BEFORE THE TARANAKI REGIONAL COUNCIL AND NEW PLYMOUTH DISTRICT COUNCIL

MT MESSENGER BYPASS PROJECT

In the matter	of the Resource Management Act 1991
and	
In the matter	of applications for resource consents, and a notice of requirement by the NZ Transport Agency for an alteration to the State Highway 3 designation in the New Plymouth District Plan, to carry out the Mt Messenger Bypass Project

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STATEMENT OF EVIDENCE OF KENNETH JOHN BOAM (PROJECT DESIGN) ON BEHALF OF THE NZ TRANSPORT AGENCY

25 May 2018

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QUALIFICATIONS AND EXPERIENCE

1. My name is **Kenneth John Boam**.

2. I am a senior consultant at WSP Opus[1] and the Design Manager for the Mt Messenger Alliance.

3. I am a Fellow of Engineering New Zealand and also hold the UK qualifications of Chartered Engineer, Fellow of the Institution of Civil Engineers and Fellow of the Chartered Institution of Highways and Transportation.

4. I have more than 40 years' experience in the design of roads and bridges. My initial experience was as a bridge designer responsible for the design of bridges and viaducts for the UK's motorway network. Subsequently, I gained hands-on experience in all aspects of road design.

5. Over the last 30 years I have managed and directed design teams working on major highways projects in the UK and New Zealand. As a Project Director I have been responsible for the design of a number of major projects in New Zealand including the original Kapiti Expressway, Haywards Interchange, Wellington Inner City Bypass and the conceptual design of the Transmission Gully motorway project.

6. My recent experience has included acting as:

    (a) the Technical Director for a tender design for one of the consortia bidding for the Transmission Gully project in 2013; and

    (b) the Design Manager for the widening of Auckland's Southern motorway (SH1) in 2015 and 2016.

7. I confirm that I have read the 'Code of Conduct' for expert witnesses contained in the Environment Court Practice Note 2014. My evidence has been prepared in compliance with that Code. In particular, unless I state otherwise, this evidence is within my sphere of expertise and I have not omitted to consider material facts known to me that might alter or detract from the opinions I express.

EXECUTIVE SUMMARY

8. An Alliance was appointed to identify the preferred route, design, obtain consents and construct the Mt Messenger Bypass Project ("**Project**") - a replacement of the section of State Highway 3 ("**SH3**") between Ahititi and Uruti to the north of New Plymouth.

9. As the Alliance Design Manager I have been responsible for the design of a number of route options. The options I developed have been subject to

[1] Registered, and formerly known as, Opus International Consultants Limited.

multi-criteria assessments by a variety of experts leading to the selection of a preferred option.

10. The preferred option has been developed to the level necessary for the consent application and, subsequently, for pricing and to provide the basis for detailed design.

11. A key tool developed to assist the design of the Project, is 'Humphrey', which is a computer generated three dimensional visualisation tool that provides a realistic appreciation of route options. Humphrey was used by the design team to develop route options and by the experts that undertook multi-criteria assessments. Humphrey is a dynamic tool that has provided invaluable assistance to the design of the Project, especially as it involved difficult terrain which less advanced tools are limited in catering for.

12. The Project objectives have driven the design of the Project, for each objective there are specific design solutions that respond to it. Each design solution has avoided, remedied and mitigated, where possible, the environmental, social, and cultural impacts of the Project.

13. The Project comprises approximately 6km in alignment, with tie-ins to the existing SH3 at either end. Compared to the existing road, the design achieves reduced gradients, increased forward visibility and lane width, wider shoulders, resilience measures to avoid rockfall, a lower summit, and a larger tunnel clearance envelope. The design enables a safe 100km/hr operating speed.

14. The Project alignment reflects a carefully considered route that '*treads lightly on the landscape*' in accordance with the design philosophy of the Project. To avoid adverse effects, the particular avoidance measures adopted in the design of the alignment are:

    (a) avoiding a significant cut through the key ridgeline adjacent to Mt Messenger dividing the Mangapepeke and Mimi catchments by incorporating a tunnel approximately 235m long under the ridge;

    (b) avoiding the effects of a cut and fill approach encroaching on the sensitive environment across a tributary valley of the Mimi River by incorporating a 120m long bridge;

    (c) avoiding significant trees, where feasible, by modifying the alignment of the road corridor or through physical works (such as retaining walls). This reduced the number of trees affected from 22 to a maximum of 17;

    (d) avoiding rockfall debris encroaching on the carriageway by earthworks design;

    (e) avoiding adverse effects on ecology by use of Mechanically Stabilised Earth ("**MSE**") embankments to provide steeper batter slopes; and

(f) mitigating the design of cuttings, embankments and landscape treatments to facilitate natural revegetation.

15. In addition to avoiding significant adverse effects, the careful design of the key design elements (including the tunnel and the bridge), provide a more resilient and safer road than the existing SH3, and for use by larger trucks, with shorter journey times for all users.

BACKGROUND AND ROLE

16. In March 2017, the N Z Transport Agency ("**Transport Agency**") appointed an Alliance to progress the design (including options assessment), consenting and construction of the Mt Messenger Bypass Project to improve the section of **SH3** between Ahititi and Uruti, to the north of New Plymouth.

17. I was the Alliance Design Manager, from March 2017 to March 2018. In that role I had overall day-to-day responsibility for:

(a) the design of the route options that were the subject of multi-criteria assessment culminating in the identification of the preferred option;

(b) the development of that option (to the level incorporated in the consent application); and

(c) subsequent development of the preferred option for pricing and to provide the basis for the detailed design process.

18. Together with key members of the design team I visited the site early in the design process to gain an appreciation of the topography and vegetation. The visit identified the challenges of designing a road in the area, in particular the rugged terrain and extensive coverage of mature native bush.

19. Usually, concept designs are developed using two-dimensional geometric models and topographic surveys. The rugged topography of the Mt Messenger area is such that it would be very difficult to gain an appreciation of the engineering requirements and the effects of options on the environment using a conventional two dimensional approach to design. This led to the development of 'Humphrey', a computer generated three dimensional visualisation tool that provides a realistic appreciation of route options.

20. 'Humphrey' is comprised of two software packages:

(a) a 12d geometric modelling software package that allows roads to be designed to meet specified geometric criteria; and

(b) a 3D digital terrain model in Autodesk InfraWorks 360 derived from a Lidar survey.[2]

21. Alignments were identified and developed using the 12d software package and superimposed on the digital terrain model.

22. The outputs from 'Humphrey' are dynamic. It enables routes to be observed from any viewpoint in the area covered by the Lidar survey. The tool has proved invaluable in assisting the design team to optimise road alignments and develop route options, as well as structural and earthworks solutions for each corridor. It has also been used by experts to assess the effects of options.

23. **Figures 1, 2 and 3** below are screen shots taken from 'Humphrey' that provide still images. The images demonstrate the level of information available to experts during the Multi Criteria Assessment ("**MCA**") process.

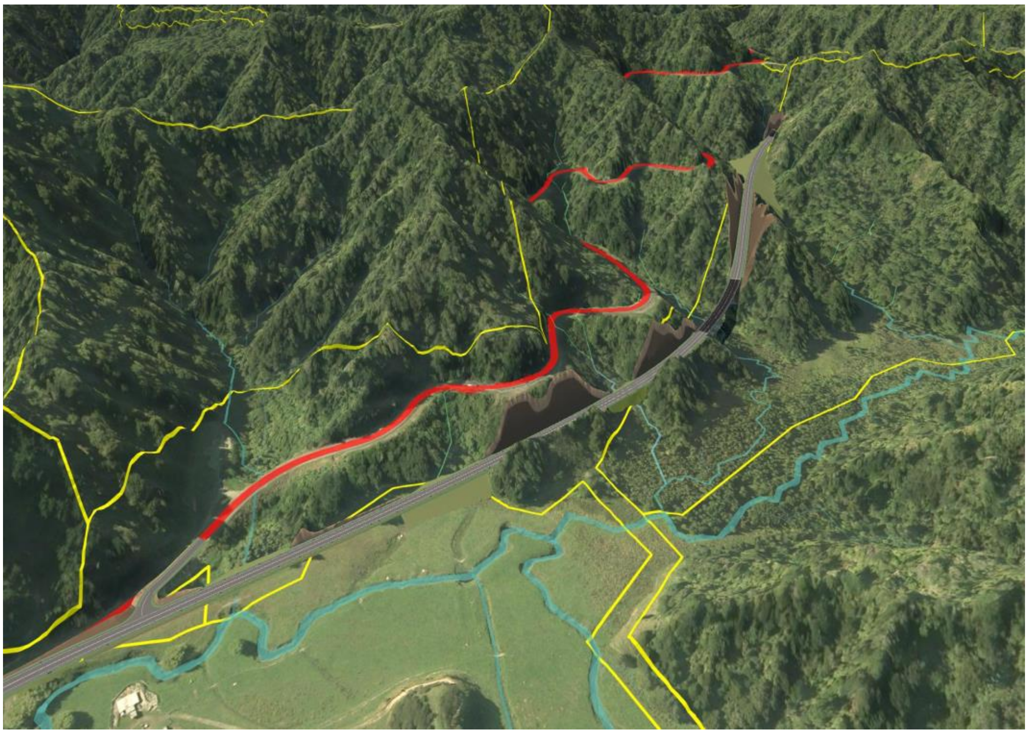

Figure 1: Option E (preferred option as presented at MCA2) looking north towards tunnel

[2] Lidar (Light Detection and Ranging) is an aerial survey method that uses pulsed radar to produce three dimensional survey data.

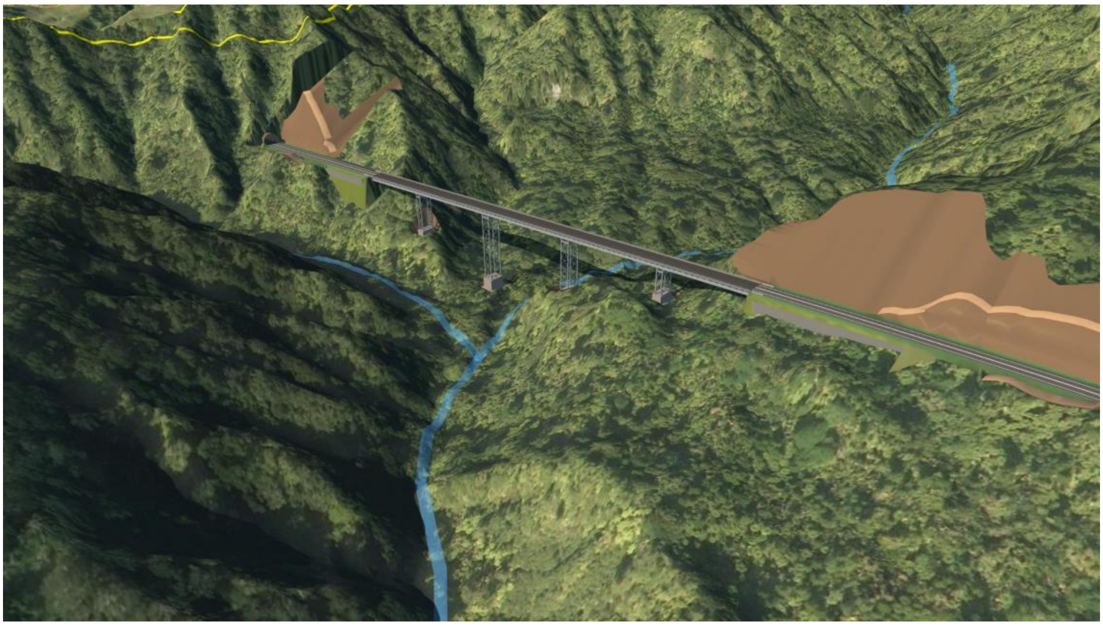

Figure 2: Option A1 – Viaduct across Waipingao Valley as presented at MCA1

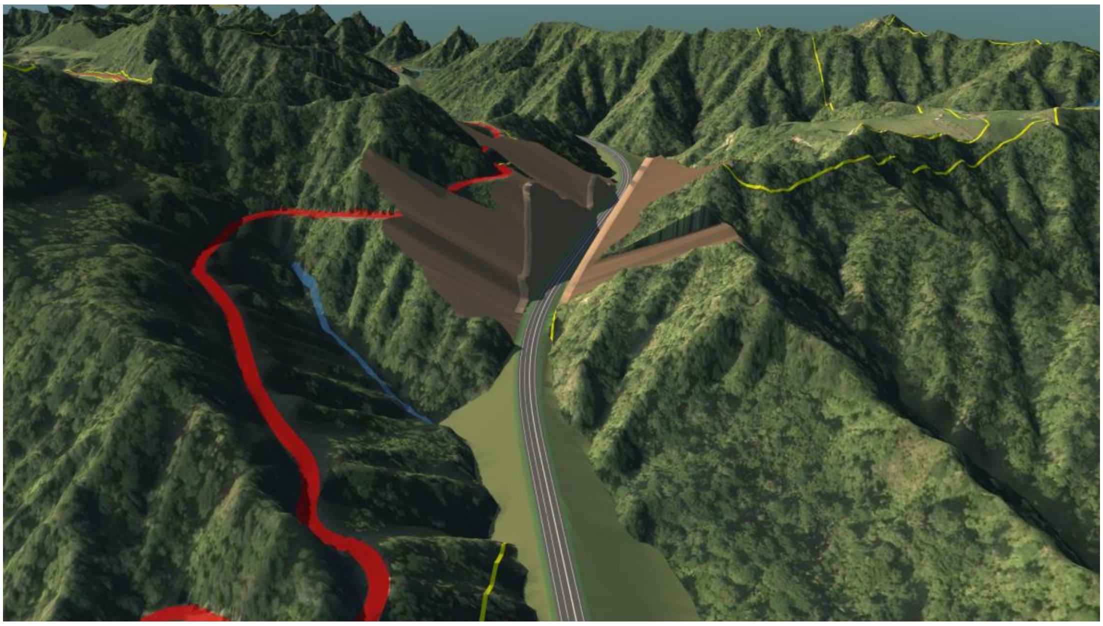

Figure 3: Option E2 – Cutting through ridgeline

24. This model is addressed further in my evidence below.

25. In preparing my evidence I have:

    (a) visited the site four times and have a detailed understanding of the Project area;

    (b) been involved in the MCA option selection workshops and specialist workshops and expert meetings;

    (c) reviewed in draft the evidence of other witnesses for the Transport Agency, including Mr Robert Napier, Mr Peter McCombs, Mr Graeme Ridley, Mr Hugh Milliken Mr Keith Hamill, and Mr Bruce Symmans; and

(d) been guided by the assessment undertaken by the various experts giving evidence for the Transport Agency, and the technical reports filed in support of the Project applications.[3]

SCOPE OF EVIDENCE

26. The purpose of my evidence is to provide an outline of the physical layout and design of the Project.

27. My evidence addresses:

    (a) the design philosophy and the overall approach including the landscape and environmental design;

    (b) design development;

    (c) assessment of alternatives;

    (d) a high-level end-to-end description of the Project alignment and its features;

    (e) details of key design elements and associated design standards;

    (f) operational stormwater (reference should be made to Mr Ridley's evidence for details of construction water management); and

    (g) responses to submissions and the Section 42A reports.

28. My evidence should be read in conjunction with the Assessment of Environmental Effects ("**AEE**") for the Project, particularly Section 4 of the AEE (Project Description).[4]

DESIGN PHILOSOPHY AND OVERALL APPROACH

Design philosophy

29. The design philosophy for the Project is to provide an outstanding scenic highway that is safe, efficient and resilient and that minimises its cultural, social and environmental impact. This aligns with the Transport Agency's Project objectives.

30. As explained in Mr Napier's evidence, the Transport Agency's objectives for the Project are:

    (a) to enhance safety of travel on SH3;

    (b) to enhance resilience and journey time reliability of the state highway network;

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[3] Volume 3 of the AEE.
[4] Mt Messenger Bypass, Assessment of Effects on the Environment, December 2017, pp 42 – 74.

(c) to contribute to enhanced local and regional economic growth and productivity for people and freight by improving connectivity and reducing journey times between the Taranaki and Waikato Regions; and

(d) to manage the immediate and long term cultural, social, land use and other environmental impacts of the Project by so far as practicable avoiding, remedying or mitigating any such effects through route and alignment selection, highway design and conditions.

31. To achieve these objectives the approach in developing the design of the Project has been based on the following philosophy:

(a) adoption of appropriate design standards to optimise safety and journey times;

(b) employing best practice in the design of cuttings, embankments and road drainage to enhance resilience and journey time reliability;

(c) adopting a 'whole of life' approach to the design, operation and maintenance of the route;

(d) maintaining connectivity to existing infrastructure, including property and farm access where required;

(e) recognising the cultural significance of the area to Ngāti Tama and providing for their kaitiaki responsibilities in the design process (including working with Ngāti Tama to incorporate cultural expression in landscape and structural elements as described in the evidence of Mr Napier and Mr Gavin Lister);

(f) adopting the concept of '*treading lightly on the landscape*';[5] and

(g) avoiding, remedying, mitigating or offsetting associated adverse effects on the environment (see below).

Design responses to Project objectives

32. **Table 1** below explains at a high level how the Project's design process has responded to and contributes to meeting the Project's objectives (Mr McCombs' evidence provides detail on each Project design response):

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[5] *'Tread lightly on the landscape'* was a concept adopted by the Alliance for the development of options (tunnels under ridges and bridges over valleys to reduce environmental effects.

Table 1: Summary of responses to Project Objectives

Objective	Project Design Response
To enhance safety of travel on State Highway 3	Improved geometry, forward visibility, and lane width provide a road that is ‘readable’ to drivers, will be safer, and consequently reduce crashes. The provision of shoulders will also improve safety (most vehicles that breakdown can park substantially off the carriageway).
To enhance resilience and journey time reliability of the state highway network	Improved safety will reduce delays caused by crashes. Cuttings are designed to avoid rockfall encroaching on the carriageway. Drainage design will ensure the carriageway remains free of standing water. These factors will significantly improve dependability of Taranaki’s key SH3 connection to and from the north. An average speed of 78 km/h along the proposed route reduces journey times by four to six and a half minutes.
To contribute to enhanced local and regional economic growth and productivity for people and freight by improving connectivity and reducing journey times between the Taranaki and Waikato Regions	Resilience and journey time reliability of the road supports the significant industries that rely on freight transport on SH3. The improved alignment, reduced gradients, and a much lower summit compared to the existing route, will reduce vehicle wear and tear and operating costs. The tunnel clearance envelope of 10m x 6m will allow over-dimension loads to use the route gaining significant reductions in journey distances and time.

Objective	Project Design Response
To manage the immediate and long term cultural, social, land use and other environmental impacts of the Project by so far as practicable avoiding, remedying or mitigating any such effects through route and alignment selection, highway design and conditions	Adopted the principle: *'Tread lightly on the landscape'*. Ngāti Tama were part of the MCA process and have been, and will continue to be, regularly engaged with on design. Active avoidance of adverse effects has been applied in the Project's options assessment and design stages. The Project has prioritised mitigation or remediation, and where that is not possible, it has incorporated offsetting and compensation, including the significant Offset Package.

Landscape and Environmental Factors Influencing Design

33. The Transport Agency's Environmental design framework guidelines ("**Guidelines**")[6] set out the applicable design policy requirements. The purpose of the Guidelines is to aid with the 'integration of large scale and / or complex infrastructure projects into the surrounding environment'.

34. The design philosophy adopted in respect of landscape and ecological values is as follows:

    (a) The route should provide a scenic driving experience and fit with the natural landscape, i.e. follow the 'grain' of the landscape – the edges between bush and pasture and between valley floor and hill slopes and also to '*tread lightly on the landscape*'.

    (b) A key ridgeline in the vicinity of Mt Messenger should be retained by using a tunnel to minimise the effects on landform and bush.

    (c) The route should avoid touching the ecologically significant Mimi wetland.

    (d) Stream and valley crossings should be minimised by keeping to the sides of valleys.

    (e) Cut faces should be designed to echo natural slopes wherever practicable.

[6] New Zealand Transport Agency: *Environmental Design Framework Guidelines*, July 2010.

(f) Where feasible the design should avoid natural features such as significant trees, water bodies and distinctive landforms. It should also promote natural succession in re-vegetation for example, permit vegetation patterns to re-establish themselves.

(g) The design should integrate landscape and ecological rehabilitation including restoring riparian vegetation.

(h) The design should provide opportunities for cultural expression and recognition.

35. A key part of the overall Project design is the incorporation of mitigation and offset measures to address effects on ecological and landscape values. This package, which is addressed in the ecology evidence, will be set out in the Ecological and Landscape Management Plan ("**ELMP**"). It is fundamental to the Project, and therefore an important part of the overall design of the Project.

36. The particular avoidance measures adopted in the design of the alignment are:

(a) avoiding a significant cut through the key ridgeline adjacent to Mt Messenger dividing the Mangapepeke and Mimi catchments by incorporating a tunnel approximately 235m long under the ridge;

(b) avoiding the effects of a cut and fill approach encroaching on the sensitive environment across a tributary valley of the Mimi River by incorporating a 120m long bridge;

(c) avoiding significant trees, where feasible, by modifying the alignment of the road corridor or through physical works (such as retaining walls). This reduced the number of trees affected from 22 to a maximum of 17;

(d) use of MSE embankments to provide steeper batter slopes that avoid adverse effects on ecology; and

(e) design of cuttings, embankments and landscape treatments to facilitate natural revegetation.

37. Environmental effects that cannot be avoided have been mitigated in the design of the alignment by:

(a) a reduced minimum stopping sight distance in some locations to reduce road widening (and earthworks) in sensitive environments while providing a road that can be driven safely at 100kph;

(b) minimising the physical landscape effects by providing a sinuous alignment as low as practicable in the landscape (**Figure 4**);

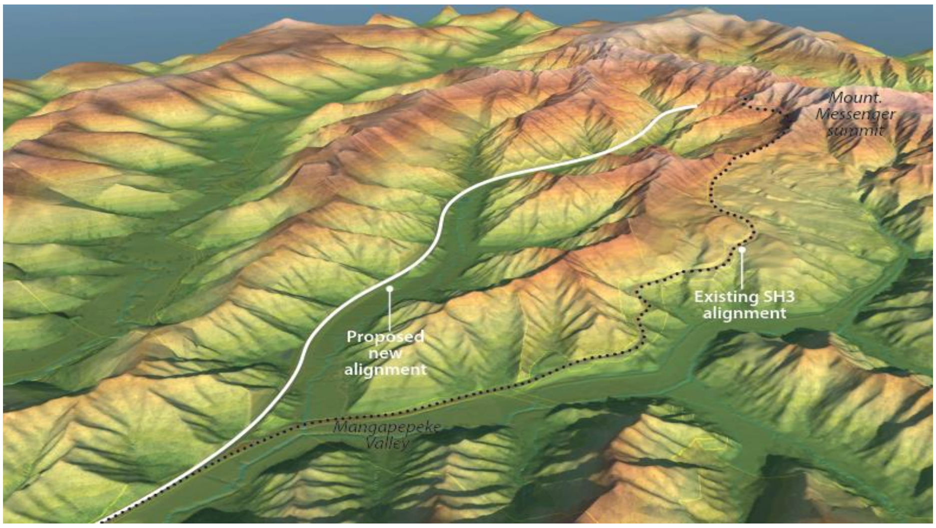

Figure 4: Schematic of alignment looking south along the Mangapepeke Valley

(c) ensuring the design of the bridge and tunnel are in harmony with the surrounding landscape;

(d) designing the bridge and tunnel features to integrate and reflect cultural values;

(e) optimising the balance between the volume of earthworks excavated from cuttings with the volume required for embankments to minimise disposal areas and avoid importation of fill;

(f) designing to minimise effects on natural streams and wetlands through the Mangapepeke Valley. By hugging the eastern flank of the valley the alignment avoids the main stem of the Mangapepeke Stream for much of its length, with modification largely being limited to the streams draining the side gullies to the east;

(g) incorporating culverts to maintain valley flows where embankments cross streams;

(h) providing for appropriate fish passage through culverts;

(i) blending cut faces into the landscape by echoing natural slope angles and allowing faces to re-vegetate naturally wherever possible;

(j) minimising encroachment of fill slopes into sensitive areas, utilising MSE fills where required, and allowing slopes to re-vegetate naturally;

(k) integrating disposal areas for excess fill with the adjoining landscape form to avoid the appearance of artificial, engineered landforms;

(l) incorporating three constructed wetlands to provide extended detention (beyond the applicable standards) and treatment of run-off from the road and cut faces to minimise contaminants (in particular sediment) reaching the Mangapepeke Stream and Mimi River;

(m) earthworks designed to avoid debris encroaching on the carriageway; and

(n) road design that can enable maintenance without significantly affecting the operation of the road.

38. The Landscape and Environmental Design Framework ("**LEDF**")[7] details the specific design considerations in accordance with the philosophy above and the particular methods that avoid and mitigate the environmental effects. It includes conceptual landscape plans that outline the proposed landscape and design features for the Project. The LEDF is discussed in more detail by Mr Lister in his evidence.

Resilience

39. In the context of the Project, resilience is the ability to resist, absorb or recover from disruption within an acceptable timeframe.[8] Such disruption could be the result of natural hazards, for example earthquake, storms and other weather events, or man-made events such as blockage of the road as a result of accidents.

40. The Project will provide an improvement in resilience to natural hazards over the existing SH3 route through reduced risk to land instability, earthquake instability and liquefaction, and the modern design and construction of earthworks, the bridge, and the operational stormwater network. The road geometry also has a role in resilience in that the much improved alignment compared to the existing road together with roadside barriers throughout will be safer and, consequently, the chances of accidents blocking the road will be less.

41. In particular, the design will provide resilience through the following methods:

(a) The earthworks and the bridge being designed in accordance with the Transport Agency's Bridge Manual[9] for a working life of 100 years. A site specific seismic hazard assessment has been undertaken[10] to provide the basis for seismic design. This is further described in the evidence of Mr Symmans.

(b) The tunnel will be designed to be resilient to natural stresses.

(c) The earthworks will be designed (including batter slopes) to minimise rockfall debris encroaching on the carriageway (collector ditch / wider shoulders).

(d) The operational stormwater network will be designed in accordance with Transport Agency requirements. This will ensure stormwater will

[7] Volume 3 of the AEE.
[8] Technical Report 3, Resilience Assessment, section 2.
[9] The Transport Agency Bridge Manual, Third Edition, 2016.
[10] GNS Science Consultancy Report 2017/193, October 2017.

not encroach on the carriageway in events with a recurrence interval of 10 years.

DESIGN DEVELOPMENT

42. The design of the Project, consistent with general project design practice, has and will continue to develop in line with the four distinct phases explained below:

    (a) Preliminary Design:

    Alignment developed to design standards to facilitate the MCA process. The route and the extent of earthworks and structures are detailed to the extent necessary to enable assessment by technical experts of options, and for the development of budget costs. At this stage detailed calculations are not prepared, and the design is derived on the basis of the topographic and geological data available using road design software and the experience of other design disciplines. For example, tunnel designs are based on tunnels constructed in similar geological conditions, and bridge designs are based on configurations appropriate for particular spans and ground conditions.

    (b) Concept Design:

    The preliminary design of the preferred option is developed and refined sufficiently to provide more information on cost, enable the designation to be established and experts to prepare technical reports. By this time a ground survey is complete that verifies the accuracy of the data sourced from the aerial survey. Also, more geotechnical data was gathered to better inform design assumptions (for example, boreholes and cone penetrometer tests to determine the strength and depth of alluvial deposits, boreholes adjacent to the tunnel to determine the properties and jointing of the rock, test pits to observe ground conditions, materials sampling for laboratory testing). An independent safety audit of the design is also undertaken at this stage.

(c) Developed Concept Design:

Further development of the design of the preferred option to enable the notice of requirement and consent applications to be lodged and robust costings to be prepared. This includes:

(i) Refining and optimising the alignment, for example:

(1) to avoid significant trees where practicable;

(2) obtain the best earthworks balance between material from cuttings and that required for embankments;

(3) remove the need for climbing lanes by reducing gradients to less than 8%; and

(4) to achieve the best alignment through the tunnel and over the bridge.

(ii) Assessing whether there were better options for some aspects of the design, for example:

(1) Was there a better configuration for the bridge over the tributary to the Mimi River, given the northern abutment can only be accessed when the tunnel is completed (in that case, it was concluded there was not as accessing the north abutment from the south would necessitate intrusion into the environmentally sensitive valley).

(2) A review of the alignment in the Mangapepeke Valley identified that moving from the western to the eastern side of the valley avoided the need to demolish a farmhouse. It also removed the need for three bridges over side valleys and the Mangapepeke Stream and provided earthworks savings from lowering the alignment.

(3) A bridge in the southern region to the south of the bridge over the tributary to the Mimi River was replaced by an MSE fill.

(iii) Progressing all aspects of the design to a stage where preliminary drawings and details can be prepared sufficiently to allow estimators to cost the project (commonly referred to as 30% design).

(iv) Assessing how designs might change as they are developed and finalised, that is assessing the risks of changes occurring based on the design team's experience, such that appropriate allowance for risk could be included in estimates.

(d) Detailed Design:

Significant detailed design work is required to be undertaken before the Project reaches the stage that drawings can be issued for construction. An indication of the design work still to be carried out is that a team of approximately 35 designers will be required over a six month period to produce the level of detail required for construction to commence. Also, further geotechnical and topographic surveys are required to provide the appropriate level of certainty in the design for construction.

43. The design, as submitted for the hearing is at the developed concept stage. This provides a high degree of certainty that the design is feasible in principle, that is the detailed design will be similar and can be constructed within the designation.

44. Additional geotechnical investigations have the greatest potential to influence the final design. However, all options can be developed within the designation boundary and will not increase the environmental effects associated with the works.

ASSESSMENT OF ALTERNATIVES

45. As explained earlier in my evidence, key members of the design team and I visited the site early in the design process to gain an appreciation of the topography and ecology. The visit identified the challenges of designing a road in the area leading to the development of 'Humphrey', a computer generated three-dimensional visualisation tool that provides a realistic appreciation of route options. Screen shots are provided in my evidence above.

46. The tool allowed options to be optimised in terms of the Project objectives and has proved very valuable in providing stakeholders and experts with an appreciation of the key aspects of options. Attached as **Appendix 1** to my evidence is a USB stick containing a ‘flyover’ produced from the model of the preferred route. I will run the ‘flyover’ during my evidence presentation to explain it to the Hearing Commissioner. The design is now more progressed such that it gives a realistic appreciation of the proposed alignment and how it will sit within the surrounding environment.

47. The process for assessing alternative options for the Project is discussed in detail in the evidence of Mr Peter Roan. In the paragraphs below I provide general comment on the 2017 alternatives process from my perspective as Design Manager.

48. Other alternative routes for a bypass of the Mt Messenger section of SH3 were proposed in 2002 and 2016. The routes identified in those studies were situated both east and west of the existing SH3 and designed to different

standards (including design speeds). All comprised "earthworks" solutions (with no tunnels or bridges) which had significant environmental effects.

49. For the 2017 MCA process, the Alliance developed 24 options that, as explained by Mr Roan, were considered at MCA1 (a number of options followed largely similar alignments to those considered in 2016). These options comprised 11 "offline" (east and west of the existing road) and one "online" corridor. The concept of '*treading lightly on the landscape'* was adopted resulting in the development of structural options that involve tunnels under ridges and bridges, or viaducts, across valleys. An 'earthworks' (cuts and fills) and 'structures' (tunnels and bridges and/or viaducts) option was also devised for each offline corridor (creating 24 options).

50. The offline options were all developed to similar design standards with a safe operating speed of 100kph.

51. Two online options were considered at MCA1. The topography of the online corridor is such that both options incorporated a number of bridges and a tunnel. Option Z2 which had a safe operating speed of 70kph to keep it clear of Ngāti Tama property, while the northern end curve radii was governed by the need to maximise the length of road on rock spurs (as opposed to on the valley floor on alluvial deposits). Option Z2 with a safe operating speed of 100kph encroached onto Ngāti Tama property while to the north a long bridge was incorporated to carry the road on a curve across the soft deposits in the valley floor.

52. MCA2 followed MCA1. Four offline options were considered in the MCA2 process, alongside a refined single Z option (combining the two Z options considered through MCA1 and called Option Z7). Refinements to the MCA2 Z option within Z7 were significant, as follows:

   (a) the number of bridges was reduced to 2 or 3;

   (b) constructability was improved by realigning the route south of Mt Messenger to the west to provide both lateral and vertical clearance to SH3, however, as explained in Mr Milliken's evidence, significant construction challenges still remained; and

   (c) north of Mt Messenger a major retaining wall was introduced to provide resilience in the area where the alignment crossed an active landslide.

53. The safe operating speed of Option Z7 was 70kph as a result of the curve radii required towards the northern end of the Project to maximise the length of road on rock spurs (as opposed to on the valley floor on alluvial deposits). The 70kph speed also permitted a lower radius vertical curve to be used through the tunnel, which assisted with constructability as the tunnel portals aligned better with the existing road rather than being above or below it.

54. Subsequent to MCA2 further work was carried out to determine whether any of the short-listed options could be modified to reduce their effects and cost.

55. Few opportunities for reducing the area affected by works and cost savings arose from applying reduced design standards, such as design speeds. This is largely because the horizontal and vertical alignments of the options were primarily dictated by the extreme topography of the area.

56. As described under 'Developed Concept Design' (above) significant development of the preferred option (Option E) was subsequently undertaken. This developed concept is the design submitted for the hearing.

END-TO-END DESCRIPTION OF THE PROJECT ALIGNMENT

The Project Area

57. Overall, the alignment of the Project is approximately 6km in length. It extends from the existing SH3 corridor approximately 1km south of Mangaonga Road through to a point near the property located at 2528 Mokau Road, Urenui where it will 'tie' (connect) back into SH3. From there the Project incorporates the existing SH3 as far as the bend near to the property at 2454 Mokau Road where sight lines around the bend will be improved.

58. A brief description of the Project and a summary of design standards are provided below with more detail and the design standards described under 'Key Design Elements'.

SH3 tie-in points

59. The connections to the existing (bypassed) section of SH3 will be in the form of local T intersection arrangements designed in accordance with Austroads guidelines. The tie-ins will be illuminated at night.

60. There are no existing local roads impacted by the Project alignment.

Provision for pedestrians and cyclists

61. Pedestrians and cyclists are not commonly seen along this section of SH3. However, the shoulders provided next to the traffic lanes along the alignment will be suitable for their use.

Maintenance bays

62. Maintenance bays will be provided in locations along the alignment where maintenance will be essential to the safe and efficient functioning of the State Highway.

Traffic services

63. Signs, road markings and safety barriers will be provided in accordance with Transport Agency requirements.

Network utilities

64. Existing services that will be affected by the Construction Works include Vodafone and Chorus cables in the verge of SH3. Depending on their exact location and depth, local diversions of these cables are likely to be necessary where the Project intersects the existing road.

Regions

65. The Project area is divided into two regions:

    (a) Northern Region: from the northern tie-in to the southern tunnel portal (Chainage 0-3625); and

    (b) Southern Region: from the southern tunnel portal to the southern curve on the existing State highway where sight lines are improved (Chainage 3625-5950).

Northern Region

66. From the northern tie-in point the alignment runs southwards up to approximately 1km to the east of the existing SH3. The alignment follows the lower Mangapepeke Valley along the eastern side of the valley floor and then the eastern valley slopes to the upper Mangapepeke catchment. From the tie-in with the existing SH3, where the elevation is approximately 12m, the route climbs with a gradient of 0.6% over a distance of approximately 2km. This will require a series of cuts and fill embankments, generally less than 5m high, with one embankment approximately 16m high.

67. From Chainage 2000 in the upper Mangapepeke Valley the gradient becomes steeper, reaching 7.5% at Chainage 2400 and continuing at that gradient to Chainage 3240, where the gradient gradually reduces to the crest of the road (elevation 114m) in the tunnel at Chainage 3550. The alignment will be located on a large fill embankment, approximately 40m high, at the northern approach to the tunnel.

68. As shown on the drawings in Volume 2 of the AEE, and included in my evidence below, a number of culverts maintain the flows of tributary streams of the Mangapepeke Stream under embankments.

69. Two constructed wetlands are located adjacent to the road.

Southern Region

70. The alignment continues south descending on a 7% gradient, staying to the east of the existing SH3 (maximum 250m from SH3). Between Chainages 3700 and 3900 it will be located on a large fill embankment up to 16m in

height. A large cut slope, up to 49m in height is located between Chainage 3900 and 4140.

71. Between Chainages 4140 and 4260 a bridge carries the alignment across part of a tributary of the Mimi River containing the ecologically significant Mimi wetland. The bridge will be approximately 120m in length and 20m above the valley.

72. The alignment then continues south through a series of smaller cuts and fills to the east of SH3 and into the Mimi Valley. The gradient decreases to less than 1% as the alignment traverses the floor of the Mimi Valley, before connecting with the existing SH3 route. The southern tie-in to SH3 will be located at Chainage 5150 at an elevation of approximately 50m.

73. The design provides for improved sight lines, including to the curve immediately south of the Project's southern tie-in, which is signed with an advisory speed of 85kph. The sight distance around the curve is substandard and the verge adjacent to the northbound lane of the existing SH3 will therefore be widened. However, with a radius of 190m the curve does not meet the requirements for a 100kph safe operating speed (the minimum radius on the new alignment will be 460m) and the curve advisory sign will therefore remain in place.

74. A constructed wetland will be situated near to the southern tie-in.

75. The design of the alignment is described below, and shown in Volume 2 of the AEE and in the LEDF.

Drawings

76. Principal details of the road can be found on the following drawings in Volume 2 of the AEE:

MMA-DES-GEM-E1-DRG-1000 to 1010 – General Arrangements

MMA-DES-GEM-E1-DRG-3001 – Typical Cross –section

MMA-DES-GEM-E1-DRG-12001 to 2009 – Plans and long sections

MMA-DES-GEM-E1-DRG-1020 to 1030 – Safety Barriers, Road Markings, Signs and Pavement Details.

DESIGN STANDARDS

77. In summary, the developed concept design has been designed in accordance with the following, as the detailed design will be:

(a) Transport Agency manuals, technical memoranda and guidelines,

(b) The Association of Australian and New Zealand road transport and traffic authorities ("**Austroads**") guidelines;

(c) Australian Standards (**“AS**”) New Zealand Standards (**“NZS”**) and relevant International Standards;

(d) Ministry of Business Innovation and Employment (**“MBIE”**) guidelines for cycling provision;

(e) NIWA design programmes;

(f) Ministry for the Environment guidance;

(g) New Zealand legislation;

(h) Concrete Society guides;

(i) British Tunnelling and Institution of Civil Engineers specifications and design guides;

(j) Federal Highways Administration circulars;

(k) US Army Corps of Engineers design guides;

(l) UK Highways Agency design manuals; and

(m) Manufacturers’ associations’ standards and design guides.

78. Full details of the design standards are provided below.

KEY DESIGN ELEMENTS

Road

79. The Project is comprised of a two lane road (one traffic lane in each direction) with a tie-in to the existing SH3 corridor at each end. Key features of the road are:

(a) An alignment sympathetic to the natural landscape following the flanks of valleys as far as possible with a bridge over a significant wetland and a tunnel under a key ridgeline (**Figure 5**);

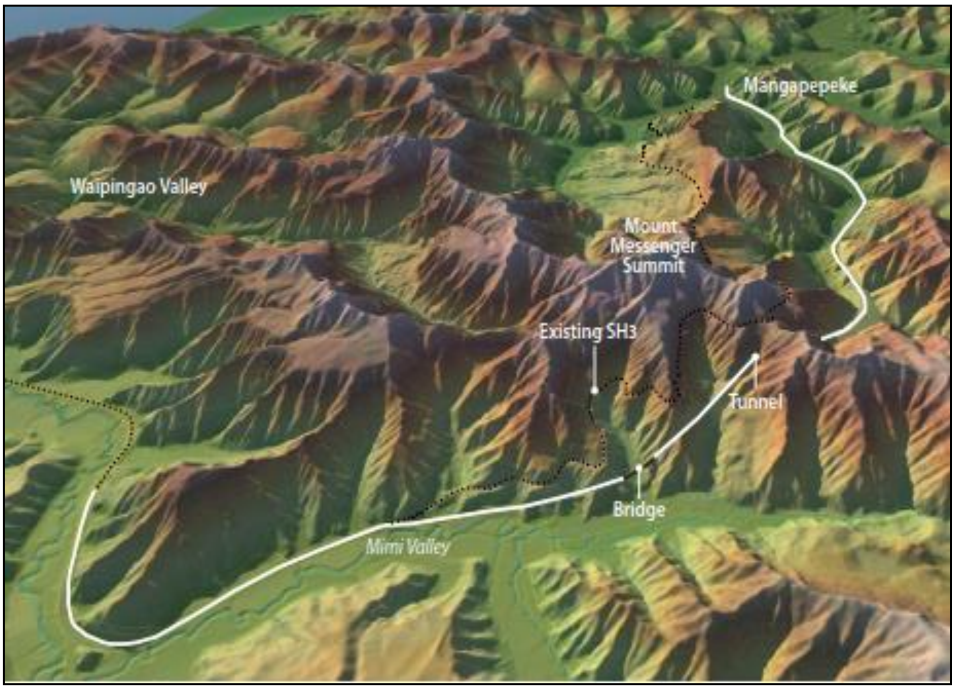

Figure 5: 3-D Representation of the route alignment

(b) 3.5m wide traffic lanes in each direction;

(c) 1.5m wide paved shoulders except on the bridge and in the tunnel. The shoulders are widened as required for sight distance around curves;

(d) 1.2m wide shoulders through the tunnel (with a 600mm wide central flush median);

(e) the outside (southbound) shoulder width on the bridge is 1.5m, and the inside shoulder is 3.0m wide to provide the required sight distance around the curve; and

(f) verges are provided along both sides of the road along the length of the alignment. The verge width varies between approximately 3 to 4.7m depending on whether the road is located in areas of cut or fill and as required to accommodate drainage swales;

80. A typical section through the road is shown in **Figure 6** and an image of the road in Mangapepeke Valley taken from 'Humphrey' is shown in **Figure 7.**

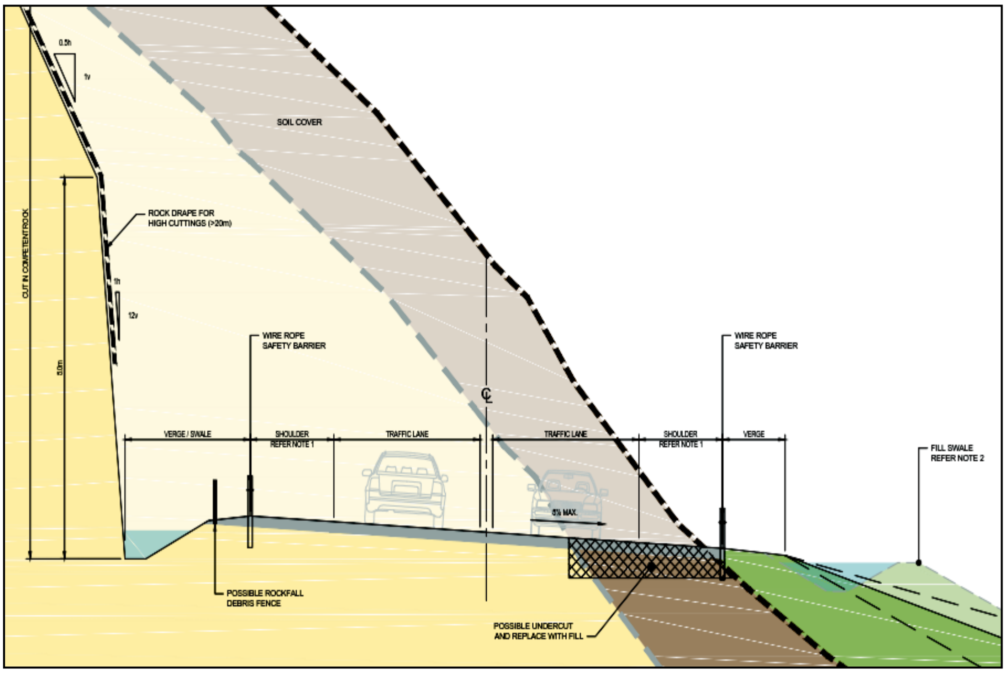

Figure 6: Typical Section through the road

Figure 7: Image of the road in the Mangapepeke Valley looking north with the Mangapepeke Stream to the left of the road

81. The alignment has been designed to be safe, efficient and resilient for a safe operating speed of 100km/h.[11] In summary, the Project Design Standards are set out in **Table 2** below.

[11] For light vehicle traffic travelling at this speed, there will be an average travel time of 3:9 minutes through the bypass.

Table 2: Project Design Standards

Parameter	Value
Posted speed	100km/h
Safe operating speed	100km/h[12]
Minimum stopping sight distance	151m[13]
Minimum curve radii	460m
Maximum gradient	• 7.5% southbound (distance of 925m with a grade greater than 6%); and • 7.0% northbound (distance of 675m with a grade greater than 6%).

82. The key features of the carriageway design are:

(a) a consistent sinuous, relatively open alignment with no surprises, that is, nothing out of context, and with a safe operating speed of 100km/h. However, a risk assessment will be undertaken as part of the development of the tunnel design to determine whether safety considerations warrant a lower posted speed through the tunnel;

(b) shoulders, a minimum of 1.5m wide (except in the tunnel where they will be 1.2m) providing 'manoeuvring room' if required and allowing most breakdowns to pull over without impeding traffic;

(c) good forward sight distances allowing cyclists to be seen in good time and providing adequate time for vehicles to stop safely or slow should there be an obstruction, such as an accident, ahead; and

(d) an illuminated tunnel designed to be driven safely at 100km/h. As discussed above a risk assessment will be undertaken as part of the development of the tunnel design to determine whether safety considerations warrant a lower posted speed through the tunnel.

83. Compared to the existing section of SH3, the key features of the alignment will result in a travel time saving for light vehicles of approximately 4:05 minutes (half the existing travel time of approximately 8 minutes, without encountering trucks, for both north-bound and south-bound traffic). The design does not seek to ensure all vehicles could travel at the posted

[12] A detailed risk assessment will be undertaken as part of the design development to determine whether safety considerations warrant a lower posted speed through the tunnel.
[13] To be corrected for grades exceeding + / - 3% (-15m / 25m) with an object height of 0.4m instead of the usual 0.2m if 0.2m has a significant effect on the sight distance required. Minimum SSD determined using the expected operating speed of 90km/h.

operating speed of 100km/h through the alignment. In particular, trucks (and cars following trucks) will likely travel at a slower speed through the steeper sections of the route.

84. Additional safety benefits of the bypass over the existing SH3 are achieved by the provision of safety barriers adjacent to both shoulders throughout the length of the bypass and earthworks designed to avoid rockfall debris encroaching on the carriageway.

85. The average operating speed across the Mt Messenger section of SH3 has been assessed as outlined in the **Table 3** below, taking into account the grades of the new alignment, along with typical vehicle composition.

Table 3: Operating speeds (average of all time periods and vehicles)

Operating Speeds (km/h)	Existing SH3 (7.4km length)	Mt Messenger Bypass (6km length)
Mt Messenger	56km/h	77.6km/h

86. Key aspects of the design are outlined in *Table 4.1 - Project Design Standards* of the AEE.[14]

Design standards

87. The carriageway design will be developed using the following documents:

(a) Austroads guide to road design (2009/2010);

(b) The Transport Agency Traffic control devices (TCD) manual, 2008;

(c) The Transport Agency Draft State Highway geometric design manual (SHGDM) 2005;

(d) The Transport Agency State Highway location referencing management system (LRMS) manual 2004;

(e) The Transport Agency Transit New Zealand Planning policy manual, 2007;

(f) The Transport Agency Technical Memorandum TM-2501: Superelevation calculations, 2013;

(g) Transport Agency Technical Memorandum TM-2502, Preferred method for calculating road surface water run-off in New Zealand, 2014;

(h) MBIE New Zealand cycle trail design guide, 2015; and

(i) Transit New Zealand: Highway surface drainage, a design guide for highways with a positive collection system 1977.

[14] AEE page 48.

BARRIERS

88. Wire rope safety barriers (**Figure 8**) will generally be provided adjacent to each shoulder along the full alignment length although consideration is being given to using steel 'W' section barriers in some areas. Concrete barriers (**Figure 9**) will be used on the bridge and in the tunnel.

Figure 8: Wire Rope Safety Barrier

Figure 9: Concrete safety barrier on the bridge

Design standards

89. Roadside wire rope and 'W' section barriers will be designed in accordance with the following:

(a) The Transport Agency Technical Memorandum TM-2503, Guidelines for Edge Protection and Medians on Dual Carriageway Roads, incorporating a Safe System Philosophy, 2013. (While the guidelines refer to dual carriageway roads, they embody the 'safe system' approach[15] to edge protection which is equally applicable to single carriageways); and

(b) Austroads Guide to Road Design - Part 6: Roadside Design, Safety and Barriers, 2013.

90. Concrete barriers on the bridge and in the tunnel will be designed to meet the requirements of the Transport Agency Bridge Manual, Third Edition, 2016.

TRAFFIC SERVICES

91. Traffic services along the Project will include: [16]

(a) permanent road signs and markings;

(b) solar powered road lighting at the intersections between the bypass and existing SH3;

(c) mains powered lighting in the tunnel and on the approaches to the tunnel; and

(d) side safety barriers.

92. These features are detailed in *Table 4.3* of the AEE.

Design standards

93. Signs and road markings will be designed in accordance with:

(a) The Transport Agency Manual of traffic signs and markings (MOTSAM) Parts 1 (Signs) and 2 (Markings), 2010;

(b) The Transport Agency Specification TNZ P/24, Traffic signs performance based specification, 2008;

(c) Road Safety Manufacturers Association (RSMA) Compliance standard for traffic signs;

(d) AS/NZS 1906.4: 2010, Part 1 Retroreflective sheeting & Part 2 Retroreflective devices;

(e) The Transport Agency Technical Memorandum TM-2014: Delineation associated with barrier systems, 2017; and

(f) The Transport Agency Code of Practice for Temporary Traffic Management (COPTTM); Part 8 of the Traffic Control Devices Manual (TCD Manual) 2012.

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[15] Recognising that drivers make mistakes, the Transport Agency has adopted the Safe System approach to reduce the severity of crashes when errors occur, e.g roadside barriers to redirect out-of-control vehicles away from potential roadside hazards.
[16] AEE, pages 52 and 53.

Provision for pedestrians and cyclists

94. While cyclists and pedestrians are not commonly seen along this section of SH3, the carriageway cross-section has been designed to be suitable for pedestrians and cyclists.

95. There is no Transport Agency standard or guidance relating to the provision for cyclists or pedestrians travelling between intersections on state highways.

96. MBIE has published a design guide for the New Zealand Cycle Trail.[17] While SH3 in Taranaki is not currently part of the New Zealand Cycle Trail, it may become so in the future. In any case, the guide provides information relevant to on-road trails and this has been taken into account in the design of the Project (and will continue to be through the detailed design).

97. The guide states it is essential that good intervisibility between cyclists and motorists is achieved, particularly for higher speed locations.[18] The sight distance design criteria for the Project will meet this objective. It will also be a significant improvement on the existing SH3 carriageway where the sinuous alignment and numerous sharp curves (**Figure 10**) provide poor forward sight distances for motorists to see cyclists.

Figure 10: SH3 South of Mt Messenger

98. The guide provides a general design specification[19] for various 'Grades' of on-road trails with the grades defined by the experience, fitness and levels of exertion expected of cyclists with the latter dictated by the steepness and length of gradients. The Project falls in the 'Intermediate' (Grade 3) category, i.e gradient 0° to 6° (up to approximately 10%). For a Grade 3, or the more

[17] Ministry of Building Innovation and Employment: New Zealand Cycle Trail Design Guide, 4th edition, February 2015 ("**MBIE Cycle Trail Design Guide**").
[18] MBIE Cycle Trail Design Guide, section 4.1, pg 39.
[19] Section 4.2. pg 40 & 41.

onerous Grade 4, and a 100kph speed limit a minimum shoulder width of 2.0m is desirable, with a range of 1.0m to 2.0m being deemed acceptable. The proposed minimum shoulder width of 1.5m (1.2m in the tunnel) are in the acceptable range. Also, it should be noted that the shoulder widths defined in the guide are for traffic volumes of up to 5000vpd, considerably more than on the Project.

99. I consider the shoulders available for use by cyclists together with the adjacent verges will provide a safe environment for the occasional pedestrian on the route.

100. The tunnel will be provided with detector loops set in the shoulders to sense cyclists approaching the tunnel. When a cyclist is detected the tunnel lighting will be restored to full brightness and Variable Message Signs will advise motorists of the presence of cyclists in the tunnel.

Maintenance bays

101. The design incorporates maintenance bays where access for workers and their equipment is necessary for the safe and efficient functioning of the State Highway corridor. These will enable the road to continue to operate without traffic being disrupted.

102. Maintenance bays are provided for:

(a) culverts where access will be required to maintain debris screens and culvert inlets;

(b) bridge abutments to permit the inspection of bearings;

(c) constructed wetlands for periodic removal of silt from forebays; and

(d) the tunnel, tunnel control building and hydrant tanks.

103. The maintenance bays will be accessed from the road, located clear of the carriageway, and protected by safety barriers.

104. The tunnel control building hard stand will be used for any maintenance of the building and to access the tunnel egress passage. Maintenance bays are not provided within the tunnel. The hydrant tanks will be accessed from the rest area close to the summit of the existing road.

105. The road drainage network minimises the use of catchpit inlets, replacing these with open drainage channels (swales). Constructed wetlands have been consolidated and located close to the ends of the Project and at Chainage 1650 to 1700,[20] where access is practical. Swales will minimise the need for maintenance by being in natural rock or, where on earthworks, will be vegetated or rip-rap lined.

[20] In the Northern Region.

Property and track access

106. Property access arrangements will be finalised through detailed design and once the Project designation is confirmed and through the SH3 revocation process. All properties will be provided with safe access onto SH3.

107. The design includes a new parking area at a suitable location adjacent to the existing SH3 carriageway that will provide safer conditions for users of the Mt Messenger and Kiwi Road walking tracks. The existing SH3 carriageway will have very low traffic volumes when the new bypass is operational.

PAVEMENTS AND SURFACING

108. The general pavement and surfacing philosophy for the Project is as follows:

  (a) Pavement – will comprise granular sub-base and base layers including in the tunnel. Cement modification of the base-course will be considered as part of the design process to improve the performance of the pavement.

  (b) Surfacing - chip seal is proposed along the alignment with the exception of the bridge deck and tunnel. It is proposed Stone Mastic Asphalt will be used for the bridge deck surfacing. A 10 to 15 year design life is required for the tunnel surfacing; while the design is still to be finalised, asphalt will meet this requirement.[21]

109. The final pavement and surfacing design will take into account the following:

  (a) subgrade strength and any differential settlement issues;

  (b) requirements for sub-surface drainage;

  (c) rehabilitation of existing pavements;

  (d) construction methodology and impact on existing traffic;

  (e) use of locally available materials and recycling of existing pavement materials where possible;

  (f) surfacing considerations, such as high vehicle stress areas; and

  (g) design standards

110. All pavements will be designed in accordance with:

  (a) Austroads: Guide to pavement technology, Part 2 Pavement structural design, 2017; and

[21] The surfacing of the tunnel will have appropriate skid resistance during its design life of 10-15 years in accordance with the notes to NZTA Specification T10 'Notes to Specification for State Highway Skid Resistance Management, 2013'

(b) The New Zealand Transport Agency: New Zealand guide to pavement structural design, 2017.

Network utilities

111. Existing services that will be affected by the Construction Works include Vodafone and Chorus cables in the verge of SH3. Depending on their exact location and depth local diversions of these cables are likely to be necessary where the Project intersects the existing road at the northern and southern ends. The extent and scope of any diversions will be discussed with the relevant authorities.

BRIDGE

112. A bridge (**Figure 11**), approximately 120m long, between Chainages 4140 and 4260[22] crosses the steep sided and flat bottomed valley upstream of the Mimi wetland. The bridge has been included to minimise effects on the wetland, which has a high ecological value as explained in the ecology evidence.

113. The key design features of the bridge are:

(a) the superstructure is comprised of a three span steel ladder deck with a composite concrete deck slab. The middle span will be approximately 50m in length while the two outer spans will be approximately 35m in length. The bridge deck will be approximately 12.8m wide overall;

(b) the sub-structure has inclined steel frame piers founded on the sides of the valley. The piers will be constructed on rock slopes on reinforced concrete pads. Depending on the depth to competent rock mini-piles may be installed. Rock bolts and/or netting drapes may need to be installed to control stability and local rock-fall above the pier foundations;

(c) the bridge abutments will be reinforced concrete, founded on rock, with bored piles as required depending on the depth to competent rock;

(d) the bridge design will enable the bridge components to be lifted in place and the bridge constructed from the abutments with large cranes. As such, access to the valley floor below and the construction of large staging platforms will not be required, minimising effects on the tributary to the Mimi wetland; and

(e) a trial is currently underway to determine the suitability of weathering steel for the construction of the bridge. The trial is ongoing, but initial results indicate weathering steel is likely to be suitable. This type of steel has the advantage over a painted structure in that it does not require painting and subsequent re-painting thereby minimising the

[22] In the Southern Region.

effects of maintenance (for example, access to the underside of the bridge, grit blasting, and painting.) on the ecologically important wetland.

(f) 

Figure 11: Bridge over tributary of Mimi River

Design standards

114. The Bridge will be designed in accordance with the relevant Transport Agency and New Zealand and Australian design standards for bridges, concrete and steel structures as follows:

(a) The Transport Agency Bridge Manual, Third Edition, 2016;

(b) NZS 1170.5; 2004 Structural Design Actions – Earthquake Actions, New Zealand;

(c) NZS 3101: 2006 Concrete Structures Standard;

(d) NZS 3404: 1997 Steel Structures Standard; and

(e) AS 5100 Australian Standard for Bridge Design.

TUNNEL

115. The alignment includes a tunnel approximately 235m in length to avoid significant adverse effects that would be associated with a cut through the ridgeline to the east of Mt Messenger. The roadway in the tunnel is approximately 95m below the crest of the ridge.

116. The key design aspects of the tunnel are:

(a) the arch shaped tunnel cross-section is dictated by the need to cater for over-dimension vehicles for which a clearance envelope of 10m x 6m is required;

(b) the inclusion of a 1.2m wide x 3.1m fire-rated emergency egress passage for pedestrians on the western side of the tunnel. The passage will meet the physical accessibility requirements of Section D1 of the

Building Code[23] and be accessed through fire rated doors spaced regularly along the length of the passage;

(c) the road cross-section in the tunnel (**Figure 12**) differs from that elsewhere along the route. While lane widths remain at 3.5m they are separated by a 600mm wide flush median. This provides separation of the bi-directional traffic while allowing people to cross the road and reach the egress passage if required in an emergency. Shoulder widths will be 1.2m which provides sufficient width for use by cyclists;

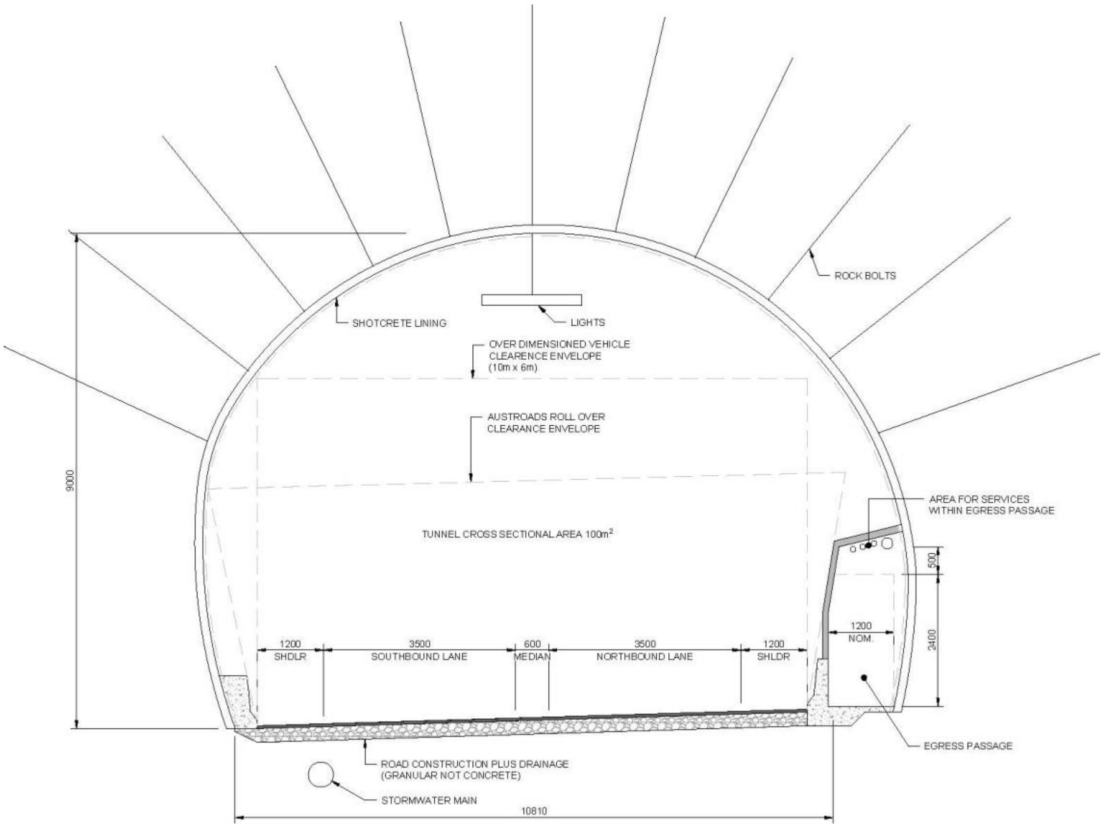

Figure 12: Section through tunnel

(d) four classes of support to the tunnel roof are proposed governed mainly by the tunnel overburden depths. The extent of each support class will be confirmed on site as ground conditions are mapped by engineering geologists during excavation;

(e) the tunnel excavation will be supported by permanently bonded crown dowels between 4m and 6m long, and fibre reinforced shotcrete lining which will vary in thickness from 100mm to 300mm depending on overburden and rock quality. The highest levels of support will include lattice girders embedded in the shotcrete;

(f) rock cuttings, approximately 25 to 30m deep, will be required at the approach to each tunnel portal. The tunnel portals will extend clear of the adjoining rock face to protect the roadway from possible rock fall debris

[23] Building Regulations 1992: Schedule 1, Building Code, Section D1 - Access Routes.

from the slopes above (**Figure 13**). The tunnel portals are a significant gateway feature along the route and provide an opportunity for cultural expression within the landscape as the road passes under the ridge from one valley system to the next. The process for determining the response to this cultural expression opportunity is detailed in the LEDF (Volume 3 of the AEE);[24]

Figure 13: Tunnel portal

(g) a fire hydrant system will deliver water to dual head hydrants located at intervals along the tunnel and accessible from the emergency egress passage. Three water tanks with a total capacity of 350,000 litres will be installed at the rest area on the existing SH3, above the tunnel (**Figure 14**). Water supply for the tanks will be by tankers; and

Figure 14: Hydrant Tanks above tunnel

[24] LEDF, pages 47 and 48.

(h) wash-down water and any hydrant water in the tunnel will be carried away via catch pits and subsurface drains connected to the main highway drainage system.

Tunnel control building

117. A tunnel control building accessed via a road off the Project (**Figure 15**) will house the main electrical control systems and plant for the operation of the tunnel. The building will be located adjacent to the northbound carriageway to the south of the tunnel and fenced and screened by planting.

Plan

Section

Figure 15: Tunnel control building

118. The tunnel will be monitored and equipment controlled from a Transport Agency's Traffic Operations Centre.

119. The electrical equipment in, or adjacent to, the control building will include:

(a) a power transformer;

(b) the main electrical switchboard and distribution panels;

(c) programmable controllers;

(d) uninterruptible power supply (UPS);

(e) batteries;

(f) emergency generator and associated fuel storage and electrical infrastructure;

(g) general lighting and power controls; and

(h) external security lighting with motion sensor controls may be installed.

120. The building will be the minimum size required (approximately 15m long, 10m wide and 4 to 5m high) to house the equipment and provide safe access for maintenance and equipment replacement in the future.

121. The tunnel is required to comply with the Building Act 2004 and regulations enacted under that Act. Fire systems are subject to the Compliance Schedules and associated regulator testing. The building and its environs will be designed to address Crime Prevention through Environmental Design considerations, primarily by access control, surveillance cameras, signage and design of the building such that it is not of interest to potential offenders.

Tunnel safety equipment

122. Provision for fire and life safety in the tunnel will be in accordance with *AS 4825 Tunnel fire safety*[25] as modified by the Transport Agency's *Guide to road tunnels*.[26]

123. *AS 4825* endorses a fire engineering assessment process that involves testing the adequacy of a proposed design through a number of scenario analyses, or through a rigorous risk analysis process. These scenarios range from a small vehicle fire through to an explosion. This assessment process also meets the Transport Agency's requirements for a risk management framework in its guide to road tunnels as well as *Safety in Design*[27] considerations.

124. The results of the assessments require significant safety equipment to be incorporated in the design although mechanical ventilation, or a deluge system are not warranted (these aspects of the assessment outcome are influenced by the length of the tunnel and the relatively low traffic volumes).

125. Tunnel safety equipment will include:

(a) Lighting of the tunnel roadway and emergency egress passage along the full length of the tunnel for general and night-time illumination. To reduce power consumption the tunnel lighting will be set to a lower light level when no traffic is detected after a set period of time. Light levels will immediately return to full levels when vehicles trigger detection

[25] Standards Australia AS 4825: Tunnel Fire Safety.
[26] New Zealand Transport Agency: Guide to Road Tunnels.
[27] Safety in Design means the proactive consideration of construction, operation and demolition safety risks during the design process to eliminate or mitigate such risks through design.

induction loops on the approaches to the tunnel. Smaller induction loops will be used for cyclists, with a secondary manual control at the approach in each direction to manually activate the tunnel lighting.

(b) Activating the induction loops or manual control will set the light level to full brightness for a set period of time to allow the motorist, or cyclist, to pass through the tunnel before returning the lighting to lower levels. A signal will be sent to the VMS to warn motorists when there is a cyclist in the tunnel.

(c) Road lighting will be provided on both tunnel approaches to provide a transition in light levels between the unlit approaches and the tunnel to enable driver's eyes to adjust at night.

(d) Emergency lighting in the tunnel and egress passage with connection to the UPS.

(e) Vehicle grade tunnel guidance control LED road markers to delineate the edge of carriageway and median (yellow edge markers between the carriageways and shoulders and red in the median).

(f) A public address system.

(g) A fire detection system.

(h) Closed circuit television (consisting of cameras mounted within the tunnels and egress passage to provide continuous coverage of the tunnel interior and portals). The systems will be monitored from a Transport Agency's Traffic Operations Centre.

(i) Signage and strobe lighting to guide pedestrians to the exit doors in an emergency.

(j) External traffic barriers and signage to prevent traffic entering the tunnel during an incident.

(k) Fire hydrants.

Power supply

126. A permanent electrical power supply to a transformer outside the tunnel control building will be provided for the operation of the tunnel. The power will be supplied through a new underground cable installed adjacent to the new alignment.

127. Resilience will be assured by a generator located in the control building that will provide back-up power for electrical systems in the tunnel.

Design standards

128. The tunnel will be designed on the basis of best practice incorporated in New Zealand and international standards, guidance and other documentation as set out in **Appendix 2**.

CUT SLOPES AND FILL EMBANKMENTS

129. The alignment will traverse steep terrain bisecting a number of valleys and ridges.

130. Accordingly, a number of cut slopes approximately 25m to 60m in height and embankments up to 40m in height will be required along the alignment.

Cut slopes

131. The design of the cut slopes is governed by the material properties of the Mount Messenger Formation (predominantly fine-grained sandstones and silty mudstones that constitute the soft rock that underlies the alluvial soils in the area).

132. The design is based on recommended practice for slopes in materials of the type at Mt Messenger[28] and the design team's experience on other projects with similar geological conditions. Also, discussions with the Network Outcomes Contractor (the contractor responsible for maintaining SH3) the existing cuttings at Mt Messenger, and elsewhere (similar to those proposed, but generally not as high) have only minor maintenance issues. The typical resultant design is as follows:

    (a) from road verge level, an 8m high cut in rock formed at 12V:1H (approximately 85°);

    (b) 1V:0.5H (approximately 63°) from the top of the 12V:1H cut;

    (c) on the upslope of the cutting (where the existing ground level typically continues to rise above the top of the cut), the 1V:0.5H profile will continue to the ground surface, with soil nails where required to stabilise the surficial materials, and

    (d) on the downslope side of the cutting (where the existing ground surface typically drops away from the top of the cut), the batter slope of the upper 5m of the cut was reduced to 1V:2H (approximately 26°) to avoid the need for soil nailing.

[28] Jennings et al, Road Engineering in Soft Rocks, 1990, RRU Bulletin 84, Vol. 4.

133. A general illustration of a cutting is shown in **Figure 16** below.

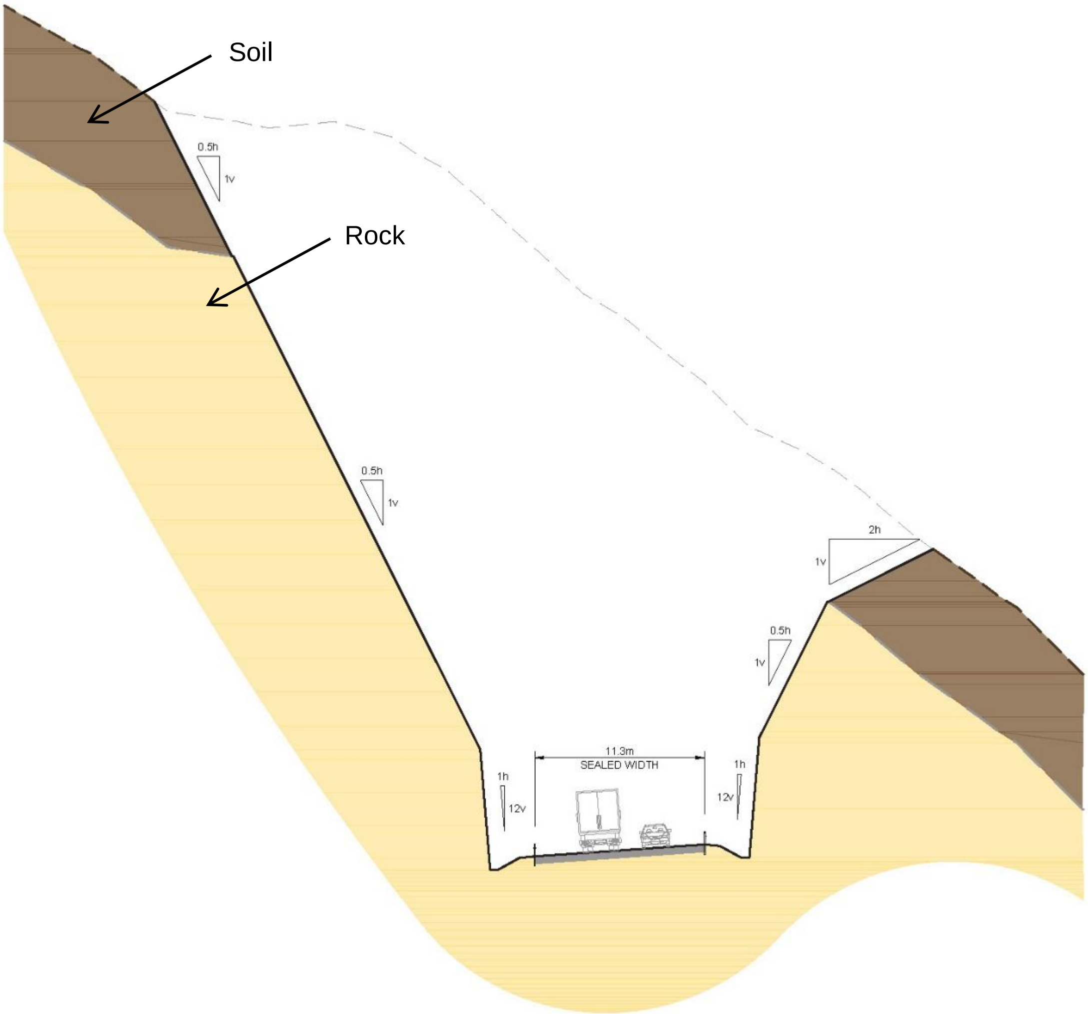

Figure 16: Typical rock cutting (Chainage 2550 approximately)

134. **Table 4** below provides metrics for the main cuttings along the alignment:

Table 4: Details of Main Cuttings

Chainage (m)		**Approx. Length (m)**	**Approx. Depth (m)**
From	**To**		
260	490	230	48
1100	1280	180	52
1560	1670	110	26
1950	2280	330	38
2450		400	57
3300	3400	100	32
3630	3680	50	29
3900	4140	240	49
4270	4370	100	31
4430	4550	120	30

Embankments

135. The embankments required along the alignment can generally be divided into two types according to height and ground conditions. The embankments will require the placement of large volumes of fill material, along with ground improvement measures. Details of the ten main embankments on the alignment are summarised in **Table 5** below.

Table 5: Details of Main Embankments

Chainage (m)		Approx. Length (m)	Approx. Height (m)	Anticipated Subgrade Materials
From	To			
550	970	420	3.0	Alluvium + slope deposits on sidelong ground.
1300	1370	70	3.5	Alluvium + slope deposits on sidelong ground.
1510	1560	50	3.5	Predominantly alluvium.
1700	1950	250	3.5	Alluvium + slope deposits on sidelong ground.
2300	2430	130	16.0	Slope deposits / Alluvium.
2850	3300	450	40.0	Across base of gully - slope and alluvial materials.
3680	3890	210	16.0	Across base of gully - slope and alluvial materials.
4370	4420	50	6.0	Slope deposits / Alluvium.
4560	4660	100	4.0	Predominantly alluvium.
4740	4790	100	1.5	Predominantly alluvium.

136. Embankments will be built from the material excavated from cuttings comprising rock, completely weathered rock and soils. The maximum finished slope profiles will be:

(a) 1V:2H (26°) if constructed with rock; or

(b) 1V:4H (14°) if constructed with soils other than rock (i.e. buttress and landscape fills) (**Figure 17**).

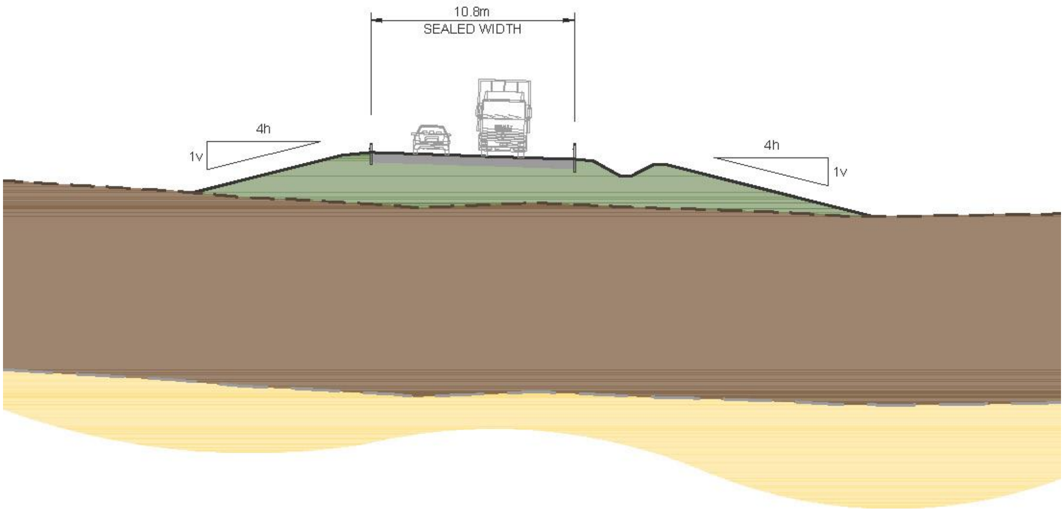

Figure 17: Typical Embankment (Chainage 600 Approximately)

137. In some instances embankments will be designed on the basis of a 'core' of rock fill with 1V:1H (45°) batters, supported by buttress slopes constructed to 1V:4H (14°) or 1V:3H (18°) (**Figure 18**). The buttress slopes will be either general fill or landscaping fill, which is not suitable for use in the core (i.e. derived from excavated soil and completely weathered rock).

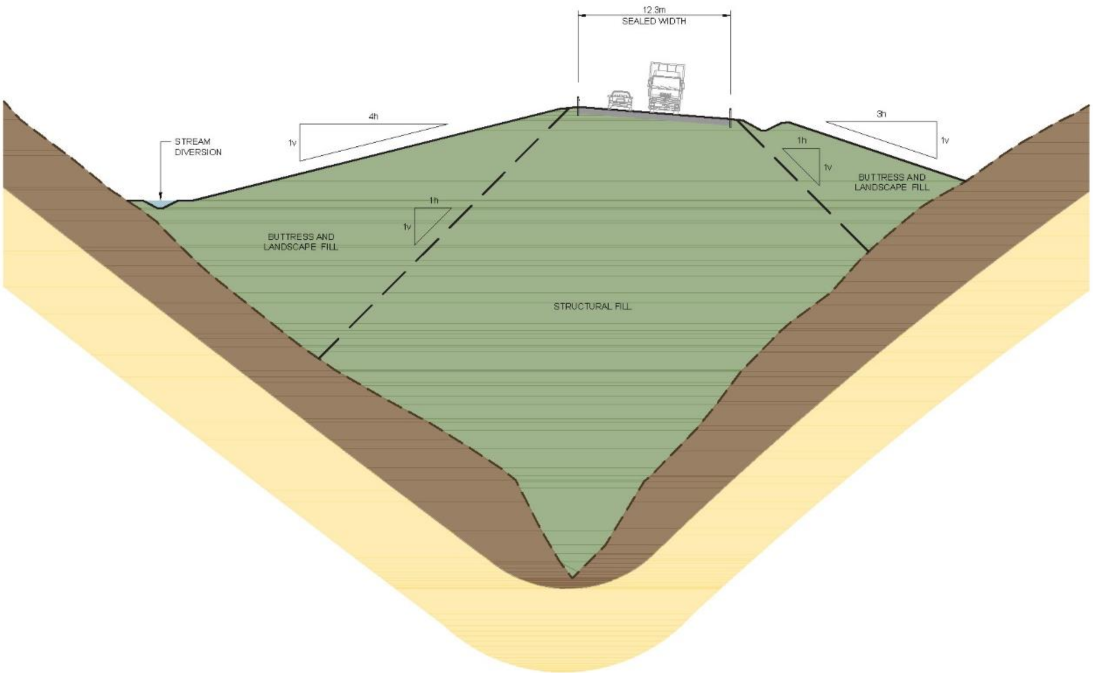

Figure 18: Typical Embankment With Buttress Fills

138. Site specific embankment designs will be carried out during detailed design. The designs will be in accordance with standard geotechnical guidelines and accepted New Zealand design criteria and standards.

139. The cutting and embankment designs are currently preliminary and profiles may change as the design development progresses. For example, changes may be required in the light of data from further geotechnical investigations, e.g. should the depth of alluvial deposits vary significantly from assumptions made at the preliminary design stage.

140. Designs may also change in response to changes in construction methods or the need for additional placement of fill.

Retaining walls and MSE fills

141. Two MSE embankments are proposed on the alignment. This is where steeper embankments (45°) are required without buttress fills because of space constraints. The space constraints are dictated by the need to avoid effects on areas of high ecological values. MSE fills will be located at:

(a) Chainage 2300 to 2430[29] which crosses a steep sided gully in the valley of the Mangapepeke Stream. The embankment will be up to 16m high and extends over a length of approximately 130m, grading into rock cuts at either end (**Figure 19**);[30] and

(b) Chainage 4370 to 4420[31] located across a short gully feeding into the Mimi River towards the southern end of the route. The embankment will be up to 6.0m high and extend over a length of around 50m.

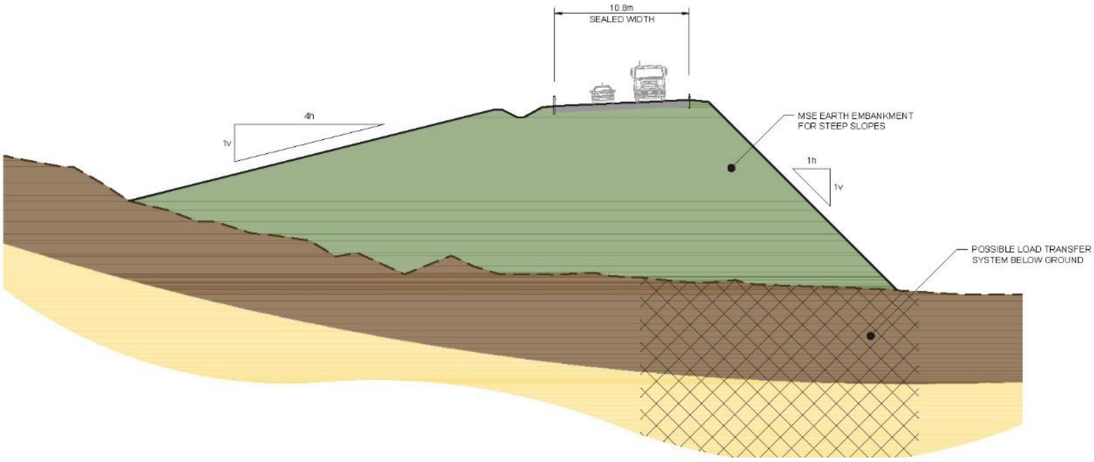

Figure 19: MSE Fill – Chainage 2300 to 2430

142. MSE fills will comprise geogrid reinforcement placed horizontally as layers of embankment fill are built up. The embankment slopes will be allowed to revegetate naturally.

143. Further MSE fills, or retaining walls, may be required at other locations along the alignment, such as the bridge abutments, or to minimise the length of culverts passing beneath high embankments. This will be confirmed during final design of the Project.

144. Further detail on MSE slopes and retaining walls can be found in the geotechnical evidence of Mr Symmans.

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[29] In the Northern Region.
[30] Recently completed geotechnical investigations at this location indicate soft soils to a depth greater than expected. While an MSE embankment is proposed at this location ongoing design development could determine that the MSE embankment is replaced by a bridge spanning the gully or an alternative embankment solution. A recent review confirms an MSE fill is the most appropriate solution.
[31] In the Southern Region.

Design standards

145. The following standards will be used for the detailed design of earthworks (cuttings and embankments including mechanically stabilised earth embankments) slope improvement works and foundations:

    (a) the Transport Agency Bridge manual, third edition, 2016;

    (b) GNS Science Consultancy: Site specific seismic hazard assessment, 2017; and

    (c) the Transport Agency TNZ F/1:1997: Specification for earthworks construction.

OPERATIONAL STORMWATER

146. Details of the Project's stormwater conveyance and treatment system are shown on Drawings MAA-DES-DNG-DRG-1000-1010 in Volume 2 of the AEE.

147. The Project design includes a stormwater management system that is fit for purpose and is appropriate for the rural environment in which the Project is located.

148. The receiving environment of the Project is the Mimi River and Mangapepeke Stream which Table 3.1 of the Treatment Standard categorises as "Priority" for water quality.

149. The stormwater drainage network and treatment system for the Project responds to the environment by avoiding and mitigating adverse environmental effects on water quality by incorporating the following design features:

    (a) Run-off will be collected in open roadside channels (swales) constructed along the alignment (and explained further below). The flows collected from the road surface and faces of cuttings that cumulatively contribute to the capacities of the constructed wetlands[32] will be conveyed downstream to the valley floors to one of three constructed wetlands.

    (b) Flows exceeding the capacity of the wetlands will be diverted into existing watercourses.

    (c) Collected stormwater will be contained, treated and detained in the wetlands, prior to discharging to the receiving environment.

    (d) The alignment crosses natural valleys and watercourses on fill embankments. Culverts will be installed to convey streams and

[32] The constructed wetlands are designed in accordance with the Transport Agency's Stormwater Treatment Standard for State Highway Infrastructure, 2010 to capture and treat flows from defined storms for a given period.

overland flowpaths from one side of an embankment to the other to ensure continuance of watercourses. Where fill embankments are located parallel to watercourses, the watercourses will be diverted along the toes of the embankments.

(e) Run-off from the bridge will be collected and conveyed along the face of the barrier.

(f) Fish passage will be provided for where it currently exists naturally.

(g) Upstream flows discharging across the bridge deck will be minimised by diverting upstream flows greater than those required to be treated in the constructed wetland.

150. The Treatment Standard indicates extended detention (provision of additional capacity in constructed wetlands allowing storage, treatment and the subsequent controlled release of storm flows in excess of the usual design requirements) is not required. However, extended detention that will provide additional treatment to storm flows and reduce channel erosion and storm flows in streams is being incorporated in the wetlands in recognition of the importance of the receiving environment.

151. As the tunnel will be located at the high-point in the road geometry, there will be no upstream catchment flowing through the tunnel. Where drainage is provided within the tunnel, this will be specifically designed to ensure that this cannot promote the spread of fire.

Swales

152. Swales will be used to convey and provide some pre-treatment of runoff from the road surface, upstream of the constructed wetlands. All swales will be designed in accordance with the Transport Agency's treatment standard. Three main swale typologies, with variants according to whether they are vegetated or rip-rap lined, will be used for the Project as follows:

(a) Types A – Vegetated swale (**Figure 20**);

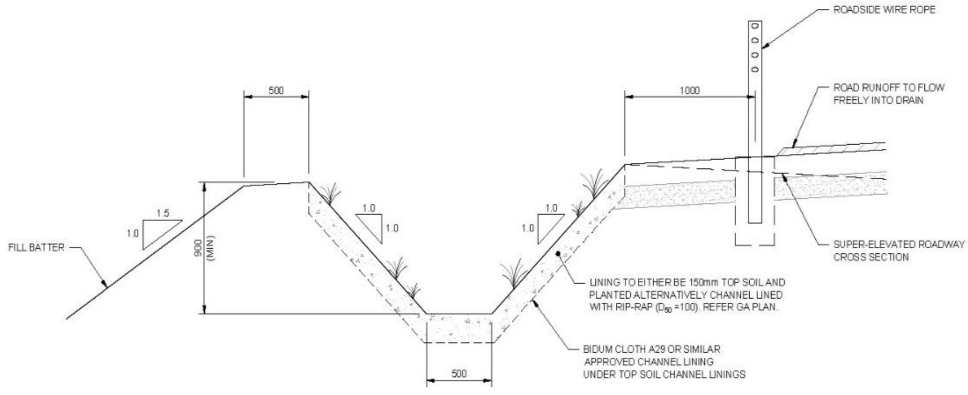

Figure 20: Type A - Vegetated swale on fill (Type D similar but rip-rap lined)

(b) Type B - Unlined swale in natural rock) (**Figure 21**); and

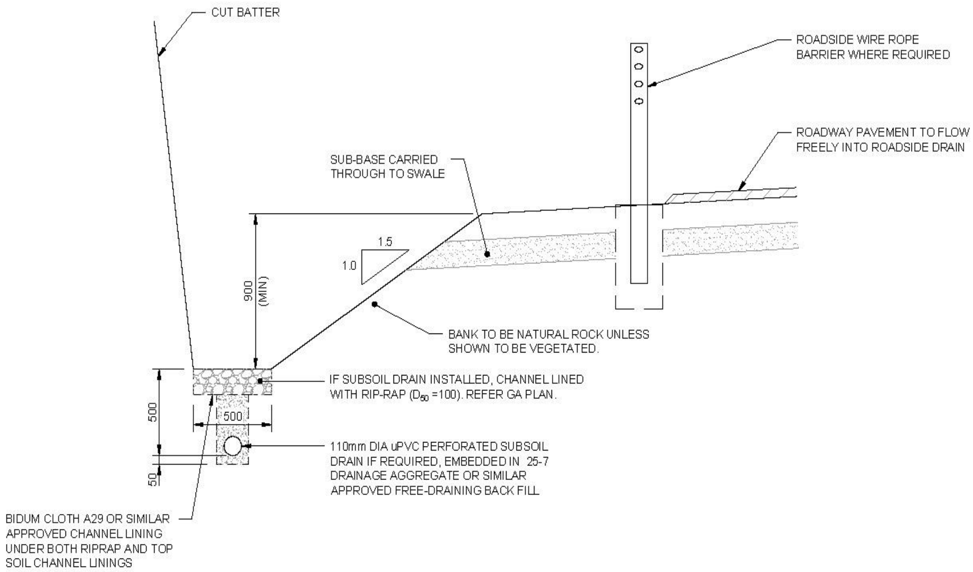

Figure 21: Type B - Unlined Swale in Natural Rock

(c) Type E - Swale at base of fill (**Figure 22**).

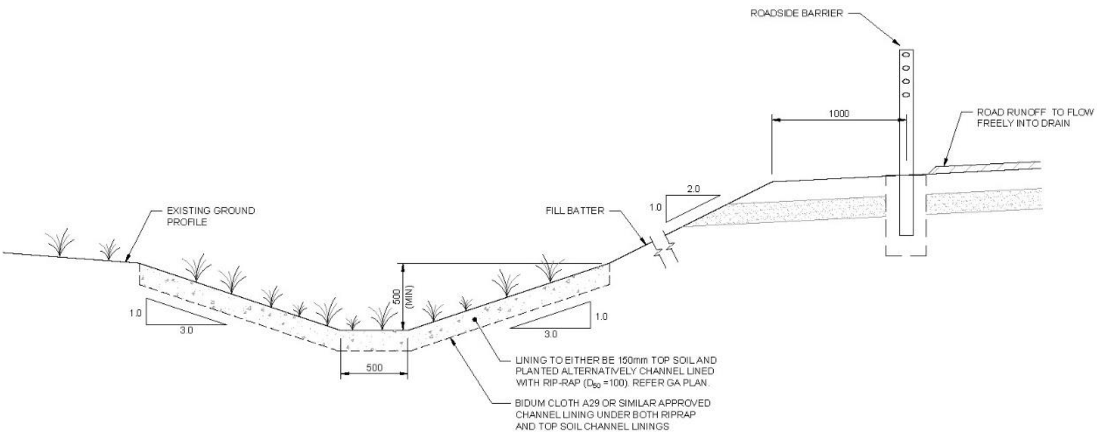

Figure 22: Type E: Swale at base of fill
(Type F similar but rip-rap lined)

153. Physical, chemical and biological process provided by vegetated swales will provide some water quality pre-treatment of run-off being conveyed to the wetlands.

154. Where practicable, vegetated swales will also be used to provide stand-alone treatment to portions of road at the extremities of the Project area.

Permanent stream diversions

155. Permanent stream diversions are required where necessary to realign a natural stream channel (or section of stream channel) for the Project, for example where an embankment is required on the line of, or across, an existing stream.

156. As described in the evidence of Mr Hamill, a combined length of approximately 3.8km of streams will require diversion.

157. As described in Section 5.3 of the LEDF, the site topography has required two stream diversion typologies to be developed as shown below. Typical details of stream diversions are shown and on the stream diversion drawing: in Volume 2 of the AEE.[33]

(a) Stream Diversion Type 1 (**Figure 23**) – Lowland stream that will require recreation of habitats associated with a natural lowland stream. Approximately 2500m of Type 2 stream diversions will be required for the Project.

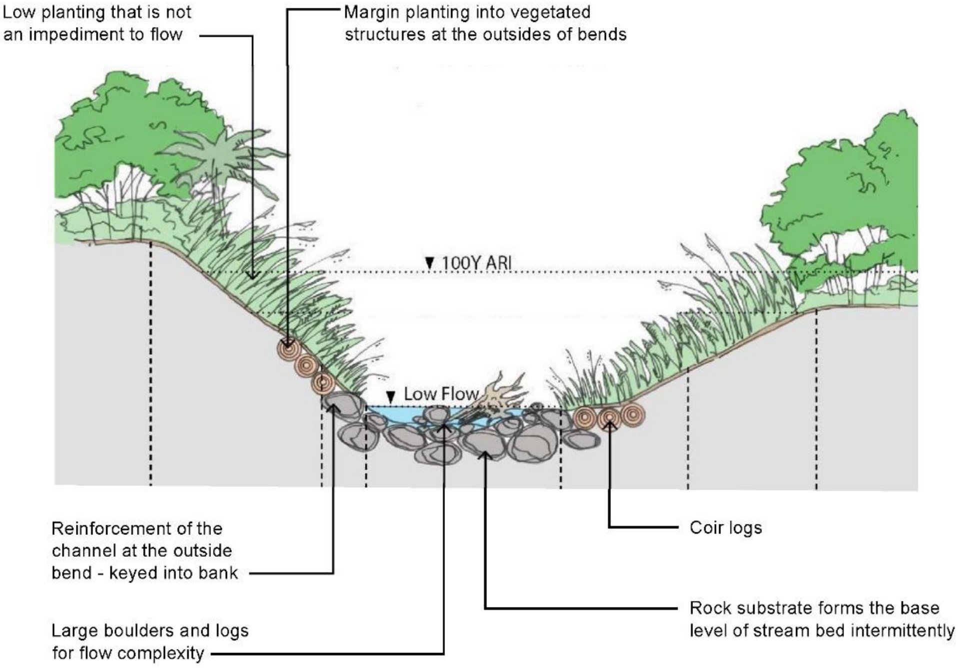

Figure 23: Typical Type 1 (Lowland Stream)

(b) Stream Diversion Type 2 (**Figure 24**) – Steep stream that will require the recreation of habitats associated with natural steep streams. Approximately 450m of Type 1 stream diversions will be required for the Project.

[33] Drawing MMA-DES-DNG-CO-DRG-4022.

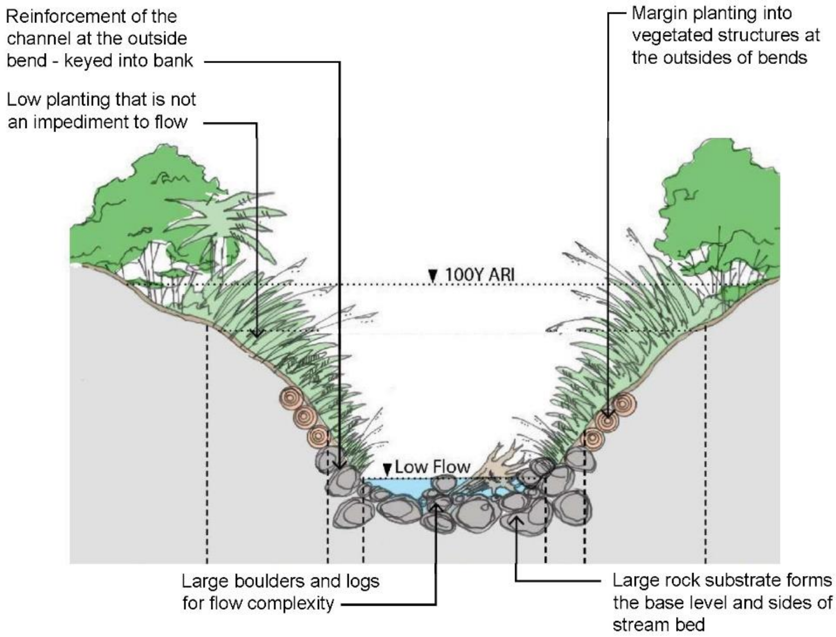

Figure 24: Typical Type 2 (Steep) Stream

Cross culverts

158. A number of embankments on the Project will cross, or run sub-parallel to, existing streams. Culverts will be provided for the conveyance of flows under embankments from one side of the alignment to the other to enable the continuation of streams and overland flowpaths. Culverts will be designed with best practice consideration of fish passage, erosion control, debris management and energy dissipation.

159. The Project requires the installation of culverts on both permanent and intermittent watercourses, as outlined in *Table 4.10*[34] in the AEE and shown on the culvert drawings in Volume 2 of the AEE. The total length of culverts to be installed along the alignment is in the order of 1200m. Typical culvert design details are included in the drawings in Volume 2 of the AEE. A long section of a typical culvert is shown in **Figure 25**.

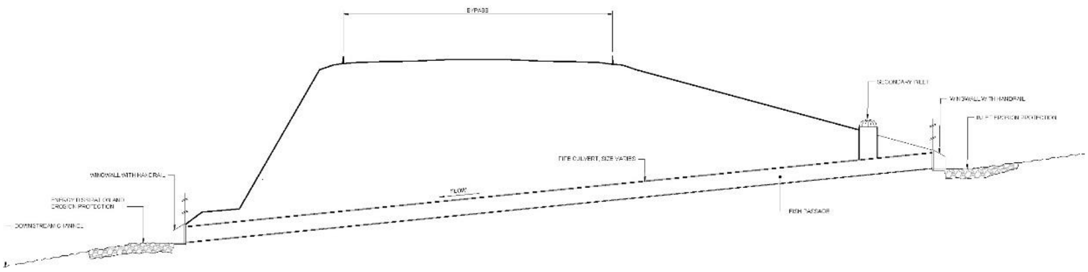

Figure 25: Long Section of a Typical Culvert

[34] AEE page 72. They are also contained in section 5.5 of TRC's s42A Report.

Culvert 9

160. The developed concept design for Culvert 9 (Chainage 1850 approximately) included in the drawings in Volume 2 of the AEE[35] comprises four 1350mm diameter pipes. This is necessitated by the minimal vertical clearance between the road surface and culvert. It is noted this is not ideal from the perspective of fish passage and alternatives are being investigated. While raising the bypass alignment would allow a more conventional culvert solution, the culvert (currently 56m long) would become longer. Current thinking is replacing the four pipes with two box culverts with suitable provision for fish passage is an appropriate solution. Further design work is being carried out to confirm this.

Fish passage

161. Fish species are limited to climbing fish in the steeper, upper reaches of the catchments within the Project area. The lower, flatter valley floors are inhabited by a mix of climbing and swimming species (refer to the evidence of Mr Hamill and Technical Report 7b, Volume 3 of the AEE).

162. As described in Mr Hamill's evidence, all except three of the 21 permanent culverts will have provision for fish passage. The three exceptions are culverts carrying ephemeral streams.

163. There are two types of culverts requiring different provision for fish passage as follows:

    (a) 4 No. steep culverts – fish passage will be provided by flexible plastic baffles that will accumulate sediment and form riffles and rest areas for fish during typical flow conditions (Type 1 fish passage – **Figure 26**); and

[35] Drawing MMA-DES-DNG-C0-DRG-1003

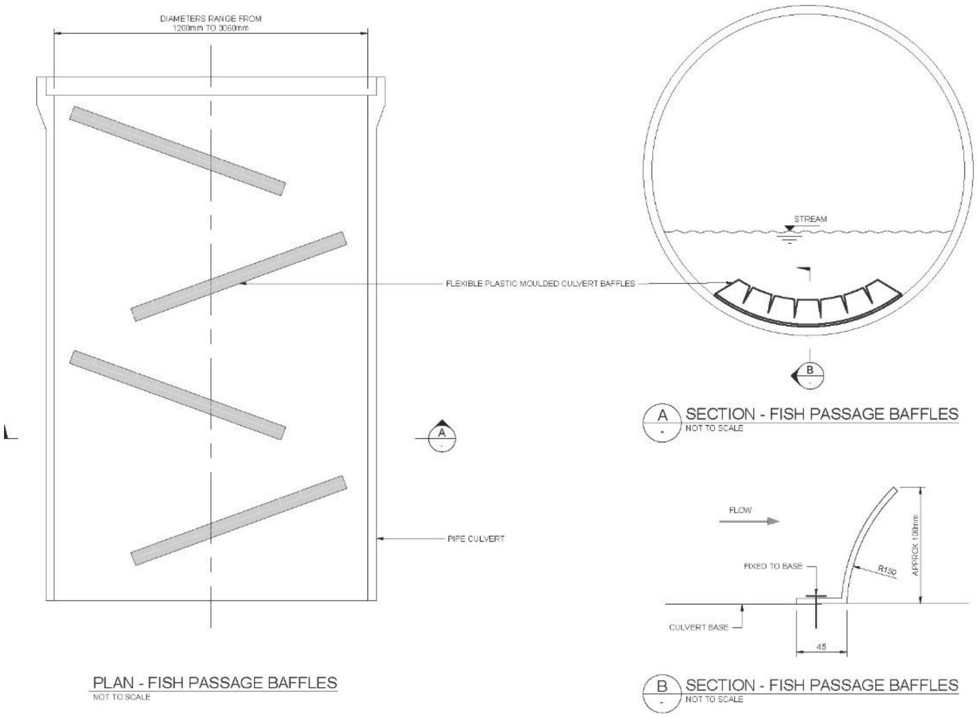

Figure 26: Fish Passage Type 1 (Steep Culverts)

(b) 14 No. shallow grade culverts - the culverts will be oversized with the invert below bed level such that the original stream bed reforms (Type 2 fish passage – **Figure 27**).

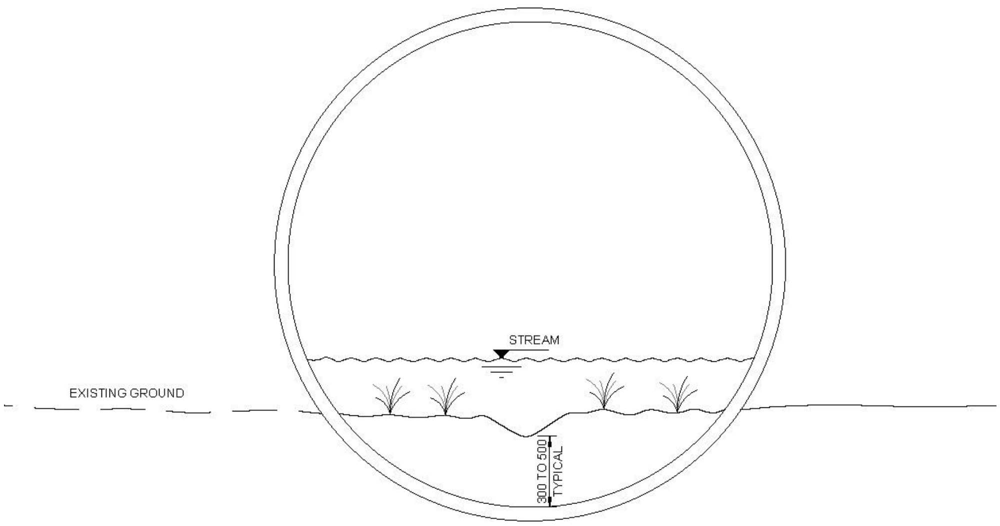

Figure 27: Fish Passage Type 2 (Shallow Grade Culverts)

Debris control measures

164. Debris can accumulate at culvert inlets, or become lodged in the inlet structure, which can lead to the blockage of culvert entrances and constrict flow through a culvert.

165. Densely vegetated areas have a high risk of debris generation, accordingly, the design includes debris control measures that will be installed at culvert inlets in those areas (refer *Table 4.10* in the AEE). Debris control fences will

be installed upstream of culverts to prevent the downstream passage of debris, such as logs, that have the potential to block culvert inlets (with the exception of Culverts 1, 2, 3, 4, 18, 19, 20 and 21 where the vegetation is such that blockage of culverts is unlikely).

166. A secondary scruffy dome inlet will also be provided in some locations as a secondary inlet to a culvert in the event that the main inlet becomes blocked. A scruffy dome (**Figure 28**) is a domed galvanised steel grille that provide a debris screen and will ensure flows are not impeded and significant ponding does not occur during a storm event. The domed design prevents build-up of debris and it prevents people and animals from entering.

Figure 28: Typical Scruffy Dome

167. Refer to the drawings in Volume 2 of the AEE for typical debris control details.

Scour protection and energy dissipation

168. High velocity flows at stormwater discharge points and culvert outlet structures can result in scour and erosion of downstream channels and stream banks. To prevent scour and erosion effects, all outlet structures will be designed with rip-rap basins to provide adequate energy dissipation and erosion protection measures. Rip-rap basins are a rock lined basin containing a pool of water at outlets. Rock aprons may be provided to further dissipate flows and reduce flow velocity before water discharges to the downstream receiving environment. Rip-rap basins will be sized for the 100 year Average Recurrence Interval ("**ARI**") storm event to minimise the requirement for maintenance given access to culverts will be difficult post construction.

169. Refer to the drawings in Volume 2 of the AEE for typical rip-rap basin details.

Constructed wetlands

170. Two constructed wetlands will be located within the northern region while a third will be located within the southern region as outlined in *Table 4.8* in the AEE.[36] The constructed wetlands will provide stormwater treatment and extended detention.

171. The purpose of extended detention is to minimise erosion of watercourses into which the wetlands discharge by providing an additional storage volume in a wetland whereby a portion of the run-off is stored and released slowly over an extended period of time thereby limiting both the magnitude and duration of peak flow.

172. The constructed wetlands will be developed in accordance with the Transport Agency Stormwater Treatment Standard for State Highway Infrastructure.

173. Figure 7.3 of the Treatment Standard indicates extended detention is not required where catchment imperviousness is less than 3%. Imperviousness of the Project catchments is less than 3% in all but the smallest sub-catchments. However, extended detention is being incorporated in the wetlands in recognition of the importance of the receiving environment. This exceeds best practice as defined by the standard and the wetlands will be designed to detain and release the first 36mm of rainfall over a 24 hour period. .

174. Constructed wetlands perform well as treatment devices, removing suspended solids (they can remove 75% total suspended solids on a long-term basis), heavy metals, hydrocarbons, and other traffic related pollutants, as well as providing additional filtering and biological treatment. They can also remove trap gross litter.

175. The wetlands will be planted. Typical design details for constructed wetlands are provided in the drawing set in Volume 2 of the AEE.

176. The surface area of the constructed wetlands will be sized based on 2% of the total contributing catchment. The catchment areas identified for stormwater treatment include:

    (a) all new road surfaces, including pavement, median, shoulder, drainage channels; and

    (b) rock cuts and re-vegetated areas above rocks cuts where stormwater cannot be readily intercepted.

[36] AEE page 68.

177. In general, the constructed wetlands will be designed and operated as follows:

(a) to detain as a minimum the extended detention volume as defined by the Treatment Standard;

(b) the surface area of the constructed wetlands will be sized based on 2% of the total contributing catchment;

(c) water depths will be typically range between 0.15 - 1m;

(d) stormwater will be discharged from the conveyance network into the wetland forebay where coarse sediment will settle out;

(e) flows will then enter the main vegetated area of the wetland, where fine particulates and dissolved pollutants will be removed; and

(f) treated water will discharge through the wetland's outlet to the receiving environment (the lower Mangapepeke Stream and the Mimi River).

Flooding

178. The road pavement and cuttings result in an increase in the impervious surfaces in the Mangapepeke Stream and Mimi River catchments. Such increase has the potential to increase flood peaks and volume and reduce the abundance of fish and invertebrates in watercourses. However, in absolute terms the impervious areas will be very low - in the lower Mangapepeke Stream the impervious surface will be about 2.4% of the catchment; while in the Mimi River it will be 0.7% of the catchment (refer Technical Report 7b in Volume 3 and the evidence of Mr Hamill, for more detailed information).

179. Comprehensive hydrological and hydraulic modelling[37] was undertaken to identify and quantify where possible:

(a) the existing flood hazard;

(b) the potential impact of the proposed alignment on the existing flood hazard; and

(c) the flood hazard to SH3 following the construction of the preferred realignment.

180. Modelling of the effects of a storm with a 1% Annual Exceedance Probability ("**AEP**") (equivalent to a storm with an ARI of 100 years) shows:

(a) SH3 is currently affected by flooding both north and south of the Project extent;

[37] Report on Hydrology and Flood Modelling, SH3 at Mt Messenger Bypass, Lizzie Fox and Kirsty Duff, Mt Messenger Alliance, January 2018.

(b) the Project has no significant impact on flood levels, or extent of flooding, on, or near, the bypass;

(c) the bypass will not be subject to flooding; and

(d) water depths will be typically range between 0.15 and 1m.

Design standards

Stormwater design standards

181. The design of the stormwater network will be based on the following:

(a) The Transport Agency Specification P46: Stormwater specification 2016;

(b) The Transport Agency Technical Memorandum TM-2502: Preferred method for calculating road surface water runoff in New Zealand, 2014;

(c) The Transport Agency Stormwater Treatment Standard for State Highway Infrastructure 2010;

(d) The Transport Agency Fish Passage Guidance for State Highways 2013;

(e) The Transport Agency Specification F/2: Specification for Pipe Subsoil Drain Construction 2013;

(f) The Transport Agency Specification F/3: Specification for Pipe Culvert Construction 2010;

(g) The Transport Agency Specification F/6: Specification for Fabric Wrapped Aggregate Subsoil Drain Construction 2003;

(h) The Transport Agency Technical Memorandum NZTA TM-4006: Traversable and Mountable Grates for Precast Concrete Headwalls 2008;

(i) The Transport Agency Bridge Manual, third edition, 2016;

(j) NIWA High Intensity Rainfall Design System (HIRDS), Version 3.0, 2016;

(k) Ministry for the Environment: Climate Change Effects and Impacts Assessment - a Guidance Manual for Local Government in New Zealand 2008;

(l) Austroads Guide to Road Design, Part 5: Drainage – General and Hydrology, Part 5A: Drainage – Road Surface, Networks, Basins and Subsurface and Part 5B: Drainage – Open Channels, Culverts and Floodways 2013);

(m) AS/NZS 2566.1 (1998), Buried Flexible Pipelines – Structural Design;

(n) AS/NZS 2566.2 (2002), Buried Flexible Pipelines – Installation;

(o) Federal Highways Administration Hydraulic Engineering Circular No.9 (HEC-9): Debris Control Structure Evaluation and Countermeasures (3rd Edition) 2005;

(p) Federal Highways Administration Hydraulic Design Series No.5 (HDS-5): Hydraulic Design of Highway Culverts (3rd Edition) 2012;

(q) Federal Highways Administration Hydraulic Engineering Circular No.11 (HEC-11), Use of Rip-rap for Bank Protection1989;

(r) Federal Highways Administration Hydraulic Engineering Circular No.14 (HEC-14), Hydraulic Design of Energy Dissipators for Culverts and Channels (3rd Edition) 2006;

(s) Federal Highways Administration HY-8: Culvert Hydraulic Analysis Program 2016;

(t) US Army Corps of Engineers Hydraulic Design of Flood Control Channels 1995;

(u) Geoscience Australia Australian Rainfall & Runoff: Blockage of Hydraulic Structures – Blockage Guidelines 2015; and

(v) Concrete Pipe Association of Australia (CPAA): Hydraulics of Precast Concrete Conduits, CPAA Design Manual 2012.

RESPONSE TO SUBMISSIONS AND SECTION 42A REPORT

182. I respond below to design issues raised in submissions on the Project and in the section 42A reports on the Project.

Submissions

183. A total of 1177 submissions[38] were received by the Councils, with 1157 being in support of the Project. Most of the submissions in support state the view that the design of the Project addresses the requirements for a modern highway, and is sensitive to the environment. This is, in a nutshell, what I and the design team have intended to achieve in designing the Project.

184. A small number of submissions in opposition to the Project raise issues related to the Project design and operation. These points relate in particular to:

(a) Concerns about the Project traversing the Mangapepeke Valley, highlighting conditions in the valley (flooding, black ice and fog)

[38] Excluding the 18 late submissions (all in support).

causing problems for the road and property (Debbie Pascoe and Tony Pascoe, Dawn Bendall, Brenda Lacy, Ronald Newman, Joy Keighley and Gordon Keighley, Sydney Bendall, Helen Piper, Saralie Cryer). Also questioning how the Project can be constructed on a 'swamp' (Dawn Bendall, Sydney Baker and Ron Newman).

(b) Concern that big cuttings will slip (Debbie Pascoe).

(c) The inclusion of the tunnel in the Project design, with concerns raised about fog being an issue in the tunnel, the tunnel being too restrictive in terms of oversized vehicles, and the need for a tunnel when going over the top of the ridge is an available option (Saralie Cryer, Helen Piper, Dawn Bendall, Sydney Baker).

(d) Queries about earthworks - where the necessary fill for the Project will be sourced, and where spoil generated (including in particular from the swamp forest will be deposited) (Helen Piper, Sydney Baker, Dawn Bendall).

(e) Mentioning the possibility for passing lanes (Sydney Baker, Helen Piper).

Traversing the Mangapepeke Valley

185. This matter, commenting on black ice and fog, is outside my sphere of expertise. I have therefore sought an opinion from Dr Mike Revell, Principal Scientist – Meteorology with NIWA on the issues raised by submitters. His opinion is provided in **Appendix 3** and summarised below**.**

Black ice and fog

186. Tony Pascoe submits that with a road near the valley floor (which I assume to be the Mangapepeke Valley) black ice and the lack of sun, will make very treacherous road conditions. Brenda Lacy submits the valley is prone to black ice and never has any sunlight.

187. Tony Pascoe, Brenda Lacy, Dawn Bendall, Helen Piper and Sydney Baker also submit that fog in the valley will be an issue.

188. Issues regarding black ice and fog are considered in the AEE[39] Technical Report 3, and in the NPDC Section 42A Report, where Mr Doherty considers this to be an operational matter and overall the Officer concludes that the Project will make driving in fog conditions safer.[40] As this area is outside my sphere of expertise and I have therefore sought an opinion from Dr Mike Revell on these matters. Dr Revell is a principal scientist with NIWA specialising in meteorology. He is also NIWA's group manager for meteorology and remote sensing. Dr Revell has 40 years' experience in

[39] At page 178.
[40] At paragraph 210.

weather forecasting, researching storm development and modelling weather systems. Dr Revell's opinion is contained in **Appendix 3** and summarised by me below.

189. Frost will form when a road surface temperature falls below freezing on clear nights with low wind speeds. Frost rarely accumulates more than 2mm, thus lessening the icing threat. Dr Revell estimates there are approximately 60 days a year when frost may occur in the Project area.

190. Shaded spots can be a degree, or two, colder than the surrounding ground. However, the road will receive a few hours of sun during the afternoon, even in winter. **Figures 29, 30** and **31** are screen shots taken from 'Humphrey' showing shading of the road in the Mangapepeke Valley in mid-winter at 10:00am, noon and 2:00pm, respectively. As may be seen at 10:00am the road is in shade, but by noon most of the road is in sunlight while at 2:00pm none of the road is shaded.

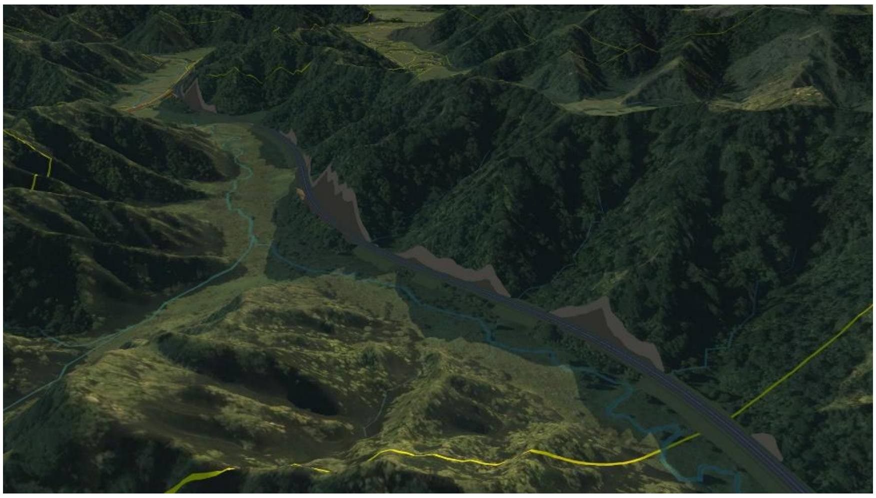

Figure 29: Shading of the road in the Mangapepeke Valley at 10:00am, mid-winter

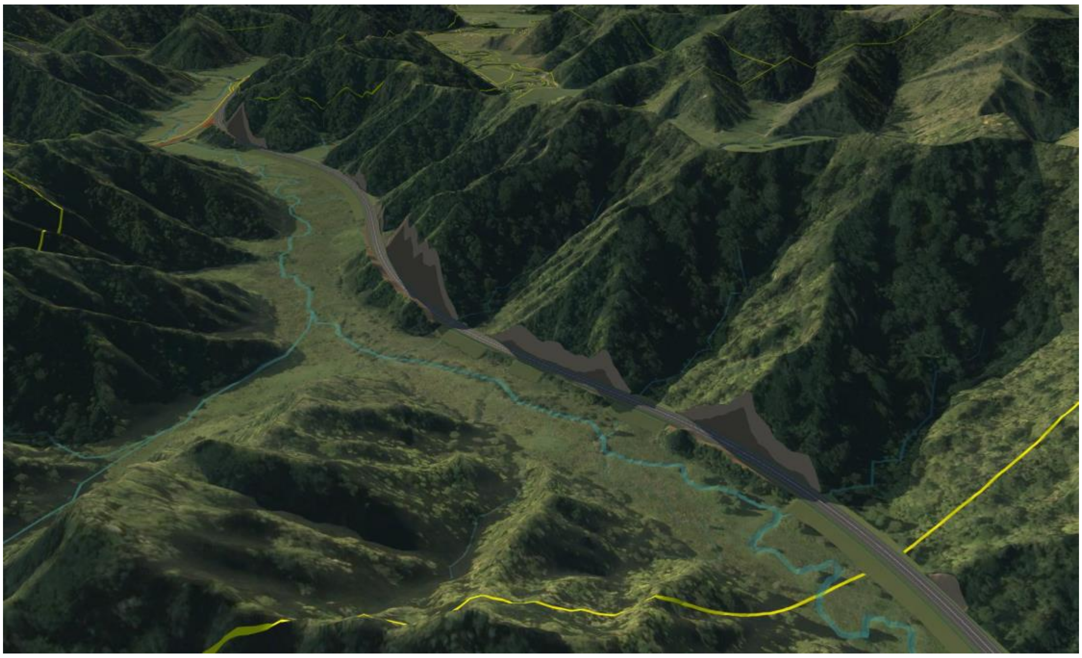

Figure 30: Shading of the road in the Mangapepeke Valley at noon, mid-winter

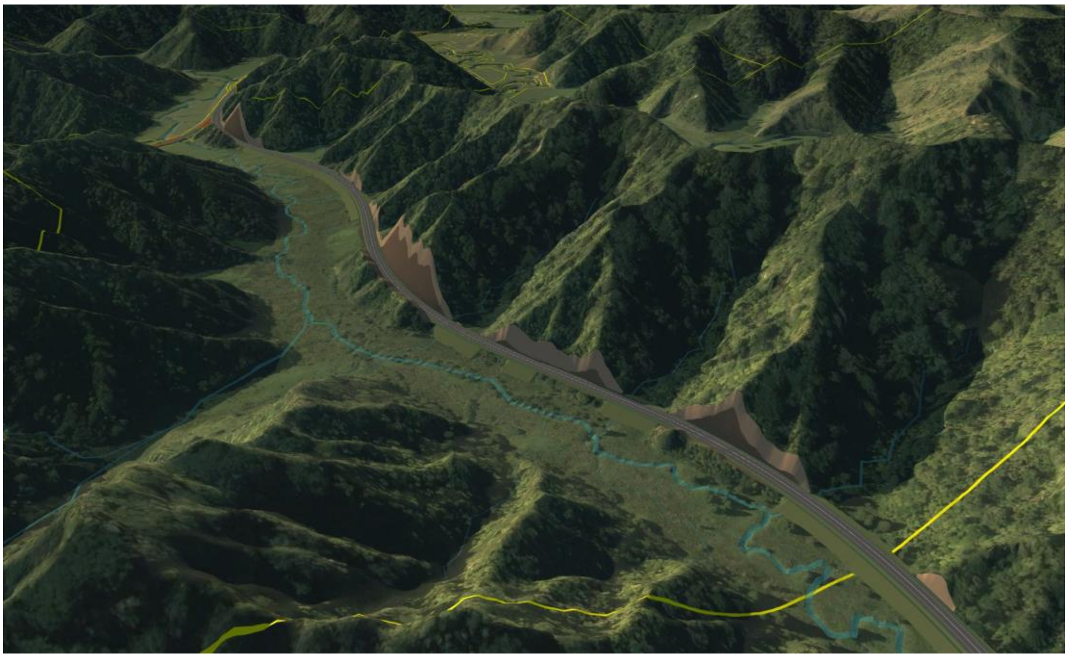

Figure 31: Shading of the road in the Mangapepeke Valley at 2:00pm, mid-winter

191. Black ice is a thin sheet of ice, relatively dark in appearance, but actually clear (so it looks like the road beneath) that may form as a result of:

(a) light rain falling on a frozen roadway surface when it is possible for a coat of ice to be deposited in minutes. For the ground to freeze the wind must be light, the skies must be clear and the air very dry. If the air is not dry fog will tend to form first preventing the surface below from freezing. However, if there has been an overnight period of light winds, clear skies and cold dry air and a band of rain arrives just before sunrise then ice is possible; or

(b) water standing on the road surface freezing at night under cold, clear still conditions. As I state below under “Flooding” the road will be designed to minimise the possibility of standing water.

192. Dr Revell states black ice is much less common in the Project area compared to the north island central high country or inland Southland and Otago. He also notes the existing road climbs approximately 100m higher than the proposed bypass and has many tight corners that don’t see the sun during the winter. This will lead to colder road temperatures (than the bypass) with an increased potential for frost and icing.

Fog

193. Radiation fog is the most common type of fog in the Project area and is most common in autumn and early winter. Radiation fog is formed by the cooling of land after sunset by thermal radiation in calm conditions with a clear sky. Radiation fog occurs at night and usually doesn’t last long after sunrise but can persist all day in winter months.

194. In calm conditions a fog layer can be less than a metre thick, but turbulence can promote a thicker layer.

195. Dr Revell estimates there are about 30 fog days a year in the Project area.

196. Dr Revell states that because the existing road is higher in the valley north of Mt Messenger than is the bypass in the Mangapepeke Valley means that the bypass would occasionally be in fog when the old route south of the northern tie-in isn’t. However, the frequency of fog on the bypass would be no higher than that north of the bypass where SH3 travels alongside the stream and Tongaporutu River.

197. Although fog may occasionally form over the road, Dr Revell does not expect it to be a problem in the tunnel as temperatures there will remain well above those outside when fog is an issue.

198. Anecdotal evidence from staff undertaking the Networks Outcomes Contract (road maintenance) in the area is that fog occurs on SH3 periodically along the flats adjacent to the Tongaporutu River.

Flooding

199. In her submission, Debbie Pascoe questions why a new road is being constructed on a valley floor that floods. Ronald Newman considers the idea of constructing a road on this land is never going to work with the amount of water that comes down the catchment when it rains. Tony Pascoe submits

that, with the very heavy rain at times in the area, the risk of flooding will increase immensely and cause problems for the wider community as well as the travelling public. Helen Piper submits that the "gully" is a huge catchment for water and flooding would be an issue. Joy and Gordon Keighley, who have property at the northern end of the project, raise concerns about water run-off as the valley floor is being built up and that the existing culvert under SH3 is not being upgraded leading to flooding of their farm as well as Ahititi Village. Saralie Cryer submits the run-off of the new road will cause extra flooding to the house and landowners in Ahititi.

200. It is recognised that the Mangapepeke valley is prone to flooding. The effects of flooding on the Project and its environs have been considered in detail in the design process. As described in my evidence above, comprehensive hydrological and hydraulic modelling[41] has been carried out to identify, and where possible, quantify:

(a) the existing flood hazard;

(b) the potential impact of the proposed alignment on the existing flood hazard; and

(c) the flood hazard to SH3 following the construction of the preferred realignment.

201. **Figure 32** reproduced from the hydrology and flood modelling report shows the predicted water depths in the Mangapepeke valley and downstream from a storm with a 1% AEP (equivalent to a storm with an average recurrence interval of 100 years). **Figure 33** shows the associated change in water levels as a result of the Project.

[41] Report on Hydrology and Flood Modelling, SH3 at Mt Messenger Bypass, Lizzie Fox and Kirsty Duff, Mt Messenger Alliance, January 2018.

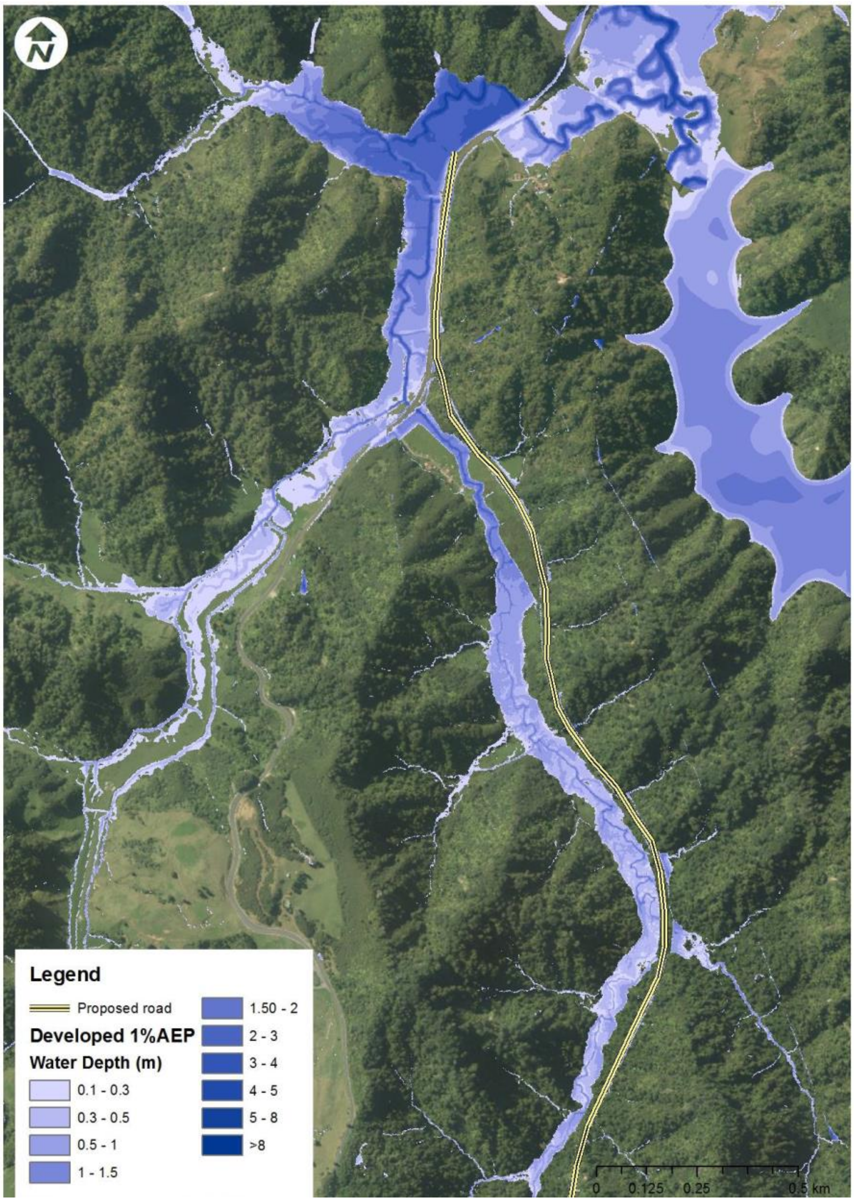

Figure 32: Flood depths during a 1% AEP design rainfall event for the proposed developed road scenario in the Northern catchment.

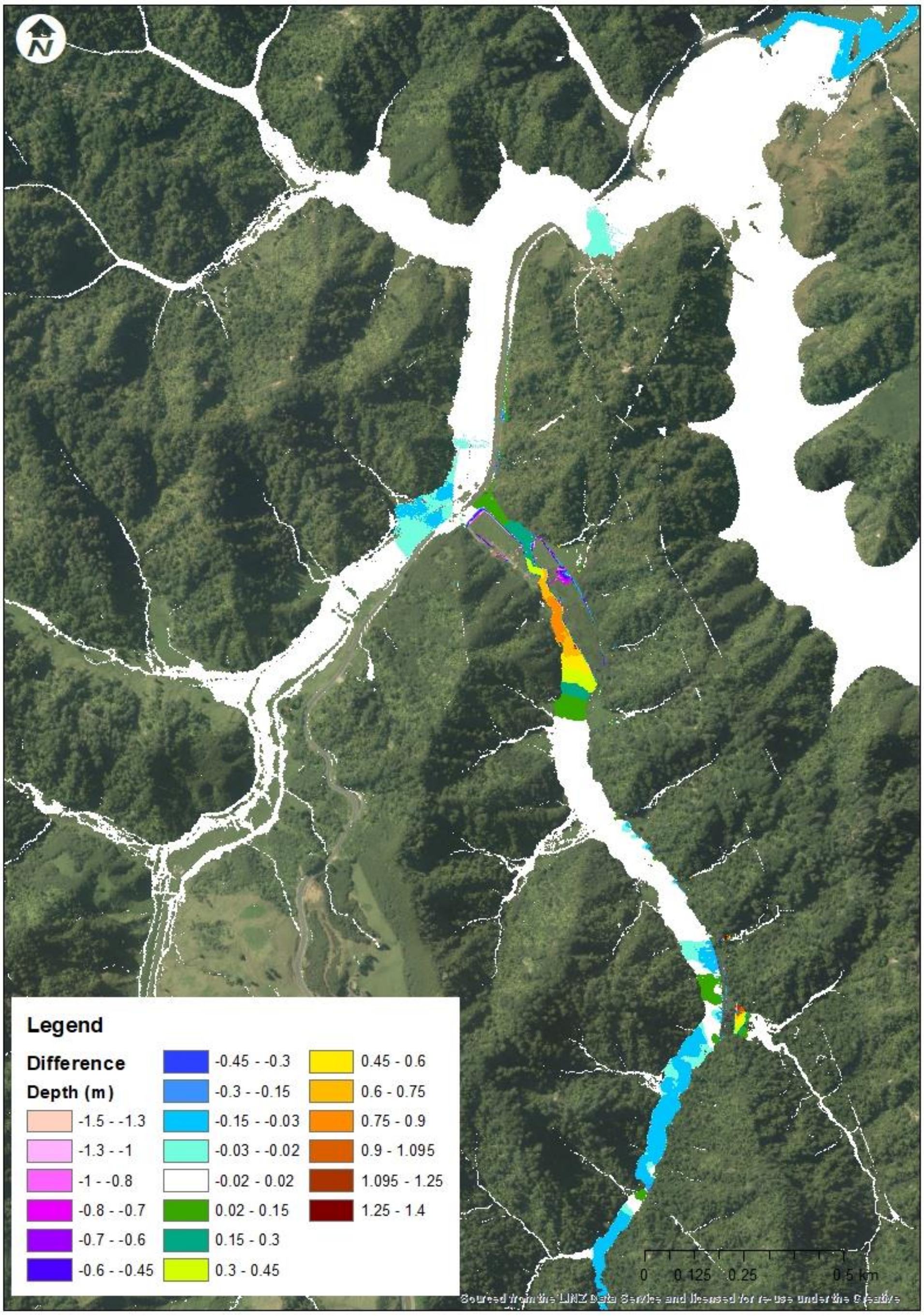

Figure 33: Differences in water depth between the existing situation and the proposed changes to the catchment as a result of the new bypass.

202. Modelling of the effects of shows:

(a) The Project will not be subject to flooding in the Mangapepeke valley, or elsewhere (the road will be situated on the valley sides elevated above the valley floor (refer to **Figure 7**).

(b) Differences in the flood levels as a result of the proposed realignment are generally small and localised. The construction of the two fill areas towards the northern end of the Project will increase the flood water levels in the catchment locally by 0.2 to 0.9m (**Figure 33**). These differences are the result of changes to the topography caused by construction of the new road. With the construction of the road, the water will be restricted to the main channel of the Mangapepeke stream; rather than spreading out to the extent of the floodplain. The modelled velocity in this area shows no significant increase, as the ponding caused by the fills has limited velocity.

(c) Referring to **Figure 32** it can be seen the model predicts flooding of SH3 north of the Project tie-in. This is an existing problem resulting from flows in the large catchment west of SH3 backing up from the Tongaporutu River. As can be seen from **Figure 33**, this flooding will not be exacerbated, or ameliorated, by construction of the Project (the change in water level is predicted to be in the range -20mm to +20mm).

203. With regard to rainfall causing problems for the travelling public, the road drainage will be designed in accordance with Transport Agency requirements, in particular Specification P46[42]. This requires the design achieves the following for storm intensities corrected for climate change:

(a) in an event with a recurrence interval of 2 years, the water depth on all trafficable areas should not exceed 4mm; and

(b) in an event with a recurrence interval of 10 years flows on the shoulders should not encroach on traffic lanes.

204. In summary, modelling shows the proposed route of the Project in the Mangapepeke valley will not be subject to flooding in storms of up to 1% AEP and that the bypass will have a negligible (if any) effect on existing flooding issues downstream of the valley. Also, the road carriageway will be trafficable in significant storm events.

Cuttings that will slip

205. Debbie Pascoe submits that the road will have big cuttings that will slip.

206. As described in my evidence above and in Mr Symmans evidence, designing a route that will be resilient is fundamental to meeting the key project objective of enhancing the resilience of the state highway network. The global stability of the cut slopes is intrinsic in the approach taken to their design, which is based on proven practice of designing cuttings in landscapes and materials similar to those at Mt Messenger. That is not to say there will not be any fretting, i.e. small pieces, or slabs, of rock detaching from the cut faces, particularly during construction, or shortly afterwards as the rock mass relaxes as a result of excavation. Careful inspection and mapping of the cut faces by an engineering geologist as excavation proceeds

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[42] Transport Agency Specification P46: Stormwater Specification. 2016.

will help identify potentially problematic sections that can be dealt with whilst access to the slopes is straightforward (for example, by the use of soil nails to maintain the integrity of potentially unstable areas). Additionally, steel mesh rock drapes will be attached to the face of cuttings greater than 20m deep from a point 8m above road level to the top of the cut. The drapes will direct any loose material down the face of cuttings and into swales constructed at the base of the cuts. In addition to conveying drainage, the swales serve the dual purpose of acting as a rock fall buffer minimising the risk of rockfall debris encroaching on the carriageway.

207. I consider that the design of cuttings is appropriate for the ground conditions at Mt Messenger and significant slips that disrupt road traffic are unlikely to occur.

Swamp

208. Dawn Bendall submits that the Mangapepeke Valley has a high water table and a 25m deep swamp. Sydney Baker refers to the valley as a swamp 25m deep while Ronald Newman submits that the amount of land fill required to construct the road will never settle and road slumping will always be an issue. In a similar vein Brenda Lacy asks, when the area is built up, how long earth will be allowed to settle before it is built on.

209. Geotechnical investigations as described by Mr Symmans confirm the valley contains significant depths of very soft to soft highly compressible alluvial deposits (soils washed down into the valley from the adjacent hillsides). These are not ideal ground conditions on which to build a road, but they are not uncommon and all the options considered in the MCA process would have had to address the challenges of building on significant depths of alluvium. Appropriate and proven engineering solutions have been adopted including minimising the lengths and heights of embankments, designing appropriate ground improvement works, and ensuring settlement of embankments is largely complete before the road pavement is constructed. These are all essential prerequisites to a successful outcome.

210. The alignment of the road has been carefully selected to be on the sidelong ground above the valley floor on the eastern flank of the lower Mangapepeke valley such that as much of possible of the road is in cutting (and hence on rock). The alignment in the lower Mangapepeke Valley requires four embankments, each up to 3.5m high, with a total length of approximately 790m. **Figure 34** shows a typical section through one of the embankments. The embankments will be is constructed directly on the alluvium. The ground improvement measures are as described in the AEE.[43] The surcharge fill (brown) that preloads the embankments to accelerate settlement and consolidate the ground beneath at a quicker rate is placed on top of the required embankment profile (green). The timing of how long preloading will

[43] AEE, Section 5.13.10.1, pg 97 and 98).

need to be in place before the pavement can be constructed will be determined from geotechnical investigations currently under way and monitoring of fills during construction. It is likely to be in the order of a year.

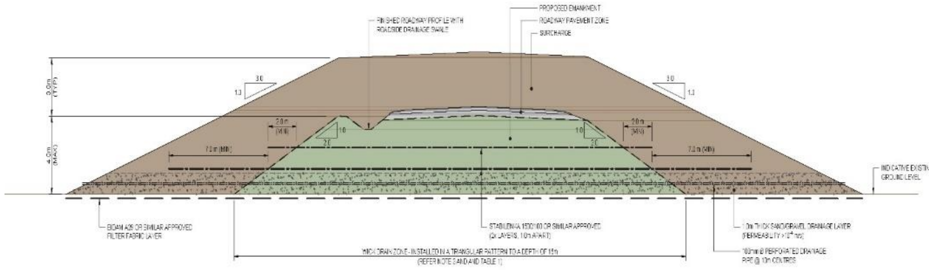

Figure 34: Typical Section Through an Embankment in the Lower Mangapepeke Valley

211. In summary, the challenges of constructing embankments on alluvium and in the Mangapepeke Valley in particular, are recognised and, in my opinion, are addressed satisfactorily.

Inclusion of a tunnel

212. Sydney Baker submits that the tunnel will restrict large cargo into and out of the Taranaki Province and questions why the "perfect pathway" over the top of Mt Messenger with no tunnel, no swamp and less risks of slips and washout isn't used in lieu of the proposed route. Helen Piper considers large vehicles would be unable to commute through the tunnel and a road without a tunnel is required. She also feels that "going over the top" is imperative. Dawn Bendall submits that the original tunnel has restricted Taranaki from moving houses and has affected other industries, so a tunnel is detrimental, and a pathway without a tunnel is needed. In her submission, Saralie Cryer submits the purpose of the new road is to do away with the tunnel.

213. As discussed in my evidence above, the tunnel has been designed with a clearance envelope 10m wide by 6m high to allow over-dimension vehicles to use the route (currently all over-dimension loads must travel via SH1 or SH4 and through Whanganui). The adopted design philosophy includes incorporating a tunnel under the key ridgeline close to Mt Messenger to minimise the effects on landform and bush. However, an earthworks option (Option E2) of constructing a cutting through the ridge was evaluated at the first MCA workshop. This required a cutting approximately 95m deep and up to 150m wide (see **Figure 3**). This option scored poorly compared to the tunnel option in terms of landscape (it was considered to be fatally flawed in terms of its effect on the landscape), ecology and cultural heritage.

214. With regard to Sydney Bakers submission that a pathway over the top of Mt Messenger without a tunnel could be utilised, options using the existing road corridor have been considered and evaluated (Options Z). However, the topography is such that tunnels would still have been required for these

options in the vicinity of Mt Messenger. The options were considered to be almost fatally flawed culturally because of their proximity to Mt Messenger and they also rated poorly compared to other options, particularly in terms of transport (steep grades and the lower design speed possible), resilience (there is an active landslide north of Mt Messenger), and constructability because of the effects on traffic flows during construction, and the difficulty of construction.

Earthworks

215. Sydney Baker questions where the fill is coming from to backfill the swamp while Helen Piper asks where the fill for the highway is going to come from, and where soil from the swamp is going to be put. Dawn Bendall submits the valley is going to need tonnes of fill.

216. As described earlier, it is not proposed to remove any alluvium (swamp). The embankments will be constructed directly on top of the existing ground.

217. The fill required to form embankments will come from cuttings. Approximately 960,000m^3 of excavated (cut) material will be generated, and 890,000m^3 of that material will be placed in fill embankments on site. An excess of approximately 145,000m^3 of surplus fill material will be generated and placed in disposal areas (the apparent discrepancy in the volume of excess fill is the result of the bulking of excavated material). These areas will be landscaped in accordance with the LEDF.

Passing lane

218. Helen Piper submits there is a need to have passing lanes on the highway and Sydney Baker asks about the possibility of passing lanes.

219. NZTA policy provides that recommended treatments for traffic volumes above 4,000 vpd in rolling and mountainous terrain such as this, are: sight distance improvements, overtaking enhancements, possible isolated shoulder widening / crawler shoulders, and slow vehicle bays with short passing lanes being provided at 10 km intervals.

220. The Project is less than 10 km in length and carries approximately 2,500 vpd. The Project provides the recommended treatments and the alignment is such that there will be informal passing opportunities. The designation sought for the Project provides sufficient width to allow passing facilities to be provided at a later date, if required.

Section 42A Report

221. Paragraph 231 of the NPDC Section 42A Report confirms a 1.2m wide shoulder in the tunnel would comply with the building code providing no more than 170 people were in the tunnel. As explained in Mr McCombs' evidence the likely number of people expected to be in the tunnel at peak flows, and with a tour bus included, is assessed as 65. It will be ensured the tunnel meets the requirements of Clause C4 of the Building Code – Movement to a Place of Safety. This will be achieved by means of smoke modelling of a fire in the tunnel with scenarios of a range of vehicles in the tunnel tested to demonstrate compliance. This will be the subject of a peer review and the approach will be documented in a Fire Engineering Brief that is in the course of preparation. Irrespective, as explained above, the tunnel is required to comply with the Building Act 2004 and the fire-rated emergency egress passage for pedestrians will be designed to meet the physical accessibility requirements of Section D1 of the Building Code.

222. Paragraph 248 of the NPDC Section 42A Report questions the need for permanent lighting at the two intersections (with the existing SH3) as it detracts from the rural character and is inconsistent with other local roads accessed from SH3. Flag lighting is presently proposed at the two intersections as a safety measure as is employed elsewhere on SH3, for example, at the intersection at Ahititi. The need for this lighting for safety will be evaluated as part of the detailed design process.

223. Paragraph 248 of the NPDC Section 42A Report also seeks clarification of the extent of lighting at the tunnel. As described in my evidence above, the tunnel will be lit throughout its length. The lighting will be set to a lower light level when no traffic is detected after a set period of time, but will return immediately to full levels when vehicles are detected on the approaches to the tunnel. As a safety measure, road lighting will also be provided on both tunnel approaches to provide a transition in light levels between the unlit approaches and the tunnel to enable driver's eyes to adjust at night.

224. Paragraph 232 of the NPDC Section 42A Report discusses the 1.2m shoulder width in the tunnel noting the Requiring Authority is satisfied the proposed carriageway arrangement satisfies its functional requirements. However Mr Doherty considers "*the response regarding the width of the shoulders is at odds with the Transport Agency's own standards in relation to safety. Both Austroads Parts 3 and 6 recommend a 1.5m shoulder width and this is the width that should be built*".

225. The Austroads Guide to Road Tunnels[44] provides guidance to those making decisions in the planning, design, operation and maintenance of new road tunnels in Australia and New Zealand. Section 4.6.3 'Shoulder Widths' of the

[44] Austroads Guide to Road Tunnels, Part 2 – Planning Design and Commissioning, 2010.

guide contains PIARC[45] recommendations on shoulder widths in road tunnels as 1.0m, or less, or 2.0m, or more. This is on the basis that dimensions between 1.0m and 2.0m lead to operational problems because of potential confusion created for drivers and potential misuse of the available road space by drivers attempting to create an additional lane. While the PIARC recommendation is noted, the tunnel shoulders also serve the function of emergency egress, for which a 1.2m width is required to meet Building Code requirements (see above). Permanently illuminated LED road markers will be installed to delineate the edge of carriageway to avoid the potential for driver confusion between what is carriageway and what is shoulder. I am therefore satisfied 1.2m wide shoulders are appropriate.

226. Paragraph 275 of the NPDC Section 42A Report seeks information on the area proposed for car parking to access the Kiwi Road and Mt Messenger tracks, and whether parking would be within the proposed designation area or on land subject to revocation. The parking area will be located in the area currently used for parking alongside SH3 at the head of Kiwi Road. The form and capacity of the parking area is to be developed as part of the detailed design. Revocation of the portion of SH3 to be bypassed is covered in the evidence of Mr Napier.

227. Paragraph 277 of the NPDC Section 42A Report refers to the potential for a soft trail for mountain bikers, trail runners and walkers in the location of construction haul roads while paragraph 282 refers to a riverside/roadside trail in the Mangepepeke valley. Construction access tracks and haul roads are shown on the construction staging drawings in Volume 2 of the AEE.[46] Most will be constructed along what will become the permanent alignment, however access through the Mangepepeke Valley will be offline. While it is currently proposed to rehabilitate haul roads after they are no longer required, consideration will be given to an opportunity to retain a reduced width haul road in the Mangapepeke Valley. The accessibility of any track will be contingent on land ownership outcomes.

[45] PIARC – Permanent International Association of Road Congresses.
[46]Drawings MMA-DES-CON-C0-DRG-1051 to 1054.

228. Paragraph 357(d) of the NPDC Section 42A Report refers to a walk or cycle track alongside the new road. The Officer comments that the Kiwi Road Track may be disrupted in the short term during construction. As discussed above, while cyclists and pedestrians are not commonly seen along this section of SH3, the carriageway cross-section has been designed to be suitable for pedestrians and cyclists and meets the requirements of MBIE's design guide for the New Zealand Cycle Trail.[47] The Kiwi Road Track will be kept open during construction as far as reasonably practicable, and as safety permits, during and after working hours and at weekends.

Kenneth John Boam
25 May 2018

[47] Ministry of Building Innovation and Employment: New Zealand Cycle Trail Design Guide, 4th edition, February 2015.

Appendix 1: USB 'flyover'

Couriered on 24 May 2018

Appendix 2: Design Standards for the Tunnel

Civil, Structural and Fire Life Safety

(a) Building Act 2004;

(b) Health and Safety in Employment Act 2015;

(c) Health and Safety in Employment (Mining Operations and Quarrying Operations) Regulations 2016;

(d) Fire and Emergency New Zealand Act 2017;

(e) Fire Safety and Evacuation of Buildings 2006;

(f) National Environmental Standards for Air Quality (NESAQ) 2004;

(g) Minex National Industry Code of Practice – Underground Mining and Tunnelling Health and Safety Council 2010;

(h) Ministry for the Environment: New Zealand Urban Design Protocol 2005;

(i) The Transport Agency Guide to Road Tunnels 2013;

(j) The Transport Agency Bridge Manual, Third Edition, 2016;

(k) The Transport Agency Policy Document S8: Tunnels Management and Inspection Policy 2017;

(l) Austroads Guide to Road Tunnels Part 2: Planning Design and Commissioning 2015;

(m) MBIE, New Zealand Building Code C1 – C6 Protection from Fire 2014;

(n) AS/NZS 1170 2004: Structural Design Actions – Earthquake Actions, New Zealand;

(o) NZS 3101:2006: Concrete Structures Standard;

(p) NZS 3404:1997: Steel Structures Standard;

(q) NZS 4219:2009: Seismic Performance of Engineering Systems in Buildings;

(r) AS 4825 2011: Tunnel Fire Safety;

(s) Concrete Society Guide TR63 Guidance for the Design of Steel-fibre Reinforced Concrete 2007;

(t) National Research Council, Advisory Committee On Technical Recommendations For Construction: Guide for the Design and Construction of Fiber-reinforced Concrete Structures 2006;

(u) Australasian Fire and Emergency Service Authorities Council: Fire Safety Guidelines for Road Tunnels;

(v) International Tunnelling Insurance Group: a Code of Practice for Risk Management of Tunnel Works 2006;

(w) The British Tunnelling Society and The Institution of Civil Engineers: Specification for Tunnelling, Third Edition, 2010;

(x) The British Tunnelling Society and the Institution of Civil Engineers: Tunnel Lining Design Guide 2004;

(y) National Fire Protection Association Standard NFPA 502: 2017: Standard for Road Tunnels, Bridges and Other Limited Access Highways;

(z) The Highways Agency BD 78/99: Design Manual for Roads and Bridges, Volume 2, Part 9: Design of Road Tunnels 1999; and

(aa) World Road Association – PIARC: Various papers on tunnels.

Mechanical and Electrical and Tunnel Control Building

(a) Building Act 2004;

(b) NZ Health and Safety in Employment Act 2015;

(c) Health and Safety in Employment (Mining Operations and Quarrying Operations) Regulations 2016;

(d) Fire and Emergency New Zealand Act 2017;

(e) Fire Safety and Evacuation of Buildings 2006;

(f) National Environmental Standards for Air Quality (NESAQ) 2004;

(g) Building Code: Clauses F6: Visibility in escape routes, F8: Signs, G8: Artificial light and G9 Electricity;

(h) Electrical (Safety) Regulations 2010;

(i) Fire Safety and Evacuation of Buildings Regulations 2006;

(j) Worksafe: NZ Electrical Handbook and Associated Codes of Practice;

(k) AS/NZS 1158: 2010 (excluding part 5): Lighting for Roads and Public Spaces;

(l) AS/NZS 1680.2.1: 2008: Interior and workplace lighting – Part 2.1: Specific applications – circulation spaces and other general areas;

(m) AS 22931: 2005: Emergency escape lighting and exit signs for buildings – system design, installation and operation (as modified by Appendix B of NZ Building Code Clause F6);

(n) AS 2293.3: 2005: Emergency Escape Lighting And Exit Signs For Buildings – Emergency Escape Luminaires And Exit Signs (As Modified By Appendix B of NZ building code Clause F6);

(o) AS/NZS3000: 2007: Wiring rules;

(p) NZS 4219: 2009: Seismic performance of engineering systems in buildings;

(q) BS 5489.2: 2016: Code of practice for the design of road lighting – Part 2: Lighting of tunnels; and

(r) NZ Metal Roofing Manufacturers: NZ metal roof and wall cladding Code of Practice.

Appendix 3: Letter from Dr Revell