OPUS

Waikato Expressway - Hamilton Section

Bat Management Plan

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1 Introduction

This Bat Management Plan (BMP) has been prepared by Opus International Consultants (Opus) for the New Zealand Transport Agency (Transport Agency) to comply with Waikato District Council (WDC) designation and Waikato Regional Council (WRC) resource consent conditions required to permit the construction and operation of the Hamilton Section of the Waikato Expressway (the Project). The BMP has been developed as a separate management plan to accompany the Ecological Management and Restoration Plan (EMRP) for the Project. Baseline bat monitoring work that forms part of the BMP commenced in the summer of 2014/15 and is ongoing. Part of the purpose of the baseline monitoring is to inform the development of the BMP and the data that has been collected and analysed to date has been used in the preparation of the plan.

The Transport Agency will have overall responsibility for the implementation of the BMP during the construction and operation phases of the life of the Project. The City Edge Alliance (Alliance) is responsible for the construction of the Project and will work under the terms of the BMP during the construction phase of the Project.

2 Project Description

The Waikato Expressway project will improve safety and reliability and reduce travel times and congestion on SH1 by delivering a four-lane highway from the Bombay Hills to south of Cambridge. The Expressway is being built in seven sections providing 102km of continuous divided four-lane highway and reducing the length of State Highway 1 by 6km. It will provide a further 12km of new or upgraded links and a new bridge over the Waikato River north of Hamilton. The Expressway will improve economic growth and productivity for Auckland, Waikato, and the Bay of Plenty through more efficient movement of people and freight. Increased capacity will make the route safer and will move through-traffic away from smaller communities like Huntly, Ngaruawahia and Cambridge. This will reduce congestion in those townships and provide journey time savings to through traffic of up to 35 minutes. The Expressway will provide route safety and faster travel times for tourists driving between Auckland and popular sites in Waitomo, Taupo, Rotorua and further south.

The benefits of the Waikato Expressway are:

- improve economic growth and productivity for Auckland, Waikato and Bay of Plenty through more efficient movement of people and freight between Auckland, Hamilton, Tauranga and Rotorua;
- improve the reliability of the transport network through a more robust and safer road between Auckland, Hamilton, Tauranga and Rotorua;
- reduce travel times between Waikato and Auckland; and
- support the growth strategy for the central Waikato.

The individual sections of the Expressway are at the stages described below (as at July 2014):

- Pokeno and Mercer Sections totalling 22.6km are completed and open.

- Longswamp section of 5.9km. Construction due to commence 2016. Target opening late 2018.
- Rangiriri Section of 4.4km. Under construction. Opens late 2016.
- Ohinewai Section of 7.0km is completed and open.
- Huntly Section of 15.2km. Under construction. Target opening 2020.
- Ngaruawahia Section of 12.3km. Completed and opened December 2013.
- Te Rapa Section of 7.3km. Completed, opened December 2012.
- Hamilton Section of 21.8km. Under construction. Target opening 2020.
- Tamahere Interchange of 2.4km is complete and open.
- Cambridge Section of 16km. Completed and opened late 2015.

The Hamilton Section (Figure 1) is a greenfield development located on the eastern side of the city of Hamilton compromising approximately 22km of 2 lane dual carriageway. It will connect with Ngaruawahia Section to the north, and the existing Tamahere Interchange to the south.

3 Designation & WRC Resource Consent Conditions

3.1 Summary of Conditions

There are a number of sets of conditions relating to bats that apply to various parts of the Hamilton Section:

3.1.1 WDC Designation Conditions

- Tamahere East-West Link (30th June 2014) – Conditions 7.4i and 7.4j

This is the only part of the Hamilton Section that is the subject of designation conditions relating to bats.

3.1.2 WRC Resource Consent Conditions

- Main Expressway alignment – AUTH 130361.01.01 (25th July 2014) - Condition 48 f)
- Tamahere East-West Link – AUTH 130382.01.01 (21st August 2014) - Condition 42 e)
- Ruakura Interchange – AUTH 133855.01.01 (15th January 2015) - Condition 48 f)

The WRC conditions relating to bats that apply to the Ruakura Interchange are the same as those that apply to the main Expressway alignment. The conditions that apply to the Tamahere East-

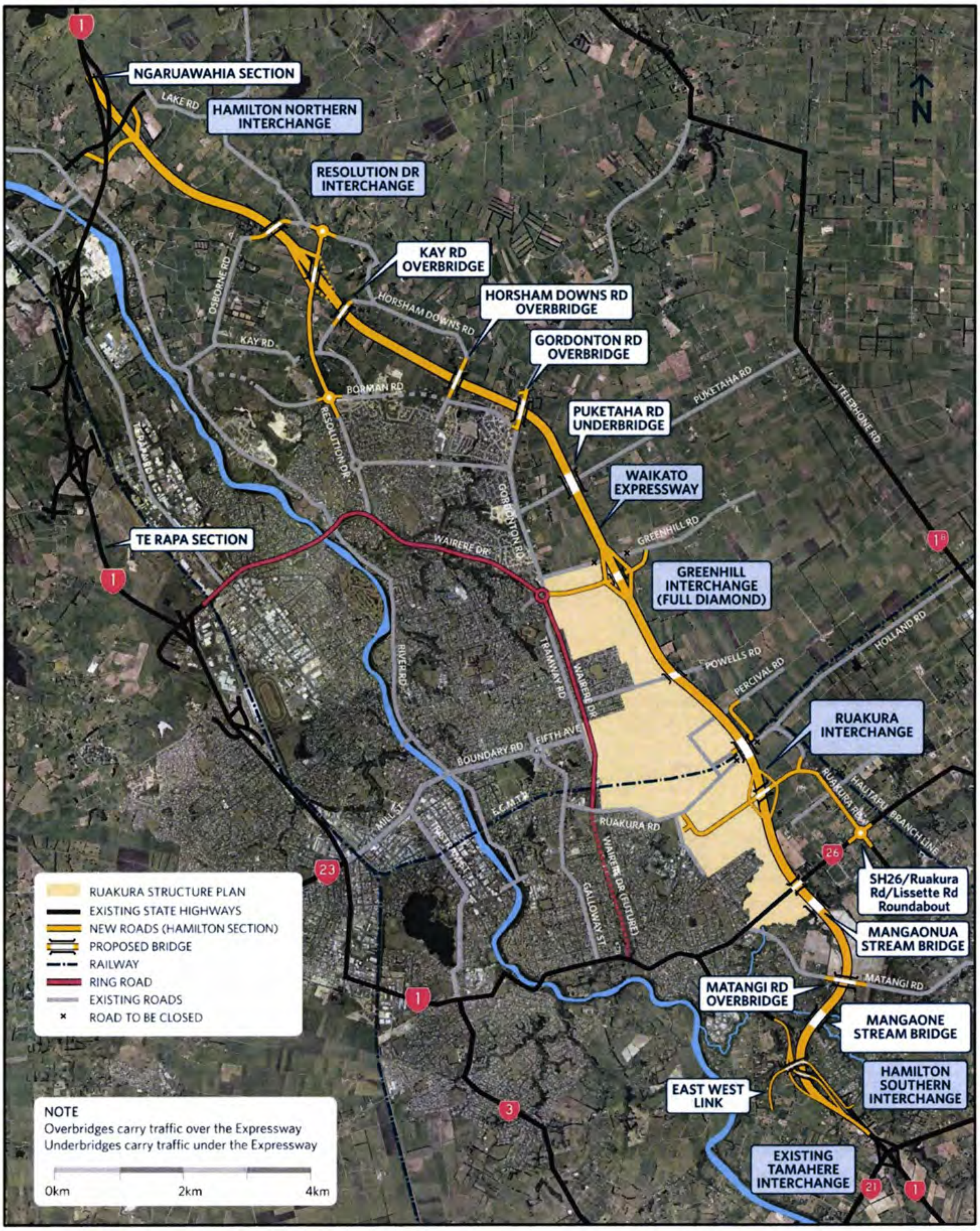

Figure 1: Waikato Expressway – Hamilton Section

West Link are essentially the same as those applying to the main Expressway alignment except for conditions 42e)iii), 42e)vi),42e)vii) and 42e)viii) (AUTH 130382.01.01), which have slightly different wording in the equivalent part of Condition 48 f) (AUTH 130361.01.01).

3.2 Compliance with WDC Designation Conditions for the Tamahere East-West Link

Table 1 states the designation conditions relating to bats that apply to the Tamahere East-West Link and details how the condition has been complied with, referencing the appropriate section of the BMP where applicable.

Table 1. WDC Designation Conditions for the Tamahere East-West Link and compliance

Designation Condition	Compliance
7.4i) A Long-Tailed Bat Management and Monitoring Plan (LTBMMP) which shall be prepared by an appropriately qualified and experienced bat ecologist following consultation with the Department of Conservation. The purpose of the LTBMP shall be to minimize impacts on bats and their habitat during construction and operation of the Tamahere East-West Link Road using best practice techniques and mitigate and compensate for the direct loss of foraging, roosting and flyway habitat using best practice techniques. The LTBMMP shall include but not necessarily be limited to the following:	
i. Details of how the bats will be protected from light generated by road construction and operation;	Addressed through lighting design and control of light operation during construction. BMP section 5.6
ii. Details of the proposed methods of installation of metal bands around the trunks of potential roost trees maintained within the restoration area, including but not limited to the three kahikatea trees next to the embankment;	BMP section 5.11
iii. Details of measures to reduce the barrier effect of the road embankment and reduce mortality from bats colliding with cars as they cross the embankment. Possible mitigation methods are creating "hop overs" for bats with planting and, or earthworks; and using downward pointing street lights to discourage bats from flying low across the road;	Addressed through landscape and lighting design. BMP sections 5.4 to 5.6 & 5.9

iv. Details of the proposed methods for developing, testing the effectiveness of and deploying artificial roost houses to replace potential roost trees that will be felled;	Artificial roost house will be installed prior to site clearance. BMP section 5.2
v. Details of proposed on-going monitoring of bat activity within the gully to assess and quantify any negative or positive effects of the road and the gully restoration project;	Bat monitoring methodology and reporting. BMP section 6.0
vi. Adaptive monitoring and evaluation approaches shall be integrated into the Long-tailed Bat Management and Monitoring Plan to ensure regular feedback and allow management to adapt to changing conditions found during monitoring;	Bat monitoring methodology and reporting. BMP section 7.0
7.4j) A finalised pre-tree felling protocol shall be prepared following consultation with the Department of Conservation. The purpose of the finalised pre-tree felling protocol shall be to avoid the injury or mortality of roosting long-tailed bats. A draft set of pre-tree felling protocols is included as Attachment B to these conditions. These protocols shall be adopted unless new best-practice protocols are developed and approved by Waikato District Council.	Tree removal protocols. BMP section 4.0

3.3 Compliance with WRC resource consent conditions

Table 2 states the resource consent conditions relating to bats that apply to the main Expressway alignment and the Ruakura Interchange and details how the condition has been complied with, referencing the appropriate section of the BMP where applicable.

Table 2. WRC resource consent conditions and compliance

Resource Consent Condition	Compliance
48 f) The consent holder shall engage an appropriately qualified and experienced bat ecologist to develop a Bat Management Plan. This plan shall address mitigation to be undertaken within, and near, the road footprint to avoid, remedy or mitigate any adverse effects from the construction and operation of the road on long-tailed bats and include, but may not be limited to, the following:	
i. Details of measures to avoid, minimise and monitor roost removal and habitat loss (including specific minimum standards	Tree removal protocols

developed by an appropriately qualified and experienced bat ecologist for roost tree identification and monitoring of roost trees before their removal, recognising the limitations for determining roost tree occupancy in some situations), as well as habitat replacement and enhancement;	BMP section 4.0 Habitat replacement and enhancement addressed through the GRIP's (Appended to EMRP) and proposed planting in the East-West Link Gully. BMP section 5.5
ii. Details of the provision of alternative roosting sites (including where possible advanced planting of indigenous or exotic trees for roost habitat) and artificial bat roosts, that are considered suitable for that purpose by an appropriately qualified and experienced bat ecologist, installed at least six months prior to the removal of trees where bat roosts are likely to occur along the alignment;	Artificial bat roosts will be installed prior to site clearance. BMP section 5.2
iii. Details of measures to minimise habitat fragmentation and other barriers to bat movement. Possible mitigation methods include the creation of bat crossing points such as "hop-overs" for bats to be formed with planting and/or earthworks, installation of bridge/tunnels/culverts, reducing the effect of road lighting by creating 'dark zones' at key bat habitats, aligning street lights in particular ways or the installation of baffles on lighting columns to reduce the 'spill' of light away from the road, accepting that lighting design for the benefit of bat movement must not conflict with the primary function of lighting for safety reasons along the Expressway;	Addressed through landscape and lighting design. BMP sections 5.4 to 5.6 & 5.9
iv. Details of measures to reduce mortality of bats from potential collisions with vehicles as bats travel along flyways that cross the Expressway. Possible mitigation methods could include the creation of "hop-overs" for bats, as outlined above, and the use of downward-oriented street lights to discourage bats from flying low across the road, the establishment of buffer zones along the Expressway route during and after construction (e.g. hedgerows) to encourage bat avoidance of the road and maintaining important bat flyway navigational references, if deemed appropriate by an appropriately qualified and experienced bat ecologist;	Addressed through landscape and lighting design. BMP sections 5.4 to 5.6 & 5.9
v. Details of measures to minimise disturbance from construction activities within the vicinity of any active roosts that are	Tree removal protocols

discovered, or already known, until such roosts are confirmed to be vacant of bats, as determined by an appropriately qualified and experienced bat ecologist using current best practice;	BMP section 4.0
vi. Details of a monitoring programme to identify and assess changes in bat activity and behavioural patterns that may occur as a result of construction and operation of the Hamilton Section of the Waikato Expressway at all locations where bats are detected during comprehensive pre-construction baseline distribution surveys required by Section 48(f)(vii). The monitoring programme should be sufficiently robust to inform the mitigation design and subsequent assessment of the effectiveness of mitigation;	Bat monitoring methodology and reporting. BMP section 6.0 and 7.0
vii. Pre-construction baseline distribution surveys shall include surveys using appropriate techniques to assess bat distribution and behaviour within areas of potential bat habitat along the entire Hamilton Section of the Waikato Expressway alignment. A minimum of two surveys shall be undertaken during the months of November to April inclusive for a minimum of two monitoring seasons, immediately prior to construction commencing. Monitoring for the surveys should take place on nights when the temperature remains above ten degrees for the first two hours after sunset and little precipitation occurs. Temperature and precipitation must be recorded;	Bat monitoring methodology and reporting. BMP section 6.1.1
viii. The consent holder shall engage an appropriately qualified and experienced bat ecologist(s) to assess and report on the effectiveness of measures to avoid, remedy and mitigate effects on the bats resulting from the establishment of the Hamilton Section of the Waikato Expressway. Such monitoring shall occur annually during the months of November to April inclusive, as a minimum, and the monitoring data shall initially be assessed and reported on annually for the first five years from the commencement of works authorised by this resource consent, and thereafter at five- yearly intervals for a period of 15 years from the commencement of works authorised by this consent. Where measures are found to be ineffective, the ecologist(s)	Bat monitoring methodology and reporting. BMP section 6.0 and 7.0

shall make recommendations for additional measures to avoid, remedy and mitigate effects resulting from the establishment of the Hamilton Section of the Waikato Expressway. Reports shall be provided to Waikato Regional Council and the Department of Conservation within two months of the completion of each assessment, and the matters contained within these reports shall be considered in accordance with the procedures for review of the EMRP required by condition 48e);	
ix. The consent holder shall implement the recommendations made by the ecologist referred to in condition 48(f)(viii) which are specified in the EMRP following review in accordance with condition 48(e) where it is practicable to do so.	BMP section 7.0

Table 3 states the WRC resource consent conditions 42e)iii), 42e)vi), 42e)vii) and 42e)viii) (AUTH 130382.01.01), which apply to the East-West Link only and that have slightly different wording to the equivalent conditions detailed in Table 2.

Table 3. WRC resource consent conditions applicable to East-West Link only

Resource Consent Condition	Compliance
42 e)	
iii. Details of measures to minimise habitat fragmentation and other barriers to bat movement. Possible mitigation methods include the creation of bat crossing points such as "hop-overs" for bats to be formed with planting and/or earthworks, aligning street lights in particular ways or the installation of baffles on lighting columns to reduce the 'spill' of light away from the road, accepting that lighting design for the benefit of bat movement must not conflict with the primary function of lighting for safety reasons along the Link Road.	Addressed through landscape and lighting design. BMP section 5.4 to 5.6
vi. Details of a monitoring programme to identify and assess changes in relative levels of bat activity that may occur as a result of construction and operation of the Link road at all locations where bats are detected during comprehensive pre-construction baseline distribution surveys required by Section 42e) vii). The monitoring programme should be sufficiently robust to inform the mitigation	Bat monitoring methodology and reporting. BMP section 6.0

design and subsequent assessment of the effectiveness of mitigation;	
vii. Pre-construction distribution surveys shall use appropriate techniques to determine baseline levels of bat activity, and to allow accurate assessment of any future changes in relative levels of bat activity along the Link road alignment. A minimum of two surveys shall be undertaken during the months of November to April inclusive for a minimum of two monitoring seasons, immediately prior to construction commencing. Monitoring shall also be conducted during construction, twice per year during the months of November to April inclusive. Surveys should take place on nights when the temperature remains above ten degrees for the first two hours after sunset and little precipitation occurs. Temperature and precipitation must be recorded.	Bat monitoring methodology and reporting. BMP section 6.1
viii. The consent holder shall engage an appropriately qualified and experienced bat ecologist(s) to assess and report on the effectiveness of measures to avoid, remedy and mitigate effects on bats resulting from the establishment of the Link Road. Such monitoring shall occur annually during the months of November to April inclusive, as a minimum, and the monitoring data shall be initially assessed and reported on annually for the first five years from the commencement of works authorised by this resource consent, and thereafter at five- year intervals for a period of 15 years from the completion of works authorised by this consent. Where measures are found to be ineffective, the ecologist(s) shall make recommendations for additional measures to avoid, remedy and mitigate effects resulting from the establishment of the Link Road. Reports shall be provided to Waikato Regional Council and Department of Conservation within two months of the completion of each assessment, and matters contained within these reports shall be considered in accordance with the procedures for review of the EMRP required by condition 42d).	Bat monitoring methodology and reporting. BMP section 6.0 and 7.0

4 Tree Removal Protocol

4.1 Introduction

This protocol applies to all trees to be felled as part of construction of the Hamilton Section of the Waikato Expressway.

The protocol aims to:

1. Provide clear, concise procedures that are to be followed prior to removal of all trees along the alignment, with the goal of avoiding mortality or injury to long-tailed bats during the tree removal process;
2. To locate long-tailed bat colonial (and where possible, solitary) roost trees that exist within the alignment prior to removal; and
3. To avoid felling of trees with potential bat roosts wherever possible, and to avoid accidentally felling trees with active bat roosts completely

There are three protocols that will be used:

Protocol A: Identification of Potential Bat Roost Habitat;

Protocol B: Pre-Felling Procedures; and

Protocol C: Bat Injury or Mortality

4.2 Roost Tree Features and Definition

4.2.1 High Risk Trees

For the purposes of this protocol, trees offering High Risk potential as bat roosts are defined as being >15cm DBH, and will have one or more of the following features:

- Cracks, crevices, cavities and/or fractured limbs large enough to support roosting bat(s)
- Sections of loose flaking bark large enough to support roosting bat(s)
- A hollow trunk, stem or branches
- Deadwood in canopy or stem of sufficient size to support roost cavities or hollows
- Bat droppings, grease marks and/or urine staining around cavities

4.2.2 Low Risk Trees

Trees with evidence of bat droppings, grease marks and/or urine staining around cavities should be noted and investigated as probable roost trees regardless of size. However, all trees <15cm DBH that lack such obvious sign of bat roosting may be felled immediately, without the need for further assessment or monitoring, and without the need for an approved ecologist to be present.

4.2.3 Dusk & Dawn Definition

For the purposes of this protocol Dusk and Dawn are defined as official civil dusk and dawn times.

4.2.4 Approved ecologists

All pre-felling tree assessments, assessment of acoustic monitoring data and assessment of behavioural observations will be made by an appropriately qualified and experienced bat ecologist. The approved bat ecologist will have demonstrable experience in finding long-tailed bat roosts and in handling bats. A document listing several ecologists and detailing the experience and qualifications relevant to enacting the requirements of this Tree Removal Protocol is attached to the BMP (Appendix E).

4.3 Protocol A: Identification of Potential Bat Roost Habitat

1. All trees (individuals and stands) to be removed along the entire alignment will be surveyed and assessed prior to tree removal as either High Risk or Low Risk in terms of providing potential bat roost habitat by the project team.

2. All High risk trees shall be subjected to pre-felling assessment as per Protocol B. Pre-felling tree assessments and acoustic monitoring (see Protocols B for details) shall be undertaken by an appropriately qualified and experienced ecologist approved by WRC.

3. All Automated Bat Monitor (ABM) data gathered during pre-felling survey shall be reviewed the same morning the survey specified in Protocol B ends. All data must be reviewed on the same day giving the tree fellers sufficient time to fell trees prior to dusk if no bats are recorded.

4.4 Protocol B: Pre-Felling Procedures

1. High Risk trees will only be removed between October 1st and April 30th. No High Risk trees will be felled outside this period unless prior permission is obtained from WRC.

2. All Low Risk trees may be felled at any time without the need for acoustic survey or for an ecologist to be present.

3. The approved ecologist should be on site for removal of all High Risk trees. The approved ecologist is not required to be present for removal of Low Risk trees but should be available if their presence becomes necessary due to discovery of bats.

4. All High Risk trees or areas of High Risk trees to be removed will be clearly marked by the approved ecologist in advance of removal. To determine roosting, High Risk trees will be acoustically monitored with ABMs overnight (between 1 hour before official dusk to one hour after official dawn) for a minimum of three nights immediately prior to removal, which may be non-consecutive depending on weather conditions. Overnight weather conditions during this time must include:

    a) Overnight temperatures not less than 7 degrees Celsius;

    b) Mean overnight wind speed not greater than 20 km/h;

    c) Maximum overnight wind gust of 60 km/h; and

d) No more than 2.5mm of rain in the first 2 hours after dusk.

5. No monitoring should take place during full moon, or 1 night either side of full moon. Where a night of monitoring is lost to adverse weather, a further night of monitoring must take place to compensate, until a total of 3 nights of monitoring is achieved.

6. Where existing monitoring data indicates that roosting bats may be present such as the Mangaonua, Mangaone/Mangaharakeke and East-West Link gullies, the approved ecologist may decide not to undertake acoustic monitoring but to assume roosting bats may be present. In this case the procedure described in item 10 below will be adopted, with each High Risk tree to be felled being assessed for bat roosts.

7. High Risk trees in the wider landscape will be monitored with ABMs placed appropriately as determined by the approved ecologist.

8. All Automated Bat Monitor (ABM) data gathered during pre-felling survey shall be reviewed the same morning the survey specified in Protocol B ends. All data must be reviewed on the same day giving the tree fellers sufficient time to fell trees prior to dusk if no bats are recorded.

9. If no bats are sighted or detected, or if no bat activity is detected on the last 2 out of 3 valid monitoring nights, the ecologist shall inform the Alliance Construction Site Manager or Environmental Manager within 1 hour of reviewing the data to give permission for the affected tree(s) to be felled.

10. If bat activity patterns suggest the possibility that bats are roosting in the vicinity of the ABM, or if a bat roost is observed, the approved ecologist shall inform the Alliance Construction Site Manager or Environmental Manager within 1 hour after reviewing the data or of observing the roost that the affected tree(s) cannot be felled until further investigations of the trees have been undertaken. If considered appropriate by the approved ecologist, likely roost trees will be climbed by an arborist trained to identify bat roosts, and photographs taken of any roosts or roost evidence found. If necessary an endoscope will be used to examine potential roost features suspected of housing bats. If climbing is not considered appropriate, the tree or trees may be observed with a thermal imaging camera over the first 2 hours following dusk and the 4 hours prior to dawn on the next valid night, to observe bats leaving or entering a roost within the tree or group of trees. If the check or observation reveals no roost is present the Alliance Construction Site Manager or Environmental Manager will be informed that the tree can be felled on the day of climbing inspection or the day following nocturnal thermal observation.

11. If bats are confirmed to be roosting within the tree, it will not be removed until further monitoring confirms that the bats have abandoned the roost. The following actions will be taken:

    a) The immediate area will be cordoned off with safety fencing and signage erected in a 10m radius around the roost, alerting any person approaching the area that a bat roost is present and to stay clear.

    b) The existence of the roost will be widely publicised to all construction staff and work instructions for the immediate area will be updated to reflect the presence of the roost and the measures to minimise disturbance.

c) All adjacent construction activities (within 100m) will be assessed for noise and vibration and where in the opinion of the approved ecologist the method of construction may disturb the roost, steps will be taken to eliminate, isolate, or minimise the disturbance wherever possible.

d) No work will take place within 100m of the roost from 1 hour before official dusk to 30 minutes after official dawn unless approval is given by the WRC & WDC.

12. Roost trees should be clearly marked and all relevant staff briefed to ensure the tree is not removed. Representatives of the TWWG, DOC, WRC (& WDC, if associated with the East-West Link Gully) will be informed by email within 1 working day, with relevant information such as photos provided. Acoustic monitoring will continue for a further 7 nights.

13. If bats are still roosting in the tree after 7 nights, the approved ecologist will contact the Alliance Environmental Manager, and representatives of the TWWG, DOC, WRC (& WDC, if associated with the East-West Link Gully), and a meeting or teleconference held within 3 days to decide an appropriate way forward. Appropriate measures may include sectioning the tree and relocating the bat roost once bats have vacated.

14. Any High Risk trees felled using a chainsaw will be inspected for bat roost sign by the approved ecologist following felling.

4.5 Protocol C: Bat Injury or Mortality

1. Any living bats found during felling will be taken to a vet immediately for assessment. Bats will be placed in a cool, dark cotton bag by or under the direction of the approved ecologist to ensure the animal is handled appropriately. Dr Andrew Gore at Hamilton Zoo should be the initial contact person.

   Dr Andrew Gore
   Hamilton Zoo
   Brymer Road
   Hamilton
   07 838 6720

2. The Alliance Environmental Manager, representatives of the TWWG, DOC (Waikato Area Office (WAO) or DOC hotline if after hours), WRC & WDC should be contacted no longer than 2 hours after an injured or dead bat is found.

   Waikato Area Office - 07 858 1000
   After Hours - 0800 DOCHOTline (0800 362 468)

3. Any bat that is found dead or injured and subsequently euthanised will be returned to:

   DOC Waikato Area Office, Northway St, Te Rapa.

   The Wildlife Act requires that in the first instance the bat is returned to DOC.

4. Bats assessed by the vet as uninjured will be transported back to site in the cotton bag and placed in an open, temporary artificial roost box suspended within a tree as close as possible to the site the animal was found, but outside the alignment. The roost box will be open to allow

the animal/s to come and go as they choose, and will be placed within the tree prior to dusk on the same day the bat is found.

5 Mitigation

5.1 Locations of bat activity

Five separate baseline surveys have been carried out along the Hamilton Section alignment between 2011 and 2016. To date, 3 reports detailing findings of these surveys have been produced (Le Roux 2012; Connolly 2015; Deakin, 2016; see Appendix A). A fourth report is in draft form and is intended for release in early July 2016. The results of these surveys have confirmed and highlighted the importance of the Mangaonua, Mangaharakeke, Mangaone and East-West Link gullies as foraging and commuting habitat for long-tailed bats in the south Hamilton landscape, with consistently high activity levels recorded at most sites surveyed within the gullies. Bat activity has also been detected at Lake Road (a single pass in 2016), with moderate activity also detected around a pond at Gordonton Road in 2016. Most of the mitigation efforts will focus on Mangaonua, Mangaharakeke, Mangaone and East-West Link gullies and areas immediately adjacent, where most bat activity has been recorded, with some mitigation to take place at Gordonton Road.

5.2 Artificial Bat Roosts

The installation of artificial bat roosts is required by both WDC Designation and WRC Resource Consent conditions, and this will be undertaken to provide short-term replacement of potential roost habitat that will be lost once tree clearance is completed.

5.2.1 Roost type

WDC Designation condition 7.4 iv requires –

> "*Details of the proposed methods for developing, testing the effectiveness of and deploying artificial roost houses to replace potential roost trees that will be felled*".

WRC Resource Consent condition 48 f) ii requires –

> "*Details of the provision of alternative roosting sites (including where possible advanced planting of indigenous or exotic trees for roost habitat) and artificial bat roosts, that are considered suitable for that purpose by an appropriately qualified and experienced bat ecologist…*"

Information on the effectiveness of artificial bat roost designs for long-tailed bats is extremely limited. Several bat box designs have been installed at sites in New Zealand, mostly with the intention of supplementing a perceived localised shortage of bat roost habitat. These include –

- A timber 'Kent' bat box design (Auckland Council);
- A timber 'Microbat box' design (Auckland Council);
- A bespoke timber design similar to the 'Kent' (Waikato Regional Council); and

- Four Schwegler 'woodcrete' designs (models 2F, 2FN, 1FF and 1FD - Department of Conservation, South Canterbury)

None of these types have been experimentally tested for effectiveness in New Zealand, and monitoring for occupancy once installed has been irregular or non-existent. However long-tailed bats were confirmed to make intermittent use of all four of the Schwegler types in South Canterbury after several years following installation. Of the 96 Schwegler boxes installed (24 of each type), bats have been recorded using 10 (three each of the 2F, 1FF and 1FD types; one of the 2FN type) (D. Anderson, C. O'Donnell, pers. comm.). No conclusions have been drawn as to preference between Schwegler types, however these designs remain the only known artificial bat roosts to have been used by long-tailed bats.

A recent literature review by Rueegger (2016) highlighted the worldwide shortage of robust information to inform the effectiveness of artificial bat roosts. Rueegger found that very few bat species use bat boxes regularly, with even fewer using them frequently to breed. This shortage of information extends to New Zealand, where several recent major infrastructure projects have consent conditions imposed requiring the installation of such boxes in mitigation for the loss of potential bat roost habitat despite the lack of research demonstrating their effectiveness for long-tailed bats. Rueegger (2016) concludes that while artificial bat roosts are one of very few mitigation options available, for species that show a reluctance to use bat boxes, species-specific research is required to identify design elements that might maximise their use. The design and robust testing of options specifically suitable for long-tailed bats would require several years, incorporating variables such as the availability of natural roosts in the wider landscape, density of predators, natural roost site characteristics, and specifics of competition or exclusion by other taxa.

Given the proven success of Schwegler boxes with similar species in Europe, their demonstrated use by long-tailed bats in South Canterbury, and the durability of their woodcrete material, Schwegler 2F boxes are the preferred design to be installed at sites along the Hamilton Section of the Waikato Expressway. This project provides an opportunity to test the effectiveness of these roosts in the Waikato landscape. Four Schwegler 2F artificial bat roosts will be installed within each of the Mangaonua, Mangaharakeke, Mangaone and East-West Link gullies, for a total of 16 artificial roosts. The roosts will be mounted to exclude predators, particularly rats and possums, using aluminium sheets mounted behind the roost against the tree.

The artificial roosts will be installed in habitat suitable for bat roosting, including -

- At a minimum height of 4 metres from the ground on an appropriate tree, with no clutter within 2m of the roost opening; and

- Within each gully, one artificial roost to be mounted facing north, one south, one east and one west.

Where possible these locations will be in close proximity to the location of the during- and post-construction bat activity monitoring devices. Obtaining permission to access land and install the roosts will influence where they can be located. The physical location of each bat house will be fully described and each bat house will be inspected for occupancy once yearly at the same time as the annual bat activity monitoring occurs. A record will be made of all bat houses occupied by bats, and all bat houses where evidence of prior use is found (e.g. presence of bat droppings). These observations will be reported in the annual bat monitoring report. The target completion date for the installation of the bat houses is the31st of July 2016.

5.2.2 Artificial roost numbers

The number of artificial bat roosts chosen for each of the Hamilton Section gullies is consistent with the number agreed by WRC for other sections of the Waikato Expressway, including Cambridge Section. In the Karapiro Gully for example, approximately 3 ha of potential bat roost habitat of a similar nature to that within the Hamilton Section gullies was cleared. The Cambridge Section BMP specified that 10 Schwegler artificial bat roosts would be installed at the Karapiro Gully in mitigation for this loss of potential roost habitat – contributing approximately 3.3 artificial roosts per hectare of potential bat roost habitat clearance. The corresponding figures for Hamilton Section are seen in Table 3.

Table 3. Density of of artificial roosts per hectare of clearance for Hamilton Section.

Gully	Potential roost habitat to be cleared (approx.)	Number of artificial roosts to be installed	**Artificial roosts per hectare of clearance**
Mangaonua	1.0 ha	4	**4.0**
Mangaharakeke/Mangaone	2.2 ha	8	**3.6**
East/West link	0.8 ha	4	**5.0**

The combined addition of artificial bat roosts and extensive additional natural bat roost habitat mitigates for the potential roost habitat being cleared within the gullies.

The effectiveness of the artificial roosts will be determined qualitatively by annual roost checks. Monitoring will provide information on:

a) Whether bats make use of the roosts at all;
b) Length of time to first use by bats;
c) Number and location of roosts occupied;
d) Whether a preference for aspect of the roost is observed;
e) Whether roost competition is found from other taxa (birds, invertebrates).

Simple non-parametric analysis may be undertaken to investigate factors such as preference for roost aspect, if bats make use of the artificial roosts.

However monitoring will not extend beyond this. A thorough, scientifically robust investigation into the effectiveness of artificial bat roost design in relation to a particular bat species would require an extensive research programme, to gather information on all confounding variables likely to influence artificial roost use. For example, relevant confounding variables that may affect the use of any design of artificial roost by long-tailed bats include:

- Population dynamics of long-tailed bats in the landscape;
- Quality and quantity of existing available roost habitat in the landscape;
- Predation pressure at all roost sites; and
- Behaviour of long-tailed bats in relation to various artificial roost design features.

Gathering robust information on each of these factors, and accounting for their influence on roost uptake would represent several years of intensive work and is clearly beyond the scope of this project. Attempting to answer such questions as part of this project would be significantly complicated by the simultaneous construction and eventual operation of the Hamilton Section road and associated structures, which in itself may potentially affect the use of artificial roosts by long-tailed bats. Such a body of work should be undertaken in isolation from these potential effects and would be more appropriately dealt with in an independent body of work aiming to answer fundamental questions regarding the effects of roads on New Zealand bats.

Given that international literature suggests artificial roosts are of limited value in similar infrastructure projects overseas, and the limited resources available to attempt to answer such complex questions on a project such as the Hamilton Section, it makes more sense to focus mitigation efforts on measures that are more likely to result in tangible benefits to long-tailed bats.

5.3 Loss and gain of potential gully roost habitat

Detailed design has not yet progressed to the point where a final decision can be made on whether individual trees will or will not be removed. However approximate areas of potential roost habitat to be lost within the gullies are as follows.

5.3.1 Mangaonua Gully

It is likely that construction of the bridge across the Mangaonua Gully will require the mechanical clearance of approximately 1 hectare of predominantly mature willow habitat from the area beneath and immediately surrounding the bridge (areas denoted as WFB, WFVC, SBUB, SBOS in the GRIP). No large mature trees will be removed on the northern gully edge with several large pines and eucalypts to be retained immediately either side of the designation. However several large kahikatea are likely to be removed from the south-eastern edge of designation within the gully base.

Long-tailed bats are known to roost in crack willows (*Salix fragilis*; Sedgeley & O'Donnell, 2004), grey willows (*Salix cinerea*; Dekrout, 2009) and kahikatea; therefore this represents the loss of approximately 1 ha of potential roost habitat.

1 ha is approximately 0.7% of the entire Mangaonua Gully system.

5.3.2 Mangaharakeke/Mangaone Gully

Approximately 1.1 hectares of fill is required in the northern arm of the Mangaharakeke gully. Vegetation to be cleared along the gully escarpments comprises a mixed canopy of mature indigenous and exotic species, including scattered emergent kahikatea, blackwoods and eucalypts. This represents potential bat roost habitat that will be lost.

Approximately a further 0.9 ha of potential roost habitat will be cleared from beneath and immediately surrounding the Mangaharakeke/Mangaone bridge, comprising mostly mature willows on the gully base and blackwood-dominated gully escarpments on the north and west faces.

This represents a total loss of approximately 2 ha of potential roost habitat, including approximately 100% of areas labelled WFB, SBUB & GEB, 50% of SBOS & WFVC, and 25% of WFP in the GRIP.

2.2 ha is approximately 0.6% of the total area within the Mangaharakeke/Mangaone Gully system.

5.3.3 Additional short-term roost habitat

The Gully Restoration Implementation Plan (GRIP) outlines the strategy for vegetative restoration of the gully areas surrounding the bridges over the Mangaonua, Mangone and Mangaharakeke gullies. Key strategies relevant to mitigation of bat habitat loss include:

1. Vegetation clearance will be kept to a minimum along the entire alignment;
2. Mature willows (and some other exotics where necessary) within those gully areas intended to undergo restoration will be poisoned and left in situ, and underplanting carried out;
3. Where possible, a number of trees earmarked for poisoning will be deliberately damaged by breaking branches with digger arms to create splits for potential bat roost habitat.
4. All dead trees within restoration areas will be retained.

A detailed description of the existing gully vegetation and habitat, the relevant restoration strategy for each habitat type and planting lists can be found in the GRIPs for each of the two major gully systems.

The GRIP strategy for restoration requires the retention of trees likely to offer bat roost habitat wherever possible. For example, aside from those relatively small areas undergoing vegetation clearance in the base of the Mangaonua and Mangaone/Mangaharakeke gullies, the extensive stands of willows adjacent will be poisoned, retained and underplanted, rather than mechanically removed. A similar approach will be taken to the canopy of mature blackwoods (*Acacia melanoxylon*) planned to be 'thinned' and underplanted on the northern gully escarpments of the Mangaharakeke gully.

These trees will take a decade or more to break down and decompose. In the meantime, trunks and branches will form cavities and hollow out, and will break and split. Long-tailed bats have shown a high propensity for roosting in dead trees in this type of landscape (Sedgeley & O'Donnell, 2004; Dekrout, 2009). This approach will result in a significant increase in the number of available roost crevices, hollows and splits in the short-medium term. This will at least partly fill the time lag between clearance of the relatively small area of low-quality potential roost habitat, and the natural formation of roost habitat that is likely to take place once exotic roost trees such as oaks and poplars reach an appropriate size.

In the Mangaonua Gully, approximately 1.5 ha of mature willow will be poisoned and left in situ, while in the Mangaonua/Mangaharakeke gullies this figure is approximately 0.9 ha, with further scattered blackwoods to be poisoned and retained on the gully escarpments. Sedgeley & O'Donnell (2004) found that 16% of trees sampled in highly modified rural and riparian habitat in South Canterbury contained cavities offering potential as roost habitat. It is reasonable to assume a similar proportion of trees to be cleared from the Hamilton Section gullies also include potential roost habitat.

Within Mangaonua Gully for example, approximately 1 ha of tree clearance will take place (representing approximately 0.7% of available habitat within the entire Mangaonua Gully system). If 16% of those trees offer potential habitat this means an area of approximately 0.16 ha (1,600 m^2) of potential roost tree habitat will be lost.

Approximately 1.5 ha (15,000 m^2) of willows will be poisoned and left in situ in the Mangaonua Gully areas marked WFP within the GRIPs. Assuming 0.24 ha (16%) of those willows already contributed potential roost habitat prior to poisoning, this leaves 1.26 ha. It is likely that most of those trees will form cavities, splits and other features conducive to roosting in a relatively short time frame as they decompose; however a very conservative figure of 50% could be used, totalling 0.63 ha of previously unavailable potential roost habitat. This represents a net gain of 0.47 ha of additional, natural, potential short-term roost habitat, or approximately 3 x the area of potential roost habitat to be cleared. A similar situation applies to the Mangaharakeke/Mangaone gullies.

Consideration of artificial cavity creation or initiation in living and/or dead exotic trees, by drilling holes, has been raised by DOC. This technique to facilitate cavity creation may be of benefit, however it is not known whether long-tailed bats would respond and make use of such features. The creation of artificial cavities is not proposed to be used as a form of mitigation on the Hamilton Section. The addition of such a mitigation measure would be highly experimental and should involve a robust monitoring regime in order to determine its effectiveness. To do so in the presence of so many confounding variables (the new road, the addition of artificial roosts, and the artificial creation of large areas of natural roost habitat with the poisoning and retention of willows and blackwoods) would simply add another variable to the mix and the effectiveness would be extremely difficult to determine. Given the small scale of loss of potential roost trees within the major gully systems in relation to remaining habitat (<1% will be cleared), and considering the extensive gain in potential short-term roost habitat as a result of the poisoning and retention of large areas of willows and blackwoods, this is considered sufficient mitigation.

5.3.4 Additional medium/long-term roost habitat

Extensive restoration planting is required under resource consent conditions and the draft Gully Restoration Implementation Plans (CityEdge Alliance, 2016) have been prepared to guide restoration planting at gully crossing sites in mitigation of ecological effects. The GRIP's are only draft at this point and will be finalised over the next few months as the planting areas are modified to reflect the final project design. However, the approach to planting and species selection is not expected to change significantly.

A number of tree species specified within the draft GRIP will potentially offer suitable bat roost habitat in the medium-long term and these trees will offset trees lost over this timeframe. These include kahikatea (*Dacrycarpus dacrydioides*), matai (*Prumnopitys taxifolia*), totara (*Podocarpus totara*), rimu (*Dacrydium cupressinum*), cabbage tree (*Cordyline australis*) and kanuka (*Kunzea ericoides*). These species are intended to be planted within the designation in the Mangaone, Mangaharakeke, Mangaonua and East-West Link gullies as specified in the draft GRIP.

Several exotic species known to offer suitable roost habitat are also specified – these include English oak (*Quercus robur*), Chinese poplar (*Populus yunnanensis*) and mess mate stringybark gum (*Eucalyptus obliqua*). These species in particular will develop roost features in a shorter timeframe than most native species and are included primarily for this reason.

A Landscape Management Plan (LMP) must be written under the Minimum Requirements, and this is intended to guide detailed planting specifications. As at June 2016 the LMP has yet to be finalised. Detailed planting requirements will need to be developed with liaison between the project ecologist and the Urban and Landscape Design Team Leader to determine other opportunities for including roost trees within the landscape design. The detailed placement of roost trees will need to be discussed and agreed with WRC, WDC and DOC as part of the consultation process associated with the LMP. It is likely that specific details within the LMP will need to be adjusted as Project Design progresses.

5.4 Minimisation of Habitat Fragmentation

The vast majority of bat activity was recorded within the Mangaonua, Mangaharakeke, Mangaone and East-West Link gullies, and it is in these gullies that potential for fragmentation of long-tailed bat habitat is greatest. As a result these gullies form the focus for minimising fragmentation.

5.4.1 Mangaonua & Mangaharakeke/Mangaone bridge underpasses

A key design feature of the Mangaonua and Mangaharakeke/Mangaone gully crossings is that these are being bridged with structures that are approximately 10m in height above the gully floor. These structures may assist in reducing fragmentation at these crossings by providing an opportunity for bats to pass under the road. The potential benefits in reducing bat habitat fragmentation was one of the factors considered when deciding on the method for crossing these gullies.

Many bat species are known to use underpasses beneath roads, with suggested minimum underpass heights of approximately 6m for edge-adapted species (Berthinussen & Altringham, 2012b). A key strategy within the GRIPs is to maintain free space leading into, beneath, and away from the gully bridges at the gully floor, to maintain a flight path following the waterway, and minimise the possibility of habitat fragmentation. To this end, for the gully base and lower escarpment slopes, the area directly beneath and out to 20m beyond the edge of the gully bridges will be planted with low-growth species only (approximate maximum 2m height); the area between 20m – 40m beyond the bridge will be planted with species up to 10m in height; and only beyond the 40m mark will the largest canopy species be planted.

Le Roux (2010) studied bat activity using acoustic monitors placed in two height tiers (4-7m, and 15-30m) associated with tree canopy heights, at two sites within and near Hamilton. Bats were detected by monitors placed within both height tiers. It is possible that long-tailed bats frequently fly at heights of 30m; however this is difficult to confirm using acoustic monitors, which may detect bats at a range of several tens of metres. Bats detected by monitors placed at a 30m height may actually have been flying much lower (or much higher).

Given the behaviours of edge-adapted species such as long-tailed bats, and based on observations, it is likely that individuals fly in reasonably close proximity to the canopy that is present, to aid both navigation (remaining close enough to detect the treeline using echolocation) and foraging (to maximise time spent where foraging success is most likely). For these reasons, a canopy that drops in height on approach and leading away from the bridges, and remains extremely low directly beneath, creates an underpass that may greatly reduce the chances of long-tailed bats flying above the bridge and into the path of vehicles using the bridges. It is intended to undertake behavioural observations in the coming season to further inform this (see sections 5.9 and 6.4).

5.5 Vegetation Retention and Planting

5.5.1 Mangaonua Gully

The GRIPs provide detail of all restoration planting locations, habitats and strategies within the Mangaonua Gully. A brief summary description follows:

As the road approaches the Mangaonua Gully from the north a cut will lower the road to approximately 10 metres beneath the gully edge. This will eliminate barriers to bat flight paths at that level; however it will also result in the bridge height being approximately 10m above the gully base. Several large kahikatea lie within the designation in the gully base and as many of these are required to be retained as possible. Planting under the bridge (Wetland on the Floodplain Under Bridge, WFB, GRIP)) will comprise mostly species such as toetoe (*Austroderia fulvida*), swamp coprosma (*Coprosma tenuicaulis*) and mingimingi (*Coprosma propinqua*), with 10% kahikatea (see section 5.4.1 regarding distance from bridges for larger species). The predominantly low-stature vegetation should allow a gap under the bridge sufficient to maintain a bat flight path.

Planting along the northern gully bank is specified within the GRIPs (South-facing Open Escarpment Planting, SFO, GRIP) and includes tall-growing species such as rimu, kahikatea, kanuka, rewarewa (*Knightia excelsa*), hinau (*Elaeocarpus dentatus*), totara and matai; other species offering reasonable height include tarata (*Pittosporum eugenioides*) and kohuhu (*Pittosporum tenuifolium*). Together these species will comprise approximately 40% of plantings that will take place in this planting area and will form a 'hop-over' along the northern bank that will line either side of the road, and force bats above the road corridor.

Planting along the southern bank (North-facing Embankment Planting Under Canopy, NFC; North-facing Open Embankment Planting, NFO, GRIP) will include a wide variety of tall-growing species including kauri (*Agathis australis*), kahikatea, rimu and totara, with other medium-height species including titoki (*Alectryon excelsus*), pigeonwood (*Hedycarya arborea*) and mahoe (*Melicytus ramiflorus*). Again these should provide a tall 'hop-over' canopy along the southern gully bank to encourage bats to gain altitude as they approach the bridge along the bank.

5.5.2 Mangaharakeke & Mangaone Gullies

The GRIPs provide detail of all restoration planting locations, habitats and strategies within the Mangaharakeke and Mangaone gullies. A brief summary description follows:

A cut of approximately 10m depth is planned for the approach to the northern bank of the Mangaharakeke Gully, again pushing the road corridor beneath potential gully-edge flight paths. The head of this section of gully will be filled and planting along the fill edge undertaken as 'Gully Escarpment Planting Under Canopy' (GEC, GRIP), which will include tall species such as totara, miro (*Prumnopitys ferriginea*), with medium-height pigeonwood and mahoe among others (again see section 5.4.1 regarding distance from bridges for larger species); however large exotic trees along the northern gully banks offering roost potential will be retained wherever possible. For the batter slopes, it is suggested that taller species should be planted at and near the gully base, and as the batter slope rises towards road level, shorter species should be gradually planted, while ensuring that those species at the road edge are still tall enough to form a canopy well above the traffic corridor. This is intended to establish a canopy that rises at a more gradual gradient than the slope on which it grows, reducing the potential for the embankment to act as a barrier to movement. These plantings should eventually provide sufficient height to minimise fragmentation to bat flyways along this section.

The road continues across a bridge at approximately 10m height above the gully floor, at approximately the confluence of the Mangaharakeke and Mangaone Gullies. Planting under the bridge will be primarily low-stature (WFB, GRIPs) and again should allow continuation of bat flight paths under both bridges.

Gully banks on both sides of the road in places heading south are a mix of Gully Escarpment Planting in Open Sites (GEO, GRIPs) and Bat Mitigation Planting (BM, GRIPs), each including a mix of tall species (kauri, rimu, kahikatea, hinau, totara in GEO; exotic species including oaks, poplars and eucalypts in BM, GRIPs). These will provide 'hop-over' habitat and represent a significant improvement over the current weed vegetation present.

5.5.3 East-West Link Gully

The East-West Link gully will be filled rather than bridged. The fill banks should be planted with a mix of sufficiently tall species to create a canopy that sits well above the traffic corridor directly alongside the road. Several kahikatea to the north of the crossing will be retained.

Designation condition 7.4 d) requires 2.6ha of gully restoration planting to be undertaken at the crossing, restoration of the road batter slopes and restoration of the stream riparian margin. This planting will be designed to provide alternative roost sites and reduce the fragmentation effects associated with the crossing. The specific details of the planting are in the process of being developed. However it is suggested that taller species should be planted at and near the gully base, and as the batter slope rises towards road level, shorter species should be gradually planted, while ensuring that those species at the road edge are still tall enough to form a canopy well above the traffic corridor. This is intended to establish a canopy that rises at a more gradual gradient than the slope on which it grows, reducing the potential for the embankment to act as a barrier to movement.

5.5.4 Gordonton Road

The detection of moderate levels of activity at a relatively isolated pond adjacent to Gordonton Road during surveys 3 and 4 (Deakin, 2016b) requires mitigation to be undertaken at that site.

The pond is sited to the south of the designation and for the most part, vegetation surrounding the pond will be retained. Approximately 80 m of hedgerow to the north will be removed. Vegetation at this site is almost entirely exotic. The head of the Huntington gully system within Hamilton City is approximately 1 km to the south-west and this seems the most likely habitat feature within the local landscape that may provide roost habitat. The Hamilton Section does not fragment connectivity with this gully system.

Planting will be undertaken along the southern edge of designation to screen vehicle lights from the pond area. A number of oaks and poplars will be planted along the designation edge to provide medium/long-term roost habitat. Given the very small size of the site available within designation and its relative isolation from any native vegetation it is not proposed to undertake native restoration planting at this site.

5.6 Road Lighting

The requirement for lighting is governed by the following standards:

- AS/NZS 1158.1.1:2005 Lighting for Roads and Public Spaces – Vehicular Traffic
- AS/NZS 1158.6:2010 Lighting for Roads and Public Spaces – Luminaires
- NZTA M30:2014 Specification and Guidelines for Road Lighting Design

- NZTA TM-2015 Guidelines for Flag Lighting (September 2015 –draft)
- CIE 88 – Guide for the Lighting of Roads Tunnels and Underpasses

Design and placement of road lighting has yet to be advanced significantly from that presented at tender. As at April 2016, no lighting was planned to be installed along the Mangaonua, Mangaharakeke/Mangaone Gully bridges. However lighting is planned for the East-West Link gully crossing.

The effects of particular lighting regimes are likely to be species-specific (e.g. Stone et al., 2012) however LED lighting should be highly directional (baffled if necessary) to minimise light spill into the surrounding environment, low intensity, longer-wavelength and lower colour temperature if at all possible. Shorter-wavelength, whiter LEDs should be avoided as these attract more invertebrates. LED colour temperature may not influence the attraction of invertebrates to LEDs in New Zealand (e.g. Pawson & Bader, 2014), however it is suggested that lower colour temperatures should be used. If technological advances allow, the use of LED lights that mix coloured light from three or more monochromatic LED sources should be investigated as this would potentially provide a high level of control over emitted wavelengths to allow adjustment if necessary. However, lighting design will ultimately be defined by human safety considerations. With planting planned along the batter slopes of the East-West Link gully crossing to the road edge, light spill into the surrounding East-West Link Gully will be minimised as much as possible. The lighting design along Cambridge Road and the Southern Interchange will be given careful consideration during the design process.

5.7 Establishment of replacement foraging habitat

In addition to the establishment of bat roosting habitat the draft GRIPs also include details of low-stature tree, shrub and sedge plantings which will enhance bat foraging habitat along the base and escarpments of the Mangaonua, Mangaharakeke, Mangaone and East-West Link gullies. In particular, these plantings will include riparian, low-stature, terrestrial and wetland areas. It is likely that all habitat types specified within the GRIPs will contribute bat foraging values once planted and restored, however riparian areas are most likely to support high aerial invertebrate numbers, including WFP, SBOS, WFVC and WFB. Species planting lists can be found within the GRIPs for each of these habitat types.

5.8 Measures to avoid/minimise/mitigate direct mortality during construction

Direct bat mortality during construction will be avoided, minimised, and mitigated via the following measures:

- Implementation of the Tree Removal Protocol.
- Minimisation of vegetation removal.

The principal action to avoid and minimise direct bat mortality during construction is the implementation of the Tree Removal Protocol (refer to section 4). Once all vegetation has been removed bats will not utilise the construction site during the day when construction machinery is present and active and therefore it is not expected that bat mortality resulting from vehicle movement will be an issue.

5.9 Minimising Potential for Direct Mortality due to Vehicle Collisions

It has been shown that bats make extensive, preferential use of the gully habitats over other nearby habitats (Dekrout, 2009). Therefore it is possible that bats may be at risk from vehicle collisions at the gully crossings once operational. Knowledge of the ways in which bats currently use the gully habitat (e.g. bat flight paths, heights, movements in relation to gully edges and slopes at the bridge sites) would inform the design of targeted and effective measures to avoid bat mortality from vehicle collisions. Without the use of a thermal imaging camera (TIC), the options to undertake observation of bat behaviour away from roosts have been extremely limited. The recent acquisition of such a camera has introduced the opportunity to undertake bat behavioural observations within the gullies for the first time in the coming 2016-17 summer season, with the ultimate goal of providing information to inform targeted mitigation measures, to assess the effectiveness of those mitigation measures, and to allow recommendations to be made if those measures are not successful.

Current planned construction dates for the gully bridges can be seen in Table 4.

Table 4. Construction start and completion dates for the Mangaonua, Mangaharakeke and Mangaone gully bridges.

Bridge	Planned start date	Planned completion date
Mangaonua Gully	February 2017	February 2018
Mangaharakeke Gully	September 2017	May 2018
Mangaone Gully	April 2017	February 2018

The expressway is due to open in 2020 and there will be no traffic across the bridges until then. A thermal imaging camera will be used to observe the behaviour of long-tailed bats prior to, during and post construction within the gully sites (see section 6.4). Although the TIC methodology is yet to be finalised, the intention is to observe the behaviour of bats at the gully crossing sites. The first season of observation will be the coming 2016-17 summer, and this will continue annually through to 5 years following construction completion. This will allow observations to take place over several seasons, in three situations:

1. With no bridge present, and no vehicles present;
2. With bridges present, but no vehicles present; and
3. With both bridges and vehicles present.

This presents an opportunity to gather valuable information on bat behaviour at the bridge sites prior to construction; subsequent behavioural responses to bridge construction over several months, without vehicles being present; and behavioural responses once vehicles are introduced. This will assist in developing solutions targeted at known or likely problems based on actual observation, prior to road operation, and will also allow an adaptive management approach to be taken in response to findings post construction if unexpected problems arise.

In the absence of this information, measures to avoid bat mortality through vehicle collision focus for the time being on maintaining an underpass at the Mangaonua, Mangaharakeke and Mangaone gully bridges (see section 5.4.1), and away from these areas, on retention and planting of tall vegetation wherever possible up to the allowable distance from the road edge. Revegetation according to specifications within the GRIPs will produce a roadside 'hop-over' vegetation canopy at a height which encourages bats to increase altitude on approach to the road, to be well above the path of oncoming traffic.

Resource Consent conditions include detailed specification of quantum of revegetation which must be undertaken, some of which is targeted at bat mitigation (bat management planting). However in reality the species composition of other, non-bat focused revegetation types will also achieve similar aims in relation to providing canopy height above the traffic zone as species composition overlaps to a large extent.

5.10 Minimising Disturbance to Active Bat Roosts

In the event that a roost is located during construction (e.g. while enacting the requirements of the Tree Removal Protocol) and is in a location where it does not need to be moved the following actions will be taken:

a) The immediate area of the roost will be cordoned off with safety fencing and signage erected in a 10m radius around the roost, alerting any person approaching the area that a bat roost is present and to stay clear.

b) The existence of the roost will be widely publicised to all construction staff and work instructions for the immediate area will be updated to reflect the presence of the roost and the measures to minimise disturbance.

c) All adjacent construction activities (within 100m) will be assessed for noise and vibration and where in the opinion of the approved ecologist the method of construction may disturb the roost steps will be taken to eliminate, isolate, or minimise the disturbance wherever possible.

No work will take place within 100m of the roost from 1 hour before official dusk to 30 minutes after official dawn unless approval is given by the WRC & WDC.

5.11 Banding trees – East-West Link

Designation condition 7.4i) ii) requires (as a minimum) that three kahikatea trees next to the embankment have metal bands installed around their trunks to prevent predators accessing their canopies. Such an approach has a low chance of success, is likely to be difficult to maintain, and poses some risk of damage to the trees. However, since the conditions require this then metal bands will be installed around the trunks of these trees. They will need to have expansion joints and will require ongoing maintenance to ensure effectiveness and protect the tree from damage. A clear zone will need to be permanently maintained around these trees so that vegetation does not grow to a height where protected tree canopies touch non protected tree canopies which will cancel any benefits that may be obtained from banding the trees. The restoration design for this gully will need to accommodate this requirement.

5.12 Pest control

Recent feedback from the Department of Conservation has indicated a preference to include pest control as an additional form of mitigation, with the aim of increasing protection for bats and other fauna in the affected area. A discussion document has been appended to the GRIP that outlines approximately 24 ha that could be targeted for pest control, with a focus on the area surrounding the Mangaonua, Mangaone and Mangaharakeke Gully crossings.

Significant difficulties exist in terms of locating sufficient public land on which to undertake pest control within the surrounding area. Very little public land exists within the Mangaonua, Mangaone and Mangaharakeke Gullies – essentially this is limited to a very thin (5-30m wide) strip of land in the base of the gullies. Clearly the merits of undertaking pest control within such a narrow strip of land are extremely limited. While private land could be considered to widen the treated area, pest control cannot be imposed upon property owners, and a legally-binding agreement would be required to allow pest control not only while agreeable property owners are in residence, but to guarantee access to land over the life of the proposed control programme (currently 10 years). This presents significant difficulties, and it is likely that, at best, an intermittent patchwork of properties may be found.

Other options include supplementing or broadening existing pest control on public land such as at Whewell's Bush (DOC Scientific Reserve) or at Hammond Park (HCC reserve); or broadening pest control at areas at more distant areas such as Maungakawa Reserve near Cambridge, another known bat site.

At this stage a stakeholder discussion is proposed to consider appropriate sites, an appropriate area and an appropriate intensity of control that should be undertaken.

6 During and Post Construction Bat Monitoring

WRC consent conditions and the designation conditions require details of bat monitoring to be undertaken during and post construction, to be able to identify and assess changes in bat activity and behavioural patterns that may occur as a result of construction and operation of the Hamilton Section of the Waikato Expressway. Construction will commence in 2016 and is scheduled to be completed by March 2020. The responsibility for all bat monitoring during construction and post construction lies with the Transport Agency. Monitoring is required for a period of 15 years from the commencement of works authorised by the WRC consents for all sections of the Expressway except the East-West Link which requires monitoring during construction and 15 years post construction.

Acoustic monitoring using Automated Bat Monitors (ABMs) will form the basis of an extensive monitoring programme aiming to detect changes in bat activity and behavioural patterns. Acoustic monitoring methodology will be applied consistently for the entire during and post construction period. The methodology makes use of acoustic data gathered during baseline surveys carried out prior to award of the construction contract, to allow detection of changes in activity levels and behavioural patterns from the pre-construction period through to the end of the required post-construction monitoring period.

6.1 Quantitative Analysis Approach

6.1.1 Baseline Surveys

Three quantitative baseline activity surveys were undertaken at sites along the entire Hamilton Section alignment over two seasons (Deakin, 2016a; Deakin, 2016b).

The 2014/15 and 2015/16 surveys provide a baseline against which future bat distribution and activity level data can be compared during and post road construction, to detect significant changes in key areas and to identify trends in activity levels over time.

During the three baseline surveys, a total of 123 sites were acoustically monitored using automated bat monitors (ABMs), under a quantitative methodology developed and agreed during consultation with WRC and DOC in early 2015 (Connolly, 2015). The monitoring produced an extensive dataset that provides a robust quantitative baseline of bat activity along the Hamilton Section alignment, against which data gathered during and post construction can be measured. For example, the 2nd 2015/16 survey produced greater than 1 million lines of data; needless to say the handling of this data has caused unintentional delays in producing reports as required under resource consent conditions.

Monitoring included 10 further ABMs deployed at Pukemokemoke Reserve as a control site to account for natural fluctuations in activity levels that may occur, but which are not caused by construction or operation of the Hamilton Section of the Waikato Expressway.

Over the course of these surveys, the great majority of activity was detected south of SH26, within the Mangaone, Mangaharakeke, Mangaonua and East-West Link gullies.

A single bat pass was detected at Lake Rd in 2015/16; very low numbers of passes were detected at Percival Rd and adjacent to SH26 in 2014/15 & 2015/16; and a moderate level of activity was detected around a pond at Gordonton Rd in 2015/16. Resource consent condition 48f)vi) requires during and post construction monitoring to be undertaken at all sites where bat activity has been detected during baseline surveys. The focus for during and post construction monitoring will therefore be confined to those sites.

6.1.2 Quantitative analysis during and post construction

Repeat surveys during and post construction will allow comparison of data with baseline monitoring results, will further inform mitigation design, and may assist with subsequent assessment of the effectiveness of mitigation, and potential changes to mitigation that may be required. Data will be analysed in order to -

a) Detect significant changes in bat activity levels over time at key sites, and allow comparison between ABM groupings and habitat types;

b) Estimate the rate of any changes in activity levels detected over time, and identify associated trends;

c) Detect significant changes in behaviour over time; and

d) Attempt to identify variables that most strongly influence any significant changes in bat activity and behaviour.

Dr Steven Miller, a bio-statistician at the University of Waikato, has advised that significant changes in levels of bat activity over time can be detected at key sites using a Generalised Linear Mixed-effects Model (GLMM), with the number of bat calls per ABM across the hours of operation each night as the response variable. GLMM can also be used to identify cumulative trends over time, e.g. a declining level of activity over 5 years upstream of a newly-constructed bridge. In a case such as this, changes in activity levels may be rapid and if so, pairwise comparisons of activity levels between individual years can assess the significance of such a change.

Random effects that can be included in the modelling include locations, nights and time of year. For each of these random effects, we would consider if it was appropriate to average over the individual responses in order to simplify the model.

Fixed effects that could be included in the modelling in future would include relative humidity, temperature, precipitation, noise levels, light levels, distance to the road centreline and habitat type. All fixed effects would be reported with a confidence interval, to allow for the limits of the average size of the effect to be considered, even if the effect itself cannot be said to be significant from the data available.

6.2 Power analysis

6.2.1 Levels of change

Analysis of statistical power measures the ability of a test to detect an effect that actually exists, and should be undertaken prior to starting any research to ensure the planned sampling regime is adequate. O'Donnell & Langton (2003) undertook power analysis in relation to the use of hand-held bat detectors along line transects, with the objective of providing power figures to conservation managers to assist in choosing options for designing monitoring programmes. The analysis recommended that programmes should aim to achieve 80-90% power, measure population changes of between 3-10% per year, and be undertaken for >10 years. This analysis used an index of bat activity levels to test the ability of a potential survey programme to detect changes in bat abundance, on the assumption that levels of bat activity correlate with population levels. To our knowledge this correlation has not been tested to date. For the purposes of this methodology we refer to changes in activity levels rather than changes in abundance, for this reason.

This methodology makes use of ABMs rather than hand-held detectors, which provide a very different set of information to hand-held detectors. The power analysis of O'Donnell & Langton (2003) is therefore not directly relevant to planning a survey which employs ABMs, however it is appropriate to attempt to meet their recommendations if possible in terms of acceptable levels of power and levels of decline to be detected.

In line with the recommendations of O'Donnell & Langton (2003), an ability to detect a 10% decline in activity per year at each location with 80% power is considered the minimum acceptable outcome.

6.2.2 Data Simulations

Although complex, power analysis can be undertaken for GLMMs by simulating data expected from the proposed monitoring (e.g. Johnson et al., 2014). A series of power analysis simulations were undertaken to ensure that sampling intensity was appropriate to detect significant changes in bat activity levels by ABM grouping over time, using GLMMs. A Poisson Mixed Effects Model with a log link function was used to estimate expected levels of bat activity and variation at a selection of sites. This information was used to simulate data from the same model over a specified number of nights and number of ABMs, for a number of years under two scenarios of proportional decline in activity. The simulated data was then analysed to detect significant declines in activity.

Simulated data sets were created and analysed 1000 times for each scenario. For each year, we recorded the proportion of simulations that detected a significant decline in activity in that year or earlier, which we refer to as the cumulative probability of detecting a significant decline in bat activity up to the year in question. The determination of what constitutes significant evidence of an effect is difficult with mixed-effect models. In addition to the simulated decline scenarios, we simulated data from a scenario where there was no change in activity. We used the results from these simulations to determine a baseline effect size that would erroneously conclude there was a decline in activity only 5% of the time.

Early simulations made use of data gathered at the Lloyd property (adjacent to the Cambridge Section of the Waikato Expressway) in the absence of data from the Hamilton Section. However recent and ongoing simulations have now focused on data gathered during the Hamilton Section 2014/15 and 2015/16 baseline surveys.

Simulations focused on detection of a 10% annual cumulative change in activity with 80% power. Parameters tested and adjusted during power analyses were –

- Number of ABMs per grouping (5, 10, 20, 60, 120); and
- Number of nights each location is monitored (5, 7, 10, 14, 21, 28).

The simulations have assisted in refining the most efficient number of ABMs for each data grouping and duration of deployment that should be employed for during and post construction monitoring. The current preference is to deploy 5 ABMs per group, for 21 nights' duration annually. Under the power analysis simulations a deployment of 5 ABMs per group over 21 nights should result in the detection of a 10% cumulative change in activity levels within the area monitored by that group, with 80% confidence, over approximately 8 years (Figure 2).

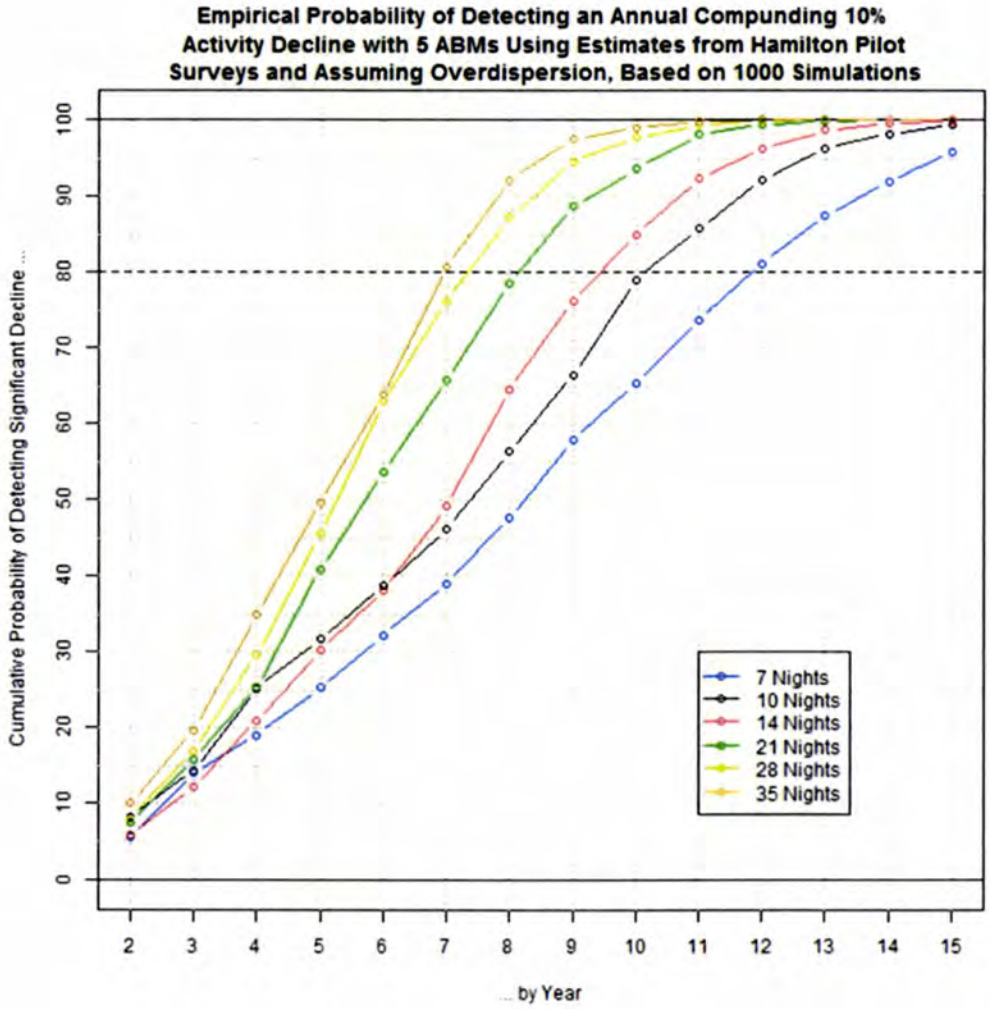

Figure 2. Latest probabilities of detecting an annual compounding activity decline, showing the effects of increasing deployment duration.

6.2.3 Overdispersion

The effects of overdispersion have been assumed for the Hamilton Section baseline data and this has been accounted for in the power analysis.

6.2.4 Variation in data between years

The possible effects of variation in activity levels between years, as well as between ABMs and nights, requires consideration. Until recently it was not possible to undertake simulations for this variable (as only a single year of data had been available until several weeks ago). However with the recent completion of the 2015/16 monitoring a second year of monitoring data is now available. We are currently estimating yearly variation in activity and analysing the effects of this in the model, which may (or may not) result in a revision of the ABM grouping size and/or deployment duration. It is expected that this should be completed before the end of July 2016.

6.2.5 Environmental variables

At each ABM location, several environmental variables will be recorded, with the intention of gathering data for inclusion in future modelling (see below) to determine the effects of each variable on any changes in activity or distribution that may become apparent following the start of construction. These variables are –

- **Distance to Expressway centreline.**
- **Relative humidity, temperature & precipitation through the night.** To be taken from the NIWA CliFlo database.
- **Noise levels.** Opus road noise specialists have used well-established road-traffic noise modelling techniques based on the Calculation of Road Traffic Noise (CRTN) model, to calculate noise levels in decibels along the entire alignment (Lester & Dravitski, 2012). Once calibrated on site and with updated traffic data, this modelling is capable of accurately determining mean noise levels according to hour of the day, at each ABM site and at specified heights above road level, before and after road construction (T. Lester, pers. comm.). This data will be incorporated into the analysis.
- **Light levels.** Baseline representative light data will be gathered at a) a site where artificial lighting is absent, and b) a site illuminated by lighting of the type and intensity planned to be used at the gully crossings, with measurements taken at set distances from the centreline. These will be used as a proxy to inform the approximate light levels that can be expected at ABM monitoring sites.
- **Habitat type.** These will be broad descriptions of habitat immediately surrounding the location of each ABM.

6.2.6 Questions of interest

The primary focus will be on detection of significant changes in activity levels over time at all locations. The GLMM approach allows a range of possible questions to be explored, including those relating to behaviour. For example,

- Is there a trend of changing activity levels within zones upstream of the new gully crossings over time compared to downstream or anywhere else along the alignment?
- Does the introduction of lighting at East-West Link Gully have an effect on activity levels that differs from the other gully crossings, where no lighting will be installed?
- Do activity levels change at key sites as mitigation plantings increase in height?
- Do environmental variables such as temperature or relative humidity influence bat activity?
- Do increased lighting or noise levels have an effect on activity levels or feeding behaviour?

The need to answer further questions may become apparent over time and the GLMM approach allows a degree of flexibility.

Key elements of the during/post construction monitoring:

- 75 ABM sites to be monitored in total -
    - o 50 within the Mangaonua, Mangaharakeke/Mangaone and East/West link gullies.
    - o 15 between SH26 and Lake Rd at sites of previous bat activity.
    - o 10 at two control sites (5 each at Pukemokemoke Reserve and Maungakawa Reserve).
- Clusters of 5 ABMs to be placed at gully sites monitored during the baseline surveys (reduced from 10 ABMs per site for baseline monitoring).
- ABMs to be deployed once annually for 21 days duration (increased from 10 days for baseline monitoring).

6.2.7 Key Sites

Key sites of monitoring interest are shown in Appendix D. These are:

- The gully crossings at the Mangaone, Mangaharakeke, Mangaonua and East-West Link gullies. Deployment of 5 ABMs upstream and downstream of each crossing.
- The Cambridge Rd/SH1 widening. 5 ABMs either side of the road at this location.

6.2.8 Monitoring Parameters

Data sourced via the ABM monitoring will be collected between 1 November and 30 April annually, under the following conditions:

1. Monitoring will occur nightly from 1 hour before official dusk to one hour after official dawn.
2. Temperatures in the first 2 hours after sunset must remain above 10 degrees Celsius.
3. Little precipitation should fall in the first 2 hours after sunset. For the purposes of providing a measurable figure and maintaining consistency with other sections of the Waikato Expressway, this should not exceed 5mm.
4. No monitoring will take place during a full moon, or one night either side of full moon.

Where a night of monitoring is lost to adverse weather, a further night of monitoring will take place to compensate, until a total of 21 nights of monitoring is achieved.

6.3 Potential alternatives to GLMM analysis

6.3.1 Ability to detect change

It is worth noting that these power simulations assume the most simple and conservative situation possible, i.e. they simply make use of the number of bat passes recorded per ABM, without considering any other variables. The addition of other explanatory data such as temperature, relative humidity, habitat type, distance to road centreline etc are likely to enable the model to detect changes far more rapidly. For example, a recent re-analysis of long-tailed bat activity data in relation to environmental variables identified relative humidity as a significant predictor of bat activity (K. Borkin, pers. comm.). Therefore the power analysis simulations are likely to represent 'worst case' scenarios, and in reality the environmental data gathered is likely to allow a much earlier detection of any significant change in bat activity, and to identify variables which most contribute to those changes.

6.3.2 Site Occupancy Analysis

However, as with most ecological monitoring, despite power analysis it is possible that actual data gathered during and post construction may not allow GLMM to provide answers in the intended timeframes, which may be extended. Dr Colin O'Donnell rightly points this out in his review of this BMP and it is acknowledged this is a possibility. Dr O'Donnell also suggests that in this case, the data gathered could be analysed using Site Occupancy Analysis to test the hypothesis that the range of bat sightings has changed over time. Such an analysis will be investigated and undertaken in addition to GLMM, in the event that data extends the timeframes over which GLMM can detect significant effects.

6.3.1 UK draft standard methodology

Prior to development of the quantitative methodology adopted for the baseline surveys for Hamilton Section (Connolly, 2015), no similar quantitative methodology existed to guide the monitoring of the effects of transport infrastructure on bats. However a document published recently by the UK's Department for Environment, Food and Rural Affairs (DEFRA) offers potential for alternative statistical and monitoring methodology (Berthinussen & Altringham, 2015). Dr Anna Berthinussen and Prof John Altringham, two eminent bat researchers of international standing, were commissioned to develop "standardised cost-effective survey methods to assess the effect of linear transport infrastructure on bats (on a landscape scale) and the effectiveness of mitigation measures such as crossing structures (on a local scale)". Their document offers a comprehensive methodology with similar aims to those within this BMP, using acoustic survey with walking transects; however the use of stationary acoustic monitors (e.g. ABMs) is mentioned as a possibility.

While we do not propose to adopt this methodology in its entirety at present, we suggest that, should it become standard methodology in the UK, consideration should be given to making use of it in New Zealand. It may be possible to effectively retro-fit the statistical methodology of Berthinussen & Altringham into the Hamilton Section monitoring into the future, however this will require careful consideration of how the two methodologies compare before a decision is made. For now, we bring the document and its methodology to the attention of all interested parties, as it represents the only published methodology of its type in the world, and it is available online in its entirety including right down to the level of the appropriate code to be used in the statistical package 'R'.

6.4 Changes in Bat Behaviour

To observe and detect behavioural changes, a FLIR thermal imaging camera (TIC) will be used to observe individual bat behaviour at key sites. These will include:

- The gully crossings at the Mangaone, Mangaharakeke, Mangaonua and East-West Link gullies; and

- The Cambridge Rd/SH1 widening.

Methodology to gather quantitative data using the TIC in this context is yet to be finalised. However it is likely to involve recording information such as number of animals observed, direction and height of flight, behaviour in relation to features such as trees and treelines, and a set of coded bat behaviours, such as:

- Commuting (including movement over and alongside the expressway);
- Foraging; and
- Behaviour on approach to a bridge – e.g. fly over, fly under, turn around and go back.

Data gathered using this methodology may be analysed using GLMM to investigate a suite of fixed and random effects on behaviour similar to the activity monitoring described above.

It is intended to develop this methodology for use in the 2016/17 season, which will be the first of the during construction monitoring seasons. The methodology will be based on similar methodology currently under development in the UK by international bat experts, who are encountering similar issues with bats in relation to road and rail infrastructure. Contact has been made with other researchers undertaking this work and this will continue during methodology development.

The TIC will be used annually at each site (including at Pukemokemoke and Maungakawa Reserves) for the duration of the construction period, and also for the first 5 years of the post construction period. However it is anticipated that sufficient information about individual bat behaviour in relation to the road will have been gathered by that point and TIC monitoring will then cease.

6.4.1 Correlation between effects on activity and effects on behaviour

Further analysis (e.g. using regression techniques) will be undertaken following GLMM modelling, with a focus on examining correlations between activity and behavioural data in the short term (e.g. between individual years). While GLMM should allow the detection of long-term trends in activity levels, the analysis of short-term activity and behavioural GLMM data should also offer an effective method to detect and assess rapid changes in bat activity and behaviour, enabling a rapid response in terms of recommendations to adjustment of mitigation.

7 Reporting

Monitoring data will be initially assessed and reported on annually for the first five years from the commencement of works authorised by the resource consents covering the main Expressway alignment (including the Ruakura Interchange) and thereafter at five year intervals for a period of 15 years from the commencement of works authorised by the consents. Monitoring data collected for the East-West Link will be initially assessed and reported on annually for the first five years from the commencement of works authorised by this resource consent, and thereafter at five year intervals for a period of 15 years from the completion of works authorised by this consent.

7.1 Effectiveness of mitigation

7.1.1 Monitoring timescales

The proposed monitoring methodology potentially allows a flexible approach to monitoring and detection of significant effects on bat activity and behaviour over a range of timescales. For example in the short term, pairwise GLMM analysis between years may reveal rapid, statistically significant changes in activity and behaviour as a result of key occurrences such as bridge construction, or the introduction of vehicle traffic; while in the long term, GLMM provides the potential to detect subtle trends such as a gradual activity decline over a decade or more.

7.1.2 Monitoring thresholds and response

No New Zealand standards exist to guide the measure of effectiveness of mitigation. In the absence of such guidelines we propose the following approach to assessing the effectiveness of mitigation:

Monitoring data will be analysed for:

a) Statistically significant changes in activity levels across all monitoring sites;
    i. Pairwise comparisons between individual years to detect significant short term changes at a localised scale and a study area scale.
    ii. Analysis over multiple years to detect significant long-term trends at a localised scale and a study area scale.
b) Statistically significant changes in behaviour patterns at localised sites; and
    i. Pairwise comparisons between individual years to detect significant short term changes at a localised scale.

c) Correlation between changes in activity levels and changes in behaviour.

In circumstances where significant adverse changes are detected in both behaviour patterns and activity a review of mitigation measures shall occur.

A statistically significant 10% cumulative annual activity decline across the entire area monitored as described in section 6, will trigger a review of mitigation measures.

A wide range of possible activity and behavioural change scenarios may be detected. Long-tailed bat activity levels are inherently variable between sites, between seasons and between years. In this respect it is potentially problematic to attempt to impose a threshold of acceptable variation in short-term activity levels, e.g. between one year and another, with which to guide the assessment of effectiveness for mitigation. Statistically significant changes to long-tailed bat behaviour are potentially much easier and quicker to detect, particularly in relation to a structure such as a bridge.

We propose the following approach to assessing differences in behaviour:

a. Annual pairwise comparison of bat behavioural data between individual years to be undertaken. Behavioural observation provides information at a very localised scale and focuses on behavioural responses to the construction and operation of structures such as bridges. Behavioural responses to such structures may be rapid and the behavioural monitoring will allow this to be detected. Berthinussen & Altringham (2015) offer a relevant methodology to assess behavioural effects of mitigation. Two questions are asked to assess the effectiveness of crossing structures:

(i) Are bats using the commuting route at a similar frequency both before and after construction and installation of the crossing structure? A statistically significant annual decline of 10% or more suggests the crossing-point mitigation is not effective. This question could be asked e.g. either side of a bridge, or within an entire gully system, between individual years.

(ii) Are at least 90% of bats using the crossing structure crossing the road safely (that is, crossing either beneath or at a height above the line of traffic)? If not, the crossing structure is likely to have a detrimental effect. It should be noted that this does not suggest that it is acceptable that 10% of bats crossing the roads are being killed; rather that if 10% of bats that cross the road are doing so at heights that place them in the potential path of oncoming traffic, then that is potentially detrimental.

Clearly a range of possible scenarios may be observed. It is problematic to attempt to predict potential problems and design solutions in advance of monitoring and the response will need to be tailored to the specific issue detected at the time. Where thresholds above are exceeded and there is evidence that mitigation measures have been ineffective, the ecologist(s) will review effectiveness of mitigation and make recommendations for an appropriate response, including, where possible and practicable, reasonable suggestions to improve and adjust mitigation measures. Note that a review may or may not result in recommendations to modify mitigation.

Reports will be provided to WRC, WDC, DOC & TWWG within two months of the completion of each assessment. Where changes to mitigation measures are recommended in response to evidence of ineffectiveness, the consent holder will consult with WRC, WDC, DOC & TWWG and obtain approval from WRC prior to implementing the measures.

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Appendices

Appendix A – Hamilton Section Long-tailed Bat Baseline Survey Methodology

OPUS

Hamilton Section: Waikato Expressway

Long-tailed Bat Pre-Construction Baseline Survey Methodology (Summer 2014/15)

Hamilton Section: Waikato Expressway

Long-tailed Bat Pre-Construction Baseline Survey Methodology (Summer 2014/15)

During and Post-Construction

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Contents

1 Introduction

1.1 Background

A series of pre-construction long-tailed bat (*Chalinolobus tuberculatus*) surveys are required to comply with WRC Consent (AUTH130361.01.01) Condition 48 (f) (vii). The condition states:

Pre-construction baseline distribution surveys shall include surveys using appropriate techniques to assess bat distribution and behaviour within areas of potential bat habitat along the entire Hamilton Section of the Waikato Expressway alignment. A minimum of two surveys shall be undertaken during the months of November to April inclusive for a minimum of two monitoring seasons, immediately prior to construction commencing. Monitoring for the surveys should take place on nights when the temperature remains above ten degrees for the first two hours after sunset and little precipitation occurs. Temperature and precipitation must be recorded.

This methodology describes the proposed approach to fulfilling this condition during summer 2014/15. Further baseline surveys will be required in summer 2015/16. While it is expected that the methodology to be used in 2015/16 will be generally consistent with that used in 2014/15, modification to the methodology may need to be made depending upon the results of the 2014/15 monitoring.

Although the goal of this methodology is to fulfill the above condition, consideration has also been made to future fulfillment of Condition 48 (f) (vi), which requires:

Details of a monitoring programme to identify and assess changes in bat activity and behavioural patterns that may occur as a result of construction and operation of the Hamilton Section of the Waikato Expressway at all locations where bats are detected during comprehensive pre-construction baseline distribution surveys required by condition 48 (f) (vii). The monitoring programme should be sufficiently robust to inform the mitigation design and subsequent assessment of the effectiveness of mitigation.

A draft version of this methodology was reviewed by Dr Kerry Borkin in her capacity as reviewer for Waikato Regional Council in October 2014 and we have included several suggestions to reflect her comments. In addition, advice from bio-statistician Dr Steven Miller regarding statistical methodology has been incorporated.

1.2 Monitoring objectives

The objectives of the 2014/15 and 2015/16 bat monitoring are to:

- Determine the distribution and, to the extent practicable, assess behaviour (principally detection of commuter routes and/or foraging areas) of bats along the alignment;
- Provide information to assist in the development of mitigation to be included in the Bat Management Plan (BMP); and
- Provide a baseline against which future bat distribution, activity level and feeding/foraging data can be compared over time during and post road construction, to detect significant changes and/or trends in relation to construction.

2 Methodology

Monitoring methods will include:

- Deployment of Automatic Bat Monitors (ABMs) within potential bat habitat along the alignment for ten nights per deployment when the temperature remains above ten degrees for the first two hours after sunset and there is little preciptation; and
- Visual /hand-held detector field observations on SH1 at the Mangaone Stream crossing.

We do not recommend undertaking more invasive forms of monitoring such as radio tracking for this project. Capture and radio-tracking of long-tailed bats was carried out in the southern Hamilton area, including the Mangaone and Mangaharakeke Gullies, by Dr Andrea Dekrout as part of her PhD research (Dekrout, 2008). Over 4 seasons, Dekrout managed to capture 24 individual bats, fitted radio transmitters to 17, and successfully tracked only 11 individuals. None were re-captured more than once, and few of these individuals were found to use the Mangaone Gully. The capture and tracking of these 11 bats was achieved only after a significant amount of effort and labour.

Dekrout set up harp traps and mist nets to capture bats in Hammond Bush alongside the Waikato River, a few hundred metres to the west of the SH1 Mangaone Gully crossing. Hammond Bush offers wide flat areas allowing easy access to public land for trapping. This contrasts with the Mangaonua and Mangaone Gullies which are surrounded by private land, with extensive dense willow, privet and gorse stands, a hazardous boggy gully base and steep sides.

Given Dr Dekrout's experiences, the difficult nature of the habitat within the gully environments, and the small bat population that is likely to inhabit the gullies, it is likely that attempting to undertake radio tracking would result in a significant amount of effort and expense for very little data. For these reasons we do not recommend undertaking a radio tracking study to meet resource consent conditions.

Non-invasive methods are the preferred approach by the Highways Agency in the UK. The Highways Agency states that radio-tracking is an expensive and specialist technique only to be used in exceptional circumstances. Their position is supported by the Bat Conservation Trust in the UK, who state in their Good Practice Guidelines (Hundt, 2012) that radio-tracking is rarely needed at potential development sites. As a consequence their guidelines do not cover the technique. The guidelines go on to state the following:

"Resolution 4.6 of the Eurobats Agreement 17 gives guidance on invasive survey techniques such as catching bats. It states that "the research being undertaken should not adversely affect the conservation status of the population and should take account of the welfare of the individual bats". It also states that radio-tracking "should only be used for well organised and authorised projects where essential data cannot be acquired through less intrusive methods". Therefore, when surveys are used for development, non-invasive methods should be exhausted first before invasive techniques are employed; where they are used, constant re-appraisal of the value of the information in relation to the potential risks to bats is essential. Disturbance caused by a survey should be the minimum required to obtain the necessary information, and the least intrusive methods possible should always be employed."

We concur with the general approach of employing non-invasive techniques for bat survey along the Hamilton Section alignment. There are few tools to choose from in the bat survey toolbox. Of these, acoustic monitors offer the most efficient alternative in the Mangaone and Mangaonua/Mangaharakeke Gullies. In comparison to radio tracking, acoustic monitoring records indices of activity (with some behavioural data) rather than recording behaviour of individual bats. We propose to undertake intensive acoustic survey using a large number of new DOC ABMs, with quantitative analysis of the resulting data to assess the effects of construction on the distribution and behaviour of long-tailed bats.

2.1 ABM types

For some time, limited availability of DOC-manufactured ABMs for purchase or hire has imposed severe limitations to undertaking bat survey. However we now have available 10 newly-released DOC 'Frequency Compression' ABMs, and have been informed that a further 20 should be available from DOC in late February/early March, for a total of 30 new ABMs.

A short test of the sensitivity of the newer ABMs in comparison to the earlier-model DOC ABMs was carried out in Hammond Park, Hillcrest on January 21st 2015. This 2-hour session highlighted the potential differences in sensitivities between the versions, and the potential problems of using both versions within the same survey. Four 'old' model ABMs were each paired with a new version ABM at Hammond Park, and deployed along a transect for two hours after dusk. Hand-held detectors indicated that bats were active and a bat was observed prior to dusk above the treeline. Results can be seen in Table 1.

Table 1. Results of a short comparison of sensitivity between 'old' and 'new' DOC ABMs.

Site	Number of passes recorded over 2 hours after dusk	
	'Old' ABM	'New' ABM
1	5	22
2	0*	26
3	1	20
4	10	24

*Possible fault

These results suggest that the new ABMs are likely to record a far greater number of passes, at a more consistent rate than the older ABMs. A more rigorous comparison may offer further insight into the differences between the ABMs, however in the absence of this information it seems that data gathered by the two versions are likely to differ greatly. For surveys simply targeting bat presence and distribution, this may not be a problem. However for quantitative surveys this difference in sensitivity is likely to introduce problems for data analysis by introducing another source of variation into an already variable dataset.

2.1.1 ABM selection

For the reasons indicated above we propose to undertake all quantitative bat monitoring using only the new version ABMs. This model will become the new standard for bat survey in New Zealand and it makes sense to future-proof the methodology as much as possible. The old model ABMs are no longer manufactured and those that still exist will inevitably wear out (as has occurred with several of our own ABMs). Therefore in the interests of maintaining as consistent an approach to data collection as possible, no old ABMs will be used in the quantitative component of this methodology, and their use will be limited to assessing bat distribution only.

ABMs will be deployed in habitat along the alignment where previous monitoring (e.g. Dekrout, 2008; Le Roux & Le Roux, 2012) has shown bats to be present or which experience suggests bats may utilise as roosting, foraging or commuting habitat i.e. gullies, groupings of mature trees, shelterbelts and hedgerows. ABM recordings will be noted for call type, including search phase calls, multiple bat calls, feeding 'buzzes' and 'social' calls.

2.2 ABM monitoring methodology & timing

2.2.1 Survey no. 1 (2014/15)

As part of the first of two 2014/15 bat surveys, all sites north of SH26 were surveyed for bat presence between January 23rd – February 5th 2015. No sites within the Mangaonua or Mangaone Gullies have yet been surveyed, as agreed with WRC and DOC in a meeting held on January 13th 2015, with the intention that this methodology should be receive WRC sign-off prior to survey taking place in those locations.

Given the continued delays in DOC ABM supply and the shortening survey season, we now propose that the first of the two 2014/15 surveys should be completed as a qualitative distribution survey, using both ABM types as currently available, in order to detect bat presence only. The resulting qualitative distribution data will still be summarised and included in a subsequent report detailing results of the 2014/15 surveys.

Changing the objectives of the first survey in this way will allow quick completion of the remainder of the survey using both ABM types, followed quickly by the 2nd (quantitative) survey immediately afterward.

ABM deployment for the 1st survey will continue to be undertaken at sites identified in previous versions of this methodology; however as previously indicated, a significant area within and surrounding these gullies is private property and deployment in these areas will depend on obtaining permission to do so from the property owners.

2.2.2 Survey no. 2 (2014/15) and all subsequent surveys

The DOC Electronics Workshop has advised that a further 20 new ABMs are on track to be delivered in late February/early March, increasing the number available to 30 new ABMs. We propose that immediately following the first survey, the second should begin, using only new ABMs. For all subsequent survey (including the remaining two pre-construction baseline surveys in 2015/16, and future during- and post-construction surveys) the same approach should be taken, ensuring data is gathered in a consistent manner with a single type of equipment.

Starting from Survey no.2, twenty new ABMs will be deployed along the alignment for each survey, with the remaining 10 concurrently monitoring a control site (below). ABM deployment for this survey is planned to begin on March 16th, and final retrieval of ABMs will take place on April 28th.

2.2.3 Control site

Pukemokemoke Reserve, approximately 22km north of the Mangaonua Gully crossing, will be monitored from Survey no. 2 onwards as a control site. The Reserve is known to provide habitat for a population of long-tailed bats and is sufficiently distant from the Hamilton Section alignment to be isolated from the effects of construction.

2.2.4 Monitoring sites along the alignment

Sites along the alignment intended for monitoring from Survey no.2 onwards can be seen in Figures 2 to 7. In those areas expected to reveal higher levels of bat activity (i.e. the Mangaonua and Mangaone/Mangaharakeke Gully areas) ABMs will be deployed in groups of 10, while those areas north of SH26 (where no bat activity has previously been recorded) will be monitored less intensively. The precise locations of sites south of SH26 will depend on gaining property owners permission. Precise locations will be determined when on site and GPS locations recorded.

2.2.5 Environmental variables

At each ABM location, several environmental variables will be recorded, with the intention of gathering data for inclusion in future modelling (see below) to determine the effects of each variable on any changes in activity or districution that may become apparent following the start of construction. These variables are –

- **Distance to Expressway centreline.**
- **Temperature & precipitation through the night.** To be taken from the NIWA CliFlo database.
- **Noise levels.** Opus road noise specialists have used well-established road-traffic noise modelling techniques based on the Calculation of Road Traffic Noise (CRTN) model, to calculate noise levels in decibels along the entire alignment (Lester & Dravitski, 2012). Once calibrated on site and with updated traffic data, this modelling is capable of accurately determining mean noise levels according to hour of the day, at each ABM site and at specified heights above road level, before and after road construction (T. Lester, pers. comm.). This data will be incorporated into the analysis.
- **Light levels.** Earlier drafts of this methodology included a proposal to measure light levels at each ABM site at night. However this presents significant health and safety risks for the majority of sites. Obtaining multiple property owners' permission for night access presents difficulties; most sites are also heavily vegetated and gathering light data at the altitude bats are active presents further challenges. Instead, we propose to obtain baseline representative light data gathered at a) a site where artificial lighting is absent, and b) a site illuminated by lighting of the type and intensity planned to be used at the gully crossings, with measurements taken at set distances from the centreline. These will be used as a proxy to inform the approximate light levels that can be expected at ABM monitoring sites.
- **Habitat type.** These will be broad descriptions of habitat immediately surrounding the location of each ABM including pasture, gully edge, gully slope/base, and indigenous forest.

2.3 Data analysis

2.3.1 Baseline Surveys

The results of the 2014/15 and 2015/16 baseline surveys will –

- Determine the distribution and contribute to knowledge of behaviour (principally identifying commuter routes and/or foraging areas, and detecting broad behavioural changes in relation to habitat use) of bats along the alignment;
- Provide information to assist in the development of mitigation to be included in the Bat Management Plan (BMP); and
- Provide a baseline against which future bat distribution and activity level data can be compared during and post road construction, to detect significant changes in key areas and to identify trends.

For the baseline surveys, qualitative data will be summarised as mean number of calls per ABM by hour after sunset for each ABM grouping, and graphed to illustrate temporal activity levels including call type. Quantitative data gathered during the 2nd of the two 2104/15 surveys and all subsequent surveys will be analysed as described below.

2.3.2 Quantitative analysis during and post construction

Repeat surveys during and post construction will allow comparison of data with baseline monitoring results, will further inform mitigation design, and may assist with subsequent assessment of the effectiveness of mitigation, and potential changes to mitigation that may be required. Data will be analysed in order to -

a) Detect significant changes in bat activity levels over time at key sites, and allow comparison between ABM groupings and habitat types;
b) Estimate the rate of any changes in activity levels detected over time, and identify associated trends;
c) Detect significant changes in patterns and locations of foraging behaviour over time; and
d) Attempt to identify variables that most strongly influence any significant changes in bat activity and feeding behaviour.

Statistical advice has been sought from Dr Steven Miller, a bio-statistician at the University of Waikato. Dr Miller has advised that significant changes in levels of bat activity over time can be detected at key sites using a Generalised Linear Mixed-effects Model (GLMM), with the number of bat calls per ABM across the hours of operation each night as the response variable. GLMM can also be used to identify cumulative trends over time, e.g. a declining level of activity over 5 years upstream of a newly-constructed bridge. In a case such as this, changes in activity levels may be rapid and if so, pairwise comparisons of activity levels between individual years can assess the significance of such a change.

Random effects that can be included in the modelling include locations and nights. For each of these random effects, we would consider if it was appropriate to average over the individual responses in order to simplify the model.

Fixed effects that could be included in the modelling in future would include temperature and precipitation, noise levels, light levels, distance to the road centreline and habitat type. All fixed effects would be reported with a confidence interval, to allow for the limits of the average size of the effect to be considered, even if the effect itself cannot be said to be significant from the data available.

2.3.3 Power analysis

Analysis of statistical power measures the ability of a test to detect an effect that actually exists, and should be undertaken prior to starting any research to ensure the planned sampling regime is adequate. O'Donnell & Langton (2003) undertook power analysis in relation to the use of hand-held bat detectors along line transects, with the objective of providing power figures to conservation managers to assist in choosing options for designing monitoring programmes. The analysis recommended that programmes should aim to achieve 80-90% power, measure population changes of between 3-10% per year, and be undertaken for >10 years. This analysis used an index of bat activity levels to test the ability of a potential survey programme to detect changes in bat abundance, on the assumption that levels of bat activity correlate with population levels. To our knowledge this correlation has not been tested to date. For the purposes of this methodology we refer to changes in activity levels rather than changes in abundance, for this reason.

This methodology makes use of ABMs rather than hand-held detectors, which provide a very different set of information to hand-held detectors. The power analysis of O'Donnell & Langton (2003) is therefore not directly relevant to planning a survey which employs ABMs, however it is appropriate to attempt to meet their recommendations if possible in terms of acceptable levels of power and levels of decline to be detected.

Although complex, power analysis can be undertaken for GLMMs by simulating data expected from the proposed monitoring (e.g. Johnson et al., 2014). A series of power analysis simulations were undertaken to ensure that sampling intensity was appropriate to detect significant changes in bat activity levels by ABM grouping over time, using GLMMs. Data previously gathered from the Lloyd property in 2012/13 (a known site of relatively high long-tailed bat activity levels between Cambridge and Hamilton) was used to simulate expected data for power analysis purposes. Although activity levels recorded at the Lloyd property were high relative to other locations monitored in the Hamilton area to date, we expect that a) bat activity within the Mangaonua and Mangaone gullies is likely to also be reasonably high, and b) that the new ABMs are likely to effectively amplify the number of recordings taken within the gullies compared to using the older model ABMs. This may result in a level of recorded activity that compares with that recorded at the Lloyd property using the older model ABMs in 2012/13.

Using the observed data from the Lloyd property, the estimated variance for the random effect term for ABMs on the log-scale was 3.310, while the estimated variance for the random effect term for nights on the log-scale was 0.072. After correcting for these random effects, the number of bat passes was estimated to be 4.0 per ABM per night (between 1.6 and 10.2, with 95% confidence), for the average ABM on an average night.

2.3.3.1 Levels of change in activity and power to detect

In line with the recommendations of O'Donnell & Langton (2003), an ability to detect a 10% decline in activity per year at each location with 80% power was considered the minimum acceptable outcome.

The ability to achieve these outcomes is dependant on the practical realities and limitations of acoustic monitoring in these gully systems, and on resource limitations. The prescribed requirements and limitations of existing resource consent conditions (specifically the number of surveys required per year and number of years survey is to be carried out) also place limits on what can be achieved. Bearing these factors in mind, multiple power analyses were undertaken with a range of combinations of parameters tested.

The parameters adjusted were:

- Number of ABMs per 'location' (10, 15, 20); and
- Number of nights each location is monitored (5, 7, 10).

2.3.3.2 Levels of change in proportion of feeding buzzes

Long-tailed bats are likely to feed extensively within both gully systems. At present, feeding 'buzzes' may be recorded in up to 10% of bat passes at gully sites along the alignment. Potentially, the construction and/or operation of the Hamilton Section may elicit changes in bat feeding behaviour; such a behavioural change may be observed by a change in the proportion of recorded bat calls that include feeding buzzes at particular sites. Such a change may also be observed in isolation to changes in activity levels – e.g. at one site activity levels may drop but the proportion of feeding buzzes may remain consistent, while other sites may record consistent activity levels but changes in feeding levels.

Power analysis was undertaken with the goal of detecting between 10% -20% decline in feeding behaviour within each zone.

2.3.4 Power analysis results

Power analysis indicates that deployment of 10 ABMs within each 'zone' (essentially an immediately adjacent to key construction sites – see below) for 10 nights will allow detection of significant changes in activity levels and feeding behaviour within that zone. Results clearly demonstrate that increasing the duration of survey has a greater effect on detection of change in activity levels than increasing the number of ABMs used; however a greater number of ABMs may increase detectability of changing feeding behaviour.

1. **Trends over time**. GLMM analysis may detect a trend of approximately 10% annual change in activity levels at individual sites after 4 years with 80% power; 7% annual change after 5 years with 80% power; and 10% annual change after 5 years with appoximately 98% power (Fig. 1, Table 2).

2. **Pairwise comparisons.** Comparisons of activity levels between individual years (e.g. year 1 vs year 4) can be made with the ability to detect significant differences of 10% with approximately 78% power after 4 years, and approximately 94% power after 5 years.

3. **Feeding activity**. Deploying 10 ABMs per zone, power analysis indicates that GLMM analysis may reveal a trend of approximately 20% annual decline in the proportion of passes that include feeding buzzes after 4 years with 89% power, and after 5 years with 98% power (Table 3).

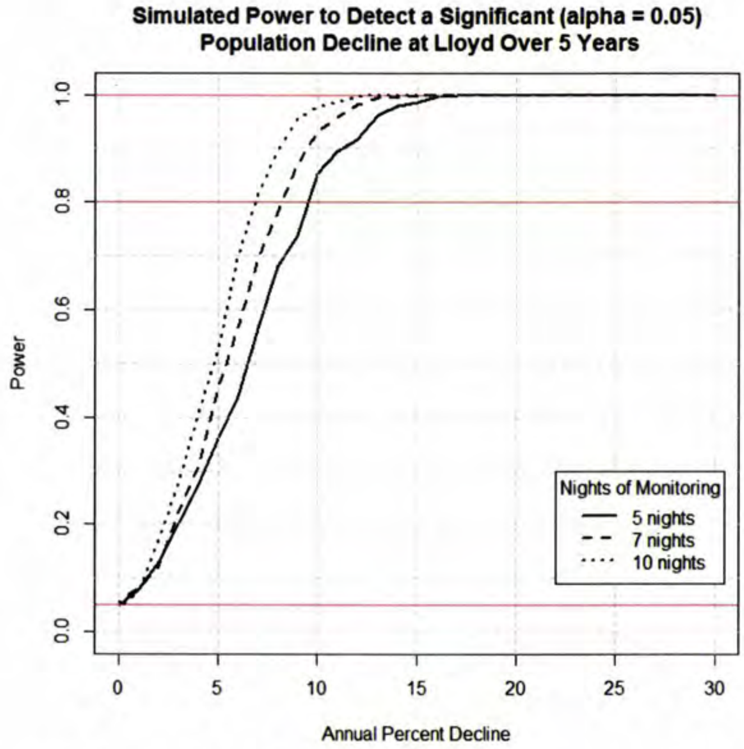

Figure 1. Power curves for detection of a significant decline in activity over 5 years, with options for duration of survey.

Table 2. Power values for detection of a significant decline in activity of 10% annually over 4 and 5 years, with options for duration of survey and number of ABMs.

		Years 1 – 4			Years 1 – 5		
		5 nights	7 nights	10 nights	5 nights	7 nights	10 nights
No. of ABMs	10	0.49	0.71	0.80	0.81	0.91	0.98
	15	0.55	0.72	0.84	0.81	0.94	0.97
	20	0.66	0.72	0.84	0.86	0.93	0.98

Table 3. Power values for detection of a significant 20% annual trending decline in feeding buzzes, with options for duration of survey and number of ABMs.

		20% decline: Years 1 – 4		20% decline: Years 1 - 5	
		7 nights	10 nights	7 nights	10 nights
No. of ABMs	10	0.76	0.89	0.92	0.98
	15	0.92	0.98	0.99	0.99
	20	0.98	0.99	0.99	1.00

The use of GLMM analysis allows data from multiple environmental variables to be included in the modelling. Power to detect changes can be increased when hourly variables such as temperature and precipitation, and representative values such as modelled noise and light levels, are included. Similarly, power will increase where location data is combined, e.g. two locations each using 10 ABMs sited upstream of the Mangaone Gully bridge.

The primary focus will be on detection of significant changes in activity levels over time at all locations. The GLMM approach allows a range of possible questions to be explored, including those relating to behaviour. For example,

- Is there a trend of changing activity levels within zones upstream of the new gully crossings over time compared to downstream or anywhere else along the alignment?
- Is there an underlying change in the proportion of recorded feeding behaviour over time at particular locations (e.g. zones upstream of the gully crossings)? Is a similar change recorded downstream of the crossings, or at other locations along the alignment?
- Do increased lighting or noise levels have an effect on activity levels or feeding behaviour?

GLMM analysis will potentially allow detection of significant changes in bat activity levels and behaviour at discrete locations in relation to the Hamilton Section footprint and construction. Where significant changes in activity are identified, the potential effects of environmental and road-related variables can be explored.

2.1 Field observations

Visual/hand-held detector field observations will be made where SH1 to the south of Hamilton crosses the Mangaone Stream. These field observations will supplement data collection via ABMs that will also be deployed upstream and downstream of the crossing. Radio tracking work undertaken by Dekrout (2008) suggests that the Mangaone Stream corridor is used by bats for commuting. As this is a high volume section of road that is illuminated by street lighting at the stream crossing it provides a potential opportunity to assess bat behaviour in response to an existing section of highway. Supplementing ABM recording with field observations along other sections of SH1 has provided valuable insight into bat behaviour in response to roads that would not have been obtained using ABMs alone. The addition of further sites to carry out this monitoring will be guided by the results of the ABM monitoring, however it is anticipated that several sites are likely to be monitored.

Field observations at the SH1/Manganone Stream crossing will occur on three of the nights during the period when ABMs are deployed. Observations will be made for a period of 2.5 hours from 30 minutes before dusk. The number and location of sites chosen for field observations will be reviewed on an ongoing basis, and may change as a result.

2.2 Thermal Imagery

The use of high-quality thermal imaging cameras was suggested by Dr Borkin, to potentially inform the specifics of long-tailed bat behaviour in relation to roads and road lighting. We have identified equipment that would be suitable for this task and ideally our methodology would include the use of such a camera. However in the short term, the very high cost of this equipment and the lack of established protocols or guidelines for its use means we are unable to carry out this type of work in the 2014/15 season. We will continue to investigate the possibility of using this equipment in the 2015/16 season.

2.3 Site identified for survey

2.3.1 North of SH26

An initial distribution survey undertaken within and adjacent to the designation in 2011 (Le Roux, 2012) found no activity was detected at nine sites north of SH26. The flat landscape surrounding these nine sites is highly modified and comprises agricultural pasture, with scattered exotic ornamental, shade and shelterbelt trees. Aerial photographs of the landscape north of SH26 were examined in an attempt to identify obvious habitat features that might serve as bat commuter routes, offering connectivity with e.g. the Mangaonua and Mangaharakeke gullies and stands of mature trees in the wider landscape, and which should be monitored as part of this survey. However, there is little connectivity between groupings of mature trees, hedgerows and shelterbelts in this landscape. If bats are commuting through this landscape across the alignment they will inevitably have to cross substantial sections of open landscape with no trees or shrubs. ABMs will therefore be deployed at the largest groupings of mature trees, hedgerows and shelterbelts which potentially could be periodically visited by bats. Sites selected for ABM deployment largely reflect the locations selected by Le Roux (2012) (Figures 2 to 5).

Figure 2. ABM sites at Lake Rd properties.

Figure 3. ABM sites at Osbourne Rd & Kay Rd properties.

Figure 4. ABM sites at Horsham Downs and Gordonton Rd properties.

Figure 5. ABM sites at Powell's Rd & Percival Rd properties.

2.3.2 The Mangaonua Gully

Bats have been confirmed as present in the Mangaonua Gully by previous monitoring (Le Roux, 2012). ABMs will be positioned to assess activity levels upstream and downstream of the gully crossing (Figure 6).

Figure 6. ABM zones within the Mangaonua Gully. Precise locations of each ABM within these zones will be determined once access is gained to private property.

2.3.3 The Mangaone/Mangaharakeke Gully, Southern Interchange, East-West Link, Cambridge Rd

Bats have been confirmed as present in the Mangaone Gully by previous monitoring (Le Roux, 2012, Dekrout 2008). ABMs will be positioned to assess activity levels upstream and downstream of key sites in this area (Figure 7). These include locations either side of the proposed Mangaone and Mangaharakeke Gully crossings, the East-West Link gully crossing (near the Southern Interchange), and the Cambridge Rd & SH1 widening.

The Cambridge Road corridor has not been monitored previously with ABMs. However, it is possible that bats use the Mangaone Gully that runs parallel to the eastern side of SH1 as a commuting route and/or feeding and roosting habitat. Interestingly, this section of SH1 is illuminated by street lighting and therefore monitoring along this corridor may provide useful insights into bat behaviour adjacent to lit sections of high traffic volume State Highway. ABMs will be positioned within the gully on both sides of SH1 to assess activity levels (Figure 7).

The SH1 Mangaone Stream location has not been monitored previously using ABMs. However, radio tracking work undertaken by Dekrout (2008) suggests that the Mangaone Stream corridor is used by bats for commuting. As this is a high volume section of road that is illuminated by street lighting at the stream crossing it provides a potential opportunity to assess bat behaviour in response to an existing section of highway. ABMs will be positioned to assess activity upstream and downstream of the existing SH1 crossing (Figure 7).

Data obtained from the ABMs will be supplemented by field observations during the period when the ABMs are deployed. The aim of the field observations will be to see if bats can be observed/detected passing over SH1. This approach has been successfully used to observe bats passing over Tauwhare Road (G. Kessels pers. comm.) along the Mangaone Gully although this is a much lower traffic volume road that is not illuminated by street lighting.

Figure 7. ABM zones within the Mangaone & Mangaharakeke Gullies either side of the new gully crossing, either side of the East-West Link, the Cambridge Rd corridor, and the SH1 Mangaone Gully crossing. Numbers of ABMs to be deployed in each zone are indicated. Precise locations of each ABM will be determined once access is gained to private property.

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Appendix B – 2014/15 Baseline Survey 1 Report

OPUS

NZ Transport Agency

Hamilton Section Long-tailed Bat Survey 2014/15

Survey 1: Long-tailed Bat Distribution

NZ Transport Agency

Hamilton Section Long-tailed Bat Survey 2014/15

Survey 1: Long-tailed Bat Distribution

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Contents

1 Introduction

1.1 Background

The New Zealand Transport Agency (NZTA) has obtained resource consent to undertake construction of the Hamilton Section of the Waikato Expressway. As part of the resource consent approval process, the Waikato Regional Council has specified consent conditions that must be met prior to, during and following the construction of the road, with regard to possible impacts on long-tailed bats (*Chalinolobus tuberculatus*).

Long-tailed bats are known to inhabit Hamilton's southern peri-urban fringe, with activity concentrated in the Waikato River corridor south of the Cobham Drive bridge, and within the Mangaonua, Mangaone and Mangaharakeke gullies. Research conducted between 2004-2007 by Dekrout (2009) found a significant preference for these river and gully habitats by long-tailed bats, and highlighted the importance of maintaining the connectivity of these systems in order to maintain the urban bat population in Hamilton.

A survey carried in 2011 out as part of the Hamilton Section Assessment of Ecological Effects (AEE) (Le Roux, 2011) confirmed the continued presence of long-tailed bats in the Mangaonua, Mangaone and Mangaharakeke Gully systems. Bat presence has also previously been confirmed within the East-West Link gully (Mueller et al., 2013). Resource consent conditions were subsequently written with the intention of minimising effects of the Hamilton Section on the local bat population, and mitigating the effects of construction and operation of the road.

WRC Consent AUTH130361.01.01 includes conditions 48 (f) (vi) and (vii), requiring -

48 (f) (vi). *Details of a monitoring programme to identify and assess changes in bat activity and behavioural patterns that may occur as a result of construction and operation of the Hamilton Section of the Waikato Expressway at all locations where bats are detected during comprehensive pre-construction baseline distribution surveys required by condition 48(f)(vii). The monitoring programme should be sufficiently robust to inform the mitigation design and subsequent assessment of the effectiveness of mitigation.*

48 (f) (vii). *Pre-construction baseline distribution surveys shall include surveys using appropriate techniques to assess bat distribution and behaviour within areas of potential bat habitat along the entire Hamilton Section of the Waikato Expressway alignment. A minimum of two surveys shall be undertaken during the months of November to April inclusive for a minimum of two monitoring seasons, immediately prior to construction commencing. Monitoring for the surveys should take place on nights when the temperature remains above 10 degrees for the first two hours after sunset and little precipitation occurs. Temperature and precipitation must be recorded.*

This interim report describes results from the first of two distribution surveys carried out in the 2014/15 monitoring season, carried out to partially fulfill condition 48 (f) (vii).

1.2 Objectives

Two baseline surveys were carried out in the 2014/15 monitoring season. The objectives of the 2014/15 bat surveys were to:

1. Determine the distribution and, to the extent practicable, assess behaviour of bats along the alignment;
2. Provide information to assist in the development of mitigation to be included in the Bat Management Plan (BMP); and
3. Provide a baseline against which future bat distribution, activity level and behavioural feeding/foraging data can be compared over time during and post road construction, to detect significant changes and/or trends in relation to construction.

Both of the 2014/15 baseline surveys have been completed; however due to the quantity of data gathered during these surveys (a total of over 120,000 individual ultrasonic recordings from the first survey alone, most of which are not bat recordings), only that gathered during the first survey has been fully analysed to date and the results are described in this report. This is intended to inform NZTA and construction tenderers as to the distribution of long-tailed bats along the alignment, in the interim.

A supplementary report will follow upon completion of data analysis from the 2nd survey, to fully summarise both surveys.

2 Methods

2.1 Overview

Two distribution surveys were required in the 2014/15 season to assess bat distribution and behaviour along the alignment (condition 48 (f) (vii)), and to provide a baseline for subsequent assessment of changes to bat activity and behaviour patterns during and post construction (condition 48 (f) (vi)). Consultation with Waikato Regional Council and the Department of Conservation (DOC) was undertaken during development of survey methodology, resulting in an agreed, 2-phase approach to fulfilling the above conditions. The agreed methodology took into account the requirements of the consent conditions, but also acknowledged logistical constraints, including:

1. The challenging topography and habitat within and surrounding the Mangaone/Mangaharakeke and Mangaonua Gully systems; and

2. The delay in availability for purchase of the new DOC frequency compression ABMs until March 2015.

The topography and vegetation of the gully systems are such that capture and radio telemetry of long-tailed bats within and through these systems was discounted as a technique to monitor bats long-term. This decision was partially based on the difficulties in capturing sufficient numbers of bats during the research of Dekrout (2009), who during 4 years of capture effort at Hammond Bush managed to successfully radio-track only 11 individual bats. The habitat within the Hamilton Section gully systems offers greater difficulties than at Hammond Bush in terms of trapping individual bats, and the steep, boggy, weed-infested nature of the gully habitat, combined with the large number of private properties surrounding the gullies, presented significant challenges in terms of tracking bats. It was therefore agreed that radio-tracking was not a technique suited to meeting the relevant resource consent conditions for long-term monitoring of effects for the Hamilton Section.

Instead, a quantitative programme of acoustic survey was devised (Connolly, 2015). Continuing delays in availability of the new DOC frequency compression ABM prompted further discussion with WRC & DOC, resulting in an agreed 2-phase approach to survey for the 2014/15 season. The first of the two 2014/15 surveys was to be undertaken purely as a distribution survey (the results of which are the focus of this report), to provide spatial information on bat presence along the alignment.

Following availability of the new DOC ABMs, the 2nd baseline survey would then be undertaken immediately afterward. This would follow a more intensive quantitative methodology, intended as the first in a series of repeatable surveys to detect significant long-term effects of road construction and operation on bat activity and behavioural patterns (Connolly, 2015). Power analysis indicated that the proposed methodology for the 2nd and subsequent surveys should enable detection of significant changes in relative abundance of bat activity over time at key sites, using a Generalised Linear Mixed-effects Model (GLMM), with the number of bat calls per ABM across the hours of operation each night as the response variable. GLMM may also be used to identify cumulative trends over time, e.g. a declining level of activity over 5 years upstream of a newly-constructed bridge in the Mangaonua Gully. In a case such as this, changes in relative abundance of activity may be rapid and if so, pairwise comparisons of relative activity levels between individual years can assess the significance of such a change.

Using GLMM analysis, repeat surveys during and post construction will allow comparison of data with baseline monitoring results, will further inform mitigation design, and may assist with subsequent assessment of the effectiveness of mitigation, and potential changes to mitigation that may be required. Data will be analysed in order to -

a) Detect significant changes in relative abundance of bat activity over time at key sites, and allow comparison between ABM groupings and habitat types;
b) Estimate the rate of any changes in relative abundance of activity detected over time, and identify associated trends;
c) Detect significant changes in patterns and locations of foraging behaviour over time; and
d) Attempt to identify variables that most strongly influence any significant changes in relative abundance of bat activity and feeding behaviour.

Further details of this quantitative methodology can be found in the document *Hamilton Section: Waikato Expressway - Long-tailed Bat Pre-Construction Baseline Survey Methodology (Summer 2014/15)* (Connolly, 2015).

2.2 1st Distribution Survey 2014/15

Sixty-two sites were monitored along the entire length of the Hamilton Section alignment between January 23rd – March 30th 2015. This survey was carried out over 8 weeks, as a result of limited availability of ABMs for purchase from DOC and ongoing methodology development and consultation. Towards the end of March the new DOC ABMs became available for purchase in large numbers, and eventually 50 were used to complete the first and second surveys.

2.2.1 ABM deployment

Sites along the alignment offering greatest potential long-tailed bat habitat were chosen for survey. A large number of individual properties lie along the alignment, particularly surrounding the Mangaonua, Mangaone and Mangaharakeke gullies, and as a result in some cases the choice of site location was restricted by access issues.

In terms of bat habitat, the landscape along the Hamilton Section is divided by SH26. North of SH26, the landscape is essentially flat, dominated by agricultural pasture with scattered exotic trees and hedgerows, and with little obvious connectivity to known bat habitat. South of SH26 the extensive, linear, deeply incised Mangaonua, Mangaone and Mangaharakeke Gully systems dominate the landscape, offering extensive potential bat habitat, with swampy willow-dominated areas in the base of the gullies and large numbers of mature exotic trees along the gully sides and edges. The gully systems extend to the Waikato River corridor, providing a significant area of foraging habitat with connectivity to a known bat population, although SH1 Cambridge Road intersects the gully system immediately to the south of Hamilton and potentially impacts upon connectivity. The survey effort reflected this difference in habitat either side of SH26, with the majority of effort focused on the gully systems.

Sites monitored are shown in Appendix A.

At each site, a DOC Frequency Compression ABM was deployed for a minimum of five nights with minimum temperatures above 10°C and with little precipitation in the first two hours after sunset, as per resource consent condition requirements. Weather data was retrieved from the NIWA CliFlo website (www.cliflo.niwa.nz), with two weather stations available within close proximity (Hamilton Ruakura 2 Ews and Holland Rd Hamilton Cws). Data from both sites was used to exclude those nights where temperature and precipitation exceeded consent conditions.

3 Results

More than 120,000 recordings were made by the ABMs during the survey. The vast majority of recordings were not long-tailed bat passes, however the large number of files required a significant amount of time to extract bat data from among the recordings. Stuart Cockburn (DOC) has since indicated that an electronic component is at fault in some units and this results in large numbers of irrelevant recordings; these components will be replaced in due course. Stuart is in the process of developing software capable of automatically extracting bat data from large numbers of recordings such as this, however this is not yet available.

Data was analysed and summarised in terms of:

- Distribution of bat activity along the alignment; and
- Levels of activity at each site.

Levels of long-tailed bat activity along the alignment are shownin Table 1 and aerial maps of locations are provided in Appendix A.

Table 1: Long-tailed bat activity at ABM sites

LOCATION	SITE	SURVEY NIGHTS	TOTAL BAT PASSES RECORDED	MEAN BAT PASSES/NIGHT
-	A1	7	0	0
-	A2	7	0	0
-	A3	7	0	0
-	A4	7	0	0
-	A5	7	0	0
-	A6	7	0	0
-	A7	7	0	0
-	A8	7	0	0
-	A9	7	0	0
-	A10	7	0	0
-	A11	6	0	0
-	A12	6	0	0
-	A13	6	0	0
-	A14	6	0	0
-	A15	6	0	0
-	A16	6	0	0
-	A17	6	0	0
-	A18	6	0	0
-	A19	6	0	0
-	A20	6	0	0
-	A21	9	6	0.7
-	A22	9	14	1.6
-	A23	9	4	0.4
-	A24	9	0	0.0
-	A25	9	0	0.0
Mangaonua	**A26**	5	**234**	**46.8**
Mangaonua	A27	5	20	4.0
Mangaonua	A28	5	45	9.0
Mangaonua	A29	5	27	5.4
Mangaonua	**A30**	16	**869**	**54.3**
Mangaonua	**A31**	5	**382**	**76.4**
Mangaone	A32	5	1	0.2
Mangaone	A33	5	2	0.4
Mangaonua	A34	5	29	5.8
Mangaonua	A35	5	2	0.4
Mangaone	A36	5	Faulty unit	-
Mangaone	A37	5	20	4.0
Mangaonua	A38	5	1	0.2
Mangaonua	A39	5	0	0.0
Mangaonua	A40	5	0	0.0
Mangaonua	A41	5	4	0.8
Mangaonua	A42	5	3	1.8
East-West Link	A43	7	31	4.4
East-West Link	A44	7	24	3.4
East-West Link	A45	1*	1	1.0
Mangaone	**A46**	10	**314**	**31.4**
Mangaone	**A47**	10	**268**	**26.8**
Mangaone	A48	2*	0	0.0
Mangaone	A49	3*	23	7.7
Mangaone	**A50**	12	**277**	**23.1**
Mangaone	A51	5	23	4.6

Mangaone	A52	5	27	5.4
Mangaharakeke	A53	5	46	9.2
Mangaharakeke	A54	5	7	1.4
Mangaharakeke	A55	5	41	8.2
Mangaharakeke	A56	5	6	1.2
Mangaharakeke	A57	5	10	2.0
Mangaone	**A58**	5	**107**	**21.4**
East-West Link	A59	5	42	8.4
East-West Link	A60	5	25	5.0
East-West Link	A61	5	2	0.4
East-West Link	A62	5	12	2.4

*ABMs experienced battery failure during survey

3.1 Activity north of SH26

Bat activity north of SH26 was detected only in areas adjacent to SH26.

- Only three of the 25 sites north of SH26 recorded bat activity. All three sites lie within 500m of SH26.
- Activity levels at these sites were relatively low, with A22 the highest (1.6 passes/night).
- No bat activity was recorded along the alignment north of site A21.

3.2 Activity south of SH26

The majority of bat activity was recorded south of SH26, as follows:

- Bat activity was recorded at 33 out of 37 sites, throughout the Mangaonua, Mangaone, Mangaharakeke and East-West link gully systems.
  - Low activity levels (<1 pass/night) at 6 sites.
  - Low-moderate activity levels (1-10 passes/night) at 20 sites.
  - High activity levels (>20 passes/night) at 7 sites.
- Only three sites south of SH26 recorded no bat activity at all (one further ABM was faulty).

3.3 Sites of high activity

Sites of high activity were concentrated in two main areas. Graphs illustrating activity by hour after sunset have been provided for these high activity sites.

3.3.1 Mangaonua Gully

Bat activity was recorded on all ABMs deployed within the Mangaonua Gully north of SH1 Cambridge Rd. Two ABMs south of SH1 recorded no activity and a third recorded only 1 pass.

Three ABMs on the northern and southern banks immediately to the west of the proposed Mangaonua Gully bridge (A26, A30 & A31) recorded the highest levels of activity anywhere along the alignment.

3.3.1.1 ABM A26

ABM A26 (mean of 46.8 passes per night) was deployed at a grove of mature kahikatea at the gully base on the southern side of the gully (Figure 1). These trees are earmarked to remain in place following construction.

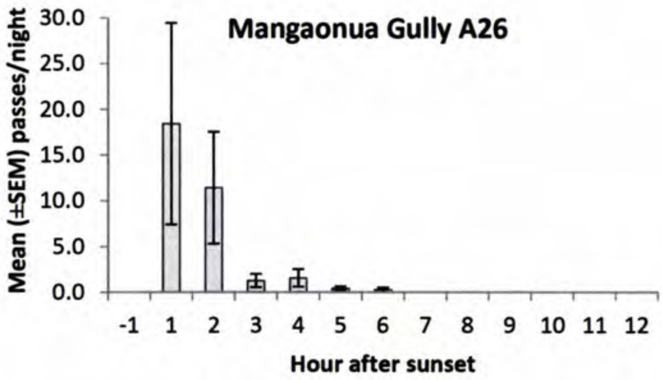

Figure 1. Mean bat activity at site A26 by hour after sunset.

The data shows a sharp spike in activity in the first 2 hours after sunset at this site, suggesting a bat roost in the vicinity. It is not known how close this roost may be, nor how many bats may have been recorded, but the large mature kahikateas at this site offer high quality potential roosting habitat, as do the eucalypts and pines on the opposite side of the gully.

3.3.1.2 ABMs A30 & A31

ABMs A30 (mean 54.3 passes/night) and A31 (mean 76.4 passes/night) were deployed on the perimeter of a large grove of mature eucalypts and pines on the northern gully edge opposite A26, at the site of a planned stormwater wetland (Figure 2). These trees are planned to be felled prior to construction.

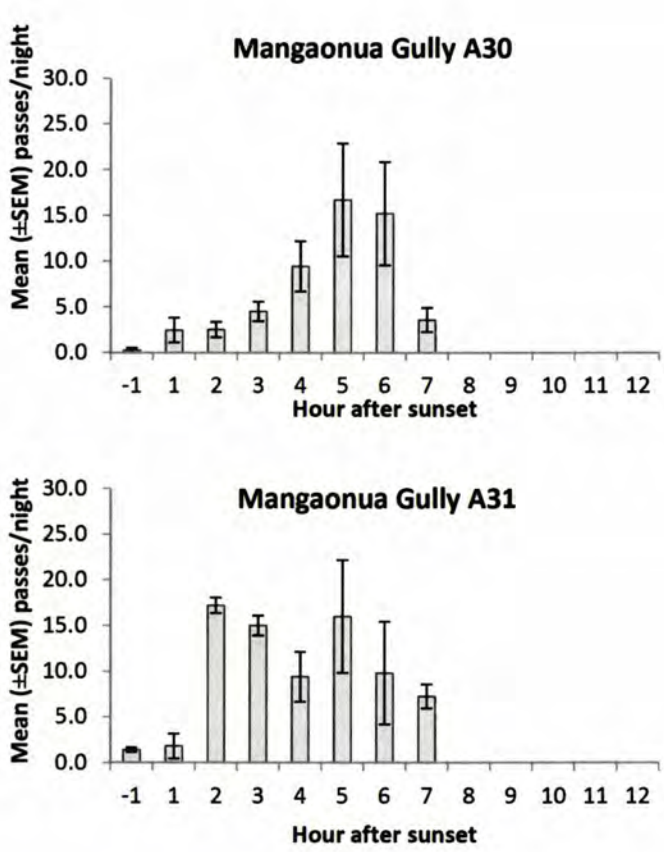

Figure 2. Mean bat activity at sites A30 and A31 by hour after sunset.

Activity at these sites differed from site A26. Very early activity in the hour before sunset was recorded at both sites. This was followed by a sharp activity increase at A31 over the first 2 hours after sunset, which remained fairly consistent through to 7 hours after sunset; whereas site A30 recorded a gradually increasing activity from the initial pre-sunset recordings to a peak in the 5th hour and a gradual drop-off.

3.3.2 Mangaone and Mangaharakeke Gully systems

Bat activity was recorded on 16 out of 17 ABMs in the Mangaone and Mangaharakeke Gully systems. Four ABMs recorded high activity levels at sites between the existing SH1 to the west and the proposed Mangaone bridge to the east. ABMs A46 (mean 31.4 passes/night) and A47 (mean 26.8 passes/night) were deployed in trees along the gully slope at the Ross property, 509 State Highway 1. ABM A50 (mean 23.1 passes/night) was deployed along the edge of the willow canopy in the gully base, at the edge of the designation on the western side of the proposed bridge. ABM A58 (mean 21.4 passes/night) was deployed in a tree on the upper gully slope on the Gilbert property at 32B Cedar Park Drive (Figure 3).

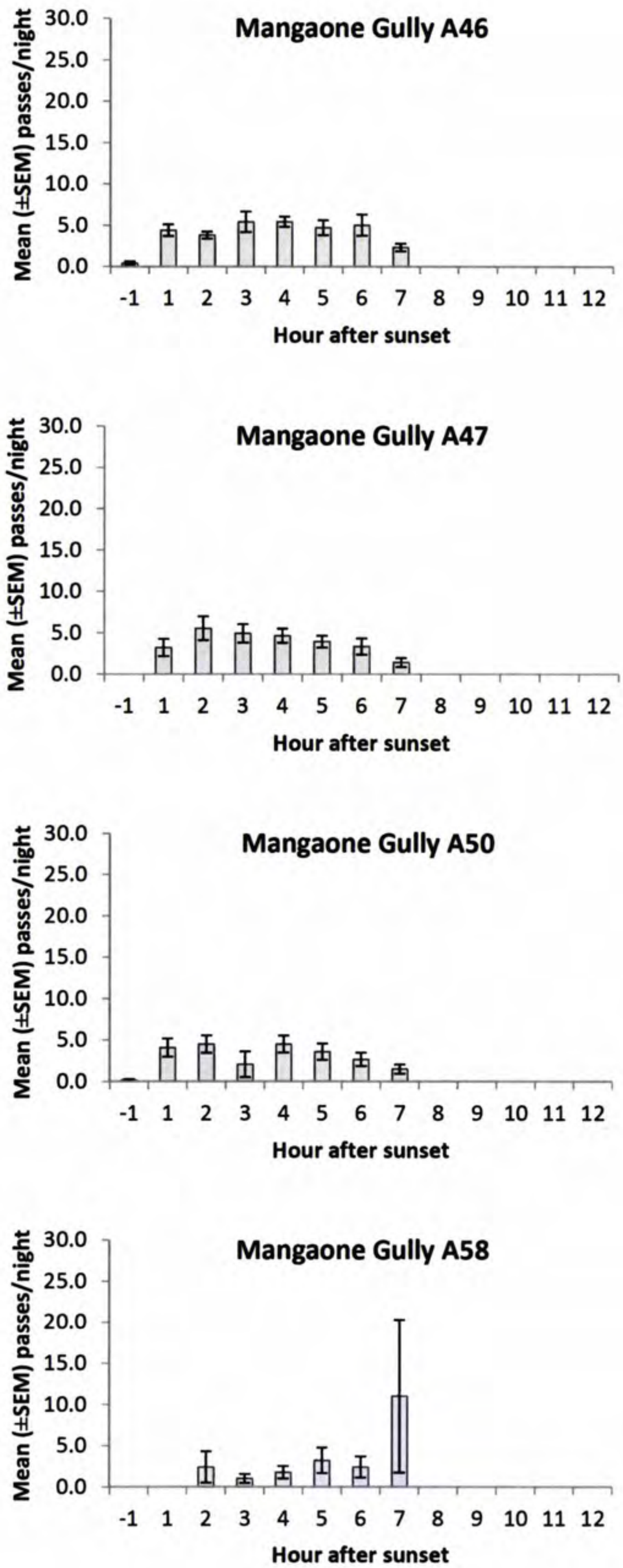

Figure 3. Mean bat activity at sites A46, A47, A50 & A58 by hour after sunset.

Activity at sites A46, A47 & A50 follow a consistent pattern with some very early pre-sunset activity at A46 & A50 followed by a consistent presence at all three sites through to the 7th hour after sunset.

3.3.3 The East-West Link gully

All ABMs deployed within the East-West Link gully recorded bat activity. ABMs were sited on both sides of the proposed fill and levels recorded were low to moderate.

4 Discussion

4.1 Activity north of SH26

Only three sites north of SH26 recorded activity and none of these were more than 500m north of SH26. Long-tailed bats were not detected north of site A21. This is not greatly surprising given the predominantly agricultural landscape and relative scarcity of suitable habitat north of SH26, and the lack of obvious connectivity to known bat habitat beyond site A21. The bat or bats active at this site may roost within the Mangaonua Gully either to the south of SH26 or in the gully arm running between the SH26/Silverdale Rd intersection and the end of Nevada Rd, although this is unknown. No street lighting exists between these 3 ABM sites and either arm of the gully.

4.2 Activity within the Mangaonua Gully

The early evening pre- and post-sunset recordings and high activity levels at sites A26, A30 & A31 suggest a bat roost or roosts currently exist in proximity to the bridge site in the Mangaonua Gully. There is ample potential roost habitat in this area of the gully including mature eucalypt and gum trees on the northern gully edge and slopes, and multiple mature kahikatea in the southern gully base. The spike in activity at both A26 and A31 during the first 2 hours post-sunset suggests foraging activity on both sides of the gully; this tails off sharply at A26 but continues for several hours at the northern gully sites. Sites A27, A28 & A29 also recorded activity but at a much lower level. The area surrounding the proposed bridge offers a number of very large mature kahikatea, pines, willows and eucalypts which are potential roost trees.

4.3 Activity within the Mangaone and Mangaharakeke Gullies

Bat Activity was recorded on almost all ABMs within these gully systems, confirming the widespread use of the gullies by long-tailed bats. The early evening activity at the four high-activity sites (including pre-sunset activity) suggests possible emergence from a nearby roost, followed by consistent activity taking in the gully slopes and base. Activity at A58 is generally at a lower level than the other 3 sites and a sharp spike in activity during the seventh hour after sunset was the result of a large number of passes on a single night. Potential roost trees are relatively common throughout the gullies including large pines, eucalypts, kahikatea and willows.

4.4 Activity within the East-West Link gully

Activity levels within this gully were low-moderate. No analysis of activity by hour after sunset has yet been completed, however activity was recorded on both sides of the proposed gully fill and on all ABMs deployed, confirming that bats are active throughout the gully. These results are consistent with the findings of Mueller et al., 2013.

This gully connects with the Mangaonua, Mangaone and Mangaharakeke Gullies to the north and therefore the presence of bat activity here is not surprising. Some potential roost habitat exists with several large mature pine trees and reasonably large kahikatea along the banks and in the gully base in places.

5 Conclusions

The widespread bat activity recorded through the gully systems and the pattern of intensive early evening activity at certain sites suggests long-tailed bats roost within and forage extensively throughout the gully systems. Given the speed at which long-tailed bats are capable of moving through the landscape and the relatively high number of large, mature native and exotic trees within and surrounding the gully systems, it is possible that the bat/s recorded at these sites may roost some distance away. However the pre-sunset activity, followed by a sharp increase in activity during the first 2 hours after sunset at several sites in particular suggests this is not the case, and that a roost or roosts are likely to exist in close proximity to the alignment within all gullies surveyed. Most likely roost trees include the kahikatea, pines and eucalypts near the Mangaonua Gully bridge, and the many mature exotic trees in the Mangaone Gully between SH1 and the proposed Mangaone Gully bridge.

5.1 Second survey 2014/15

Data from a more intensive 2nd survey completed immediately after the first is currently being analysed and summarised. This data will expand on the results of the 1st survey, provide a baseline for future repeat quantitative survey and will further contribute to design of effective mitigation (Connolly, 2015).

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