Assessment of Ecological Effects – Ecological Mitigation and Offset

December 2017

Mt Messenger Alliance

Technical Report 7h

Mt Messenger Bypass

New Zealand Government

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Contents

Glossary

Term	Meaning
AEE	Assessment of Effects on the Environment Report
AWA	Additional works area outside the direct road footprint, where temporary works could occur during construction
BBOP	Business and Biodiversity Offsets Programme
Biodiversity Offsetting Guidance	NZ Government's 'Guidance on Good Practice Biodiversity Offsetting in New Zealand' (August 2014)
Carrying capacity	The maximum population size of a species that the environment can sustain indefinitely.
DOC	Department of Conservation
EcIA guidelines	Ecological Impact Assessment guidelines
EIANZ	Environment Institute of Australia and New Zealand
ELMP	Ecological and Landscape Management Plan
Freshwater Ecology Technical Report	Assessment of Ecological Effects – Freshwater Ecology (Technical Report 7b, Volume 3 of the AEE)
Herpetofauna Technical Report	Assessment of Ecological Effects – Herpetofauna (Technical Report 7d, Volume 3 of the AEE)
Ngāti Tama Eastern Forest Block	The area of land located east of existing SH3, including Ngāti Tama land, DOC land and QE2 covenanted land, approximately 3,098ha in size.
NPBV	Net present biodiversity value
Parininihi	The area spanning the Waipingao Stream catchment located to the west of existing SH3, approximately 1332ha in size
Pest Management Area	Area of land proposed to be actively managed for pests, across a number of parcels of land.
Project	The Mt Messenger Bypass project
Project footprint	The road footprint (i.e. the road and its anticipated batters and cuts, spoil disposal sites, haul roads and stormwater ponds), the Additional Works Area (AWA) and the 5 m edge effects area
RMA	Resource Management Act 1991

Term	Meaning
RTC	Residual trap catch
SEV	Stream Ecological Valuation method
SH3	State Highway 3
Transport Agency	New Zealand Transport Agency
TRC	Taranaki Regional Council
Vegetation Technical Report	Ecological Effects Assessment – Vegetation (Technical Report 7a, Volume 3 of the AEE)
Wider Project area	Area approximately 4,430ha in size, which encompasses the Project footprint, Parininihi, DOC and the Ngāti Tama Eastern forest block

Executive Summary

This report forms part of a suite of technical reports prepared for the NZ Transport Agency's Mt Messenger Bypass project (the Project).

This report sets out a package of ecological mitigation that will mitigate or offset the ecological effects of the construction and operation of the Project.

The ecological values present in the Project footprint and adjacent forested and wetland areas are high, although considerably diminished from their full potential because of the long term and largely unchecked impact of farm livestock and animal pests. The Project will result in the removal or modification of 34ha of predominantly indigenous vegetation and habitat, including the removal of 15 significant large trees, and 3.5km of freshwater habitat. This, combined with the diverse and high value nature of the ecology, means that the potential ecological effects generated by the construction, operation and maintenance of the new road will also be high.

Considerable effort has been focused on choosing a route that will minimise ecological effects and modifying the road design to minimise effects. However, considerable residual ecological effects will occur. A comprehensive biodiversity offset and mitigation package has been developed to address all potential residual effects.

The proposed biodiversity offset – mitigation package has been generated by using the Biodiversity Offset Accounting Model (Maseyk et al 2015). The proposed package is for pest management over approximately 560ha in perpetuity (or until such time as pest management in the form we know of it today is no longer necessary to sustain the levels of biodiversity created), restoration planting of 6ha of swamp forest and wetland, restoration of 8.9km of riparian margin, replacement mitigation planting of 9ha and revegetation of as much of the construction footprint that will not be road as is practicable. The offset – mitigation package has a high likelihood of substantially reversing the diminished state of the ecology and achieving a net gain in biodiversity within 10 to 15 years following construction.

Many aspects of the indigenous flora and fauna present in the Project area will benefit from the management of pest animals to permanently low densities and the establishment of substantial new areas of swamp forest, shrubland and riparian habitat. The proposed mitigation will not only increase the area of healthy indigenous vegetation but will greatly improve the connectedness of the forested areas. The net result will be a significant increase in healthy available habitat; enhanced recruitment rates amongst a wide range of indigenous animals; improved condition of the remaining significant forest trees, especially totara and rata; and increased regeneration of many of the more palatable plant species. The Biodiversity Offset Accounting Model predicts that 35 years after road construction the Net Present Biodiversity Value (NPBV) of the offset sites will be 1.62, 29.46 and 1.42 for the WF8, WF13 and WF14 vegetation communities respectively (compared to a NPBV of 0 for each at year 10); a substantial net biodiversity gain as a result of the offset programme.

Over time, further ecological benefits will accrue as a result of the offset programme. The conditions created in the offset area will increase the likelihood of the survival and successful nesting of those kōkako that choose to move east from the release sites in the western Ngāti Tama block. Other species, especially more mobile long-tailed bats and forest birds, will begin to move into adjacent forest areas as carrying capacity limits are met.

Overall it is considered that the proposed mitigation and offset package for the Project as set out in this report will appropriately address all of the residual ecological effects of the Project, and over time, create ecological effects that are beneficial and positive.

1 Introduction

1.1 Purpose and scope of this report

This report forms part of a suite of technical reports prepared for the NZ Transport Agency's Mt Messenger Bypass project (the Project). Its purpose is to inform the Assessment of Effects on the Environment Report (AEE) and to support the resource consent applications and Notice of Requirement to alter the existing State Highway designation, which are required to enable the Project to proceed.

This report sets out a package of ecological mitigation that will mitigate or offset the ecological effects of the construction and operation of the Project.

Specifically, the purpose of this report is to:

a Highlight the nature of the measures recommended by the ecology specialists to avoid, remedy or mitigate potential effects.

b Propose remediation, mitigation and biodiversity offsetting measures for all identified potential residual ecological effects.

c Present a comprehensive ecological mitigation package that integrates effectively with the landscape treatment and road construction elements of the Project and delivers net biodiversity gain 10 to 15 years following completion of construction.

1.2 Project description

The Project involves the construction and ongoing operation of a new section of State Highway 3 (SH3), generally between Uruti and Ahititi to the north of New Plymouth (**Error! Reference source not found.**). This new section of SH3 will bypass the existing steep, narrow and winding section of highway at Mt Messenger. The Project comprises a new section of two lane highway, approximately 6 km in length, located to the east of the existing SH3 alignment (**Error! Reference source not found.** and **Error! Reference source not found.**).

The primary objectives of the Project are to enhance the safety, resilience and journey time reliability of travel on SH3 and contribute to enhanced local and regional economic growth and productivity for people and freight.

A full description of the Project including its design, construction and operation is provided in the AEE (Volume 1) and accompanying Drawing Set (Volume 2).

1.3 Physical and ecological description of the Project footprint and the wider Project area

The Mt Messenger – Parininihi area is characterised by heavily eroded and dissected landforms of marine derived mudstone sediments. The erodible nature of the geology and the high and intense rainfall experienced has created a mix of steep and eroded ridges and slopes and a mosaic of different vegetation age classes and composition, containing a significant proportion of younger stages of succession developing towards mature broadleaved dominant forest (Assessment of Ecological Effects – Vegetation (Technical Report 7a, Volume 3 of the AEE) (Vegetation Technical Report).

Warm, humid summers and mild, wet winters create conditions suitable for dense broadleaved dominant forest with an abundance of lianes and epiphytic plants over mostly hill country land, and kahikatea (*Dacrycarpus dacrydioides*), pukatea (*Laurelia novae-zelandiae*) and swamp maire (*Syzygium maire*) forest and associated wetlands in valley floor areas. The wider Project area, approximately 4,430ha in size, (Figure 1.1) is situated in the North Taranaki Ecological District and straddles an ecological boundary between two broad forest classes with podocarp, broadleaved forest largely in the Mimi catchment and the upper Mangapepeke Valley, and podocarp, broadleaved beech forest within the lower Mangapepeke Catchment and northwards.

The Parininihi land, previously known as "Whitecliffs Conservation Area" is located west of the existing SH3 corridor and is a tract of mainly primary forest approximately 1,332ha in size and centred on the Waipingao Stream. Parininihi, which will not be affected by the Project, encompasses a rare continuous forest sequence through coastal, semi-coastal and lowland bioclimatic zones. As such, the area is regarded as being ecologically significant, and is described as "the best example of primary coastal hardwood-podocarp forest on the west coast of the North Island" by eminent forest ecologist John Nicholls (in the Vegetation Technical Report).

Ecological management of the Parininihi land was started in the early 1990s by the Department of Conservation (DOC), and involved possum and goat pest control activities. Since being returned to Ngāti Tama in 2003, management of these pests has continued, and control of rodents, mustelids and feral cats has also occurred with the result that the area is now healthy and ecologically functioning with vulnerable, browse-sensitive plants regenerating.

The area through which the new road will pass is dominated by two river catchments: the Mimi River and tributaries flowing to the south, and the Mangapepeke and tributaries flowing to the north (). The upper sections of both rivers flow through moderately steep incised valleys but these open up into wider, more gently sloping, sediment-filled valleys through the middle and lower reaches of each river.

The dominant forest on the Ngāti Tama block to the east of the existing SH3 corridor would have originally been very similar to the Parininihi land to the west, however it has not had consistent pest control. Consequently, the ecological condition of this area is poorer, with fewer palatable canopy trees remaining, such as thin-barked totara (*Podocarpus laetus*) and northern rata (*Metrosideros robusta*). Within the Mangapepeke Stream catchment, vegetation communities are more modified and have been affected by long-term stock grazing, fire and logging with the result being a transition to large open and grazed rushlands and poor quality pastureland further down the valley towards SH3. This valley bottom would once have been dense swamp forest.

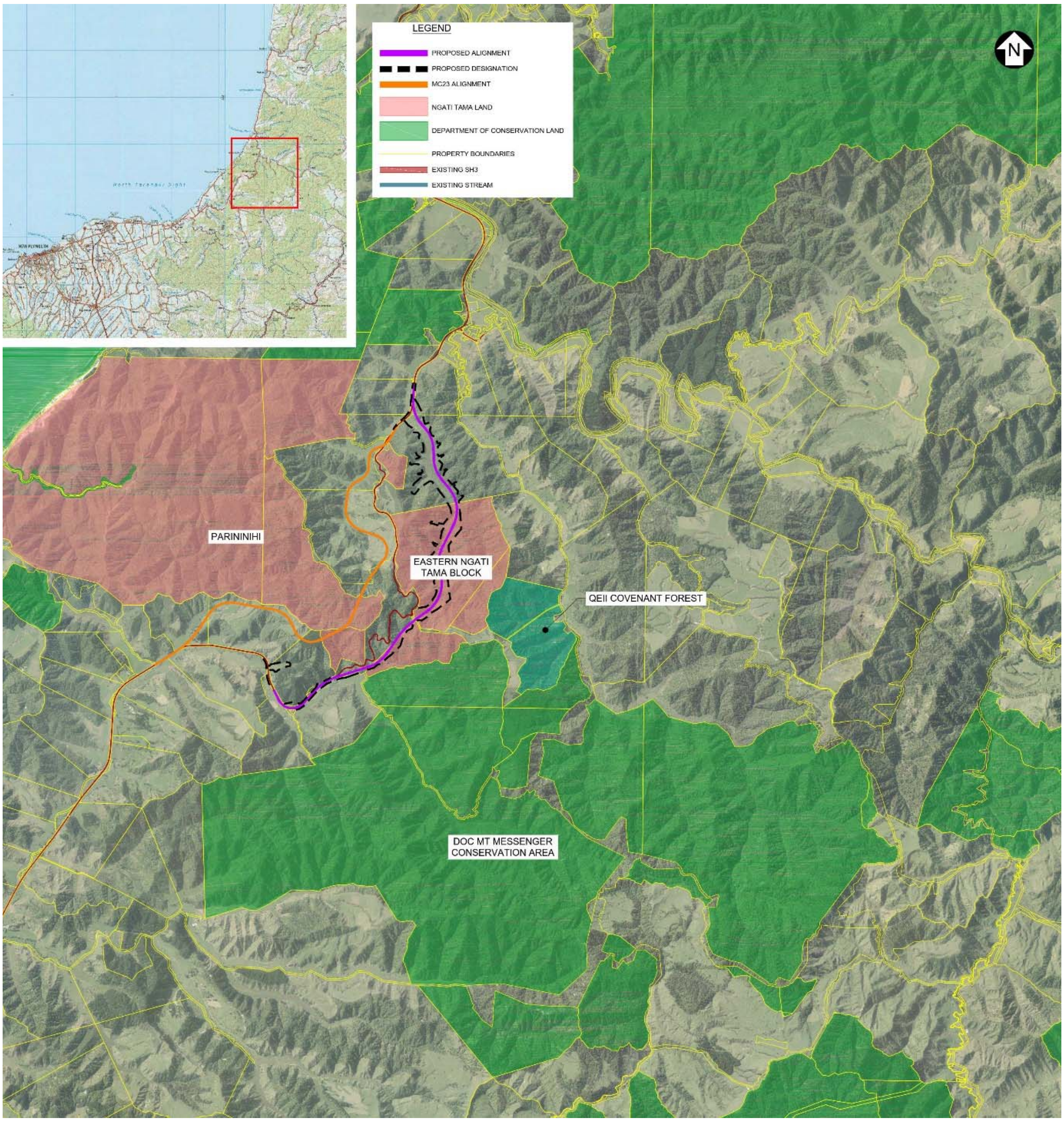

Figure 1.1 - The wider Project area, showing Parininihi (the western Ngāti Tama block), the Project footprint, eastern Ngāti Tama Block, and the Department of Conservation Mt Messenger Conservation Area.

Of greatest ecological significance in the wider Project area to the east of SH3 area is the hydrologically intact swamp forest and non-forest wetland areas in the valley floor of the northern Mimi River catchment (Figure 1.2). The valley floor sequence within the northern tributary of the Mimi River represents a full range of swamp forest, scrub and non-forest wetland communities that would once have been more common throughout this area.

In forest areas unaffected by fire, the largest change has been the loss of kohekohe as a canopy dominant since 1948 and the later extensive dieback of kamahi, northern rata and thin-barked totara, all of which are likely to have been caused by possum browse, as these tree species are preferentially selected (Clout 2006). Consequently, today in many parts of the wider Project area, especially on the eastern Ngāti Tama forest block, the forest composition is now dominated by canopy trees of lower palatability such as tawa (*Beilschmiedia tawa*), rewarewa (*Knightia excelsa*), nikau (*Rhopalostylis sapida*) and tree-ferns (Vegetation Technical Report).

There are a significant number of large, emergent trees in the wider Project area, with rimu (*Dacrydium cupressinum*) and miro (*Prumnopitys ferruginea*) being most common, as well as large northern rata and thin-barked totara which support a diverse range of epiphytes. These large, old trees play a significant ecological role in the forest ecosystem and provide important habitat for wildlife (e.g. roosting and nesting sites for bats and birds), and act as a source of pollinators for the rest of the ecosystem. They also provide food sources for a wide range of birds, lizards and invertebrates.

The North Island brown kiwi (*Apteryx mantelli*) is present in the wider Project area and is listed as Nationally Vulnerable. Three other bird species listed as At Risk or Naturally Uncommon which may be present in the area are black shag (*Phalacrocorax aristotelis*), long-tailed cuckoo (*Urodynamis taitensis*) and pipit (*Anthus novaeseelandiae*). The wetland area to the east of the existing SH3 corridor (adjacent to the southern portion of the Project footprint), is existing high quality habitat suitable for wetland birds including fernbird (*Megalurus punctatus)* and spotless crake (*Porzana tabuensis*). Ngāti Tama have also recently reintroduced kōkako (*Callaeas wilsoni*) into the Parininihi Reserve. Five kōkako pairs and two individuals were translocated from Tiritiri Matangi Island and released to a central area of the Parininihi land, approximately 2.5km to the west of the Project footprint, on May 28th 2017. A further four pairs were released on 2nd July 2017.

The North Island long-tailed bat (*Chalinolobus tuberculatus*) is a Nationally Vulnerable species and is present in the wider Project area. The central lesser short-tailed bats (*Mystacina tuberculate rhyacobi*), listed as At Risk - Declining, may also be present in the wider Project area although they have not yet been detected in recent surveys. Lesser short-tailed bats are dependent on large tracts of old growth native forest and the wider Project area overlaps with the known national distribution of this sub-species.

The mature forest habitat in the wider Project area and particularly the large number of epiphyte plants present provide habitat for a number of different lizard species. Arboreal or semi-arboreal species such as goldstripe gecko (*Woodworthia chrysosireticus*) elegant gecko (*Naultinus elegans elegans*), Pacific gecko (*Dactylocnemis pacificus*), and striped skink (*Oligosoma striatum*) favour epiphyte habitat as a food source and for refuge and reproduction. The trunks and loose bark of canopy trees are used by most of the above species, and particularly common gecko (*Woodworthia maculatus*), for refuge. Forest geckos (*Mokopirirakau granulatus*) are often found on trunks and larger branches of trees in mature forest. Groundcover plants such as young tree ferns, fallen epiphytes, flax and sedges provide habitat for striped skink and goldstripe gecko. Woody debris and leaf litter on the forest floor provide refuge for copper and ornate skink.

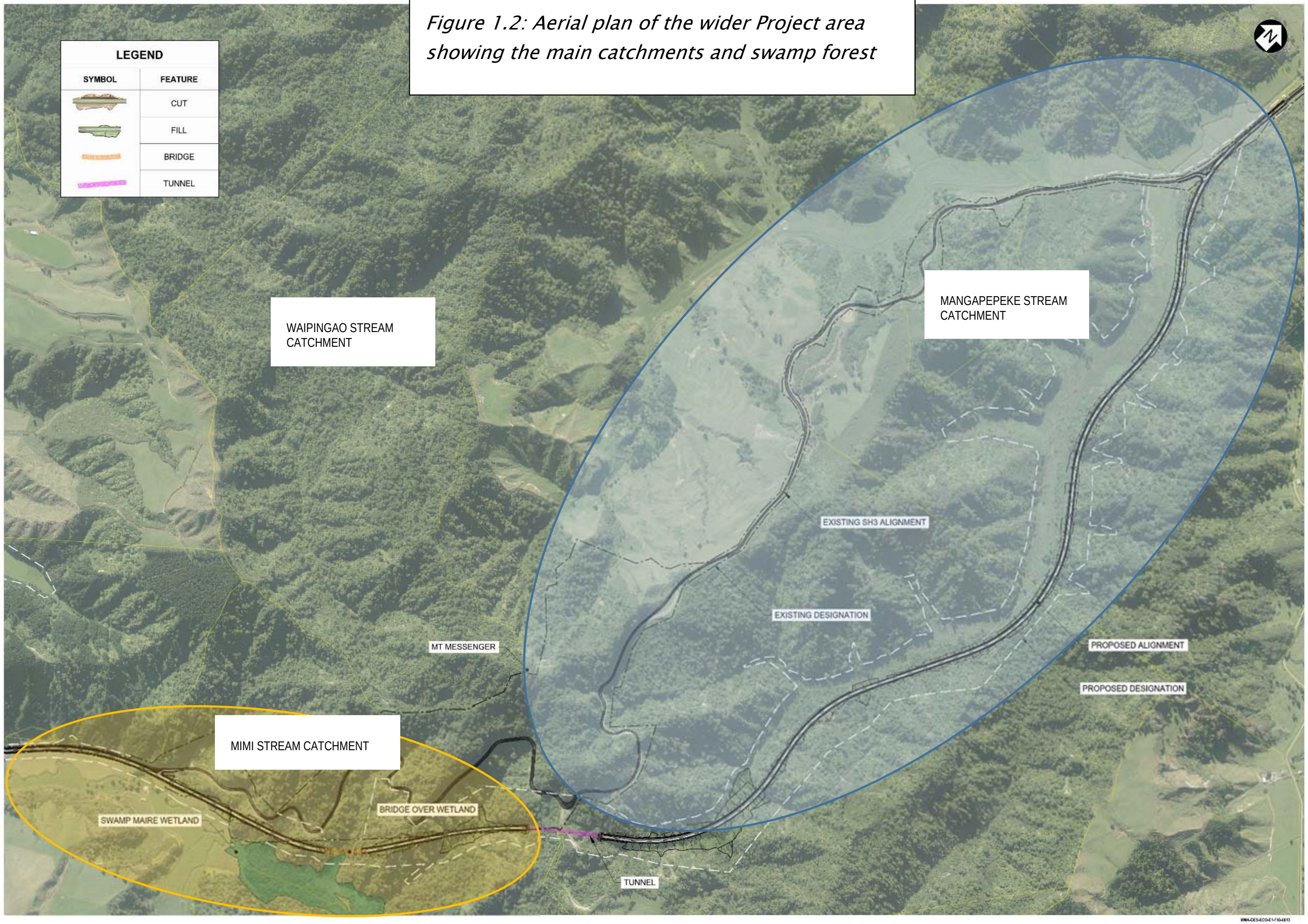

Figure 1.2: Aerial plan of the wider Project area showing the main catchments and swamp forest

Herpetofauna records show that the goldstripe gecko (At Risk – Relict), striped skink (At Risk – Declining), copper skink (*Cyclodina aenea*) (Not Threatened), forest gecko (At Risk – Declining), Hochstetter's frog (*Leiopelma hochstetteri*) (At Risk – Declining) and Duvaucel's gecko (*Hoplodactylus duvaucelii*) (At Risk – Relict) have all been found within a 50km radius of the wider Project area; all (with the exception of Duvaucels' gecko) within recent years (Assessment of Ecological Effects – Herpetofauna (Technical Report 7d, Volume 3 of the AEE) (Herpetofauna Technical Report).

While there is a paucity of entomological knowledge of the Mt Messenger and wider Project area, the invertebrate fauna that has been found in the area is 'typical' of communities inhabiting primary forests of the southern portion of the North Island. The forest habitat available to invertebrates is considered to be of high quality, with deep leaf litter layers, an abundance of dead wood and numerous potential plant hosts. In total, 179 invertebrate taxa have been recorded at Mt Messenger and there are no known nationally threatened species in the area.

The waterways in the wider Project area provide high quality habitat for freshwater fish and invertebrates. Waterways draining north to the Mangapepeke Stream and headwater tributaries draining to the Mimi River on the south side of Mt Messenger all present high ecological values. The lower section of the Mangapepeke Stream has an aquatic macroinvertebrate community that indicates good water quality and there is a good diversity of fish present including adult inanga (*Galaxias maculatus*), longfin eel (*Anguilla dieffenbachia*), koura/crayfish (*Paranephrops planifrons*) and redfin bully (*Gobiomorphus huttoni*) (all classified as At Risk – Declining), whilst common bully (*Gobiomorphus* cotidianus) and paratya shrimp (Not Threatened) are also present. The main tributaries in the upper catchment are dominated by indigenous forest and macroinvertebrate communities that are indicative of excellent water quality/habitat. The headwaters of the Mimi River are very small and have seasonally intermittent flow. The forested sections have moderate to high habitat values and good to excellent water quality.

As described above, the forest and natural habitat along and adjacent to the Project footprint east of the existing SH3 retains indigenous plant and animal communities that are considered to have high ecological value. However, the full ecological potential of the area has been greatly diminished over many decades by the largely uncontrolled impact of browsing, grazing and predatory animal pests and unfenced cattle. The evidence of this is clear when the ecology of the Project footprint is compared to the nearby forest of Parininihi immediately to the west of SH3. Over a decade of intensive pest management in this western forest has produced much more diverse and healthy flora from canopy to forest floor, and substantially greater habitat for the diversity of indigenous fauna that live there.

2 Methodology

2.1 Ecological mitigation principles and approach

2.1.1 Mitigation vs biodiversity offsetting

The purpose of the Resource Management Act 1991 (RMA) is to promote the sustainable management of natural and physical resources on private and public land, while avoiding, remedying, or mitigating adverse effects on the environment. While there is no statutory hierarchy for the application of these terms, international guidelines on the management of ecological effects, particularly those espoused by the Business and Biodiversity Offsets Programme (BBOP), promote a "mitigation hierarchy" or an "effects management hierarchy" that prioritises the sequence with which management of the effects should be approached:

AVOID ⇨ REMEDY ⇨ MITIGATE

The term *mitigate* in the RMA does not include "biodiversity offsetting" as the mitigation relates to the reduction of effects at or on the site where the effects were created. Instead offsetting provides new positive effects at another location (ideally close by). While recognising that the RMA is not a "no effects" statute, development of offsetting in the New Zealand context has led to an extended effects management hierarchy or order of priority:

AVOID ⇨ REMEDY ⇨ MITIGATE ⇨ OFFSET ⇨ COMPENSATE.

Compensate in this regard refers to less conventional approaches, such as cash payments towards achieving an environmental benefit, where mitigation and offsetting may not be possible.

This discussion is relevant to the management of ecological effects on the Project because, as is highlighted in sections below, it is not possible to avoid, remedy or fully mitigate the net residual ecological effects within the Project footprint. Significant ecological effects created by the construction and operation of the Project will need to be offset.

2.1.2 Definition and principles of biodiversity offsetting

The publication "Guidance on Good Practice Biodiversity Offsetting in New Zealand" (Biodiversity Offsetting Guidance), produced for the NZ Government in August 2014, draws on the BBOP definition to define a biodiversity offset as:

> *'Measureable conservation outcomes resulting from actions designed to compensate for significant residual adverse biodiversity impacts arising from project development after appropriate prevention and mitigation measures have been taken. The goal of biodiversity offsets is to achieve no net loss and preferably a net gain of biodiversity on the ground'.*

BBOP developed ten principles of biodiversity offsetting (BBOP 2009) and a Biodiversity Offsetting Standard (BBOP 2012) which sets out how each of the standards should be met. DOC and the Ministry for the Environment, through the Biodiversity Offsetting Guidance, have essentially adopted these principles for New Zealand:

- **Adherence to the mitigation hierarchy** (As discussed above). This is now referred to more commonly as the "effects management hierarchy".
- **Limits to what can be offset.** There are situations where residual adverse effects cannot be fully compensated for because of the irreplaceability or vulnerability of the biodiversity affected.
- **Landscape context.** A biodiversity offset should be designed and implemented in a way that is appropriate across the wider landscape.
- **No net loss.** A biodiversity offset should be designed and implemented to achieve *in situ* conservation outcomes where the result is no net loss and preferably a net gain of biodiversity.
- **Additional conservation outcomes** (sometimes referred to as "**additionality**"). A biodiversity offset should achieve conservation outcomes above and beyond results that would have occurred if the offset had not taken place.
- **Stakeholder participation.** In areas affected by the project and by the biodiversity offset, the effective participation of stakeholders should be ensured in decision making about biodiversity offsets.
- **Equity.** A biodiversity offset should be designed and implemented so that the rights and responsibilities, and risks and rewards associated with the offset are shared equitably amongst stakeholders including indigenous peoples and local communities.
- **Long-term outcomes.** The design and implementation of a biodiversity offset should have the objective of securing outcomes that last at least as long as the project's impacts and, preferably, in perpetuity.
- **Transparency.** The design and implementation of a biodiversity offset, and communication of its results to the public, should be undertaken in a transparent and timely manner.
- **Science and traditional knowledge.** The design and implementation of a biodiversity offset should be a documented process informed by sound science, including an appropriate consideration of traditional knowledge.

The mitigation and offsetting package outlined in subsequent sections of this report has been designed to achieve these principles, as appropriate. In addition, the following ecology principles of best practice have also been applied in the development of the mitigation and offsetting package:

1. **Ecological equivalence.** The design and implementation of mitigation and offsetting should endeavour, wherever possible, to replace the affected form of biodiversity with the same or similar form or taxa (ie. preference for replacement of 'like for like').
2. **Ecological proximity.** Ecological equivalence and the achievement of no net loss of biodiversity will normally be achieved most effectively when the offset is undertaken at or close to where the effects occur.
3. **Connectedness.** The value of ecological mitigation and offsetting will be greater where the result is improved connection with similar adjacent habitat which, in turn, creates improved opportunity for the dispersal and movement of indigenous biota.
4. **High likelihood of success.** Any offsetting activity should have a high likelihood of success and perseverance. In other words, it should be based on sound science and proven practice.

2.1.3 How much biodiversity offset is necessary?

Biodiversity offsetting remains a developing field; consequently, the determination of how much offset is sufficient to achieve “no net loss”, and over what time frame no net loss should be achieved, tends to fall back on the professional view of each ecologist. Accordingly, a wide range of multipliers (ratio of biodiversity offsetting undertaken to biodiversity lost) have been offered and agreed to through RMA processes.

In attempting to determine the amount of offsetting to be implemented, accounting for the time lag that invariably exists between the loss of ecological values (due to the removal of habitat that may be decades or centuries old), and the time it takes for restored habitat to reach an equivalent age and state, presents a challenge. Multipliers of between 1:1 and 150:1 have been applied in New Zealand depending on the significance, rarity and age of the ecological values lost and the nature of the mitigation or offset provided.

The Stream Ecological Valuation (SEV) method, developed by a group of expert freshwater ecologists for Auckland Regional Council in 2006, is a method now commonly used to quantify the ecological value of a stream or section of stream that may be lost or damaged as a result of a development project. Quantification of the values that will be lost using SEV enables the amount of stream and riparian restoration required to compensate for that loss to be calculated for any stream selected for offsetting. The SEV calculator is generally accepted by freshwater ecologists as an appropriate method for the determination of freshwater habitat values and offset compensation and has been adopted in the Assessment of Ecological Effects – Freshwater Ecology (Technical Report 7b, Volume 3 of the AEE) (Freshwater Ecology Technical Report).

Until recently no such standardised method or calculator existed for the quantification of terrestrial ecological values and the determination of mitigation or biodiversity offset required to compensate for terrestrial values lost. However, in 2015 DOC developed a biodiversity offset accounting model that quantifies biodiversity losses and gains, and expresses the results in a common currency (Catalyst Group 2015). This model calculates net present biodiversity value (NPBV; Overton et al 2013) for individual biodiversity attributes and average NPBV across a range of attributes, and uses NPBV to estimate whether no net loss is achieved (for ‘like for like’ biodiversity trades only).

While the Biodiversity Offsets Accounting Model (Appendix A) has not been used previously for the determination of biodiversity offsets for national roading projects, Nicholas Singers, the author of the report applying this model to the Project, has previously used the model for two small-scale projects. Given the complexity and high value of the biodiversity in the wider Project area, and with the understanding that the model has been well-tested in a variety of scenarios, and recommended for use by DOC, the model is considered to be the most appropriate method to determine the offsetting requirements for the vegetation and habitat that will be lost or modified along the Project footprint.

The Biodiversity Offsets Accounting Model is explained in more detail in the Biodiversity Offset Calculation Report attached in Appendix A:. The Stream Ecological Valuation (SEV) model and how it has been used for the Project is further described in the Freshwater Ecology Technical Report.

All potential biodiversity losses arising from the Project that cannot be replaced or replicated have been passed through the Biodiversity Offsets Accounting Model or the SEV model to generate the areas of offset required. However, a sizeable area of vegetation that will be removed (approximately 9ha) consists of early successional plant species (including manuka scrub and manuka-tree fern bush) that can be replanted immediately after construction provided the growing conditions, particularly soil and hydrology, remain similar to what was there previously. Replacement planting of these areas will be treated as mitigation and undertaken on a 'one for one' basis - one square metre of replacement planting for every square metre lost or damaged.

3 Recommendations from Ecology Specialist Reports

3.1 Introduction

The following is a summary of the avoidance, minimisation, mitigation, offset and monitoring actions proposed by the Project ecology specialists. This information has then been used to develop a comprehensive ecological mitigation and offsets package for the Project as detailed in later sections.

Details of potential significant ecological effects identified can be found in individual Assessment of Ecological Effects reports (Volume 3 of the AEE).

3.2 Avoidance and minimisation measures undertaken

The nature and extent of potential effects of the Project on ecological values have been considerably reduced through the route selection and design refinement process.

A large number of route options were considered before the Project route was selected. The assessment of ecological effects of the various options played an important part in route selection. The options assessment process has meant routes affecting Parininihi have been avoided.

Before and after the selection of the preferred route, significant alterations to the road design have occurred to minimise the likely ecological effects. These include:

- Inclusion of a 235m long tunnel through the ridge dividing the Mangapepeke and Mimi catchments. The tunnel has greatly reduced the size of the cut and fill area that would otherwise have been required and has preserved the important east – west connectivity of habitat (ridge to coast) and mobile animal movement (especially bats).
- Incorporation of a 120m long bridge across a tributary valley of the Mimi River on the south side of the route. This bridge sits very close to the ecologically significant wetland area and has significantly reduced the effects that a cut and fill approach would have had on the wetland.
- Introduction of construction techniques to reduce ecological effects. For example, the bridge mentioned above has been designed in a way that will allow it to be constructed from each side rather than from the valley bottom. This will reduce the amount of ground and vegetation disturbance compared to a more conventional approach of building the bridge from the valley bottom, and it will also reduce the risk of sediment erosion down into the wetland.
- Minor adjustments to the route to avoid the need to fell significant trees. The number of significant trees potentially needing to be felled has been reduced from 22 to 15 by this means.
- Realignment of the road corridor, including shifting part of the corridor further from the ecologically significant wetland area.

- Location of construction yards, laydown areas, construction access tracks and haul roads away from ecologically sensitive/significant areas to minimise the extent of disturbance and vegetation clearance.
- Use of retaining walls to avoid loss of significant trees where possible.
- Location of spoil fill areas in areas likely to cause the least ecological effects.
- Implementation of vegetation removal, construction and sediment management best practices to minimise effects on adjoining vegetation, habitat and fauna.
- Physical delineation (such as fencing or flagging tape) will be used to clearly mark the extent of vegetation clearance to be undertaken, along with vegetation to be protected.
- Installation of an effective waste management system to minimise the chances of attracting pest mammals.
- Having an ecologist on site to advise the construction teams when vegetation is being cleared near wetlands.
- Management of light spill associated with construction lighting through careful consideration of the layout and arrangement of temporary lighting (including shrouding and spectrum limits to minimise impacts on adjacent ecological habitats).

3.3 Vegetation

3.3.1 Summary of potential ecological effects

The Vegetation Technical Report has described the potential effects on vegetation of the Project footprint as being:

- Loss of approximately 33.3ha of indigenous dominant vegetation communities, including communities that are now rare, highly representative and of high ecological value. An additional 11.12ha of mixed indigenous exotic vegetation communities will also be lost of which 1.37ha of sedgeland wetland is considered to be of significant value.
- Edge effects.
- Loss of large significant trees, which provide significant habitat and resources for a range of other species. Fifteen significant trees have been identified that may need to be removed.
- Loss of plants classified as ‘at risk – declining’, such as kohurangi (*Brachyglottis kirkii* var. *kirkii*), or recognised as regionally distinctive, including *Pittosporum cornifolium* and swamp maire.
- Sedimentation through the high value wetland and alluvial flood plain of the northern tributary of the Mimi River if control measures are overwhelmed during significant storm events.

Table 3.1 – Summary of vegetation communities that will be lost or disturbed by the Project (from the Vegetation Technical Report)

Potential Ecosystem Type	Vegetation community	Project footprint total (ha)	Ecological value
WF8: Kahikatea pukatea forest	Kahikatea swamp maire forest	0.186	High
	Kahikatea forest	1.045	High
	Pukatea treefern treeland	0.721	Moderate
	Manuka scrub	0.372	Low
	Rushland sedgeland mosaic*	11.117	Low — Moderate
WF13: Tawa kohekohe, rewarewa, hinau, podocarp forest	Tawa rewarewa kamahi forest	6.509	High — Very High
	Tawa nikau treefern forest	8.731	Moderate
	Miro rewarewa kamahi forest	0.536	High — Very High
	Pukatea nikau forest	1.258	High
	Secondary mixed broadleaved forest	2.221	Moderate
	Manuka treefern scrub	0.146	Low
	Manuka succession	0.451	Moderate
WF14: Kamahi, tawa, podocarp, hard beech forest	Hard beech forest	0.081	Moderate
	Manuka treefern rewarewa forest	3.599	Low–Moderate
	Manuka treefern scrub	5.929	Low
	Manuka scrub	1.108	Low
CL6: *Hebe*, wharariki flaxl/ rockland	Dry cliff	0.399	Moderate
Total hectares		44.409	

*=Rushland sedgeland mosaic is a mixed indigenous and exotic vegetation community; contains1.37ha of significant sedgeland.

3.3.2 Proposed mitigation and offset

3.3.2.1 Mitigation

- Restoration planting of all secondary scrub areas along the footprint, plus of temporary access tracks and storage areas where these retain soil, hydrology and growing conditions suitable for reinstatement (approximately 9ha).
- Capture, direct transfer and deposition of forest duff, topsoil, and woody material (decomposing and freshly felled) back onto temporary work areas that will be rehabilitated, and onto fill areas to provide habitat and food for forest fauna and to encourage regeneration (from seed) and succession.
- Utilisation of plant species tolerant of relocation, especially tree ferns and nikau, to revegetate newly created fill sites and undertake riparian restoration.
- Relocation or cultivation (from seeds or cuttings) of any threatened plants found, such as collecting cuttings of kohurangi when significant trees are felled or transplanting king fern found within the Project footprint.
- Strategic planting of suitable plant species (such as Olearia townsonii) above newly created cut faces to promote more rapid regeneration of cliff face vegetation.

3.3.2.2 Offset of residual effects (as derived from the Biodiversity Offset Calculation Report – see Appendix A)

- Intensive long term integrated pest management over a core area of 222ha plus an additional 340ha buffer area, for a total area to be managed for pests of approximately 560ha.
- Restoration planting of 6ha of swamp forest and wetland habitat to achieve a net biodiversity gain scenario (when added to the pest management) for the loss of swamp forest.
- Restoration planting of 1.37ha of sedgeland wetland that will be lost (included as part of the 9ha of mitigation replacement planting referred to in Section 4.3.2.1).
- Exclusion of livestock and riparian planting along 8.9km of stream margin.
- Offsetting the loss of significant trees by planting a minimum of 200 seedlings for each significant tree lost. The seedlings to be of the same species as the trees that will be removed and will be planted in areas where growing conditions are considered favourable for each species.

3.3.3 Proposed Monitoring

- Pre-construction monitoring of pest densities and biodiversity monitoring indicators in the proposed Pest Management Area to serve as a baseline against which the success of the campaign can be measured.
- Pre-construction vegetation monitoring to provide more detailed baseline information on forest condition including the composition and abundance of palatable vegetation.
- Pre-construction survey of wetland vegetation composition and structure to assist planning for the swamp forest restoration planting.

- Monitoring of sedimentation both prior to and during the construction period.
- Survey of actual vegetation loss immediately following construction.
- Targeted monitoring of palatable plant species and forest canopy condition as a measure of verification of the success of the pest management programme.
- Monitoring of pest densities to verify that pests are being successfully managed at or below target levels.

3.4 Bats

3.4.1 Summary of potential ecological effects

The Assessment of Ecological Effects – Bats (Technical Report 7f, Volume 3 of the AEE) has identified the following potential effects of the construction and operation of the Project on native bats:

- Loss of roosts and effects on roosting bats.
- Loss of foraging habitat.
- Habitat fragmentation, severance and isolation.
- Impact of construction noise, vibration, light disturbance during night works, and operational lighting.
- Mortality or injury on roads through vehicle strike.

3.4.2 Proposed mitigation and offset

3.4.2.1 Avoidance

- Avoid the risk of bat mortality as a result of felling roost trees containing bats, by applying the current best practice vegetation clearance protocols which specify a suite of techniques that ensure that any potential bat roost trees are only felled when they are not occupied by bats.
- Radio tracking bats prior to the commencement of construction to identify the location of bat roosts.

3.4.2.2 Mitigation

- Revegetation of the margins next to the road footprint with suitable indigenous forest edge species.

3.4.2.3 Offset of residual effects

- The most beneficial long-term form of offset for the loss of bat habitat will be intensive long-term mammalian pest management within the forested areas in the vicinity of the Project footprint that are not currently controlled.

3.4.2.4 Monitoring

No specific post-construction monitoring is recommended for bats.

3.5 Avifauna

3.5.1 Summary of potential ecological effects

The Assessment of Ecological Effects – Avifauna (Technical Report 7e, Volume 3 of the AEE) has identified a range of potential ecological effects on the avifauna along and adjacent to the Project footprint.

Potential effects as a result of road construction include:

- Direct removal or degradation of habitat used for nesting or foraging.
- The creation of habitat edge effects.
- Direct mortality of nests and their contents.
- Habitat fragmentation and isolation.
- Construction noise disturbance.
- Sediment runoff to wetlands and watercourses affecting the quality of wetland bird habitat.

Potential ongoing effects resulting from operation and maintenance of the road include:

- Effect of vehicle noise on birds.
- Decreased landscape and habitat connectivity through fragmentation.
- Mortality or injury on roads through bird strike or road kill.
- The increased presence of people and introduced species in previously less accessible areas.
- Lost opportunities for creating wildlife corridors.
- Degradation of the quality of the wetland and riparian habitat of wetland bird species.

3.5.2 Proposed mitigation and offset

3.5.2.1 Avoidance

Kiwi:

A. Pre-construction

- Pre-construction kiwi radio-tracking programme to ensure that all kiwi potentially at risk of harm during construction are not harmed when the road is built.
- Any kiwi found roosting in the Project footprint will be uplifted and moved to another part of their territory.
- Location and uplifting of kiwi eggs found along the Project footprint to an incubation facility.
- Construction of temporary fences on each side of the road footprint (in appropriate places) to exclude kiwi from the construction zone.

B. During construction

- It is desirable for vegetation removal to occur as much as possible outside of the main breeding period (October to January).

C. Post construction

- Construction of permanent fences in selected locations along the new road in areas where kiwi could enter the road corridor and find it difficult to escape.
- Appropriate signage to be erected alerting motorists of the presence of kiwi along the road.

3.5.2.2 Offset of significant residual effects

- Intensive long-term pest management over approximately a 560ha area.
- Restoration of 6ha of swamp forest and wetland habitat.
- Exclusion of livestock and riparian planting along 8.9km of stream margin.
- Planting of 200 seedlings of the same species for every significant tree that has to be felled.
- Restoration planting of all secondary scrub areas along the footprint, and of temporary access tracks and storage areas where these retain soil, hydrology and growing conditions suitable for reinstatement (9ha).

3.5.3 Monitoring

- Pre-construction avifauna monitoring to provide more detailed baseline information on the composition and relative abundance/conspicuousness of birds in the Project footprint and immediate surrounds (potentially affected areas).
- Pre-construction monitoring of pest densities and biodiversity monitoring indicators in the proposed pest management area to provide information to develop the pest management strategy and to serve as a baseline against which the results of the campaign can be measured.
- Avifauna monitoring in the Pest Management Area in Years 1, 2, 5, 10 and 20 post-construction to confirm that the expected biodiversity gains have been achieved.

3.6 Herpetofauna

3.6.1 Summary of potential ecological effects

The Assessment of Ecological Effects – Herpetofauna (Technical Report 7d, Volume 3 of the AEE) (Herpetofauna Technical Report) has identified a range of potential ecological effects on herpetofauna along and adjacent to the Project footprint. While no lizards or frogs were found in the initial surveys undertaken, the Herpetofauna Technical Report notes the potential for species to be present in the Project footprint.

If some herpetofauna species are present, potential ecological effects include:

- Habitat loss.
- Habitat fragmentation.
- Vehicle strikes.

3.6.2 Proposed mitigation and offset

3.6.2.1 Avoidance and mitigation

- Targeted pre-construction surveys will be undertaken within the Project footprint to determine which (if any) species are present and where.
- Populations detected within the Project footprint will be captured and relocated to safe locations.
- Inclusion of herpetofauna-specific measures in the Ecological and Landscape Management Plan (ELMP). These measures will describe search, capture, handling and relocation methods and timing; identification of release sites capable of supporting additional lizards; habitat enhancement, including provision of extra refuges; long-term security of release sites; post-release monitoring; and Tangata Whenua engagement before, during and after implementation.
- Revegetation next to the footprint. Ground cover plants could be included in revegetation or follow up enrichment planting to provide habitat for terrestrial lizards that utilise this habitat type.
- Revegetation should aim for heterogeneity as opposed to a homogenised flat surface prior to planting. Habitat complexity could be incorporated with artificially created mounds and mounds and slump as well as the importation of woody debris from tree felling.

3.6.2.2 Offset of significant residual effects

- Pest Control: While there is a paucity of published evidence that native herpetofauna populations in mainland forest habitats benefit from large-scale pest management programmes, this probably reflects the challenges associated with monitoring forest-dwelling herpetofauna. It is considered reasonable to assume that the proposed long-term pest management programme will contribute to mitigating residual effects on herpetofauna.

3.6.3 Monitoring

No post-construction monitoring of herpetofauna is recommended but on-going pest density monitoring is considered a suitable indicator of likely biodiversity benefits.

3.7 Freshwater ecology

3.7.1 Summary of potential ecological effects

The Freshwater Ecology Technical Report identified a range of potential ecological effects on freshwater ecology within and adjacent to the Project footprint, including:

3.7.1.1 Potential short term effects.

- Sedimentation resulting from vegetation clearance and construction activity.
- Direct removal of fish from streams.
- Short-term loss of fish passage in some areas.

- Short term loss of stream habitat where temporary culverts are used.
- Contamination of water when in direct contact with wet concrete.
- Water takes for the purpose of dust suppression.

3.7.1.2 Potential long term effects

- Loss of stream habitat and functions. 3825m of stream in the Mangapepeke and Mimi catchments will be diverted, culverted or substantially altered as a result of the Project. The affected streams have moderate to high ecological values, and a diverse fish community.
- Reduced fish passage.
- Effects of road stormwater on stream hydrology and water quality.

Of these effects, the Freshwater Ecology Technical Report states that habitat loss is considered to have the greatest effect on the freshwater ecology of the Project footprint.

3.7.2 Proposed mitigation and offset

3.7.2.1 Avoidance and mitigation

- Develop and implement Fish Recovery Protocols for the recovery, rescue and relocation of native fish.
- Minimise the effect on upstream fish passage of temporary culverts that will be required for more than a few days. This can be done by installing spat rope through temporary culverts as required.
- Provide permanent fish passage through culverts and stream diversions that is appropriate for the fish present in the stream.
- Install fish habitat devices within low gradient culverts on the larger streams (>25 ha) in order to mitigate their effect on fish habitat.
- Minimise disturbance of streams and riparian areas during construction.
- Base the design of stream diversions on Ecological Design Principles.
- Develop and implement a Stream Restoration Plan (developed as part of the ELMP) for stream diversions and streams affected in the short term by the works.
- An experienced ecologist should be available to give advice and guidance during construction of the new stream channel.
- Implement the Construction Water Management Plan to minimise and mitigate the effects of erosion and sedimentation.
- A Vegetation Clearance Management Plan (developed as part of the ELMP) should be prepared.

3.7.2.2 Offset of residual effects

- In total, the margins of 8724m^2 (Table 3.2) of stream channel– equating to approximately 9km of stream length– will need to be restored (planted with effective exclusion of livestock) to offset the stream area affected. Ten metre planted margins on each side of the stream are recommended. The nature and location of this offset is discussed in later mitigation package sections.

- Areas chosen for compensation should ideally be 'on-site' and within the same catchment, but in practice this is often challenging. If the compensation streams are off-site then they should aim to be in, or as close as possible to the affected catchment (e.g. adjacent catchment), and a similar size and order.
- The Mangapepeke Stream and Mimi River upstream of the current SH3 road have high potential for successfully improving stream values through riparian planting and restoration, and are therefore the most favoured sites for offset. This is because the restoration can be contiguous with the forested headwaters, which helps ensure good water quality, a source of plant seed and wood, and more rapid colonisation by invertebrates and fish.
- Development of a Stream Restoration Plan (as part of the ELMP) to ensure use of appropriate species and sufficient overall improvement of stream values at the restoration sites.

Table 3.2 - Area of stream affected by the Project and the area of offset to achieve 'no net loss' (calculated by the SEV method). Taken from the Freshwater Ecology Technical Report (Table 4.9).

		Impact		Offset	
Footprint	Catchment	Length (m)	Area (m^2)	Length (m)	Area (m^2)
Permanent	Mangapepeke	1100	969	4346	4150
	Mimi	523	476	1958	1865
Short term & diversions	Mangapepeke	1347	1464	1859	2258
	Mimi	500	333	769	450
Total		3470	3242	8932	8724

3.7.3 Monitoring

- Undertake baseline and ongoing monitoring during the construction period of water quality and fish at selected sites to assess the effect of construction works. The baseline water quality monitoring should characterise natural variation in sediment concentration or deposition that occurs within the streams
- Monitor the success of implanted stream diversions to ensure they are tracking towards achieving the ecological values assumed in the SEV.
- Consideration should be given to initiating early baseline monitoring of settleable sediment, particularly in the tributary to the Mimi River.

3.8 Marine ecology

3.8.1 Summary of potential ecological effects

The Assessment of Ecological Effects - Marine Ecology (Technical Report 7g, Volume 3 of the AEE) (Marine Ecology Technical Report) has concluded that the overall risk of potential adverse effects on marine ecological values ranges between low or no ecological effect depending on the habitat or species. Any potential effects on the marine environment will arise from the release of sediment from construction via the Mimi or Mangapepeke/ Tongaporutu Rivers.

3.8.2 Proposed mitigation and offset

Overall, the life-supporting capacity of marine ecosystems will be maintained through the efforts of best practice erosion and sediment control measures as set out in the Construction Water Management Plan (Volume 5 of the AEE).

3.8.3 Monitoring

Monitoring of the marine environment is not proposed given that the Project is expected to have no measurable effects on marine ecological values.

3.9 Terrestrial invertebrates

3.9.1 Summary of potential ecological effects

The Assessment of Ecological Effects- Terrestrial Invertebrates (Technical Report 7c, Volume 3 of the AEE) (Invertebrate Technical Report) refers to the invertebrate fauna of the Project footprint as 'typical' of communities inhabiting native forests of southern North Island and northern South Island.

Potential effects of the Project on the invertebrate fauna are summarised as:

- Habitat loss and degradation. In total, 44.4ha of vegetation will be removed or degraded of which 33.3ha is predominantly indigenous vegetation that is habitat suitable for a range of indigenous invertebrates.
- Habitat fragmentation and isolation.
- The creation of habitat edge effects.
- Introduction of new exotic invertebrate taxa during construction.

3.9.2 Proposed mitigation and offset

- Intensive pest management focused on rodents and possums over the area proposed for the pest management programme in the Ecological Mitigation and Offset report (Appendix A:). There is a clear link between the health of vegetation communities and the health of invertebrate communities, as there is between the health of vegetation communities and the level of pest management.
- Restoration planting and habitat enhancement creates habitat, improves ecological connectivity and reduces edge effects on existing vegetation, all of which are likely to benefit the terrestrial invertebrate community affected by the Project. The proposed restoration planting of 6ha of swamp forest, approximately 9km of riparian margins, 9ha of early successional vegetation and the planting of 200 seedlings of the same species for every significant tree that has to be felled will be of direct benefit to terrestrial invertebrate populations.

- Replanting cuts, fills, and other disturbed areas with native plants along the Project footprint to reduce edge effects, and especially to restore forest floor litter communities.
- Placement of felled logs within mitigation sites to improve biodiversity values for a number of plants and animals.
- Direct transfer of habitat– the salvage and replacement of intact ‘sods’ of vegetation together with underlying soil– minimises soil disturbance, and allows the transfer of reasonably intact ecological communities.
- Restoration actions for individual taxa of conservation interest that are potentially within the Project footprint should be considered if these invertebrates are found to be present along the Project footprint prior to construction.

3.9.3 Monitoring

It is recommended that invertebrates do not need to be monitored in the mitigation and biodiversity off-set site(s) (and any such monitoring would likely be of little real benefit). It is appropriate and reasonable to assume that the general level of benefits for invertebrates discussed above will accrue from the proposed pest management programme, restoration planting, and habitat enhancement.

4 Proposed Mitigation and Offset Package

4.1 Background

Restoration mitigation of natural or semi-natural sites that have been altered by infrastructure works can be achieved by a range and combination of methods, including:

- Planting of trees, shrubs and grasses
- Application of seed
- Promotion of natural regeneration by creating conditions suitable for that to occur
- Weed management or removal
- Construction of new natural habitat (e.g. new stream sections; new lizard habitat)
- Construction of artificial habitat (e.g. bat roosting boxes)
- Construction of artificial barriers to minimise sound and light
- Construction of passageways for fauna over or under the structure
- Translocation/relocation of fauna to alternative existing habitat or newly created habitat
- Relocation of fauna and their habitat together
- Management / control of one or several pest animal species
- Pest animal eradication or exclusion

Mitigation of the ecological effects of road construction in New Zealand typically has a significant replanting component, especially where native vegetation has been removed in the process of road construction. In pursuit of “no net loss of biodiversity”, planting is, in most cases, necessary to enable the eventual replacement of the vegetation types and habitat that have been lost. However, in circumstances where mature forest has been removed, the time span between planting and the achievement of conditions that resemble what has been lost can take decades or centuries. When planting is the only mitigation strategy used, the time lag to achieve no net loss is of the same magnitude – decades or centuries.

The main threats to indigenous biodiversity in New Zealand are the adverse effects of introduced mammals (Clout 2001). Most unmanaged, or minimally managed natural forested sites exhibit reduced and altered plant and animal diversity, elevated indigenous plant and animal mortality and decreased plant and animal recruitment as a result of the impact of pest animals (Byrom et al 2016; Leathwick et al 1983; O’Donnell 1996; Timmins 2002; Wilson et al 2003; Gillies et al 2010). The initiation of effective, targeted and enduring animal pest control has repeatedly shown substantial improvements in the survival and recruitment of multiple forest bird species (Gillies et al 2003), long-tailed bats (O’Donnell et al 2017) and lizards (Towns 1994; Reardon et al 2012), and reduced mortality, increased seedling regeneration and increased foliage growth in forest vegetation (Meads 1976; Timmins 2002; Gillies et al 2003; Wilson et al 2003). Reduction of mammals (particularly rodents) has usually resulted in altered invertebrate abundance (Green 2002; Watts et al. 2011, 2014), species richness (Sinclair et al. 2005), and behaviour (Rufaut & Gibbs 2003;

Watts et al. 2011), although over time predation by mammals can be replaced by increased predation by natural indigenous predators.

4.2 Biodiversity mitigation / offset approach for the Project

The Vegetation Technical Report refers to forest of varying successional stages and age along and in the vicinity of the Project footprint. The kahikatea forest on the Mangapepeke valley edge has trees between 50 and 80 years of age and some of the emergent rimu, rata and totara are likely to be several hundred years old. Replacement of the forest area lost, by planting, will eventually recreate habitat equivalent to that lost, but not for many decades.

Based on the experiences of many New Zealand studies (see Section 4.1), and the success of the pest management campaign over the past 15 years in the Waipingao catchment, the introduction of intensive pest management over the forest areas adjacent to the road footprint is proposed and will result in reasonably rapid recovery of forest biodiversity. The benefit of this pest management will continue for the duration of the pest management programme. Furthermore, as populations increase, the young of mobile animals such as bats and flighted birds will disperse further afield and increase populations in those areas as well. It is for this reason that intensive pest management is proposed as the primary focus of offset for the residual ecological effects that will occur with the Project.

The details of the pest management strategy, as well as the other aspects of the proposed mitigation / offset strategy, are covered in Sections 4.3 to 4.8 below. In summary the proposed mitigation / biodiversity offset approach that addresses the residual ecological effects of the Project will involve:

- Pest management to reduce all major introduced mammalian predators and herbivores (including livestock) from a core management area to levels sufficiently low to induce significant indigenous flora and fauna recovery.
- Planting of high value forest types, especially swamp forest, for which there is insufficient habitat type within a reasonable distance of the Project footprint to offset effects through pest management.
- Planting of seedlings of the same species for every significant tree that has to be removed.
- Restoration planting and fencing along stream margins, the quantity of which will be determined using SEV.
- Restoration/replacement planting of all secondary scrub areas along the footprint, plus temporary access tracks and storage areas where these retain soil, hydrology and growing conditions suitable for reinstatement.
- Rehabilitation of fill areas along the new road footprint to fast-track reversion to indigenous forest and to create habitat for a range of fauna.
- Enhancement of steep cut faces to promote natural regeneration.

As explained above, the amount / area of pest management and restoration planting to be undertaken has been determined through utilisation of the Biodiversity Offsets Accounting Model, a model supported for use on this Project by DOC. The detail as to how this model has been used and the offset areas it has produced for this Project can be found the Biodiversity Offset Calculation Report (Appendix A), and a summary can be found in Section 4.3. The extent of stream and riparian restoration to be undertaken has been determined by using the Stream Ecological Valuation (SEV) method and the details about how this method was used for this Project can be found in the Freshwater Ecology Technical Report.

The area of vegetation and habitat loss or damage that will require mitigation or offsetting includes the following (collectively defined as the "Project footprint"):

- All vegetated land, stream and wetland areas permanently lost to the road footprint;
- Additional work areas (AWA) along the footprint that will be cleared in the process of construction, including areas of cut and fill that lie beyond the paved road area;
- Temporary work areas, such as access tracks and storage areas, which will be reinstated after road construction has been completed.
- Those vegetated areas, mostly forest, where clearance of vegetation has created edge effects that were not previously present. The affected edge areas have been calculated as being a 5m margin along all newly created forest edge.

Of these areas,, those that retain growing conditions after the completion of road construction that will allow relatively quick return to the vegetation type removed (when standard restoration techniques are applied), will be treated as mitigation. Vegetation types that are most likely to fall into this category are modified secondary forest/bush areas including manuka scrub and manuka-tree fern bush.

All other more advanced forest types lost will require offset compensation (in the form of restoration planting for swamp forest and pest management for the remainder). This is because the cut and fill areas created in forming the road will not be suitable (in terms of soil type, hydrology and growing conditions) for restoration directly back to the forest type removed. Early successional species will be planted on these areas but it will take many decades before conditions will be suitable for later successional forest species to establish.

4.3 Summary of the Biodiversity Accounting Model Calculations

The Biodiversity Accounting Model (the Model) has been used to determine the amount of offsetting required to achieve a net gain in biodiversity. The calculations and details about how the Model has been used can be found in the Biodiversity Offset Calculation report in Appendix A:.

The Model requires that the types of offsetting, or restoration methods used and the duration by which no net loss of biodiversity, or net gain, is to be attained are pre-determined and then fed into the Model. An intensive, multi-species pest management programme will be the primary method of offsetting undertaken, for the reasons explained in sections below and in the technical report summaries in Section 3. Restoration planting of vegetation communities that are less common in the wider Project area and/or less likely to benefit from pest management has been chosen as the supporting offsetting method.

The overall ecological aim for the Project is to ensure no net overall loss of biodiversity values in the short to medium term. This will be achieved through the proposed offsetting package, which is expected to achieve a net biodiversity gain within 10 to 15 years of construction. This timeframe is considered to be a realistic target given the current state and condition of the habitat that will be treated, and the wish to have a high level of confidence, based on current knowledge and past experience, of achieving successful outcomes.

The vegetation communities making up the three forest ecosystems that will be affected by the Project (WF8, 13 and 14), as described in the Vegetation Technical Report, have been used to determine the levels of offset. These vegetation types occupy 25.26ha along the Project footprint. Each vegetation community type has been allocated a biodiversity attribute (%) which, in effect, is a measure of ecological integrity (or ecological value) of those areas of that vegetation community currently occupying the Project footprint. The higher the value, the better the current condition of the vegetation type. The range for vegetation communities affected by the Project is from 79% (highest) for the primary tawa, rewarewa, kamahi forest areas to 7.5% for modified, secondary manuka scrub areas (see Table 2.2 in the Biodiversity Offset Calculation Report). The Model predicts that when, as a result of offset treatment, the ecological integrity ratings of the offset areas exceed those before construction then net biodiversity gain is achieved.

The pest management area required to offset the loss of all vegetation types and provide net biodiversity gain within 10 to 15 years was calculated using the Model. A key consideration in determining whether an offset method is achievable is whether enough area of each vegetation type is available for treatment in reasonably close proximity to the Project site. The application of the Model has led to the conclusion that there is sufficient available offset vegetation to enable net biodiversity gain to be achieved within 15 years for all vegetation communities except one, and that 222ha of intensive, multi-species pest management is required to achieve this (Table 4.1and Table 4.2). The exception is the kahikatea, swamp forest / kahikatea forest vegetation community. The 22 ha of this vegetation type that will remain in close proximity to the Project footprint after road construction is insufficient to generate the biodiversity gains necessary by pest management alone.

The residual biodiversity deficit for the kahikatea, swamp forest vegetation community was separately run through the Model to determine how much restoration planting is needed to exceed this deficit and achieve an overall net biodiversity gain outcome. A figure of 6ha of kahikatea, swamp forest / kahikatea forest planting was generated.

In summary, application of the Biodiversity Accounting Model has determined that 222ha of intensive, multi-species pest management plus 6ha of kahikatea, swamp forest / kahikatea forest restoration planting will be sufficient to offset the loss of 25.26ha of significant value vegetation and the fauna that inhabits that vegetation (Table 4.2). Net biodiversity gain will be achieved for all vegetation communities within 15 years of the completion of construction.

Furthermore, the biodiversity gains continue to accrue with each year that pest management is continued. Compared to a Year 10 Net Present Biodiversity Value of 0 (ie. having achieved no net loss) the Model predicts that the Net Present Biodiversity Value (NPBV) when measured at Year 35 will be 1.62, 29.46 and 1.42 for WF8, WF13 and WF14 respectively; a substantial net biodiversity gain as a result of the offset programme.

The remaining 9ha of predominantly indigenous vegetation that will be removed by the Project has not been put through the Model because one-for-one replacement planting is considered to be appropriate mitigation (this is explained more fully in sections below).

Table 4.1 – Summary of the area of vegetation communities and how they will be offset

Potential Ecosystem Type	Vegetation community	Project footprint total (ha)	Offset required	Mitigation/offset treatment
WF8: Kahikatea pukatea forest	Kahikatea swamp maire forest & kahikatea forest	1.231	18	Offset: Intensive pest management
		0.372*	6	Offset: Swamp forest restoration planting
	Pukatea treefern treeland	0.721	3	Offset: Intensive pest management
	Manuka scrub	0.372	1	Offset: Intensive pest management
	Rushland sedgeland mosaic**	11.117	1.37	Mitigation: replacement planting 1.37ha of sedgeland
WF13: Tawa kohekohe, rewarewa, hinau, podocarp forest	Tawa rewarewa kamahi forest	6.509	95	Offset: Intensive pest management
	Tawa nikau treefern forest	8.731	58	Offset: Intensive pest management
	Miro rewarewa kamahi forest	0.536	8	Offset: Intensive pest management
	Pukatea nikau forest	1.258	15	Offset: Intensive pest management
	Secondary mixed broadleaved forest	2.221	15	Offset: Intensive pest management
	Manuka treefern scrub	0.146	0.146	Mitigation: replacement planting
	Manuka succession	0.451	0.451	Mitigation: replacement planting
WF14: Kamahi, tawa, podocarp, hard beech forest	Hard beech forest	0.081	1	Offset: Intensive pest management
	Manuka treefern rewarewa forest	3.599	8	Offset: Intensive pest management

Potential Ecosystem Type	Vegetation community	Project footprint total (ha)	Offset required	Mitigation/offset treatment
	Manuka treefern scrub	5.929	5.929	Mitigation: replacement planting
	Manuka scrub	1.108	1.108	Mitigation: replacement planting
CL6: *Hebe*, flax rockland	Dry cliff	0.399		Treat to enhance natural regeneration
Total hectares		44.409		

Notes:
*= This area (0.372ha) is the residual biodiversity deficit after pest management to achieve net biodiversity gain. It equates to 30.2% of the 1.231 ha of this forest community that will be lost.
**=Rushland sedgeland mosaic is a mixed indigenous and exotic vegetation community that includes approximately 1.37 ha of *Carex virgata* sedgeland.

Table 4.2 – Summary of the proposed areas of offset treatment as generated by the Biodiversity Accounting Model, and additional mitigation planting

Mitigation / offset treatment	Total treatment area (ha)
Intensive pest management	222
Swamp forest restoration planting	6
Mitigation replacement planting	9

4.4 Proposed pest management

4.4.1 Justification

The ecology technical reports prepared for the Project (Volume 3 of the AEE) have identified introduced animal pests as having significant impact on the indigenous plants and animals in the forest and wetland areas within and adjacent to the Project footprint. Pest management is therefore the priority focus for offsetting as it will result in the most immediate and sizeable ecological benefit.

Feral goats, feral pigs, possums, stoats, and ship rats have been identified as common pests in the forested areas of the Mangapepeke and Mimi catchments. In addition, feral cats, ferrets and weasels are predators likely to be present in the forest or along its margins. Norway rats will also be predators along wetland margin areas; rabbits, hares and hedgehogs will venture into bush margins along farmed pasture boundaries; and mice will be feeding on invertebrates and seed throughout the forest. Red deer may also be found occasionally in the adjacent forests.

Of these animal pests, stoats and ship rats are the most devastating predators of forest birds (and their nests) on the ground and in trees (O'Donnell 1996). Ship rats, stoats and cats are implicated in the decline of long-tailed and short-tailed bats (O'Donnell et al 2017; Scrimgeour et al 2012); Norway rats, ship rats, cats and stoats have severely reduced wetland bird populations (O'Donnell et al 2015); cats, ferrets, rats and mice have been shown to greatly reduce lizard numbers (Reardon et al 2012); and rats, hedgehogs and mice have been shown to be important predators of invertebrates (Byrom et al 2016; Miller et al 1995). Mice have even been shown to prey upon inanga eggs in streams (Baker 2006). Many studies have highlighted the impact possums have on the mortality of forest canopy species (Cowan et al 1997) and the impact of rats, mice and possums on seedling establishment / regeneration in forest sites (Wilson et al 2003). Feral goats, pigs and deer are known to heavily browse palatable seedlings on the forest floor and can alter forest composition in a significant way when their numbers are left unchecked (Parkes 1993).

In addition to the impact of introduced mammalian pests, farm livestock have had a significant impact on forest and wetland vegetation through much of the forested block to the east of the existing SH3 (now largely owned by Ngāti Tama). There are no fences to prevent cattle from private farm land entering the forest and wetland/riparian flats along the Mangapepeke Stream and the grazing and trampling impact of the cattle is readily apparent. Removal of all cattle from the forested Ngāti Tama land would result in rapid and positive changes to forest floor regeneration (Timmins 2002).

The sizeable benefits of intensive and on-going pest management in this part of the country were observed and very apparent to several members of the Project ecology team when initial Project route options were inspected. Intensive pest control over an area of 1332ha in the Parininihi land for 15 years using a trapping and bait station grid has resulted in noticeable improvements in forest canopy health– especially rata and totara crowns (see Vegetation Technical Report)– and forest regeneration compared to the Ngāti Tama land to the east of SH3. This in turn has been sufficiently successful to allow the recent reintroduction of kōkako to the area.

4.4.2 Proposed pest management strategy

The pest management strategy proposed as the major focus of mitigation to compensate for the residual ecological effects caused by the Project, is as follows.

The use of the Biodiversity Accounting Model has calculated that a core pest management area of 222ha should be established in which multiple pest species are held permanently at very low densities. To achieve this, it is proposed that an additional pest management buffer be established around the Core Pest Management Area where habitat suitable for forest-occupying pest animals adjoins the core pest management area.

Studies have shown that more mobile pest species, notably feral goats, feral pigs, possums, mustelids and feral cats, will move over large distances to reach feeding areas, and that pest management buffers are required to fully protect core areas from regular pest incursion (Norbury et al 2014; Reardon et al 2012). The size or depth of the buffer required varies depending on the pest species managed, the intensity (bait stations and/or traps per ha) and regularity of pest management effort, and the nature of the terrain. Buffers used vary between 500m for possums (Waikato Regional Council 2014) and 5km for feral deer (Auckland Regional Council 2007). For this Project it is proposed that a pest management buffer 1km deep is established where sizeable areas of forest habitat that are largely unmanaged for pests adjoin the core management area, and where it is practicable to maintain such a buffer.

A multi-pest species, ground-based poison and trapping regime, or a combined aerial and ground-based approach over the full approximately 560ha area will be required to reduce predator levels to densities likely to result in increased bird, bat, herpetofauna and invertebrate survival. Residual trap catch (RTC) targets will be set for each pest species, that New Zealand research to generate the increased survival required.

A network grid with bait stations no further than100 metres apart is necessary to achieve effective and sustained possum and rat control (Smith at al 2009; Speedy et al 2007). Feral cats and mustelids (ferrets, stoats and weasels) can be controlled to low levels by secondary poisoning and periodic trap sets along the networks. Research has shown that different poisons need to be used in rotation to reduce the likelihood of a build-up of bait shyness amongst the rat population in particular (Smith et al 2009).

In addition to the ground-based network, periodic (annual once numbers have been reduced) hunting of feral goats, pigs and deer is recommended to keep numbers low although the omnivorous pig may reduce in numbers by secondary poisoning (consumption of the carcasses of poisoned possums or rats).

Depending on the location of land chosen for pest management, farm livestock will need to be excluded completely by the construction of permanent eight-wire post and batten fences wherever effective fences don't currently exist.

The proposed Pest Management Area (see Section 4.4.3 below) should receive pest management, as described above, in perpetuity, or until such time as pest management in the form we know of it today is no longer necessary to sustain the levels of biodiversity created. This situation might arise, for example, if new technologies are developed that allow more effective pest control or eradication.

A detailed Pest Management Plan will need to be produced by a person with expertise in the management of multiple pest species in forested and wetland environments. This plan will form a section in the Ecological and Landscape Management Plan (ELMP) and will need to be well integrated with all other restoration activities proposed for the Project. The pest aspects of the ELMP will contain information about appropriate residual trap catch (RTC) targets to achieve the desired biodiversity outcomes; grid line and trap and bait station spacings; the timing of bait applications, trap set and hunting effort; monitoring requirements to determine if the target outcomes are being achieved; and the skill requirements of the personnel employed to undertake this work.

Pre-construction monitoring of pest densities in the proposed Pest Management Area will be necessary to help develop the details of the Pest Management Plan and to serve as a baseline against which the successfulness of the campaign can be measured.

4.4.3 Pest management area

Ideally, the area(s) chosen for pest management should occur in reasonably close proximity to the Project footprint, have vegetation types and habitat of a similar nature to that being lost, and be on land that does not currently receive pest management of the nature and intensity proposed. To meet these requirements the core pest management area needs to include the 22ha of mature standing swamp forest that exists close to the Project footprint on the southwestern tip of the Ngāti Tama Eastern Forest Block and on DOC land in the upper Mimi Stream valley (Figure 4.4) in order to offset the loss of WF8 ecosystem type swamp forest.

Sites suitable for pest management exist on Ngāti Tama land (Ngāti Tama Eastern Forest Block), DOC land (the Mt Messenger Conservation Area) and adjacent private land (multiple properties) but at this stage the formal approval of the landowners has not been obtained.

Ngāti Tama own 255ha of largely forested land to the east of SH3 (through which the Project footprint will pass) which currently receives no intensive pest management (Figure 4.1). The ecology of this area is noticeably in poorer condition than the Ngāti Tama area to the west of SH3 that is being managed for pests and would, therefore, benefit substantially from long-term intensive pest management. This 255ha block is proposed as the preferred Core Pest Management area (should the Ngāti Tama owners be supportive of this) along with the 16ha of standing swamp forest area on DOC land in the upper Mimi valley (Figure 4.1 (area 2)).

A second option for the Core Pest Management Area is the DOC land to the southeast of the Ngāti Tama block (Figure 4.1 (area 6 and area 2)). This block contains forest of a similar nature to that along the Project footprint and is large enough to provide all but 6ha of the 222ha core area required. The addition of the adjacent 6ha Ngāti Tama block of standing swamp forest would fully meet the 222ha Core Pest Management Area requirement. The surrounding DOC administered forest could also provide much of the required pest management buffer area. The approval of DOC to use this land would be required.

The Ngāti Tama – DOC land that is proposed as the Core Pest Management Area is largely protected from pest reinvasion from the west because of the intensive pest management being undertaken in the Paraninihi. It is also protected from pest reinvasion to a reasonable extent from the east because of the open farmland that forms the Mangaongaonga valley. However, a pest management buffer is required to the south where largely unmanaged forested habitat adjoins the proposed Core Pest Management Area, and to a lesser extent from the adjoining bush areas to the north.

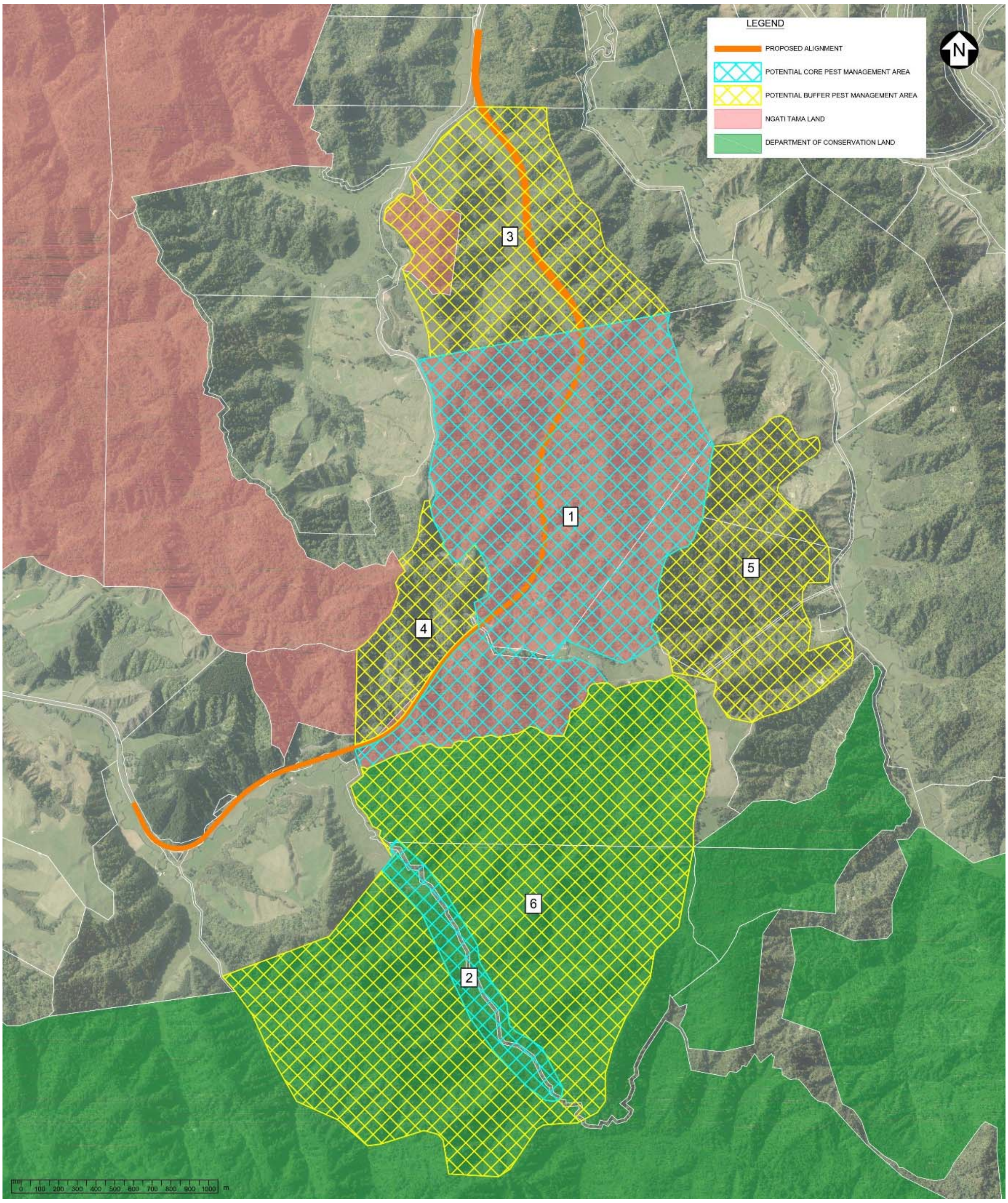

Figure 4.1– Preferred Core Pest Management areas (blue cross hatched) and potential buffer pest management areas (yellow cross hatched). 1 = Ngāti Tama Eastern Forest Block proposed as the Core Pest Management Area; 2 = Mimi swamp forest required as additional Core Pest Management Area in addition to the Ngāti Tama Eastern Forest Block. 3, 4, 5 and 6 = possible buffer pest management areas if Ngāti Tama and area 2 are selected as the core pest management areas. Note that the approval of all landowners has yet to be sought.

A buffer pest management area of 340ha is proposed that will provide a buffer depth of about 1km to the south and 1km to the north of the Core Pest Management Area (Figure 4.1). This buffer area, if managed to the same intensity as the core area, is expected to be sufficient to reduce to low levels the number of pests that reach the core management area. The buffer area will also need to be located to protect the more pest-sensitive vegetation communities, especially the 22ha swamp forest area at the head of the Mimi on DOC land and Ngāti Tama land (Figure 4.4).

It is proposed that this programme of pest management will be continued in perpetuity (or until such time as pest management in the form we know of it today is no longer necessary to sustain the levels of biodiversity created), delivering beneficial outcomes from its implementation and into the future.

4.4.4 Likely outcomes from intensive long-term pest management

Intensive, effective and enduring pest management, with a focus on all animal pests down to the size of rats, can be expected to generate biodiversity benefits across a wide range of plants and animals. Bats (long-tailed and short-tailed, assuming the latter exist in this area), kiwi, many forest birds species, most wetland bird species, reptiles and many invertebrate species will increase in number as predatory pressures are greatly reduced and habitat recovery increases local carrying capacities. Plant biomass and diversity will increase as grazing and browsing pressure is reduced, the diversity and abundance of more palatable species will increase as seedling survival improves, and the health of old emergent forest giants especially rata and totara will improve as their foliage rebounds in the absence of possums in particular.

As forest and vegetation health improves in the low-pest environment, the carrying capacity within the pest management area for many indigenous animal species will increase substantially. When the carrying capacity of each species is met, “surplus” juveniles of mobile species (birds and bats) will move out into the wider Project area and increase populations in those areas. This is sometimes referred to as the “halo effect”. Because the pest management is proposed in perpetuity (or until such time as pest management in the form we know of it today is no longer necessary to sustain the levels of biodiversity created) the ecological benefits throughout the region should be permanent.

The western Ngāti Tama block (Parininihi) has been intensively managed for pests for 15 years now and the evidence of the value of an intensive pest management approach is visually very apparent, with the canopies of “old man” rata and totara in good condition and the diversity and volume of forest regeneration far greater than in the unmanaged Ngāti Tama Eastern Forest block.

4.5 Proposed kahikatea and swamp forest creation

4.5.1 Restoration planting area calculation

The Vegetation Technical Report states that 2.324ha of swamp forest / wetland habitat that is predominantly of indigenous composition will be lost. This is made up of 1.231ha of kahikatea and kahikatea-swamp maire forest, 0.721ha of pukatea-treefern forest, and

0.372ha of manuka scrub (Figure 4.1). Intensive, multi-species pest management will offset all of the pukatea-treefern forest and manuka scrub lost, and partially offset the kahikatea and kahikatea-swamp maire forest lost.

Six hectares of swamp forest restoration planting is proposed to fully offset the loss of the kahikatea and swamp maire forest affected by the Project. Restoration planting, in addition to pest management, is proposed because there is only a small amount of this vegetation type (especially swamp maire) remaining in the wider Project area the result of land clearance and drainage and the impact of pests. Increasing the area of this forest type by planting, and with the support of pest management in perpetuity, will improve the likelihood of swamp forest species expanding naturally back into suitable habitat in the wider Project area.

4.5.2 Potential swamp forest restoration planting locations

There are several suitable potential sites for the establishment of new kahikatea and swamp maire forest. Most of the potential sites are also preferred locations for stream and riparian restoration (see section below) and so the areas given below as available for swamp forest restoration are after deduction of the area required for stream restoration.

Between 2 and 6ha of suitable swamp forest restoration areas exist along the Mangapepeke Stream valley on Ngāti Tama land and on the Pascoe property. Determination of exactly how much area along the valley is suitable for planting will require a thorough ground survey.

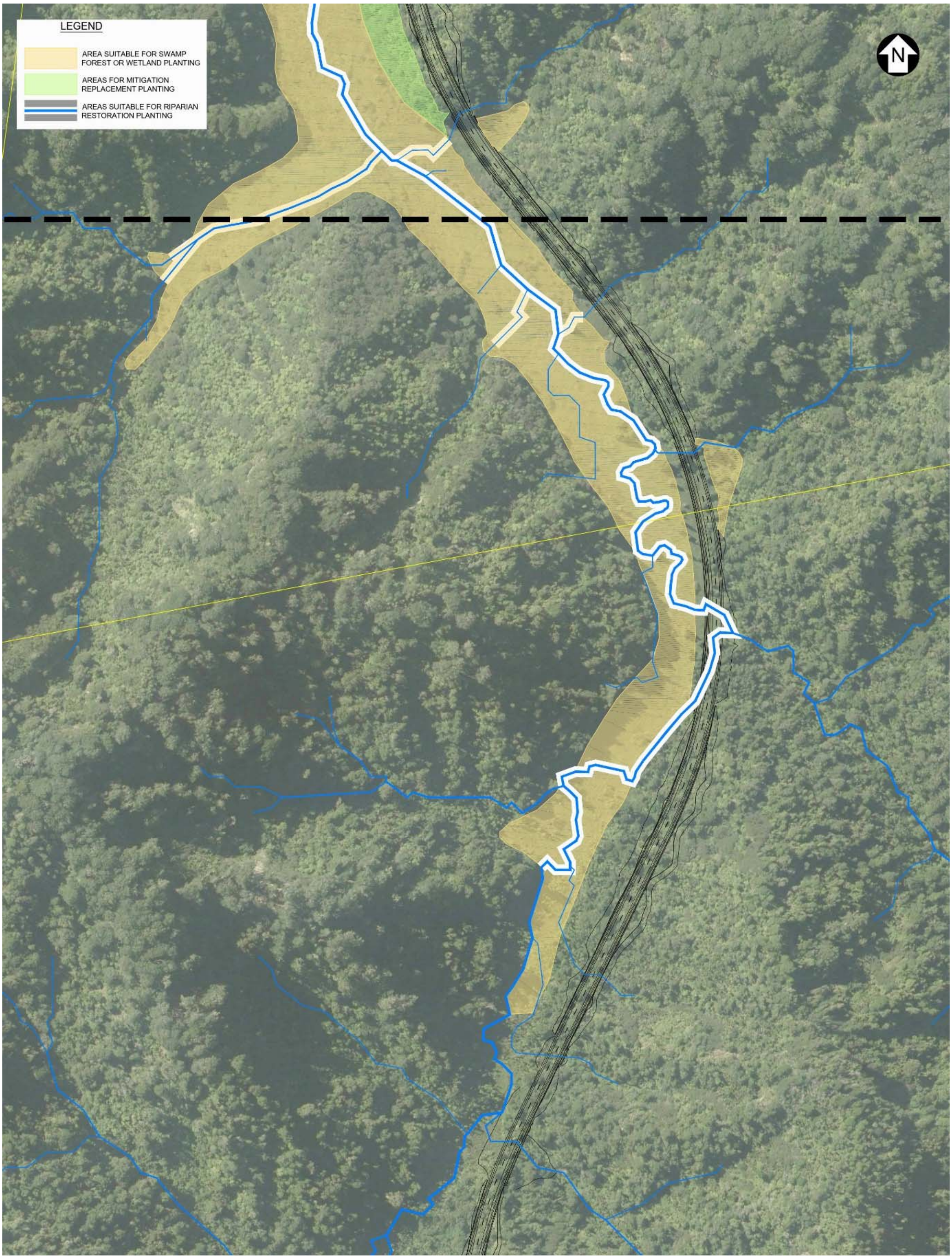

Figure 4.2 – Upper section of the eastern branch of the Mangapepeke Stream showing areas likely to be suitable for swamp forest or wetland planting (beige colour), or mitigation replacement planting (green). Sections of the stream and its tributaries that are suitable for riparian restoration are marked in white. Figures 4 and 5 join at the black dotted line.

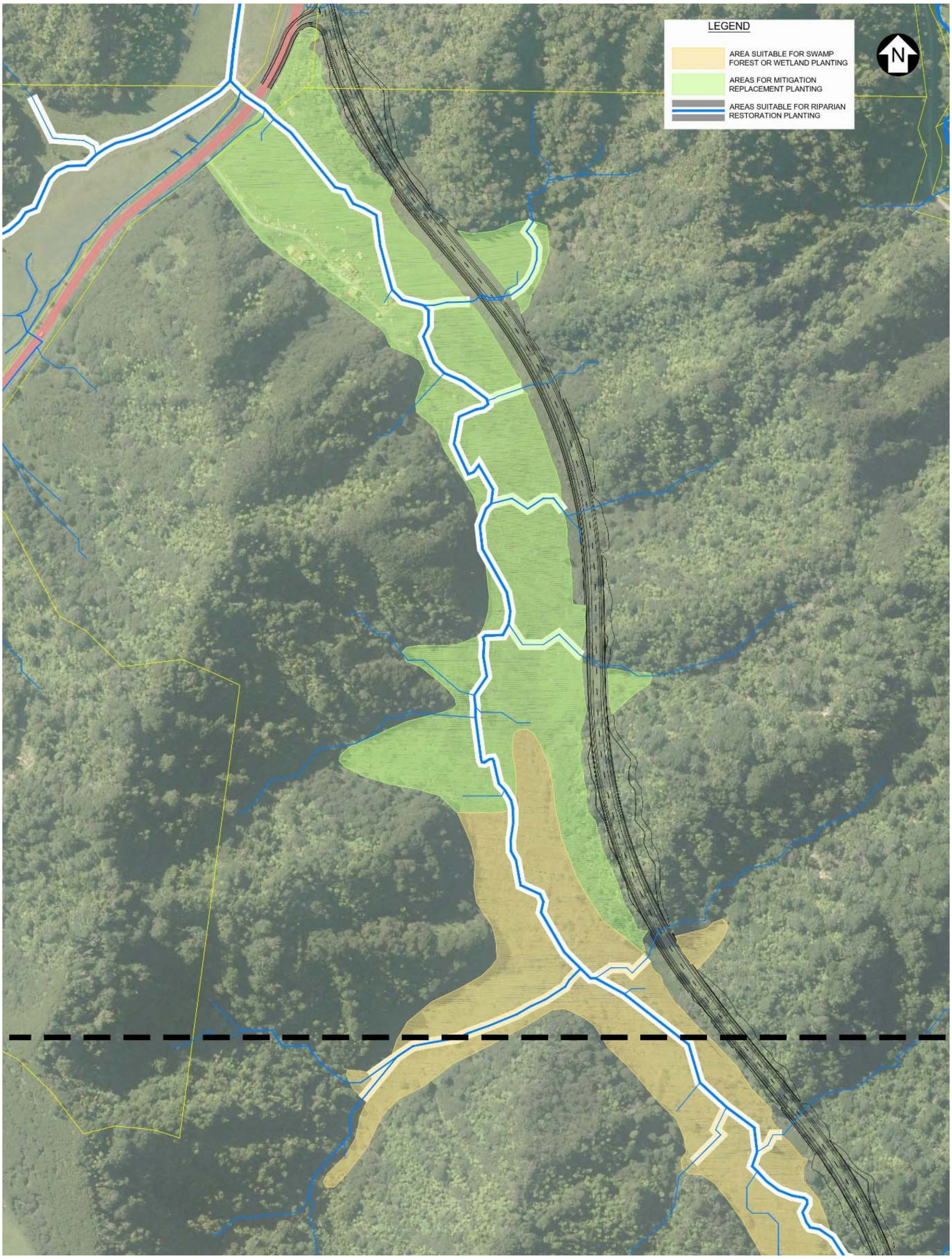

Figure 4.3 – Lower section of the eastern branch of the Mangapepeke Stream showing areas likely to be suitable for swamp forest or wetland planting (beige colour), or mitigation replacement planting (green). Sections of the stream and its tributaries that are suitable for riparian restoration are marked in white.

Areas that remain permanently covered in surface water are not suitable for the establishment of nursery-raised seedlings so the sites suitable for swamp forest establishment will be confined to those areas that stay above water for at least part of the year.

The Mangapepeke valley is considered to be the best location for swamp forest establishment (Figure 4.2 and Figure 4.3) because the integration of the swamp forest and riparian plantings to fully vegetate the valley floor will improve habitat connectedness in a significant way, generating a substantial additional net biodiversity benefit. It is also the area closest to the vegetation removed by the Project so delivers on the best practice principle of proximity. However, if the required 6ha cannot be found in the valley, 2.3ha of suitable swamp forest habitat exists on DOC land at the head of the Mimi Stream (Figure 4.4).

Livestock exclusion by the construction of fencing, and pest management will be required in these areas to support the restoration planting efforts and the recovery of the remnant swamp forest trees.

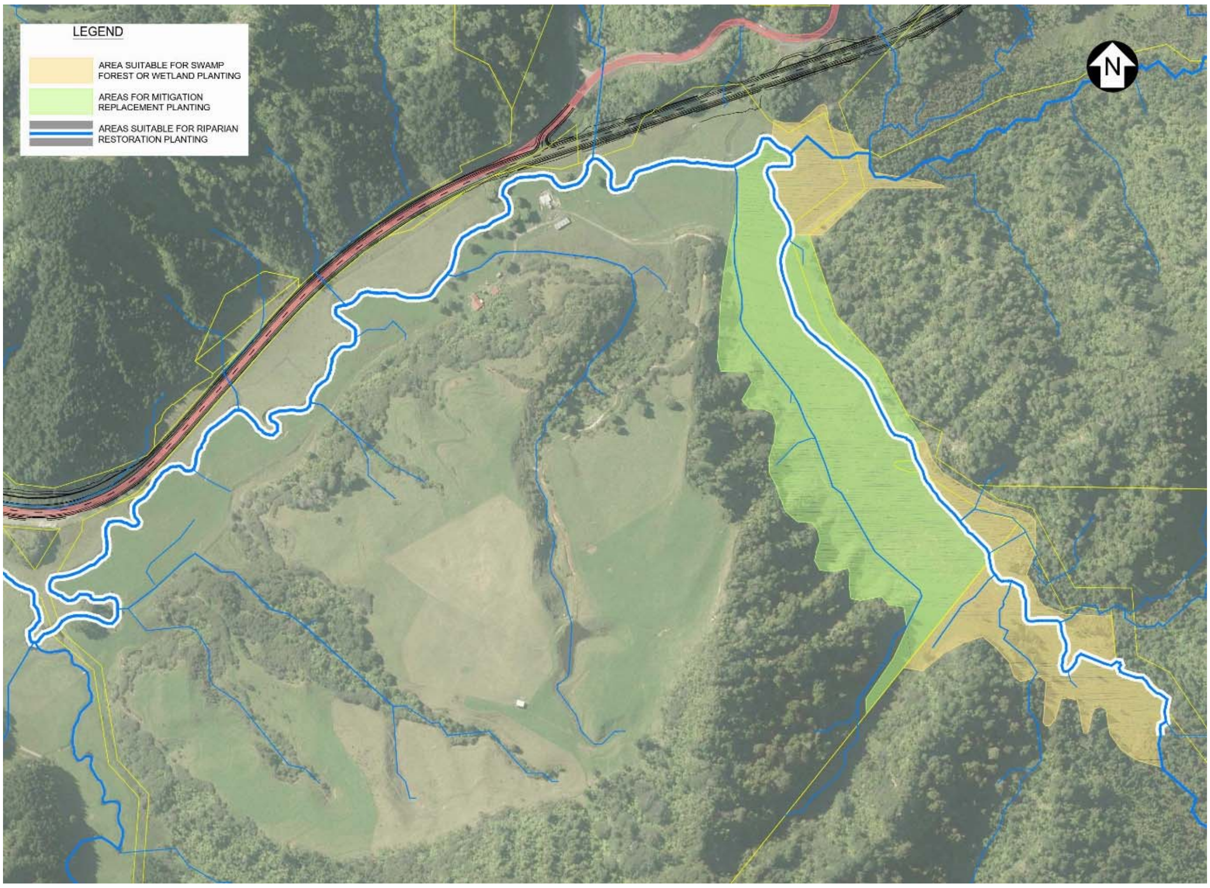

Figure 4.4 – Upper tributary and main branch of the Mimi Stream showing areas likely to be suitable for swamp forest or wetland planting (beige colour), or mitigation replacement planting (green). Sections of the stream and its tributaries that are suitable for riparian restoration are marked in white.

4.5.3 Nature of the swamp forest restoration and likely outcomes

The intention of the restoration planting will be to transform those grass-, rush- and sedge-dominated areas that are suitable for planting into swamp forest into stands of kahikatea, pukatea and swamp maire, with small areas of rimu and matai where ground conditions are not as saturated. Because of the challenging growing conditions for nursery-raised seedling establishment, initial planting will need to consist of hardy, early successional swamp species including manuka, hukihuki, ramarama, houhere, putaputaweta, kaikomako, wineberry, koromiko, karamu, toetoe and wharariki. The tree species can be inter-planted once the initial shrub - small tree layer is well-established.

While transition to a diverse mature swamp forest will take many decades, the ecological value will begin to improve immediately because of the removal of livestock and the management of pests. Ultimately the valley will transform into a diverse, high value swamp/wetland ecosystem.

4.5.4 Restoration Management Plan

The design and management of the swamp forest restoration will need to be undertaken by a qualified restoration ecologist who also has considerable practical experience in the successful establishment of new habitat in challenging natural conditions. A detailed Restoration Management Plan will need to be produced for the swamp forest and wetland planting areas as well as the other areas of biodiversity mitigation planting. The Restoration Management Plan, which will be a section within the Ecological and Landscape Management Plan, should include details of the following:

- Local sources of seed from which the swamp forest and wetland seedlings will be propagated.
- Collection and seed processing methods to maximise germination.
- Selection of an appropriate native plant nursery(ies) to produce the plants.
- Mapping of the planting areas, including those specified for swamp forest and wetlands, for their growing conditions and selection of appropriate plant species for each planting zone.
- Production of a weed and pest management strategy including site preparation work (which may require some work with an excavator).
- Fencing plan to exclude farm livestock.
- Development of a site preparation, planting and post-planting maintenance programme to fit with the road construction schedule.
- Selection and management of a planting crew experienced in natural site restoration work.
- Restoration site monitoring programme to verify establishment success.

4.6 Proposed plantings to replace significant trees

It is proposed that 200 seedlings of the same species should be planted for every significant tree that has to be felled along the Project footprint. The Vegetation Technical Report states that 15 significant trees may have to be removed during road construction. While efforts will be made to reduce the number of these trees that do have to be removed, if all 15 are lost then 3000 seedlings will be planted in their place.

Care will need to be taken to plant the seedlings in locations that provide growing conditions suitable for each species and where the likelihood of survival is high. There are only limited areas available along the Project footprint that are suitable for planting species such as rimu. The deforested tributary valleys of the Mangapepeke, especially along the forest edges, offer the best planting sites for these seedlings.

It is recommended that the details of where and when these seedlings will be planted (as well as the eco-sourcing and propagation details) should be included in the Restoration Management Plan.

4.7 Proposed mitigation replacement planting

Nine hectares of predominantly indigenous vegetation that will be removed or disturbed by the Project will not be offset by pest management or swamp forest restoration planting. This vegetation consists of early successional plant material including manuka-treefern scrub, manuka scrub and manuka succession vegetation, plus 1.37ha of rushland-sedgeland vegetation (Table 4.1).

The loss of this vegetation will be mitigated for by one-for-one replacement planting of the same or similar indigenous species. The priority areas for mitigation planting will be those disturbed AWA sites where the original soil cover and hydrology is retained or can be restored and it is appropriate to re-establish the original vegetation type to that site. Because it is likely that there will be less than 9ha of these "recoverable" sites available for planting, the remaining mitigation planting, with the exception of 1.37ha of rushland-sedgeland planting, will be undertaken on less water-logged areas of pasture and low grade rushland. Suitable sites, mostly on privately-owned land, exist in the middle and lower sections of the Mangapepeke Stream valley (Figure 4.2 and Figure 4.3) and the sections of the upper Mimi Stream adjacent to DOC and Ngāti Tama land (Figure 4.4). Landowner permission to undertake this planting has not yet been sought.

Sites suitable for the establishment of 1.37ha of rush and sedge wetlands exist on the downstream sections of the Mangapepeke Stream on Ngāti Tama land. These areas are wet all or most of the year but have been significantly damaged by decades of grazing cattle.

A qualified restoration ecologist will determine, following road construction, which areas are in suitable condition to be re-established in their original vegetation. Details of the site preparation, species planting mixes, planting methods and post-planting maintenance will be included in a specific section in the Restoration Management Plan.

4.8 Proposed stream restoration

4.8.1 Stream restoration area calculation

The waterways that will be affected by the Project have been assessed in the Freshwater Ecology Technical Report using the Stream Ecological Valuation (SEV) calculator. The

Freshwater Ecology Technical Report assessed that 3242 square metres of stream surface area of variable ecological value will be adversely affected by the construction and operation of the Project, and the SEV model has calculated that restoration of 8724 square metres of stream will be necessary to compensate for those impacts (Table 3.2). This equates to approximately 8932 lineal metres of stream length (generally the streams affected have an average width of approximately 1 metre).

4.8.2 Potential stream restoration planting locations

As is the case for all biodiversity offsetting, it is best practice to undertake stream restoration efforts close to the affected area and in similar environmental conditions. Suitable stream restoration sites exist in the areas adjacent to and near the Project but all lie on private land and will require landowner approval to be used.

The following areas, in descending order of preference, are considered suitable sites for stream-riparian restoration:

- 2.6km length of the Mangapepeke Stream that passes through pasture and sedge-rushland on Ngāti Tama land (1km) (Figure 4.2) and the Pascoe property (1.6km) (Figure 4.2 and Figure 4.3);
- Up to 0.8km of tributary streams that flow into the Mangapepeke Stream, mostly on the Pascoe property, that are currently in pasture or sedges/rushes.
- Approximately 1.0km of the eastern branch of the Mimi Stream on DOC land and on the Thomson property down to where the branch meets SH3 (Figure 4.4).
- Up to 3.5km of the Mimi Stream, through multiple properties, where it flows south parallel to SH3 (Figure 4.4).
- Up to 2.1km of main channel along the western branch of the Mangapepeke Stream on the Washer and Pascoe properties, an additional 1.4km along the western secondary channel (assuming it is practical to fence and plant both this and the main channel), and a further 2.7km of tributaries flowing into both channels from the bush (Figure 4.5).
- Up to 11km along the Mangaongaonga Stream in the catchment to the east of the Mangapepeke (multiple landowners).

Alternative opportunities for stream restoration exist to the north (Tongaporutu River and tributaries) and south (Mimi River and tributaries) of the Project site if required.

All riparian restoration areas used will require the Transport Agency to acquire the necessary rights to implement the restoration programme.

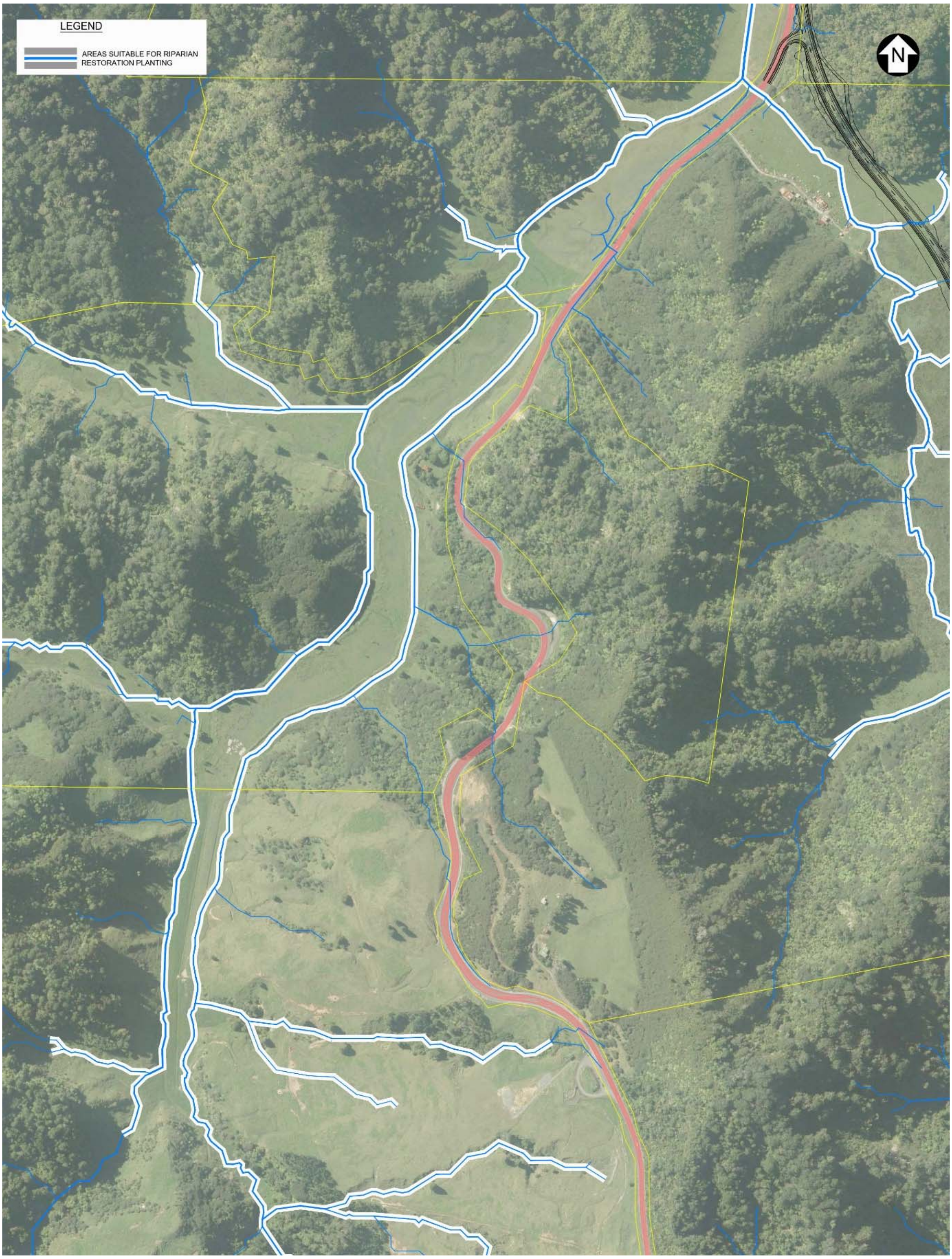

Figure 4.5 – Upper reaches of the western branch of the Mangapepeke Stream showing sections potentially suitable for riparian restoration (marked in white).

4.8.3 Nature of the stream restoration and likely outcomes

Stream restoration work will consist mostly of planting of a 10m buffer on each side of the channel and fencing of the stream and buffer plantings from livestock. None of the streams under consideration are currently fenced.

Stream buffer plantings will consist of a mix of indigenous riparian margin sedges, shrubs and trees. The primary objective will be to provide shade and organic matter to the stream channel to improve the quality of habitat for native fish and invertebrates. A reduction of sediment and nutrient loads entering the streams will also be achieved by fencing and planting, especially along the stream sections that pass unfenced through farmland.

Where the swamp forest restoration planting and stream restoration planting areas can coincide along the Mangapepeke Stream valley (through Ngāti Tama and Pascoe land) and the eastern branch of the Mimi Stream valley (through Thomson land and immediately adjacent to DOC administered land) the net ecological benefit will be substantial and considerably greater than if the swamp forest and riparian forest restoration plantings were undertaken in fragmented fashion. The result will be the conversion of these valleys back to fully forested connected swamp and riparian forest and the elimination of forest edge.

4.8.4 Stream restoration section in the Restoration Management Plan

The proposed stream restoration works will be designed and managed by a suitably qualified and experienced restoration ecologist who also has considerable practical experience in restoring waterways in challenging natural conditions.

The details of site preparation, plant procurement, planting and post-planting maintenance requirements will be incorporated in a specific stream restoration section of the Restoration Management Plan. Details of how the riparian planting will be merged into the swamp and terrestrial planting areas will also be included.

4.9 Roadside rehabilitation

After the completion of road construction the disturbed land area not covered by road surface and not mitigated by replacement planting will consist of:

a Steep cut faces

b Constructed fill slopes

c Newly constructed stream channels (stream diversions).

All fill areas and road margins and construction zones that cannot be returned reasonably quickly to the vegetation types present before construction will be revegetated with appropriate early successional plant species. This treatment also applies to the stream diversions that will be constructed on new fill sites. The loss of the original vegetation will be offset by pest management and the restoration of swamp forest areas as described in sections above.

The design of the site rehabilitation areas should be undertaken by qualified landscape architects and restoration ecologists working together. The details of work to be done, treatment methods to be used and post-treatment maintenance requirements will be included in the Restoration Management Plan for the Project.

4.9.1 Revegetation techniques

A variety of restoration and revegetation techniques are proposed to accelerate successional processes on newly created cut and fill surfaces. These will be detailed in the Restoration Management Plan and are summarised below.

4.9.1.1 Cut faces

It will not be practical to plant seedlings into the steep cut faces that will be formed along parts of the new road. The mudstone substrate is not suitable for the establishment of nursery-raised seedlings and the steep nature of the faces would make the exercise of planting a challenging one. To facilitate natural regeneration of cliff face vegetation – as has established on the faces above the existing road at Mt Messenger – a selection of revegetation techniques will be considered. These techniques include the planting of species that can inhabit steep faces along the upper edge of the face to serve as a supply of seed to the cut face surface. *Olearia* spp, tutu and manuka are examples of species that could be used in this way. Constructability and safety issues may constrain the techniques that can be used and such constraints will be set out in the Ecological and Landscape Management Plan.

4.9.1.2 Fill areas

The mudstone substrate that predominates in the wider Project area does not serve as a suitable substrate for the establishment of nursery-raised seedlings when used as fill for the construction of a road platform. When left to nature, these surfaces will gradually weather and accumulate soil and organic material and over time create conditions for native plants to establish. This process can be accelerated by applying the soil, duff, and woody debris collected when the surface for the new road is cleared back on to the fill surface. This material provides a suitable growing substrate for several colonising and early successional species.

Other techniques that will enhance fill site revegetation include:

- The placement of manuka slash (with seed-filled capsules attached) over the ground surface. This well-proven technique provides a constant trickle of seed and creates weather-protected, moisture retaining microhabitat that will enhance seedling germination and survival. The manuka slash can be tied down on steeper slopes to keep it from moving down the slope. This technique is only recommended for use in areas where manuka needs to be cleared to construct the road.
- Transplantation of tree fern trunks. Freshly cut tree fern trunks can be laid or anchored horizontally across damp slopes or on stream banks, notched with an axe to expose the "green" inner trunk tissue, from which new tree fern shoots will emerge.

The retrieval, stockpile and re-use of topsoil and organic material will be practised wherever possible. The other revegetation practices proposed above, plus others used on similar sites successfully, will be used as and where practicable; their use will often depend on the availability and proximity of suitable material.

The fill areas that will be created in constructing the road also offer opportunities for the creation of lizard and invertebrate habitat. Further ideas for the treatment and rehabilitation of the fill areas can be found in the Landscape, Natural Character and Visual Assessment report (Technical Report 8a, Volume 3 of the AEE).

4.10 Mitigation and offset monitoring

Periodic monitoring of animal pest densities throughout the pest management area is proposed as the primary measure of the effectiveness of the offset and mitigation programme. This monitoring will serve to verify that the contractors undertaking the pest management work are achieving the pre-set residual densities for all target pests, and in this regard will serve as a performance evaluation for the pest management contractors. Pest density monitoring is proposed to occur prior to construction (to set a baseline level and aid the development of an effective pest management plan), and then in each of the first three years following commencement of the pest management programme. The frequency of monitoring after three years will depend on whether target pest densities have been achieved. Once target densities are achieved, monitoring at three- to five-year intervals is likely to be sufficient.

Achievement and retention of pest densities at or below target densities is considered to be an appropriate surrogate measure of ecological recovery. This is because there is a substantial library of peer-reviewed, New Zealand based research to show that when pest densities are reduced below prescribed levels, many indigenous plant and animal populations will recover by way of improved survival and recruitment (birds, bats, herpetofauna, invertebrates and palatable plant species), or will show visible signs of improvement in health (forest tree canopy, diversity and abundance of vegetation regeneration), or both.

Three additional areas of post-construction monitoring are proposed to serve to verify that the expected ecological recovery is occurring. Avifauna, palatable plant species regeneration and forest canopy health monitoring are proposed to confirm that the expected biodiversity gains are being achieved. It is proposed that monitoring of all three measures of habitat recovery occur at 1, 2, 5, and 10 years post-construction, with an optional additional assessment at 20 years if any of the three indices are other than expected by 10 years. Pre-construction assessment of all three measures will need to occur to set the baseline for comparison.

Bat, herpetofauna and invertebrate post-construction monitoring is not proposed. This is because of the inherent difficulties associated with obtaining and interpreting meaningful ‘before’ and ‘after’ comparative data on population densities for these taxa in forest environments; and because benefits to bats, herpetofauna and invertebrates can be expected to result from a reduction in predators.

4.11 Stakeholder and cultural engagement

Early dialogue with Ngāti Tama representatives and DOC staff has enabled a constructive and informed approach to the development of the mitigation and offset package presented in this report.

4.12 Alignment with biodiversity offset principles

The biodiversity mitigation and offset package detailed in the sections above meets all of the guiding principles of biodiversity offset:

- **Adherence to the mitigation hierarchy**: Significant ecological improvements have occurred as a result of an early focus on avoidance and minimisation of ecological effects by changes to the road design and footprint. 'On-footprint' mitigation has occurred where ecologically appropriate, and offsetting has been considered when mitigation options were exhausted.
- **Limits to what can be offset.** We are fortunate with the Project site, and as a result of the efforts of the full Project team, that all anticipated residual adverse ecological effects should be able to be mitigated or offset.
- **Landscape context.** The mitigation and offset package adds considerable additional ecological benefit by better linking important indigenous habitat across the wider Project area, and will in time lead to increased dispersal of mobile native animals out into surrounding areas.
- **No net loss.** It is expected that there will be a net gain in biodiversity within 10 to 15 years of completion of construction.
- **Additional conservation outcomes.** The offset package of multi-species pest management and swamp forest restoration are additional inputs that are not currently occurring on the preferred offset sites.
- **Stakeholder participation.** Stakeholder participation and support in developing the package has been important and their continued involvement will be essential if successful ecological outcomes are to occur.
- **Equity.** The ecological outcomes that will result will have positive effects across the wider Project area and will be of benefit to the wider North Taranaki community.
- **Long-term outcomes.** Multi-species pest management in perpetuity (or until such time as pest management in the form we know of it today is no longer necessary to sustain the levels of biodiversity created) will ensure the ecological benefits continue indefinitely.
- **Transparency.** The RMA process is a very public one and opportunities for public critique of the package will be available.
- **Science and traditional knowledge.** While the development of the mitigation and offset package has relied heavily on "western science", iwi have had involvement in all steps along the way. It is intended that iwi will contribute in a significant way to the formation of the detail within the restoration management plan.
- **Ecological equivalence.** The package developed has managed to achieve the requirement of replacing like-with-like in an ecological context.
- **Ecological proximity.** All of the offset actions will be undertaken in close proximity to the Project site.
- **Connectedness.** The end result of the offset actions will be substantially improved habitat connectedness across the wider Project area.

- **High likelihood of success.** Development of the offset package has focused very much on using practices that have a high likelihood of succeeding, based on previous relevant New Zealand experience and peer-reviewed science.

4.13 Summary of the proposed mitigation and offset package

The mitigation package proposed to compensate for the ecological effects of the Project will consist of:

- Pest management over a core area of no less than 222ha with a buffer area of an additional 340ha (totalling over 560ha). Pest management will focus on controlling rats, possums, mustelids, feral cats, feral pigs and goats at very low densities in perpetuity (or until such time as pest management in the form we know of it today is no longer necessary to sustain the levels of biodiversity created), and will exclude all farm livestock.
- Restoration planting of 6ha of swamp forest.
- Planting of 200 seedlings of the same species for every significant tree that has to be felled.
- Riparian planting and exclusion from livestock of approximately 8.9km of existing stream. Planted riparian margins of 10m each side of the channel will be created. Where these 10m margins are immediately adjacent to terrestrial planting areas, each planting area will be designed with reference to the other in order to create a 'seamless' sequence from wetland to riparian to dryland vegetation.
- Restoration planting of all secondary scrub areas along the footprint, plus of temporary access tracks and storage areas where these retain soil, hydrology and growing conditions suitable for reinstatement (9ha).
- Rehabilitation of all fill areas with early successional species, and stream diversion channels with riparian species.
- Enhancement of steep cut faces to promote natural regeneration.

Once implemented the proposed offset and mitigation package has a high likelihood of achieving a net gain of biodiversity, compared to the present state, between 10 and 15 years following the completion of construction. Because the plan includes pest management in perpetuity (or until such time as pest management in the form we know of it today is no longer necessary to sustain the levels of biodiversity created) the biodiversity gains will increase indefinitely with every year after that, as habitat quality improves, fauna carrying capacities increase, and surplus juvenile animals disperse into the wider Project area. The Biodiversity Offset Accounting Model predicts that the Net Present Biodiversity Value (NPBV) when measured at Year 35 will be 1.62, 29.46 and 1.42 for the WF8, WF13 and WF14 forest vegetation communities respectively; a substantial net biodiversity gain as a result of the offset programme.

5 Conclusions

The ecological values present in the Project footprint and adjacent forested and wetland areas are high although considerably diminished from their full potential because of the long term and largely unchecked impact of farm livestock and animal pests.

The Project will result in the removal or modification of 34ha of predominantly indigenous vegetation and habitat and 3.5km of freshwater habitat. This, combined with the diverse and high value nature of the ecology, means that the potential ecological effects generated by the construction, operation and maintenance of the new road will also be high.

The proposed biodiversity offset – mitigation package comprises pest management in perpetuity (or until such time as pest management in the form we know of it today is no longer necessary to sustain the levels of biodiversity created) over approximately 560ha, restoration planting of 6ha of swamp forest, 9ha of mitigation replacement planting, restoration of 8.9km of riparian margin and revegetation of as much of the construction footprint that will not be road as is practicable. The package has a high likelihood of substantially reversing the diminished state of the ecology and achieving a net gain in biodiversity within 10 to 15 years following construction.

Many aspects of the indigenous flora and fauna present in the area will benefit from the management of pest animals to permanently low densities and the establishment of substantial new areas of swamp forest, shrubland and riparian habitat. The proposed mitigation will not only increase the area of healthy indigenous vegetation but will greatly improve the connectedness of the forested areas. The net result will be a significant increase in healthy available habitat, enhanced recruitment rates amongst a wide range of indigenous animals, improved condition of the remaining significant forest trees, especially totara and rata, and increased regeneration of many of the more palatable plant species.

Over time further ecological benefits will accrue as a result of the offset programme. The conditions created in the offset area will increase the likelihood of the survival and successful nesting of those kōkako that choose to move east from the release sites in the western Ngāti Tama block. Other species, especially more mobile long-tailed bats and forest birds, will begin to move into adjacent forest areas as carrying capacity limits are met.

Overall it is considered that the proposed mitigation and offset package set out in this report will appropriately address all of the residual ecological effects of the Project and over time create ecological effects that are beneficial and positive.

6 References

Auckland Regional Council. 2007. Auckland Regional Pest Management Strategy 2007-2012.

Baker, C. 2006. Predation of inanga (Galaxias maculatus) eggs by field mice (Mus musculus). Journal of the Royal Society of New Zealand 36: 4, 143-147.

Basse, B., McLennan, J. and Wake, G. 1999. Analysis of the impact of stoats, Mustela erminea, on northern brown kiwi, Apteryx mantelli, in New Zealand. Wildlife Research 26(2): 227-237.

Brown, K., Elliott, G, Innes, J. Kemp, J. 2015. Ship rat, stoat and possum control on mainland New Zealand: an overview of techniques, successes and challenges. Department of Conservation, Wellington. 36 p.

Brown, M., Clarkson, B., Barton, B. and Joshi, C. 2013. Ecological compensation: an evaluation of regulatory compliance in New Zealand, Impact Assessment and Project Appraisal. 1: 1-11.

Business and Biodiversity Offsets Programme (BBOP). 2012. Biodiversity offset design handbook. June 2012.

Business and Biodiversity Offsets Programe (BBOP). 2012. Resource paper: No net loss and loss-gain calculations in biodiversity offsets. March 2012.

Byrom AE, Innes J, Binny RN. 2016. A review of biodiversity outcomes from possum-focused pest control in New Zealand. Wildlife Research 43: 228-253.

Christensen, M. and Barker-Galloway, M. 2013. Biodiversity offsets - The latest on the law. October 2013. Anderson Lloyd Lawyers 1: 1-31.

Clout, M. 2006. Keystone aliens? The multiple impacts of brushtail possums. In: Biological Invasions in New Zealand. Ecological Studies Series. Springer Berlin Heidelberg 186.

Clout, M. 2001. Where protection is not enough: active conservation in New Zealand. Trends in Ecology and Evolution 16: 8, 415.

Cowan, P., Chilvers, B., Efford, M. and McElrea, G. 1997. Effects of possum browsing on northern rata, Orongorongo Valley, Wellington, New Zealand. Journal of the Royal Society of New Zealand 27: 2, 173-179.

EIANZ. 2015. Ecological Impact Assessment (EcIA): EIANZ guidelines for use in New Zealand: terrestrial and freshwater ecosystems.

Gillies, C. (Comp.) 2002. Managing rodents in the New Zealand mainland - what options are currently available? Summary of a workshop session at the Department of Conservation 'mainland island' hui, Omapere. 20-23 August 2001. DOC Science Internal Series 47. Department of Conservation, Wellington. 20 p.

Gillies, C., Leach, M., Coad, N., Theobald, S., Campbell, J., Herbert, T., Graham, P. and Pierce, R. 2003. Six years of intensive pest mammal control at Trounson Kauri Park, a Department of Conservation "mainland island", June 1996–July 2002. New Zealand Journal of Zoology 30: 399–420.

Hamill, K. 2017. Mt Messenger Bypass Investigation: Effect on stream values. Prepared for Opus International Consultants by River Lake Ltd.

Harper, G. and Bunbury, N. 2015. Invasive rats on tropical islands: Their population biology and impacts on native species. February 2015. Global Ecology and Conservation 3: 607–627.

Innes, J., King, C., Bartlam, S., Forrester, G. and Howitt, R. 2015. Predator control improves nesting success in Waikato forest fragments. Landcare Research, School of Science 39: 2, 245–253.

Innes, J., Nugent, G., Prime, K., and Spurr, E. 2004. Responses of kukupa (Hemiphaga novaeseelandiae) and other birds to mammal pest control at Motatau, Northland. New Zealand Journal of Ecology 73–81.

Innes, J. and Saunders, A. 2011. Eradicating multiple pests: an overview. In: Veitch, C.R.; Clout, M.N. and Towns, D.R. (eds). 2011. Island invasives: eradication and management. IUCN, Gland, Switzerland.

Innes, J., Warburton, B., Williams, D., Speed, H. and Bradfield P. 1995. Large-scale poisoning of ship rats (*Rattus rattus*) in indigenous forests of the North Island New Zealand. Landcare Research, Department of Conservation 19: 1, 5–17.

King, C. and Scurr, D. 2013. Optimizing the ratio of captures to trapping effort in a black rat *Rattus rattus* control programme New Zealand. Centre for Biodiversity and Ecological Research 10: 95–97.

Leathwick, J., Hay, J. and Fitzgerald, A. 1983. The influence of browsing by introduced mammals on the decline of North Island Kokako. Forest Research Institute, Royal Forest and Bird Protection Society 6: 55–70.

Maseyk, F., Maron, M., Seaton, R. and Dutson, G. 2015. A biodiversity offsets accounting model for New Zealand. March 2015. The Catalyst Group 1–67.

Meads, M. 1976. Effects of opossum browsing on northern rata tress in the Orongorongo Valley, Wellington, New Zealand. New Zealand Journal of Zoology 3: 2, 127–139.

Moorhouse, R., Greene, T., Dilks, P., Powlesland, R., Moran, L., Taylor, G., Fraser, I. 2003. Control of introduced mammalian predators improves kaka Nestor meridionalis breeding success: reversing the decline of a threatened New Zealand parrot. Biological Conservation 110: 1, 33–44.

Murphy, E. and Dowding, J. 1995. Ecology of the stoat in Nothofagus Forest: Home range, habitat use and diet at different stages of the beech mast cycle. Department of Conservation 19: 2, 97–109.

New Zealand Government. Guidance on good practice biodiversity offsetting in New Zealand. August 2014.

Nicholls, J.L. 1976. A revised classification of the North Island indigenous forests. New Zealand Journal of Forestry 28: 105–132.

Neale, M., Storey, R., Rowe, D., Collier, K., Hatton, C., Joy, M., Parkyn, S., Maxted, J., Moore, S., Phillips, N. Quinn, J. 2011. Stream Ecological Valuation (SEV): A User's Guide. Auckland Council Guideline Document 2011/001

Neale, M., Storey, R. and Quinn, J. 2016. Stream Ecological Valuation: application to intermittent streams. Prepared by Golder Associates (NZ) Limited for Auckland Council. Auckland Council technical report TR2016/023.

Norbury, G., Hutcheon, A., Reardon, J., Daigneault, A. (2014). Pest fencing or pest trapping: A bio-economic analysis of cost-effectiveness. Austral Ecology 39:7, 795–807.

O'Donnell, C., Clapperton, B. and Monks, J. 2015. Impacts of introduced mammalian predators on indigenous birds of freshwater wetlands in New Zealand. Department of Conservation 39: 1, 19–33.

O'Donnell, C. and Hoare, J. 2012. Quantifying the benefits of long-term integrated pest control for forest bird populations in a New Zealand temperate rainforest. New Zealand Journal of Ecology 131–140.

O'Donnell, C., Pryde, M., Dam-Bates, P. and Elliot, G. 2017. Controlling invasive predators enhances the long-term survival of endangered New Zealand long-tailed bats (*Chalinolobus tuberculatus*): Implications for conservation of bats on oceanic islands. Department of Conservation 156–167.

O'Donnell, C. 1996. Predators and the decline of New Zealand forest birds: An introduction to the hole-nesting bird and predator programme. New Zealand Journal of Zoology 23: 213-219.

Opus International Consultants Limited. 2017a. Mt Messenger Bypass Investigation – Bat Baseline Survey. April 2017. Unpublished Report prepared for the NZ Transport Agency.

Opus International Consultants Limited. 2017b. Mt Messenger Bypass: Option MC23 – Bat Survey Addendum. Unpublished Memo dated 25 July 2017.

Parkes, J. and Murphy, E. Management of introduced mammals in New Zealand. New Zealand Journal of Zoology 30: 4, 335–359.

Parkes, J., Nugent, G., Forsyth, D., Byrom, A., Pech, R., Warburton, B. and Choquenot, D. 2017. Past, present and two potential futures for managing New Zealand's mammalian pests. Kurahaupo Consulting, Landcare Research, Arthur Rylah Institute for Environmental Research, Institute of Applied Ecology 41: 1, 1–11.

Parkes, J. 1993. Feral goats: Designing solutions for a designer pest. Landcare Research 17: 2, 71–83.

Pryde, M., Dilks, P. and Fraser, I. 2005. The home range of ship rats (*Rattus rattus*) in beech forest in the Eglinton Valley, Fiordland, New Zealand: A pilot study. New Zealand Journal of Zoology 32: 3, 139-142.

Reardon, J., Whitmore, N., Holmes, K., Judd, L., Hutcheon, A., Norbury, G. and Mackenzie, D. 2012. Predator control allows critically endangered lizards to recover on mainland New Zealand. May 2012. Department of Conservation, Landcare Research. 36: 2, 141-150.

Rowe, D., Collier, K., Hatton, C., Joy, M., Maxted, J., Neale, M., Parkyn, S., Phillips, N. and Quinn, J. 2008. Stream Ecological Valuation (SEV): a method for scoring the ecological performance of Auckland streams and for quantifying environmental compensations - 2nd Edition. Prepared by NIWA for Auckland Regional Council.

Scrimgeour, J., Beath, A., Swanney, M. 2012. Cat predation of short-tailed bats (*Mystacina tuberculata rhyocobia*) in Rangataua Forest, Mount Ruapehu, Central North Island, New Zealand.

Singers, N. and Bayler, C. 2017. Mt Messenger Bypass Investigation. Botanical Investigation and Assessment of Effects. Unpublished Contract report of Opus International Consultants Ltd by Nicholas Singers Environmental Solutions.

Smith, D., Murphy, E., Christie, J. and Hill, G. 2009. The effectiveness of poison bait stations at reducing ship rat abundance during an irruption in a Nothofagus forest 36: 1, 13-21.

Speedy, C., Day, T. and Innes, J. 2007. Pest eradication technology - the critical partner to pest exclusion technology: The Maungatautari experience. August 2007. University of Nebraska - Lincoln 115-126.

Timmins, S. 2002. Impact of cattle on conservation land licensed for grazing in South Westland, New Zealand. Science and Research Unit, Department of Conservation 26: 2, 107-120.

Towns, D. 1994. The role of ecological restoration in the conservation of Whitaker's skink (*Cyclodina whitakeri*), a rare New Zealand lizard (Lacertilia: Scincidae). New Zealand Journal of Zoology 21: 457-471.

Waikato Regional Council. 2014. Waikato Regional Pest Management Plan 2014-2024.

Wilson, D., Lee, W., Webster, R. and Allen, R. 2003. Effects of possums and rats on seedling establishment at two forest sites in New Zealand. Landcare Research, Wildland Consultants 27: 2, 47-155

Appendices

Appendix A: Biodiversity Offset Calculation report

Mt Messenger Bypass

Biodiversity Offset Calculation Report

December 2017

Nicholas Singers Ecological Solutions Ltd

NZ TRANSPORT AGENCY
WAKA KOTAHI
Mt Messenger Bypass

New Zealand Government

Quality Assurance Statement			
Prepared by:		Nicholas Singers	NSES Ltd
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Revision schedule		
Rev. Number	**Date**	**Description**
0.	December 2017	Final for lodgement

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Contents

Executive Summary

This report presents an assessment of the biodiversity loss predicted for the NZ Transport Agency's (Transport Agency) Mt Messenger Bypass project (the Project), along with the predicted biodiversity offset required to ultimately achieve no net biodiversity loss.

The Biodiversity Accounting Model (the Model) developed for the Department of Conservation by Maseyk *et al.* (2014) has been used to calculate the biodiversity offset required. More specifically, the Model has been applied to determine what level of offset is required to achieve No Net Loss of biodiversity values within 10 to 15 years.

The Model was developed as part of the New Zealand Government's '*Guidance on Good Practice Biodiversity Offsetting in New Zealand'* (August 2014) and is consistent with international guidelines on biodiversity offsetting. The Model applies a two-step process to calculate the biodiversity offset required:

1 The 'impact model', which determines the area and quality of vegetation to be impacted by the Project; and

2 The 'offset model', which takes the results from the impact model and determines the offsets required, the quality of the proposed offset areas, and then determines the final offset areas and approaches required for the Project, in order to achieve the No Net Loss (or Net Gain) goals.

This report explains the operation of the Model in general terms on a step-by-step basis; and then explains the application of the Model to the Project and offset site to achieve 'like for like', 'No Net Loss', ecosystem connectivity, and be additional to management currently occurring. As explained in the report, the inputs to the Model have been determined on a conservative basis.

The Model has been applied to 25.631 of high-value habitat that will be lost as a result of the Project, in three broad categories: WF8 (Kahikatea, pukatea forest), WF13 (Tawa, kohekohe, rewarewa, hinau, podocarp forest) and WF14 (Kamahi, tawa, podocarp, hard beech forest).

The Model calculated that an area of 200 ha of vegetation is required to offset the loss of vegetation communities of WF13: and WF14: ecosystems, using the integrated pest management approach selected for the Project, within an identified target area in the Mimi catchment. To offset the loss of WF8 habitat 22 ha of integrated pest management will be required; along with a further 6 ha of restoration planting.

Net biodiversity gain (measured as Net Present Biodiversity Value (NPBV)) is forecast by Year 15 for all vegetation communities lost. By year 35, significant biodiversity benefits compared to the current situation are expected as a result of the offsetting programme for the Project. Measured at Year 35, NPBV is forecast at values of 1.62, 29.46 and 1.42 for WF8, WF13 and WF14 respectively.

Glossary

Term	Meaning
AEE	Assessment of Effects on the Environment Report
AWA	Additional Works Area
DOC	Department of Conservation
Eastern Ngāti Tama forest block	The area of land largely owned by Ngāti Tama located east of existing SH3, including the Project footprint, approximately 3,098 ha in size
EcIA guidelines	Ecological Impact Assessment guidelines
EIANZ	Environment Institute of Australia and New Zealand
Model	The Biodiversity Offsets Accounting Model
North Taranaki Ecological District	Part of the Taranaki Ecological Region, encompasses approximately 166,300 ha, including the Project footprint
Parininihi	The area spanning the Waipingao Stream catchment located to the west of existing SH3, approximately 1,332ha in size
Pest Management Area	The area proposed for integrated pest management, as part of the mitigation and offset package.
Project	The Mt Messenger Bypass project
Project footprint	The Project footprint includes the road footprint (i.e. the road and its anticipated batters and cuts, spoil disposal sites, haul roads and stormwater ponds), and includes an Additional Works Area (AWA) and 5 m edge effects parcel.
RMA	Resource Management Act 1991
RTC	Residual trap catch
SH3	State Highway 3
Transport Agency	New Zealand Transport Agency
TRC	Taranaki Regional Council
Wider Project area	An area approximately 4,430 ha in size which encompasses Parininihi and the Ngāti Tama Eastern forest block, and includes the Project footprint.

1 Introduction

1.1 Purpose and scope of this report

This report presents an assessment of the biodiversity loss predicted for the NZ Transport Agency's (Transport Agency) Mt Messenger Bypass project (the Project); along with the predicted biodiversity offset required to ultimately achieve no net biodiversity loss. This report is an attachment to the Ecological Effects Assessment – Ecological Mitigation and Offset report (Technical Report 7h, Volume 3 of the Assessment of Effects on the Environment report (AEE)); referred to in this report as the 'Mitigation and Offset Report'.

The Project comprises a new section of two lane highway, 6km in length, located to the east of the existing SH3 alignment (Figure 1.1). A full description of the Project including its design, construction and operation is provided in the AEE (Volume 1) and accompanying Drawing Set (Volume 2).

Figure 1.1: Location of the Project in the Taranaki Region

The majority of the Project footprint is sited on land that was returned to Ngāti Tama ownership in 2003, referred to as the Ngāti Tama Eastern forest block. In the north and extreme south the remainder of the Project footprint is situated on private land and road reserve.

The Project involves bypassing to the east of the existing SH3 and Mt Messenger. The Project footprint is approximately 6 km long and is approximately 44.41 ha in area and comprises:

- the road footprint (i.e. the road and its anticipated batters and cuts, spoil disposal sites, haul roads and stormwater ponds);
- the Additional Works Area (AWA), accounting for additional habitat loss for construction access, laydown areas and temporary stormwater drains (Figure 3, Appendix A); and
- 5 m edge effects parcel.

1.2 Biodiversity Offsetting

As recorded in the Mitigation and Offset Report, it is not possible to avoid, remedy or mitigate (in the traditional sense) all the effects the Project will have on ecological values. There will be significant residual effects of the Project that need to be addressed through biodiversity offsetting. The process of offsetting seeks to counter-balance the unavoidable impacts of development on biodiversity by enhancing the state of biodiversity elsewhere. The goal of biodiversity offsetting is to achieve No Net Loss or a Net Gain of biodiversity, in comparison to the baseline (Ledec & Johnson 2016).

Biodiversity offsets can include securing or setting aside areas for conservation, enhanced management of habitats or species, and other defined activities. They can be used to:

- create, expand or buffer existing protected areas;
- enhance, link or restore habitats; and
- protect or manage species of conservation interest (either within a designated conservation area or more broadly across the habitat where the species occurs).

Irrespective of the specific focus of the offset activities, measurable conservation outcomes should be achieved (Ledec & Johnson 2016).

Additionality, equivalence and permanence all need to be taken into account in any proposed biodiversity offsets. These are described in further detail below:

- For any offset to be real, it must be additional, therefore biodiversity offsets must deliver conservation gains beyond those that would be achieved by ongoing or planned activities that are not part of the offset. For offsets that intend to strengthen the protection and management of existing protected areas, the question of additionality is particularly relevant. Existing protected areas with low threat levels and adequate funding are unlikely to be suitable for biodiversity offsets as it would be difficult to demonstrate much additionality. However protected areas that are underfunded, lack adequate management, or face significant threats may benefit substantially from the additional support provided by offsets (Ledec & Johnson 2016). The proposed offset sites for the Project fall under the second category.

- Biodiversity offsets should conserve the same biodiversity values (ecosystems, habitats, species or ecological functions) as those lost to the development project, following a principle known as like-for-like (Ledec & Johnson 2016).
- Biodiversity offsets are normally expected to persist for at least as long as the adverse biodiversity impacts from the original project; in practical terms, this often means in perpetuity. Like other conservation projects, biodiversity offsets are ideally designed to last over the very long term. Lasting conservation outcomes will ultimately depend upon the actions of future generations as well as present-day decision-makers. Thus, project proponents often cannot credibly promise that a biodiversity offset will be maintained “forever”, but it should be for at least the operating life of the original project and ideally longer (Ledec & Johnson 2016).
- The precautionary principle should always be applied and projects should err on the side of caution with respect to protecting biodiversity. Applying a precautionary approach requires careful judgement, since the available biodiversity information on any site is always incomplete (Ledec & Johnson 2016).
- In order to confirm that the biodiversity offset has achieved No Net Loss or Net Gain, field-based monitoring is necessary. Outcome monitoring should be feasible, able to obtain relevant information, and avoid undue complexity (Ledec and Johnson, 2016).

A discussion on the principles of biodiversity offsetting is set out in the Mitigation and Offset Report.

2 Approaches to offsetting

2.1 Traditional approach to biodiversity offsetting

Biodiversity offsetting is a relatively new approach to addressing residual ecological effects of projects. Traditionally, biodiversity offsetting has been based on the subjective application of multipliers or ratios. These approaches calculated the areas of ecosystems or habitats to be affected by a project, and ecologists would apply a multiplier based on the habitat or ecosystem type and value of those areas, to determine the biodiversity offset areas. For example, an ecologist may allocate a relatively high multiplier (or ratio) of offset where a project affects an area of significant, representative primary forest with little human or pest degradation.

The problem with such an approach is that it could not be standardised and had the potential to be arbitrarily determined. Due to local and regional variations in vegetation types, it was difficult to develop consistent approaches to offsetting. This was particularly the case in areas of complex ecosystems.

2.2 Development of the Biodiversity Offsets Accounting Model

In response to the difficulties in applying multipliers for biodiversity offsets, there have been considerable developments in offsetting in recent years. This includes a more systematic approach being developed globally, as noted in the World Bank's *Biodiversity offsets: a user guide* (Ledec and Johnson, 2016) (the World Bank Offsets Guide).

The Biodiversity Offsets Accounting Model (Maseyk *et al.* 2014) (the Model) was developed as part of a New Zealand Government-funded project to develop the *Guidance on Good Practice Biodiversity Offsetting in New Zealand* (August 2014) (Offsetting Guidance). The Offsetting Guidance was a collaborative document developed by a number of Government organisations.[1]

The methodology in the Model, driven by the principles in the Offsetting Guidance, is consistent with the World Bank Offsets Guide. The Model also broadly aligns with the approach in the Stream Ecological Valuation method, a freshwater offsetting model which has been used in New Zealand since 2006 (and is being used in respect of stream values for this Project).

The Model is considered to be appropriate for use in calculating biodiversity offsets for the Project, because it is consistent with the New Zealand Government's best practice guidance document.

[1] The Ministry for the Environment, the Department of Conservation, the Ministry for Primary Industries, the Ministry of Business, Innovation and Employment, and Land Information New Zealand.

Therefore, to calculate the biodiversity loss of the Project and the required biodiversity offset, the methodology described in the Model has been applied. This assessment was peer reviewed by Maseyk (2017), the lead author of the Model.

A description of the operation of the Model is set out in the following sections of this report.

2.3 Introduction to the operation of the Model

The Model broadly operates by taking the areas and quality of vegetation communities and habitat to be removed or affected by the Project, and calculating how much biodiversity offsetting is required to account for those effects.

This turns biodiversity into a unit of measure, akin to a currency, and the model determines the offsets required to achieve a No Net Loss or Net Gain outcome in the medium term following the completion of the Project.

The Model uses two steps to calculate offsets:

1. The 'impact model': determining the amount of biodiversity loss, its condition, allocating a benchmark ecosystem area in the North Taranaki Ecological District, and ultimately calculating the biodiversity value (BV) (see Section 2.4 for further detail).
2. The 'offset model': which takes the value of loss, applies a 'discount rate' for the loss, applies the relevant type of offsetting (i.e. pest management and/or restoration planting), and determines the required areas of offsetting to generate a No Net Loss or Net Gain scenario (see Section 2.5 for further detail) and ultimately calculating the net present biodiversity value (NPBV).

The Model operates on a 'like for like' basis (see Section 1.2 above), so the offsets calculated are aimed at achieving No Net Loss (or Net Gain) by exchanging similar areas of habitat.

One key aspect of the application of the Model to this Project is that it accounts for vegetation (or habitat) loss, but losses of specific animal species have not been calculated. This is considered appropriate given the difficulties in determining the full range of and the abundance of animal species in the Project footprint, and because the offset actions (i.e. integrated pest management and restoration planting) will improve habitat values across the offset area, which will benefit animal species.

3 Guide to the application of the Model

This section provides a step by step guide to the operation of the Model.

3.1 Impact model

The first stage in the Model is to apply the 'impact model'. This determines the biodiversity value (BV) of the area of loss (i.e. the area in the Project footprint). This is determined through the following stages.

3.1.1 Calculating loss

The impact model requires the classification and quantification of biodiversity impacted by the Project footprint. There is a three-tiered classification system for biodiversity:

1. Biodiversity types: the high level classification of the vegetation group type in an area within the Project footprint;
2. Biodiversity components: the specific ecosystem units in the various areas of the Project footprint;
3. Biodiversity attributes: the specific vegetation types within these potential ecosystem units.

This report relies on the categorisations set out in the Assessment of Ecological Effects – Vegetation (Technical Report 7a, Volume 3 of the AEE) (Vegetation Report). As explained in the Vegetation Report, this categorisation was based on the spatial mapping from field surveys and drone imagery analysis, as well as Recce plots.

Following this, the Model requires the calculation of areas of each biodiversity attribute to be lost due to the Project. After these areas of loss have been determined, the Model requires an assessment of the ecological integrity of each 'biodiversity attribute', based on the approach taken in Leathwick (2015). The process for this application of the Model, however, differed slightly from Leathwick's, in that a weighting for ecosystem rarity was removed from the model of ecological integrity or representativeness.

The two elements of ecological integrity, current state and habitat condition, are essentially analogous to a value of "representativeness". The formula used to assess ecological integrity is:

- Ecological integrity = Current state * Condition.

These scores have been multiplied by 100 to provide percentage values, which have been used to populate the Model.

3.1.1.1 Current state

This approach allocates a value between 1 (theoretical pristine state) to 0.05 (highly modified vegetation), based on professional judgement. This is based on the degree of human and pest animal modification, such as logging or fire.

3.1.1.2 Habitat condition

A value of between 1 (habitat condition is essentially intact) and 0.05 (highly degraded habitat condition) is also put into the Model. The following formula is used to determine habitat condition: condition = (Canopy condition * Understorey condition * Native dominance).

Habitat condition assessed three structural and compositional ecosystem components:

- canopy condition to assess the impact of possums;
- understorey condition to assess the impact of ungulates here including feral goats, pigs and domestic cattle;
- native dominance to assess the competitive impact of invasive weeds.

Native dominance was scored from 1 – 0.05, and was assessed entirely on the percent cover of invasive weed species, with 1 indicating entirely native dominated vegetation and 0.05 indicating vegetation comprising almost entirely of weed species.

3.1.2 Setting a benchmark for each ecosystem type

The Model requires the condition of ecosystem types to be measured against 'benchmark sites'.

The benchmark provides a mechanism to weight the loss of attributes of different biodiversity value at the Impact Site (i.e. within the Project footprint). This weights attributes of higher biodiversity value greater than attributes of lower biodiversity value. It is important to understand that reaching the same quality as the benchmark sites is not the same as reaching No Net Loss.

3.1.3 Calculate the discount rate

To account for the uncertainties in potential biodiversity gains, and recognising the time lag between the loss (from the Project) and the subsequent gains, a discount rate is applied to the calculation. The notion of applying a discount rate is comparable to adding 'interest' to the calculation to account for this time lag, and is based on principles in social equity (DOC Guidelines, Section 4.5.5). Discount rates are typically between 0 and 4%.

3.1.4 Output from impact model

The impact model assumes that no biodiversity remains within the Project footprint following the Project. As such, the biodiversity calculated is the value of loss, so will be a negative number. This number will then be fed into the offset model, the second stage in the Model, to determine the level of offset required.

3.2 Offset model

The offset model takes the biodiversity attribute of both the Project footprint and the target site(s) (as in, where it is anticipated offsetting would occur) to determine the area of biodiversity offsets required.

3.2.1 Determining appropriate offset actions

Based on the ecosystem types being affected by the Project, the ecologists working on the Project collectively determined, based on professional judgement, the appropriate offset actions required.

As set out in the Mitigation and Offset Report (and discussed in more detail below), two types of offset are proposed for the Project: ecosystem and habitat preservation (more specifically, intensive pest management); and restoration planting (in respect of kahikatea-swamp maire forest specifically).

An assumption of the Model is that the same level of benefits result from each type of offset action.

3.2.2 Offset site selection

Based on the appropriate offset actions to be implemented (and therefore used in the Model), appropriate potential or target sites for offsets need to be selected.

Given the Model operates on a 'like for like' basis, it is important that offset sites are located in relatively close proximity to the area of loss and have similar ecosystem composition and structure.

3.2.3 Determining the ecological integrity of the offset sites and conservation outcomes

To provide a baseline for the offset sites, the ecological integrity of the ecosystem units within these sites has to be determined, as with the process for determining the ecological integrity of the sites presumed to be lost as a result of the project.

This process provides the starting point for assessing conservation outcomes from the offset actions over time; allowing for a determined point in time in which No Net Loss will be reached (that determination also depends on the amount of offset land being targeted).

3.2.4 Assessing confidence in the proposed offset actions

To apply a practical lens onto the offset calculation, it is important to factor in the level of confidence that the experts have in the proposed offset actions. This can differ depending on habitat types, local circumstance and evidence of previous success.

The following are the three confidence levels that are used in the Model. A lower confidence level may increase the offset area required or lengthen the amount of time it takes for No Net Loss to be achieved.

1. Low confidence: the proposed offset action would use methods that have either been successfully implemented in New Zealand or in the situation and context relevant to the offset site but infrequently, or the outcomes of the proposed offset action are not well proven or documented, or success rates elsewhere have been shown to be variable. The likelihood of success is > 50% but < 75%.
2. Confident: the proposed offset action would use well known and often implemented methods which have been proven to succeed greater than 75% of the time although

enough complicating factors and/or expert opinion exists to not have greater confidence in this offset action. The likelihood of success is greater than 75% but less than 90%.

3 Very confident: the proposed offset action would use methods that are well tested and repeatedly proven to be very reliable for the situation and context relevant to the offset site; evidence-based expert opinion is that success is very likely. The likelihood of success is > 90% (Maseyk et al. 2014).

3.2.5 Calculating the areas of offset required

Once the above attributes are inputted into the Model, the Model can be used to calculate the gains achieved over time through the operation of the offset programme. The Model allows the user to choose how to define the time horizon of an offset calculation by use of a finite endpoint or calculation of accrued Net Present Biodiversity Value (NPBV) at five yearly intervals across 35 years (Maseyk *et al.* 2014). This measure has also been used to recognise the biodiversity gains which management of pressures accrues over a 35 year timeframe, such as the recovery of palatable flora by controlling possums and ungulates, to low or very low levels.

At the point where the Model gives a '0' number, a No Net Loss of biodiversity values (in terms of the loss that has been considered through the Model) is achieved. From that point, positive numbers will be returned, indicating a Net Gain.

The time at which No Net Loss will be achieved will depend on a range of factors, including in particular the area (ha) of land subject to the offset programme.

4 The application of the Model to the Project

This section of the report explains how the Model has been applied to the Project, in order to determine the proposed offset package.

In applying the Model to the Project, the aim has been to reach a No Net Loss point within a short to medium timeframe. More specifically, the target has been to reach No Net Loss or Net Gain within 10 to 15 years for each of the ecosystem units put through the Model. It would not be realistic to achieve No Net Loss within a shorter timeframe.

A precautionary, or conservative, approach has been taken in applying the Model to this Project. This conservatism has been applied in a number of cumulative ways including:

- A conservative definition of the Project footprint (i.e. the area of vegetation assumed to be lost for the purposes of the Model);
- assessing the ecological integrity of the existing ecosystems;
- allocating benchmarks and assessing ecological integrity for these;
- setting a 'discount rate'; and
- determining confidence in the offset actions (such as the ability of plants to establish in restoration planting).

4.1 Impact model

The results of the impact model step of the calculation for the Project are summarised in Table 4.1 below.

Further description of the areas of vegetation loss, the ecological integrity scores, the benchmarks and the discount rate are included in Sections 4.1.1–4.1.3 below.

Table 4.1 – Inputs into impact model

Ecosystem unit	Forest Type	Level of forest intactness	Offset Biodiversity Attribute #	Ecological Integrity (%)	Total Habitat Loss (Ha)
WF8	Kahikatea swamp maire forest and kahikatea forest	Advanced secondary forest	0.1a	69	1.231
	Pukatea treefern treeland	Modified secondary forest	0.1b	11	0.721

Ecosystem unit	Forest Type	Level of forest intactness	Offset Biodiversity Attribute #	Ecological Integrity (%)	Total Habitat Loss (Ha)
	Manuka scrub	Modified secondary forest	0.1c	75	0.372
WF13	Tawa rewarewa kamahi forest	Intact primary forest	0.2a	79	6.509
	Tawa nikau tree-fern forest	Modified primary forest	0.2b	31	8.731
	Miro rewarewa kamahi forest	Intact primary forest	0.2c	61	0.536
	Pukatea nikau forest	Intact primary forest	0.2d	45	1.258
	Secondary broadleaved forest	Modified secondary forest	0.2e	32	2.221
WF14	Hard beech forest	Intact primary forest	0.3a	36	0.081
	Manuka tree-fern rewarewa forest	Modified secondary forest	0.3b	15	3.599

4.1.1 Areas of vegetation loss

The areas of vegetation loss, broken down into potential ecosystem type, vegetation type, and level of condition, are detailed in the Vegetation Technical Report and are set out in Table 4.1 above.

Overall, the vegetation to be removed is indigenous dominant or mixed exotic/ indigenous dominant. Within the Project footprint, 19.466ha of primary vegetation communities are present, and 13.826 and 11.117ha of secondary scrub/forest and rushland, sedgeland mosaic respectively.

The areas of highest ecological integrity within the Project footprint are 1.231ha of forest dominated by kahikatea, and areas of tawa, rewarewa, kamahi forest south of the tunnel in the Mimi catchment (a subset of the WF8 ecosystem unit within the Project footprint).

North of the tunnel in the Mangapepeke catchment, the vegetation is of comparatively lower ecological value, having been subjected to browsing by cattle, as well as introduced pests such as possums, goats and pigs. These areas are of much lower quality than the vegetation in Parininihi, to the west of SH3.

Figures 4.1 and 4.2 show the areas of loss, and vegetation communities lost, in the Mimi and Mangapepeke catchments.

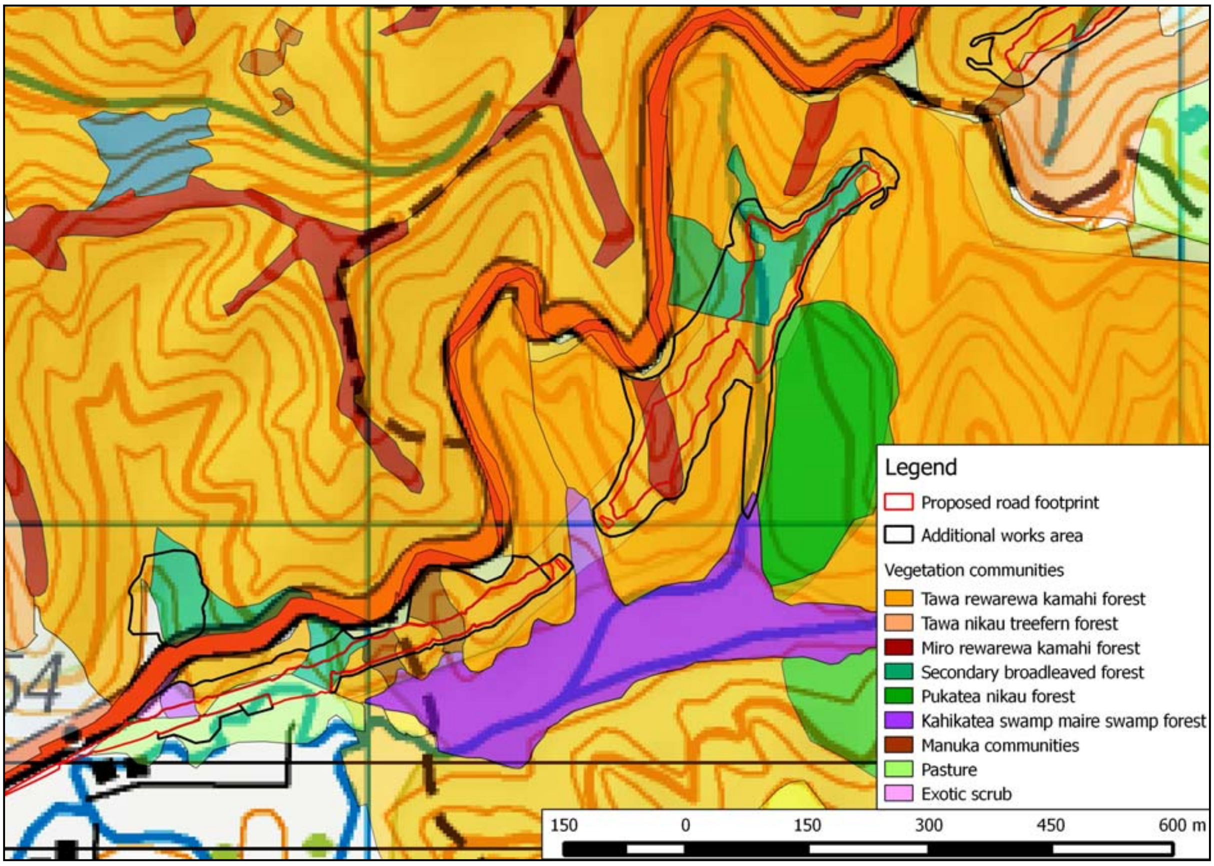

Figure 4.1 – Vegetation communities in the Mimi catchment within the road footprint and the AWA (together the Project footprint)

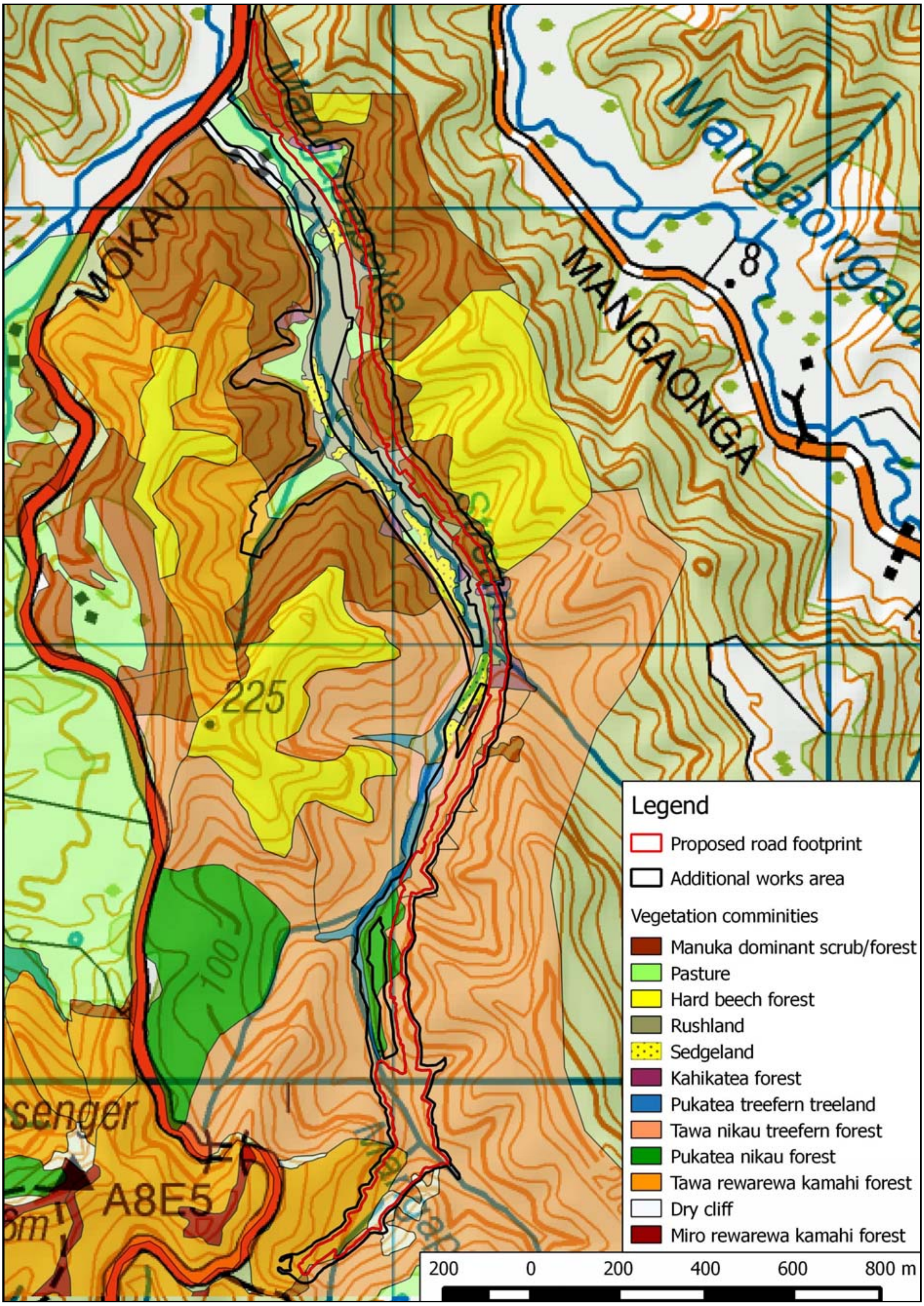

Figure 4.2 - Vegetation communities in the Mangapepeke catchment within the Project footprint

4.1.2 Ecological integrity calculation

The ecological integrity scores for 'current state' and 'habitat condition' are set out in Sections 4.1.2.1–2 below, and the final integrity scores (applying the formula set out in Section 4.5.3) are in Table 4.1 above. These scores were assigned based on expert judgement.

4.1.2.1 Current state

When determining the biodiversity attributes, areas which have had no logging, burning or land clearance activities were given scores of 0.95. Conversely, highly modified secondary vegetation such as manuka scrub which has developed following land clearance was given a score of 0.25; and areas of exotic pasture were given a score of 0.05.

4.1.2.2 Habitat condition

Canopy and understorey condition scores ranged from 1 – 0.5. Scores of 1 were only given to areas where the structural and compositional integrity was essentially intact (or representative compared to the potential).

As an example, a score of 1 was given for understorey condition to areas where a high abundance and diversity of palatable plants occurred, such as hen and chicken fern, king fern, large leaved coprosma shrubs, hangehange and native shrubby honeysuckle, which become uncommon even with a low level of ungulate browse.

Possum browse was scored similarly and lower scores were given to areas where browse on palatable species was common and noticeably heavy to severe (Figure 4.3). Conversely, scores of 0.5 to 0.6 were given to areas where complete loss of these species and additionally loss of moderately palatable species has occurred. Under this level of browse pressure, understorey and ground cover vegetation is often replaced by unpalatable species, such as crown fern, silver fern, hook grass and bush rice grass (Figure 4.3 & 4.4).

Since weed abundance is generally low throughout most of the area, this had limited influence on the ecological integrity score result with native dominance scores ranging from 1 to 0.8.

4.1.3 Setting benchmarks

The relevant benchmarks for the three ecosystem types input in the model are set out in Table 4.2 below. These benchmark attribute percentages were input into the Model as shown in the worksheets in Appendix A. It should be emphasised that the high value of the two benchmark sites forms part of the conservative approach taken in applying the Model. The Hutiwai Stream and Parininihi are very high value, being considered as nationally significant.

Table 4.2 – Benchmark sites selected for input into the Model

Ecosystem type	Benchmark site	Biodiversity attribute (%)	Reason for selection
WF8 (Kahikatea, pukatea forest)	Hutiwai Stream	80	Hutiwai Stream is a northern tributary of the Tongaporutu River. The stream environment contains approximately 189 ha of stream terraces of kahikatea, pukatea forest and associated non-forest wetlands, surrounded entirely by native forest. The area receives conservation management by DOC, primarily involving regular aerial 1080 operations to control possums and predators. It is regarded as one of the best remaining examples of this type in New Zealand.
WF13 (Tawa,kohekohe, rewarewa, hinau,podocarp forest) and WF14 (Kamahi, tawa, podocarp, hard beech forest)	Parininihi	85	While it primarily includes WF13 forest it occupies the transition zone between these two broad forest types and within the management area, small areas of hard beech forest are present. Parininihi is regarded as the best remaining example of this type within the Taranaki Region.

4.1.4 Application of the discount rate

As noted in Section 3.1.3 above, the Model requires a discount rate to be applied, to account for time lag between biodiversity loss and the subsequent gains. The rate for the Model applied was based on expert judgement following discussions with Fleur Maseyk, the author of the Model, who advised that, applying a conservative approach, a discount rate of 3% was appropriate for the Project. This is also the recommended rate for Habitat Equivalency Analysis in the United States, which reflects the social time preference for public goods (Gibbons *et al.* 2015).

4.2 Offset model

4.2.1 Appropriate offsets

The appropriate offsets for each type of vegetation being lost were determined using professional judgement. These are set out in the Mitigation and Offset Report (Technical Report 7h).

In particular, it is important to understand that the offset model approach was not applied to all the vegetation communities within the Project footprint.

The loss of lower value vegetation communities will be addressed through replacement (on a 1 to 1 basis) planting. Furthermore, only the loss of the highest value portion of the affected rushland sedgeland mosaic (heavily grazed and modified *Carex virgata* wetland; accounting for 1.37ha of 11.117ha total rushland sedgeland mosaic) will be directly addressed, through 1 to 1 replacement planting. The dry cliff vegetation community will also be treated differently. A very small loss of this type of habitat will occur. Complementary habitat creation, supplementary planting and weed control along the highway edge will result in significantly more habitat of this type (up to 6 to 1) being created than is being lost.

The vegetation communities being dealt with through the proposed offset programme, and that have therefore been subject to the application of the Model, are highlighted in yellow below.

Of these communities, most are being addressed solely through intensive pest management. However, there is not sufficient suitable existing kahikatea swamp maire forest habitat to offset what is being lost through pest management. That NPBV 'deficit' is being addressed through additional restoration planting offset for that community type.

Table 4.3 – Mitigation / offset approach by vegetation community

Potential Ecosystem Type	Vegetation community	Mitigation / offset approach
WF8: Kahikatea pukatea forest	Kahikatea swamp maire forest	Offset: Integrated pest management plus restoration planting
	Kahikatea forest	Offset: Integrated pest management plus restoration planting
	Pukatea treefern treeland	Offset: Integrated pest management
	Manuka scrub	Offset: Integrated pest management
	Rushland sedgeland mosaic*	Mitigation of 1.37ha of sedgeland via replacement planting
WF13: Tawa kohekohe,	Tawa rewarewa kamahi forest	Offset: Integrated pest management

Potential Ecosystem Type	Vegetation community	Mitigation / offset approach
rewarewa, hinau, podocarp forest	Tawa nikau treefern forest	Offset: Integrated pest management
	Miro rewarewa kamahi forest	Offset: Integrated pest management
	Pukatea nikau forest	Offset: Integrated pest management
	Secondary mixed broadleaved forest	Offset: Integrated pest management
	Manuka treefern scrub	Mitigation: replacement planting
	Manuka succession	Mitigation: replacement planting
WF14: Kamahi, tawa, podocarp, hard beech forest	Hard beech forest	Offset: Integrated pest management
	Manuka treefern rewarewa forest	Offset: Integrated pest management
	Manuka treefern scrub	Mitigation: replacement planting
	Manuka scrub	Mitigation: replacement planting
CL6: *Hebe*, wharariki flaxland/ rockland	Dry cliff	Treatment to enhance natural regeneration: Compensatory habitat creation, planting and weed control

4.2.2 Offset site selection

The biodiversity offset calculator requires a predetermined offset site in order to give accurate results, as an understanding of vegetation (habitat) composition, the current ecological integrity, site pressures and management requirements are prerequisite information for populating the calculator fields.

The offset site in the Mimi catchment was selected for its ecosystem diversity — representative examples of all three ecosystems impacted by the Project are present, including the regionally rare WF8 Kahikatea, pukatea forest ecosystem. The two areas of WF8 Kahikatea, pukatea forest in tributaries of the Mimi River are the only examples in the wider Project area where offsetting of this ecosystem can occur using integrated pest management. The offset site additionally contains areas of tawa, kamahi, rewarewa forest and pukatea, nikau forest (WF13) and hard beech forest (WF14) in moderate ecological condition. The site contains moderate abundance of significant trees including rimu, northern rata and totara and several threatened species including fernbird, kohurangi and N.I. kiwi. Connectivity to Parininihi and the feasibility of establishing an effective offset site were also primary considerations. This site will allow offsetting on a 'like for like' basis in respect of what will be lost. The land identified includes part of the Mt Messenger Conservation Area and Ngāti Tama covenanted land (Figure 4.3).

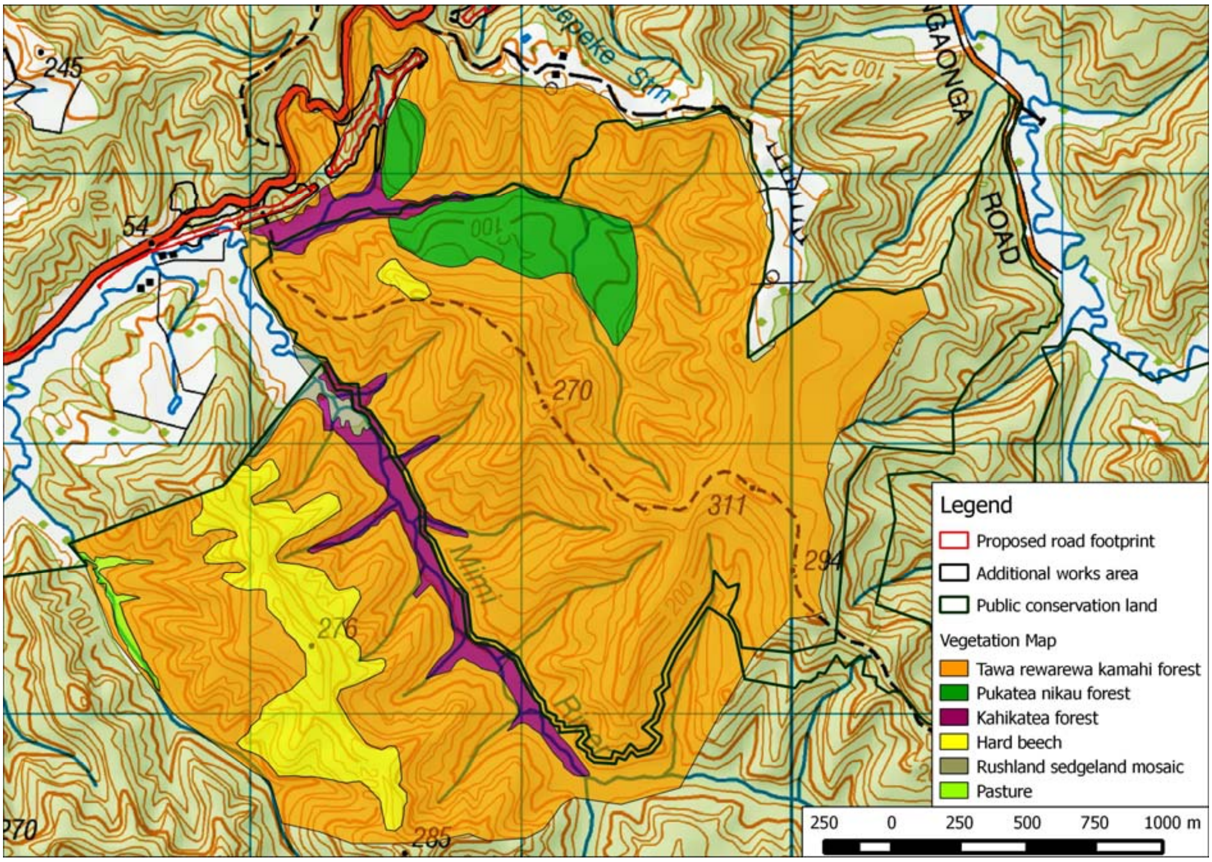

Figure 4.3 – Potential Pest Management Area to achieve high ecological integrity within 222ha

4.2.3 Ecological integrity calculation and determining conservation outcomes

As noted in Section 3.2.3 above, the ecological integrity of the existing offset areas needs to be calculated, in order for the conservation outcomes to be forecast. The expected conservation outcome is that habitat management, over time, will result in habitat of high ecological integrity, in simple terms habitat that is 'healthy and functioning'. Applicable specific indicators of 'healthy and functioning' habitat for this site may include:

- A measureable increase in common native forest birds, especially functionally important pollinators and seed dispersers such as tui and bellbird.

- An increase in the browse tier, palatable ground ferns especially pikopiko (*Asplenium* spp.) and palatable shrubs especially hangehange, large leafed coprosma species and shrubby honeysuckle
- Recovery of possum browsed canopies such as swamp maire (Figure 4.8) and increased flower and fruit production of species suppressed by browse.

Expert judgement is required to assign the current value of the targeted offset sites, as well as the anticipated value of the sites with the offset programme in place after 35 years. This scoring process has been informed by qualitative data collected from Recce Plots at the offset site; and the Parininihi benchmark site which has received approximately 25 years of integrated pest management.

Scoring ecological integrity has been broken down by the vegetation communities, as detailed in Sections 4.2.3.1-2 below. For WF8 communities ecological integrity scores were aggregated using the highest ecological value scores for the level of forest composition, i.e. forest and secondary treeland and scrub forest (Table 4.1). This was precautionary, as although some of the areas lost were more degraded, forest lost is in a young stage of succession and over time biodiversity value is expected to increase (without intervention) as stand productivity and habitat value for fauna improved. Further, although biologically somewhat modified, these areas are still hydrologically intact and there is no doubt that given sufficient time and appropriate pest and weed control these areas would naturally regenerate.

4.2.3.1 Ecological integrity of WF8 offset area

Integrated pest management

The current ecological integrity value of WF8 habitat within the Pest Management Areas has been assessed using variable area Recce plots and applying professional ecological judgement, as 39% (see Figure 3.6 for an example of the degraded forest in this area). The pest management sites include a mosaic of advanced secondary kahikatea forest, secondary broadleaved forest and tree-fernland, kahikatea treeland and small carex and raupo dominant wetland communities, all occupying alluvial terrace landforms.

With the implementation of pest management, over 35 years the ecological integrity value of the Pest Management Area is expected to increase to 58% through:

- recovery and regeneration of palatable flora, especially canopy dominants such as pukatea, swamp maire, ground cover and sub-canopy vegetation in the browse tier and;
- recovery of vulnerable fauna (Figure 4.5).

Integrated pest management of 22ha of WF8 offset area is available within the proposed offset area.

Figure 4.4 – Heavily browsed understorey of WF8 forest in the Pest Management Area in the Mimi catchment showing an absence of palatable shrubs and ferns and the forest floor dominated by the unpalatable bush rice grass. Seedlings of pukatea (<10cm) are numerous.

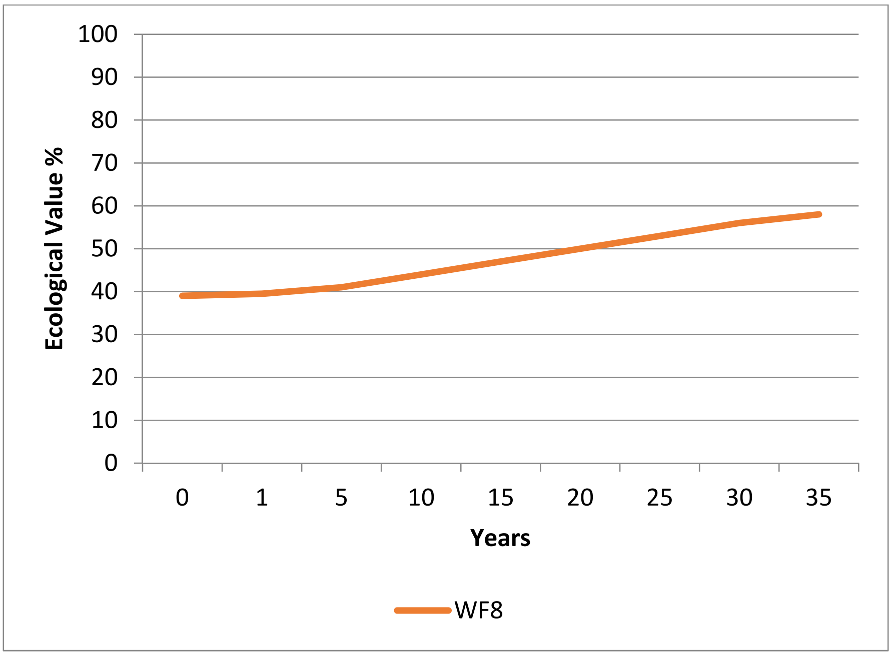

Figure 4.5 – Forecast increase in ecological integrity in targeted WF8 integrated pest management habitat

Restoration planting

An additional area for restoration planting to kahikatea – kahikatea swamp maire forest has been identified, because there is not sufficient existing habitat to allow for a full offset of the loss of kahikatea swamp maire forest through integrated pest management alone. The deficit NPBV was transformed into an impact site hectare figure, which equated to an area of 0.372ha.

Potential restoration planting areas in the Mangapepeke and Mimi catchments are essentially wet exotic pasture at present, with an assessed ecological integrity value of 1.2%. At Year 35 its value is forecast to be 50% (Figure 3.8). The rate of increase is expected initially to be low, as nurse crop revegetation species reach canopy closure at between 4-5 years. Kahikatea and other canopy tree seedlings would not be planted until at least the 3rd year. The rate of increase in ecological integrity increases, especially after year 20, more rapidly after canopy closure as other species, such as tree-ferns, found in the vicinity naturally colonise and forest fauna occupy the habitat.

Figure 4.6 – Forecast increase in ecological integrity in offset restoration planting kahikatea forest habitat

4.2.3.2 Ecological Integrity of WF13 and WF14 offset area

The current ecological integrity of the targeted offset area for the WF13 and WF14 has been assessed at 44%. This area is mature forest with a closed canopy, but heavily browsed and otherwise degraded through pest activity (see Figures 4.7 and 4.8).

The ecological integrity is expected to increase quickly between Years 10 and 25 once pest numbers have been reduced to low levels. Vegetation quality will recover, and bird abundance will increase rapidly as breeding populations recover. After Year 25 recovery will likely slow somewhat as the forest nears its carrying capacity for avifauna, thus the rate of increase of ecological integrity is slower after Year 25 (Figure 4.9). However, by year 35 the predicted ecological integrity of this targeted area is just under 80% – close to the value of the benchmark site.

Figure 4.7 – Heavily browsed understorey of WF13 forest in the potential biodiversity offset site in the Mimi River catchment (showing an absence palatable shrubs and ferns, and most of the ground covered in leaf litter and a sparse cover of small unpalatable tree

Figure 4.8 – Heavily possum browsed swamp maire tree in the proposed biodiversity offset site showing limited foliage and dieback. Possum scratch marks on the trunk of this tree were evident. Located in the northern tributary of the Mimi River (NZTM 1738205; 56928

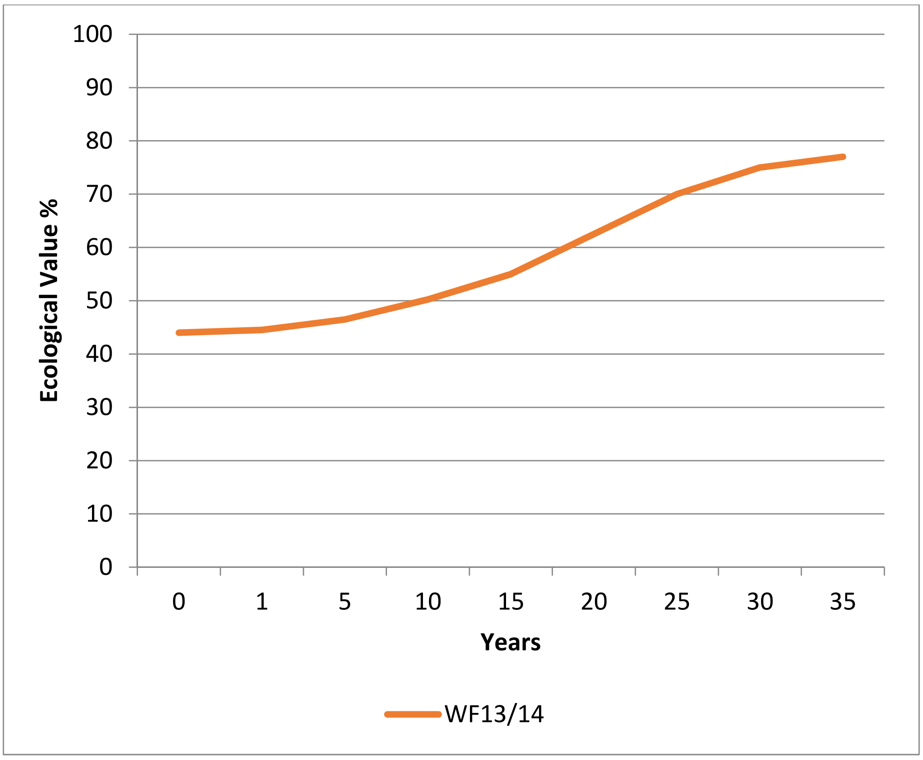

Figure 4.9 – Forecast increase in ecological integrity in WF13 and WF14 Pest Management Area

4.2.4 Confidence levels

The confidence levels reflect the level of confidence the ecologist has that the proposed offset action will work. The confidence levels of the offset actions proposed are set out in Sections 4.2.4.1-3 below.

4.2.4.1 Integrated pest management of WF13 and WF14 forest

The confidence level assigned for the integrated pest management in WF13 and WF14 ecosystems are 'very confident' (>90%). This is because integrated pest management in tawa and beech dominant forest has been proven to be highly successful in achieving desired conservation outcomes throughout the North Island. In particular, the adjacent Parininihi reserve is an exemplar of this approach, where pest management over 25+ years has produced significant ecological outcomes. This is a clear demonstration of the effectiveness of pest management in this location.

4.2.4.2 Integrated pest management of WF8 ecosystems

Integrated pest management in the WF8 ecosystem has been assigned a confidence level of 'confident' (>75<90%). This is because the integrated pest management required is a well-known and proven method in achieving desired conservation outcomes generally and it is expected that pest management will achieve the desired conservation outcomes for WF8. However, a level of conservatism has been applied on the basis that there is limited documented evidence available specifically in respect of this ecosystem type, mainly because there is very little of this ecosystem type remaining. The 'confident' level is therefore a conservative approach.

4.2.4.3 Restoration planting of WF8 ecosystems

For restoration planting of WF8 ecosystems, we have also assigned a 'confident' level (>75<90%). Riparian restoration planting is a proven method of restoration and has been carried out successfully throughout New Zealand, including large areas in the Taranaki Region. The climate is warm and humid supporting plant growth throughout much of the year and importantly there is little risk of seedlings dying from drought. However a lower confidence level has been applied because there is an inherent risk in attempting to recreate the variety of vegetation communities suitable for the subtle changes in alluvial landforms, corresponding soil pattern and water table present. Further when seedlings are small, impacts from floods or herbivores such as feral goats could result in significant plant losses. This restoration planting will be reliant on having achieved reductions in herbivore numbers to be successful.

5 Results

The results from the Model showed that using integrated pest management alone in the offset sites for WF8, WF13 and WF14 achieves No Net Loss in ten years for all the impacted vegetation communities, with the exception of kahikatea swamp maire & kahikatea forest, where No Net Loss can be realistically achieved within 15 years.

The results from the Model are set out in Table 5.1 below. These show the areas required to be subject to the offset programme in order to achieve No Net Loss within the targeted timeframe.

From the point that No Net Loss is achieved, Net Gain begins to accrue for all three ecosystem types. By Year 35, significant biodiversity benefits are expected as a result of the offsetting programme for the Project.

More detail on the offsets for each ecosystem unit are included in Sections 5.1–3 below, and the full biodiversity offset calculation worksheets can be found in Appendix A.

Table 5.1 – Results from the Model

Ecosystem type	Biodiversity attribute	Impact area (ha)	Proposed offset	Offset required (ha)	Years until No Net Loss
WF8	Kahikatea swamp maire & Kahikatea forest	0.859	Integrated pest management	18	10
	Kahikatea swamp maire & Kahikatea forest	0.372	Restoration planting	6	10
	Pukatea treefern treeland	0.721	Integrated pest management	3	10
	Manuka scrub	0.372	Integrated pest management	1	10
WF13	Tawa rewarewa kamahi forest	6.509	Integrated pest management	95	10
	Tawa nikau treefern forest	8.731	Integrated pest management	58	10

Ecosystem type	Biodiversity attribute	Impact area (ha)	Proposed offset	Offset required (ha)	Years until No Net Loss
	Miro rewarewa kamahi forest	0.536	Integrated pest management	8	10
	Pukatea nikau forest	1.258	Integrated pest management	15	10
	Secondary mixed broadleaved forest	2.221	Integrated pest management	15	10
WF14	Hard beech forest	0.081	Integrated pest management	1	10
	Manuka treefern scrub	3.599	Integrated pest management	8	10

5.1 Offsetting WF8 habitat

5.1.1 Integrated pest management

The Model was run with the full 1.231ha of kahikatea swamp maire and kahikatea forest using the offset action of integrated pest management. However there were only 22ha of WF8 habitat available for integrated pest management offsetting and this was not enough to achieve No Net Loss by Year 10. The residual area was worked back through the Model to give a figure of 0.372ha not offset by integrated pest management.

Integrated pest management for 0.859ha (1.231 – 0.372) of WF8 achieves No Net Loss by Year 10 and Net Gain by Year 15 from the 22 hectares available. The additional area of restoration planting area was included, which equates to an impact area of 0.372ha. This calculation resulted in an additional 6 ha of restoration planting being required, to achieve No Net Loss by Year 10 and Net Gain by Year 15 for WF8 (Figure 5.1).

Net Present Biodiversity Value (NPBV) has been plotted in Figure 5.1. This predicts that NPBV will exceed 1.5 over the 35 Year timespan.

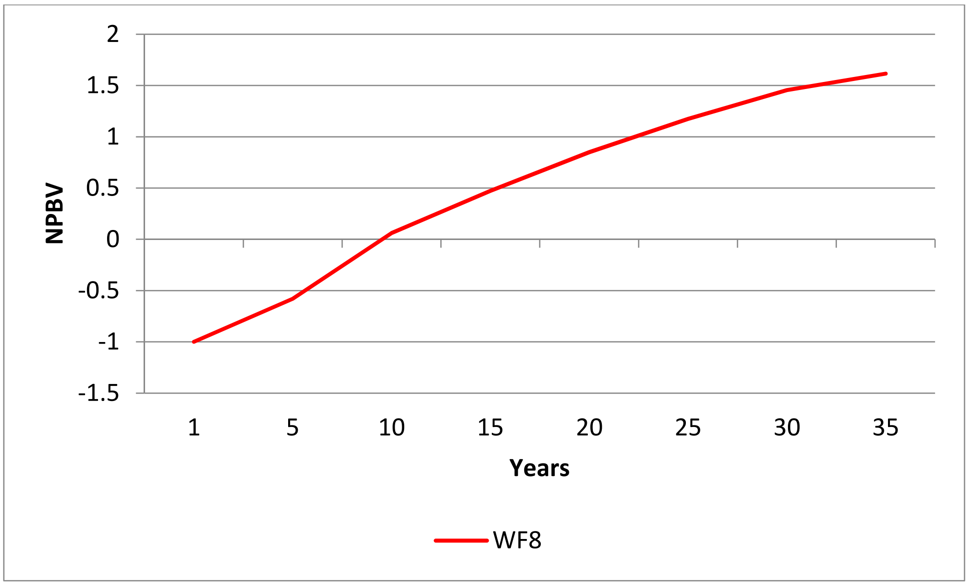

Figure 5.1 – The change in NPBV for WF8 over 35 years combined for both integrated pest management and restoration planting. Note that No Net Loss is achieved at Year 10

5.2 Offsetting loss of WF13 and WF14 habitat

The offset calculation results show that it is possible to achieve No Net Loss by Year 10, and Net Gain by Year 15, using integrated pest management over a 200ha of WF13/ WF14 habitat (Figures 5.2 & 5.3).

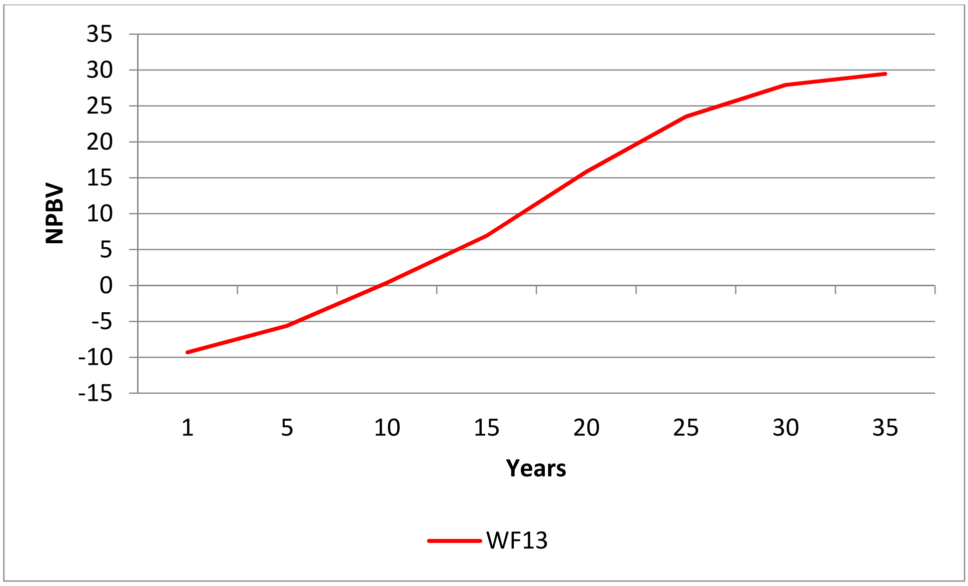

Figure 5.2 – The change in NPBV for WF13 over 35 years

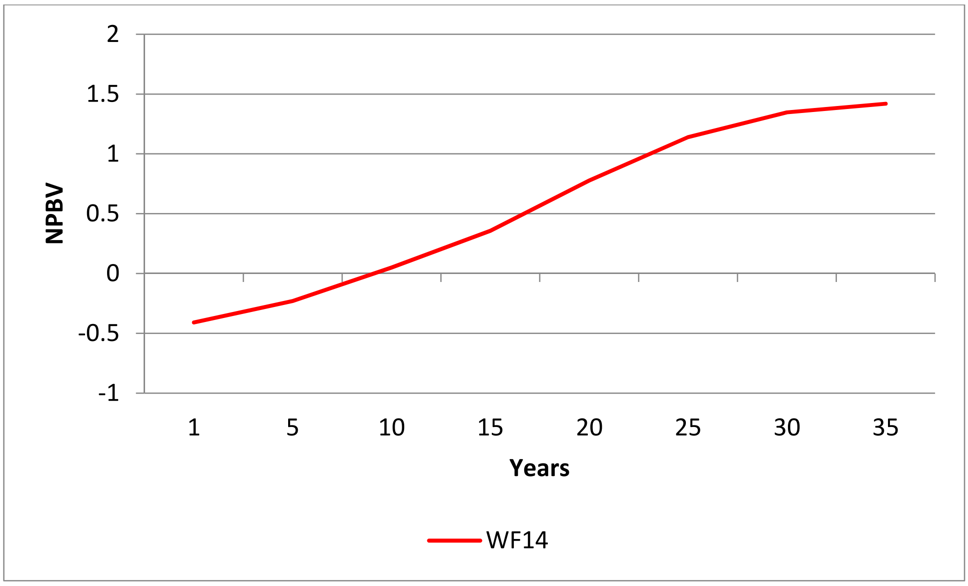

Figure 5.3 – The change in NPBV for WF14 over 35 years

NPBV has been plotted in Figures 5.2 and 5.3. This predicts that NPBV are close to 30 and 1.5 for WF13 and WF14 respectively over the 35 Year timespan.

6 Conclusion

The Model has demonstrated that No Net Loss of biodiversity is possible within 10 years of completing construction for ecosystem types WF8, WF13 and WF14, and Net Gain in 15 years. This is based on biodiversity offsets through integrated pest management and restoration planting, as described in the Mitigation and Offset Report.

The proposed offset site in the Mimi catchment is considered to be the most suitable location within the wider Project area to offset the loss of 'like for like' habitat associated with the Project footprint and achieve high ecological integrity. This is because all three ecosystems are present in close proximity to each other and surround the largest areas of kahikatea forest (WF8) vegetation communities within the wider Project area. These communities contain some unique features such as populations of fernbird, spotless crake and swamp maire.

The hill-country forests also have a higher abundance of significant trees, including rimu, matai, kahikatea, miro, totara and northern rata and populations of threatened species such as kohurangi, long-tailed bats and N.I. brown kiwi also occur. The area is sited between Parininihi and the wider part of the Mt Messenger Conservation area (of approximately 2700ha), enabling enhanced population viability and connectivity for vulnerable fauna, such as N.I. brown kiwi and potentially kokako in the future. Limited conservation management has occurred at this site and threats to values will continue to degrade these habitats without management. Integrated pest management proposed will be additional to the current management that is occurring and is expected to be successful.

7 References

Gibbons, P., Evans, M. C., Maron, M., Gordon, A., Le Roux, D., von Hase, A., Lindenmayer, D. B. and Possingham, H. P. (2016), A Loss-Gain Calculator for Biodiversity Offsets and the Circumstances in Which No Net Loss Is Feasible. *Conservation Letters*, 9: 252-259. doi:10.1111/conl.12206.

Ledec, G.C. and Johnson, S.D.R. (2016). *Biodiversity offsets : a user guide*. Washington, D.C.: World Bank Group. http://documents.worldbank.org/curated/en/344901481176051661/Biodiversity-offsets-a-user-guide

MacGibbon, R. (2017). SH3 Mount Messenger Bypass Project. Assessment of Effects — Ecological Mitigation and Offset.

Maseyk, F.J.F.; Barea, L.; Stephens, R.T.T.; Possingham, H.P.; Dutson, G.; Maron, M. (2016). A disaggregated biodiversity offset accounting model to improve estimation of ecological equivalency and no-net-loss. *Biological Conservation 204*:322-332.

Maseyk, F.; Maron, M.; Seaton, R.; Dutson, G. (2014). A Biodiversity Offset Accounting Model for New Zealand. User Manual. The Catalyst Group Contract Report No. 2014-008 prepared for Department of Conservation.

Maseyk, F. (2017). SH3 Mt Messenger bypass project. Review of the Mt Messenger biodiversity offsetting proposal. The Catalyst Group Report. TCG017/112. August 2017.

Ngāti Tama Claims Settlement Act (2003). http://www.legislation.govt.nz/act/public/2003/0126/16.0/DLM233715.html.

Nicholls, J.L. (1976). A revised classification of the North Island indigenous forests. *New Zealand Journal of Forestry 28*: 105–132.

Singers, N.J.D. & Rogers, G.M. (2014). A classification of New Zealand's terrestrial ecosystems. *Science for Conservation*, *325*. http://www.conservation.co.nz/Documents/science-and-technical/sfc325entire.pdf

Singers, N. (2017). Ecology Specialist Report. Vegetation. September 2017.

Singers, N. J. D. unpublished. Potential Vegetation of the Taranaki Region (2015) based upon N J D Singers & G M Rogers (2014), A classification of New Zealand's terrestrial ecosystems, Science for Conservation 325, Department of Conservation, Wellington.

Appendices

Appendix A: Biodiversity Offsetting Worksheets

WF8 Impact Model — Offset Action Integrated Pest Management

	This section captures which elements of biodiversity, and over what area, will be impacted by the proposal					This section is where the change in measure of each Biodiversity Attribute due to the proposed Impact is quantified, and Attribute Biodiversity Value calculated. Inputs are derived from direct measures, existing data or models where available, or expert estimated predictions			
	Biodiversity Component	**Biodiversity Attribute**		**Measurement Unit**	**Area of Impact (ha)**	**Benchmark**	**Measure prior to Impact**	**Measure after Impact**	**Biodiversity Value**
0.1	WF8	0.1a	69	%	0.859	80	69	0	-0.74
		0.1b	11	%	0.721	80	11	0	-0.10
		0.1c	7.5	%	0.372	80	7.5	0	-0.03

WF8 Offset Model — Offset Action Integrated Pest Management

	This section captures which elements of biodiversity are to be accounted for, and the benchmark value for the Attribute. The information matches that in the Impact Model					These cells provide information about the proposed Offset Actions			Calculations can be made for a finite end point, or at five yearly time-steps over 35 years. Indicate preference in Column K and Follow the instructions in Column L		This section is where the marginal change in the measure of Biodiversity Attribute due to the Offset Action is quantified. Inputs are derived from direct measure, existing data or models where available, or expert estimated predictions. Attribute Biodiversity Value at the Offset Site is compared to the Attribute Biodiversity Value at the Impact Site to calculate the Net Present Biodiversity Value for each Attribute						This is the average Net Present Biodiversity Value for the Biodiversity Component
	Biodiversity Component	Biodiversity Attribute		Measurement Unit	Benchmark	Proposed Offset Actions	Offset area (ha)	Confidence in Offset Actions			Measure prior to Offset	Measure after Offset	Time till endpoint (years)	Biodiversity Value at Offset Site	Biodiversity Value at Impact Site	Attribute Net Present Biodiversity Value	Component Net Present Biodiversity Value
0.1	WF8	0.1a	69	%	80	Integrated Pest Management	18	Confident 75-90%	Five yearly time-step	Switch to Offset Model_5 yearly					-0.74	0.00	0.01
		0.1b	11	%	80	Integrated Pest Management	3	Confident 75-90%	Five yearly time-step	Switch to Offset Model_5 yearly					-0.10	0.02	
		0.1c	7.5	%	80	Integrated Pest Management	1	Confident 75-90%	Five yearly time-step	Switch to Offset Model_5 yearly					-0.03	0.01	

WF8 5 Yearly Offset Model — Offset Action Integrated Pest Management

		The marginal change in the measure of Biodiversity Attribute due to the Offset Action is predicted for each time-step. Inputs are derived from direct measurement (Attribute measure prior to Offset), existing data or models where available, or expert estimated predictions (Attribute measure post Offset). Attribute Net Present Biodiversity Value is then calculated for each time-step.																
Biodiversity Component		Measure prior to Offset	Measure at YEAR 1	NPBV at Year 1	Measure at YEAR 5	NPBV at Year 5	Measure at YEAR 10	NPBV at Year 10	Measure at YEAR 15	NPBV at Year 15	Measure at YEAR 20	NPBV at Year 20	Measure at YEAR 25	NPBV at Year 25	Measure at YEAR 30	NPBV at Year 30	Measure at YEAR 35	NPBV at Year 35
WF8	0.1a	39.00	39.50	-0.65	41.00	-0.41	44.00	0.00	47.00	0.36	50.00	0.67	53.00	0.94	56.00	1.16	58.00	1.30
	0.1b	39.00	39.50	-0.08	41.00	-0.04	44.00	0.02	47.00	0.08	50.00	0.14	53.00	0.18	56.00	0.22	58.00	0.24
	0.1c	39.00	39.50	-0.03	41.00	-0.02	44.00	0.01	47.00	0.03	50.00	0.04	53.00	0.06	56.00	0.07	58.00	0.08

WF8 Residual Impact Model — Offset Action Restoration Planting

	This section captures which elements of biodiversity, and over what area, will be impacted by the proposal					This section is where the change in measure of each Biodiversity Attribute due to the proposed Impact is quantified, and Attribute Biodiversity Value calculated. Inputs are derived from direct measures, existing data or models where available, or expert estimated predictions			
	Biodiversity Component	Biodiversity Attribute		Measurement Unit	Area of Impact (ha)	Benchmark	Measure prior to Impact	Measure after Impact	Biodiversity Value
0.5	Residual WF8	0.5a	69	%	0.372	80	69	0	-0.32

WF8 Residual Offset Model — Offset Action Restoration Planting

	This section captures which elements of biodiversity are to be accounted for, and the benchmark value for the Attribute. The information matches that in the Impact Model					These cells provide information about the proposed Offset Actions			Calculations can be made for a finite end point, or at five yearly time-steps over 35 years. Indicate preference in Column K and Follow the instructions in Column L		This section is where the marginal change in the measure of Biodiversity Attribute due to the Offset Action is quantified. Inputs are derived from direct measure, existing data or models where available, or expert estimated predictions. Attribute Biodiversity Value at the Offset Site is compared to the Attribute Biodiversity Value at the Impact Site to calculate the Net Present Biodiversity Value for each Attribute						This is the average Net Present Biodiversity Value for the Biodiversity Component
	Biodiversity Component	Biodiversity Attribute		Measurement Unit	Benchmark	Proposed Offset Actions	Offset area (ha)	Confidence in Offset Actions			Measure prior to Offset	Measure after Offset	Time till endpoint (years)	Biodiversity Value at Offset Site	Biodiversity Value at Impact Site	Attribute Net Present Biodiversity Value	Component Net Present Biodiversity Value
0.5	Residual WF8	0.5a	69	%	80	Restoration planting	6	Confident 75-90%	Five yearly time-step	Switch to Offset Model_5 yearly					-0.32	0.03	0.02

WF8 Residual 5 Yearly Offset Model — Offset Action Restoration Planting

Biodiversity Component		Measure prior to Offset	Measure at YEAR 1	NPBV at Year 1	Measure at YEAR 5	NPBV at Year 5	Measure at YEAR 10	NPBV at Year 10	Measure at YEAR 15	NPBV at Year 15	Measure at YEAR 20	NPBV at Year 20	Measure at YEAR 25	NPBV at Year 25	Measure at YEAR 30	NPBV at Year 30	Measure at YEAR 35	NPBV at Year 35
Residual WF8	0.5a	1.20	2.50	-0.24	5.00	-0.11	8.00	0.03	13.00	0.23	20.00	0.47	30.00	0.76	40.00	1.02	50.00	1.24

WF13 Impact Model

	This section captures which elements of biodiversity, and over what area, will be impacted by the proposal					This section is where the change in measure of each Biodiversity Attribute due to the proposed Impact is quantified, and Attribute Biodiversity Value calculated. Inputs are derived from direct measures, existing data or models where available, or expert estimated predictions			
	Biodiversity Component	**Biodiversity Attribute**		**Measurement Unit**	**Area of Impact (ha)**	**Benchmark**	**Measure prior to Impact**	**Measure after Impact**	**Biodiversity Value**
0.2	WF13	**0.2a**	69	%	6.509	85	69	0	-5.28
		0.2b	31	%	8.731	85	31	0	-3.18
		0.2c	61	%	0.536	85	61	0	-0.38
		0.2d	45	%	1.258	85	45	0	-0.67
		0.2e	32	%	2.221	85	32	0	-0.84

WF13 Offset Model

	This section captures which elements of biodiversity are to be accounted for, and the benchmark value for the Attribute. The information matches that in the Impact Model					These cells provide information about the proposed Offset Actions			Calculations can be made for a finite end point, or at five yearly time-steps over 35 years. Indicate preference in Column K and Follow the instructions in Column L		This section is where the marginal change in the measure of Biodiversity Attribute due to the Offset Action is quantified. Inputs are derived from direct measure, existing data or models where available, or expert estimated predictions. Attribute Biodiversity Value at the Offset Site is compared to the Attribute Biodiversity Value at the Impact Site to calculate the Net Present Biodiversity Value for each Attribute						This is the average Net Present Biodiversity Value for the Biodiversity Component
	Biodiversity Component	Biodiversity Attribute		Measurement Unit	Benchmark	Proposed Offset Actions	Offset area (ha)	Confidence in Offset Actions			Measure prior to Offset	Measure after Offset	Time till endpoint (years)	Biodiversity Value at Offset Site	Biodiversity Value at Impact Site	Attribute Net Present Biodiversity Value	Component Net Present Biodiversity Value
0.2	WF13	0.2a	69	%	85	Integrated Pest Management	95	Very confident >90%	Five yearly time-step	Switch to Offset Model_5 yearly					-5.28	0.05	0.08
		0.2b	31	%	85	Integrated Pest Management	58	Very confident >90%	Five yearly time-step	Switch to Offset Model_5 yearly					-3.18	0.07	
		0.2c	61	%	85	Integrated Pest Management	8	Very confident >90%	Five yearly time-step	Switch to Offset Model_5 yearly					-0.38	0.06	
		0.2d	45	%	85	Integrated Pest Management	15	Very confident >90%	Five yearly time-step	Switch to Offset Model_5 yearly					-0.67	0.18	
		0.2e	32	%	85	Integrated Pest Management	15	Very confident >90%	Five yearly time-step	Switch to Offset Model_5 yearly					-0.84	0.01	

WF13 5 Yearly Offset Model

The marginal change in the measure of Biodiversity Attribute due to the Offset Action is predicted for each time-step. Inputs are derived from direct measurement (Attribute measure prior to Offset), existing data or models where available, or expert estimated predictions (Attribute measure post Offset). Attribute Net Present Biodiversity Value is then calculated for each time-step.

	Measure prior to Offset	Measure at YEAR 1	NPBV at Year 1	Measure at YEAR 5	NPBV at Year 5	Measure at YEAR 10	NPBV at Year 10	Measure at YEAR 15	NPBV at Year 15	Measure at YEAR 20	NPBV at Year 20	Measure at YEAR 25	NPBV at Year 25	Measure at YEAR 30	NPBV at Year 30	Measure at YEAR 35	NPBV at Year 35
0.2a	44.00	44.50	-4.77	46.50	-2.92	50.25	0.05	55.00	3.31	62.50	7.74	70.00	11.56	75.00	13.76	77.00	14.52
0.2b	44.00	44.50	-2.87	46.50	-1.74	50.25	0.07	55.00	2.06	62.50	4.77	70.00	7.10	75.00	8.44	77.00	8.91
0.2c	44.00	44.50	-0.34	46.50	-0.19	50.25	0.06	55.00	0.34	62.50	0.71	70.00	1.03	75.00	1.22	77.00	1.28
0.2d	44.00	44.50	-0.58	46.50	-0.29	50.25	0.18	55.00	0.69	62.50	1.39	70.00	1.99	75.00	2.34	77.00	2.46
0.2e	44.00	44.50	-0.75	46.50	-0.46	50.25	0.01	55.00	0.52	62.50	1.22	70.00	1.82	75.00	2.17	77.00	2.29

WF14 Impact Model

	This section captures which elements of biodiversity, and over what area, will be impacted by the proposal					This section is where the change in measure of each Biodiversity Attribute due to the proposed Impact is quantified, and Attribute Biodiversity Value calculated. Inputs are derived from direct measures, existing data or models where available, or expert estimated predictions			
	Biodiversity Component	**Biodiversity Attribute**		**Measurement Unit**	**Area of Impact (ha)**	**Benchmark**	**Measure prior to Impact**	**Measure after Impact**	**Biodiversity Value**
0.3	WF14	**0.3a**	35	%	0.081	85	35	0	-0.03
		0.3b	10	%	3.599	85	10	0	-0.42

WF14 Offset Model

	This section captures which elements of biodiversity are to be accounted for, and the benchmark value for the Attribute. The information matches that in the Impact Model					These cells provide information about the proposed Offset Actions			Calculations can be made for a finite end point, or at five yearly time-steps over 35 years. Indicate preference in Column K and Follow the instructions in Column L		This section is where the marginal change in the measure of Biodiversity Attribute due to the Offset Action is quantified. Inputs are derived from direct measure, existing data or models where available, or expert estimated predictions. Attribute Biodiversity Value at the Offset Site is compared to the Attribute Biodiversity Value at the Impact Site to calculate the Net Present Biodiversity Value for each Attribute						This is the average Net Present Biodiversity Value for the Biodiversity Component
	Biodiversity Component	Biodiversity Attribute		Measurement Unit	Benchmark	Proposed Offset Actions	Offset area (ha)	Confidence in Offset Actions			Measure prior to Offset	Measure after Offset	Time till endpoint (years)	Biodiversity Value at Offset Site	Biodiversity Value at Impact Site	Attribute Net Present Biodiversity Value	Component Net Present Biodiversity Value
0.3	WF14	0.3a	35	%	85	Integrated Pest Management	1	Very confident >90%	Five yearly time-step	Switch to Offset Model_5 yearly					-0.03	0.02	0.02
		0.3b	10	%	85	Integrated Pest Management	8	Very confident >90%	Five yearly time-step	Switch to Offset Model_5 yearly					-0.42	0.03	

WF14 5 Yearly Offset Model

The marginal change in the measure of Biodiversity Attribute due to the Offset Action is predicted for each time-step. Inputs are derived from direct measurement (Attribute measure prior to Offset), existing data or models where available, or expert estimated predictions (Attribute measure post Offset). Attribute Net Present Biodiversity Value is then calculated for each time-step.

	Measure prior to Offset	Measure at YEAR 1	NPBV at Year 1	Measure at YEAR 5	NPBV at Year 5	Measure at YEAR 10	NPBV at Year 10	Measure at YEAR 15	NPBV at Year 15	Measure at YEAR 20	NPBV at Year 20	Measure at YEAR 25	NPBV at Year 25	Measure at YEAR 30	NPBV at Year 30	Measure at YEAR 35	NPBV at Year 35
0.3a	44.00	44.50	-0.03	46.50	-0.01	50.25	0.02	55.00	0.06	62.50	0.10	70.00	0.14	75.00	0.17	77.00	0.18
0.3b	44.00	44.50	-0.38	46.50	-0.22	50.25	0.03	55.00	0.30	62.50	0.67	70.00	1.00	75.00	1.18	77.00	1.24