXISTING ALIGNMENT

SCALE 1 : 20000 HORIZONTAL 1:10000 VERTICAL

NOT FOR CONSTRUCTION

REV	REVISIONS	DRAWN	CHECKED	APPROVED	DATE
B	FOR INFORMATION	CPA	PAC	CDP	19/10/12

	Name	Date
SURVEYED	LIDAR	
DESIGNED	SW BRENNAN	10/12
DESIGN CHECK	AC DROVER	10/12
DRAWN	CP AJOC	10/12
DRAWING CHECK	PA CHILTON	10/12
APPROVED	CD PITCHFORD	19/10/12

MWH

NZ TRANSPORT AGENCY
WAKA KOTAHI

NZTA NEW ZEALAND
SH 3 MANAWATU GORGE ALTERNATIVE ROUTE

MANAWATU GORGE SLIP
EXISTING REHABILITATION PLAN

Status Stamp: FOR INFORMATION

Date Stamp: 18/10/2012

SCALES (A1) 1:10,000 1:20,000 A3

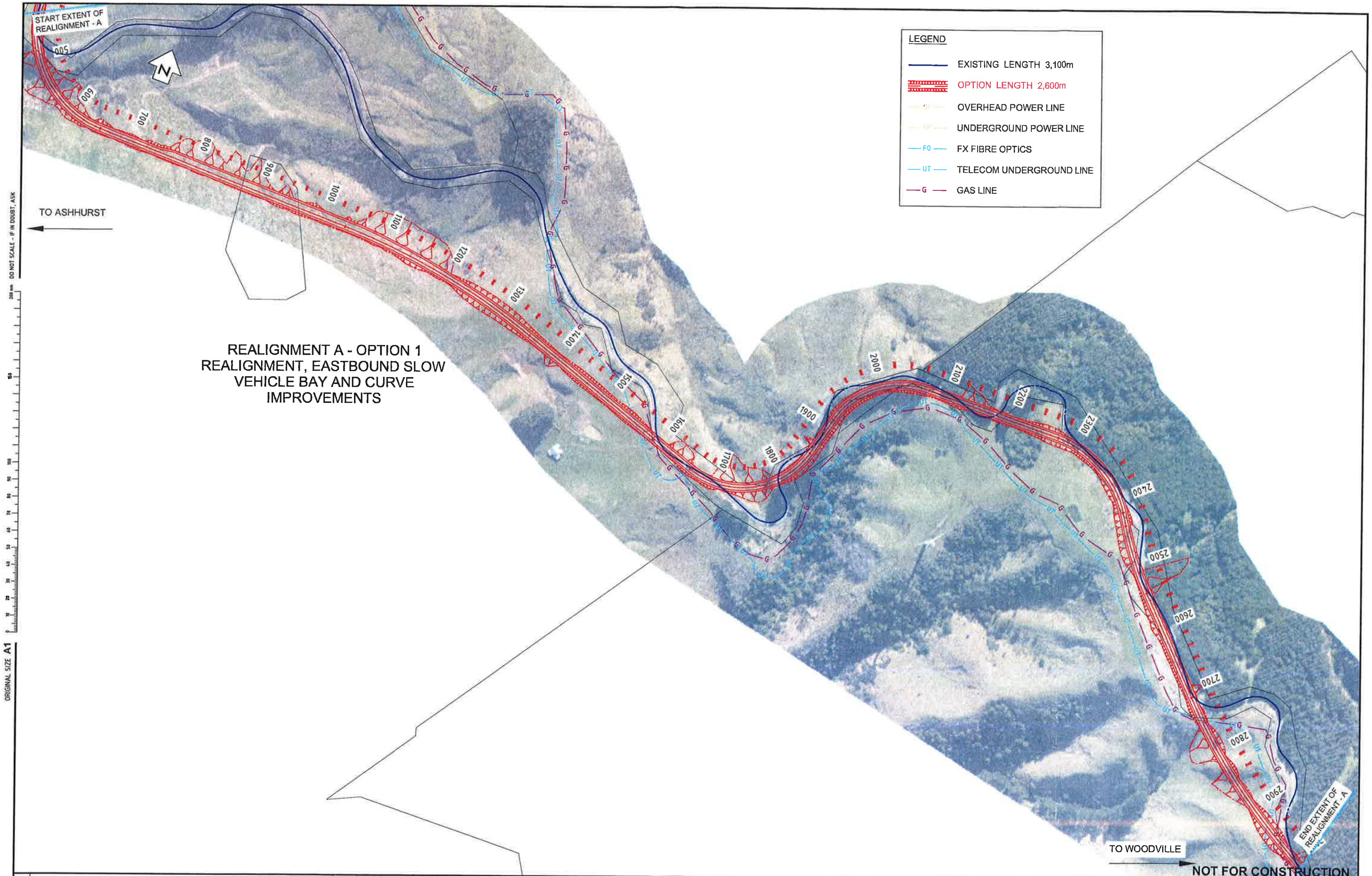
Drawing No. 80500655

Sheet No. D011

Rev. B

XREFS x_aerial, x_contour, x_survey, x_services, X_Design_Realignment A with SVB, X_Design_Realignment B OPTB
X_Design_Realignment C widen with SVB, X_Design_Realignment D optB, X_Design_Realignment E optA, existing centreline

\\nzwanfs01\projects_2012 Onwards\NZ Transport Agency\SH3 Manwatu Gorge Alt Route 80000655\80500655 SH3 Manawatu Gorge Alternative Route\CAD\D011_017 Existing Rehabilitation plan.dwg



NOT FOR CONSTRUCTION

REV	REVISIONS	DRAWN	CHECKED	APPROVED	DATE
B	FOR INFORMATION	CPA	PAC	CDP	19/10/12

	Name	Date
SURVEYED	LIDAR	
DESIGNED	SW BRENNAN	10/12
DESIGN CHECK	AC DROVER	10/12
DRAWN	CP AJOC	10/12
DRAWING CHECK	PA CHILTON	10/12
APPROVED	CD PITCHFORD	19/10/12

MWH

NZ TRANSPORT AGENCY
WAKA KOTAHI

NZTA NEW ZEALAND
SH 3 MANAWATU GORGE ALTERNATIVE ROUTE

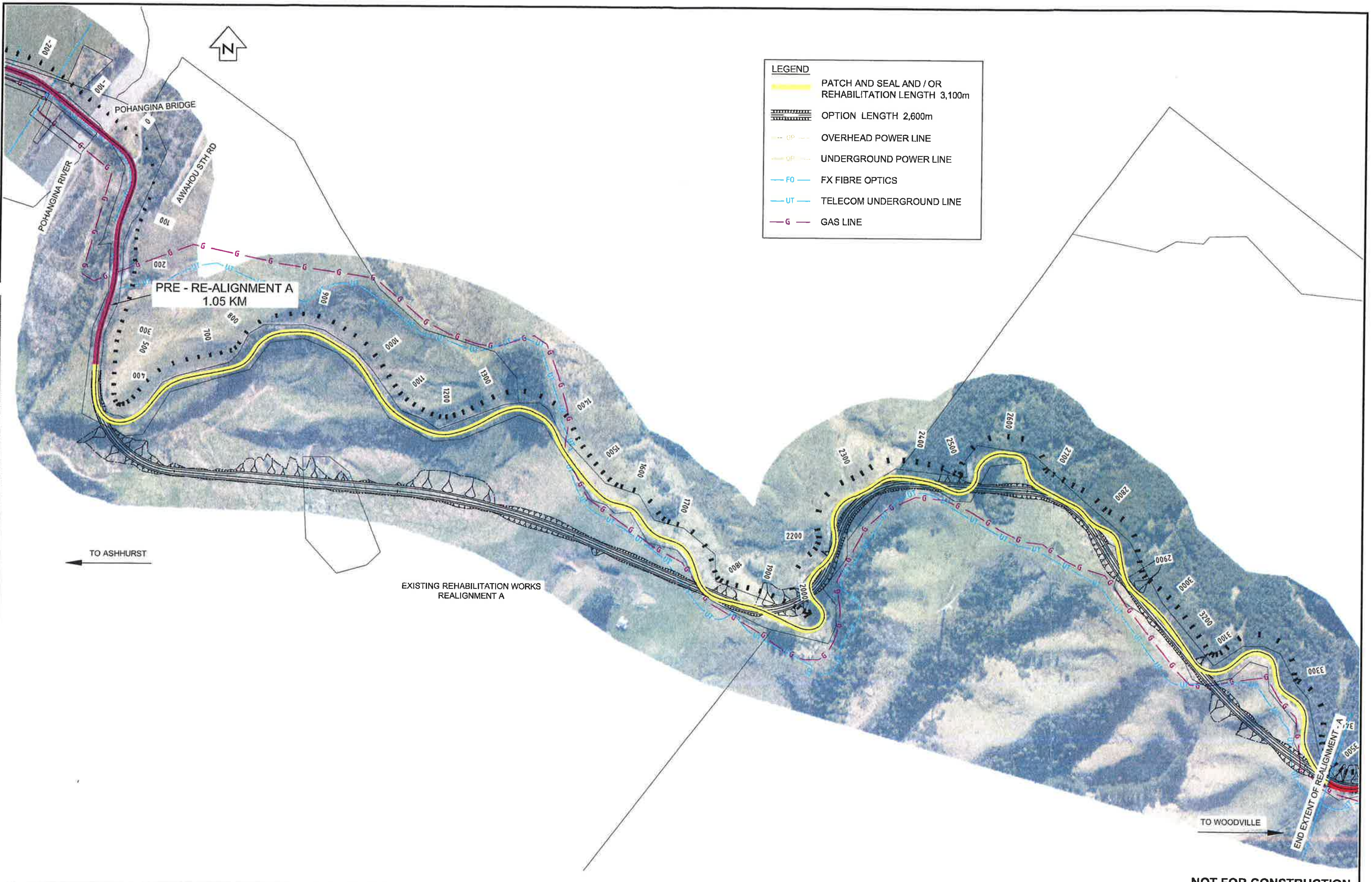
SADDLE ROAD REALIGNMENT OPTIONS
PROPOSED REALIGNMENT A

Status Stamp: **FOR INFORMATION**
Date Stamp: 19/10/2012
SCALES (A1) 1:2500 1:5000 (A3)

Drawing No.	Sheet No.	Rev.
80500655	D004	B

XREFS : x_aerial, x_contour, x_survey, x_services, X_Design_Realignment A with SVB

\\nzwanls01\projects_2012 Onwards\NZ Transport Agency\SH3 Manwatu Gorge Alt Route 80000655\80500655 SH3 Manawatu Gorge Alternative Route\CAD\D004 Realignment A Plan.dwg



LEGEND

🟨	PATCH AND SEAL AND / OR REHABILITATION LENGTH 3,100m
▤	OPTION LENGTH 2,600m
— OP —	OVERHEAD POWER LINE
— UP —	UNDERGROUND POWER LINE
— FO —	FX FIBRE OPTICS
— UT —	TELECOM UNDERGROUND LINE
— G —	GAS LINE

DO NOT SCALE - IF IN DOUBT, ASK

ORIGINAL SIZE A1

NOT FOR CONSTRUCTION

REV	REVISIONS	DRAWN	CHECKED	APPROVED	DATE
B	FOR INFORMATION	CPA	PAC	CDP	19/10/12

	Name	Date
SURVEYED	LIDAR	
DESIGNED	SW BRENNAN	10/12
DESIGN CHECK	AC DROVER	10/12
DRAWN	CP AJOC	10/12
DRAWING CHECK	PA CHILTON	10/12
APPROVED	CD PITCHFORD	19/10/12

MWH

NZ TRANSPORT AGENCY
WAKA KOTAHI

NZTA NEW ZEALAND
SH 3 MANAWATU GORGE ALTERNATIVE ROUTE

MANAWATU GORGE SLIP
EXISTING REHABILITATION WORKS - REALIGNMENT A

Status Stamp FOR INFORMATION

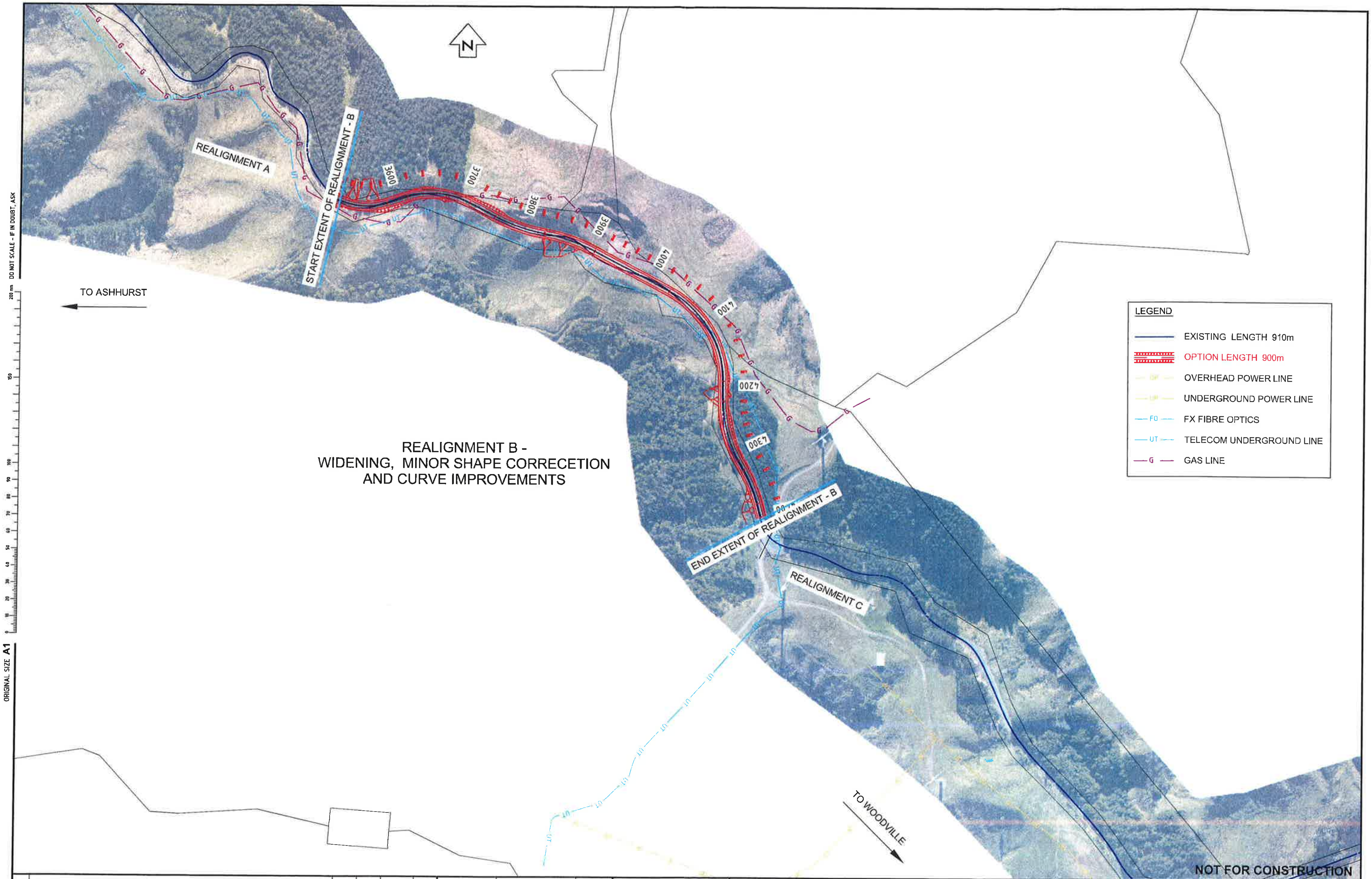
Date Stamp 19/10/2012

SCALES (A1) 1:3,000 1:6,000 A3

Drawing No.	Sheet No.	Rev.
80500655	D 012	B

XREFS x_aerial, x_contour, x_survey, x_services, X_Design_Realignment A with SVB, X_Design_Realignment B OPTB
X_Design_Realignment C widen with SVB, X_Design_Realignment D optB, X_Design_Realignment E optA, existing centreline

\\nzwants01\projects_2012 Onwards\NZ Transport Agency\SH3 Manwatu Gorge Alt Route 80000655\80500655 SH3 Manawatu Gorge Alternative Route\CAD\D011_017 Existing Rehabilitation plan.dwg



REV	REVISIONS	DRAWN	CHECKED	APPROVED	DATE
B	FOR INFORMATION	CPA	PAC	CDP	19/10/12

	Name	Date
SURVEYED	LIDAR	
DESIGNED	SW BRENNAN	10/12
DESIGN CHECK	AC DROVER	10/12
DRAWN	CP AJOC	10/12
DRAWING CHECK	PA CHILTON	10/12
APPROVED	CD PITCHFORD	19/10/12

XREFS : x_aerial, x_contour, x_survey, x_services, X_Design_Realignment B OPTB

MWH

NZ TRANSPORT AGENCY
WAKA KOTAHI

NZTA NEW ZEALAND
SH 3 MANAWATU GORGE ALTERNATIVE ROUTE

SADDLE ROAD REALIGNMENT OPTIONS
PROPOSED REALIGNMENT B

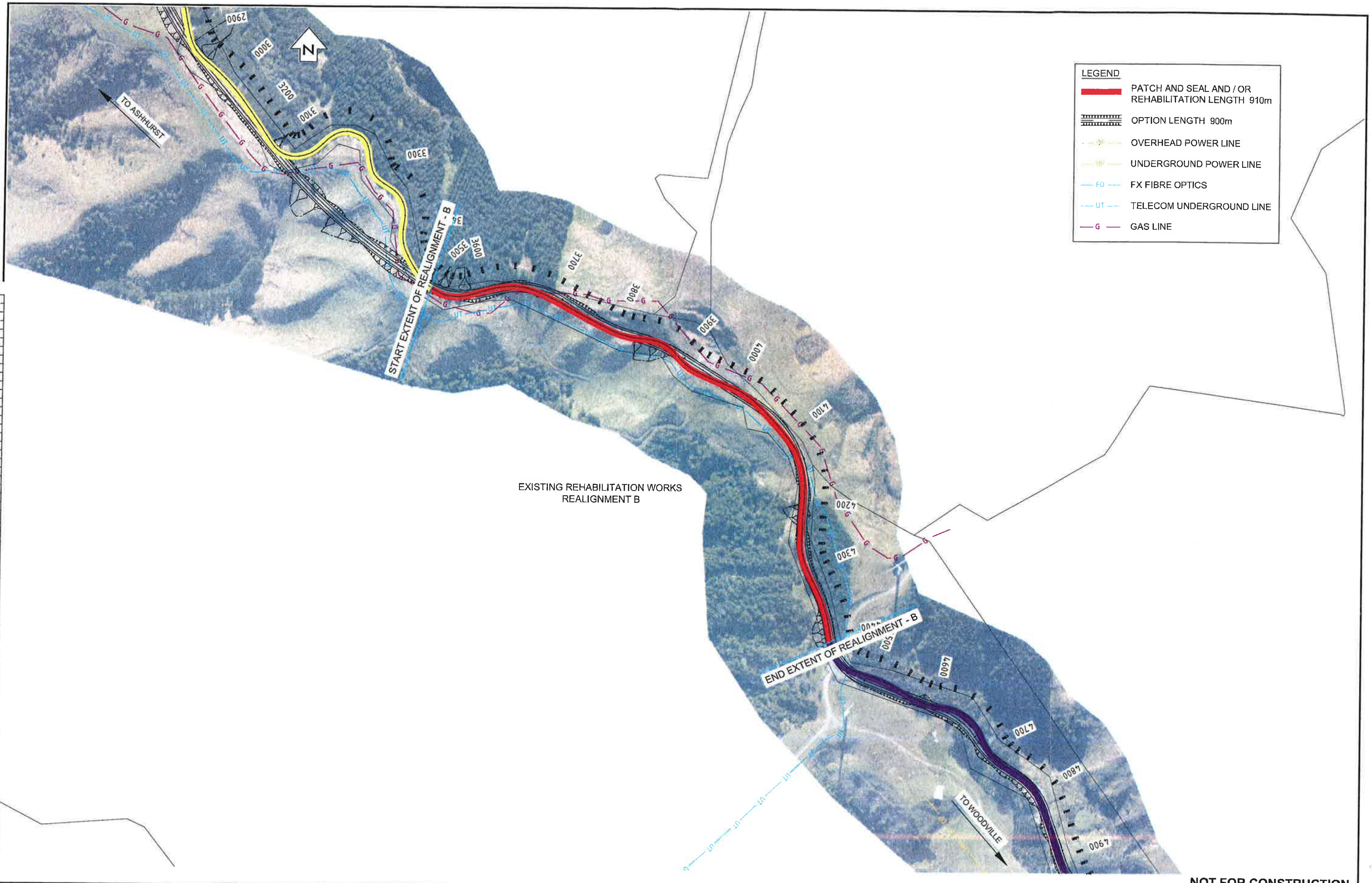
Status Stamp: **FOR INFORMATION**
Date Stamp: 19/10/2012
SCALES (A1) 1:2,500 1:5,000 (A3)

Drawing No.	Sheet No.	Rev.
80500655	D005	B

\\nzwanls01\projects_2012 Onwards\NZ Transport Agency\SH3 Manwatu Gorge Alt Route 80000655\80500655 SH3 Manawatu Gorge Alternative Route\CAD\D005 Realignment B Plan.dwg

DO NOT SCALE - IF IN DOUBT, ASK

ORIGINAL SIZE A1



EXISTING REHABILITATION WORKS
REALIGNMENT B

NOT FOR CONSTRUCTION

REV	REVISIONS	DRAWN	CHECKED	APPROVED	DATE
B	FOR INFORMATION	CPA	PAC	CDP	19/10/12

	Name	Date
SURVEYED	LIDAR	
DESIGNED	SW BRENNAN	10/12
DESIGN CHECK	AC DROVER	10/12
DRAWN	CP AJOC	10/12
DRAWING CHECK	PA CHILTON	10/12
APPROVED	CD PITCHFORD	19/10/12

MWH

NZ TRANSPORT AGENCY
WAKA KOTAHI

NZTA NEW ZEALAND
SH 3 MANAWATU GORGE ALTERNATIVE ROUTE

MANAWATU GORGE SLIP
EXISTING REHABILITATION WORKS - REALIGNMENT B

Status Stamp: **FOR INFORMATION**

Date Stamp: 19/10/2012

SCALES (A1) 1:2,500 1:5,000 A3

Drawing No. 80500655

Sheet No. D 013

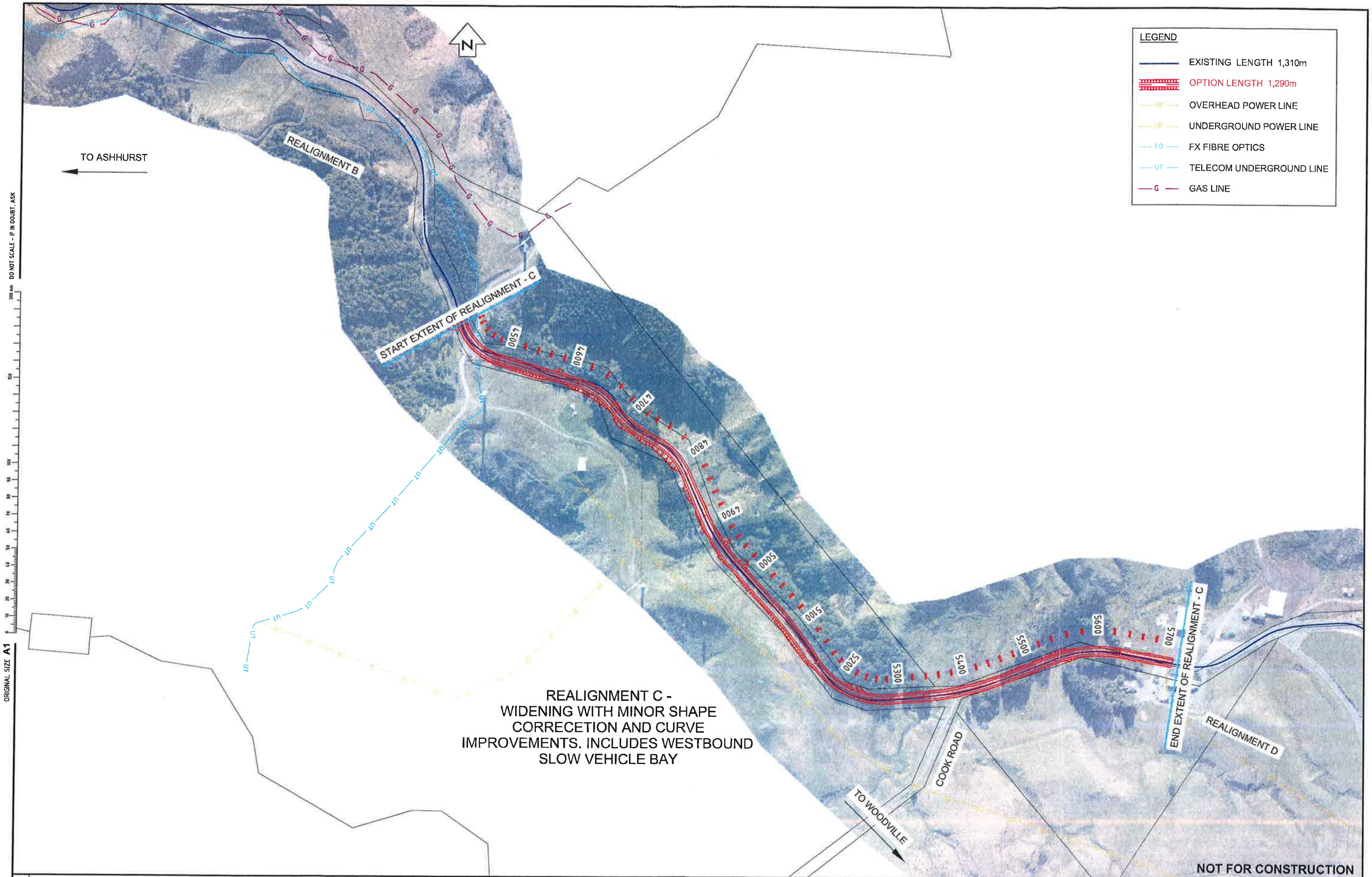
Rev. B

XREFS : x_aerial, x_contour, x_survey, x_services, X_Design_Realignment A with SVB, X_Design_Realignment B OPTB
X_Design_Realignment C widen with SVB, X_Design_Realignment D optB, X_Design_Realignment E optA, existing centreline

\\nzwanls01\projects_2012 Onwards\NZ Transport Agency\SH3 Manwatu Gorge Alt Route 80000655\80500655 SH3 Manawatu Gorge Alternative Route\CAD\D011_017 Existing Rehabilitation plan.dwg

DO NOT SCALE - IF IN DOUBT, ASK

ORIGINAL SIZE A1



REALIGNMENT C -
WIDENING WITH MINOR SHAPE
CORRECETION AND CURVE
IMPROVEMENTS. INCLUDES WESTBOUND
SLOW VEHICLE BAY

NOT FOR CONSTRUCTION

REV	REVISIONS	DRAWN	CHECKED	APPROVED	DATE
B	FOR INFORMATION	CPA	PAC	CDP	19/10/12

	Name	Date
SURVEYED	LIDAR	
DESIGNED	SW BRENNAN	10/12
DESIGN CHECK	AC DROVER	10/12
DRAWN	CP AJOC	10/12
DRAWING CHECK	PA CHILTON	10/12
APPROVED	CD PITHFORD	19/10/12

MWH

NZ TRANSPORT AGENCY
WAKA KOTAHI

NZTA NEW ZEALAND
SH 3 MANAWATU GORGE ALTERNATIVE ROUTE

SADDLE ROAD REALIGNMENT OPTIONS
REALIGNMENT C

Status Stamp **FOR INFORMATION**

Date Stamp 19/10/2012

SCALES (A1) 1:2,500 1:5,000 (A3)

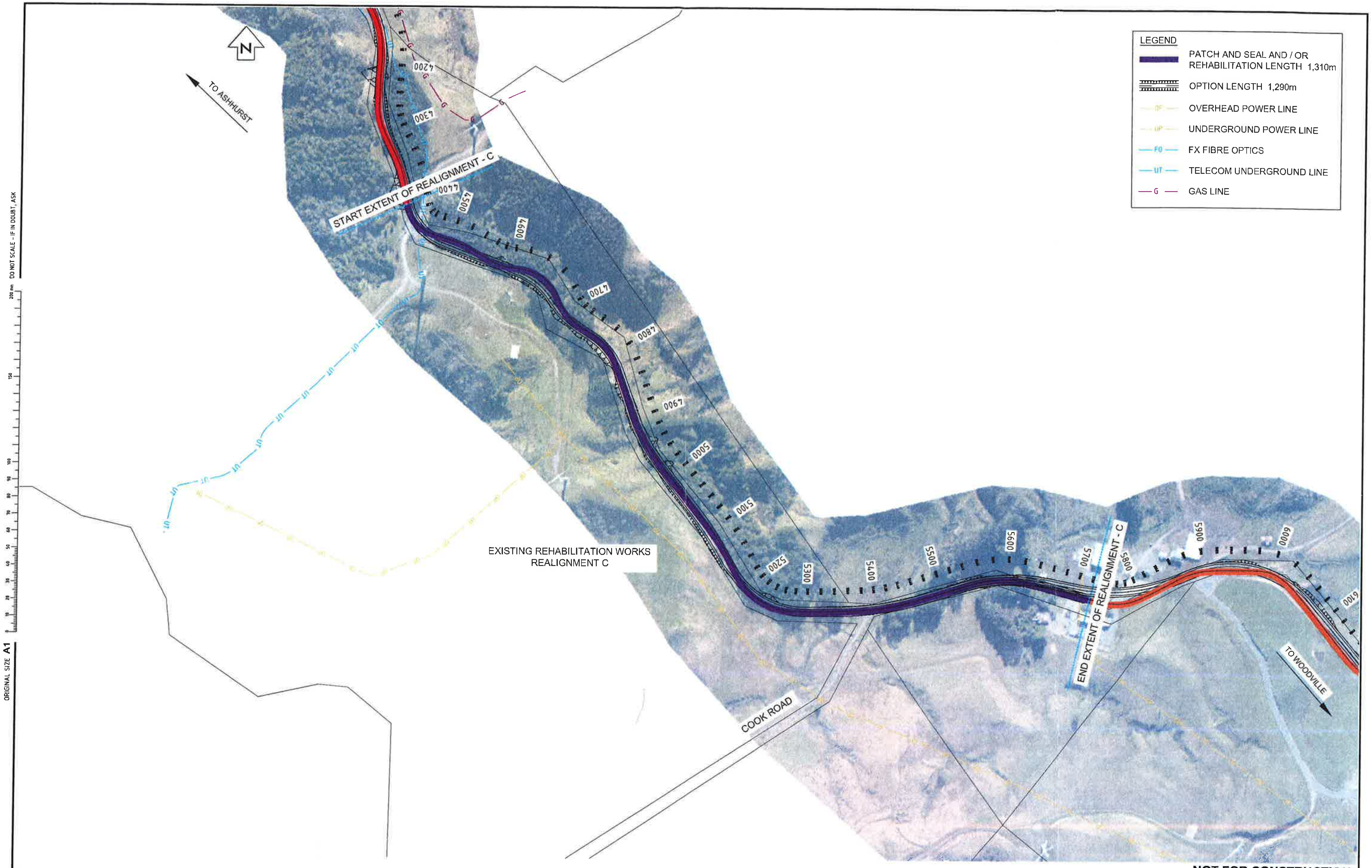
Drawing No.	Sheet No.	Rev.
80500655	D006	B

XREFS : x_aerial, x_contour, x_survey, x_services, X_Design_Realignment C widen with SVB

\\nzwan1s01\projects_2012 Onwards\NZ Transport Agency\SH3 Manwatu Gorge Alt Route 80000655\80500655 SH3 Manawatu Gorge Alternative Route\CAD\D006 Realignment C Plan.dwg

DO NOT SCALE - IF IN DOUBT, ASK

ORIGINAL SIZE A1



LEGEND

▬	PATCH AND SEAL AND / OR REHABILITATION LENGTH 1,310m
▤	OPTION LENGTH 1,290m
— OP —	OVERHEAD POWER LINE
— UP —	UNDERGROUND POWER LINE
— FO —	FX FIBRE OPTICS
— UT —	TELECOM UNDERGROUND LINE
— G —	GAS LINE

B	FOR INFORMATION	CPA	PAC	CDP	19/10/12
REV	REVISIONS	DRAWN	CHECKED	APPROVED	DATE

	Name	Date
SURVEYED	LIDAR	
DESIGNED	SW BRENNAN	10/12
DESIGN CHECK	AC DROVER	10/12
DRAWN	CP AJOC	10/12
DRAWING CHECK	PA CHILTON	10/12
APPROVED	CD PITCHFORD	19/10/12

MWH

NZ TRANSPORT AGENCY
WAKA KOTAHI

NZTA NEW ZEALAND
SH 3 MANAWATU GORGE ALTERNATIVE ROUTE

MANAWATU GORGE SLIP
EXISTING REHABILITATION WORKS - REALIGNMENT C

NOT FOR CONSTRUCTION

Status Stamp **FOR INFORMATION**

Date Stamp 19/10/2012

SCALES (A1) 1:2,500 1:5,000 A3

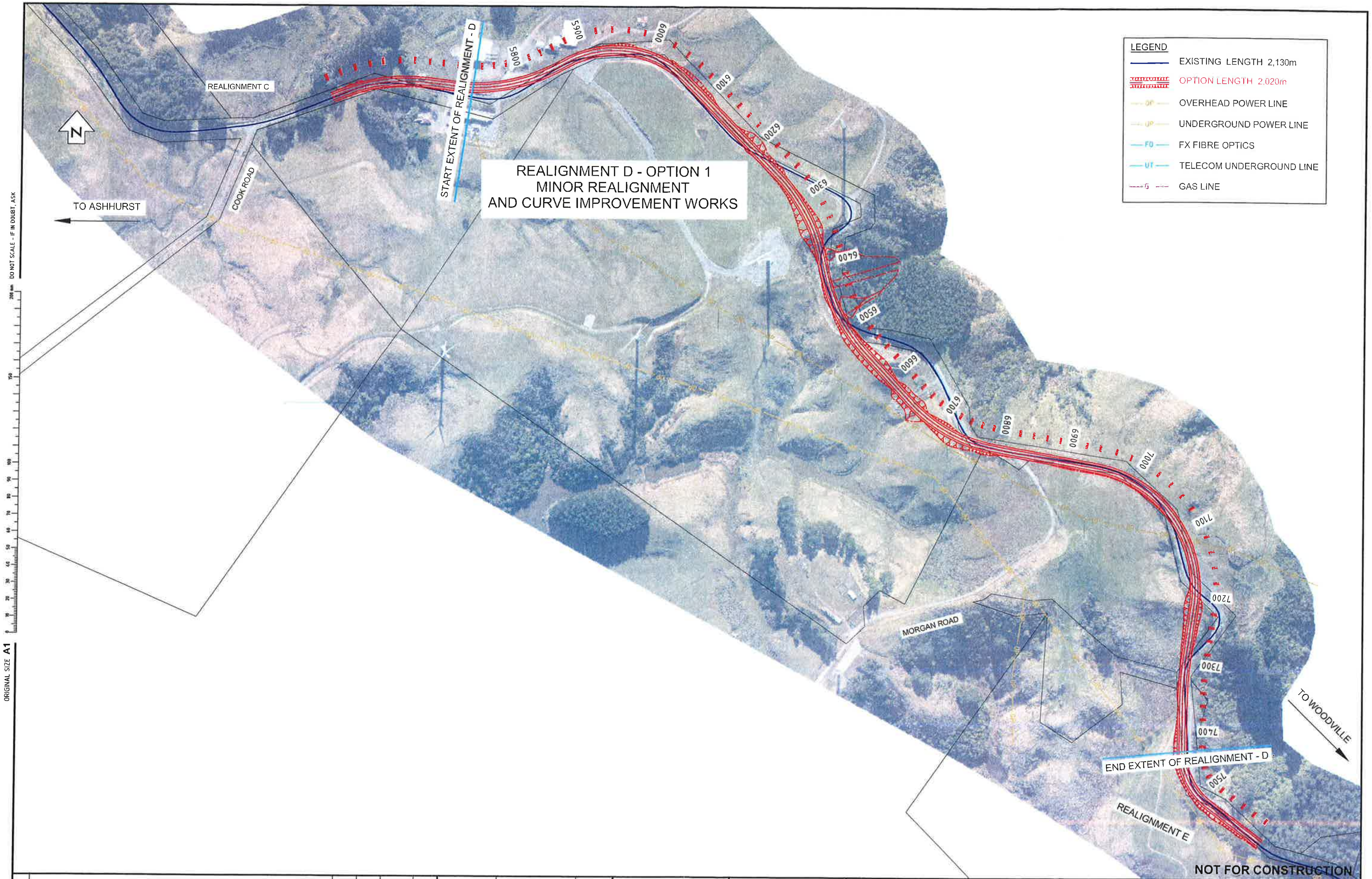
Drawing No. 80500655 Sheet No. D 014 Rev. B

XREFS : x_aerial, x_contour, x_survey, x_services, X_Design_Realignment A with SVB, X_Design_Realignment B OPTB X_Design_Realignment C widen with SVB, X_Design_Realignment D optB, X_Design_Realignment E optA, existing centreline

\\nzwan1s01\projects_2012 Onwards\NZ Transport Agency\SH3 Manawatu Gorge Alt Route 80000655\80500655 SH3 Manawatu Gorge Alternative Route\CAD\D011_017 Existing Rehabilitation plan.dwg

ORIGINAL SIZE A1

DO NOT SCALE - IF IN DOUBT, ASK



REV	REVISIONS	DRAWN	CHECKED	APPROVED	DATE
B	FOR INFORMATION	CPA	PAC	CDP	19/10/12

	Name	Date
SURVEYED	LIDAR	
DESIGNED	SW BRENNAN	10/12
DESIGN CHECK	AC DROVER	10/12
DRAWN	CP AJOC	10/12
DRAWING CHECK	PA CHILTON	10/12
APPROVED	CD PITCHFORD	19/10/12

MWH

NZ TRANSPORT AGENCY
WAKA KOTAHI

NZTA NEW ZEALAND
SH 3 MANAWATU GORGE ALTERNATIVE ROUTE

SADDLE ROAD REALIGNMENT OPTIONS
REALIGNMENT D

Status Stamp **FOR INFORMATION**

Date Stamp 19/10/2012

SCALES (A1) 1:2,500 1:5,000 (A3)

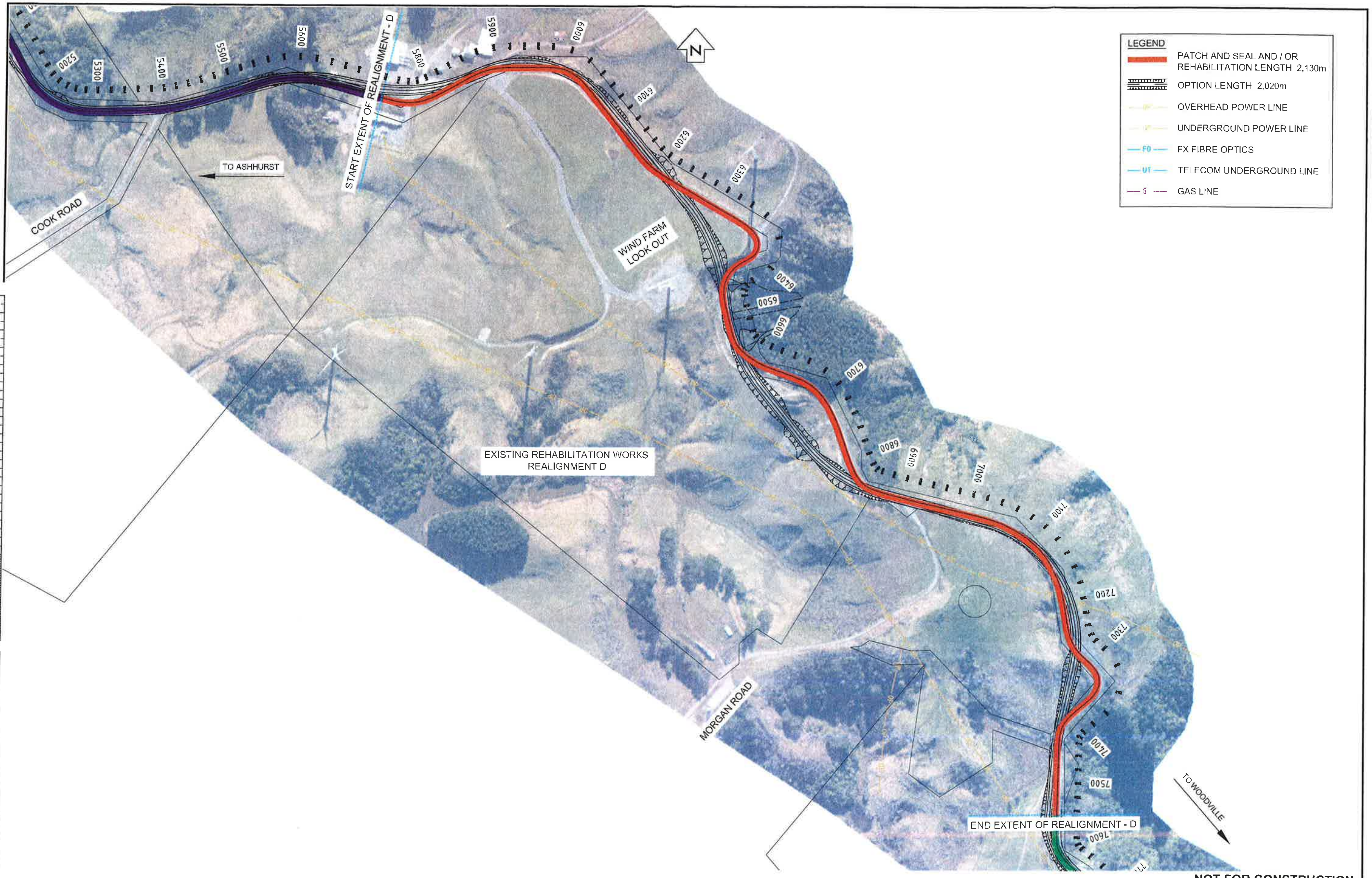
Drawing No.	Sheet No.	Rev.
80500655	D007	B

XREFS : x_aerial, x_contour, x_survey, x_services, X_Design_Realignment D opt8

\\nzwan1s01\projects_2012 Onwards\NZ Transport Agency\SH3 Manwatu Gorge Alt Route 80000655\80500655 SH3 Manawatu Gorge Alternative Route\CAD\D007 Realignment D Plan.dwg

ORIGINAL SIZE A1

DO NOT SCALE - IF IN DOUBT, ASK



NOT FOR CONSTRUCTION

B	FOR INFORMATION	CPA	PAC	CDP	19/10/12
REV	REVISIONS	DRAWN	CHECKED	APPROVED	DATE

	Name	Date
SURVEYED	LIDAR	
DESIGNED	SW BRENNAN	10/12
DESIGN CHECK	AC DROVER	10/12
DRAWN	CP AJOC	10/12
DRAWING CHECK	PA CHILTON	10/12
APPROVED	CD PITCHFORD	19/10/12

MWH

NZ TRANSPORT AGENCY
WAKA KOTAHI

NZTA NEW ZEALAND
SH 3 MANAWATU GORGE ALTERNATIVE ROUTE

MANAWATU GORGE SLIP
EXISTING REHABILITATION WORKS - REALIGNMENT D

Status Stamp **FOR INFORMATION**

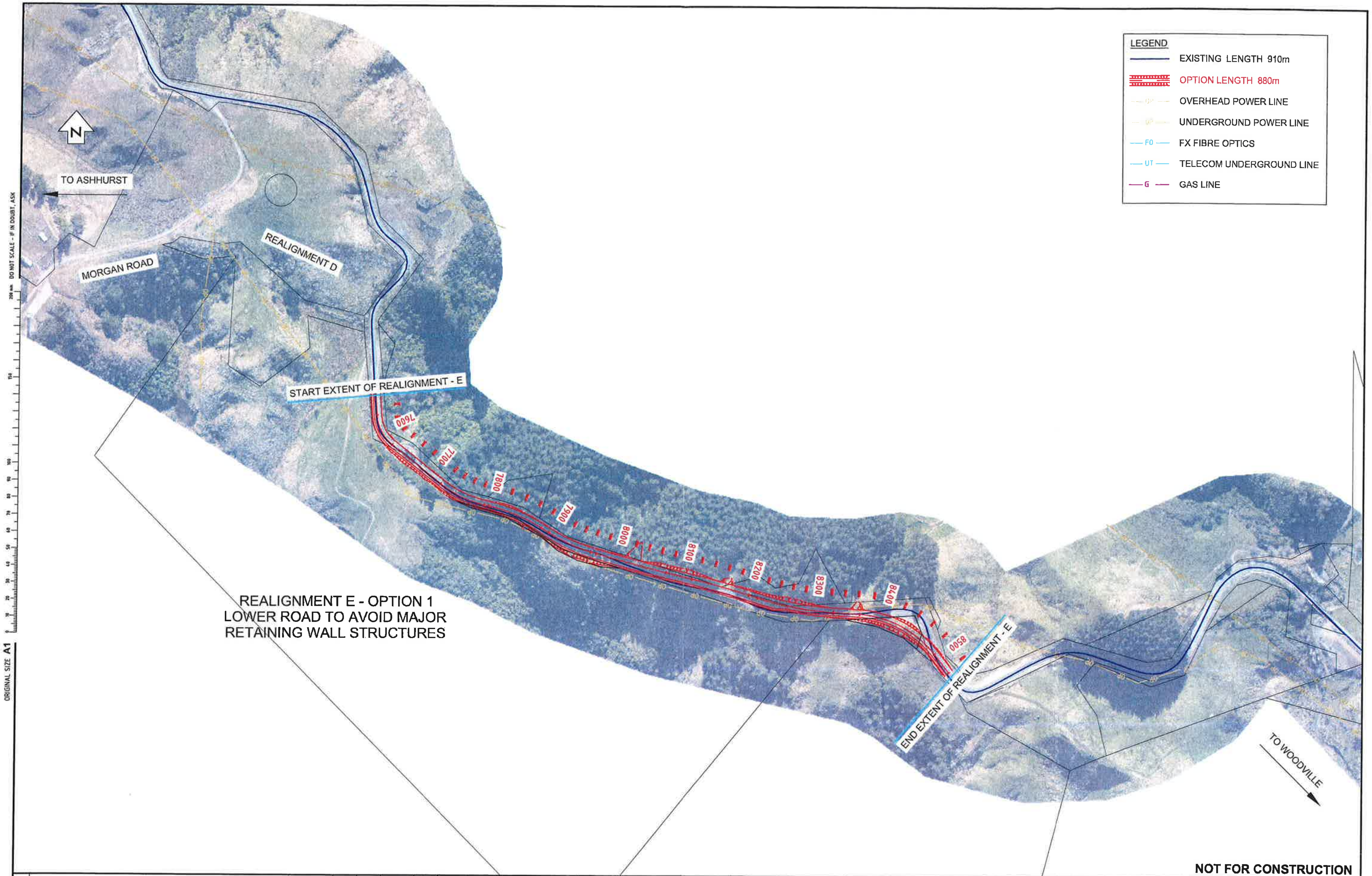
Date Stamp 19/10/2012

SCALES (A1) 1:2,500 1:5,000 A3

Drawing No.	Sheet No.	Rev.
80500655	D 015	B

XREFS: x_aerial, x_contour, x_survey, x_services, X_Design_Realignment A with SVB, X_Design_Realignment B OPTB
X_Design_Realignment C widen with SVB, X_Design_Realignment D optB, X_Design_Realignment E optA, existing centreline

\\nzwanls01\projects_2012 Onwards\NZ Transport Agency\SH3 Manwatu Gorge Alt Route 80000655\00500655 SH3 Manawatu Gorge Alternative Route\CAD\D011_017 Existing Rehabilitation plan.dwg



ORIGINAL SIZE A1

DO NOT SCALE - IF IN DOUBT, ASK

NOT FOR CONSTRUCTION

REV	REVISIONS	DRAWN	CHECKED	APPROVED	DATE
B	FOR INFROMATION	CPA	PAC	CDP	19/10/12

	Name	Date
SURVEYED	LIDAR	
DESIGNED	SW BRENNAN	10/12
DESIGN CHECK	AC DROVER	10/12
DRAWN	CP AJOC	10/12
DRAWING CHECK	PA CHILTON	10/12
APPROVED	CD PITCHFORD	19/10/12

MWH

NZ TRANSPORT AGENCY
WAKA KOTAHI

NZTA NEW ZEALAND
SH 3 MANAWATU GORGE ALTERNATIVE ROUTE

SADDLE ROAD REALIGNMENT OPTIONS
REALIGNMENT E

Status Stamp **FOR INFORMATION**

Date Stamp 19/10/2012

SCALES (A1) 1:2,500 1:5,000 (A3)

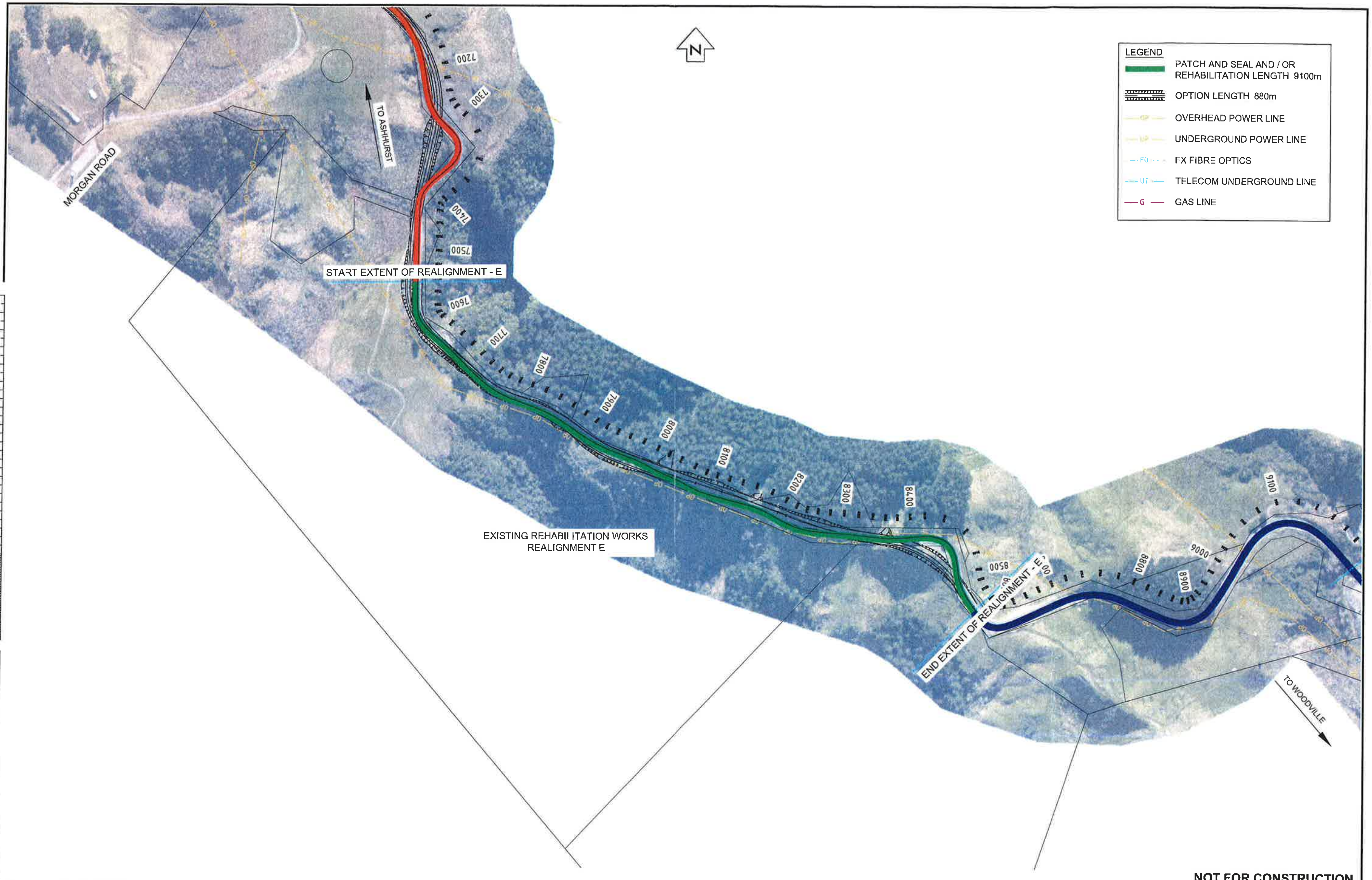
Drawing No.	Sheet No.	Rev.
80500655	D 008	B

XREFS - x_aerial, x_contour, x_survey, x_services, X_Design_Realignment E optA

\\nzwan1s01\projects_2012 Onwards\NZ Transport Agency\SH3 Manwatu Gorge Alt Route 80000655\80500655 SH3 Manawatu Gorge Alternative Route\CAD\D008 Realignment E Plan.dwg

DO NOT SCALE - IF IN DOUBT, ASK

ORIGINAL SIZE A1



NOT FOR CONSTRUCTION

REV	REVISIONS	DRAWN	CHECKED	APPROVED	DATE
B	FOR INFORMATION	CPA	PAC	CDP	19/10/12

	Name	Date
SURVEYED	LIDAR	
DESIGNED	SW BRENNAN	10/12
DESIGN CHECK	AC DROVER	10/12
DRAWN	CP AJOC	10/12
DRAWING CHECK	PA CHILTON	10/12
APPROVED	CD PITCHFORD	19/10/12

MWH

NZ TRANSPORT AGENCY
WAKA KOTAHI

NZTA NEW ZEALAND
SH 3 MANAWATU GORGE ALTERNATIVE ROUTE

MANAWATU GORGE SLIP
EXISTING REHABILITATION WORKS - REALIGNMENT E

Status Stamp **FOR INFORMATION**
Date Stamp 19/10/2012
SCALES (A1) 1:2,500 1:5,000 A3

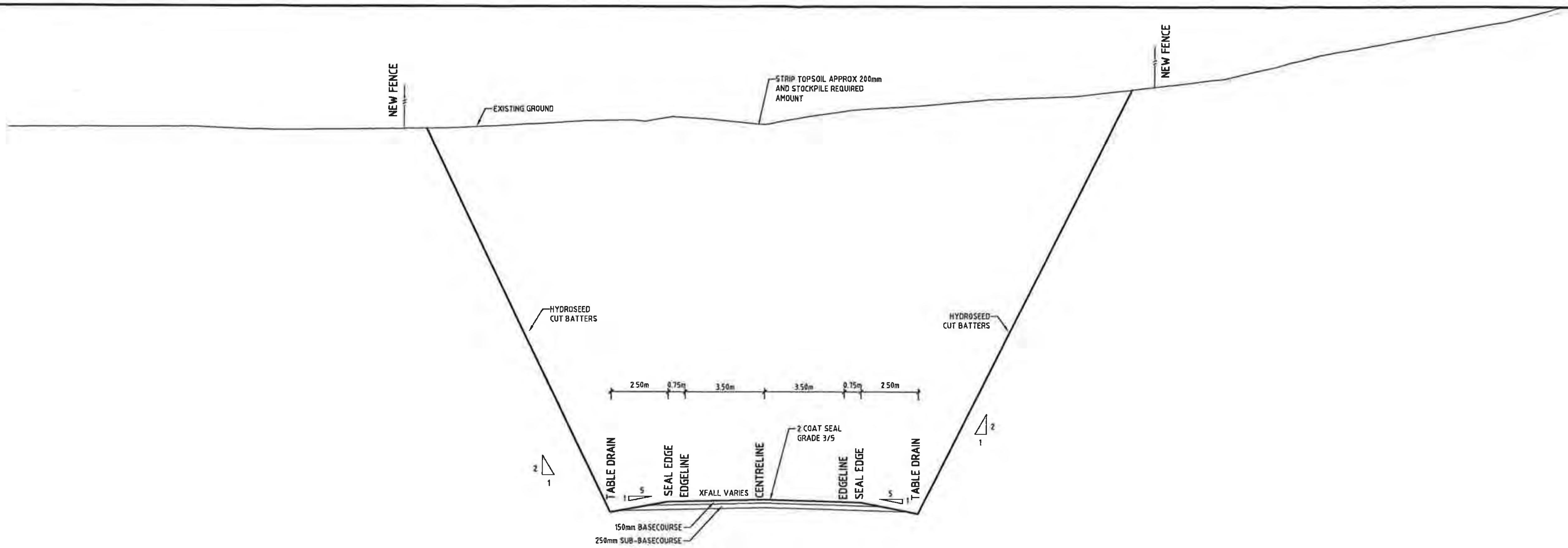
Drawing No.	Sheet No.	Rev.
80500655	D 016	B

XREFS : x_aerial, x_contour, x_survey, x_services, X_Design_Realignment A with SVB, X_Design_Realignment B OPTB
X_Design_Realignment C widen with SVB, X_Design_Realignment D optB, X_Design_Realignment E optA, existing centreline

\\nzwanls01\projects_2012 Onwards\NZ Transport Agency\SH3 Manwatu Gorge Alt Route 80000655\80500655 SH3 Manawatu Gorge Alternative Route\CAD\D011_017 Existing Rehabilitation plan.dwg

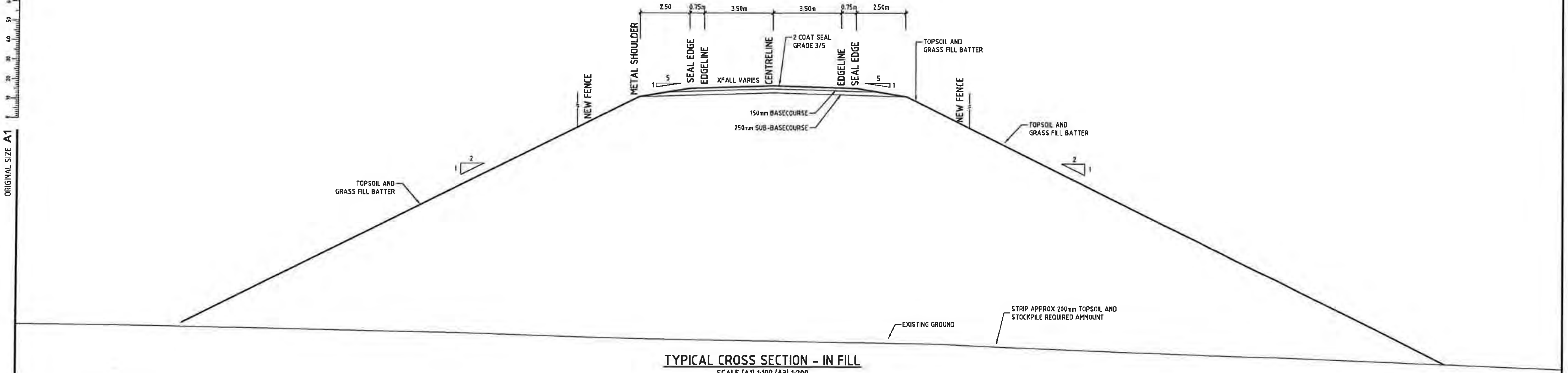
DO NOT SCALE - IF IN DOUBT, ASK

ORIGINAL SIZE A1



TYPICAL CROSS SECTION - IN CUT

SCALE (A1) 1:100 (A3) 1:200



TYPICAL CROSS SECTION - IN FILL

SCALE (A1) 1:100 (A3) 1:200

NOT FOR CONSTRUCTION

REV		REVISIONS	DRAWN	CHECKED	APPROVED	DATE
B	FOR INFORMATION		CPA	PAC	CDP	19/10/12

	Name	Date
SURVEYED	LIDAR	
DESIGNED	SW BRENNAN	10/12
DESIGN CHECK	AC DROVER	10/12
DRAWN	CP AJOC	10/12
DRAWING CHECK	PA CHILTON	10/12
APPROVED	CD PITCHFORD	19/10/12

XREFS :

MWH

NZ TRANSPORT AGENCY
WAKA KOTAHI

NZTA NEW ZEALAND
SH 3 MANAWATU GORGE ALTERNATIVE ROUTE

SADDLE ROAD REALIGNMENT OPTIONS
TYPICAL CROSS SECTIONS

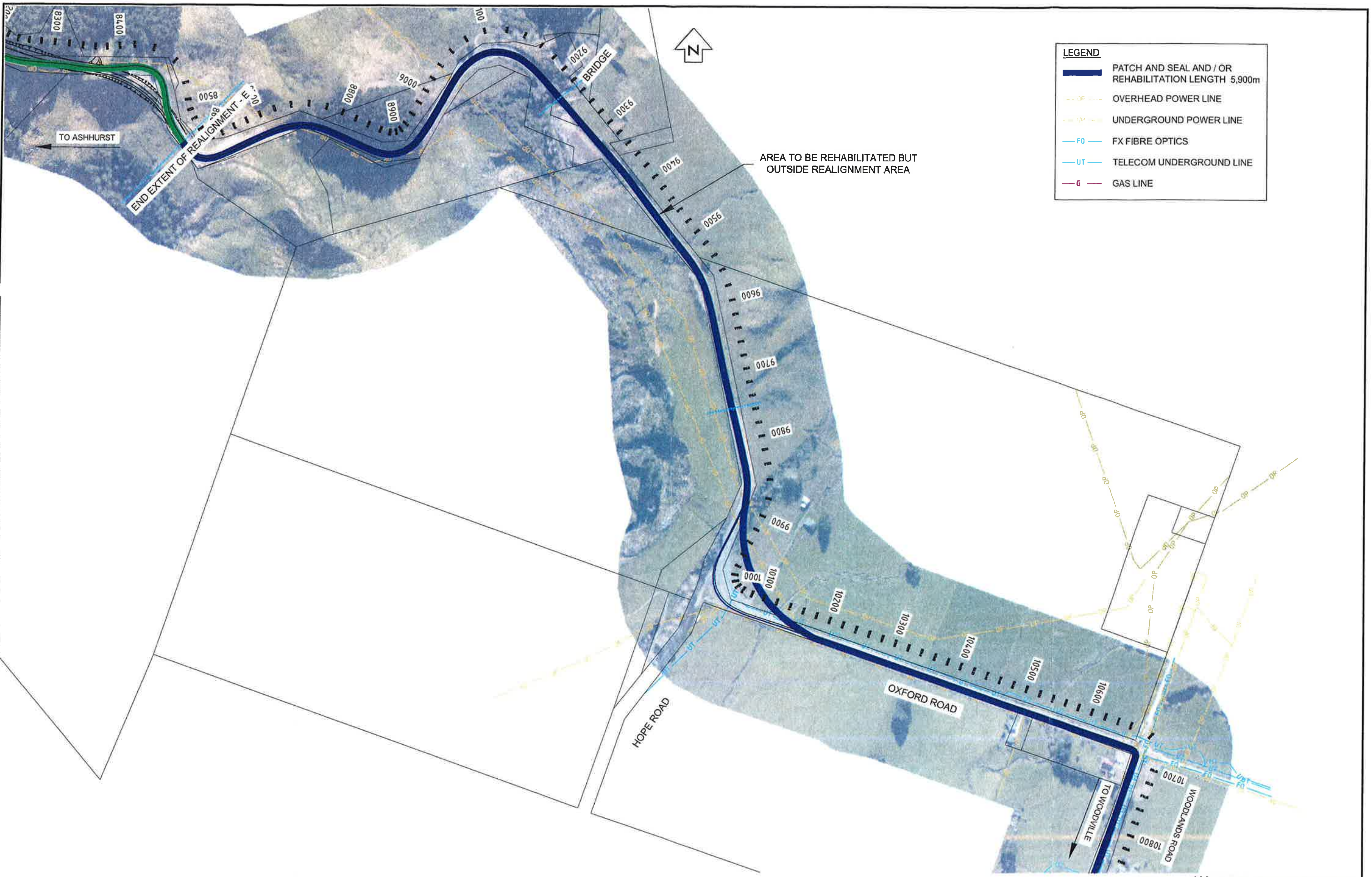
Status Stamp **FOR INFORMATION**

Date Stamp **19/10/2012**

SCALES (A1) AS SHOWN

Drawing No.	Sheet No	Rev.
80500655	D009	B

\\nzwanfs01\projects_2012 Onwards\NZ Transport Agency\SH3 Manwatu Gorge Alt Route 80000655\80500655 SH3 Manawatu Gorge Alternative Route\CAD\D009 Typical Crossection.dwg



DO NOT SCALE - IF IN DOUBT, ASK

ORIGINAL SIZE A1

NOT FOR CONSTRUCTION

REV	REVISIONS	DRAWN	CHECKED	APPROVED	DATE
B	FOR INFORMATION	CPA	PAC	CDP	19/10/12

	Name	Date
SURVEYED	LIDAR	
DESIGNED	SW BRENNAN	10/12
DESIGN CHECK	AC DROVER	10/12
DRAWN	CP AJOC	10/12
DRAWING CHECK	PA CHILTON	10/12
APPROVED	CD PITCHFORD	19/10/12

MWH

NZ TRANSPORT AGENCY
WAKA KOTAHI

NZTA NEW ZEALAND
SH 3 MANAWATU GORGE ALTERNATIVE ROUTE

MANAWATU GORGE SLIP
REHABILITATION WORKS - COMPLETED TO DATE

Status Stamp: FOR INFORMATION

Date Stamp: 19/10/2012

SCALES (A1) 1:2,500 1:5,000 A3

Drawing No.	Sheet No.	Rev.
80500655	D 017	B

XREFS - x_aerial, x_contour, x_survey, x_services, X_Design_Realignment A with SVB, X_Design_Realignment B OPTB
X_Design_Realignment C widen with SVB, X_Design_Realignment D optB, X_Design_Realignment E optA, existing centreline

\\nzwants01\projects_2012 Onwards\NZ Transport Agency\SH3 Manwatu Gorge Alt Route 80000655\80500655 SH3 Manawatu Gorge Alternative Route\CAD\D011_017 Existing Rehabilitation plan.dwg

Appendix E Cost Estimates

E.1 Alternative Route Estimates

NZ TRANSPORT AGENCY
WAKA KOTAHI

Gorge detour Options - Route Option A Greenfields option South of the existing gorge route (Green)

-

ITEM	DESCRIPTION	UNIT	QNTY	RATE	AMOUNT
1	**PRELIMINARY AND GENERAL**				
1.1	Establishment and Removal of Site Set Out	LS	1	500000.00	500,000
1.2	Quality Plan inc Operation	LS	1	10000.00	10,000
1.3	Health and Safety Plan inc Operation	LS	1	1250.00	1,250
1.4	Environmental Management	LS	1	500000.00	500,000
1.5	As Built Diagrams and RAMM Updates	LS	1	10000.00	10,000
1.6	Public Liaison and Advertising	LS	1	50000.00	50,000
1.7	Survey Mark Relocation	LS	1	5000.00	5,000
				SubTotal	1,076,250
2	**Temporary Traffic Control**				
2.1	Preparation of Traffic Management Plan	LS	1	5000.00	5,000
2.2	Management of TMP	LS	1	100000.00	100,000
				SubTotal	105,000
3	**EARTHWORKS**				
3.1	Site Clearance (Including removal of all trees within extent of works)	LS	1	25000.00	25,000
3.2	Strip Topsoil (200mm), Stockpile and Respread as Directed	m^3	15,000	10.00	150,000
3.3	Cut to Fill	m^3	1,000,000	7.00	7,000,000
3.4	Cut to Waste onsite(Inc Unused Ex Topsoil)	m^3	52000000	5.00	260,000,000
				SubTotal	267,175,000
4	**PAVEMENT CONSTRUCTION**				
4.1	Sawcut Seal	m		1.75	
4.2	Trim and Compact Formation	m^2	25,000	0.20	5,000
4.3	Import, Lay and Compact Sub Base @ 250mm	m^3	17,000	40.00	680,000
4.4	Import, Lay and Compact Base Course @150mm	m^3	8500	80.00	680,000
				SubTotal	1,365,000
5	**BRIDGE**				
5.1	New bridge	m^2	1,600	2500.00	4,000,000
				SubTotal	4,000,000
6	**SURFACING**				
6.1	Grade 3/5 Seal (Inc Accessways)	m^2	50,000	5.00	250,000
				SubTotal	250,000
7	**DRAINAGE**				
7.1	**Culverts**				
7.1.1	375mm RCRRJ Class 4 Pipe	m	1,000	175.00	175,000
7.1.2	450mm RCRRJ Class 4 Pipe	m	500	270.00	135,000
7.1.3	600mm RCRRJ Class 4 Pipe	m	200	320.00	64,000
7.2	**Headwalls**				
7.2.1	375mm Tapered Headwalls	no	30	650.00	19,500
7.2.2	450mm Tapered Headwalls	no	20	775.00	15,500
7.2.3	600mm Precast Headwalls	no	6	850.00	5,100
7.2.4	Rural Inlet Sumps	no	20	2000.00	40,000
7.2.5	Subsoil	m	10,000	35.00	350,000
7.2.6	Flushing eyes	no	100	500.00	50,000
				SubTotal	854,100
8	**Traffic services**				
8.1	Relocating Signage(incl. ERP's, AWS, Bridge Markers & Mailboxes)	no	50	200.00	10,000
8.2	Edge Marker Posts	no	200	25.00	5,000
8.3	New Linemarking	LS	1	10000.00	10,000
8.4	New RRPM's	no	250	25.00	6,250
				SubTotal	31,250
9	**Landscaping & Fencing**				
9.1	Temp Fence	m	10000	11.00	110,000
9.2	New P&W Fence	m	10000	18.00	180,000
9.3	Relocate Gates	no	20	375.00	7,500
9.4	Grassing	m^2	80,000	0.65	52,000
9.5	Hydroseeding	m^2	100,000	1.00	100,000
				SubTotal	449,500
10	**Relocation of Services**				
10.1	Powerpole relocation	PS	1	100000.00	100,000
10.2	Telecommunications Cable relocation	PS	1	100000.00	100,000
10.3	Wind Turbine relocation	PS	1	5000000.00	5,000,000
				SubTotal	5,200,000
10	**Miscelleneous**				
10.1	Contingency	PS	1	28000000.00	28,000,000
10.2	Land Acquisition	Ha	66	7500.00	495,000
				SubTotal	28,495,000
				PROJECT TOTAL	**309,001,100**

NZ TRANSPORT AGENCY
WAKA KOTAHI

Gorge detour Options - Route Option B Bridging Option (Blue)

-

ITEM	DESCRIPTION	UNIT	QNTY	RATE	AMOUNT
1	**PRELIMINARY AND GENERAL**				
1.1	Establishment and Removal of Site Set Out	LS	1	1000000.00	1,000,000
1.2	Quality Plan inc Operation	LS	1	10000.00	10,000
1.3	Health and Safety Plan inc Operation	LS	1	1250.00	1,250
1.4	Environmental Management	LS	1	20000000.00	20,000,000
1.5	As Built Diagrams and RAMM Updates	LS	1	20000.00	20,000
1.6	Public Liaison and Advertising	LS	1	500000.00	500,000
1.7	Survey Mark Relocation	LS	1	5000.00	5,000
				SubTotal	**21,536,250**
2	**Temporary Traffic Control**				
2.1	Preparation of Traffic Management Plan	LS	1	5000.00	5,000
2.2	Management of TMP	LS	1	1000000.00	1,000,000
				SubTotal	**1,005,000**
3	**EARTHWORKS**				
3.1	Site Clearance (Including removal of all trees within extent of works)	LS	1	20000.00	20,000
3.2	Strip Topsoil (200mm), Stockpile and Respread as Directed	m^3	10,000	10.00	100,000
3.3	Cut to Fill	m^3	20,000	7.00	140,000
3.4	Cut to Waste onsite(Inc Unused Ex Topsoil)	m^3	20000	10.00	200,000
				SubTotal	**460,000**
4	**PAVEMENT CONSTRUCTION**				
4.1	Sawcut Seal	m	50	2.50	125
4.2	Trim and Compact Formation	m^2	10,000	1.50	15,000
4.3	Import, Lay and Compact Sub Base @ 250mm	m^3	300	50.00	15,000
4.4	Import, Lay and Compact Base Course @150mm	m^3	500	90.00	45,000
				SubTotal	**75,125**
5	**BRIDGE**				
5.1	New bridge	m^2	80,040	3500.00	280,140,000
				SubTotal	**280,140,000**
6	**SURFACING**				
6.1	Grade 3/5 Seal (Inc Accessways)	m^2	80,040	10.00	800,400
				SubTotal	**800,400**
7	**DRAINAGE**				
7.1	**Culverts**				
7.1.1	375mm RCRRJ Class 4 Pipe	m	1,500	175.00	262,500
7.1.2	450mm RCRRJ Class 4 Pipe	m	750	270.00	202,500
7.1.3	600mm RCRRJ Class 4 Pipe	m	6,670	320.00	2,134,400
				SubTotal	**2,599,400**
8	**Traffic services**				
8.1	Relocating Signage(incl. ERP's, AWS, Bridge Markers & Mailboxes)	no	50	200.00	10,000
8.2	Edge Marker Posts	no	300	25.00	7,500
8.3	New Linemarking	LS	1	20000.00	20,000
8.4	New RRPM's	no	300	25.00	7,500
8.5	TL3 Cycle Lane Separation Barrier	m	13,340	300.00	4,002,000
				SubTotal	**4,047,000**
9	**Landscaping & Fencing**				
				SubTotal	
10	**Relocation of Services**				
10.1	Powerpole	LS	1	2000000.00	2,000,000
10.2	Telecommunications Cable relocation	PS	1	200000.00	200,000
				SubTotal	2,200,000
10	**Miscelleneous**				
10.1	Contingency	PS	1	100000000.00	100,000,000
10.2	Land Acquisition	Ha			
				SubTotal	100,000,000
				PROJECT TOTAL	**412,863,175**

NZ TRANSPORT AGENCY
WAKA KOTAHI

Gorge detour Options - Route Option C North of the existing gorge route (Orange)

ITEM	DESCRIPTION	UNIT	QNTY	RATE	AMOUNT
1	**PRELIMINARY AND GENERAL**				
1.1	Establishment and Removal of Site Set Out	LS	1	1000000.00	1,000,000
1.2	Quality Plan inc Operation	LS	1	10000.00	10,000
1.3	Health and Safety Plan inc Operation	LS	1	1250.00	1,250
1.4	Environmental Management	LS	1	500000.00	500,000
1.5	As Built Diagrams and RAMM Updates	LS	1	20000.00	20,000
1.6	Public Liaison and Advertising	LS	1	100000.00	100,000
1.7	Survey Mark Relocation	LS	1	5000.00	5,000
				SubTotal	1,636,250
2	**Temporary Traffic Control**				
2.1	Preparation of Traffic Management Plan	LS	1	5000.00	5,000
2.2	Management of TMP	LS	1	1000000.00	1,000,000
				SubTotal	1,005,000
3	**EARTHWORKS**				
3.1	Site Clearance (Including removal of all trees within extent of works)	LS	1	250000.00	250,000
3.2	Strip Topsoil (200mm), Stockpile and Respread as Directed	m^3	500,000	10.00	5,000,000
3.3	Cut to Fill	m^3	3,000,000	7.00	21,000,000
3.4	Cut to Waste onsite(Inc Unused Ex Topsoil)	m^3	2000000	10.00	20,000,000
				SubTotal	46,250,000
4	**PAVEMENT CONSTRUCTION**				
4.1	Sawcut Seal	m		1.75	
4.2	Trim and Compact Formation	m^2	90,000	0.20	18,000
4.3	Import, Lay and Compact Sub Base @ 250mm	m^3	30,000	40.00	1,200,000
4.4	Import, Lay and Compact Base Course @150mm	m^3	20,000	80.00	1,600,000
				SubTotal	2,818,000
5	**BRIDGE**				
5.1	New bridge	m^2	2,000	2500.00	5,000,000
				SubTotal	5,000,000
6	**SURFACING**				
6.1	Grade 3/5 Seal (Inc Accessways)	m^2	90,000	10.00	900,000
				SubTotal	900,000
7	**DRAINAGE**				
7.1	**Culverts**				
7.1.1	375mm RCRRJ Class 4 Pipe	m	1,500	175.00	262,500
7.1.2	450mm RCRRJ Class 4 Pipe	m	750	270.00	202,500
7.1.3	600mm RCRRJ Class 4 Pipe	m	500	320.00	160,000
7.2	**Headwalls**				
7.2.1	375mm Tapered Headwalls	no	40	650.00	26,000
7.2.2	450mm Tapered Headwalls	no	30	775.00	23,250
7.2.3	600mm Precast Headwalls	no	10	850.00	8,500
7.2.4	Rural Inlet Sumps	no	30	2000.00	60,000
7.2.5	Subsoil	m	6,000	35.00	210,000
7.2.6	Flushing eyes	no	60	500.00	30,000
				SubTotal	982,750
8	**Traffic services**				
8.1	Relocating Signage(incl. ERP's, AWS, Bridge Markers & Mailboxes)	no	50	200.00	10,000
8.2	Edge Marker Posts	no	300	25.00	7,500
8.3	New Linemarking	LS	1	20000.00	20,000
8.4	New RRPM's	no	300	25.00	7,500
				SubTotal	45,000
9	**Landscaping & Fencing**				
9.1	Temp Fence	m	20000	11.00	220,000
9.2	New P&W Fence	m	20000	18.00	360,000
9.3	Relocate Gates	no	30	375.00	11,250
9.4	Grassing	m^2	250,000	5.00	1,250,000
9.5	Hydroseeding	m^2	250,000	5.00	1,250,000
				SubTotal	3,091,250
10	**Relocation of Services**				
10.1	Powerpole relocation	PS	1	200000.00	200,000
10.2	Telecommunications Cable relocation	PS	1	200000.00	200,000
				SubTotal	400,000
10	**Miscelleneous**				
10.1	Contingency	PS	1	10000000.00	10,000,000
10.2	Land Acquisition	Ha	200	7500.00	1,500,000
				SubTotal	11,500,000
				PROJECT TOTAL	**117,628,250**

NZ TRANSPORT AGENCY
WAKA KOTAHI

__Gorge detour Options - Route Option D Tunnelling Option South of the existing gorge route (Red)__

-

ITEM	DESCRIPTION	UNIT	QNTY	RATE	AMOUNT
1	**PRELIMINARY AND GENERAL**				
1.1	Establishment and Removal of Site Set Out	LS	1	1000000.00	1,000,000
1.2	Quality Plan inc Operation	LS	1	10000.00	10,000
1.3	Health and Safety Plan inc Operation	LS	1	1250.00	1,250
1.4	Environmental Management	LS	1	2000000.00	2,000,000
1.5	As Built Diagrams and RAMM Updates	LS	1	20000.00	20,000
1.6	Public Liaison and Advertising	LS	1	500000.00	500,000
1.7	Survey Mark Relocation	LS	1	5000.00	5,000
				SubTotal	3,536,250
2	**Temporary Traffic Control**				
2.1	Preparation of Traffic Management Plan	LS	1	5000.00	5,000
2.2	Management of TMP	LS	1	500000.00	500,000
				SubTotal	505,000
3	**Tunneling**				
3.1	Construct 4 lane tunnel 5380m@300K per lm	m	5380	300000.00	1,614,000,000
				SubTotal	1,614,000,000
4	**PAVEMENT CONSTRUCTION**				
4.1	Sawcut Seal	m	50	2.50	125
4.2	Trim and Compact Formation	m^2	10,000	1.50	15,000
4.3	Import, Lay and Compact Sub Base @ 250mm	m^3	300	50.00	15,000
4.4	Import, Lay and Compact Base Course @150mm	m^3	500	90.00	45,000
				SubTotal	75,125
5	**BRIDGE**				
5.1	New bridge	m^2			
				SubTotal	
6	**SURFACING**				
6.1	Grade 3/5 Seal (Inc Accessways)	m^2	80,040	10.00	800,400
				SubTotal	800,400
7	**DRAINAGE**				
7.1	**Culverts**				
7.1.1	375mm RCRRJ Class 4 Pipe	m	500	175.00	87,500
7.1.3	600mm RCRRJ Class 4 Pipe	m	5,380	320.00	1,721,600
				SubTotal	1,809,100
8	**Traffic services**				
8.1	Relocating Signage(incl. ERP's, AWS, Bridge Markers & Mailboxes)	no	50	200.00	10,000
8.2	Edge Marker Posts	no	300	25.00	7,500
8.3	New Linemarking	LS	1	20000.00	20,000
8.4	New RRPM's	no	300	25.00	7,500
8.5	TL3 Cycle Lane Separation Barrier	m	13,340	300.00	4,002,000
9	**Landscaping & Fencing**			SubTotal	4,047,000
				SubTotal	
10	**Relocation of Services**				
10.1	Powerpole	LS			
10.2	Telecommunications Cable relocation	PS	1	200000.00	200,000
			1	200000.00	200,000
10	**Miscelleneous**			SubTotal	400,000
10.1	Contingency	PS	1	170000000.00	170,000,000
10.2	Land Acquisition	Ha	50	7500.00	375,000
				SubTotal	170,375,000
				PROJECT TOTAL	1,795,547,875

E.2 Saddle Road Upgrade Estimates

NZ TRANSPORT AGENCY
WAKA KOTAHI

Saddle Realignment A

-

ITEM	DESCRIPTION	UNIT	QNTY	RATE	AMOUNT
1	**PRELIMINARY AND GENERAL**				
1.1	Establishment and Removal of Site Set Out	LS	1	50000.00	50,000
1.2	Quality Plan inc Operation	LS	1	1250.00	1,250
1.3	Health and Safety Plan inc Operation	LS	1	1250.00	1,250
1.4	Environmental Management	LS	1	1250.00	1,250
1.5	As Built Diagrams and RAMM Updates	LS	1	5000.00	5,000
1.6	Public Liaison and Advertising	LS	1	500.00	500
1.7	Survey Mark Relocation	LS	1	3500.00	3,500
				SubTotal	62,750
2	**Temporary Traffic Control**				
2.1	Preparation of Traffic Management Plan	LS	1	750.00	750
2.2	Management of TMP	LS	1	5000.00	5,000
				SubTotal	5,750
3	**EARTHWORKS**				
3.1	Site Clearance (Including removal of all trees within extent of works)	LS	1	10000.00	10,000
3.2	Strip Topsoil (200mm), Stockpile and Respread as Directed	m^3	15,000	10.00	150,000
3.3	Cut to Fill	m^3	120,000	7.00	840,000
3.4	Cut to Waste onsite(Inc Unused Ex Topsoil)	m^3	44000	5.00	220,000
				SubTotal	1,220,000
4	**PAVEMENT CONSTRUCTION**				
4.1	Sawcut Seal	m		1.75	
4.2	Trim and Compact Formation	m^2	25,000	0.20	5,000
4.3	Import, Lay and Compact Sub Base @ 250mm	m^3	7,600	40.00	304,000
4.4	Import, Lay and Compact Base Course @150mm	m^3	4000	80.00	320,000
				SubTotal	629,000
5	**SURFACING**				
5.1	Grade 3/5 Seal (Inc Accessways)	m^2	25,000	5.00	125,000
				SubTotal	125,000
6	**DRAINAGE**				
6.1	**Culverts**				
6.1.1	375mm RCRRJ Class 4 Pipe	m	300	175.00	52,500
6.1.2	450mm RCRRJ Class 4 Pipe	m	100	270.00	27,000
6.1.3	600mm RCRRJ Class 4 Pipe	m	100	320.00	32,000
6.2	**Headwalls**				
6.2.1	375mm Tapered Headwalls	no	15	650.00	9,750
6.2.2	450mm Tapered Headwalls	no	10	775.00	7,750
6.2.3	600mm Precast Headwalls	no	2	850.00	1,700
6.3	Rural Inlet Sumps	no	11	2000.00	22,000
6.4	Subsoil	m	2,000	35.00	70,000
6.5	Flushing eyes	no	20	500.00	10,000
				SubTotal	232,700
7	**Traffic services**				
7.1	Relocating Signage(incl. ERP's, AWS, Bridge Markers & Mailboxes)	no	12	200.00	2,400
7.2	Edge Marker Posts	no	50	25.00	1,250
7.3	New Linemarking	LS	1	2000.00	2,000
7.4	New RRPM's	no	50	25.00	1,250
				SubTotal	6,900
8	**Landscaping & Fencing**				
8.1	Temp Fence	m	4600	11.00	50,600
8.2	New P&W Fence	m	4600	18.00	82,800
8.3	Relocate Gates	no	14	375.00	5,250
8.4	Grassing	m^2	50,000	0.65	32,500
8.5	Hydroseeding	m^2	20,000	1.00	20,000
				SubTotal	191,150
9	**Relocation of Services**				
9.1	Powerpole relocation	PS	1	3000.00	3,000
9.2	Telecommunications Cable relocation	PS	1	2000.00	2,000
9.3	Gas relocation	PS	1	15000.00	15,000
				SubTotal	20,000
10	**Miscellaneous**				
10.1	Contingency	PS	1	500000.00	500,000
10.2	Land Acquisition	Ha	7,500	11.00	82,500
				SubTotal	582,500
				PROJECT TOTAL	**3,075,750**

Saddle Realignment B

ITEM	DESCRIPTION	UNIT	QNTY	RATE	AMOUNT
1	**PRELIMINARY AND GENERAL**				
1.1	Establishment and Removal of Site Set Out	LS	1	20000.00	20,000
1.2	Quality Plan inc Operation	LS	1	1250.00	1,250
1.3	Health and Safety Plan inc Operation	LS	1	1250.00	1,250
1.4	Environmental Management	LS	1	1250.00	1,250
1.5	As Built Diagrams and RAMM Updates	LS	1	3000.00	3,000
1.6	Public Liaison and Advertising	LS	1	500.00	500
1.7	Survey Mark Relocation	LS	1	3500.00	3,500
				SubTotal	30,750
2	**Temporary Traffic Control**				
2.1	Preparation of Traffic Management Plan	LS	1	750.00	750
2.2	Management of TMP	LS	1	3000.00	3,000
				SubTotal	3,750
3	**EARTHWORKS**				
3.1	Site Clearance (Including removal of all trees within extent of works)	LS	1	5000.00	5,000
3.2	Strip Topsoil (200mm), Stockpile and Respread as Directed	m^3	3600	10.00	36,000
3.3	Cut to Fill	m^3	6500	8.00	52,000
3.4	Cut to Waste onsite (Inc Unused Ex Topsoil)	m^3	3500	6.00	21,000
				SubTotal	114,000
4	**PAVEMENT CONSTRUCTION**				
4.1	Sawcut Seal	m	0	1.75	0
4.2	Trim and Compact Formation	m^2	8,000	0.20	1,600
4.3	Import, Lay and Compact Sub Base @ 250mm	m^3	1,800	40.00	72,000
4.4	Import, Lay and Compact Base Course @150mm	m^3	1200	80.00	96,000
				SubTotal	169,600
5	**SURFACING**				
5.1	Grade 3/5 Seal (Inc Accessways)	m^2	8000	5.00	40,000
				SubTotal	40,000
6	**DRAINAGE**				
6.1	**Culverts**				
6.1.1	375mm RCRRJ Class 4 Pipe	m	0	175.00	0
6.1.2	450mm RCRRJ Class 4 Pipe	m	40	270.00	10,800
6.1.3	600mm RCRRJ Class 4 Pipe	m	0	320.00	0
6.2	**Headwalls**				0
6.2.1	375mm Tapered Headwalls	no	0	650.00	0
6.2.2	450mm Tapered Headwalls	no	8	775.00	6,200
6.2.3	600mm Precast Headwalls	no	0	850.00	0
6.3	Remove Existing Culverts	LS	0	2500.00	0
				SubTotal	17,000
7	**Traffic services**				
7.1	Relocating Signage(incl. ERP's, AWS, Bridge Markers & Mailboxes)	no	12	200.00	2,400
7.2	Edge Marker Posts	no	25	25.00	625
7.3	New Linemarking	LS	1	2000.00	2,000
7.4	New RRPM's	no	50	25.00	1,250
				SubTotal	6,275
8	**Landscaping & Fencing**				
8.1	Temp Fence	m	2000	11.00	22,000
8.2	New P&W Fence	m	2000	18.00	36,000
8.3	Relocate Gates	no	5	375.00	1,875
8.4	Grassing	m^2	20,000	0.65	13,000
				SubTotal	72,875
9	**Relocation of Services**				0
9.1	Powerpole relocation	PS	1	3000.00	3,000
9.2	Telecommunications Cable relocation	PS	1	15000.00	15,000
				SubTotal	18,000
10	**Miscelleneous**				
10.1	Contingency	PS	1	100000.00	100,000
10.2	Land Acquisition	Ha	7,500	0.10	750
				SubTotal	100,750
				PROJECT TOTAL	**573,000**

Saddle Realignment C

ITEM	DESCRIPTION	UNIT	QNTY	RATE	AMOUNT
1	**PRELIMINARY AND GENERAL**				
1.1	Establishment and Removal of Site Set Out	LS	1	25000.00	25,000
1.2	Quality Plan inc Operation	LS	1	1250.00	1,250
1.3	Health and Safety Plan inc Operation	LS	1	1250.00	1,250
1.4	Environmental Management	LS	1	1250.00	1,250
1.5	As Built Diagrams and RAMM Updates	LS	1	1650.00	1,650
1.6	Public Liaison and Advertising	LS	1	500.00	500
1.7	Survey Mark Relocation	LS	1	3500.00	3,500
				SubTotal	34,400
2	**Temporary Traffic Control**				
2.1	Preparation of Traffic Management Plan	LS	1	750.00	750
2.2	Management of TMP	LS	1	5000.00	5,000
				SubTotal	5,750
3	**EARTHWORKS**				
3.1	Site Clearance (Including removal of all trees within extent of works)	LS	1	5000.00	5,000
3.2	Strip Topsoil (200mm), Stockpile and Respread as Directed	m^3	5200	10.00	52,000
3.3	Cut to Fill	m^3	2000	9.00	18,000
3.4	Cut to Waste on site(Inc Unused Ex Topsoil)	m^3	20000	8.00	160,000
				SubTotal	235,000
4	**PAVEMENT CONSTRUCTION**				
4.1	Sawcut Seal	m	0	1.75	0
4.2	Trim and Compact Formation	m^2	13,000	0.20	2,600
4.3	Import, Lay and Compact Sub Base @ 250mm	m^3	2,600	40.00	104,000
4.4	Import, Lay and Compact Base Course @150mm	m^3	1900	80.00	152,000
				SubTotal	258,600
5	**SURFACING**				
5.1	Grade 3/5 Seal (Inc Accessways)	m^2	13000	5.00	65,000
				SubTotal	65,000
6	**DRAINAGE**				
6.1	**Culverts**				
6.1.1	375mm RCRRJ Class 4 Pipe	m	50	175.00	8,750
6.1.2	450mm RCRRJ Class 4 Pipe	m	0	270.00	0
6.1.3	600mm RCRRJ Class 4 Pipe	m	45	320.00	14,400
6.2	**Headwalls**				0
6.2.1	375mm Tapered Headwalls	no	50	650.00	32,500
6.2.2	450mm Tapered Headwalls	no	0	775.00	0
6.2.3	600mm Precast Headwalls	no	6	850.00	5,100
6.3	Remove Existing Culverts	LS	0	2500.00	0
				SubTotal	60,750
7	**Traffic services**				
7.1	Relocating Signage(incl. ERP's, AWS, Bridge Markers & Mailboxes)	no	12	200.00	2,400
7.2	Edge Marker Posts	no	25	25.00	625
7.3	New Linemarking	LS	1	2000.00	2,000
7.4	New RRPM's	no	50	25.00	1,250
				SubTotal	6,275
8	**Landscaping & Fencing**				
8.1	Temp Fence	m	1600	11.00	17,600
8.2	New P&W Fence	m	1600	18.00	28,800
8.3	Relocate Gates	no	5	375.00	1,875
8.4	Grassing	m^2	26,000	0.65	16,900
				SubTotal	65,175
9	**Relocation of Services**				0
9.1	Powerpole relocation	PS	1	3000.00	3,000
9.2	Telecommunications Cable relocation	PS	1	15000.00	15,000
				SubTotal	18,000
10	**Miscelleneous**				
10.1	Contingency	PS	1	150000.00	150,000
10.2	Land Acquisition	Ha	7,500	0.10	750
				SubTotal	150,750
				PROJECT TOTAL	**899,700**

Saddle Realignment D - Option 1

ITEM	DESCRIPTION	UNIT	QNTY	RATE	AMOUNT
1	**PRELIMINARY AND GENERAL**				
1.1	Establishment and Removal of Site Set Out	LS	1	25000.00	25,000
1.2	Quality Plan inc Operation	LS	1	1250.00	1,250
1.3	Health and Safety Plan inc Operation	LS	1	1250.00	1,250
1.4	Environmental Management	LS	1	1250.00	1,250
1.5	As Built Diagrams and RAMM Updates	LS	1	5000.00	5,000
1.6	Public Liaison and Advertising	LS	1	500.00	500
1.7	Survey Mark Relocation	LS	1	3500.00	3,500
				SubTotal	37,750
2	**Temporary Traffic Control**				
2.1	Preparation of Traffic Management Plan	LS	1	750.00	750
2.2	Management of TMP	LS	1	10000.00	10,000
				SubTotal	10,750
3	**EARTHWORKS**				
3.1	Site Clearance (Including removal of all trees within extent of works)	LS	1	50000.00	50,000
3.2	Strip Topsoil (200mm), Stockpile and Respread as Directed	m^3	7500	10.00	75,000
3.3	Cut to Fill	m^3	28000	9.00	252,000
3.4	Cut to Waste (Inc Unused Ex Topsoil)	m^3	50000	6.00	300,000
				SubTotal	677,000
4	**PAVEMENT CONSTRUCTION**				
4.1	Sawcut Seal	m	0	1.75	0
4.2	Trim and Compact Formation	m^2	16,000	0.20	3,200
4.3	Import, Lay and Compact Sub Base @ 250mm	m^3	4,600	40.00	184,000
4.4	Import, Lay and Compact Base Course @150mm	m^3	2700	80.00	216,000
				SubTotal	403,200
5	**SURFACING**				
5.1	Grade 3/5 Seal (Inc Accessways)	m^2	16000	5.00	80,000
				SubTotal	80,000
6	**DRAINAGE**				
6.1	**Culverts**				
6.1.1	375mm RCRRJ Class 4 Pipe	m	0	175.00	0
6.1.2	450mm RCRRJ Class 4 Pipe	m	100	270.00	27,000
6.1.3	600mm RCRRJ Class 4 Pipe	m	0	320.00	0
6.2	**Headwalls**				0
6.2.1	375mm Tapered Headwalls	no	0	650.00	0
6.2.2	450mm Tapered Headwalls	no	10	775.00	7,750
6.2.3	600mm Precast Headwalls	no	0	850.00	0
6.3	Remove Existing Culverts	LS	0	2500.00	0
6.3	Rural Inlet Sumps	no	2	2000.00	4,000
6.4	Subsoil	m	300	35.00	10,500
6.5	Flushing eyes	no	5	500.00	2,500
				SubTotal	51,750
7	**Traffic services**				
7.1	Relocating Signage(incl. ERP's, AWS, Bridge Markers & Mailboxes)	no	12	200.00	2,400
7.2	Edge Marker Posts	no	50	25.00	1,250
7.3	New Linemarking	LS	1	2000.00	2,000
7.4	New RRPM's	no	50	25.00	1,250
7.5	Water Valve Lid relevel	no	0	300.00	0
				SubTotal	6,900
8	**Landscaping & Fencing**				
8.1	Temp Fence	m	3200	11.00	35,200
8.2	New P&W Fence	m	3200	18.00	57,600
8.3	Relocate Gates	no	5	375.00	1,875
8.4	Grassing	m^2	32,000	0.65	20,800
				SubTotal	115,475
9	**Relocation of Services**				0
9.1	Powerpole relocation	PS	1	3000.00	3,000
9.2	Telecommunications Cable relocation	PS	1	15000.00	15,000
				SubTotal	18,000
10	**Miscelleneous**				
10.1	Contingency	PS	1	300000.00	300,000
10.2	Land Acquisition	Ha	7,500	3.40	25,500
				SubTotal	325,500
				PROJECT TOTAL	**1,726,325**

Saddle Realignment E

ITEM	DESCRIPTION	UNIT	QNTY	RATE	AMOUNT
1	**PRELIMINARY AND GENERAL**				
1.1	Establishment and Removal of Site Set Out	LS	1	25000.00	25,000
1.2	Quality Plan inc Operation	LS	1	1250.00	1,250
1.3	Health and Safety Plan inc Operation	LS	1	1250.00	1,250
1.4	Environmental Management	LS	1	1250.00	1,250
1.5	As Built Diagrams and RAMM Updates	LS	1	3000.00	3,000
1.6	Public Liaison and Advertising	LS	1	500.00	500
1.7	Survey Mark Relocation	LS	1	3500.00	3,500
				SubTotal	35,750
2	**Temporary Traffic Control**				
2.1	Preparation of Traffic Management Plan	LS	1	750.00	750
2.2	Management of TMP	LS	1	10000.00	10,000
				SubTotal	10,750
3	**EARTHWORKS**				
3.1	Site Clearance (Including removal of all trees within extent of works)	LS	1	10000.00	10,000
3.2	Strip Topsoil (200mm), Stockpile and Respread as Directed	m^3	3700	10.00	37,000
3.3	Cut to Fill	m^3	2000	9.00	18,000
3.4	Cut to Waste (Inc Unused Ex Topsoil)	m^3	37000	7.00	259,000
				SubTotal	324,000
4	**PAVEMENT CONSTRUCTION**				
4.1	Sawcut Seal	m	0	1.75	0
4.2	Trim and Compact Formation	m^2	10,000	0.20	2,000
4.3	Import, Lay and Compact Sub Base @ 250mm	m^3	3,200	40.00	128,000
4.4	Import, Lay and Compact Base Course @150mm	m^3	1600	80.00	128,000
				SubTotal	258,000
5	**SURFACING**				
5.1	Grade 3/5 Seal (Inc Accessways)	m^2	10000	5.00	50,000
				SubTotal	50,000
6	**DRAINAGE**				
6.1	**Culverts**				
6.1.1	375mm RCRRJ Class 4 Pipe	m	0	175.00	0
6.1.2	450mm RCRRJ Class 4 Pipe	m	100	270.00	27,000
6.1.3	600mm RCRRJ Class 4 Pipe	m	0	320.00	0
6.2	**Headwalls**				0
6.2.1	375mm Tapered Headwalls	no	0	650.00	0
6.2.2	450mm Tapered Headwalls	no	5	775.00	3,875
6.2.3	600mm Precast Headwalls	no	0	850.00	0
6.3	Rural Inlet Sumps	no	5	2000.00	10,000
6.4	Subsoil	m	800	35.00	28,000
6.5	Flushing eyes	no	8	500.00	4,000
				SubTotal	72,875
7	**Traffic services**				
7.1	Relocating Signage(incl. ERP's, AWS, Bridge Markers & Mailboxes)	no	12	200.00	2,400
7.2	Edge Marker Posts	no	50	25.00	1,250
7.3	New Linemarking	LS	1	2000.00	2,000
7.4	New RRPM's	no	50	25.00	1,250
7.5	Retaining Wall	m^2	100	800.00	80,000
				SubTotal	86,900
8	**Landscaping & Fencing**				
8.1	Temp Fence	m	2000	11.00	22,000
8.2	New P&W Fence	m	2000	18.00	36,000
8.3	Relocate Gates	no	5	375.00	1,875
8.4	Grassing	m^2	20,000	0.65	13,000
				SubTotal	72,875
9	**Relocation of Services**				0
9.1	Powerpole relocation	PS	1	10000.00	10,000
9.2	Telecommunications Cable relocation	PS	1	2000.00	2,000
				SubTotal	12,000
10	**Miscelleneous**				
10.1	Contingency	PS	1	200000.00	200,000
10.2	Land Acquisition	Ha	7,500	0.33	2,475
				SubTotal	202,475
				PROJECT TOTAL	**1,125,625**

Appendix F Economic Analysis

Manawatu Gorge Alternative Route: Traffic & Economics

1 Traffic and Economics Model (TEM)

1.1 Introduction

A spreadsheet traffic analysis model was created for the existing routes and assessed options. Given the complexity of the routing choices, the scope of the project and the likely differences between the options, some simplifications were needed to be made to facilitate comparison between the options. At the same time the traffic model was established to allow sensitivity testing and the potential testing of other options at a later date, including consideration of restricting some routes to certain vehicle classes.

To facilitate comparison between route, as a starting basis a common start and end point for each was established. Namely the intersection of SH3 with Cambridge Avenue, Ashhurst, and the intersection of SH3 with Woodlands and Troup Roads west of Woodville. Choosing the latter rather than the SH3 intersection with SH2 in Woodville or with Pinfold and Nelson Roads just east of Woodville simplified the traffic model need to consider different routing choices near Woodville and the effect of recent road improvements along Oxford Road. Furthermore from the limited information available it appears that this choice of the end reference point is consistent with route choices for traffic detouring from the closed Manawatu Gorge route via Saddle Road or Pahiatua Track. Subsequently the alternative routes via the Pahiatua Track were deemed to start from its intersection with SH57 by Aokautere, with modification to add the distance from this intersection to the SH3/57 or SH3/Cambridge Avenue intersection as appropriate to the option being considered.

Each route was split into five sections for economic evaluation purposes for which the length, average absolute grade (for both directions), assumed roughness and the estimated number of isolated speed change cycles were input. The assumed cost of each speed change was input based on the EEM values for Rural roads; a basic value of 25 cents per speed change was assumed in all cases. The average travel speed for each section was input for light, medium and heavy vehicles to take into account the road geometry and to facilitate taking into account the effect of passing lanes (and slow vehicle bays).

1.2 Average Speeds

To calibrate the traffic model the travel times along each route were obtained using the eRUCs (eROAD) database. It had been hoped to also derive information pertaining to the origin and destination of (heavy) vehicles using each route by a "select link analysis" procedure but this is still currently unavailable except for within the Wellington Transport Strategic Model area (that is basically Wellington Region).

For each of the three main routes, the travel times in each direction for each captured vehicle travelling along each section were obtained for one month during and before the Manawatu Gorge closure. Since the eRUCS system is still in its infancy (refer Beca paper presented at the NZMUGS 5th annual conference, 10-11 September 2012, Auckland) a generic analysis spreadsheet was developed. This included the ability to graph the travel times and filter out those presumed to be abnormally slow (short stop along the way). The average section speeds were used as the basis for the input medium and heavy vehicle speeds, while the average plus the standard deviation of speeds was used as the basis for the input light vehicle speeds.

1.3 Economic parameters

The value of time for each EEM class was derived from creating a table based on the occupancy values in EEM Table A2.4, the values of time in Table A4.1 and the vehicle and freight values given in Table A4.2. A check was made using the default traffic composition values in Table A2.3, that the default composite values of time given in Table A4.3 (due to a typing error might it was labelled as A4.1) were reproduced.

The vehicle running costs by speed and gradient were derived for each EEM class using the formulae given in Table A5.11. Unfortunately the EEM does not distinguish between uphill and downhill grades for which the assumed speeds are often different. This partly influenced our economic analysis being based on both directions, although from inspection of the eRUC speeds and the road geometry of the options, the impact of having to undertake a two-way analysis is considered acceptable.

Since it is apparent that the closure of the Manawatu Gorge has had a big impact on the "soundness" of the Saddle Road route road surface and pavement, and since options involved new routes that would likely to be high quality, the additional VOC due to roughness was also included. This used the equation and coefficient values given in Table A5.15 for rural roads. However, in checking the results against the values in Table A5.17 it was evident that there was a mistake in the EEM for Passenger Cars; after some lengthy investigation a typing error was identified for coefficient c, namely -224.6 should be -1224.6. Assumptions were then made about the average NAASRA / IRI for each route-section from which the additional roughness costs were derived.

In terms of other additional costs, it was assumed that the volume to capacity ratio for each section was sufficiently low that there would be no congestion related travel time or vehicle operating costs for any of the options or existing routes, including the Saddle Road route when the Manawatu Gorge is closed.

1.4 Traffic flows.

The table below summaries the flows provided by Tararua District Council

Road	Disp	Survey Period (1 week counts)	Gorge Closed	Gorge Open (June 2012)	Comment
Saddle Road	804	7/9/11-23/12/11, 20/1/12-25/5/12	4300 [375]	Diff=2760 [285]	
		1/6/12-22/6/12		1540 [90]	Higher than expected
Oxford Road	2400	14/9/11-9/12/11, 20/1/12-25/5/12	1490 [35]	Diff=750 [20]	
		1/6/12-29/6/12		740 [20]	
Woodlands Rd	1669	14/9/11-9/11/11, 3/2/12-25/5/12	2825 [370]	Diff=1880 [255]	
		1/6/12-29/6/12		945 [115]	
Pinfold Rd	2044	14/9/11-9/12/12	890 [35]		Chicanes installed at Oxford during survey
Pahiatua Track	30	16/9/11-23/12/11, 20/1/12-25/5/12	3140 [180]	Diff=1195 [80]	
		8/6/12-29/6/12		1945 [95]	Higher than expected
Ballance Valley Rd	350	3/2/12-25/5/12	675 [40]	Diff=415 [30]	
		1/6/12-29/6/12		260 [10]	
Nikau Road	130	7/10/11-23/12/11, 20/1/12-25/5/12	1085 [75]	Diff=240 [30]	
		1/6/12-22/6/12		845 [45]	
Manawatu Gorge		16/9/10-20/12/10, 20/1/11-25/5/11	6935 [570] (MCV=285)		The year before.
		1/6/12-29/6/12		3515 [465]	Lower than expected

Flows are given to the nearest 5 vpd. Flows in [] are heavy commercial vehicles.
The Manawatu Gorge values from NZTA's TMS .

These purport to show that 2760 vehicles detour via Saddle Road and nearly 1200 via Pahiatua Track when the Gorge was closed for almost nine months. However during June 2012 when the Gorge was reopened, it was not to its former state so that there was an average of 3515 vpd , approximately 3400-3450 vpd lower than previous traffic flows through the Gorge. Adding this to the approximately 3950 vph detoured to Saddle Road or the Pahiatua Track gives a total of 7350-7400 vpd, greater than expected.

The NZTA released a two page summary of their summary of the gorge closure based on 2011 data. The table below reproduces the figures from the 1 March 2012 summary.

Road	Survey Period (1 week counts)	Before Gorge Closed	Gorge closed	Comment
SH2 Rimutaka between Upper Hutt & Wairarapa	Jan'11 to Aug'11	5685 [345]	Diff=+355 [+20]	1/1-24/7, 27/7-13/8
	Aug'11 to Dec'11		6040 [365]	12/10-31/12 (msg data)
SH2 Norsewood, between Masterton & Carterton	Jan'11 to Aug'11	3850 [610]	Diff=-5 [-15]	
	Aug'11 to Dec'11		3845 [595]	
SH2 Clareville, between Masterton & Carterton	Jan'11 to Aug'11	10440 [565]	Diff=+600 [+45]	
	Aug'11 to Dec'11		11040 [610]	
SH3 Manawatu Gorge Ashhurst – Woodville	Jan'11 to Aug'11	6915 [800]	Diff=-6915 [-800]	1/1-18/8 average ADT is 6770 [800] not 6915.
	Aug'11 to Dec'11		0 [0]	
TDC Saddle Road Ashhurst – Woodville		315 [5]	Diff=-+4035 [+380]	TDC values in RAMM average about 140 vpd
	7/9/11 to 23/12/11, 20/1/12 25/5/12		4350 [385]	8.8% HV
	NZTA adjusted		4650 [575]	Diff=4335 [570]
TDC Pahiatua Track Aokautere – Pahiatua		1290 [45]	Diff=-+1825 [+115]	
	16/9/11 to 25/5/12		3113 [160]	
	NZTA adjusted		3275 [240]	Diff=1985 [195]

Flows are reproduced to the nearest 5 vpd. Flows in [] are stated as being heavy vehicles.
The NZTA adjusted "after slip" (gorge closed) flows were based on distributing the mis-close error (-462 vd) by the observed distribution split (62% Saddle Road, 29% Pahiatua Track and 9% [600 vpd] via SH2 Wairarapa.
The SH2 Rimutaka flows have been derived by MWH from the TMS values as a cross-check.

Of the traffic detouring using the Pahiatua Track, from the increase in traffic on Nikau Road about 20% head south of Pahiatua and naturally would not pass through Norsewood. About 35% head north via Balance Valley Road and presumably pass through Woodville. This leaves 45% presumably travelling through Pahiatua and to where afterwards is not known from the available data.

Of the traffic detouring using Saddle Road, from the increase in traffic on Oxford Road about 27% head east potentially skirting around Woodville. About 68% travel along Woodlands Road to SH3 and either head east to pass through Woodville or potentially head south via Troup Road. Note that the NZTA figure of 315 vpd along Saddle Road before the gorge closed differs from the TDC values in their RAMM database of about 140 vpd. Furthermore the actual average of the 1/1/2011 to 18/8/2011 ADTs for Manawatu Gorge (excluding 13/7 which had missing data for the w/b direction in the evening) was 6770 and not 6915/6 as stated by NZTA. Taking these errors into account explains 320 vpd of the NZTA derived 460 vpd mis-close.

A further issues is that the heavy vehicle figures for the NZTA telemetry sites includes medium commercial vehicles (MCV equated as 50% of the 5.5-11m vehicle length bin), whereas re-processing of the TDC MetroCount files reveals that the published TDC values exclude MCVs, that is they comprise only heavy commercial vehicles (HCV).

To better compare the NZTA telemetry sites, the same five month (150 days) period was chosen for the before and during gorge closure (re-opened for a period from 31 May 2012). The results are tabulated below.

These results differ from those presented by NZTA and their interpretation of 600 vehicle trips (45 heavy vehicle trips) being diverted from SH3 Manawatu Gorge to being via SH2. In addition since the provided TDC summary data excluded the amount of MCV, we reprocessed many of the March 2012 MetroCount classified data to obtain the percentage of MCV, as well as the split of the HCV data into HCV1 and HCV2.

Road	Survey Period (1 week counts)	Before Gorge Closed	Gorge closed	Comment
SH2 Norsewood, between Masterton & Carterton	1/1/-17/3; 19/3-12/5, 16/5-31/5/12	4100 [665]	Diff=-110 [-70]	Decrease -2.7%
	1/1/-15/3; 17/3-10/5, 14/5-30/5/12		3990 [595]	147 days

SH2 Clareville, between Masterton & Carterton	1/1/11 to 31/5/11	10735 [615]	Diff=+130 [+ 5]	Increase +1.2% consistent with annual traffic growth?
	1/1/12 to 30/5/12		10865 [620]	151 days
SH2 Rimutaka between Upper Hutt & Wairarapa	1/1/11 to 12/2/11 16/2/11 to 15/3/11	6395 [390]	Diff=-30 [-10]	Average over 71 days Minimal 0.5% decrease
	1/1/12 to 12/2/12 16/2 to 14/3/12		6365 [380]	Mid-Mar to end April missing; leap year

Flows are reproduced to the nearest 5 vpd. Flows in [] are heavy commercial vehicles (HCV1+HCV2).

Having considered the available traffic data and endeavouring to achieve an acceptablebalance, the following assumptions were made.

Route	Gorge open			Gorge closed			Difference (vpd)		
	All	MCV	HCV	All	MCV	HCV	All	MCV	HCV
Manawatu Gorge	6935	285	570	0	0	0	-6935	-285	-570
Saddle Road via Oxford (Pinfold)	50	5	5	1600	35	40	+1550	30	+ 35
Saddle Road via Woodlands Rd	100	10	40	3050	205	400	+2950	195	+360
Saddle Road via other	0	0	0	0	0	0	0	0	0
Pahiatua Track via BV & Gorge Rds	75	(0)	15	715	20	45	+640	20	+ 30
Pahiatua Track via Nikau Rd	845	20	45	1145	35	85	+300	15	+ 40
Pahiatua Track via Pahiatua / other	400	10	20	1450	35	80	+1050	25	+ 60
SH2 via Rimutakas & Clareville							0	0	0
Previous vehicle trips no longer made							445	0	45
SUM of differences							0	0	0

For modelling purposes the Saddle Road traffic was all modelled as via Woodlands Road given that all traffic was assumed to be heading east to the Hawke's Bay for comparison purposes and modeling the route through/around Woodville is considered both unnecessary without better information and beyond the intended project scope. Similarly the traffic along Pahiatua Track via Balance Valley Road and that not via Nikau Road was assumed to be heading east to the Hawkes Bay via Balance Valley Road and Gorge Road.

Traffic detoured to Nikau Road has been ignored in the traffic model as has that purportedly detouring via the Rimutakas (presumably having an origin or destination in the Wellington metropolitan area).

It is recognised that this leaves an "imbalance" but given that the options essentially provide a link between Ashhurst and Woodville rather than Aokautere and Pahiatua, it is considered that the model provides a fit for the purpose comparison, and with an ability to undertake sensitivity testing.

2 Economic Evaluation

Economic evaluation was undertaken using NZTA's Economic Evaluation Manual (EEM), Volume 1, July 2010.

The base year for costs is September 2012 and Time zero is July 2013. The standard 8 percent discount rate has been applied. The update values given for September 2010 were applied (latest yet to be released).

Initially the construction for all options was assumed to occur from July 2015 and last for three years, with a small amount of the projects costs (e.g. land purchase) assumed to be incurred in year 1 with the remainder equally divided over the construction period. Benefits were thus assumed to accrue from July 2018 for the next 27 years. This scenario in essence assumed fast tracking of the consenting process and fast construction.

Subsequently different pre-contruction and construction periods were adopted for each option, and with designs costs (set at 6% of construction costs) attributed to the first two years and consenting costs attributed to the remaining pre-construction period. The EEM defined 30 year analysis period was still assumed to coincide with the start of construction.

A base level of traffic growth of 1.5 percent per annum has been applied for all vehicles. This is the less than the EEM default value for Rural Strategic highways in the Manawatu – Wanganui region of 2.0 percent but is consistent with the historical growth for the SH3 Manawatu Gorge continuous telemetry site (albeit possibly slightly high).

The adopted time zero AADT for the Manawatu Gorge was 6935, which is lower than the predicted AADT for 2013 based on the 1992 to 2010 AADTs, but is more consistent with recent AADTs (refer Apppendix F)

2.1 Benefits: Travel Time and Vehicle Operating Costs

As before the modelling is being undertaken on a daily basis. Examination of the eRUC speeds reveals generally only minor variation with the average speed for each section for different time periods.

The travel time benefits are based on the assumed average speeds for each section by EEM vehicle class and the all period value of time for each vehicle class. The latter were initially derived based on the rural values but subsequently amended to the urban values for the Saddle Road traffic passing through Ashhurst, although arguably the same rural values for the Saddle Road traffic should be applied.

The running cost component of the vehicle operating costs (VOC) are based on the assumed grade for each section and the assumed speed for each vehicle class. These are independent of the road category.

The additional roughness costs component of VOC have been incorporated but the existing average roughness for each section has been set using arbitrary selective values[1]. For the options the assumed roughness has been set as about 60 NAASRA counts (IRI 2.5, for which EEM computes no additional roughness).

While their contribution to the overall VOC costs was initially found to be comparatively low, the additional speed change cost component of VOC were included in the model. They were derived by inputting the manual number of "isolated" sharp bends and an arbitrary cost for passenger cars based on the EEM Table A5.41. As the computation of speed change costs varies for a host of different approach and curve speeds and no forumale are provided in the EEM, these were factored for the other EEM vehicle classes using global multipliers, derived by inspection from Tables A5.27, A5.29, A5.31 and A5.33.

2.2 CO2 costs

The CO_2 costs were taken as a fixed 4.0 % of the total VOC (running costs, roughness, and speed change).

2.3 Benefits: Accident Costs

From NZTA's Crash Analysis System (CAS) the history of reported crashes in the ten years prior to the September 2011 to August 2012 closure of the Manawatu Gorge was obtained.

Section	RP	Site Ref	1 July 2001	to	30 Jun 2006	1 July 2006	to	30 Jun 2011	7/07-6/11	Comments
			F+S	Minor	Non	F+S	Minor	Non	DSI	
SH3/Cambridge Ave	474/13.45	33	0	0	2	0	0	1	0	
SH3/Cambridge-SH3/57	474/13.48-474/14.80	37	1F,1S	2	3	0	0	5	0	(Fatal 28/4/2003)
SH3/57	474/14.84	573	1S	1	4	1S	1	1	2	
SH3/57-Car Park	488/0.03-488/0.90	351	0	0	3	0	1	2	0	
SH3 Car Park – Gorge	488/0.90-	352	1F,2S	7	32	1F,6S	14	27	7	Fatal 24/3/2010

---

[1] For example, NAASRA values 78, 105, 131 and 184 used (respective IRI values of 3,4,5,7).

Section	RP	Site Ref	1 July 2001	to	30 Jun 2006	1 July 2006	to	30 Jun 2011	7/07-6/11	Comments
Bridge	491/4.00									(and 7/4/2003)
SH3 Bridge – Gorge Rd	491/4.00-491/4.67	354	0	0	4	0	0	3	0	
SH3/Gorge Rd	491/4.70	355	0	1	2	0	1	0	0	
SH3/Gorge – SH3/Woodlands Rd	491/4.73-491/7.65	356	2F	9	10	2S	2	14	2	(Fatal 9/6/2003 and 21/12/2001)
SH3/Woodlands Rd	491/7.68	358	0	0	0	0	0	1	0	
SH57: Pahiatua Aokautere Road	50/3.51	575	0	1	3	0	0	1	0	
SH57: Pahiatua Aokautere to SH3/57	50/3.54-50/14.67	577	1S	10	16	1F,2S	5	18	3	Fatal 6/8/2006 single veh LOC
Cambridge, Mulgrave & Salisbury, Ashhurst		111-115	0	0	4	0	3	1	0	
Saddle Road		11	0	3	6	2S	2	5	2	
Oxford Rd: Saddle Rd – Woodlands Road			0	0	0	0	0	0	0	
Woodlands Rd: SH3-Oxford Rd/Saddle Rd		151	0	0	1	1S	0	1	1	Serious LOC single veh ax
Pahiatua Aokautere Rd: & Pahiatua Track		557	5S	12	37	1F,6S	7	23	8	Fatal 9/6/2008 single veh LOC
MakoMako Rd: Ballance Valley – Ballance Gorge		555	1S	5	15	1F,3S	6	14	11	3 ax had multiple severe injuries
Pahiatua Mangahau Rd: BV – Mangatainoka Br		552	0	3	9	1S	4	9	1	
Ballance Gorge Rd		554	0	2	1	2S	0	2	2	
Gorge Rd: BV-SH3		553	1S	0	0	0	1	1	0	
Tararua Road		556	0	1	0	0	0	0	0	

Crashes at intersections include those along the highway within 30 metres. DSi=Deaths & Serious casualties.

Examination of the table reveals that most severe crashes from 1 July 2007 to 30 June 2011 resulted in only DSi (Death or Seriously injured) casualty. There were two people seriously injured in the serious injury crash at the SH3/57 intersection and also for one of the serious injury crashes along Pahiatua Aokautere Road. For the same five year period, the greatest number of multiple severe injuries occurred for the severe crashes along MakoMako Road, with one death and ten seriously injured casualties for the four severe crashes.

From the SH 57 intersection to Woodlands Road, for the latest five year period there were 1 fatal, 8 serious, 18 minor and 46 non-injury crashes along this 10.4 km of SH3 through the Manawatu Gorge. Applying an average of 6800 vehicles per day (vpd) results in a reported 10.7 injury crashes per 100 million vehicle kilometres; the severe crash rate is one third of this or 3.6 fatal or serious injury crashes per 100 million vehicle kilometres. These crash rates are comparatively low for a rural two lane highway.

From the outskirts of Ashhurst to its intersection with Woodlands Road and Oxford Street, along the approximately 10.9 km length of Saddle Road (including 0.65 km of Oxford Road) in the past ten years there were 0 fatal, 2 serious, 5 minor and 11 non-injury crashes reported. Adopting an average 140 vehicles per day results in a reported 126 injury crashes per 100 million vehicle kilometres; the severe crash rate is 36 fatal or serious injury crashes per 100 million vehicle kilometres. These crash rates appear to be high. By comparison assuming an average of 250 vpd, the injury crash rate for the 1.8 km section of Woodlands Road between Oxford Rd and SH3 is approximately 60 injury crashes per 100 million vehicle kilometres, but this is based on only one (serious) injury crash in ten years.

The current annual cost of crashes for each route was derived and divided by the annual vehicle kilometres of travel to get the normalised crash cost. For the existing routes these were (per million veh-km):

SH3 route: west end	$ 70,900
SH3 route: gorge	$ 187,300
SH3 route: east end	$ 141,800
Saddle Road west end	$3,361,700
Saddle Road hilly portion	$1,365,600
Oxford Rd & Woodlands Rd	$1,660,600
Pahiatua Track north route	$ 644,800
Pahiatua Track east route	$ 383,400

These reveal as would be expected, that the SH3 route is the safest, followed by the Pahiatua Track route(s) and the Saddle Road route. Therefore transference of traffic from SH3 onto the other existing routes would result in increased road safety costs.

For the options being considered, the assumed equivalent road safety costs for the options were:

Greenfields route	$ 250,000
Bridge route: bridging sections	$ 100,000
Tunnel route: tunnel section	$ 50,000
Worley option C	$ 400,000
Saddle Road west of summit	$1,000,000
Saddle Road east of summit	$1,100,000

For small increases in traffic on a route the change in accident costs is likely to be proportional to the change in traffic flows, given that no fundamental network changes occur.

However closure of the gorge results in some substantial increase in traffic, amounting to an increase in typical flows over Saddle Road of 31 times the existing situation. Instead of assuming a 3000 percent increase in the accident rate, the accident multiplier used was the traffic growth multiplier raised to a constant. An arbitrary exponent of 0.60 was applied that resulted in the Saddle Road accidents being 25% of the directly proportionate accident costs; the respective values for the Pahiatua northern and eastern routes were 41% and 60%.

The outcome of the accident analysis procedure was that for the closure of the gorge without any upgrade options, the accident disbenefits from traffic being detoured to less safe existing routes were approximately 26½ % of the total disbenefits (36 % travel time, 37 % VOC + CO_2).

The model allows for the effect of varying the accident assumptions to be easily quantified. For example, changing the assumed unit accident cost for the Saddle Road realignments option can result in a large overall effect, illustrating that the overall benefit is particularly sensitive to the assumption regarding the safety of the option alignments.

3 Costs

3.1 Project costs

The undiscounted construction cost estimates ($000) for the options are provided in the table below. The investigation, consenting process and design costs are not included.

OPTION	Property Purchase	MSQA & Construct	Contingency (%MSQA+Cons)	Other costs	TOTAL $ million	Length (km)	$ million per km
SADDLE ROAD							
realignment A1	83	2,439	500 (20.1%)	-	**3.08**	2.60	1.2
realignment B	1	472	100 (21.2%)	-	**0.57**	0.90	0.6
realignment C	1	749	150 (20.0%)	-	**0.90**	1.29	0.7
realignment D1	26	1,401	300 (21.4%)	-	**1.73**	2.02	0.9
realignment E1	2	923	200 (21.7%)	-	**1.13**	0.88	1.3
					7.40	7.69	
SADDLE 1 (A1+E1)					**4.20**	3.48	1.2
GREENFIELDS	495	279,432	2,000 (0.7%)	5,000	**309.0**	5.70	54.2
BRIDGING	0	262,470	10,000 (3.8%)	0	**412.9**	6.00	69.9
TUNNEL	375	1,778,433	100,000 (5.6%)	0	**1,795.6**	5.38	333.8
WORLEY option C	1,500	62,124	10,000 (16.1%)	44,000	**117.6**	10.0	11.8

Other costs include relocation of wind turbines. The extra $2.49 million of rehabilitation etc for Saddle Road is excluded.

Note that while a Pahiatua Track upgrade option(s) is not considered, PNCC and TDC are planning some minor upgrades to the route, noting that these are unlikely to significantly affect driver's route choice.

The assumed base construction period for each option is 3.5, 4.0, 6.0, and 5.5 years for the Greenfields, Bridging, Tunnel and Worley option C respectively (with base pre-construction period of 4.0 years for each). The Saddle Road realignment (and rehabilitation) option has an assumed 4.5 year construction (and 3.0 years pre-construction) period.

3.2 Design and consenting costs

At this preliminiary stage, design costs have been set as 6% of the construction costs given above. It has been assumed design will be undertaken in the first two years.

Consenting costs (including Scheme Appraisal Report) have been arbitrarily set as two million dollars for the alternative routes, and nominally 0.15 million dollars for the Saddle Road realignment option.

3.3 Maintenance Costs

The consideration of maintenance costs is complex.

During closure of the Manawatu Gorge and since its re-opening there has been considerable expenditure on the Saddle Road due to the effect of the detoured traffic. For example, heavy vehicles are unable to keep to the existing narrow sealed carriageway around many of the tight bends, which has necessitated pavement and drainage repair and local widening. The several million dollars spent to date has been treated as a sunk cost.

An allowance of approximately $840,000 for patching of Saddle Road has been attributed to the committed cost of maintaining the existing study area network.

For the Saddle Road realignment option, additional maintenance costs for the non-realigned sections of approximately $2.01, $0.68 and $0.55 million for rehabilitation, widening and drainage respectively (total of $3.24 million) has been attributed to the third and fourth years of construction.

Maintenance costs for the other far more expensive options have been ignored as have the maintenance costs for the Manawatu Gorge, recognising that these options result in closure of the Gorge route.

3.4 Manawatu Gorge slip closure costs

The probability of the Gorge being closed to a slip has been assumed as follows:

Medium slip:	Closed for one to two weeks	once every three to five years
Large slip:	Closed for two to three months	once every five years

The cost of reinstatement of a medium and large slip has been set as $0.8 and $4.0 million respectively while the detour disbenefits (excluding any additional maintenance costs) have been estimated as $74,500 per day.

In addition for the Greenfields option the same slip probabilities were assumed, and 75% of the above reinstatement costs, and the closure for a large slip lowered from 75 to 60 days. For simplicity the same detour disbenefits were assumed.

3.5 Benefit Cost Ratio (BCR)

The indicative benefit cost ratio for the options involving permanent closure of the Manawatu Gorge are tabulated below. These include the probabilistic risk assessment of the Gorge closure slip costs.

OPTION (Gorge is closed)	TTC benefits	VOC+CO_2 benefits	Accident benefits	Total benefits	Rough net costs	BCR	Comment
GREENFIELDS	121.6	108.9	71.4	301.8	**222.3**	1.4	Significant risk of slips
BRIDGING	95.2	101.3	77.1	273.6	**296.0**	0.9	Significant risk of slips
TUNNEL	102.8	95.5	77.1	275.4	**1191.7**	0.2	
WORLEY option C	75.4	54.6	-23.7	106.3	**69.1**	1.5	
SADDLE ROAD 1 (realign sections A&E)	30.5	34.5	-235.3	-170.4	**4.6**	<0	Highly sensitive to certain assumptions – see below

This shows that there appears to be little merit in the Saddle Road realignments upgrade option as far as being a suitable alternative for the permanent closure of the Manawatu Gorge.

For the other bypass options the Worleys option C has a higher BCR than the Greenfields and tunnel options and the Worley option C is significantly cheaper.

For the Saddle Road realignments in terms of the Manawatu Gorge route staying open, the benefits to the existing Saddle Road traffic from the realignments (to sections A and E) are given in the table below.

OPTION (Gorge is open)	TTC benefits	VOC+CO_2 benefits	Accident benefits	Total benefits	Net costs	BCR	Comment
SADDLE ROAD 1	1.0	1.1	1.5	3.6	**4.6**	0.8	Minimal reduction in travel time assumed for realignment E section

This indicates that there is little merit in undertaking the section A and E realignments of Saddle Road with further rehabilitation of the non-realigned sections, although the latter would also be beneficial for any traffic diverting as a result of further temporary closures of the Manawatu Gorge.

3.6 Sensitivity Analysis

Using the advantage of the developed model and analysis procedure to facilitate changing the values of assumptions, selective sensitivity testing was undertaken. Note that some changes affect only the Saddle Road realignments option.

OPTION (Gorge is closed)	TTC benefits	VOC+CO_2 benefits	Accident benefits	Total benefits	Rough net costs	BCR	Comment
GREENFIELDS	156.5	140.2	94.1	390.8	**222.4**	1.8	Fast tracking the project timing to 2 years pre-construction and 2 years construction
WORLEY option C	110.5	80.1	-36.1	154.5	**69.1**	2.2	
GREENFIELDS	121.6	126.7	71.4	319.7	**222.3**	1.4	Increasing roughness costs for existing Man Gorge and Saddle Rd from 5 to 7 IRI
WORLEY option C	75.4	70.3	-23.7	122.0	**69.1**	1.8	
BRIDGING	132.0	140.4	106.1	378.5	**325.3**	1.2	Reduce the discount rate from 8% to 6%
BRIDGING	95.2	101.3	71.5	268.0	**296.0**	0.9	Increase ax unit rate from 150,000 to 200,000
TUNNEL	129.1	119.9	99.3	348.4	**1332.2**	0.3	Construction completed 3½ years earlier
WORLEY option C	59.4	43.1	-17.9	84.6	**69.1**	1.2	Reduce traffic growth from 1.5% to 0% p.a.
WORLEY option C	69.2	56.5	-23.7	101.9	**69.1**	1.5	Reduce option average LV speed by 10 km/h
WORLEY option C	75.4	60.4	-23.7	112.1	**69.1**	1.6	Reduce option average grade by 1 percent
SADDLE ROAD 1	30.5	34.5	-216.5	-151.5	**4.6**	<0	Reducing the accident unit rate by $100,000

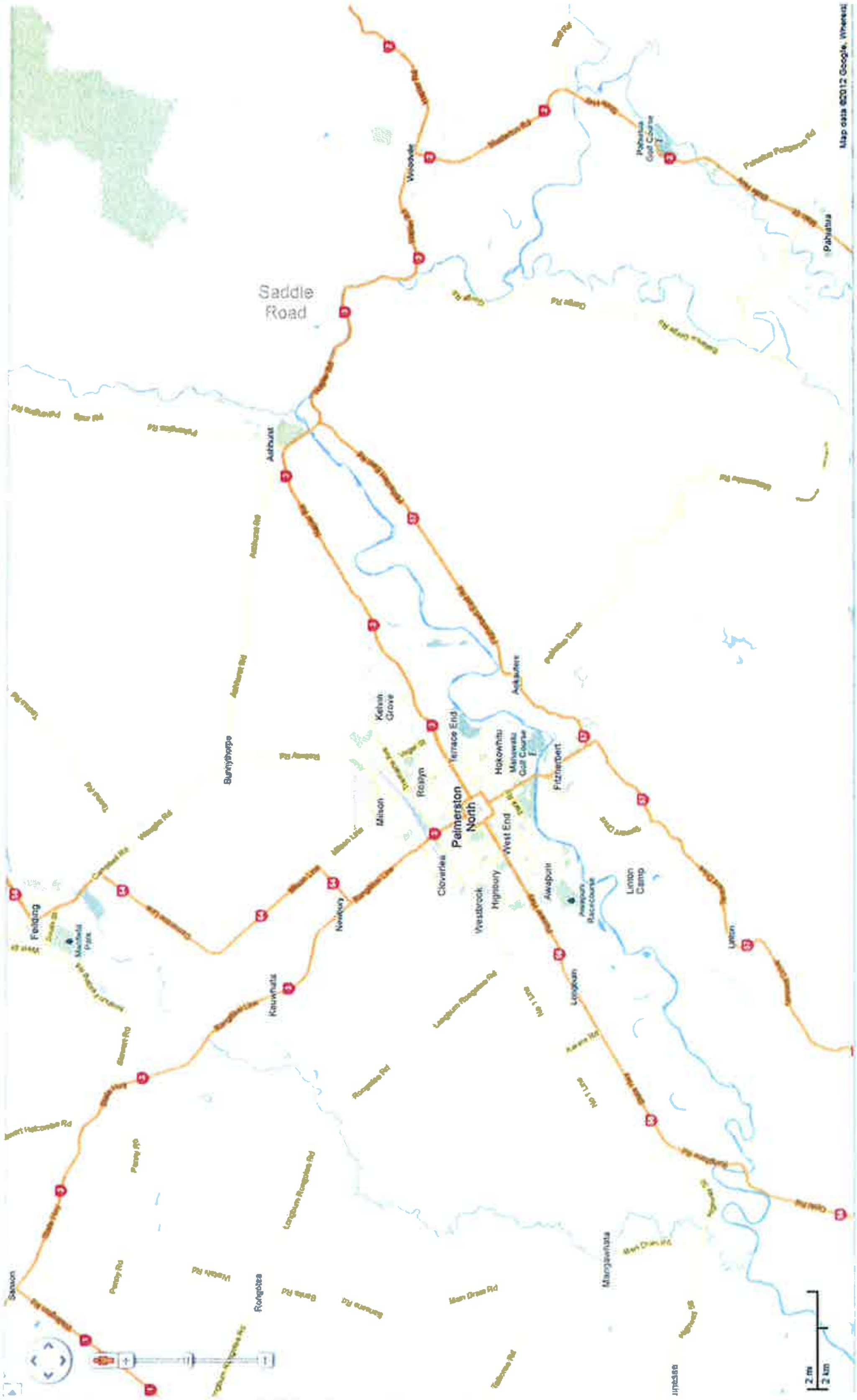
These results indicate that since the benefits can change by over $5 million and as much as $20 million. The effect is not significant for the bypass options and also not for the Saddle Road option since the overall benefits remain negative. The BCR for the Worley option C generally remains between 1½ and 2.

OPTION (Gorge is open)	TTC benefits	VOC+CO_2 benefits	Accident benefits	Total benefits	Net costs	BCR	Comment
SADDLE ROAD 1	1.0	1.9	1.5	4.4	**4.6**	1.0	Increasing roughness costs for existing Man. Gorge and Saddle Rd from 5 to 7 IRI
SADDLE ROAD 1	1.0	1.1	1.9	4.0	**4.6**	0.9	Reducing the accident unit rate by $100,000
SADDLE ROAD 1	1.7	2.1	2.8	6.6	**4.6**	1.4	Increasing the diversion from Pahiatua Track north from 0% to 20 %
SADDLE ROAD 1	1.3	1.4	2.0	4.6	**4.6**	1.0	Fast tracking the project timing to 2 + 2 years

The sensitivity testing for the benefits of the Saddle Road realignments for existing traffic reveals that the BCR is still at or just below 1.0 except for the unlikely case of the upgrade attracting some traffic from the Pahiatua Track route in which case it might exceed 1.

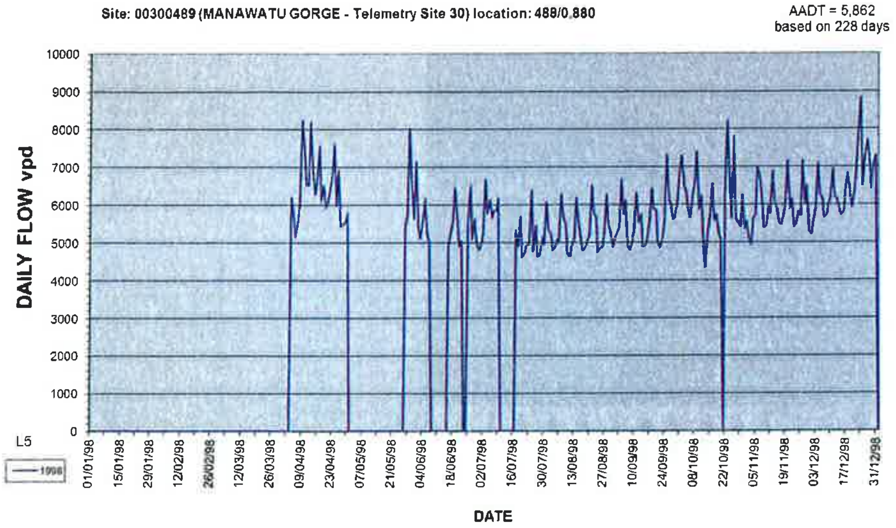
APPENDICES

APPENDIX A: Region Location Map

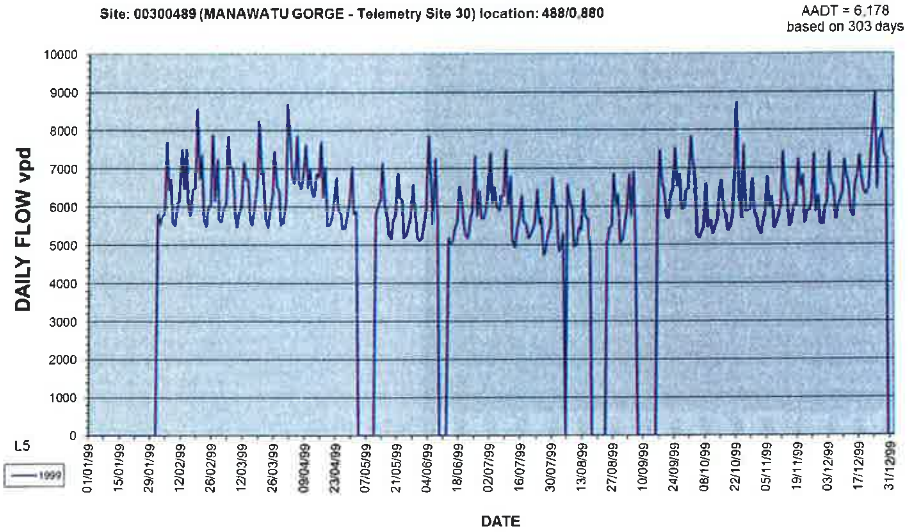


Refer to Appendices J and K for the option routes

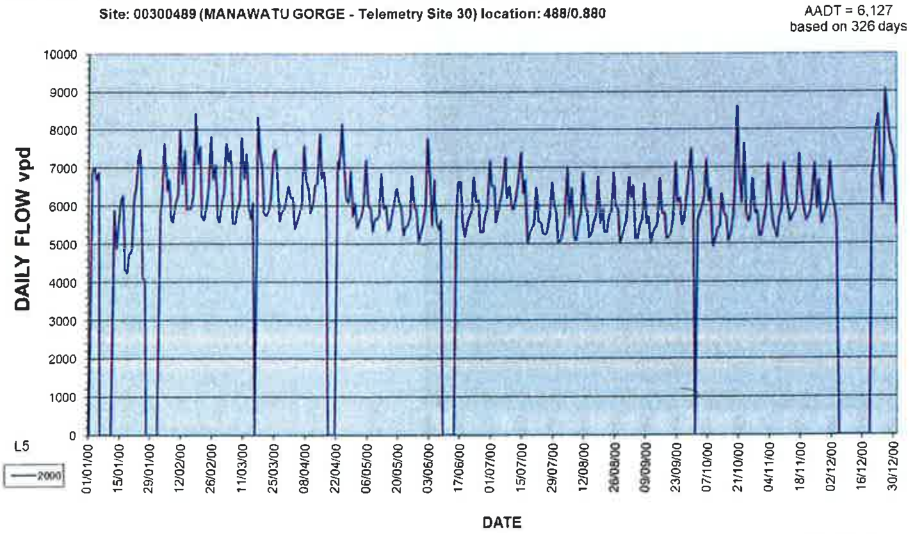
APPENDIX B: Manawatu Gorge daily flows: 1998 to 2011



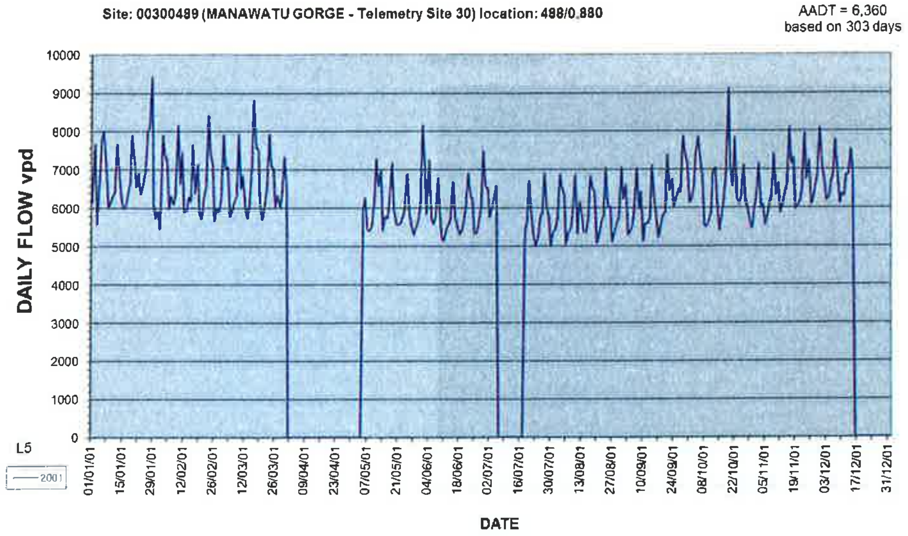
Hourly flow data. No earlier data stored in public TMS.



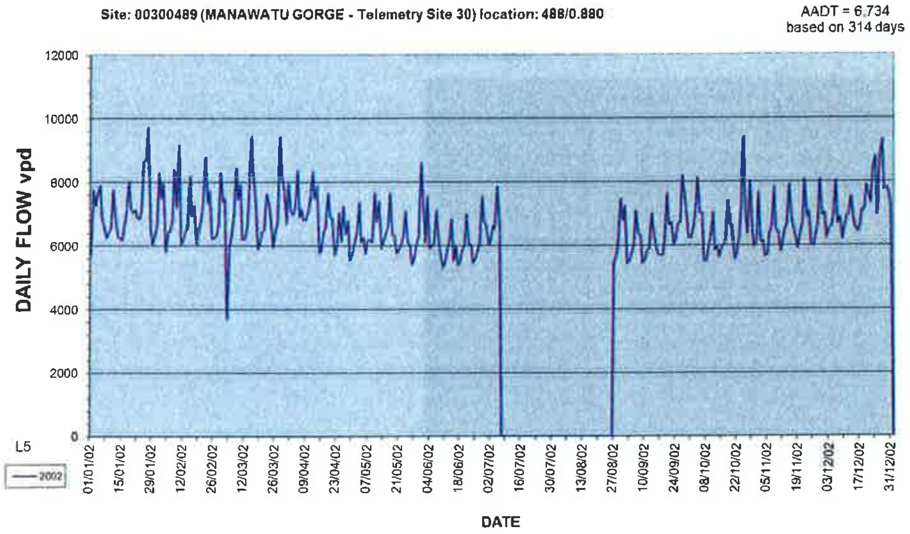
Hourly until 2 Dec. TMS error in exporting length data needed correcting using MWH raw data



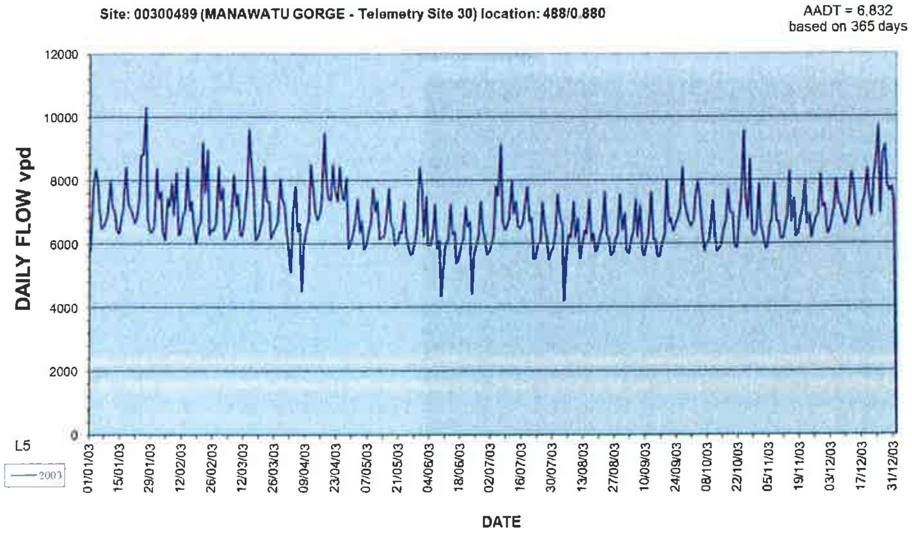
Quarter hour data (had 17 & 18 minute interval data – corrected for 6- 9 June 2000)


Site: 00300489 (MANAWATU GORGE - Telemetry Site 30) location: 488/0.880

AADT = 6,360
based on 303 days

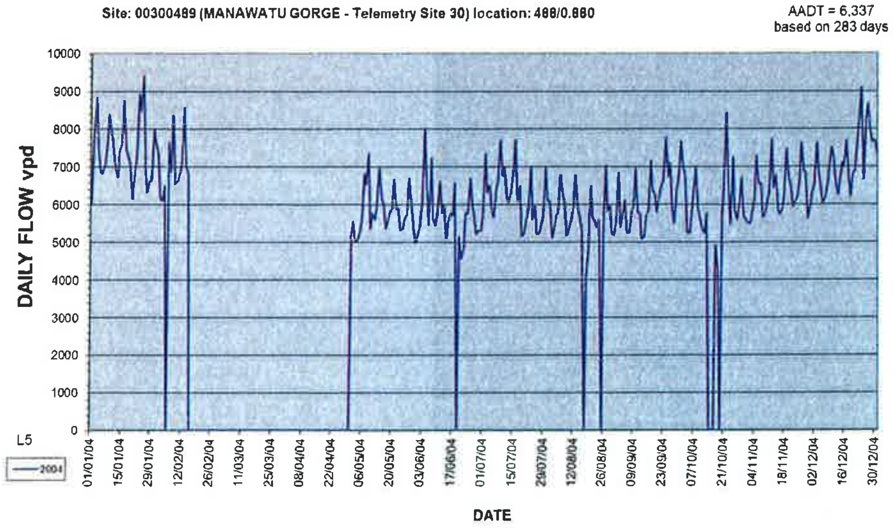

Site: 00300489 (MANAWATU GORGE - Telemetry Site 30) location: 488/0.880

AADT = 6,734
based on 314 days

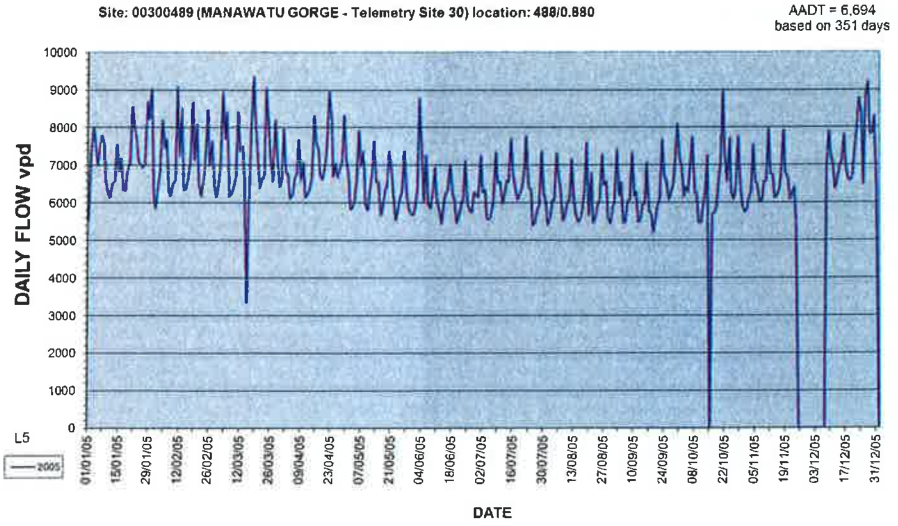

Site: 00300489 (MANAWATU GORGE - Telemetry Site 30) location: 488/0.880

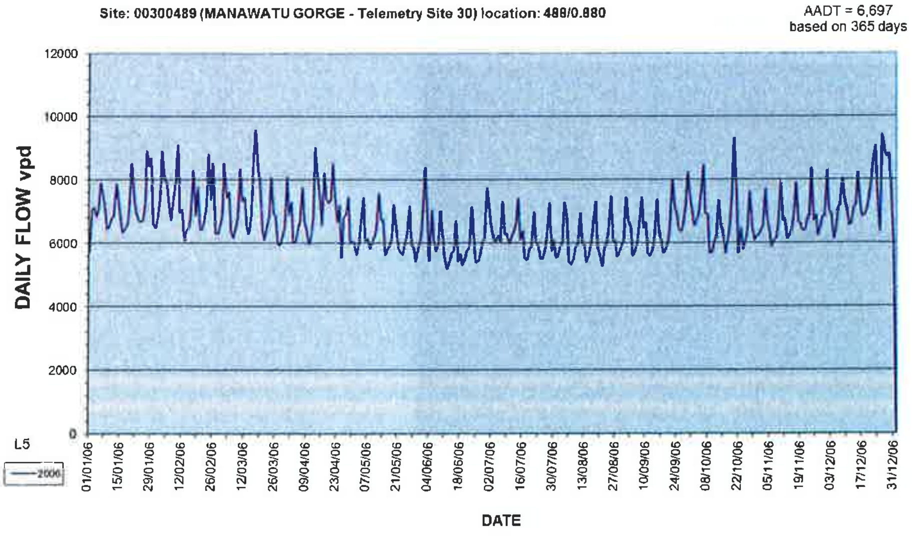
AADT = 6,832
based on 365 days

No missing data

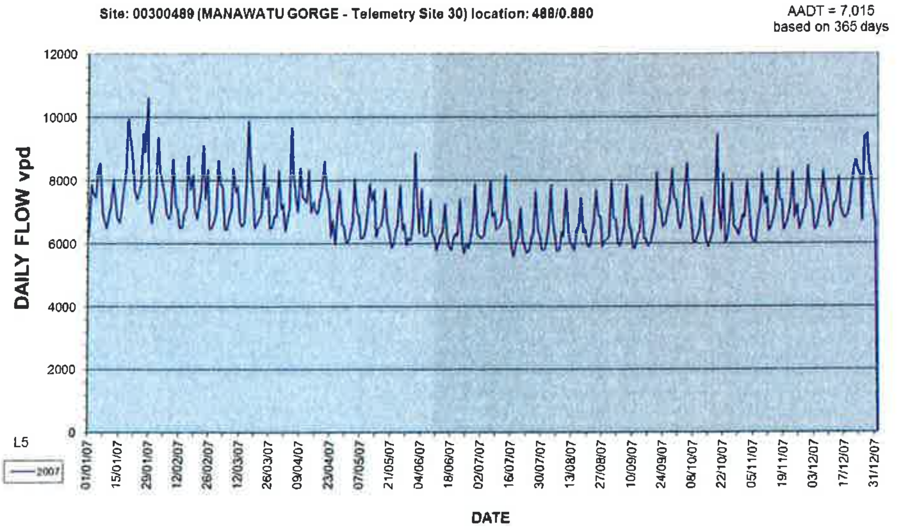


16 Feb-27 April 2004, Gorge closed, 28-30 Apr open to eastbound (incr RP) traffic

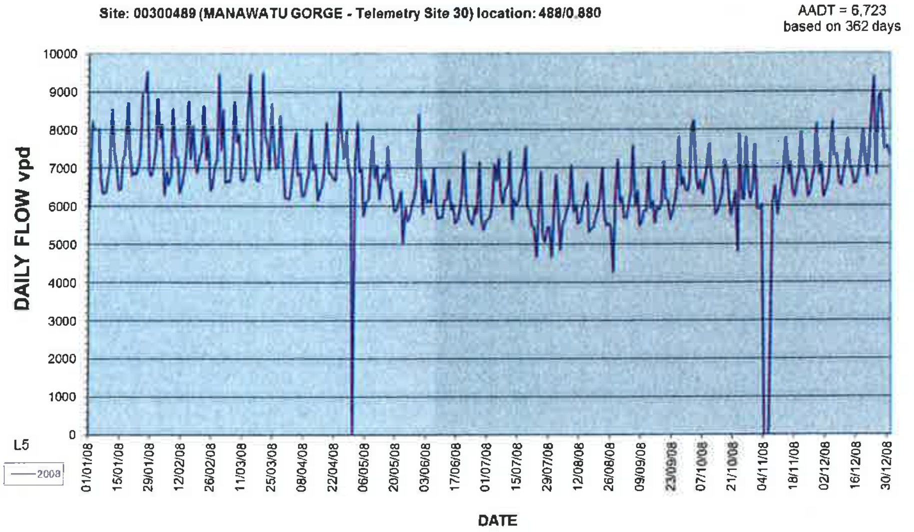




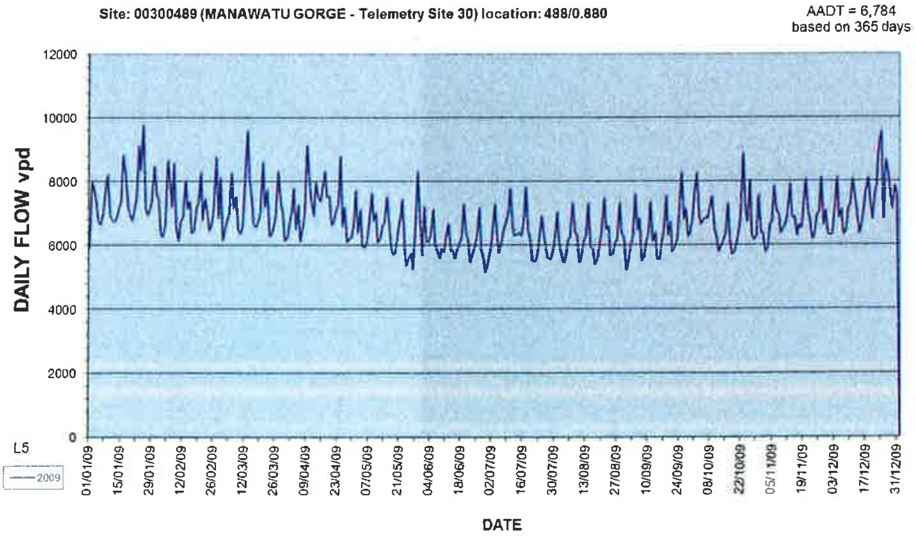
No missing data



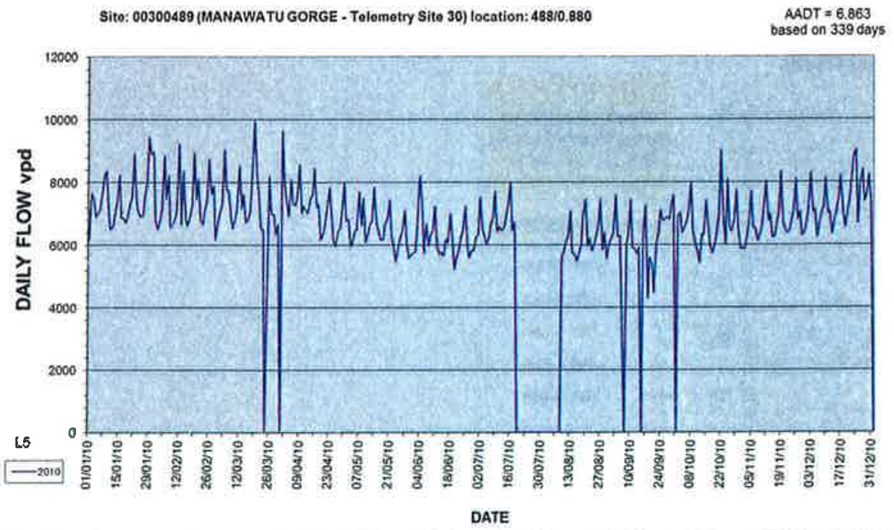
No missing data



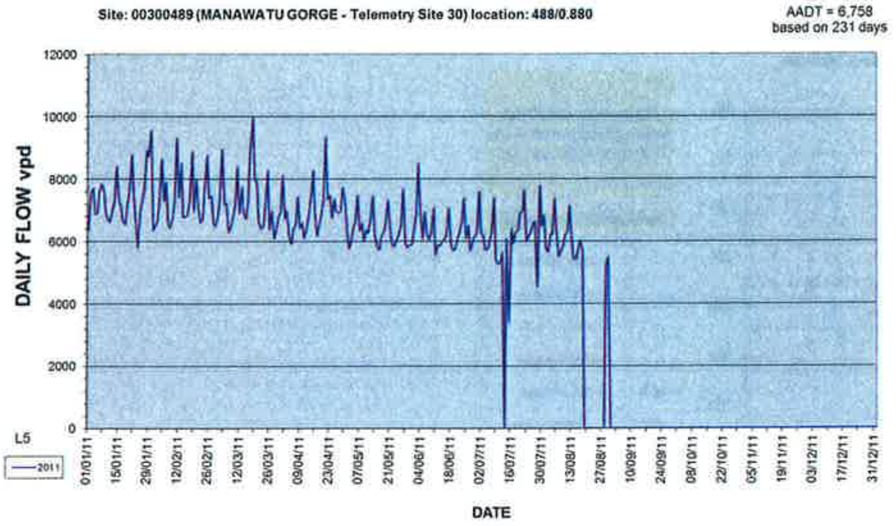
4-7 Nov 2008, Gorge closed both directions.



No missing data



Partial Gorge closures: 24-25 Mar 2010, 6-7 Sep 2010; 15 Sep 2010; 21 Sep 2010; 1 Oct 2010

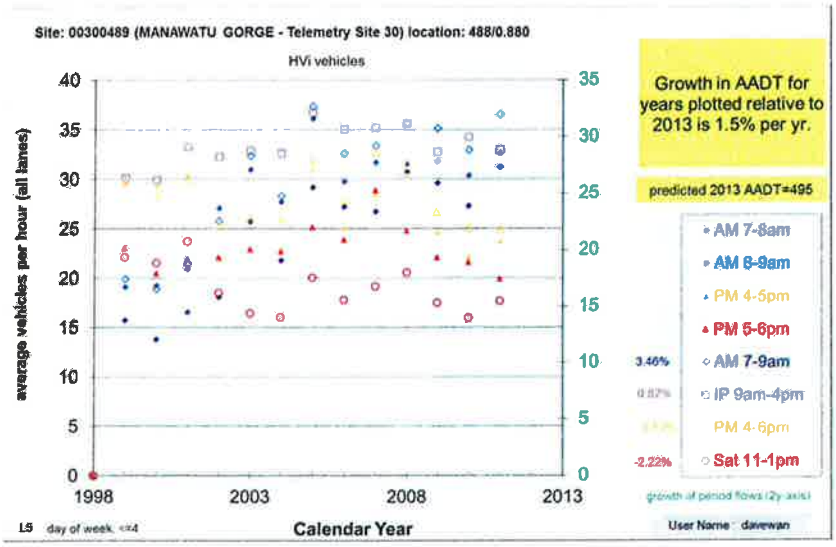


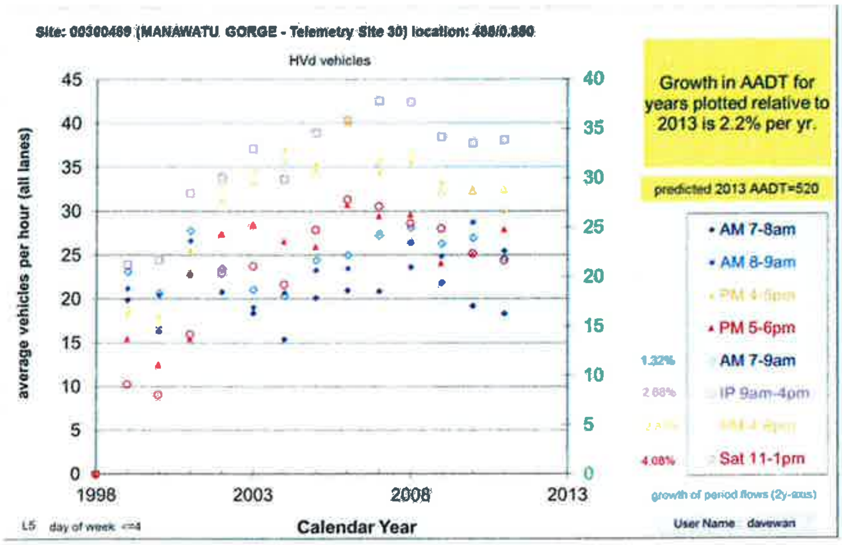
Partial Gorge closures: 13, 15, 28 July 2011.
Gorge closed evening 18 Aug – 31 Dec 2011 except for midday 28 Aug – early 31 Aug 2011

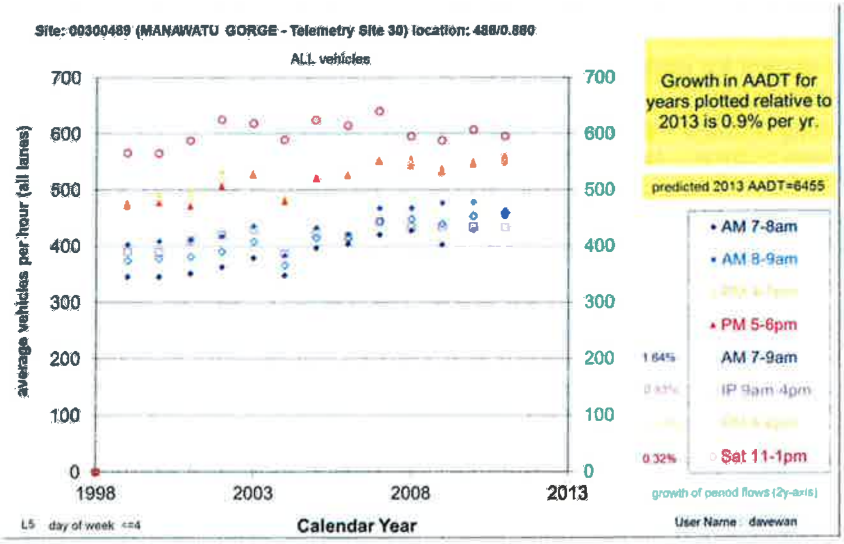
Gorge closed 1 Jan 2012 to present time except for periods as follows:
Temporarily re-opened to traffic during 20 May 2012
Temporarily re-opened to w/b traffic: evening 31 May – midday 2 July, evening 3– late 5 July
Temporarily re-opened to e/b traffic: evening 1 June – late 5 July at different times

Considerable construction traffic during Gorge closures recorded at the telemetry site.

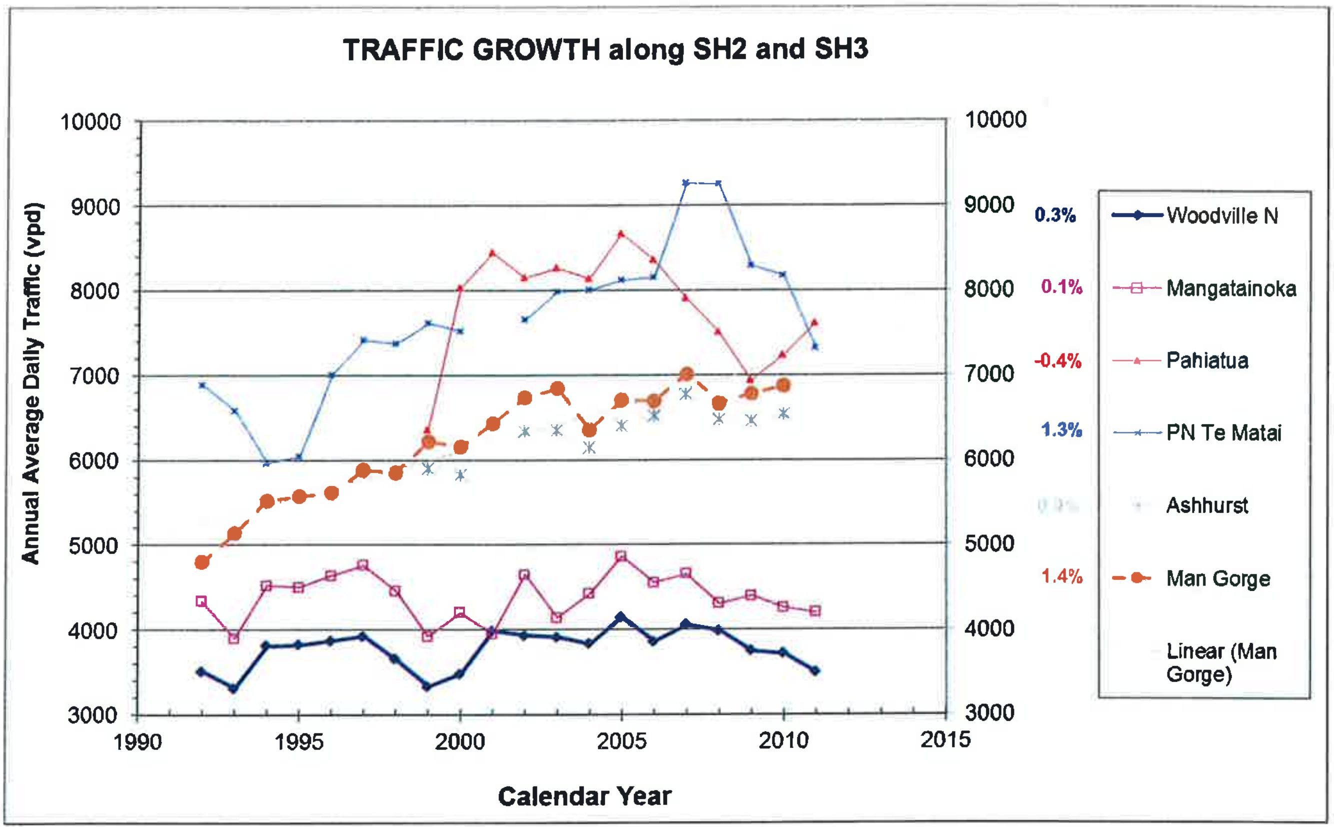
APPENDIX C: SH3 Manawatu Gorge Traffic growth (based on same 4 week period)







APPENDIX D: SH2 and SH3 Traffic Growth: 1992 to 2010/2011



The publihsed 2011 AADTs for SH3 at Ashhurst and Manawatu Groge were 5256 and 4353.
The linear regression traffic growths are relative to the predicted 2013 AADT

APPENDIX E: Travel Speeds: eRUCS/eROADS analysis

Saddle Road westbound (March 2012)

PERIOD2	1 (Bend in Saddle Rd)-2 (River)			2 (River)-3 (first U bend)			3 (first U bend)-4 (Dip)			4 (Dip)-5 (Cook Road)			5 (Cook Road)-6 (Look out)			6 (Look out)-7 (Start of Straight)			7 (Start of Straight)-8 (Bridge)			8 (Bridge)-9 (Prior to Hope Road Intersection)		
Segment,dir,len	1	i	0.90	2	i	2.10	3	i	1.60	4	i	1.80	5	i	1.10	6	i	1.20	7	i	1.60	8	i	0.80
WESTBOUND																								
M-F day 7-6	min-max	0.5	2	min-max	0.5	8	min-max	0.5	8	min-max	0.5	6	min-max	0.5	8	min-max	0.5	6	min-max	0.5	7	min-max	0.5	8
avg,SD,freq	00:49	00:05	436	02:51	00:30	439	02:59	00:39	441	02:31	00:37	443	01:14	00:15	448	01:55	00:34	455	03:12	01:01	455	01:28	00:35	430
min,max, <	00:38	01:11	0	01:56	04:49	0	01:40	05:40	0	01:24	05:07	0	00:51	03:25	0	01:03	04:55	0	01:35	06:59	0	00:43	04:25	0
avg,avg+sd ,>	65.7	73.2	3	44.2	53.5	0	32.1	41.0	0	42.8	56.6	1	53.3	66.8	0	37.7	53.8	1	30.1	44.1	3	32.8	54.4	0
min,max, reject	45.6	85.3	0.7%	26.2	65.2	0.0%	16.9	57.6	0.0%	21.1	77.1	0.2%	19.3	77.6	0.0%	14.6	68.6	0.2%	13.7	60.6	0.7%	10.9	67.0	0.0%
M-F night	min-max	0.5	2	min-max	0.5	8	min-max	0.5	8	min-max	0.5	6	min-max	0.5	8	min-max	0.5	6	min-max	0.5	7	min-max	0.5	8
avg,SD,freq	00:50	00:06	127	03:02	00:23	127	03:07	00:29	125	02:30	00:25	121	01:17	00:10	122	01:48	00:23	123	02:50	00:46	123	01:02	00:15	95
min,max, <	00:37	01:14	0	02:10	04:04	0	02:00	04:15	0	01:29	03:39	0	00:48	02:05	0	01:10	03:57	0	01:25	06:34	0	00:43	02:51	0
avg,avg+sd ,>	64.5	72.6	0	41.6	47.7	0	30.9	36.5	0	43.2	51.9	0	51.4	59.0	0	40.0	51.1	0	34.0	46.5	0	46.1	60.5	0
min,max, reject	43.8	87.6	0.0%	31.0	58.2	0.0%	22.6	48.0	0.0%	29.6	72.8	0.0%	31.7	82.5	0.0%	18.2	61.7	0.0%	14.6	67.8	0.0%	16.8	67.0	0.0%
S-S day 7-6	min-max	0.5	2	min-max	0.5	8	min-max	0.5	8	min-max	0.5	6	min-max	0.5	8	min-max	0.5	6	min-max	0.5	7	min-max	0.5	8
avg,SD,freq	00:49	00:05	55	02:44	00:29	55	02:48	00:31	55	02:26	00:37	56	01:14	00:10	55	01:47	00:25	55	02:41	00:43	54	01:09	00:19	47
min,max, <	00:36	01:06	0	01:42	04:23	0	01:53	04:22	0	01:44	05:37	0	00:56	01:50	0	01:12	03:44	0	01:36	05:48	0	00:44	02:28	0
avg,avg+sd ,>	66.5	73.9	1	46.1	56.0	1	34.2	41.9	1	44.4	59.5	0	53.7	62.1	0	40.4	53.0	0	35.9	48.9	1	41.8	58.3	0
min,max, reject	49.1	90.0	1.8%	28.7	74.1	1.8%	22.0	51.0	1.8%	19.2	62.3	0.0%	36.0	70.7	0.0%	19.3	60.0	0.0%	16.6	60.0	1.8%	19.5	65.5	0.0%
S-S night	min-max	0.5	2	min-max	0.5	8	min-max	0.5	8	min-max	0.5	6	min-max	0.5	8	min-max	0.5	6	min-max	0.5	7	min-max	0.5	8
avg,SD,freq	00:49	00:07	16	02:54	00:23	16	02:58	00:30	16	02:20	00:20	16	01:13	00:11	17	01:42	00:23	17	02:37	00:55	17	01:00	00:12	16
min,max, <	00:38	01:01	0	02:06	03:28	0	02:09	03:51	0	01:57	03:11	0	01:01	01:39	0	01:14	02:52	0	01:48	05:49	0	00:43	01:28	0
avg,avg+sd ,>	66.6	78.4	0	43.6	50.3	0	32.3	38.7	0	46.3	54.0	0	54.4	63.7	0	42.2	54.7	0	36.7	56.4	0	48.0	59.6	0
min,max, reject	53.1	85.3	0.0%	36.3	60.0	0.0%	24.9	44.7	0.0%	33.9	55.4	0.0%	40.0	64.9	0.0%	25.1	58.4	0.0%	16.5	53.3	0.0%	32.7	67.0	0.0%
PERIOD3																								
daytime	min-max	0.5	2	min-max	0.5	8	min-max	0.5	8	min-max	0.5	6	min-max	0.5	8	min-max	0.5	6	min-max	0.5	7	min-max	0.5	8
avg,SD,freq	00:49	00:05	491	02:50	00:30	494	02:58	00:38	496	02:31	00:37	499	01:14	00:15	503	01:54	00:34	510	03:08	01:00	509	01:26	00:34	477
min,max, <	00:36	01:11	0	01:42	04:49	0	01:40	05:40	0	01:24	05:37	0	00:51	03:25	0	01:03	04:55	0	01:35	06:59	0	00:43	04:25	0
avg,avg+sd ,>	65.8	73.3	4	44.4	53.7	1	32.3	41.2	1	42.9	56.9	1	53.3	66.3	0	38.0	53.9	1	30.6	44.9	4	33.5	55.6	0
min,max, reject	45.6	90.0	0.8%	26.2	74.1	0.2%	16.9	57.6	0.2%	19.2	77.1	0.2%	19.3	77.6	0.0%	14.6	68.6	0.2%	13.7	60.6	0.8%	10.9	67.0	0.0%
nighttime	min-max	0.5	2	min-max	0.5	8	min-max	0.5	8	min-max	0.5	6	min-max	0.5	8	min-max	0.5	6	min-max	0.5	7	min-max	0.5	8
avg,SD,freq	00:50	00:06	143	03:01	00:23	143	03:06	00:29	141	02:29	00:25	137	01:16	00:10	139	01:47	00:23	140	02:48	00:47	140	01:02	00:14	111
min,max, <	00:37	01:14	0	02:06	04:04	0	02:00	04:15	0	01:29	03:39	0	00:48	02:05	0	01:10	03:57	0	01:25	06:34	0	00:43	02:51	0
avg,avg+sd ,>	64.7	73.2	0	41.8	48.0	0	31.0	36.7	0	43.6	52.2	0	51.8	59.6	0	40.3	51.5	0	34.3	47.5	0	46.4	60.4	0
min,max, reject	43.8	87.6	0.0%	31.0	60.0	0.0%	22.6	48.0	0.0%	29.6	72.8	0.0%	31.7	82.5	0.0%	18.2	61.7	0.0%	14.6	67.8	0.0%	16.8	67.0	0.0%
whole wk/mth	min-max	0.5	2	min-max	0.5	8	min-max	0.5	8	min-max	0.5	6	min-max	0.5	8	min-max	0.5	6	min-max	0.5	7	min-max	0.5	8
avg,SD,freq	00:49	00:05	634	02:53	00:29	637	03:00	00:37	637	02:30	00:35	636	01:15	00:14	642	01:52	00:32	650	03:04	00:58	649	01:21	00:33	588
min,max, <	00:36	01:14	0	01:42	04:49	0	01:40	05:40	0	01:24	05:37	0	00:48	03:25	0	01:03	04:55	0	01:25	06:59	0	00:43	04:25	0
avg,avg+sd ,>	65.6	73.3	4	43.8	52.5	1	32.0	40.2	1	43.1	56.0	1	53.0	64.9	0	38.4	53.6	1	31.3	45.8	4	35.4	59.1	0
min,max, reject	43.8	90.0	0.6%	26.2	74.1	0.2%	16.9	57.6	0.2%	19.2	77.1	0.2%	19.3	82.5	0.0%	14.6	68.6	0.2%	13.7	67.8	0.6%	10.9	67.0	0.0%
Start day:	Fri 2012-03-02			Fri 2012-03-02			Fri 2012-03-02			Fri 2012-03-02			Fri 2012-03-02			Fri 2012-03-02			Fri 2012-03-02			Fri 2012-03-02		

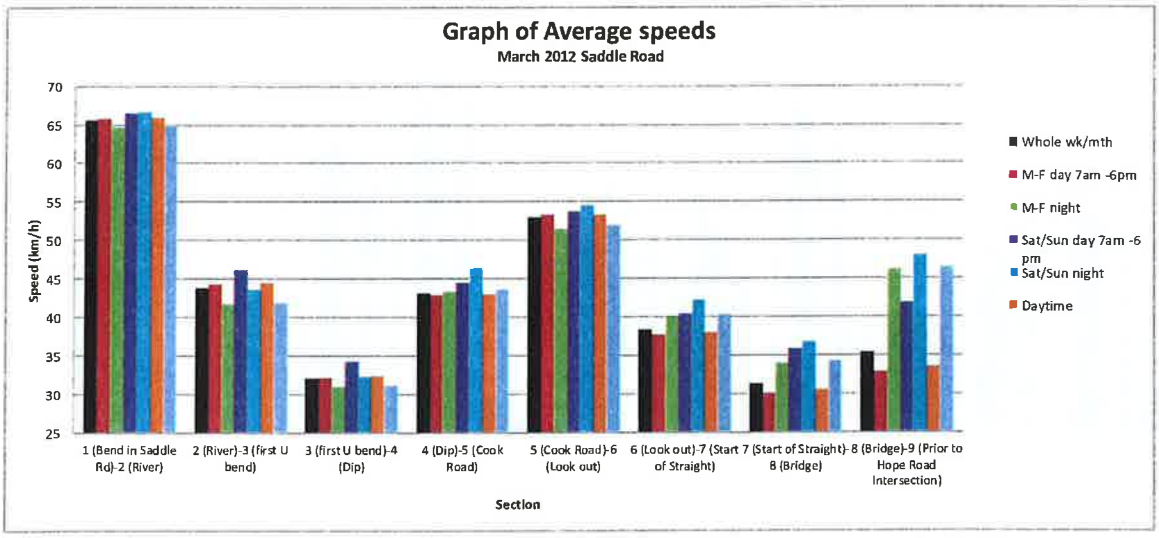
Saddle Road eastbound (March 2012)

PERIOD2	1 (Bend in Saddle Rd)-2 (River)			2 (River)-3 (first U bend)			3 (first U bend)-4 (Dip)			4 (Dip)-5 (Cook Road)			5 (Cook Road)-6 (Look out)			6 (Look out)-7 (Start of Straight)			7 (Start of Straight)-8 (Bridge)			8 (Bridge)-9 (Prior to Hope Road Intersection)		
Segment,dir,len	1	d	0.90	2	d	2.10	3	d	1.60	4	d	1.80	5	d	1.10	6	d	1.20	7	d	1.60	8	d	0.80
EASTBOUND																								
M-F day 7-6	min-max	0.5	2	min-max	0.5	8	min-max	0.5	8	min-max	0.5	6	min-max	0.5	8	min-max	0.5	6	min-max	0.5	7	min-max	0.5	8
avg,SD,freq	00:47	00:05	459	03:13	00:43	465	03:07	00:38	468	02:31	00:29	466	01:20	00:17	468	01:38	00:19	484	02:47	00:46	485	01:26	00:36	488
min,max, <	00:32	01:15	0	02:02	06:15	0	01:53	05:41	0	01:37	05:23	0	00:51	03:26	0	01:04	04:12	0	01:34	06:26	0	00:43	03:47	0
avg,avg+sd ,>	68.8	76.6	4	39.1	50.4	0	30.8	38.7	0	42.9	53.2	1	49.8	63.7	0	44.3	55.1	0	34.5	47.8	0	33.6	57.4	0
min,max, reject	43.2	101.2	0.9%	20.2	62.0	0.0%	16.9	51.0	0.0%	20.1	66.8	0.2%	19.2	77.6	0.0%	17.1	67.5	0.0%	14.9	61.3	0.0%	12.7	67.0	0.0%
M-F night	min-max	0.5	2	min-max	0.5	8	min-max	0.5	8	min-max	0.5	6	min-max	0.5	8	min-max	0.5	6	min-max	0.5	7	min-max	0.5	8
avg,SD,freq	00:49	00:05	160	03:18	00:35	157	03:08	00:31	156	02:32	00:19	155	01:20	00:11	156	01:42	00:14	156	02:35	00:33	153	00:58	00:07	153
min,max, <	00:37	01:01	0	02:08	04:51	0	02:03	04:40	0	01:47	03:26	0	00:58	02:08	0	01:07	02:34	0	01:26	06:56	0	00:39	01:19	0
avg,avg+sd ,>	66.8	73.7	0	38.2	46.5	0	30.6	36.6	0	42.7	48.9	1	49.2	56.6	0	42.4	49.3	0	37.3	47.5	0	49.9	56.9	0
min,max, reject	53.1	87.6	0.0%	26.0	59.1	0.0%	20.6	46.8	0.0%	31.5	60.6	0.6%	30.9	68.3	0.0%	28.1	64.5	0.0%	13.8	67.0	0.0%	36.5	73.8	0.0%
S-S day 7-6	min-max	0.5	2	min-max	0.5	8	min-max	0.5	8	min-max	0.5	6	min-max	0.5	8	min-max	0.5	6	min-max	0.5	7	min-max	0.5	8
avg,SD,freq	00:48	00:05	49	03:07	00:39	49	02:57	00:35	49	02:27	00:27	49	01:18	00:19	49	01:34	00:14	48	02:23	00:31	49	01:02	00:22	48
min,max, <	00:37	01:01	0	02:05	04:27	0	01:50	04:17	0	01:36	03:31	0	00:55	02:57	0	01:02	02:10	0	01:31	03:32	0	00:43	03:06	0
avg,avg+sd ,>	67.2	75.8	0	40.3	50.9	0	32.5	40.7	0	44.1	53.9	0	50.5	66.4	0	45.8	53.9	0	40.2	51.2	0	46.2	72.1	0
min,max, reject	53.1	87.6	0.0%	28.3	60.5	0.0%	22.4	52.4	0.0%	30.7	67.5	0.0%	22.4	72.0	0.0%	33.2	69.7	0.0%	27.2	63.3	0.0%	15.5	67.0	0.0%
S-S night	min-max	0.5	2	min-max	0.5	8	min-max	0.5	8	min-max	0.5	6	min-max	0.5	8	min-max	0.5	6	min-max	0.5	7	min-max	0.5	8
avg,SD,freq	00:49	00:05	36	03:18	00:34	36	03:10	00:29	35	02:36	00:22	35	01:22	00:11	35	01:45	00:15	35	02:32	00:30	35	01:00	00:07	36
min,max, <	00:39	01:01	0	01:55	05:06	0	01:51	04:11	0	01:38	03:24	0	00:56	01:49	0	01:02	02:14	0	01:24	04:07	0	00:50	01:22	0
avg,avg+sd ,>	65.6	72.9	0	38.1	45.9	0	30.3	35.7	0	41.6	48.4	0	48.1	55.5	0	41.3	47.9	0	37.8	47.1	0	47.9	53.9	0
min,max, reject	53.1	83.1	0.0%	24.7	65.7	0.0%	22.9	51.9	0.0%	31.8	66.1	0.0%	36.3	70.7	0.0%	32.2	69.7	0.0%	23.3	68.6	0.0%	35.1	57.6	0.0%
PERIOD3																								
daytime	min-max	0.5	2	min-max	0.5	8	min-max	0.5	8	min-max	0.5	6	min-max	0.5	8	min-max	0.5	6	min-max	0.5	7	min-max	0.5	8
avg,SD,freq	00:47	00:05	508	03:13	00:43	514	03:06	00:38	517	02:31	00:29	515	01:19	00:18	517	01:37	00:19	532	02:45	00:46	534	01:24	00:35	536
min,max, <	00:32	01:15	0	02:02	06:15	0	01:50	05:41	0	01:36	05:23	0	00:51	03:26	0	01:02	04:12	0	01:31	06:26	0	00:43	03:47	0
avg,avg+sd ,>	68.7	76.6	4	39.2	50.4	0	30.9	38.9	0	43.0	53.3	1	49.8	63.9	0	44.4	55.0	0	35.0	48.4	0	34.4	59.5	0
min,max, reject	43.2	101.2	0.8%	20.2	62.0	0.0%	16.9	52.4	0.0%	20.1	67.5	0.2%	19.2	77.6	0.0%	17.1	69.7	0.0%	14.9	63.3	0.0%	12.7	67.0	0.0%
nighttime	min-max	0.5	2	min-max	0.5	8	min-max	0.5	8	min-max	0.5	6	min-max	0.5	8	min-max	0.5	6	min-max	0.5	7	min-max	0.5	8
avg,SD,freq	00:49	00:05	196	03:18	00:35	193	03:09	00:31	191	02:33	00:20	190	01:21	00:11	191	01:42	00:14	191	02:34	00:33	188	00:58	00:07	189
min,max, <	00:37	01:01	0	01:55	05:06	0	01:51	04:40	0	01:38	03:26	0	00:56	02:08	0	01:02	02:34	0	01:24	06:56	0	00:39	01:22	0
avg,avg+sd ,>	66.6	73.6	0	38.2	46.4	0	30.5	36.5	0	42.5	48.8	1	49.0	56.4	0	42.2	49.1	0	37.4	47.4	0	49.5	56.4	0
min,max, reject	53.1	87.6	0.0%	24.7	65.7	0.0%	20.6	51.9	0.0%	31.5	66.1	0.5%	30.9	70.7	0.0%	28.1	69.7	0.0%	13.8	68.6	0.0%	35.1	73.8	0.0%
whole wk/mth	min-max	0.5	2	min-max	0.5	8	min-max	0.5	8	min-max	0.5	6	min-max	0.5	8	min-max	0.5	6	min-max	0.5	7	min-max	0.5	8
avg,SD,freq	00:48	00:05	704	03:14	00:41	707	03:07	00:36	708	02:31	00:27	705	01:20	00:16	708	01:39	00:18	723	02:42	00:43	722	01:17	00:33	725
min,max, <	00:32	01:15	0	01:55	06:15	0	01:50	05:41	0	01:36	05:23	0	00:51	03:26	0	01:02	04:12	0	01:24	06:56	0	00:39	03:47	0
avg,avg+sd ,>	68.1	75.8	4	39.0	49.3	0	30.8	38.3	0	42.9	52.1	2	49.6	62.0	0	43.8	53.4	0	35.6	48.4	0	37.4	64.7	0
min,max, reject	43.2	101.2	0.6%	20.2	65.7	0.0%	16.9	52.4	0.0%	20.1	67.5	0.3%	19.2	77.6	0.0%	17.1	69.7	0.0%	13.8	68.6	0.0%	12.7	73.8	0.0%
Start day:	Fri 2012-03-02			Fri 2012-03-02			Fri 2012-03-02			Fri 2012-03-02			Fri 2012-03-02			Fri 2012-03-02			Fri 2012-03-02			Fri 2012-03-02		

For March 2011 there were only 2 vehicles recorded in each direction (when Manawatu Gorge open)

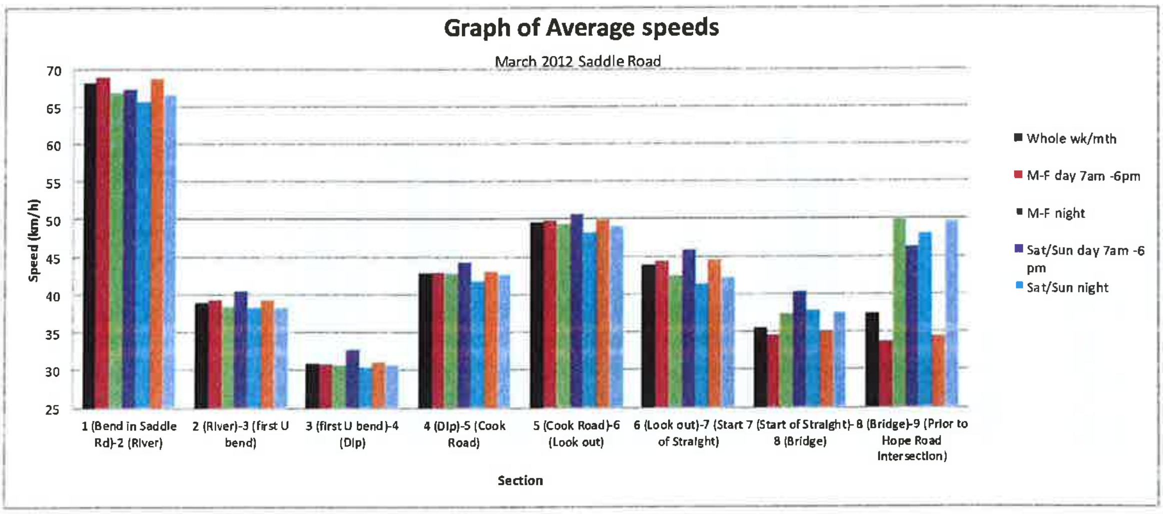
Saddle Road westbound (March 2012)

SADDLE RD: Mar'12	Average Speed (km/h)							
WESTBOUND	Section 1	Section 2	Section 3	Section 4	Section 5	Section 6	Section 7	Section 8
Time	1 (Bend in Saddle Rd)-2 (River)	2 (River)-3 (first U bend)	3 (first U bend)-4 (Dip)	4 (Dip)-5 (Cook Road)	5 (Cook Road)-6 (Look out)	6 (Look out)-7 (Start of Straight)	7 (Start of Straight)-8 (Bridge)	8 (Bridge)-9 (Prior to Hope Road Intersection)
Whole wk/mth	65.6	43.8	32.0	43.1	53.0	38.4	31.3	35.4
M-F day 7am -6pm	65.7	44.2	32.1	42.8	53.3	37.7	30.1	32.8
M-F night	64.5	41.6	30.9	43.2	51.4	40.0	34.0	46.1
Sat/Sun day 7am -6	66.5	46.1	34.2	44.4	53.7	40.4	35.9	41.8
Sat/Sun night	66.6	43.6	32.3	46.3	54.4	42.2	36.7	48.0
Daytime	65.8	44.4	32.3	42.9	53.3	38.0	30.6	33.5
Night time	64.7	41.8	31.0	43.6	51.8	40.3	34.3	46.4



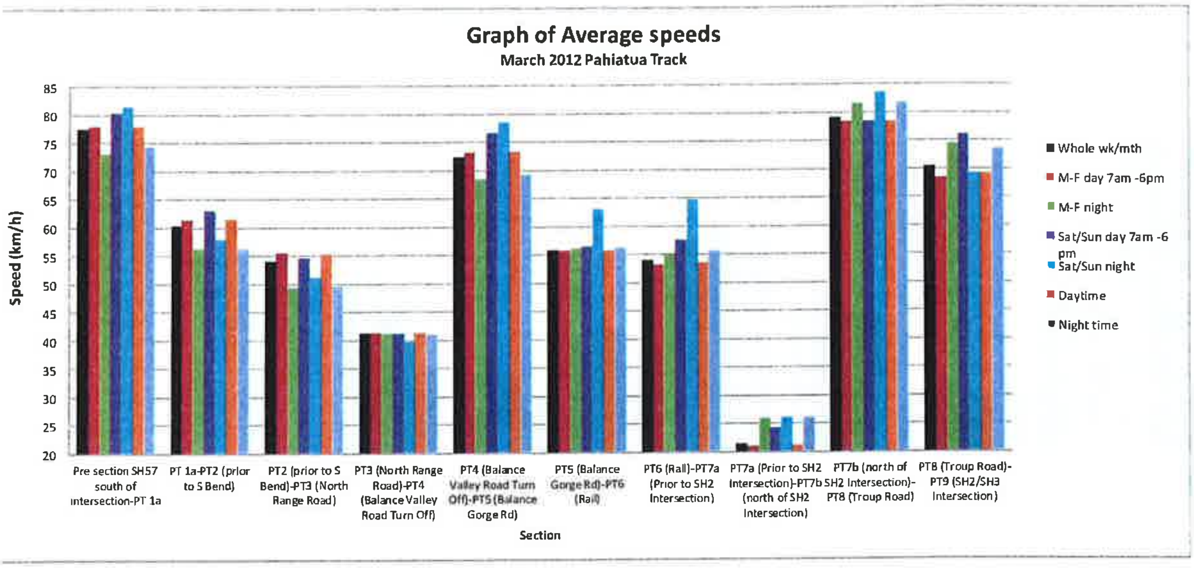
Saddle Road eastbound (March 2012)

SADDLE RD: Mar'12	Average Speed (km/h)							
EASTBOUND	Section 1	Section 2	Section 3	Section 4	Section 5	Section 6	Section 7	Section 8
Time	1 (Bend in Saddle Rd)-2 (River)	2 (River)-3 (first U bend)	3 (first U bend)-4 (Dip)	4 (Dip)-5 (Cook Road)	5 (Cook Road)-6 (Look out)	6 (Look out)-7 (Start of Straight)	7 (Start of Straight)-8 (Bridge)	8 (Bridge)-9 (Prior to Hope Road Intersection)
Whole wk/mth	68.1	39.0	30.8	42.9	49.6	43.8	35.6	37.4
M-F day 7am -6pm	68.8	39.1	30.8	42.9	49.8	44.3	34.5	33.6
M-F night	66.8	38.2	30.6	42.7	49.2	42.4	37.3	49.9
Sat/Sun day 7am -6	67.2	40.3	32.5	44.1	50.5	45.8	40.2	46.2
Sat/Sun night	65.6	38.1	30.3	41.6	48.1	41.3	37.8	47.9
Daytime	68.7	39.2	30.9	43.0	49.8	44.4	35.0	34.4
Night time	66.6	38.2	30.5	42.5	49.0	42.2	37.4	49.5



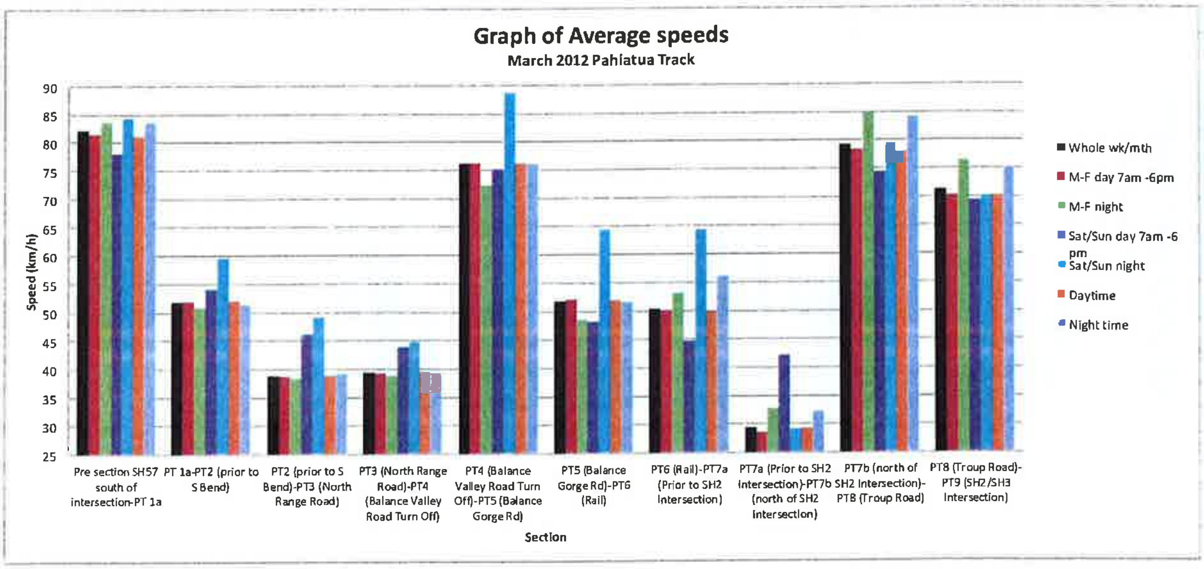
Pahiatua Track westbound (March 2012)

PAHIATUA TRACK WESTBOUND	Average Speed (km/h)									
	Section 1	Section 2	Section 3	Section 4	Section 5	Section 6	Section 7	Section 8	Section 9	Section 10
Time	Pre section SH57 south of intersection-PT 1a	PT 1a-PT2 (prior to S Bend)	PT2 (prior to S Bend)-PT3 (North Range Road)	PT3 (North Range Road)-PT4 (Balance Valley Road Turn Off)	PT4 (Balance Valley Road Turn Off)-PT5 (Balance Gorge Rd)	PT5 (Balance Gorge Rd)-PT6 (Rail)	PT6 (Rail)-PT7a (Prior to SH2 Intersection)	PT7a (Prior to SH2 Intersection)-PT7b (north of SH2 Intersection)	PT7b (north of SH2 Intersection)-PT8 (Troup Road)	PT8 (Troup Road)-PT9 (SH2/SH3 Intersection)
Whole wk/mth	77.4	60.4	54.0	41.3	72.4	55.8	54.0	21.6	79.1	70.4
M-F day 7am -6pm	77.8	61.4	55.4	41.3	73.2	55.6	53.2	20.9	78.4	68.4
M-F night	72.9	56.1	49.4	41.1	68.4	56.0	54.9	26.0	81.4	74.5
Sat/Sun day 7am -6 pm	80.2	63.0	54.6	41.1	76.5	56.4	57.4	24.2	78.4	76.1
Sat/Sun night	81.4	57.9	51.2	39.7	78.3	62.9	64.5	26.1	83.5	69.2
Daytime	77.9	61.5	55.4	41.3	73.4	55.7	53.4	21.1	78.4	69.2
Night time	74.2	56.3	49.5	41.0	69.1	56.3	55.4	26.0	81.7	73.6

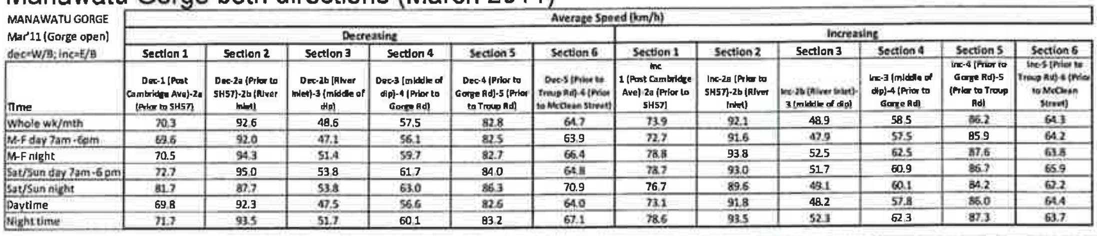


Pahiatua Track eastbound (March 2012)

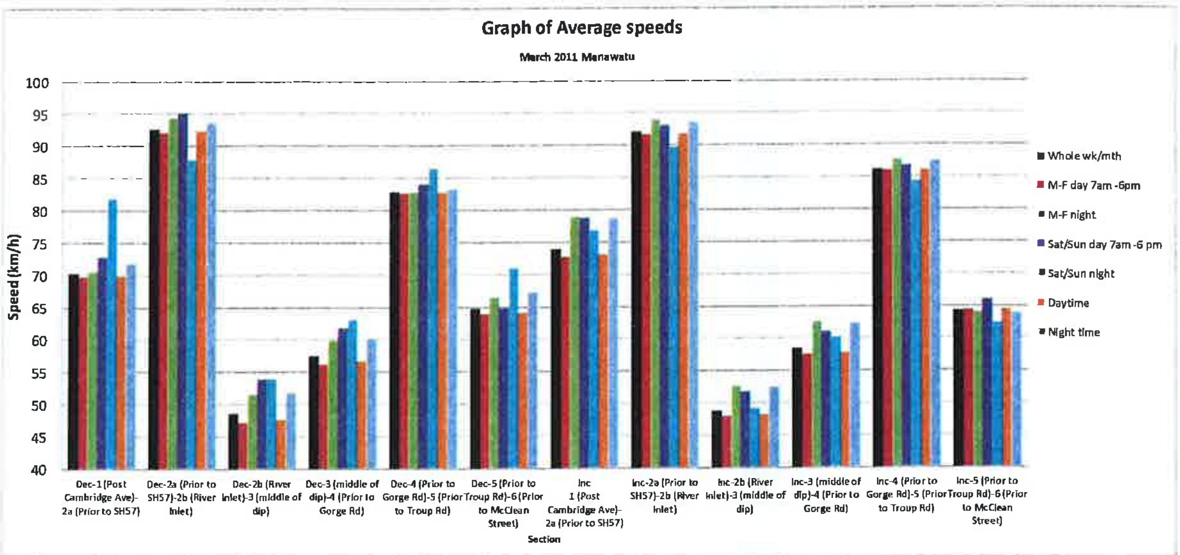
PAHIATUA TRACK EASTBOUND	Average Speed (km/h)									
	Section 1	Section 2	Section 3	Section 4	Section 5	Section 6	Section 7	Section 8	Section 9	Section 10
Time	Pre section SH57 south of intersection-PT 1a	PT 1a-PT2 (prior to S Bend)	PT2 (prior to S Bend)-PT3 (North Range Road)	PT3 (North Range Road)-PT4 (Balance Valley Road Turn Off)	PT4 (Balance Valley Road Turn Off)-PT5 (Balance Gorge Rd)	PT5 (Balance Gorge Rd)-PT6 (Rail)	PT6 (Rail)-PT7a (Prior to SH2 Intersection)	PT7a (Prior to SH2 Intersection)-PT7b (north of SH2 Intersection)	PT7b (north of SH2 Intersection)-PT8 (Troup Road)	PT8 (Troup Road)-PT9 (SH2/SH3 Intersection)
Whole wk/mth	82.2	51.8	38.9	39.3	76.1	51.8	50.4	29.4	79.3	71.3
M-F day 7am -6pm	81.4	51.9	38.5	39.1	76.2	52.0	50.1	28.6	78.3	70.3
M-F night	83.5	50.7	38.2	38.6	72.2	48.4	53.0	32.6	84.8	76.3
Sat/Sun day 7am -6 pm	78.1	53.9	46.0	43.6	75.0	47.9	44.6	42.0	74.5	69.3
Sat/Sun night	84.3	59.4	48.9	44.6	88.7	64.2	64.3	29.1	79.5	70.0
Daytime	81.0	52.0	38.8	39.3	76.2	51.8	49.8	29.1	78.0	70.2
Night time	83.6	51.3	39.0	39.1	76.1	51.5	55.9	32.1	84.2	75.0



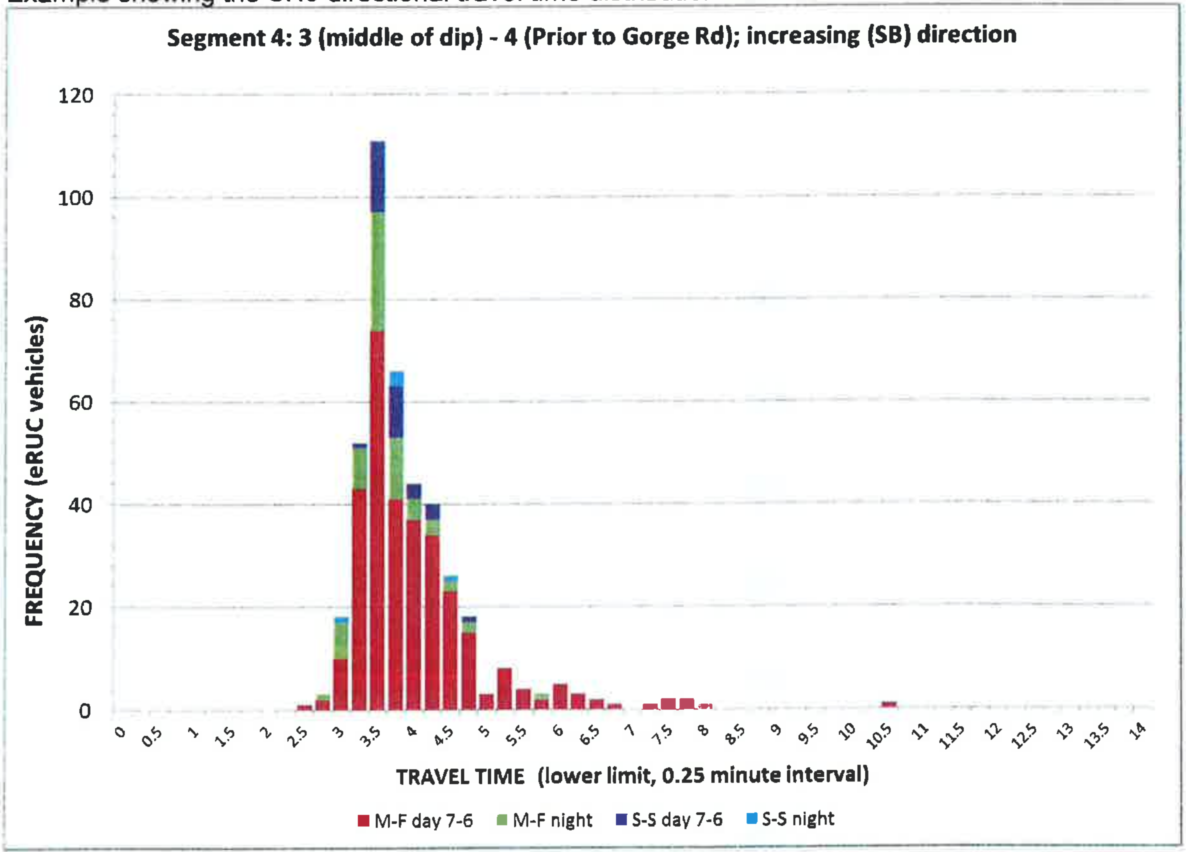
Manawatu Gorge both directions (March 2011)



MANAWATU GORGE	Average Speed (km/h)											
Mar'11 (Gorge open)	Decreasing						Increasing					
dec=W/B; inc=E/B	Section 1	Section 2	Section 3	Section 4	Section 5	Section 6	Section 1	Section 2	Section 3	Section 4	Section 5	Section 6
Time	Dec-1 (Post Cambridge Ave)-2a (Prior to SH57)	Dec-2a (Prior to SH57)-2b (River Inlet)	Dec-2b (River Inlet)-3 (middle of dip)	Dec-3 (middle of dip)-4 (Prior to Gorge Rd)	Dec-4 (Prior to Gorge Rd)-5 (Prior to Troup Rd)	Dec-5 (Prior to Troup Rd)-6 (Prior to McClean Street)	Inc 1 (Post Cambridge Ave) 2a (Prior to SH57)	Inc-2a (Prior to SH57)-2b (River Inlet)	Inc-2b (River Inlet)-3 (middle of dip)	Inc-3 (middle of dip)-4 (Prior to Gorge Rd)	Inc-4 (Prior to Gorge Rd)-5 (Prior to Troup Rd)	Inc-5 (Prior to Troup Rd)-6 (Prior to McClean Street)
Whole wk/mth	70.3	92.6	48.6	57.5	82.8	64.7	73.9	92.1	48.9	58.5	86.2	64.3
M-F day 7am -6pm	69.6	92.0	47.1	56.1	82.5	63.9	72.7	91.6	47.9	57.5	85.9	64.2
M-F night	70.5	94.3	51.4	59.7	82.7	66.4	78.8	93.8	52.5	62.5	87.6	63.8
Sat/Sun day 7am -6 pm	72.7	95.0	53.8	61.7	84.0	64.8	78.7	93.0	51.7	60.9	86.7	65.9
Sat/Sun night	81.7	87.7	53.8	63.0	86.3	70.9	76.7	89.6	49.1	60.1	84.2	62.2
Daytime	69.8	92.3	47.5	56.6	82.6	64.0	73.1	91.8	48.2	57.8	86.0	64.4
Night time	71.7	93.5	51.7	60.1	83.2	67.1	78.6	93.5	52.3	62.3	87.3	63.7

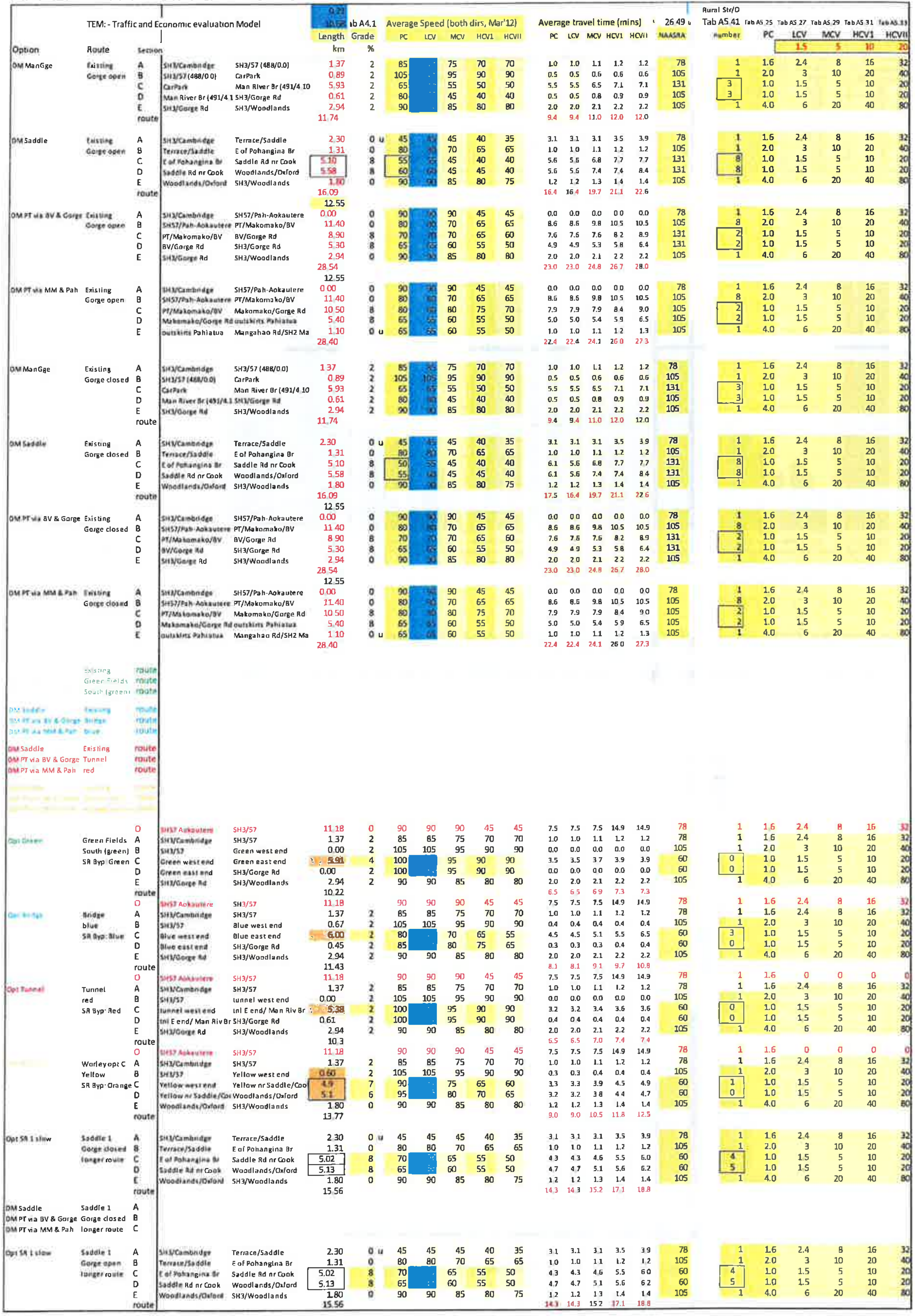


Example showing the SH3 directional travel time distribution for a section

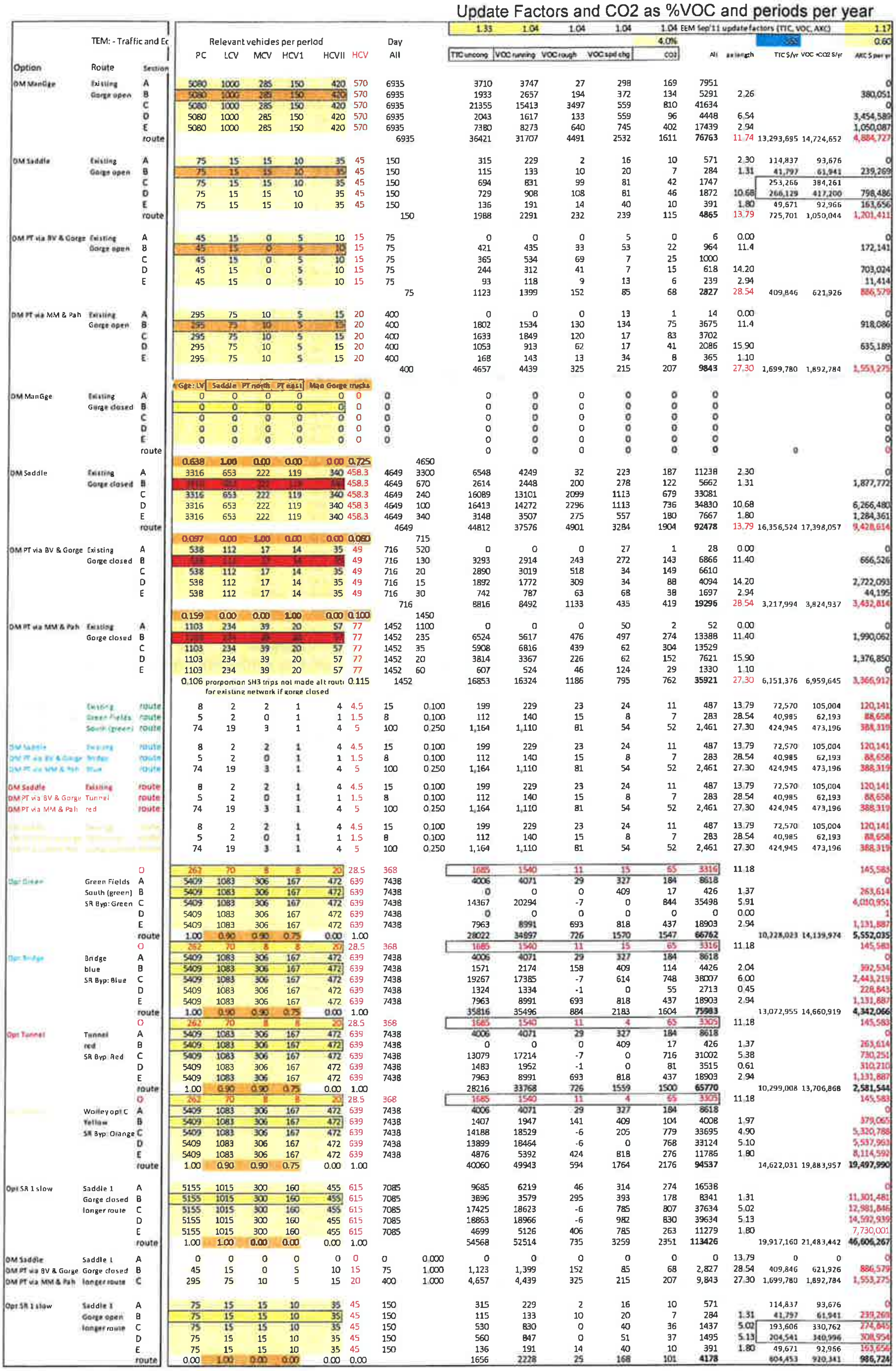


The computed statistics were based on a maximum observed travel time for each section

APPENDIX F: Traffic and Economic Model



	TEM: - Traffic and Economic evaluation Model				0.22 [illegible]	ab A4.1	Average Speed (both dirs, Mar'12)					Average travel time (mins)					26 49 u	Rural Str/D Tab AS 41	Tab AS 25	Tab AS 27	Tab AS 29	Tab AS 31	Tab AS 33
					Length	Grade	PC	LCV	MCV	HCV1	HCVII	PC	LCV	MCV	HCV1	HCVII	NAASRA	Number	PC	LCV	MCV	HCV1	HCVII
Option	Route	Section			km	%														1.5	5	10	20
DM ManGge	Existing	A	SH3/Cambridge	SH3/57 (488/0.0)	1.37	2	85		75	70	70	1.0	1.0	1.1	1.2	1.2	78	1	1.6	2.4	8	16	32
	Gorge open	B	SH3/57 (488/0.0)	CarPark	0.89	2	105		95	90	90	0.5	0.5	0.6	0.6	0.6	105	1	2.0	3	10	20	40
		C	CarPark	Man River Br (491/4.10	5.93	2	65		55	50	50	5.5	5.5	6.5	7.1	7.1	131	3	1.0	1.5	5	10	20
		D	Man River Br (491/4.1	SH3/Gorge Rd	0.61	2	80		45	40	40	0.5	0.5	0.8	0.9	0.9	105	3	1.0	1.5	5	10	20
		E	SH3/Gorge Rd	SH3/Woodlands	2.94	2	90		85	80	80	2.0	2.0	2.1	2.2	2.2	105	1	4.0	6	20	40	80
		route			11.74							9.4	9.4	11.0	12.0	12.0							
DM Saddle	Existing	A	SH3/Cambridge	Terrace/Saddle	2.30	0 u	45	[illegible]	45	40	35	3.1	3.1	3.1	3.5	3.9	78	1	1.6	2.4	8	16	32
	Gorge open	B	Terrace/Saddle	E of Pohangina Br	1.31	0	80	[illegible]	70	65	65	1.0	1.0	1.1	1.2	1.2	105	1	2.0	3	10	20	40
		C	E of Pohangina Br	Saddle Rd nr Cook	5.10	8	55	[illegible]	45	40	40	5.6	5.6	6.8	7.7	7.7	131	8	1.0	1.5	5	10	20
		D	Saddle Rd nr Cook	Woodlands/Oxford	5.58	8	60	[illegible]	45	45	40	5.6	5.6	7.4	7.4	8.4	131	8	1.0	1.5	5	10	20
		E	Woodlands/Oxford	SH3/Woodlands	1.80	0	90	[illegible]	85	80	75	1.2	1.2	1.3	1.4	1.4	105	1	4.0	6	20	40	80
		route			16.09							16.4	16.4	19.7	21.1	22.6							
					12.55																		
DM PT via BV & Gorge	Existing	A	SH3/Cambridge	SH57/Pah-Aokautere	0.00	0	90	[illegible]	90	45	45	0.0	0.0	0.0	0.0	0.0	78	1	1.6	2.4	8	16	32
	Gorge open	B	SH57/Pah-Aokautere	PT/Makomako/BV	11.40	0	80	[illegible]	70	65	65	8.6	8.6	9.8	10.5	10.5	105	8	2.0	3	10	20	40
		C	PT/Makomako/BV	BV/Gorge Rd	8.90	8	70	[illegible]	70	65	60	7.6	7.6	7.6	8.2	8.9	131	2	1.0	1.5	5	10	20
		D	BV/Gorge Rd	SH3/Gorge Rd	5.30	8	65	[illegible]	60	55	50	4.9	4.9	5.3	5.8	6.4	131	2	1.0	1.5	5	10	20
		E	SH3/Gorge Rd	SH3/Woodlands	2.94	0	90	[illegible]	85	80	80	2.0	2.0	2.1	2.2	2.2	105	1	4.0	6	20	40	80
					28.54							23.0	23.0	24.8	26.7	28.0							
					12.55																		
DM PT via MM & Pah	Existing	A	SH3/Cambridge	SH57/Pah-Aokautere	0.00	0	90	[illegible]	90	45	45	0.0	0.0	0.0	0.0	0.0	78	1	1.6	2.4	8	16	32
	Gorge open	B	SH57/Pah-Aokautere	PT/Makomako/BV	11.40	0	80	[illegible]	70	65	65	8.6	8.6	9.8	10.5	10.5	105	8	2.0	3	10	20	40
		C	PT/Makomako/BV	Makomako/Gorge Rd	10.50	8	80	[illegible]	80	75	70	7.9	7.9	7.9	8.4	9.0	105	2	1.0	1.5	5	10	20
		D	Makomako/Gorge Rd	outskirts Pahiatua	5.40	8	65	[illegible]	60	55	50	5.0	5.0	5.4	5.9	6.5	105	2	1.0	1.5	5	10	20
		E	outskirts Pahiatua	Mangahao Rd/SH2 Ma	1.10	0 u	65	[illegible]	60	55	50	1.0	1.0	1.1	1.2	1.3	105	1	4.0	6	20	40	80
					28.40							22.4	22.4	24.1	26.0	27.3							
DM ManGge	Existing	A	SH3/Cambridge	SH3/57 (488/0.0)	1.37	2	85	85	75	70	70	1.0	1.0	1.1	1.2	1.2	78	1	1.6	2.4	8	16	32
	Gorge closed	B	SH3/57 (488/0.0)	CarPark	0.89	2	105	105	95	90	90	0.5	0.5	0.6	0.6	0.6	105	1	2.0	3	10	20	40
		C	CarPark	Man River Br (491/4.10	5.93	2	65	65	55	50	50	5.5	5.5	6.5	7.1	7.1	131	3	1.0	1.5	5	10	20
		D	Man River Br (491/4.1	SH3/Gorge Rd	0.61	2	80	80	45	40	40	0.5	0.5	0.8	0.9	0.9	105	3	1.0	1.5	5	10	20
		E	SH3/Gorge Rd	SH3/Woodlands	2.94	2	90	90	85	80	80	2.0	2.0	2.1	2.2	2.2	105	1	4.0	6	20	40	80
		route			11.74							9.4	9.4	11.0	12.0	12.0							
DM Saddle	Existing	A	SH3/Cambridge	Terrace/Saddle	2.30	0 u	45	[illegible]	45	40	35	3.1	3.1	3.1	3.5	3.9	78	1	1.6	2.4	8	16	32
	Gorge closed	B	Terrace/Saddle	E of Pohangina Br	1.31	0	80	[illegible]	70	65	65	1.0	1.0	1.1	1.2	1.2	105	1	2.0	3	10	20	40
		C	E of Pohangina Br	Saddle Rd nr Cook	5.10	8	50	[illegible]	45	40	40	6.1	5.6	6.8	7.7	7.7	131	8	1.0	1.5	5	10	20
		D	Saddle Rd nr Cook	Woodlands/Oxford	5.58	8	55	[illegible]	45	45	40	6.1	5.6	7.4	7.4	8.4	131	8	1.0	1.5	5	10	20
		E	Woodlands/Oxford	SH3/Woodlands	1.80	0	90	[illegible]	85	80	75	1.2	1.2	1.3	1.4	1.4	105	1	4.0	6	20	40	80
		route			16.09							17.5	16.4	19.7	21.1	22.6							
					12.55																		
DM PT via BV & Gorge	Existing	A	SH3/Cambridge	SH57/Pah-Aokautere	0.00	0	90	[illegible]	90	45	45	0.0	0.0	0.0	0.0	0.0	78	1	1.6	2.4	8	16	32
	Gorge closed	B	SH57/Pah-Aokautere	PT/Makomako/BV	11.40	0	80	[illegible]	70	65	65	8.6	8.6	9.8	10.5	10.5	105	8	2.0	3	10	20	40
		C	PT/Makomako/BV	BV/Gorge Rd	8.90	8	70	[illegible]	70	65	60	7.6	7.6	7.6	8.2	8.9	131	2	1.0	1.5	5	10	20
		D	BV/Gorge Rd	SH3/Gorge Rd	5.30	8	65	[illegible]	60	55	50	4.9	4.9	5.3	5.8	6.4	131	2	1.0	1.5	5	10	20
		E	SH3/Gorge Rd	SH3/Woodlands	2.94	0	90	[illegible]	85	80	80	2.0	2.0	2.1	2.2	2.2	105	1	4.0	6	20	40	80
					28.54							23.0	23.0	24.8	26.7	28.0							
					12.55																		
DM PT via MM & Pah	Existing	A	SH3/Cambridge	SH57/Pah-Aokautere	0.00	0	90	[illegible]	90	45	45	0.0	0.0	0.0	0.0	0.0	78	1	1.6	2.4	8	16	32
	Gorge closed	B	SH57/Pah-Aokautere	PT/Makomako/BV	11.40	0	80	[illegible]	70	65	65	8.6	8.6	9.8	10.5	10.5	105	8	2.0	3	10	20	40
		C	PT/Makomako/BV	Makomako/Gorge Rd	10.50	8	80	[illegible]	80	75	70	7.9	7.9	7.9	8.4	9.0	105	2	1.0	1.5	5	10	20
		D	Makomako/Gorge Rd	outskirts Pahiatua	5.40	8	65	[illegible]	60	55	50	5.0	5.0	5.4	5.9	6.5	105	2	1.0	1.5	5	10	20
		E	outskirts Pahiatua	Mangahao Rd/SH2 Ma	1.10	0 u	65	[illegible]	60	55	50	1.0	1.0	1.1	1.2	1.3	105	1	4.0	6	20	40	80
					28.40							22.4	22.4	24.1	26.0	27.3							
	Existing	route																					
	Green Fields	route																					
	South (green)	route																					
DM Saddle	Existing	route																					
DM PT via BV & Gorge	Bridge	route																					
DM PT via MM & Pah	blue	route																					
DM Saddle	Existing	route																					
DM PT via BV & Gorge	Tunnel	route																					
DM PT via MM & Pah	red	route																					
		O	SH57 Aokautere	SH3/57	11.18	0	90	90	90	45	45	7.5	7.5	7.5	14.9	14.9	78	1	1.6	2.4	8	16	32
Opt Green	Green Fields	A	SH3/Cambridge	SH3/57	1.37	2	85	85	75	70	70	1.0	1.0	1.1	1.2	1.2	78	1	1.6	2.4	8	16	32
	South (green)	B	SH3/57	Green west end	0.00	2	105	105	95	90	90	0.0	0.0	0.0	0.0	0.0	105	1	2.0	3	10	20	40
	SR Byp: Green	C	Green west end	Green east end	5.91	4	100		95	90	90	3.5	3.5	3.7	3.9	3.9	60	0	1.0	1.5	5	10	20
		D	Green east end	SH3/Gorge Rd	0.00	2	100		95	90	90	0.0	0.0	0.0	0.0	0.0	60	0	1.0	1.5	5	10	20
		E	SH3/Gorge Rd	SH3/Woodlands	2.94	2	90	90	85	80	80	2.0	2.0	2.1	2.2	2.2	105	1	4.0	6	20	40	80
		route			10.22							6.5	6.5	6.9	7.3	7.3							
		O	SH57 Aokautere	SH3/57	11.18		90	90	90	45	45	7.5	7.5	7.5	14.9	14.9	78	1	1.6	2.4	8	16	32
Opt Bridge	Bridge	A	SH3/Cambridge	SH3/57	1.37	2	85	85	75	70	70	1.0	1.0	1.1	1.2	1.2	78	1	1.6	2.4	8	16	32
	blue	B	SH3/57	Blue west end	0.67	2	105	105	95	90	90	0.4	0.4	0.4	0.4	0.4	105	1	2.0	3	10	20	40
	SR Byp: Blue	C	Blue west end	Blue east end	6.00	2	80		70	65	55	4.5	4.5	5.1	5.5	6.5	60	3	1.0	1.5	5	10	20
		D	Blue east end	SH3/Gorge Rd	0.45	2	85		80	75	65	0.3	0.3	0.3	0.4	0.4	60	0	1.0	1.5	5	10	20
		E	SH3/Gorge Rd	SH3/Woodlands	2.94	2	90	90	85	80	80	2.0	2.0	2.1	2.2	2.2	105	1	4.0	6	20	40	80
		route			11.43							8.1	8.1	9.1	9.7	10.8							
		O	SH57 Aokautere	SH3/57	11.18		90	90	90	45	45	7.5	7.5	7.5	14.9	14.9	78	1	1.6	0	0	0	0
Opt Tunnel	Tunnel	A	SH3/Cambridge	SH3/57	1.37	2	85	85	75	70	70	1.0	1.0	1.1	1.2	1.2	78	1	1.6	2.4	8	16	32
	red	B	SH3/57	tunnel west end	0.00	2	105	105	95	90	90	0.0	0.0	0.0	0.0	0.0	105	1	2.0	3	10	20	40
	SR Byp: Red	C	tunnel west end	tnl E end/ Man Riv Br	5.38	2	100		95	90	90	3.2	3.2	3.4	3.6	3.6	60	0	1.0	1.5	5	10	20
		D	tnl E end/ Man Riv Br	SH3/Gorge Rd	0.61	2	100		95	90	90	0.4	0.4	0.4	0.4	0.4	60	0	1.0	1.5	5	10	20
		E	SH3/Gorge Rd	SH3/Woodlands	2.94	2	90	90	85	80	80	2.0	2.0	2.1	2.2	2.2	105	1	4.0	6	20	40	80
		route			10.3							6.5	6.5	7.0	7.4	7.4							
		O	SH57 Aokautere	SH3/57	11.18		90	90	90	45	45	7.5	7.5	7.5	14.9	14.9	78	1	1.6	0	0	0	0
	Worley opt C	A	SH3/Cambridge	SH3/57	1.37	2	85	85	75	70	70	1.0	1.0	1.1	1.2	1.2	78	1	1.6	2.4	8	16	32
	Yellow	B	SH3/57	Yellow west end	0.60	2	105	105	95	90	90	0.3	0.3	0.4	0.4	0.4	105	1	2.0	3	10	20	40
	SR Byp: Orange	C	Yellow west end	Yellow nr Saddle/Coo	4.9	7	90		75	65	60	3.3	3.3	3.9	4.5	4.9	60	1	1.0	1.5	5	10	20
		D	Yellow nr Saddle/Coi	Woodlands/Oxford	5.1	6	95		80	70	65	3.2	3.2	3.8	4.4	4.7	60	0	1.0	1.5	5	10	20
		E	Woodlands/Oxford	SH3/Woodlands	1.80	0	90	90	85	80	80	1.2	1.2	1.3	1.4	1.4	105	1	4.0	6	20	40	80
		route			13.77							9.0	9.0	10.5	11.8	12.5							
Opt SR 1 slow	Saddle 1	A	SH3/Cambridge	Terrace/Saddle	2.30	0 u	45	45	45	40	35	3.1	3.1	3.1	3.5	3.9	78	1	1.6	2.4	8	16	32
	Gorge closed	B	Terrace/Saddle	E of Pohangina Br	1.31	0	80	80	70	65	65	1.0	1.0	1.1	1.2	1.2	105	1	2.0	3	10	20	40
	longer route	C	E of Pohangina Br	Saddle Rd nr Cook	5.02	8	70		65	55	50	4.3	4.3	4.6	5.5	6.0	60	4	1.0	1.5	5	10	20
		D	Saddle Rd nr Cook	Woodlands/Oxford	5.13	8	65		60	55	50	4.7	4.7	5.1	5.6	6.2	60	5	1.0	1.5	5	10	20
		E	Woodlands/Oxford	SH3/Woodlands	1.80	0	90	90	85	80	75	1.2	1.2	1.3	1.4	1.4	105	1	4.0	6	20	40	80
		route			15.56							14.3	14.3	15.2	17.1	18.8							
DM Saddle	Saddle 1	A																					
DM PT via BV & Gorge	Gorge closed	B																					
DM PT via MM & Pah	longer route	C																					
Opt SR 1 slow	Saddle 1	A	SH3/Cambridge	Terrace/Saddle	2.30	0 u	45	45	45	40	35	3.1	3.1	3.1	3.5	3.9	78	1	1.6	2.4	8	16	32
	Gorge open	B	Terrace/Saddle	E of Pohangina Br	1.31	0	80	80	70	65	65	1.0	1.0	1.1	1.2	1.2	105	1	2.0	3	10	20	40
	longer route	C	E of Pohangina Br	Saddle Rd nr Cook	5.02	8	70		65	55	50	4.3	4.3	4.6	5.5	6.0	60	4	1.0	1.5	5	10	20
		D	Saddle Rd nr Cook	Woodlands/Oxford	5.13	8	65		60	55	50	4.7	4.7	5.1	5.6	6.2	60	5	1.0	1.5	5	10	20
		E	Woodlands/Oxford	SH3/Woodlands	1.80	0	90	90	85	80	75	1.2	1.2	1.3	1.4	1.4	105	1	4.0	6	20	40	80
		route			15.56							14.3	14.3	15.2	17.1	18.8							



Update Factors and CO2 as %VOC and periods per year

											1.33	1.04	1.04	1.04	1.04	EEM Sep'11 update factors (TTC, VOC, AKC)				1.17
	TEM: - Traffic and Ec			Relevant vehicles per period					Day						4.0%			[illegible]		0.60
			PC	LCV	MCV	HCV1	HCVII	HCV	All		TTC uncong	VOC running	VOC rough	VOC spd chg	CO2	All	av length	TTC $/yr	VOC +CO2 $/yr	AKC $ per yr
Option	Route	Section																		
DM ManGge	Existing	A	5080	1000	285	150	420	570	6935		3710	3747	27	298	169	7951				0
	Gorge open	B	5080	1000	285	150	420	570	6935		1933	2657	194	372	134	5291	2.26			380,051
		C	5080	1000	285	150	420	570	6935		21355	15413	3497	559	810	41634				0
		D	5080	1000	285	150	420	570	6935		2043	1617	133	559	96	4448	6.54			3,454,589
		E	5080	1000	285	150	420	570	6935		7380	8273	640	745	402	17439	2.94			1,050,087
		route							6935		36421	31707	4491	2532	1611	76763	11.74	13,293,695	14,724,652	4,884,727
DM Saddle	Existing	A	75	15	15	10	35	45	150		315	229	2	16	10	571	2.30	114,837	93,676	0
	Gorge open	B	75	15	15	10	35	45	150		115	133	10	20	7	284	1.31	41,797	61,941	239,269
		C	75	15	15	10	35	45	150		694	831	99	81	42	1747		253,266	384,261	
		D	75	15	15	10	35	45	150		729	908	108	81	46	1872	10.68	266,129	417,200	798,486
		E	75	15	15	10	35	45	150		136	191	14	40	10	391	1.80	49,671	92,966	163,656
		route							150		1988	2291	232	239	115	4865	13.79	725,701	1,050,044	1,201,411
DM PT via BV & Gorge	Existing	A	45	15	0	5	10	15	75		0	0	0	5	0	6	0.00			0
	Gorge open	B	45	15	0	5	10	15	75		421	435	33	53	22	964	11.4			172,141
		C	45	15	0	5	10	15	75		365	534	69	7	25	1000				
		D	45	15	0	5	10	15	75		244	312	41	7	15	618	14.20			703,024
		E	45	15	0	5	10	15	75		93	118	9	13	6	239	2.94			11,414
									75		1123	1399	152	85	68	2827	28.54	409,846	621,926	886,579
DM PT via MM & Pah	Existing	A	295	75	10	5	15	20	400		0	0	0	13	1	14	0.00			0
	Gorge open	B	295	75	10	5	15	20	400		1802	1534	130	134	75	3675	11.4			918,086
		C	295	75	10	5	15	20	400		1633	1849	120	17	83	3702				
		D	295	75	10	5	15	20	400		1053	913	62	17	41	2086	15.90			635,189
		E	295	75	10	5	15	20	400		168	143	13	34	8	365	1.10			0
									400		4657	4439	325	215	207	9843	27.30	1,699,780	1,892,784	1,553,275
			Gge: LV	Saddle	PT north	PT east	Man Gorge trucks													
DM ManGge	Existing	A	0	0	0	0	0	0	0		0	0	0	0	0	0				0
	Gorge closed	B	0	0	0	0	0	0	0		0	0	0	0	0	0				0
		C	0	0	0	0	0	0	0		0	0	0	0	0	0				0
		D	0	0	0	0	0	0	0		0	0	0	0	0	0				0
		E	0	0	0	0	0	0	0		0	0	0	0	0	0				0
		route									0	0	0	0	0	0		0		0
			0.638	1.00	0.00	0.00	0.00	0.725		4650										
DM Saddle	Existing	A	3316	653	222	119	340	458.3	4649	3300	6548	4249	32	223	187	11238	2.30			0
	Gorge closed	B	3316	653	222	119	340	458.3	4649	670	2614	2448	200	278	122	5662	1.31			1,877,772
		C	3316	653	222	119	340	458.3	4649	240	16089	13101	2099	1113	679	33081				
		D	3316	653	222	119	340	458.3	4649	100	16413	14272	2296	1113	736	34830	10.68			6,266,480
		E	3316	653	222	119	340	458.3	4649	340	3148	3507	275	557	180	7667	1.80			1,284,361
		route							4649		44812	37576	4901	3284	1904	92478	13.79	16,356,524	17,398,057	9,428,614
			0.097	0.00	1.00	0.00	0.00	0.080		715										
DM PT via BV & Gorge	Existing	A	538	112	17	14	35	49	716	520	0	0	0	27	1	28	0.00			0
	Gorge closed	B	538	112	17	14	35	49	716	130	3293	2914	243	272	143	6866	11.40			666,526
		C	538	112	17	14	35	49	716	20	2890	3019	518	34	149	6610				
		D	538	112	17	14	35	49	716	15	1892	1772	309	34	88	4094	14.20			2,722,093
		E	538	112	17	14	35	49	716	30	742	787	63	68	38	1697	2.94			44,195
									716		8816	8492	1133	435	419	19296	28.54	3,217,994	3,824,937	3,432,814
			0.159	0.00	0.00	1.00	0.00	0.100		1450										
DM PT via MM & Pah	Existing	A	1103	234	39	20	57	77	1452	1100	0	0	0	50	2	52	0.00			0
	Gorge closed	B	1103	234	39	20	57	77	1452	235	6524	5617	476	497	274	13388	11.40			1,990,062
		C	1103	234	39	20	57	77	1452	35	5908	6816	439	62	304	13529				
		D	1103	234	39	20	57	77	1452	20	3814	3367	226	62	152	7621	15.90			1,376,850
		E	1103	234	39	20	57	77	1452	60	607	524	46	124	29	1330	1.10			0
			0.106	proportion SH3 trips not made alt routi for existing network if gorge closed				0.115	1452		16853	16324	1186	795	762	35921	27.30	6,151,376	6,959,645	3,366,912
	Existing	route	8	2	2	1	4	4.5	15	0.100	199	229	23	24	11	487	13.79	72,570	105,004	120,141
	Green Fields	route	5	2	0	1	1	1.5	8	0.100	112	140	15	8	7	283	28.54	40,985	62,193	88,658
	South (green)	route	74	19	3	1	4	5	100	0.250	1,164	1,110	81	54	52	2,461	27.30	424,945	473,196	388,319
DM Saddle	Existing	route	8	2	2	1	4	4.5	15	0.100	199	229	23	24	11	487	13.79	72,570	105,004	120,141
DM PT via BV & Gorge	Bridge	route	5	2	0	1	1	1.5	8	0.100	112	140	15	8	7	283	28.54	40,985	62,193	88,658
DM PT via MM & Pah	Blue	route	74	19	3	1	4	5	100	0.250	1,164	1,110	81	54	52	2,461	27.30	424,945	473,196	388,319
DM Saddle	Existing	route	8	2	2	1	4	4.5	15	0.100	199	229	23	24	11	487	13.79	72,570	105,004	120,141
DM PT via BV & Gorge	Tunnel	route	5	2	0	1	1	1.5	8	0.100	112	140	15	8	7	283	28.54	40,985	62,193	88,658
DM PT via MM & Pah	red	route	74	19	3	1	4	5	100	0.250	1,164	1,110	81	54	52	2,461	27.30	424,945	473,196	388,319
[illegible]	[illegible]	[illegible]	8	2	2	1	4	4.5	15	0.100	199	229	23	24	11	487	13.79	72,570	105,004	120,141
[illegible]	[illegible]	[illegible]	5	2	0	1	1	1.5	8	0.100	112	140	15	8	7	283	28.54	40,985	62,193	88,658
[illegible]	[illegible]	[illegible]	74	19	3	1	4	5	100	0.250	1,164	1,110	81	54	52	2,461	27.30	424,945	473,196	388,319
		O	262	70	8	8	20	28.5	368		1685	1540	11	15	65	3316	11.18			145,583
Opt Green	Green Fields	A	5409	1083	306	167	472	639	7438		4006	4071	29	327	184	8618				0
	South (green)	B	5409	1083	306	167	472	639	7438		0	0	0	409	17	426	1.37			263,614
	SR Byp: Green	C	5409	1083	306	167	472	639	7438		14367	20294	-7	0	844	35498	5.91			4,010,951
		D	5409	1083	306	167	472	639	7438		0	0	0	0	0	0	0.00			1
		E	5409	1083	306	167	472	639	7438		7963	8991	693	818	437	18903	2.94			1,131,887
		route	1.00	0.90	0.90	0.75	0.00	1.00			28022	34897	726	1570	1547	66762		10,228,023	14,139,974	5,552,035
		O	262	70	8	8	20	28.5	368		1685	1540	11	15	65	3316	11.18			145,583
Opt Bridge	Bridge	A	5409	1083	306	167	472	639	7438		4006	4071	29	327	184	8618				0
	blue	B	5409	1083	306	167	472	639	7438		1571	2174	158	409	114	4426	2.04			392,534
	SR Byp: Blue	C	5409	1083	306	167	472	639	7438		19267	17385	-7	614	748	38007	6.00			2,443,219
		D	5409	1083	306	167	472	639	7438		1324	1334	-1	0	55	2713	0.45			228,843
		E	5409	1083	306	167	472	639	7438		7963	8991	693	818	437	18903	2.94			1,131,887
		route	1.00	0.90	0.90	0.75	0.00	1.00			35816	35496	884	2183	1604	75983		13,072,955	14,660,919	4,342,066
		O	262	70	8	8	20	28.5	368		1685	1540	11	4	65	3305	11.18			145,583
Opt Tunnel	Tunnel	A	5409	1083	306	167	472	639	7438		4006	4071	29	327	184	8618				0
	red	B	5409	1083	306	167	472	639	7438		0	0	0	409	17	426	1.37			263,614
	SR Byp Red	C	5409	1083	306	167	472	639	7438		13079	17214	-7	0	716	31002	5.38			730,251
		D	5409	1083	306	167	472	639	7438		1483	1952	-1	0	81	3515	0.61			310,210
		E	5409	1083	306	167	472	639	7438		7963	8991	693	818	437	18903	2.94			1,131,887
		route	1.00	0.90	0.90	0.75	0.00	1.00			28216	33768	726	1559	1500	65770		10,299,008	13,706,868	2,581,544
		O	262	70	8	8	20	28.5	368		1685	1540	11	4	65	3305	11.18			145,583
[illegible]	Wolley opt C	A	5409	1083	306	167	472	639	7438		4006	4071	29	327	184	8618				0
	Yellow	B	5409	1083	306	167	472	639	7438		1407	1947	141	409	104	4008	1.97			379,065
	SR Byp: Orange	C	5409	1083	306	167	472	639	7438		14188	18529	-6	205	779	33695	4.90			5,320,788
		D	5409	1083	306	167	472	639	7438		13899	18464	-6	0	768	33124	5.10			5,537,963
		E	5409	1083	306	167	472	639	7438		4876	5392	424	818	276	11786	1.80			8,114,592
		route	1.00	0.90	0.90	0.75	0.00	1.00			40060	49943	594	1764	2176	94537		14,622,031	19,883,957	19,497,990
Opt SR 1 slow	Saddle 1	A	5155	1015	300	160	455	615	7085		9685	6219	46	314	274	16538				0
	Gorge closed	B	5155	1015	300	160	455	615	7085		3896	3579	295	393	178	8341	1.31			11,301,481
	longer route	C	5155	1015	300	160	455	615	7085		17425	18623	-6	785	807	37634	5.02			12,981,846
		D	5155	1015	300	160	455	615	7085		18863	18966	-6	982	830	39634	5.13			14,592,939
		E	5155	1015	300	160	455	615	7085		4699	5126	406	785	263	11279	1.80			7,730,001
		route	1.00	1.00	0.00	0.00	0.00	1.00			54568	52514	735	3259	2351	113426		19,917,160	21,483,442	46,606,267
DM Saddle	Saddle 1	A	0	0	0	0	0	0	0	0.000	0	0	0	0	0	0	13.79	0	0	0
DM PT via BV & Gorge	Gorge closed	B	45	15	0	5	10	15	75	1.000	1,123	1,399	152	85	68	2,827	28.54	409,846	621,926	886,579
DM PT via MM & Pah	longer route	C	295	75	10	5	15	20	400	1.000	4,657	4,439	325	215	207	9,843	27.30	1,699,780	1,892,784	1,553,275
Opt SR 1 slow	Saddle 1	A	75	15	15	10	35	45	150		315	229	2	16	10	571		114,837	93,676	0
	Gorge open	B	75	15	15	10	35	45	150		115	133	10	20	7	284	1.31	41,797	61,941	239,269
	longer route	C	75	15	15	10	35	45	150		530	830	0	40	36	1437	5.02	193,606	330,762	274,845
		D	75	15	15	10	35	45	150		560	847	0	51	37	1495	5.13	204,541	340,996	308,954
		E	75	15	15	10	35	45	150		136	191	14	40	10	391	1.80	49,671	92,966	163,656
		route	0.00	1.00	0.00	0.00	0.00	0.00			1656	2228	25	168	101	4178		804,453	920,341	986,724

APPENDIX G: Annual Benefits

Do Minimum (disbenefits arising from Gorge closure without network upgrade)

								LV: 3969	MCV: 222	HCV: 340	divert to Saddle Rd		LV: 63.8%	HV: 72.5%	1.5%	Traffic growth
Sens test	allday	0						LV: 650	MCV: 17	HCV: 35	divert to Pah Track N		LV: 9.7%	HV: 6.0%	0.5%	Ax growth
								LV: 1337	MCV: 39	HCV: 57	divert to Pah Track E		LV: 15.9%	HV: 10.0%	0.60	Ax exponent
discount	8%	Do Min	Gorge open - no network upgrade				Option	Gorge closed - no network upgrade					Benefits (negative values = disbenefit)			
millions $	1,000,000		TTC	VOC+CO2	AXC	Sum		TTC	VOC+CO2	AXC	Sum		TTC	VOC+CO2	AXC	Sum
0	1.000	1	16.13	18.29	8.53	42.94	1	25.73	28.18	16.23	70.14	2013	-9.60	-9.89	-7.70	-27.19
1	0.926	1	15.16	17.19	7.93	40.28	1	24.18	26.49	15.10	65.77	2014	-9.02	-9.30	-7.17	-25.48
2	0.857	1	14.24	16.15	7.38	37.78	1	22.72	24.89	14.05	61.66	2015	-8.47	-8.74	-6.67	-23.88
3	0.794	1	13.38	15.17	6.87	35.42	1	21.34	23.38	13.08	57.80	2016	-7.96	-8.21	-6.21	-22.37
4	0.735	1	12.57	14.25	6.39	33.21	1	20.04	21.96	12.17	54.17	2017	-7.48	-7.71	-5.77	-20.96
5	0.681	1	11.80	13.38	5.95	31.13	1	18.82	20.62	11.32	50.76	2018	-7.02	-7.24	-5.37	-19.63
6	0.630	1	11.08	12.56	5.53	29.18	1	17.67	19.36	10.53	47.56	2019	-6.59	-6.80	-5.00	-18.39
7	0.583	1	10.40	11.79	5.15	27.34	1	16.59	18.17	9.80	44.56	2020	-6.19	-6.38	-4.65	-17.22
8	0.540	1	9.76	11.07	4.79	25.62	1	15.57	17.05	9.12	41.74	2021	-5.81	-5.99	-4.33	-16.12
9	0.500	1	9.16	10.38	4.46	24.00	1	14.61	16.00	8.48	39.09	2022	-5.45	-5.62	-4.03	-15.09
10	0.463	1	8.59	9.74	4.15	22.48	1	13.70	15.01	7.89	36.61	2023	-5.11	-5.27	-3.75	-14.13
11	0.429	1	8.06	9.14	3.86	21.05	1	12.85	14.08	7.34	34.28	2024	-4.80	-4.94	-3.49	-13.22
12	0.397	1	7.56	8.57	3.59	19.72	1	12.06	13.21	6.83	32.09	2025	-4.50	-4.64	-3.24	-12.38
13	0.368	1	7.09	8.04	3.34	18.46	1	11.30	12.38	6.35	30.04	2026	-4.22	-4.35	-3.02	-11.58
14	0.340	1	6.64	7.53	3.11	17.28	1	10.60	11.61	5.91	28.12	2027	-3.95	-4.08	-2.81	-10.84
15	0.315	1	6.23	7.06	2.89	16.18	1	9.93	10.88	5.50	26.32	2028	-3.71	-3.82	-2.61	-10.14
16	0.292	1	5.84	6.62	2.69	15.15	1	9.31	10.20	5.12	24.63	2029	-3.47	-3.58	-2.43	-9.48
17	0.270	1	5.47	6.20	2.50	14.17	1	8.73	9.56	4.76	23.04	2030	-3.26	-3.36	-2.26	-8.87
18	0.250	1	5.13	5.81	2.33	13.26	1	8.18	8.96	4.43	21.56	2031	-3.05	-3.14	-2.10	-8.30
19	0.232	1	4.80	5.45	2.16	12.41	1	7.66	8.39	4.12	20.17	2032	-2.86	-2.95	-1.95	-7.76
20	0.215	1	4.50	5.10	2.01	11.61	1	7.18	7.86	3.83	18.87	2033	-2.68	-2.76	-1.82	-7.25
21	0.199	1	4.21	4.78	1.87	10.86	1	6.72	7.36	3.56	17.65	2034	-2.51	-2.58	-1.69	-6.78
22	0.184	1	3.95	4.47	1.74	10.16	1	6.29	6.89	3.31	16.50	2035	-2.35	-2.42	-1.57	-6.34
23	0.170	1	3.69	4.19	1.62	9.50	1	5.89	6.46	3.08	15.43	2036	-2.20	-2.27	-1.46	-5.93
24	0.158	1	3.46	3.92	1.51	8.89	1	5.52	6.04	2.87	14.43	2037	-2.06	-2.12	-1.36	-5.54
25	0.146	1	3.24	3.67	1.40	8.31	1	5.17	5.66	2.67	13.49	2038	-1.93	-1.99	-1.27	-5.18
26	0.135	1	3.03	3.44	1.30	7.77	1	4.83	5.30	2.48	12.61	2039	-1.80	-1.86	-1.18	-4.84
27	0.125	1	2.84	3.22	1.21	7.27	1	4.52	4.96	2.31	11.79	2040	-1.69	-1.74	-1.09	-4.52
28	0.116	1	2.65	3.01	1.13	6.79	1	4.23	4.64	2.14	11.02	2041	-1.58	-1.63	-1.02	-4.23
29	0.107	1	2.48	2.82	1.05	6.35	1	3.96	4.34	1.99	10.30	2042	-1.48	-1.52	-0.95	-3.95
30	0.099	0	0.00	0.00	0.00	0.00	0	0.00	0.00	0.00	0.00	2043	0.00	0.00	0.00	0.00
31	0.092	0	0.00	0.00	0.00	0.00	0	0.00	0.00	0.00	0.00	2044	0.00	0.00	0.00	0.00
32	0.085	0	0.00	0.00	0.00	0.00	0	0.00	0.00	0.00	0.00	2045	0.00	0.00	0.00	0.00
33	0.079	0	0.00	0.00	0.00	0.00	0	0.00	0.00	0.00	0.00	2046	0.00	0.00	0.00	0.00
34	0.073	0	0.00	0.00	0.00	0.00	0	0.00	0.00	0.00	0.00	2047	0.00	0.00	0.00	0.00
35	0.068	0	0.00	0.00	0.00	0.00	0	0.00	0.00	0.00	0.00	2048	0.00	0.00	0.00	0.00
$ million	annual	30	223.14	253.02	108.43	584.58	30	355.90	389.89	206.38	952.17		-132.77	-136.87	-97.95	-367.58
$ thousand	daily	365	611.3	693.2	297.1	1601.6		975.1	1068.2	565.4	2608.7		-363.7	-375.0	-268.4	-1007.1
0	1.000	1	16.13	18.29	8.53	42.94	1	25.73	28.18	16.23	70.14	2013	-9.60	-9.89	-7.70	-27.19
$ thousand	T0 day	365	44.2	50.1	23.4	117.7		70.5	77.2	44.5	192.2		-26.3	-27.1	-21.1	[redacted]

This indicates that the disbenefits of closing the Gorge are approximately $74,500 per day excluding reinstatement costs.

Greenfields option

							Length	5.91	LV vol,spd	6493	100	90%	divert from Saddle Rd		1.5%	Traffic growth
Sens test	allday	0					Grade	4%	MCV: vol,spd	306	95	90%	divert from Pah Track N		0.5%	Ax growth
							Traffic	7438	HCV: vol,spd	639	90,90	75%	divert from Pah Track E		368	Diverted
discount	8%	Do Min	Gorge closed - no network upgrade				Option	Greenfields Green route					Benefits (negative values = disbenefit)			
millions $	1,000,000		TTC	VOC+CO2	AXC	Sum		TTC	VOC+CO2	AXC	Sum		TTC	VOC+CO2	AXC	Sum
0	1.000	1	25.73	28.18	16.23	70.14	0	25.73	28.18	16.23	70.14	2013	0.00	0.00	0.00	0.00
1	0.926	1	24.18	26.49	15.10	65.77	0	24.18	26.49	15.10	65.77	2014	0.00	0.00	0.00	0.00
2	0.857	1	22.72	24.89	14.05	61.66	0	22.72	24.89	14.05	61.66	2015	0.00	0.00	0.00	0.00
3	0.794	1	21.34	23.38	13.08	57.80	0	21.34	23.38	13.08	57.80	2016	0.00	0.00	0.00	0.00
4	0.735	1	20.04	21.96	12.17	54.17	0	20.04	21.96	12.17	54.17	2017	0.00	0.00	0.00	0.00
5	0.681	1	18.82	20.62	11.32	50.76	0	18.82	20.62	11.32	50.76	2018	0.00	0.00	0.00	0.00
6	0.630	1	17.67	19.36	10.53	47.56	0	17.67	19.36	10.53	47.56	2019	0.00	0.00	0.00	0.00
7	0.583	0.5	8.29	9.09	4.90	22.28	0.5	3.47	4.76	1.86	10.09	2020	4.82	4.32	3.04	12.19
8	0.540	1	15.57	17.05	9.12	41.74	1	6.51	8.94	3.46	18.91	2021	9.05	8.11	5.66	22.82
9	0.500	1	14.61	16.00	8.48	39.09	1	6.11	8.39	3.21	17.72	2022	8.49	7.61	5.27	21.37
10	0.463	1	13.70	15.01	7.89	36.61	1	5.74	7.87	2.99	16.60	2023	7.97	7.14	4.90	20.01
11	0.429	1	12.85	14.08	7.34	34.28	1	5.38	7.38	2.78	15.55	2024	7.47	6.70	4.56	18.73
12	0.397	1	12.06	13.21	6.83	32.09	1	5.05	6.93	2.59	14.56	2025	7.01	6.28	4.24	17.53
13	0.368	1	11.30	12.38	6.35	30.04	1	4.73	6.49	2.41	13.63	2026	6.57	5.89	3.95	16.41
14	0.340	1	10.60	11.61	5.91	28.12	1	4.44	6.09	2.24	12.76	2027	6.16	5.52	3.67	15.36
15	0.315	1	9.93	10.88	5.50	26.32	1	4.16	5.71	2.08	11.95	2028	5.78	5.18	3.42	14.37
16	0.292	1	9.31	10.20	5.12	24.63	1	3.90	5.35	1.94	11.19	2029	5.41	4.85	3.18	13.44
17	0.270	1	8.73	9.56	4.76	23.04	1	3.65	5.01	1.80	10.47	2030	5.07	4.55	2.96	12.58
18	0.250	1	8.18	8.96	4.43	21.56	1	3.42	4.70	1.68	9.80	2031	4.75	4.26	2.75	11.76
19	0.232	1	7.66	8.39	4.12	20.17	1	3.21	4.40	1.56	9.17	2032	4.45	3.99	2.56	11.00
20	0.215	1	7.18	7.86	3.83	18.87	1	3.00	4.12	1.45	8.58	2033	4.17	3.74	2.38	10.29
21	0.199	1	6.72	7.36	3.56	17.65	1	2.81	3.86	1.35	8.02	2034	3.91	3.50	2.21	9.62
22	0.184	1	6.29	6.89	3.31	16.50	1	2.63	3.62	1.26	7.51	2035	3.66	3.28	2.06	9.00
23	0.170	1	5.89	6.46	3.08	15.43	1	2.47	3.39	1.17	7.02	2036	3.43	3.07	1.91	8.41
24	0.158	1	5.52	6.04	2.87	14.43	1	2.31	3.17	1.09	6.57	2037	3.21	2.87	1.78	7.86
25	0.146	1	5.17	5.66	2.67	13.49	1	2.16	2.97	1.01	6.14	2038	3.00	2.69	1.66	7.35
26	0.135	1	4.83	5.30	2.48	12.61	1	2.02	2.78	0.94	5.74	2039	2.81	2.52	1.54	6.87
27	0.125	1	4.52	4.96	2.31	11.79	1	1.89	2.60	0.87	5.37	2040	2.63	2.36	1.43	6.42
28	0.116	1	4.23	4.64	2.14	11.02	1	1.77	2.43	0.81	5.02	2041	2.46	2.21	1.33	6.00
29	0.107	1	3.96	4.34	1.99	10.30	1	1.66	2.28	0.76	4.69	2042	2.30	2.06	1.24	5.61
30	0.099	1	3.71	4.06	1.85	9.62	1	1.55	2.13	0.70	4.38	2043	2.16	1.93	1.15	5.24
31	0.092	1	3.47	3.80	1.72	8.99	1	1.45	1.99	0.65	4.10	2044	2.02	1.81	1.07	4.89
32	0.085	1	3.24	3.55	1.60	8.40	1	1.36	1.86	0.61	3.83	2045	1.89	1.69	1.00	4.57
33	0.079	0.5	1.52	1.66	0.75	3.92	0.5	0.63	0.87	0.28	1.79	2046	0.88	0.79	0.46	2.14
34	0.073	0	0.00	0.00	0.00	0.00	0	0.00	0.00	0.00	0.00	2047	0.00	0.00	0.00	0.00
35	0.068	0	0.00	0.00	0.00	0.00	0	0.00	0.00	0.00	0.00	2048	0.00	0.00	0.00	0.00
$ million	annual	33	359.54	393.88	207.41	960.83	26	237.99	284.97	136.03	658.99		121.56	108.91	71.38	301.84
$ thousand	daily	365	985.1	1079.1	568.2	2632.4		652.0	780.8	372.7	1805.4		333.0	298.4	195.6	827.0
													40.3%	36.1%	23.6%	
0	1.000	1	25.73	28.18	16.23	70.14	1	10.77	14.78	6.15	31.70	2013	14.96	13.40	10.08	38.44
$ thousand	T0 day	365	70.5	77.2	44.5	192.2		29.5	40.5	16.8	86.8		41.0	36.7	27.6	105.3

Bridging option

Length	6.00	LV: vol,spd	6493	80	90%	divert from Saddle Rd	1.5%	Traffic growth
Grade	2%	MCV: vol,spd	306	70	90%	divert from Pah Track N	0.5%	Ax growth
Traffic	7438	HCV: vol,spd	639	55,55	75%	divert from Pah Track E	368	Diverted

Sens test allday 0

discount	8%	Do Min	Gorge closed - no network upgrade				Option	Bridging route					Benefits (negative values = disbenefit)			
millions $	1,000,000		TTC	VOC+CO2	AXC	Sum		TTC	VOC+CO2	AXC	Sum		TTC	VOC+CO2	AXC	Sum
0	1.000	1	25.73	28.18	16.23	70.14	0	25.73	28.18	16.23	70.14	2013	0.00	0.00	0.00	0.00
1	0.926	1	24.18	26.49	15.10	65.77	0	24.18	26.49	15.10	65.77	2014	0.00	0.00	0.00	0.00
2	0.857	1	22.72	24.89	14.05	61.66	0	22.72	24.89	14.05	61.66	2015	0.00	0.00	0.00	0.00
3	0.794	1	21.34	23.38	13.08	57.80	0	21.34	23.38	13.08	57.80	2016	0.00	0.00	0.00	0.00
4	0.735	1	20.04	21.96	12.17	54.17	0	20.04	21.96	12.17	54.17	2017	0.00	0.00	0.00	0.00
5	0.681	1	18.82	20.62	11.32	50.76	0	18.82	20.62	11.32	50.76	2018	0.00	0.00	0.00	0.00
6	0.630	1	17.67	19.36	10.53	47.56	0	17.67	19.36	10.53	47.56	2019	0.00	0.00	0.00	0.00
7	0.583	1	16.59	18.17	9.80	44.56	0	16.59	18.17	9.80	44.56	2020	0.00	0.00	0.00	0.00
8	0.540	1	15.57	17.05	9.12	41.74	1	8.24	9.26	2.78	20.27	2021	7.33	7.79	6.34	21.47
9	0.500	1	14.61	16.00	8.48	39.09	1	7.73	8.69	2.58	19.00	2022	6.88	7.31	5.90	20.09
10	0.463	1	13.70	15.01	7.89	36.61	1	7.25	8.15	2.40	17.80	2023	6.45	6.86	5.49	18.81
11	0.429	1	12.85	14.08	7.34	34.28	1	6.80	7.65	2.23	16.68	2024	6.05	6.44	5.11	17.60
12	0.397	1	12.06	13.21	6.83	32.09	1	6.38	7.17	2.08	15.63	2025	5.68	6.04	4.75	16.46
13	0.368	1	11.30	12.38	6.35	30.04	1	5.98	6.72	1.93	14.64	2026	5.32	5.66	4.42	15.40
14	0.340	1	10.60	11.61	5.91	28.12	1	5.61	6.30	1.80	13.71	2027	4.99	5.31	4.11	14.41
15	0.315	1	9.93	10.88	5.50	26.32	1	5.26	5.91	1.67	12.84	2028	4.68	4.97	3.83	13.48
16	0.292	1	9.31	10.20	5.12	24.63	1	4.93	5.54	1.56	12.02	2029	4.38	4.66	3.56	12.61
17	0.270	1	8.73	9.56	4.76	23.04	1	4.62	5.19	1.45	11.26	2030	4.11	4.37	3.31	11.79
18	0.250	1	8.18	8.96	4.43	21.56	1	4.33	4.86	1.35	10.54	2031	3.85	4.09	3.08	11.02
19	0.232	1	7.66	8.39	4.12	20.17	1	4.05	4.56	1.25	9.86	2032	3.61	3.84	2.86	10.31
20	0.215	1	7.18	7.86	3.83	18.87	1	3.80	4.27	1.17	9.23	2033	3.38	3.59	2.66	9.64
21	0.199	1	6.72	7.36	3.56	17.65	1	3.56	4.00	1.08	8.64	2034	3.16	3.37	2.48	9.01
22	0.184	1	6.29	6.89	3.31	16.50	1	3.33	3.74	1.01	8.08	2035	2.96	3.15	2.30	8.42
23	0.170	1	5.89	6.46	3.08	15.43	1	3.12	3.51	0.94	7.56	2036	2.78	2.95	2.14	7.87
24	0.158	1	5.52	6.04	2.87	14.43	1	2.92	3.28	0.87	7.07	2037	2.60	2.76	1.99	7.35
25	0.146	1	5.17	5.66	2.67	13.49	1	2.73	3.07	0.81	6.62	2038	2.43	2.59	1.85	6.87
26	0.135	1	4.83	5.30	2.48	12.61	1	2.56	2.88	0.75	6.19	2039	2.28	2.42	1.72	6.42
27	0.125	1	4.52	4.96	2.31	11.79	1	2.39	2.69	0.70	5.79	2040	2.13	2.27	1.60	6.00
28	0.116	1	4.23	4.64	2.14	11.02	1	2.24	2.52	0.65	5.41	2041	1.99	2.12	1.49	5.61
29	0.107	1	3.96	4.34	1.99	10.30	1	2.10	2.36	0.61	5.06	2042	1.87	1.98	1.39	5.24
30	0.099	1	3.71	4.06	1.85	9.62	1	1.96	2.20	0.56	4.73	2043	1.75	1.86	1.29	4.89
31	0.092	1	3.47	3.80	1.72	8.99	1	1.83	2.06	0.52	4.42	2044	1.63	1.74	1.20	4.57
32	0.085	1	3.24	3.55	1.60	8.40	1	1.72	1.93	0.49	4.13	2045	1.53	1.62	1.12	4.27
33	0.079	1	3.03	3.32	1.49	7.85	1	1.61	1.80	0.45	3.86	2046	1.43	1.52	1.04	3.99
34	0.073	0	0.00	0.00	0.00	0.00	0	0.00	0.00	0.00	0.00	2047	0.00	0.00	0.00	0.00
35	0.068	0	0.00	0.00	0.00	0.00	0	0.00	0.00	0.00	0.00	2048	0.00	0.00	0.00	0.00
$ million	annual	34	369.36	404.63	213.05	987.03	26	274.11	303.35	135.99	713.45		95.25	101.28	77.06	273.59
$ thousand	daily	365	1011.9	1108.6	583.7	2704.2		751.0	831.1	372.6	1954.6		261.0	277.5	211.1	749.6
													34.8%	37.0%	28.2%	
0	1.000	1	25.73	28.18	16.23	70.14	1	13.61	15.30	4.94	33.85	2013	12.11	12.88	11.29	36.28
$ thousand	T0 day	365	70.5	77.2	44.5	192.2		37.3	41.9	13.5	92.7		33.2	35.3	30.9	99.4

Length excludes the 0.60 km along existing SH3 from the SH3/57 intersection

Tunnel option

Length	5.38	LV: vol,spd	6493	100	90%	divert from Saddle Rd	1.5%	Traffic growth
Grade	2%	MCV: vol,spd	306	95	90%	divert from Pah Track N	0.5%	Ax growth
Traffic	7438	HCV: vol,spd	639	90,90	75%	divert from Pah Track E	368	Diverted

Sens test allday 0

discount	8%	Do Min	Gorge closed - no network upgrade				Option	Tunnel route					Benefits (negative values = disbenefit)			
millions $	1,000,000		TTC	VOC+CO2	AXC	Sum		TTC	VOC+CO2	AXC	Sum		TTC	VOC+CO2	AXC	Sum
0	1.000	1	25.73	28.18	16.23	70.14	0	25.73	28.18	16.23	70.14	2013	0.00	0.00	0.00	0.00
1	0.926	1	24.18	26.49	15.10	65.77	0	24.18	26.49	15.10	65.77	2014	0.00	0.00	0.00	0.00
2	0.857	1	22.72	24.89	14.05	61.66	0	22.72	24.89	14.05	61.66	2015	0.00	0.00	0.00	0.00
3	0.794	1	21.34	23.38	13.08	57.80	0	21.34	23.38	13.08	57.80	2016	0.00	0.00	0.00	0.00
4	0.735	1	20.04	21.96	12.17	54.17	0	20.04	21.96	12.17	54.17	2017	0.00	0.00	0.00	0.00
5	0.681	1	18.82	20.62	11.32	50.76	0	18.82	20.62	11.32	50.76	2018	0.00	0.00	0.00	0.00
6	0.630	1	17.67	19.36	10.53	47.56	0	17.67	19.36	10.53	47.56	2019	0.00	0.00	0.00	0.00
7	0.583	1	16.59	18.17	9.80	44.56	0	16.59	18.17	9.80	44.56	2020	0.00	0.00	0.00	0.00
8	0.540	1	15.57	17.05	9.12	41.74	0	15.57	17.05	9.12	41.74	2021	0.00	0.00	0.00	0.00
9	0.500	1	14.61	16.00	8.48	39.09	0	14.61	16.00	8.48	39.09	2022	0.00	0.00	0.00	0.00
10	0.463	1	13.70	15.01	7.89	36.61	1	5.77	7.64	1.55	14.96	2023	7.93	7.37	6.35	21.65
11	0.429	1	12.85	14.08	7.34	34.28	1	5.41	7.17	1.44	14.02	2024	7.44	6.91	5.90	20.26
12	0.397	1	12.06	13.21	6.83	32.09	1	5.08	6.72	1.34	13.14	2025	6.98	6.48	5.49	18.95
13	0.368	1	11.30	12.38	6.35	30.04	1	4.76	6.30	1.24	12.31	2026	6.54	6.08	5.11	17.73
14	0.340	1	10.60	11.61	5.91	28.12	1	4.46	5.91	1.16	11.53	2027	6.13	5.70	4.75	16.59
15	0.315	1	9.93	10.88	5.50	26.32	1	4.19	5.54	1.08	10.80	2028	5.75	5.34	4.42	15.51
16	0.292	1	9.31	10.20	5.12	24.63	1	3.92	5.19	1.00	10.12	2029	5.39	5.01	4.11	14.51
17	0.270	1	8.73	9.56	4.76	23.04	1	3.68	4.87	0.93	9.47	2030	5.05	4.69	3.83	13.57
18	0.250	1	8.18	8.96	4.43	21.56	1	3.44	4.56	0.87	8.87	2031	4.73	4.40	3.56	12.69
19	0.232	1	7.66	8.39	4.12	20.17	1	3.23	4.27	0.81	8.31	2032	4.43	4.12	3.31	11.86
20	0.215	1	7.18	7.86	3.83	18.87	1	3.02	4.00	0.75	7.77	2033	4.15	3.86	3.08	11.09
21	0.199	1	6.72	7.36	3.56	17.65	1	2.83	3.75	0.70	7.28	2034	3.89	3.61	2.86	10.37
22	0.184	1	6.29	6.89	3.31	16.50	1	2.65	3.51	0.65	6.81	2035	3.64	3.38	2.66	9.69
23	0.170	1	5.89	6.46	3.08	15.43	1	2.48	3.29	0.60	6.37	2036	3.41	3.17	2.48	9.06
24	0.158	1	5.52	6.04	2.87	14.43	1	2.32	3.08	0.56	5.96	2037	3.19	2.97	2.30	8.47
25	0.146	1	5.17	5.66	2.67	13.49	1	2.18	2.88	0.52	5.58	2038	2.99	2.78	2.14	7.91
26	0.135	1	4.83	5.30	2.48	12.61	1	2.04	2.70	0.49	5.22	2039	2.80	2.60	1.99	7.39
27	0.125	1	4.52	4.96	2.31	11.79	1	1.91	2.52	0.45	4.88	2040	2.62	2.43	1.85	6.91
28	0.116	1	4.23	4.64	2.14	11.02	1	1.78	2.36	0.42	4.57	2041	2.45	2.28	1.72	6.45
29	0.107	1	3.96	4.34	1.99	10.30	1	1.67	2.21	0.39	4.27	2042	2.29	2.13	1.60	6.03
30	0.099	1	3.71	4.06	1.85	9.62	1	1.56	2.07	0.36	3.99	2043	2.15	1.99	1.49	5.63
31	0.092	1	3.47	3.80	1.72	8.99	1	1.46	1.93	0.34	3.73	2044	2.01	1.87	1.39	5.26
32	0.085	1	3.24	3.55	1.60	8.40	1	1.37	1.81	0.31	3.49	2045	1.88	1.74	1.29	4.91
33	0.079	1	3.03	3.32	1.49	7.85	1	1.28	1.69	0.29	3.26	2046	1.76	1.63	1.20	4.59
34	0.073	1	2.84	3.11	1.39	7.33	1	1.20	1.58	0.27	3.05	2047	1.64	1.53	1.12	4.28
35	0.068	1	2.65	2.91	1.29	6.85	1	1.12	1.48	0.25	2.85	2048	1.54	1.43	1.04	4.00
$ million	annual	36	374.85	410.64	215.73	1001.22	26	272.07	315.14	138.66	725.86		102.78	95.51	77.07	275.35
$ thousand	daily	365	1027.0	1125.0	591.0	2743.1		745.4	863.4	379.9	1988.7		281.6	261.7	211.2	754.4
													37.3%	34.7%	28.0%	
0	1.000	1	25.73	28.18	16.23	70.14	1	10.84	14.35	3.18	28.36	2013	14.89	13.84	13.05	41.77
$ thousand	T0 day	365	70.5	77.2	44.5	192.2		29.7	39.3	8.7	77.7		40.8	37.9	35.8	114.4

Worley C option

Sens test allday 0

Length	10.00	LV: vol,spd	6493	90	90%	divert from Saddle Rd	1.5%	Traffic growth
Grade	7,6	MCV: vol,spd	306	75	90%	divert from Pah Track N	0.5%	Ax growth
Traffic	7438	HCV: vol,spd	639	60,60	75%	divert from Pah Track E	368	Diverted

discount	8%	Do Min	Gorge closed - no network upgrade				Option	Worley option C route					Benefits (negative values = disbenefit)			
millions $	1,000,000		TTC	VOC+CO2	AXC	Sum		TTC	VOC+CO2	AXC	Sum		TTC	VOC+CO2	AXC	Sum
0	1.000	1	25.73	28.18	16.23	70.14	0	25.73	28.18	16.23	70.14	2013	0.00	0.00	0.00	0.00
1	0.926	1	24.18	26.49	15.10	65.77	0	24.18	26.49	15.10	65.77	2014	0.00	0.00	0.00	0.00
2	0.857	1	22.72	24.89	14.05	61.66	0	22.72	24.89	14.05	61.66	2015	0.00	0.00	0.00	0.00
3	0.794	1	21.34	23.38	13.08	57.80	0	21.34	23.38	13.08	57.80	2016	0.00	0.00	0.00	0.00
4	0.735	1	20.04	21.96	12.17	54.17	0	20.04	21.96	12.17	54.17	2017	0.00	0.00	0.00	0.00
5	0.681	1	18.82	20.62	11.32	50.76	0	18.82	20.62	11.32	50.76	2018	0.00	0.00	0.00	0.00
6	0.630	1	17.67	19.36	10.53	47.56	0	17.67	19.36	10.53	47.56	2019	0.00	0.00	0.00	0.00
7	0.583	1	16.59	18.17	9.80	44.56	0	16.59	18.17	9.80	44.56	2020	0.00	0.00	0.00	0.00
8	0.540	1	15.57	17.05	9.12	41.74	0	15.57	17.05	9.12	41.74	2021	0.00	0.00	0.00	0.00
9	0.500	0.5	7.30	8.00	4.24	19.55	0.5	4.30	5.83	5.25	15.38	2022	3.00	2.17	-1.01	4.16
10	0.463	1	13.70	15.01	7.89	36.61	1	8.08	10.93	9.77	28.78	2023	5.63	4.08	-1.88	7.83
11	0.429	1	12.85	14.08	7.34	34.28	1	7.57	10.25	9.09	26.92	2024	5.28	3.83	-1.75	7.36
12	0.397	1	12.06	13.21	6.83	32.09	1	7.10	9.62	8.46	25.18	2025	4.95	3.59	-1.63	6.91
13	0.368	1	11.30	12.38	6.35	30.04	1	6.66	9.02	7.87	23.55	2026	4.64	3.37	-1.51	6.49
14	0.340	1	10.60	11.61	5.91	28.12	1	6.25	8.46	7.32	22.02	2027	4.35	3.15	-1.41	6.10
15	0.315	1	9.93	10.88	5.50	26.32	1	5.85	7.93	6.81	20.59	2028	4.08	2.96	-1.31	5.73
16	0.292	1	9.31	10.20	5.12	24.63	1	5.49	7.43	6.33	19.25	2029	3.82	2.77	-1.22	5.38
17	0.270	1	8.73	9.56	4.76	23.04	1	5.14	6.96	5.89	18.00	2030	3.58	2.60	-1.13	5.05
18	0.250	1	8.18	8.96	4.43	21.56	1	4.82	6.52	5.48	16.82	2031	3.36	2.43	-1.05	4.74
19	0.232	1	7.66	8.39	4.12	20.17	1	4.51	6.11	5.10	15.72	2032	3.15	2.28	-0.98	4.44
20	0.215	1	7.18	7.86	3.83	18.87	1	4.23	5.72	4.74	14.70	2033	2.95	2.14	-0.91	4.17
21	0.199	1	6.72	7.36	3.56	17.65	1	3.96	5.36	4.41	13.73	2034	2.76	2.00	-0.85	3.91
22	0.184	1	6.29	6.89	3.31	16.50	1	3.71	5.02	4.10	12.83	2035	2.58	1.87	-0.79	3.67
23	0.170	1	5.89	6.46	3.08	15.43	1	3.47	4.70	3.82	11.99	2036	2.42	1.75	-0.73	3.44
24	0.158	1	5.52	6.04	2.87	14.43	1	3.25	4.40	3.55	11.20	2037	2.27	1.64	-0.68	3.23
25	0.146	1	5.17	5.66	2.67	13.49	1	3.04	4.12	3.30	10.47	2038	2.12	1.54	-0.64	3.02
26	0.135	1	4.83	5.30	2.48	12.61	1	2.85	3.86	3.07	9.78	2039	1.99	1.44	-0.59	2.83
27	0.125	1	4.52	4.96	2.31	11.79	1	2.67	3.61	2.86	9.13	2040	1.86	1.35	-0.55	2.66
28	0.116	1	4.23	4.64	2.14	11.02	1	2.50	3.38	2.66	8.53	2041	1.74	1.26	-0.51	2.49
29	0.107	1	3.96	4.34	1.99	10.30	1	2.33	3.16	2.47	7.97	2042	1.63	1.18	-0.48	2.33
30	0.099	1	3.71	4.06	1.85	9.62	1	2.18	2.96	2.30	7.44	2043	1.52	1.10	-0.44	2.18
31	0.092	1	3.47	3.80	1.72	8.99	1	2.04	2.77	2.14	6.95	2044	1.42	1.03	-0.41	2.05
32	0.085	1	3.24	3.55	1.60	8.40	1	1.91	2.59	1.99	6.49	2045	1.33	0.97	-0.38	1.92
33	0.079	1	3.03	3.32	1.49	7.85	1	1.79	2.42	1.85	6.06	2046	1.25	0.90	-0.36	1.79
34	0.073	1	2.84	3.11	1.39	7.33	1	1.67	2.26	1.72	5.65	2047	1.17	0.84	-0.33	1.68
35	0.068	0.5	1.33	1.45	0.64	3.42	0.5	0.78	1.06	0.80	2.64	2048	0.54	0.39	-0.15	0.79
$ million	annual	35	366.22	401.19	210.84	978.25	26	290.83	346.54	234.54	871.91		75.39	54.64	-23.69	106.34
$ thousand	daily	365	1003.3	1099.1	577.6	2680.1		796.8	949.4	642.6	2388.8		206.5	149.7	-64.9	291.3
													70.9%	51.4%	-22.3%	
0	1.000	1	25.73	28.18	16.23	70.14	1	15.16	20.52	20.10	55.78	2013	10.57	7.66	-3.87	14.36
$ thousand	T0 day	365	70.5	77.2	44.5	192.2		41.5	56.2	55.1	152.8		28.9	21.0	-10.6	39.3

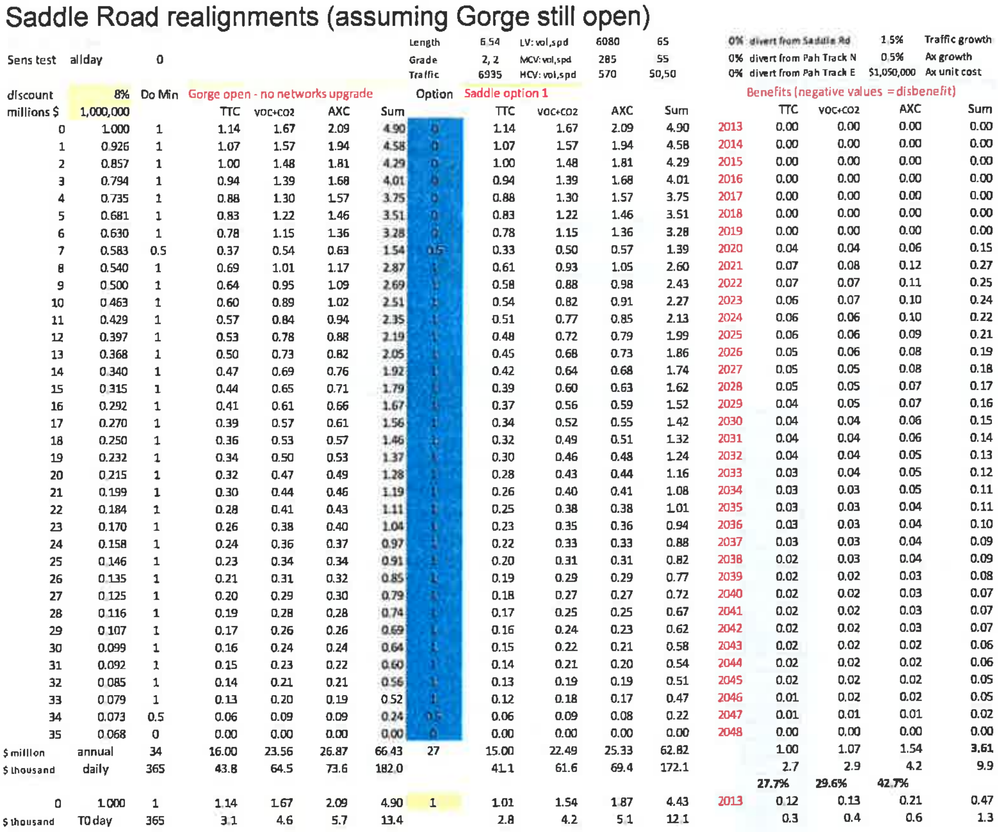
Length excludes the 0.60 km along existing SH3 from the SH3/57 intersection

Saddle Road realignments

Sens test allday 0

Length	10.15	LV: vol,spd	6170	70	100%	divert from Saddle Rd	1.5%	Traffic growth
Grade	8, 8	MCV: vol,spd	300	65	0%	divert from Pah Track N	0.5%	Ax growth
Traffic	7085	HCV: vol,spd	615	50,50	0%	divert from Pah Track E	$1,050,000	Ax unit cost

discount	8%	Do Min	Gorge closed - no network upgrade				Option	Saddle option 1					Benefits (negative values = disbenefit)			
millions $	1,000,000		TTC	VOC+CO2	AXC	Sum		TTC	VOC+CO2	AXC	Sum		TTC	VOC+CO2	AXC	Sum
0	1.000	1	25.73	28.18	16.23	70.14	0	25.73	28.18	16.23	70.14	2013	0.00	0.00	0.00	0.00
1	0.926	1	24.18	26.49	15.10	65.77	0	24.18	26.49	15.10	65.77	2014	0.00	0.00	0.00	0.00
2	0.857	1	22.72	24.89	14.05	61.66	0	22.72	24.89	14.05	61.66	2015	0.00	0.00	0.00	0.00
3	0.794	1	21.34	23.38	13.08	57.80	0	21.34	23.38	13.08	57.80	2016	0.00	0.00	0.00	0.00
4	0.735	1	20.04	21.96	12.17	54.17	0	20.04	21.96	12.17	54.17	2017	0.00	0.00	0.00	0.00
5	0.681	1	18.82	20.62	11.32	50.76	0	18.82	20.62	11.32	50.76	2018	0.00	0.00	0.00	0.00
6	0.630	1	17.67	19.36	10.53	47.56	0	17.67	19.36	10.53	47.56	2019	0.00	0.00	0.00	0.00
7	0.583	0.5	8.29	9.09	4.90	22.28	0.5	7.10	7.74	14.81	29.65	2020	1.19	1.35	-9.91	-7.37
8	0.540	1	15.57	17.05	9.12	41.74	1	13.33	14.52	27.56	55.41	2021	2.24	2.53	-18.44	-13.67
9	0.500	1	14.61	16.00	8.48	39.09	1	12.51	13.63	25.64	51.77	2022	2.10	2.38	-17.16	-12.68
10	0.463	1	13.70	15.01	7.89	36.61	1	11.73	12.78	23.85	48.37	2023	1.97	2.23	-15.96	-11.76
11	0.429	1	12.85	14.08	7.34	34.28	1	11.01	11.99	22.19	45.19	2024	1.85	2.09	-14.85	-10.91
12	0.397	1	12.06	13.21	6.83	32.09	1	10.32	11.25	20.65	42.21	2025	1.73	1.96	-13.81	-10.12
13	0.368	1	11.30	12.38	6.35	30.04	1	9.68	10.54	19.21	39.43	2026	1.63	1.84	-12.85	-9.39
14	0.340	1	10.60	11.61	5.91	28.12	1	9.07	9.89	17.87	36.83	2027	1.52	1.72	-11.96	-8.71
15	0.315	1	9.93	10.88	5.50	26.32	1	8.51	9.27	16.62	34.39	2028	1.43	1.62	-11.12	-8.08
16	0.292	1	9.31	10.20	5.12	24.63	1	7.97	8.69	15.46	32.12	2029	1.34	1.51	-10.35	-7.49
17	0.270	1	8.73	9.56	4.76	23.04	1	7.47	8.14	14.38	29.99	2030	1.25	1.42	-9.62	-6.95
18	0.250	1	8.18	8.96	4.43	21.56	1	7.00	7.63	13.38	28.01	2031	1.18	1.33	-8.95	-6.45
19	0.232	1	7.66	8.39	4.12	20.17	1	6.56	7.15	12.44	26.15	2032	1.10	1.25	-8.33	-5.98
20	0.215	1	7.18	7.86	3.83	18.87	1	6.14	6.69	11.58	24.41	2033	1.03	1.17	-7.75	-5.55
21	0.199	1	6.72	7.36	3.56	17.65	1	5.75	6.27	10.77	22.79	2034	0.97	1.09	-7.20	-5.14
22	0.184	1	6.29	6.89	3.31	16.50	1	5.39	5.87	10.01	21.27	2035	0.90	1.02	-6.70	-4.77
23	0.170	1	5.89	6.46	3.08	15.43	1	5.05	5.50	9.31	19.86	2036	0.85	0.96	-6.23	-4.43
24	0.158	1	5.52	6.04	2.87	14.43	1	4.72	5.15	8.66	18.53	2037	0.79	0.90	-5.80	-4.11
25	0.146	1	5.17	5.66	2.67	13.49	1	4.42	4.82	8.06	17.30	2038	0.74	0.84	-5.39	-3.81
26	0.135	1	4.83	5.30	2.48	12.61	1	4.14	4.51	7.49	16.14	2039	0.70	0.79	-5.01	-3.53
27	0.125	1	4.52	4.96	2.31	11.79	1	3.87	4.22	6.97	15.06	2040	0.65	0.74	-4.66	-3.28
28	0.116	1	4.23	4.64	2.14	11.02	1	3.63	3.95	6.48	14.06	2041	0.61	0.69	-4.34	-3.04
29	0.107	1	3.96	4.34	1.99	10.30	1	3.39	3.70	6.03	13.12	2042	0.57	0.64	-4.03	-2.82
30	0.099	1	3.71	4.06	1.85	9.62	1	3.17	3.46	5.61	12.24	2043	0.53	0.60	-3.75	-2.61
31	0.092	1	3.47	3.80	1.72	8.99	1	2.97	3.24	5.21	11.42	2044	0.50	0.56	-3.49	-2.43
32	0.085	1	3.24	3.55	1.60	8.40	1	2.78	3.03	4.85	10.65	2045	0.47	0.53	-3.24	-2.25
33	0.079	1	3.03	3.32	1.49	7.85	1	2.60	2.83	4.51	9.94	2046	0.44	0.49	-3.02	-2.09
34	0.073	0.5	1.42	1.55	0.69	3.67	0.5	1.21	1.32	2.10	4.63	2047	0.20	0.23	-1.40	-0.97
35	0.068	0	0.00	0.00	0.00	0.00	0	0.00	0.00	0.00	0.00	2048	0.00	0.00	0.00	0.00
$ million	annual	34	362.48	397.10	208.84	968.42	27	332.00	362.62	444.17	1138.78		30.48	34.48	-235.32	-170.36
$ thousand	daily	365	993.1	1087.9	572.2	2653.2		909.6	993.5	1216.9	3119.9		83.5	94.5	-644.7	-466.7
0	1.000	1	25.73	28.18	16.23	70.14	1	22.03	24.00	49.05	95.07	2013	3.70	4.18	-32.82	-24.93
$ thousand	T0 day	365	70.5	77.2	44.5	192.2		60.3	65.7	134.4	260.5		10.1	11.5	-89.9	-68.3



Saddle Road realignments (assuming Gorge still open)

Sens test allday 0

Length 6.54 LV: vol,spd 6080 65

Grade 2, 2 MCV: vol,spd 285 55

Traffic 6935 HCV: vol,spd 570 50,50

0% divert from Saddle Rd 1.5% Traffic growth

0% divert from Pah Track N 0.5% Ax growth

0% divert from Pah Track E $1,050,000 Ax unit cost

discount	8%	Do Min	Gorge open - no networks upgrade				Option	Saddle option 1				Benefits (negative values = disbenefit)				
millions $	1,000,000		TTC	VOC+CO2	AXC	Sum		TTC	VOC+CO2	AXC	Sum		TTC	VOC+CO2	AXC	Sum
0	1.000	1	1.14	1.67	2.09	4.90	0	1.14	1.67	2.09	4.90	2013	0.00	0.00	0.00	0.00
1	0.926	1	1.07	1.57	1.94	4.58	0	1.07	1.57	1.94	4.58	2014	0.00	0.00	0.00	0.00
2	0.857	1	1.00	1.48	1.81	4.29	0	1.00	1.48	1.81	4.29	2015	0.00	0.00	0.00	0.00
3	0.794	1	0.94	1.39	1.68	4.01	0	0.94	1.39	1.68	4.01	2016	0.00	0.00	0.00	0.00
4	0.735	1	0.88	1.30	1.57	3.75	0	0.88	1.30	1.57	3.75	2017	0.00	0.00	0.00	0.00
5	0.681	1	0.83	1.22	1.46	3.51	0	0.83	1.22	1.46	3.51	2018	0.00	0.00	0.00	0.00
6	0.630	1	0.78	1.15	1.36	3.28	0	0.78	1.15	1.36	3.28	2019	0.00	0.00	0.00	0.00
7	0.583	0.5	0.37	0.54	0.63	1.54	0.5	0.33	0.50	0.57	1.39	2020	0.04	0.04	0.06	0.15
8	0.540	1	0.69	1.01	1.17	2.87	1	0.61	0.93	1.05	2.60	2021	0.07	0.08	0.12	0.27
9	0.500	1	0.64	0.95	1.09	2.69	1	0.58	0.88	0.98	2.43	2022	0.07	0.07	0.11	0.25
10	0.463	1	0.60	0.89	1.02	2.51	1	0.54	0.82	0.91	2.27	2023	0.06	0.07	0.10	0.24
11	0.429	1	0.57	0.84	0.94	2.35	1	0.51	0.77	0.85	2.13	2024	0.06	0.06	0.10	0.22
12	0.397	1	0.53	0.78	0.88	2.19	1	0.48	0.72	0.79	1.99	2025	0.06	0.06	0.09	0.21
13	0.368	1	0.50	0.73	0.82	2.05	1	0.45	0.68	0.73	1.86	2026	0.05	0.06	0.08	0.19
14	0.340	1	0.47	0.69	0.76	1.92	1	0.42	0.64	0.68	1.74	2027	0.05	0.05	0.08	0.18
15	0.315	1	0.44	0.65	0.71	1.79	1	0.39	0.60	0.63	1.62	2028	0.05	0.05	0.07	0.17
16	0.292	1	0.41	0.61	0.66	1.67	1	0.37	0.56	0.59	1.52	2029	0.04	0.05	0.07	0.16
17	0.270	1	0.39	0.57	0.61	1.56	1	0.34	0.52	0.55	1.42	2030	0.04	0.04	0.06	0.15
18	0.250	1	0.36	0.53	0.57	1.46	1	0.32	0.49	0.51	1.32	2031	0.04	0.04	0.06	0.14
19	0.232	1	0.34	0.50	0.53	1.37	1	0.30	0.46	0.48	1.24	2032	0.04	0.04	0.05	0.13
20	0.215	1	0.32	0.47	0.49	1.28	1	0.28	0.43	0.44	1.16	2033	0.03	0.04	0.05	0.12
21	0.199	1	0.30	0.44	0.46	1.19	1	0.26	0.40	0.41	1.08	2034	0.03	0.03	0.05	0.11
22	0.184	1	0.28	0.41	0.43	1.11	1	0.25	0.38	0.38	1.01	2035	0.03	0.03	0.04	0.11
23	0.170	1	0.26	0.38	0.40	1.04	1	0.23	0.35	0.36	0.94	2036	0.03	0.03	0.04	0.10
24	0.158	1	0.24	0.36	0.37	0.97	1	0.22	0.33	0.33	0.88	2037	0.03	0.03	0.04	0.09
25	0.146	1	0.23	0.34	0.34	0.91	1	0.20	0.31	0.31	0.82	2038	0.02	0.03	0.04	0.09
26	0.135	1	0.21	0.31	0.32	0.85	1	0.19	0.29	0.29	0.77	2039	0.02	0.02	0.03	0.08
27	0.125	1	0.20	0.29	0.30	0.79	1	0.18	0.27	0.27	0.72	2040	0.02	0.02	0.03	0.07
28	0.116	1	0.19	0.28	0.28	0.74	1	0.17	0.25	0.25	0.67	2041	0.02	0.02	0.03	0.07
29	0.107	1	0.17	0.26	0.26	0.69	1	0.16	0.24	0.23	0.62	2042	0.02	0.02	0.03	0.07
30	0.099	1	0.16	0.24	0.24	0.64	1	0.15	0.22	0.21	0.58	2043	0.02	0.02	0.02	0.06
31	0.092	1	0.15	0.23	0.22	0.60	1	0.14	0.21	0.20	0.54	2044	0.02	0.02	0.02	0.06
32	0.085	1	0.14	0.21	0.21	0.56	1	0.13	0.19	0.19	0.51	2045	0.02	0.02	0.02	0.05
33	0.079	1	0.13	0.20	0.19	0.52	1	0.12	0.18	0.17	0.47	2046	0.01	0.02	0.02	0.05
34	0.073	0.5	0.06	0.09	0.09	0.24	0.5	0.06	0.09	0.08	0.22	2047	0.01	0.01	0.01	0.02
35	0.068	0	0.00	0.00	0.00	0.00	0	0.00	0.00	0.00	0.00	2048	0.00	0.00	0.00	0.00
$ million	annual	34	16.00	23.56	26.87	66.43	27	15.00	22.49	25.33	62.82		1.00	1.07	1.54	3.61
$ thousand	daily	365	43.8	64.5	73.6	182.0		41.1	61.6	69.4	172.1		2.7	2.9	4.2	9.9
													27.7%	29.6%	42.7%	
0	1.000	1	1.14	1.67	2.09	4.90	1	1.01	1.54	1.87	4.43	2013	0.12	0.13	0.21	0.47
$ thousand	T0 day	365	3.1	4.6	5.7	13.4		2.8	4.2	5.1	12.1		0.3	0.4	0.6	1.3

APPENDIX H: Slip Risk Costs

SH3 Manawatu Gorge alternative routes Economic Evaluation
Risk Analysis - Probability of Significant Slip Event

medium slip size	5-20	thousand m^3	
Slip Return Period	4	Years	
	20%	Repair costs	
Reinstatement =	$ 800,000	$ -	$ 800,000
Detour cost per day =	$ 74,500	7	$ 521,500
		no. of days	
Total			$ 1,321,500

large slip size	20-100	thousand m^3	
Slip Return Period	5		
round to nearest $	100	Repair costs	
Reinstatement =	$ 4,000,000	$ -	$ 4,000,000
Detour cost/day =	$ 74,500	75	$ 5,587,500
		no. of days	
			$ 9,587,500

Year	8% Discounted	Risk Analysis Probability	Costs	EV Costs	
0	1.000	0.250	$ 1,321,500	$ 330,375	1
1	0.926	0.250	$ 1,321,500	$ 305,903	1
2	0.857	0.250	$ 1,321,500	$ 283,243	1
3	0.794	0.250	$ 1,321,500	$ 262,262	1
4	0.735	0.250	$ 1,321,500	$ 242,835	1
5	0.681	0.250	$ 1,321,500	$ 224,848	1
6	0.630	0.250	$ 1,321,500	$ 208,192	1
7	0.583	0.250	$ 1,321,500	$ 192,771	1
8	0.540	0.250	$ 1,321,500	$ 178,491	1
9	0.500	0.250	$ 1,321,500	$ 165,270	1
10	0.463	0.250	$ 1,321,500	$ 153,028	1
11	0.429	0.250	$ 1,321,500	$ 141,692	1
12	0.397	0.250	$ 1,321,500	$ 131,196	1
13	0.368	0.250	$ 1,321,500	$ 121,478	1
14	0.340	0.250	$ 1,321,500	$ 112,480	1
15	0.315	0.250	$ 1,321,500	$ 104,148	1
16	0.292	0.250	$ 1,321,500	$ 96,433	1
17	0.270	0.250	$ 1,321,500	$ 89,290	1
18	0.250	0.250	$ 1,321,500	$ 82,676	1
19	0.232	0.250	$ 1,321,500	$ 76,552	1
20	0.215	0.250	$ 1,321,500	$ 70,881	1
21	0.199	0.250	$ 1,321,500	$ 65,631	1
22	0.184	0.250	$ 1,321,500	$ 60,769	1
23	0.170	0.250	$ 1,321,500	$ 56,268	1
24	0.158	0.250	$ 1,321,500	$ 52,100	1
25	0.146	0.250	$ 1,321,500	$ 48,241	1
26	0.135	0.250	$ 1,321,500	$ 44,667	1
27	0.125	0.250	$ 1,321,500	$ 41,359	1
28	0.116	0.250	$ 1,321,500	$ 38,295	1
29	0.107	0.250	$ 1,321,500	$ 35,458	1
30	0.099	0.250	$ 1,321,500	$ -	0
31	0.092	0.250	$ 1,321,500	$ -	0
32	0.085	0.250	$ 1,321,500	$ -	0
33	0.079	0.250	$ 1,321,500	$ -	0
34	0.073	0.250	$ 1,321,500	$ -	0
35	0.068	0.250	$ 1,321,500	$ -	0
			$ 4,016,833	$ 4,016,833	

Year	Risk Analysis Probability	Costs	EV Costs
0	0.200	$ 9,587,500	$ 1,917,500
1	0.200	$ 9,587,500	$ 1,775,463
2	0.200	$ 9,587,500	$ 1,643,947
3	0.200	$ 9,587,500	$ 1,522,173
4	0.200	$ 9,587,500	$ 1,409,420
5	0.200	$ 9,587,500	$ 1,305,018
6	0.200	$ 9,587,500	$ 1,208,350
7	0.200	$ 9,587,500	$ 1,118,843
8	0.200	$ 9,587,500	$ 1,035,966
9	0.200	$ 9,587,500	$ 959,227
10	0.200	$ 9,587,500	$ 888,174
11	0.200	$ 9,587,500	$ 822,383
12	0.200	$ 9,587,500	$ 761,466
13	0.200	$ 9,587,500	$ 705,061
14	0.200	$ 9,587,500	$ 652,834
15	0.200	$ 9,587,500	$ 604,476
16	0.200	$ 9,587,500	$ 559,700
17	0.200	$ 9,587,500	$ 518,241
18	0.200	$ 9,587,500	$ 479,853
19	0.200	$ 9,587,500	$ 444,308
20	0.200	$ 9,587,500	$ 411,396
21	0.200	$ 9,587,500	$ 380,922
22	0.200	$ 9,587,500	$ 352,706
23	0.200	$ 9,587,500	$ 326,580
24	0.200	$ 9,587,500	$ 302,388
25	0.200	$ 9,587,500	$ 279,989
26	0.200	$ 9,587,500	$ 259,249
27	0.200	$ 9,587,500	$ 240,046
28	0.200	$ 9,587,500	$ 222,265
29	0.200	$ 9,587,500	$ 205,801
30	0.200	$ 9,587,500	$ -
31	0.200	$ 9,587,500	$ -
32	0.200	$ 9,587,500	$ -
33	0.200	$ 9,587,500	$ -
34	0.200	$ 9,587,500	$ -
35	0.200	$ 9,587,500	$ -
		$ 23,313,744	$ 23,313,744
		$ 27,330,577	$ 27,330,577

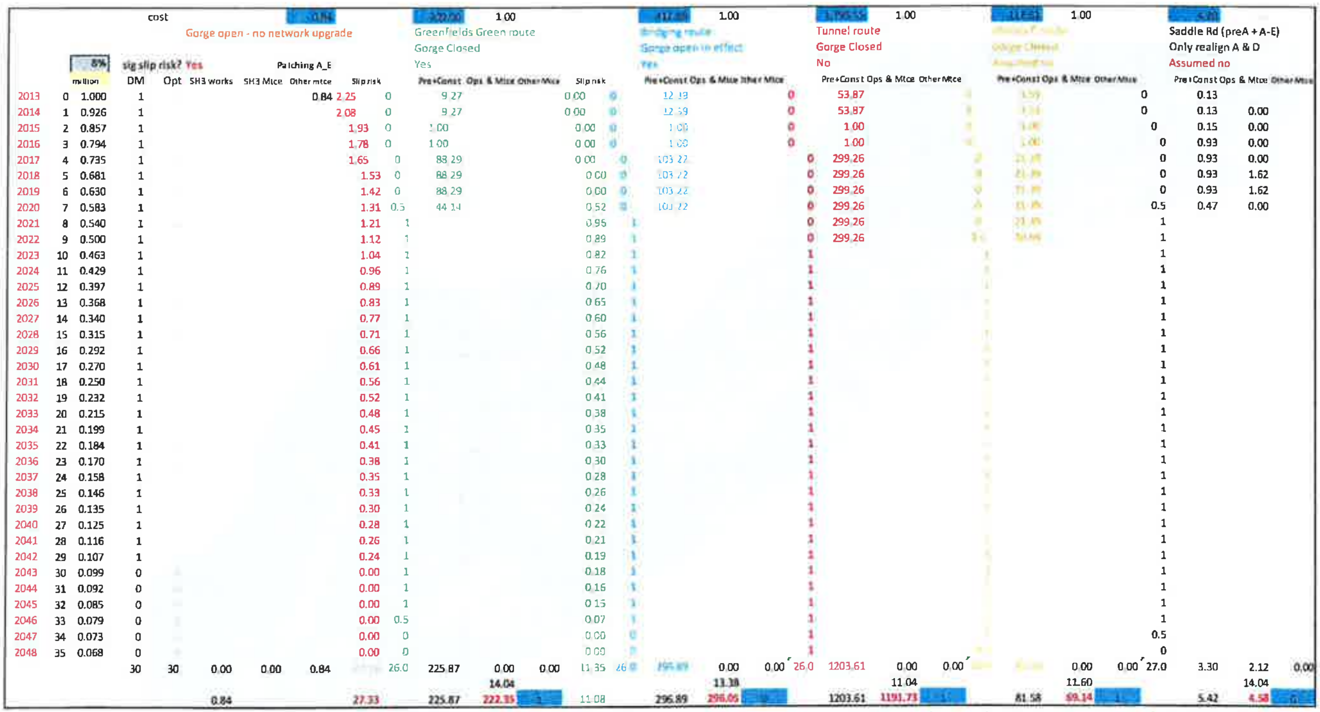
Greenfields option

medium slip size	5-20	thousand m^3	
Slip Return Period	4	Years	
	20%	Repair costs	
Reinstatement =	$ 600,000	$ -	$ 600,000
Detour cost per day =	$ 74,500	7	$ 521,500
		no. of days	
Total			$ 1,121,500
		$ 1,839,209	$ 1,839,209

large slip size	20-100	thousand m^3	
Slip Return Period	5		
round to nearest $	100	Repair costs	
Reinstatement =	$ 3,000,000	$ -	$ 3,000,000
Detour cost/day =	$ 74,500	60	$ 4,470,000
		no. of days	
			$ 7,470,000
		$ 9,800,370	$ 9,800,370
		$ 11,639,579	$ 11,639,579

APPENDIX I: Undiscounted option construction costs and net discounted costs

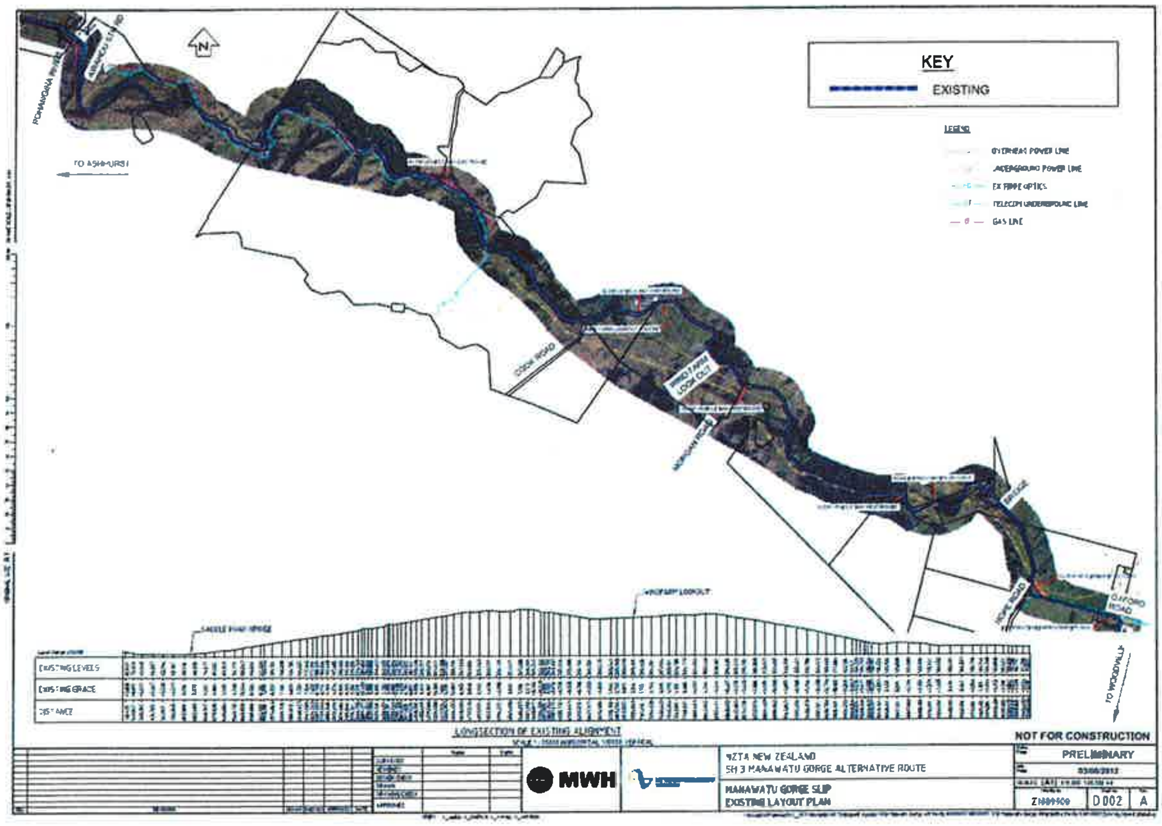
	Saddle Road realignment sub-option					Saddle	Greenfields	Bridging	Tunnel	WorleyC
	A1	B	C1	D1	E1	**Total**	Green	Blue	Red	Orange
PRELIMINARY AND GENERAL	62,750	30,750	34,400	37,750	35,750	**201,400**	1,076,250	21,536,250	3,536,250	1,638,250
TEMPORARY TRAFFIC CONTROL	5,750	3,750	5,750	10,750	10,750	**36,750**	105,000	1,005,000	505,000	1,005,000
EARTHWORKS	1,220,000	114,000	235,000	677,000	324,000	**2,570,000**	267,175,000	460,000	1,614,000,000	46,250,000
PAVEMENT CONSTRUCTION	629,000	169,600	258,600	403,200	258,000	**1,718,400**	1,365,000	75,125	75,125	2,818,000
BRIDGE	0	0	0	0	0	**0**	4,000,000	280,140,000	0	5,000,000
SURFACING	125,000	40,000	65,000	80,000	50,000	**360,000**	250,000	800,400	800,400	900,000
DRAINAGE	232,700	17,000	60,750	51,750	72,875	**435,075**	854,100	2,599,400	1,809,100	982,750
TRAFFIC SERVICES	6,900	6,275	6,275	6,900	86,900	**113,250**	31,250	4,047,000	4,047,000	45,000
LANDSCAPING & FENCING	191,150	72,875	65,175	115,475	72,875	**517,550**	449,500	0	0	3,091,250
RELOCATION OF SERVICES power poles and telecoms	20,000	18,000	18,000	18,000	12,000	**86,000**	200,000	2,200,000	400,000	400,000
MISCELLANEOUS										
Contingency	500,000	100,000	150,000	300,000	200,000	**1,250,000**	28,000,000	100,000,000	170,000,000	10,000,000
Land Acquisition	82,500	750	750	25,500	2,475	**111,975**	495,000	0	375,000	1,500,000
other (Wind turbines)							5,000,000			44,000,000
Contingency as % of Total - Misc	20.1%	21.2%	20.0%	21.4%	21.7%	**20.7%**	10.2%	32.0%	10.5%	16.1%
Sub-total excl Misc ($000)	2,493.3	472.3	749.0	1,400.8	923.2	**6,038.4**	275,506.1	312,863.2	1,625,172.9	62,128.3
Realignment TOTAL ($000,000)	3.08	0.57	0.90	1.73	1.13	**7.40**	309.00	412.86	1,795.55	117.63



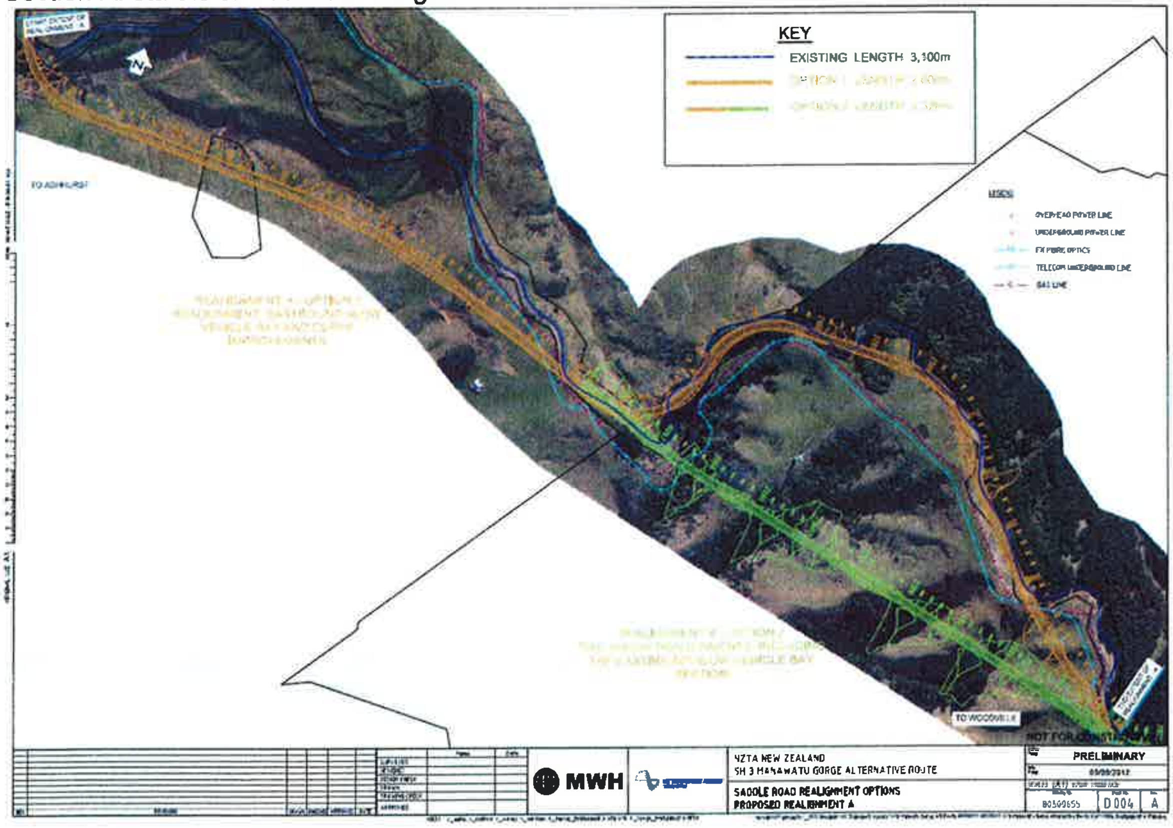
					cost			[illegible]		[illegible]	1.00		[illegible]	1.00	[illegible]	1.00	[illegible]	1.00	[illegible]	
							Gorge open - no network upgrade			Greenfields Green route			Bridging route		Tunnel route		[illegible]		Saddle Rd (preA + A-E)	
										Gorge Closed			Gorge open in effect		Gorge Closed		[illegible]		Only realign A & D	
		8%	sig slip risk? Yes				Patching A_E			Yes			Yes		No		[illegible]		Assumed no	
		million	DM	Opt	SH3 works	SH3 Mtce	Other mtce	Slip risk		Pre+Const Ops & Mtce Other Mtce	Slip risk		Pre+Const Ops & Mtce Other Mtce		Pre+Const Ops & Mtce Other Mtce		Pre+Const Ops & Mtce Other Mtce		Pre+Const Ops & Mtce	Other Mtce
2013	0	1.000	1				0.84	2.25	0	9.27	0.00	0	12.19	0	53.87	[illegible]	[illegible]	0	0.13	
2014	1	0.926	1					2.08	0	9.27	0.00	0	12.59	0	53.87	[illegible]	[illegible]	0	0.13	0.00
2015	2	0.857	1					1.93	0	1.00	0.00	0	1.00	0	1.00	[illegible]	[illegible]	0	0.15	0.00
2016	3	0.794	1					1.78	0	1.00	0.00	0	1.00	0	1.00	[illegible]	[illegible]	0	0.93	0.00
2017	4	0.735	1					1.65	0	88.29	0.00	0	103.22	0	299.26	[illegible]	[illegible]	0	0.93	0.00
2018	5	0.681	1					1.53	0	88.29	0.00	0	103.72	0	299.26	[illegible]	[illegible]	0	0.93	1.62
2019	6	0.630	1					1.42	0	88.29	0.00	0	103.22	0	299.26	[illegible]	[illegible]	0	0.93	1.62
2020	7	0.583	1					1.31	0.5	44.14	0.52	0	103.22	0	299.26	[illegible]	[illegible]	0.5	0.47	0.00
2021	8	0.540	1					1.21	1		0.95	1		0	299.26	[illegible]	[illegible]	1		
2022	9	0.500	1					1.12	1		0.89	1		0	299.26	[illegible]	[illegible]	1		
2023	10	0.463	1					1.04	1		0.82	1		1				1		
2024	11	0.429	1					0.96	1		0.76	1		1				1		
2025	12	0.397	1					0.89	1		0.70	1		1				1		
2026	13	0.368	1					0.83	1		0.65	1		1				1		
2027	14	0.340	1					0.77	1		0.60	1		1				1		
2028	15	0.315	1					0.71	1		0.56	1		1				1		
2029	16	0.292	1					0.66	1		0.52	1		1				1		
2030	17	0.270	1					0.61	1		0.48	1		1				1		
2031	18	0.250	1					0.56	1		0.44	1		1				1		
2032	19	0.232	1					0.52	1		0.41	1		1				1		
2033	20	0.215	1					0.48	1		0.38	1		1				1		
2034	21	0.199	1					0.45	1		0.35	1		1				1		
2035	22	0.184	1					0.41	1		0.33	1		1				1		
2036	23	0.170	1					0.38	1		0.30	1		1				1		
2037	24	0.158	1					0.35	1		0.28	1		1				1		
2038	25	0.146	1					0.33	1		0.26	1		1				1		
2039	26	0.135	1					0.30	1		0.24	1		1				1		
2040	27	0.125	1					0.28	1		0.22	1		1				1		
2041	28	0.116	1					0.26	1		0.21	1		1				1		
2042	29	0.107	1					0.24	1		0.19	1		1				1		
2043	30	0.099	0					0.00	1		0.18	1		1				1		
2044	31	0.092	0					0.00	1		0.16	1		1				1		
2045	32	0.085	0					0.00	1		0.15	1		1				1		
2046	33	0.079	0					0.00	0.5		0.07	1		1				1		
2047	34	0.073	0					0.00	0		0.00	0		1				0.5		
2048	35	0.068	0					0.00	0		0.00	0		1				0		
			30	30	0.00	0.00	0.84		26.0	225.87 0.00 0.00	11.35	26.0	295.89 0.00 0.00	26.0	1203.61 0.00 0.00	[illegible]	[illegible] 0.00 0.00	27.0	3.30	2.12 0.00
										14.04			13.38		11.04		11.60			14.04
					0.84			27.33		225.87 222.35	11.08		296.89 296.05		1203.61 1191.73		81.58 69.14		5.42	4.58

The approx. $27 million net slip resinstatement costs for Manawatu Gorge comprises the reinstatement and detour costs.

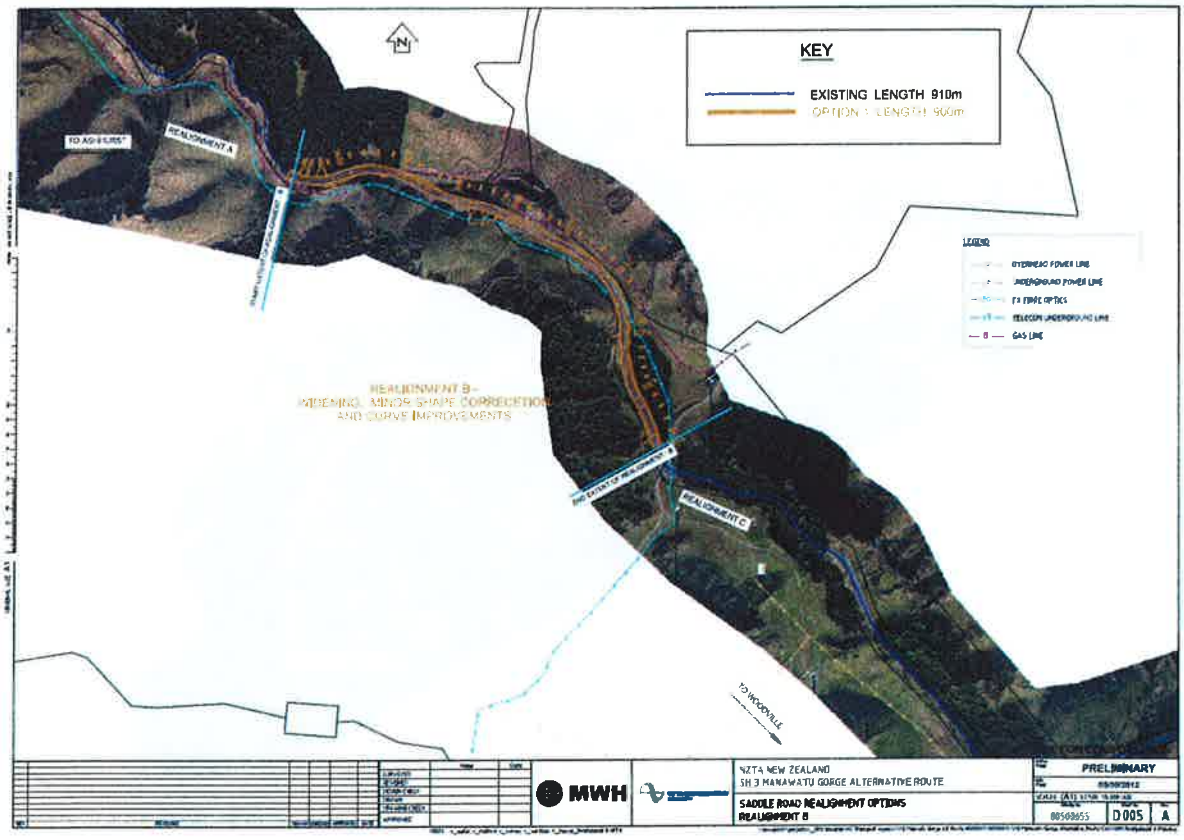
APPENDIX J: Saddle Road existing and options



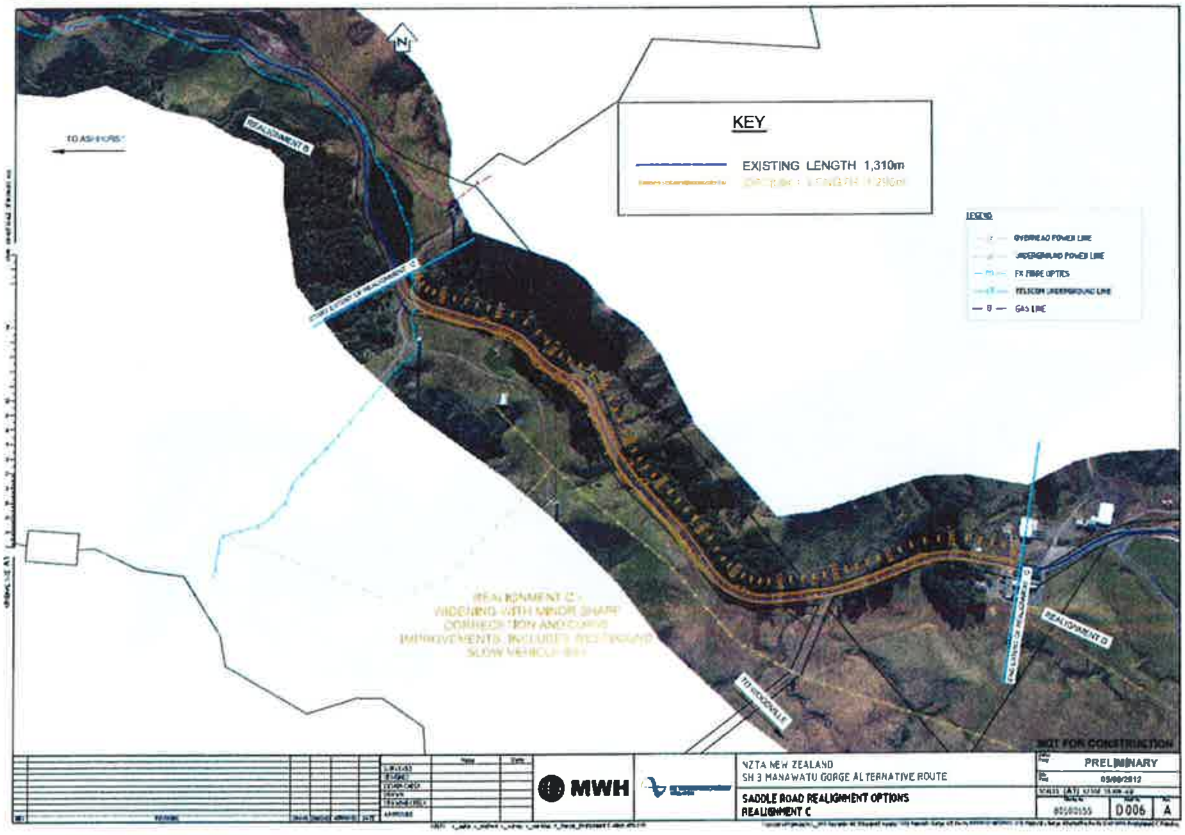
Section A: start is 0. From the bridge



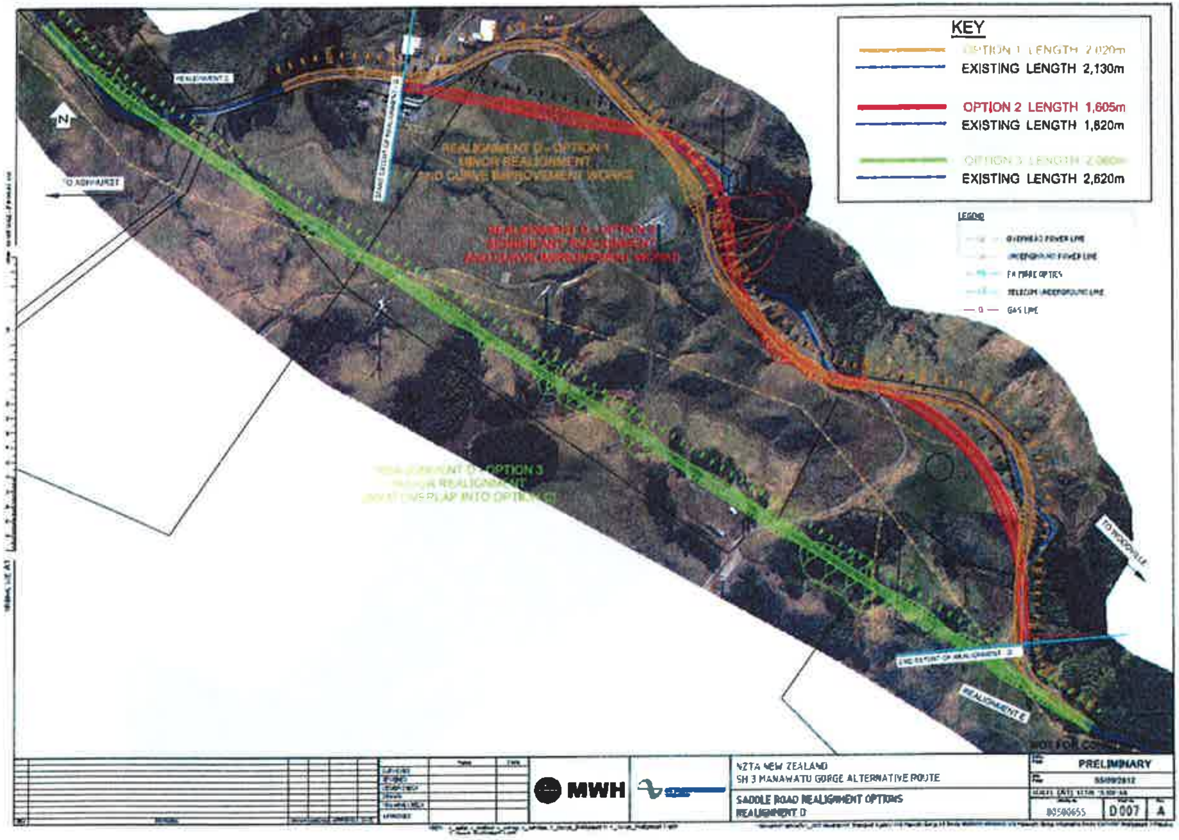
Section B



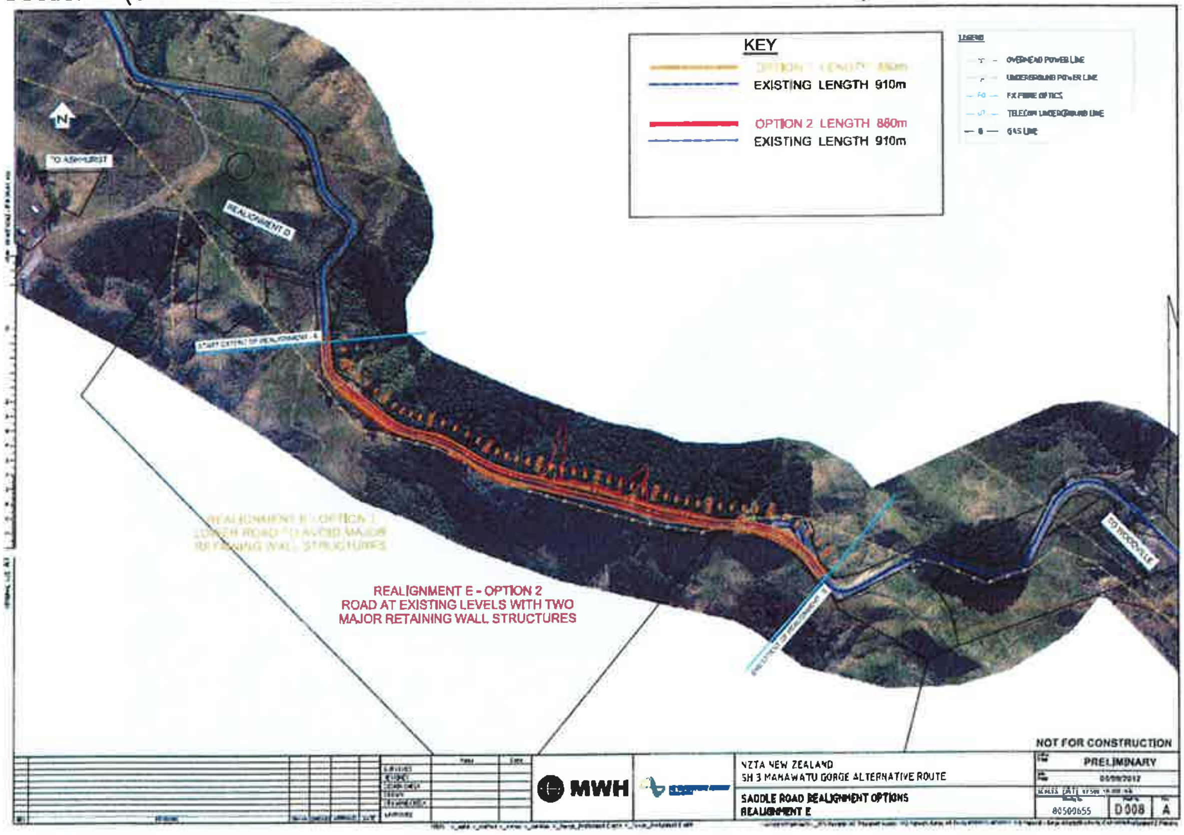
Section C



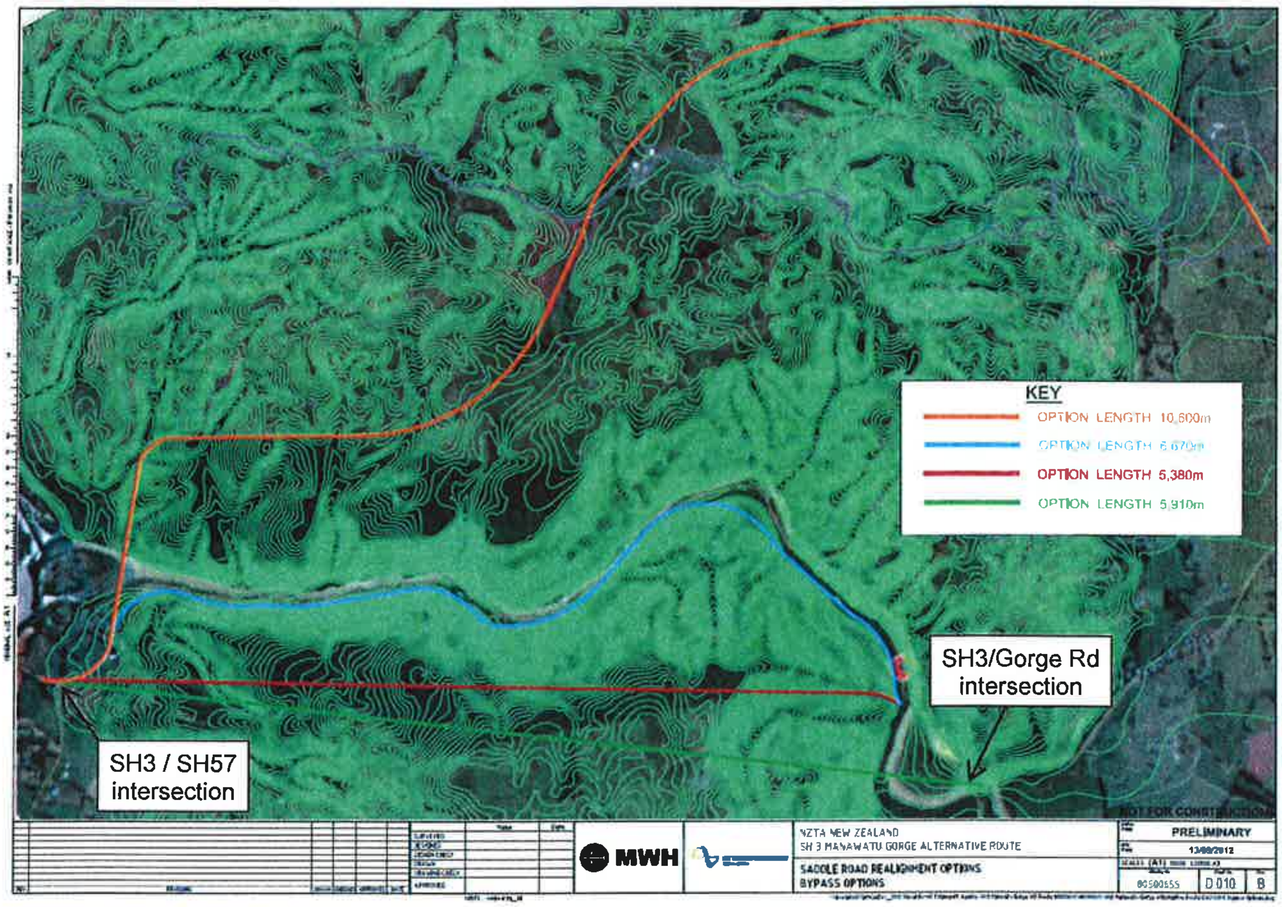
Section D



Section E (ends 2.12 km from the Oxford Rd/ Woodlands Rd intersection)



APPENDIX K: Manawatu Gorge Bypass options



Orange- Worley option C; Blue- Bridging option; Red- Tunnel option; Green- Greenfields option

Appendix G NPV Calculations

Spreadsheet v 1.02 (03-June-10)

SP1 Road Renewals continued

Worksheet 1 – Evaluation summary

1	Evaluator(s)		Alex Drover	
	Reviewer(s)			
2	Activity/package details			
	Approved organisation name		NZTA	
	Activity/package name		Saddle Road	
	Your reference		Return to Council What If - Close Cycle 4 Years	
	Activity description		Patch and Seal/Rehabilitate Pavement	
	Describe the issues to be addressed		High maintenance, multiple seal layers, SCRIM, roughness etc	
3	Location			
	Brief description of location		Saddle Road from Bridge to RP 12 Rehab RP2 - RP12 inc Widening and Drainage	
4	Alternatives and options			
	Describe the do-minimum		Existing maintenance strategy Water blasting, heavy maintenance and reseal cycle	
	Summarise the options assessed		Rehabilitate with Overlay and Drainage Improvements Shallow overlay and stabilise 70,000m2 higher risk	
5	Timing			
	Time zero (assumed construction start date)	1 July	2012	
	Expected duration of construction (months)		6	
6	Economic efficiency			
	Date economic evaluation completed (mm/yyyy)		2012	
	Base date for costs and benefits	1 July	2012	
	AADT at time zero		4291	
	Traffic growth rate at time zero (%)		0 or 2	
	PV cost of do-minimum (existing maintenance strategy)	$	3908233	**A**
	PV cost of preferred option	$	5074357	**B**
7	Present value cost saving	**(A - B) =** $	-1166124	

Note: The preferred option is justified if the PV cost saving is positive.

SP1 Road Renewals continued

Worksheet 2 – Cost of existing maintenance strategy

1 Historic maintenance cost data (indicate whether assessed or actual)

Maintenance costs for the site over the last three years

Year 1	$	0
Year 2	$	0
Year 3	$	0
Maintenance costs for the site this year	$	0
Assessed future maintenance costs	$	0

2 PV of annual maintenance costs

Total = $ 178290 x 11.70 = $ 2085993 **(a)**

3 PV of periodic maintenance costs

Time zero 1st July in the year 2012/13

Year	Type of maintenance	Amount $	SPPWF	Present value
2012/13	Water Blasting 2000m2 @ $11.00m2	22000	0.93	20370
2012/13	Stab Patching 10000m2 @ $31.0m2	310000	0.93	287037
2012/13	Reseal 70125m2 @ $7.6m2	532950	0.93	493472
2016/17	Water Blasting 2000m2 @ $11.00m2	22000	0.68	14973
2016/17	Stab Patching 10000m2 @ $31.0m2	310000	0.68	210981
2016/17	Reseal 70125m2 @ $7.6m2	532950	0.68	362717
2020/21	Water Blasting 2000m2 @ $11.00m2	22000	0.50	11005
2020/21	Stab Patching 10000m2 @ $31.0m2	310000	0.50	155077
2020/21	Reseal 70125m2 @ $7.6m2	532950	0.50	266608

Sum of PV of periodic maintenance costs $ 1822240 **(b)**

4 PV cost of existing maintenance strategy

(a) + (b) = $ 3908233 **A**

Transfered the PV cost of the existing maintenance stratety **A**, to **A** in worksheet 1.

SP1 Road Renewals continued

Worksheet 3 - Cost of the option(s)

1 PV of estimated cost (as per attached estimate sheets)

$ 4477640 x 0.93 = $ 4164205 **(a)**

2 PV of annual maintenance in year 1 (enter actual dollar amount) = $ 0 **(b)**

3 PV of annual maintenance and inspection costs following completion of works (year 2 to 30 inclusive)

$ 1000 x 10.74 = $ 10740 **(c)**

4 PV of periodic maintenance costs (including second coat seal if appropriate)

Time zero 1st July in the year 2012/13

Year	Type of maintenance	Amount $	SPPWF	Present Value
2013/14	2nd Coat Seal 79475m2 @ $7.60m2	604010	0.86	517841
2025/26	Reseal 79475m2 @ $7.60m2	604010	0.34	205642
2033/34	Reseal 79475m2 @ $7.60m2	604010	0.18	111102
2040/41	Reseal 79475m2 @ $7.60m2	604010	0.11	64827

Sum of PV of periodic maintenance costs $ 899412 **(d)**

5 PV of total costs of option

(a) + **(b)** + **(c)** + **(d)** = $ 5074357 **B**

Transfer PV of total costs for the preferred option **B**, to **B** on worksheet 1

Spreadsheet v 1.02 (03-June-10)

SP1 Road Renewals continued

Worksheet 1 – Evaluation summary

1	Evaluator(s)		Alex Drover	
	Reviewer(s)			
2	Activity/package details			
	Approved organisation name		NZTA	
	Activity/package name		Saddle Road	
	Your reference		Return to Council What If - Close Cycle 4 Years	
	Activity description		Patch and Seal/Rehabilitate Pavement	
	Describe the issues to be addressed		High maintenance, multiple seal layers, SCRIM, roughness etc	
3	Location			
	Brief description of location		Saddle Road from Bridge to RP 12 Rehab	
			RP2 - RP12	
4	Alternatives and options			
	Describe the do-minimum		Existing maintenance strategy	
			Water blasting, heavy maintenance and reseal cycle	
	Summarise the options assessed		Rehabilitate with Overlay and Drainage Improvements	
			Shallow overlay and stabilise 70,000m2 higher risk	
5	Timing			
	Time zero (assumed construction start date)	1 July	2012	
	Expected duration of construction (months)		6	
6	Economic efficiency			
	Date economic evaluation completed (mm/yyyy)		2012	
	Base date for costs and benefits	1 July	2012	
	AADT at time zero		4291	
	Traffic growth rate at time zero (%)		0 or 2	
	PV cost of do-minimum (existing maintenance strategy)	$	3908233	**A**
	PV cost of preferred option	$	2963744	**B**
7	Present value cost saving	**(A - B)** = $	944489	

Note: The preferred option is justified if the PV cost saving is positive.

SP1 Road Renewals continued

Worksheet 2 – Cost of existing maintenance strategy

1 Historic maintenance cost data (indicate whether assessed or actual)

Maintenance costs for the site over the last three years

Year 1	$	0
Year 2	$	0
Year 3	$	0
Maintenance costs for the site this year	$	0
Assessed future maintenance costs	$	0

2 PV of annual maintenance costs

Total = $ 178290 x 11.70 = $ 2085993 **(a)**

3 PV of periodic maintenance costs

Time zero — 1st July in the year 2012/13

Year	Type of maintenance	Amount $	SPPWF	Present value
2012/13	Water Blasting 2000m2 @ $11.00m2	22000	0.93	20370
2012/13	Stab Patching 10000m2 @ $31.0m2	310000	0.93	287037
2012/13	Reseal 70125m2 @ $7.6m2	532950	0.93	493472
2016/17	Water Blasting 2000m2 @ $11.00m2	22000	0.68	14973
2016/17	Stab Patching 10000m2 @ $31.0m2	310000	0.68	210981
2016/17	Reseal 70125m2 @ $7.6m2	532950	0.68	362717
2020/21	Water Blasting 2000m2 @ $11.00m2	22000	0.50	11005
2020/21	Stab Patching 10000m2 @ $31.0m2	310000	0.50	155077
2020/21	Reseal 70125m2 @ $7.6m2	532950	0.50	266608

Sum of PV of periodic maintenance costs $ 1822240 **(b)**

4 PV cost of existing maintenance strategy

(a) + (b) = $ 3908233 **A**

Transfered the PV cost of the existing maintenance stratety **A**, to **A** in worksheet 1.

SP1 Road Renewals continued

Worksheet 3 - Cost of the option(s)

1 PV of estimated cost (as per attached estimate sheets)

$ 2321942 x 0.93 = $ 2159406 **(a)**

2 PV of annual maintenance in year 1 (enter actual dollar amount) = $ 0 **(b)**

3 PV of annual maintenance and inspection costs following completion of works (year 2 to 30 inclusive)

$ 1000 x 10.74 = $ 10740 **(c)**

4 PV of periodic maintenance costs (including second coat seal if appropriate)

Time zero 1st July in the year 2012/13

Year	Type of maintenance	Amount $	SPPWF	Present Value
2013/14	2nd Coat Seal 70125m2 @ $7.60m2	532950	0.86	456919
2025/26	Reseal 70125m2 @ $7.60m2	532950	0.34	181449
2033/34	Reseal 70125m2 @ $7.60m2	532950	0.18	98031
2040/41	Reseal 70125m2 @ $7.60m2	532950	0.11	57200

Sum of PV of periodic maintenance costs $ 793599 **(d)**

5 PV of total costs of option

(a) + **(b)** + **(c)** + **(d)** = $ 2963744 **B**

Transfer PV of total costs for the preferred option **B**, to **B** on worksheet 1

Spreadsheet v 1.02 (03-June-10)

SP1 Road Renewals continued

Worksheet 1 – Evaluation summary

1	Evaluator(s)		Alex Drover	
	Reviewer(s)			
2	Activity/package details			
	Approved organisation name		NZTA	
	Activity/package name		Saddle Road	
	Your reference		Return to Council What If - Close Cycle 4 Years	
	Activity description		Patch and Seal/Rehabilitate Pavement	
	Describe the issues to be addressed		High maintenance, multiple seal layers, SCRIM, roughness etc	
3	Location			
	Brief description of location		Maintenance v Rehab	
			Option E Realignment plus Improvement	
4	Alternatives and options			
	Describe the do-minimum		Existing maintenance strategy	
			Water blasting, heavy maintenance and reseal cycle	
	Summarise the options assessed		Rehabilitate with Overlay and Drainage Improvements	
			Shallow overlay and stabilise high risk	
5	Timing			
	Time zero (assumed construction start date)	1 July	2012	
	Expected duration of construction (months)		6	
6	Economic efficiency			
	Date economic evaluation completed (mm/yyyy)		2012	
	Base date for costs and benefits	1 July	2012	
	AADT at time zero		4291	
	Traffic growth rate at time zero (%)		0 or 2	
	PV cost of do-minimum (existing maintenance strategy)	$	381405	**A**
	PV cost of preferred option	$	506475	**B**
7	Present value cost saving	**(A - B) =** $	-125070	

Note: The preferred option is justified if the PV cost saving is positive.

SP1 Road Renewals continued

Worksheet 2 – Cost of existing maintenance strategy

1 Historic maintenance cost data (indicate whether assessed or actual)

Maintenance costs for the site over the last three years

Year 1	$	0
Year 2	$	0
Year 3	$	0
Maintenance costs for the site this year	$	0
Assessed future maintenance costs	$	0

2 PV of annual maintenance costs

Total = $ 17352 x 11.70 = $ 203022 **(a)**

3 PV of periodic maintenance costs

Time zero 1st July in the year 2012/13

Year	Type of maintenance	Amount $	SPPWF	Present value
2012/13	Water Blasting	2500	0.93	2315
2012/13	Stab Patching	30219	0.93	27981
2012/13	Reseal	51953	0.93	48105
2016/17	Water Blasting	2500	0.68	1701
2016/17	Stab Patching	30219	0.68	20567
2016/17	Reseal	51953	0.68	35358
2020/21	Water Blasting	2500	0.50	1251
2020/21	Stab Patching	30219	0.50	15117
2020/21	Reseal	51953	0.50	25989

Sum of PV of periodic maintenance costs $ 178383 **(b)**

4 PV cost of existing maintenance strategy

(a) + (b) = $ 381405 **A**

Transfered the PV cost of the existing maintenance stratety **A**, to **A** in worksheet 1.

SP1 Road Renewals continued

Worksheet 3 - Cost of the option(s)

1 PV of estimated cost (as per attached estimate sheets)

$ 435792 x 0.93 = $ 405286 **(a)**

2 PV of annual maintenance in year 1 (enter actual dollar amount) = $ 0 **(b)**

3 PV of annual maintenance and inspection costs following completion of works (year 2 to 30 inclusive)

$ 1000 x 10.74 = $ 10740 **(c)**

4 PV of periodic maintenance costs (including second coat seal if appropriate)

Time zero 1st July in the year 2012/13

Year	Type of maintenance	Amount $	SPPWF	Present Value
2013/14	2nd Coat Seal	58786	0.86	50400
2025/26	Reseal	58786	0.34	20014
2033/34	Stab Patching	10000	0.18	1839
2033/34	Reseal	58786	0.18	10813
2040/41	Stab Patching	10000	0.11	1073
2040/41	Reseal	58786	0.11	6309

Sum of PV of periodic maintenance costs $ 90449 **(d)**

5 PV of total costs of option

(a) + **(b)** + **(c)** + **(d)** = $ 506475 **B**

Transfer PV of total costs for the preferred option **B**, to **B** on worksheet 1

Spreadsheet v 1.02 (03-June-10)

SP1 Road Renewals continued

Worksheet 1 – Evaluation summary

1	Evaluator(s)		Alex Drover	
	Reviewer(s)			
2	Activity/package details			
	Approved organisation name		NZTA	
	Activity/package name		Saddle Road	
	Your reference		Return to Council What If - Close Cycle 4 Years	
	Activity description		Patch and Seal/Rehabilitate Pavement	
	Describe the issues to be addressed		High maintenance, multiple seal layers, SCRIM, roughness etc	
3	Location			
	Brief description of location		Maintenance v Rehab	
			Option A Realignment plus Widening	
4	Alternatives and options			
	Describe the do-minimum		Existing maintenance strategy	
			Water blasting, heavy maintenance and reseal cycle	
	Summarise the options assessed		Rehabilitate with Overlay and Drainage Improvements	
			Shallow overlay and stabilise high risk	
5	Timing			
	Time zero (assumed construction start date)	1 July	2012	
	Expected duration of construction (months)		6	
6	Economic efficiency			
	Date economic evaluation completed (mm/yyyy)		2012	
	Base date for costs and benefits	1 July	2012	
	AADT at time zero		4291	
	Traffic growth rate at time zero (%)		0 or 2	
	PV cost of do-minimum (existing maintenance strategy)	$	1291887	**A**
	PV cost of preferred option	$	1696868	**B**
7	Present value cost saving	**(A - B) =** $	-404981	

Note: The preferred option is justified if the PV cost saving is positive.

SP1 Road Renewals continued

Worksheet 2 – Cost of existing maintenance strategy

1 Historic maintenance cost data (indicate whether assessed or actual)

Maintenance costs for the site over the last three years

Year 1	$	0
Year 2	$	0
Year 3	$	0
Maintenance costs for the site this year	$	0
Assessed future maintenance costs	$	0

2 PV of annual maintenance costs

Total = $ 59112 x 11.70 = $ 691612 **(a)**

3 PV of periodic maintenance costs

Time zero 1st July in the year 2012/13

Year	Type of maintenance	Amount $	SPPWF	Present value
2012/ 13	Water Blasting	5000	0.93	4630
2012/ 13	Stab Patching	102945	0.93	95319
2012/ 13	Reseal	176983	0.93	163873
2016/ 17	Water Blasting	5000	0.68	3403
2016/ 17	Stab Patching	102945	0.68	70063
2016/ 17	Reseal	176983	0.68	120452
2020/ 21	Water Blasting	5000	0.50	2501
2020/ 21	Stab Patching	102945	0.50	51498
2020/ 21	Reseal	176983	0.50	88536

Sum of PV of periodic maintenance costs $ 600274 **(b)**

4 PV cost of existing maintenance strategy

(a) + (b) = $ 1291887 **A**

Transfered the PV cost of the existing maintenance stratety **A**, to **A** in worksheet 1.

SP1 Road Renewals continued

Worksheet 3 - Cost of the option(s)

1 PV of estimated cost (as per attached estimate sheets)

$ 1484565 x 0.93 = $ 1380646 **(a)**

2 PV of annual maintenance in year 1 (enter actual dollar amount) = $ 0 **(b)**

3 PV of annual maintenance and inspection costs following completion of works (year 2 to 30 inclusive)

$ 1000 x 10.74 = $ 10740 **(c)**

4 PV of periodic maintenance costs (including second coat seal if appropriate)

Time zero 1st July in the year 2012/13

Year	Type of maintenance	Amount $	SPPWF	Present Value
2013/14	2nd Coat Seal	200260	0.86	171691
2025/26	Reseal	200260	0.34	68181
2033/34	Stab Patching	25000	0.18	4599
2033/34	Reseal	200260	0.18	36836
2040/41	Stab Patching	25000	0.11	2683
2040/41	Reseal	200260	0.11	21493

Sum of PV of periodic maintenance costs $ 305482 **(d)**

5 PV of total costs of option

(a) + **(b)** + **(c)** + **(d)** = $ 1696868 **B**

Transfer PV of total costs for the preferred option **B**, to **B** on worksheet 1

MWH

BUILDING A BETTER WORLD

ABOUT MWH IN NEW ZEALAND

MWH in New Zealand has been providing private and public sector clients with infrastructure and environmental expertise for over 100 years.

Our offices across New Zealand are part of a global operation of 7000 staff in 35 countries giving us an unparalleled ability to combine local knowledge with international expertise.

Around the world our purpose is to work with clients and communities to help build a better world.

In New Zealand our extensive range of services covers the following disciplines:

- Asset Management
- Business Solutions
- Civil and Structural Engineering
- Energy Generation
- Environmental Science and Management
- Geoscience and Geotechnical
- Mechanical, Electrical and Building Services
- Planning, Policy and Resource Management
- Programme Management
- Roads and Highways
- Solid Waste
- Stormwater
- Surveying
- Transport Planning
- Water Resources
- Water Supply
- Wastewater

To find out more about what we do and how we can assist visit **www.mwhglobal.co.nz** or **www.mwhglobal.com**