GEODATABASE FOR THE KAURI MAPPING PROJECT

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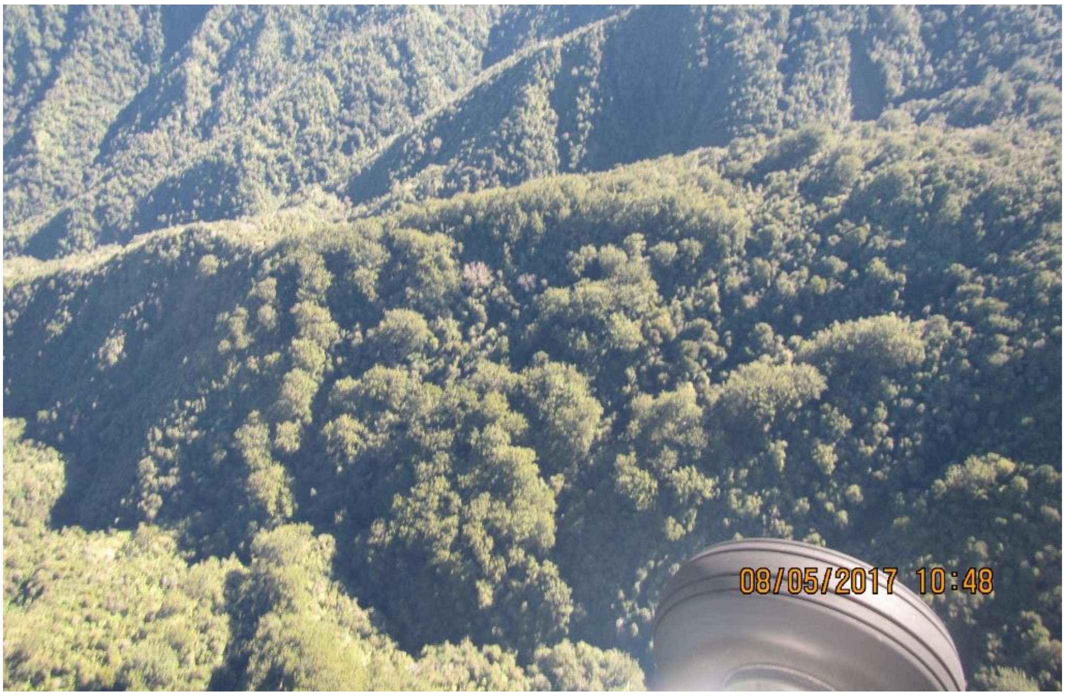

Kauri forest in Warawara Forest, 8 May 2017.

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Project Team:
Nick Ranger - Project management
Tim Martin - Technical advice, desktop mapping, aerial survey, report author
Sarah Budd - Desktop mapping, aerial survey, report author
Sarah Beadel - Technical advice
William Shaw - Technical advice, peer review
Joshua Wium - Desktop mapping, report author
Lance Salt - Desktop mapping
Angela Simpson - Desktop mapping
Gavin Mathews - Desktop mapping
Brent Henry - Desktop mapping

Prepared for:
Ministry for Primary Industries
Pastoral House
25 The Terrace
Wellington

AUCKLAND OFFICE: 12 NIXON STREET, GREY LYNN, AUCKLAND 1021
P.O. BOX 46-299, HERNE BAY, AUCKLAND 1001, Ph 09-377-4886; Fax 09-377-4889

HEAD OFFICE: 99 SALA STREET, P.O. BOX 7137, TE NGAE, ROTORUA
Ph 07-343-9017; Fax 07-343-9018, email ecology@wildlands.co.nz, www.wildlands.co.nz

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Reviewed and approved for release by:

W.B. Shaw
Director/Principal Ecologist
Wildland Consultants Ltd

1. INTRODUCTION

Kauri (*Agathis australis*) is a highly important tree species for Aotearoa/New Zealand. Ecologically, kauri plays a crucial role in shaping the soils, forest dynamics, and landscapes of the northern North Island (Ecroyd 1982). In addition to its ecological importance, kauri also has cultural, social, economic and historical significance to the people of New Zealand (Boswijk 2005).

In 2007, kauri tree deaths in the Waitakere Ranges, west of Auckland, led to the formal identification of *Phytophthora* taxon *Agathis* (Kauri Dieback) (Beever *et al.* 2007, Ministry for Primary Industries 2014). Kauri Dieback was found to be highly pathogenic to kauri trees of all ages as the resulting infection caused collar rot near the base of the trunk. This prevents the tree from transferring water and essential nutrients from the soil to the body of the tree (Beever *et al.* 2007, Ministry for Primary Industries 2014).

In 2009 a partnership programme was established to promote the effective management of Kauri Dieback and aid collaboration between interest groups. Key groups within the partnership are tāngata whenua, Ministry for Primary Industries (MPI), Department of Conservation, and district and regional councils within the natural range of kauri. These groups have worked collaboratively to prepare a management strategy for Kauri Dieback, which outlines four key goals (Ministry for Primary Industries 2014):

- To deliver effective operations.
- To build knowledge and tools.
- To engage and enable people and communities.
- To effectively manage the Kauri Dieback Management Programme.

In order to achieve these goals the partnership identified that more information was required on the current distribution, abundance, and maturity of kauri and kauri-dominated ecosystems. As such, in 2015 MPI engaged the services of Wildland Consultants to develop a geospatial database (geodatabase) of kauri throughout its naturally-occurring range. The aim of the project was to provide a tool that would support the efficient management of Kauri Dieback by allowing managers to focus their efforts on areas that will bring the biggest gains, and to be able to target their resources at the appropriate scale. To achieve this aim, the objectives of the project were to:

- Quantify the extent of kauri forest within all of its natural range.

- Quantify the relative extent of different maturity classes, e.g. ricker versus mature versus old-growth.

- Quantify the extent of different kauri forest associations, e.g. kauri-podocarp-broadleaved forest.

- Estimate the extent of scrub and shrubland within which kauri is not known to occur in the canopy, but where kauri seedlings and saplings may be present (potential kauri forest).

- Provide an accurate and consistent understanding of where forests containing naturally-occurring kauri currently exist in the landscape.
- Produce a spatial representation of how the abundance and maturity (successional stage) of kauri varies within these forests.
- Produce a spatial representation of the forest communities that kauri is part of.
- Generate a geodatabase that can be hosted on MPI's geospatial platform.

In October 2017 a draft version of the geodatabase was provided to MPI. Following a review, additional mapping work was carried out in prioritised areas, and the final version of the geodatabase was submitted in June 2019. Following additional feedback from key partners, a separate database was requested to model the potential location of kauri seedlings and saplings within the landscape. This report describes key stages of the project and the methodologies used to create the main geodatabase and the seedling/sapling geodatabase.

2. DESKTOP REVIEW: MARCH-JULY 2016

2.1 Information sources

Numerous data sets were sourced through MPI, its partners, and other third parties. These data sets and various internal Wildlands resources were assessed for their potential usefulness, and compatibility with mapping methods.

Most of the externally-supplied data sets used in the project were received in February 2016, with other data sets provided as they were received by MPI. Information supplied by Auckland Council, which was very useful for pilot mapping in the Auckland Region, was not received until early March 2016. This led to a compressed timeframe for the pilot mapping phase.

A combination of data sets was used during the project. The particular data sets used in specific areas of kauri distribution were based on the merits of the data sets available for each location. Some data sets provided excellent quality information that was limited to specific areas. For example, Protected Natural Area Programme (PNAP) survey reports provided useful information in some Ecological Districts, and not in others. Overall, the best quality information available at the time was used in each area.

A summary of the data sets used during the initial desktop review and subsequent stages of the project is presented in Appendix 1.

2.2 Definition of distributional limits

Accurately mapping the distributional limits of kauri was an important first step in defining the area to be mapped. Literature was reviewed to assess how the southern limit had been previously determined, e.g. Ecroyd 1982, Steward and Beveridge 2010. Whilst there was general agreement, there was also notable variation in the Bay of

Plenty and inland Waikato Regions. Ecroyd (1982) placed the eastern limit of kauri on the Bay of Plenty coast near Papamoa, while Steward and Beveridge (2010) placed the eastern limit on the coast near Matatā. Herbarium data was obtained from Auckland Museum, Te Papa, Scion, and Landcare Research and overlaid on maps. These herbarium records, in conjunction with personal knowledge of the sites and kauri location data contained in other reports and publications, were used to map the distributional limit of kauri. A map of the southern distributional limit is presented in Appendix 2.

The distributional limit in the Waikato Region can be approximated by a herbarium record from the southern limit near Kawhia (AK312231). From here, the distributional limit follows the inland (eastern) edge of hill country formed, in a south to north direction, by Mount Pirongia, the Harikamata Range, and the Taupiri Range (Ecroyd 1982). From the Taupiri Range, the distributional limit follows a line eastwards to include two areas of low hill country to the north of Morrinsville - the Pukemokemoke and Hangawera Hills (Ecroyd 1982) - before continuing eastwards to the Kaimai Range. The line then turns southwards to reach the southern limit on the western side of the Mamaku Plateau at Kakahu Stream (Ecroyd 1982, supported by a herbarium voucher (NZFRI 11989)). Thus the inland Waikato distributional limit excludes the low-lying and intensively-farmed Hamilton basin. The remaining distributional limit, from the Kaimai Range to Oropi and then the Bay of Plenty coast, is documented by herbarium records (NZFRI 17407) and personal knowledge of the area (Sarah Beadel, pers. comm. 2016).

It should be noted that the distributional limit marks the furthest extent of occurrence of naturally-occurring kauri individuals, not the extent of kauri forest. Distributional limits are typically formed by outlying populations, and in the case of kauri, it is typically absent from large areas when approaching its distributional limit. This is particularly the case on the west coast near Kawhia, and in the Bay of Plenty. The southern limit of forests that contain a significant kauri component would, in places, occur considerably north or west of the distributional limit of individual kauri trees. Also notable is a gap in the distribution of kauri between Ahipara and North Cape, on the Aupouri Peninsula. Kauri is absent for a distance of approximately 70 kilometres, on the low-lying sand tombolo that links Northland to the volcanic hills at Te Paki, at the northern end of the peninsula (Ecroyd 1982).

2.3 Extent of kauri

The remaining extent of 'virgin or primary' kauri forest[1] in Northland was surveyed in 1975 and was estimated to be 6,239 hectares, with a further 63,220 hectares of secondary forest, scrub and shrubland that contain kauri (Lloyd and Guild 1976). An estimate of the extent of kauri across its entire natural range could not be found.

Prior to work commencing on the current geodatabase, it was hypothesised that the current estimated extent of unmodified kauri forest in Northland may have decreased from the 1975 estimate. Areas of unmodified kauri forest are relatively well-known, and are unlikely to have been overlooked in previous assessments of extent. Under the

[1] Interpreted here as meeting the definition of "unmodified", i.e. unlogged, for example.

current project however, mapping of kauri forest at a finer scale may identify areas within "unmodified" kauri forest that are secondary, or that are not dominated by kauri. At some sites, old-growth kauri trees occur in areas that have been subject to selective logging. It is unclear whether historic estimates of unmodified forest included all areas where old-growth trees remain, or only those areas where old-growth trees occur and there was a lack of evidence for logging.

In addition, the current estimated extent of kauri-containing secondary forest, scrub, and shrubland in Northland could be less than was estimated in 1976, primarily due to further land clearance over the past 40 years. However, reductions in the extent of secondary kauri forest may be masked by the increased accuracy of the current project. Relatively small sites, which were captured during this project, may have been omitted in 1976. Such smaller areas of kauri forest are likely to be of greater significance in highly modified landscapes, where the cumulative extent of small areas could comprise a significant portion of the total remaining area.

3. PILOT MAPPING: FEBRUARY-APRIL 2016

Pilot mapping was undertaken using the Google Earth Pro platform. The pilot mapping process assessed sites representative of the types of sites expected to be encountered during the mapping phase of the project. The aim of the pilot mapping was to test the methods, to ensure that they would address all possible situations adequately, including mixed forest, forest/urban fringe, urban/forest mosaic, rural/forest mosaic, exotic forest/kauri forest mosaic, general urban, and general rural areas. The sites selected for the pilot mapping work included:

- Sites that were familiar to staff.
- Sites where staff had limited or no knowledge.
- Sites with good data sets.
- Sites with poor data sets (e.g. low quality aerial imagery).

The areas selected using these criteria included:

- Urban areas near Birkenhead and Birkdale, North Shore, Auckland: urban and urban/forest mosaic.

- Rural areas near Muriwai, Auckland: rural, rural/forest mosaic, and forest/exotic plantation forest mosaic.

- Thames coastline, Tapu-Coroglen Road northwards to Sailors Grave (and surrounds), Coromandel: Coromandel type vegetation - largely modified, and some higher altitude vegetation types.

Some pilot mapping was also undertaken in the southern Waitakere Range - mixed forest/scrub types, and the forest/urban fringe - very early on in the process to help test and refine methods. As a result, this mapping was not 100% consistent with the final mapping methods. The southern Waitakere pilot area was therefore checked and remapped as required during the main mapping programme.

4. DEVELOPMENT OF THE ATTRIBUTES TABLE

The attribute table for mapped areas of kauri was developed throughout the duration of the project and was continually updated as methodologies were improved and new resources became available. A description of its development is provided below and a summary table of the final attribute table is provided in Appendix 3.

4.1 Kauri presence

4.1.1 Initial methodology

Data relating to the extent of kauri within the landscape was obtained by classifying polygons as either 'kauri present' or 'kauri absent' in the attribute table. All 'kauri present' polygons then required data to be entered into all of the other attribute table columns. All 'kauri absent' polygons required attributes to be entered only in the ecosystem and anthropogenic sections of the attribute table.

4.1.2 Revised methodology

As the project progressed it became clear that collecting data on ecosystem type and anthropogenic impacts for 'kauri absent' polygons was highly labour intensive, and provided little additional data to inform the effective management of Kauri Dieback. In December 2016, MPI approved a trial of a new method, in which areas that had no evidence of kauri presence were not mapped. This method proved to be significantly less time-consuming, while still ensuring the collection of useful data relevant to the management of the Kauri Dieback Programme. As such, this revised methodology was adopted for the remainder of the project. A map of all 'kauri absent' polygons that was created using the initial methodology is provided in Appendix 4.

4.2 Presence of kauri seedlings and saplings

4.2.1 Initial methodology

During the desktop analysis and pilot study phase of the project, it was thought that data relating to the presence or absence of kauri seedlings and saplings would be best collated within the attributes table. A preliminary decision matrix (Table 1) was compiled and was used only for polygons for which no kauri were visible in the canopy. The likelihood of the presence of seedling and/or sapling kauri was based on the suitability of ecosystem types for kauri regeneration, and the distance from a potential seed source. Expert opinion was then applied to some polygons to modify results from the decision matrix, i.e. if the matrix assessed an area of mānuka scrub <1.5 kilometres from kauri as being 'likely' for the presence of kauri seedlings and/or saplings, this could be classified as 'kauri absent' if the mānuka scrub was within a wetland.

Table 1: Preliminary decision matrix for assessment of the presence or absence of kauri seedlings and saplings.

Ecosystem Classification	Distance from Kauri (Ricker, Mature, Old-Growth)		
	<1.5 km	1.5-5 km	>5 km
VS2 Kānuka scrub/forest	Likely	More likely than not	Absent
VS3 Mānuka-kānuka scrub	Likely	More likely than not	Absent
VS4 Mānuka scrub	Likely	More likely than not	Absent
VS5 Broadleaved species scrub/forest[1]	More likely than not	Absent	Absent
WF4 Pōhutukawa-pūriri-broadleaved forest	More likely than not	Absent	Absent
WL1 Mānuka gumland[2]	Likely	More likely than not	Absent
MF6 Tānekaha forest locally with beech	Likely	More likely than not	Absent
WF8 Tōtara-mataī-pūriri forest	More likely than not	Absent	Absent

1 Increase to 'likely' for <1.5 km and 'more likely than not' for 1.5-5 km if confident the site is dominated by tōwai or māmāngi, or in Coromandel/Kaimai Ranges
2 Only applies if mānuka gumland is on a hillslope (contours will be used to ascertain this). For mānuka gumland on flat land, kauri seedlings and saplings will be treated as absent for all distances as in these instances the mānuka is likely to occur within a wetland.

The suitability of vegetation types for kauri regeneration was assessed via a literature review, with some revision following the pilot mapping. Vegetation types with mānuka (*Leptospermum scoparium*) and/or kānuka (*Kunzea* sp.) as canopy dominants are well recognised as key environments for kauri establishment, e.g. McKelvey and Nicholls 1959, Mirams 1957, Burns and Smale 1990, Nicholls 1976. However, to consider that mānuka and kānuka associations are the only vegetation types suitable for kauri regeneration is an oversimplification. Kauri can regenerate within a wide range of early successional vegetation types if the conditions are suitable. Forest dominated by a range of different species including tōwai (*Weinmannia silvicola*) (Ecroyd 1982), hard beech (*Fuscospora truncata*) (Ecroyd 1982), tānekaha (*Phyllocladus trichomanoides*) (Burns and Smale 1990), māmāngi (*Coprosma arborea*) (Burns and Smale 1990), and even ponga (*Cyathea dealbata*) (Burns and Smale 1990), can facilitate regeneration of kauri. Pilot mapping on the Coromandel Peninsula provided further evidence for the regeneration of kauri within a wide range of early successional vegetation types, with rickers frequently seen within scrub dominated by broadleaved species (VS5: broadleaved species scrub/forest), and on alluvial terraces in association with tōtara (WF8: tōtara-mataī-pūriri forest). Kauri rickers were also mapped along the eastern coastline of the Coromandel Peninsula in association with pōhutukawa (WF4: pōhutukawa-pūriri-broadleaved forest).

Like most wind- and gravity-dispersed tree species, the majority of kauri seed falls a short distance from the parent tree, with most falling within the drip-line of the parent (Sando 1936). Smaller numbers of seed are dispersed greater distances, to adjacent sites where kauri is not present in the canopy (Mirams 1957). Burns and Smale (1990) found 200-400 kauri seedlings per hectare in scrub within 100 metres of seeding kauri, with numbers declining with increasing distance from the parent trees. The maximum potential dispersal distance of kauri is poorly known. Dispersal up to 1.5 kilometres has been reported (Ecroyd 1982), but kauri are known to occur at sites where dispersal must have occurred over much greater distances. Kauri are present on Rangitoto

Island (Ecroyd 1982), four kilometres from the nearest possible seed source on the Auckland mainland. They also occur on offshore islands such as the Hen and Chicken and Poor Knights Islands, 10 and 20 kilometres from the mainland respectively. On the Hen and Chicken and Poor Knights Islands the source of kauri, and the potential for their presence to be human-mediated, is unknown. In the absence of more reliable data, it is therefore reasonable to regard sites within 1.5 kilometres of mature kauri as commonly receiving seeds, and sites 1.5 to five kilometres also receiving seeds, but in much reduced quantities. Sites further than five kilometres from mature kauri may also receive seeds, but in the absence of evidence of presence, are best regarded as not supporting kauri seedlings or saplings, as seed arrival is likely to be a relatively rare event.

4.2.2 Revised methodology

During the mapping phase of the project it was identified that the process of estimating the presence or absence of kauri seedlings in each polygon was very time-consuming, and that an assessment of the likelihood of kauri seedlings and saplings being present could be achieved more efficiently using GIS analysis of the basic attribute data. As such, mapping staff were directed to stop considering the potential presence of seedlings and saplings when filling in the attributes table. A map of the 'kauri present' polygons that were mapped based on the original seedlings and saplings decision matrix is provided in Appendix 5.

In order to undertake a GIS analysis of the likelihood of seedlings and saplings being present it was assumed that seedlings and saplings would be 'likely' to occur in areas that were mapped as 'kauri present'. To assess the likelihood of kauri seedlings and saplings being present outside the 'kauri present' polygons, a new decision matrix was developed based on the Land Cover Database (LCDB) vegetation types. The LCDB was chosen as the underlying database for this analysis as (1) it covers the entire natural range of kauri; and (2) it provides polygon boundaries that closely match ecosystem type boundaries.

The 'Mānuka and/or Kānuka' landcover class includes the ecosystem types VS2, VS3, VS4 and WL1, which were identified in the original decision matrix as providing habitat suitable for kauri regeneration. The 'Indigenous Forest' landcover class includes forests that contain tānekaha and/or beech species, and therefore may also contain kauri seedlings and saplings. As such, both of these landcover classes were given a likelihood of kauri seedling/sapling presence of 'likely' if they were less than 1.5 kilometres from a polygon that had been identified as 'kauri present'[1], or 'more likely than not' if they were between 1.5 and five kilometres from a 'kauri present' polygon (excluding urban areas where the expected kauri density is likely to be very low).

[1] This includes polygons classifed as 'kauri present' with all associated likelihood categories

The ‘Fernland’ landcover class is commonly found on low fertility sites and is usually dominated by species such as bracken (*Pteridium esculentum*), tangle fern (*Gleichenia dicarpa*), and ring fern (*Paesia scaberula*). The ‘Matagouri or Grey Scrub’ landcover class usually comprises small-leaved divaricating shrubs. If left undisturbed, both of these landcover classes can follow a successional trajectory into mānuka scrub and eventually to a climax ecosystem that includes kauri. Since ‘Fernland’ and ‘Matagouri or Grey Scrub’ areas represent a very early successional stage, both were only given a kauri seedling/sapling presence likelihood of ‘more likely than not’ when within 1.5 kilometres of a ‘kauri present’ polygon (excluding urban areas).

The ‘Broadleaved Indigenous Hardwoods’ landcover class was identified as being equivalent to VS5 (broadleaved species scrub/forest). As such, it was given the same likelihood values as VS5 in the original decision matrix.

All other vegetation types identified within the LCDB were not considered to provide conditions appropriate for the regeneration of kauri. As such they were deemed to be ‘kauri absent’, regardless of their proximity to areas mapped as ‘kauri present’

The final decision matrix for the GIS analysis of where kauri seedlings or saplings may be present is provided in Table 2. Only polygons larger than 0.1 hectare (1,000 m^2) were included in the geodatabase.

Following the submission of an earlier draft geodatabase it was found that the information provided by the seedling and sapling analysis was frequently misinterpreted by users. Some users did not understand the way these polygons had been developed, and found it confusing that areas of vegetation that did not contain kauri trees had, on the basis of seedling/sapling presence, been shown in the draft geodatabase as ‘kauri present’. To avoid this misinterpretation, and the subsequent confusion it caused, the seedling and sapling analysis has now been provided as a separate geodatabase. This will enable users to separately assess the distribution of trees (based on assessment of individual polygons) and the distribution of seedlings and saplings (that has been derived from a modelling approach).

Refinements to the boundaries of ‘kauri present’ polygons during mapping means that in many places these boundaries do not match with the LCDB layer. These variations resulted in the creation of thousands of small ‘seedling and sapling’ polygons around the edges of some ‘kauri present’ polygons. To address this, all polygons smaller than 0.1 hectare (1,000 m^2) were removed from the seedlings and saplings layer. Long narrow polygons that occur on the edge of ‘kauri present’ polygons and are greater than 1,000 m^2 are likely to be an artefact of differences between the main geodatabase and the LCDB.

It should also be noted that the presence of seedling and sapling polygons has been generated based on the location of polygons where mature kauri have been mapped as present. As such, any gaps in the mapping of mature kauri will also result in gaps where seedlings and saplings may be present, but have not been modelled.

Table 2: GIS decision matrix for seedling and sapling analysis.

Landcover Class	Distance from Kauri Trees Mapped at all Likelihood Values, (includes ricker, mature and old-growth)		
	<1.5 km	1.5-5 km	>5 km
Mānuka and/or Kānuka	Likely	More likely than not	Absent
Indigenous Forest	Likely	More likely than not	Absent
Fernland	More likely than not	Absent	Absent
Matagouri or Grey Scrub	More likely than not	Absent	Absent
Broadleaved Indigenous Hardwoods	More likely than not	Absent	Absent

4.3 Cover

Cover was estimated as the proportion of the canopy in the polygon comprising kauri, represented by a whole integer to the nearest 5%, except for sites of very low density which were assigned the value ≤1%. 1% should be interpreted as ≤1% as the limited nature of the software required the use of integers only. Using these cover values, the total area (hectares) of kauri canopy cover can then be estimated by summing the products of the proportion and the polygon area.

4.4 Maturity

Data relating to the maturity of the kauri present within a polygon was obtained by estimating the proportion (%) of the kauri canopy within each of three maturity classes. These classes were 'rickers', 'mature', and 'old-growth'. Most polygons contained a mixture of these classes and distinguishing between them on the basis of aerial photography can be difficult. Canopy change is continuous, not categorical, and stem diameters are not visible[1] when using aerial imagery.

Canopy diameters of known old-growth, mature, and ricker kauri were assessed using Google Earth Pro in areas throughout the natural range of kauri, including Waipoua (Northland), Parry Kauri Park (Warkworth), Cascades (Waitakere Range), and the Tapu-Coroglen Road (Coromandel). The relationship between stem diameter and canopy diameters was confirmed where possible by comparing oblique photographs (from Google Street View) with aerial photographs.

In areas with a closed-canopy, ricker kauri with stem diameters less than *c.*0.5 metres had crown diameters up to five metres diameter. Occasionally, open-grown ricker trees had crown diameters up to seven metres. Mature trees, from 0.5-2 metres stem diameter had crown diameters of 5-20 metres. Appearance on aerial photographs, in terms of colour and texture, is similar to rickers with a conical to broadly rounded crown, and foliage congregated into a rounded 'pom-pom'-like appearance. Ricker and mature trees often had foliage that was of blue-green appearance due to the presence of new foliage. Old-growth trees, typically larger than two metres stem diameter, had crown diameters greater than 20 metres. As well as having larger canopies, old-growth trees also often appeared flat-topped, and rather than canopy

[1] This precludes the application of the same size classes used by the Kauri Dieback Soil Sampling Programme data record sheets, as these use stem diameter to distinguish maturity classes.

foliage having a 'pom-pom'-like appearance, the canopy was more finely stippled, and often grey-brown in colour.

To categorise tree maturity using aerial photographs, canopy diameter was therefore used to define each maturity class as follows:

- Ricker trees: <5 metres canopy diameter (Note: discretion was used as open-grown rickers can have a canopy diameter of 5-7 metres).
- Mature trees: 5-20 metres canopy diameter, canopy of "pom-pom"-like appearance.
- Old-growth trees: >20 metres canopy diameter, canopy often "flat-topped" and grey-brown in colour.

4.5 Spatial distribution

For each polygon where kauri was present, the spatial distribution of kauri within the polygon was classified into one of five categories as follows:

- **Single tree** (only one kauri tree is known to occur within the polygon).
- **Random** (random distribution of individual trees with no visible aggregation (clustering or clumped) of trees.
- **Clustered** (aggregation of kauri trees with canopies not touching).
- **Clumped** (aggregation of kauri trees with joined canopies).
- **Random-mixed** (polygon includes areas with random distribution and areas where kauri are clustered and/or clumped).

A schematic presentation of these categories is provided in Appendix 6.

4.6 Ecosystem type

Some 26 ecosystem classifications were identified during the desktop analysis and pilot study. As the project progressed some of these types were renamed (e.g. 'Treeland -TL' became 'Exotic/Indigenous Treeland - TL'), and additional types were added as required. At the end of the project 35 ecosystem types had been identified and mapped (refer to Appendix 3 for the full list).

Ecosystem types were listed in the order they appear in Singers and Rogers (2014), and additional types added subsequently were appended to the end of the list. The ecosystem types 'exotic forestry/exotic grassland' and 'exotic grassland/urban area' were added as some highly modified areas had complex landscapes with mixed land use. Inclusion of these ecosystem types increased efficiency when attribute data was still being collected for 'kauri absent' polygons. This allowed urban environments amongst farmland, and small mixed blocks of forestry and grassland (i.e. lifestyle blocks) to be combined. Within such areas, all areas of kauri forest greater than one hectare were mapped as separate polygons, as required by the methods.

Where possible, areas of indigenous vegetation were assigned to an ecosystem type using the Singers and Rogers (2014) classification. The Singers and Rogers classification is not intended to be quantitatively applied. As such, there were no established percentage thresholds for classifying ecosystem types according to the cover of particular species. For consistency of approach between mappers, percentage cover thresholds were therefore devised (Appendix 7). These percentage thresholds are based on the terms used to describe the abundance of a species in the ecosystem description (e.g. abundant, occasional) and the percentage cover assigned to these abundance classes by Atkinson (1985). As per Atkinson (1985), if a species is listed for the ecosystem unit name, this denotes that this species is common (20-50% cover) or abundant (>50% cover). It is important to note that the type names assigned by Singers and Rogers are not intended to be an abbreviation of the ecosystem description i.e. the ecosystem class MF24: rimu-tawa forest doesn't necessarily include rimu *and* tawa. Instead they are intended as 'tag' names for the ecosystem type. Polygons were assigned an ecosystem type based on the ecosystem description provided by Singers and Rogers, read in conjunction with the quantitative thresholds developed for this project.

It should also be noted that the Singers and Rogers ecosystem classification has two versions, one from 2011, and a revised version published in 2014. Codes used for the ecosystem types were revised for the second version, e.g. kauri forest was originally WF11, but is now WF10. The spatial layers use a combination of the old and new codes, depending on the area covered, e.g. the Department of Conservation layer uses the 2011 codes and the Auckland Council layer uses the 2014 codes. Care needed to be taken to ensure that the ecosystem classification assigned to each polygon is correct, and that reporting is consistent with the codes used in the revised version (Singers and Rogers 2014).

If a vegetation type did not fit the description and quantitative threshold of a Singers and Roger ecosystem type, it was not used. If a vegetation type could not be assigned to an ecosystem class provided, this was raised with the project managers and MPI, and a solution was found (such as a new ecosystem type being created). The use of ecosystem types that are not from Singers and Rogers to describe 'kauri present' polygons was supported by field verification during pilot mapping, and species associations described for kauri herbarium records.

Water bodies were mapped by default where forest containing kauri surrounded water bodies larger than one hectare.

The 'Extensive Forest Tract - Information Poor' ecosystem type was added during the mapping process. This ecosystem type was used for large areas of forest where kauri forest was very likely to be present, within a mosaic of other indigenous ecosystem types. If the aerial imagery for the area was too poor to be able to accurately delineate areas of kauri from the surrounding ecosystem type, the whole area was classified as the 'Extensive Forest Tract - Information Poor' ecosystem type. In these cases the other attributes of the polygon (cover, maturity, distribution and anthropogenic impacts) could not be assessed and were labelled as 'N/A'.

4.7 Anthropogenic impacts

The five categories used to describe the anthropogenic impacts that have occurred within each polygon are:

- Unmodified.
- Clearance - Non Harvest.
- Logging/Harvest.
- Plantation.
- Restoration.

The 'Clearance - Non Harvest' category was applied to areas where forests where cleared by fire or other methods, but trees were not actively harvested for timber. In contrast, the 'Logging/Harvest' category was used when forests had been harvested. This included areas that were completely cleared as a result of logging and areas where selective logging has taken place.

'Unmodified' areas are those where the virgin unlogged forest is still standing, while 'Restoration' areas are those where indigenous plants have been planted in order to restore an indigenous ecosystem to the site.

'Plantation' areas are those were stands of kauri have been planted for forestry.

4.8 Evidence

Key evidence sources were recorded within the attributes table for the Kauri Presence, Maturity, Distribution, Ecosystem and Anthropogenic attributes. As the number of data sources used across the project was very large, key evidence types were grouped into categories (Table 3).

Table 3: Key evidence categories used for the Kauri presence, maturity, distribution, ecosystem, and anthropogenic attributes.

Kauri Presence	**Maturity**	**Distribution**	**Ecosystem**	**Anthropogenic**
Aerial imagery	Aerial imagery	Aerial imagery	Aerial imagery	Aerial imagery
Expert opinion	Expert opinion	Expert opinion	Expert opinion	Expert opinion
Field observation	Field observation	Field observation	Field observation	Field observation
Oblique photo	Oblique photos	Oblique photos	Oblique photos	Oblique photos
Report/ Publication	Reports/ Publications	Reports/ Publications	Reports/ Publications	Reports/ publications
Other mapping			Kauri Distribution Layer	
			Auckland Council Ecosystem Layer	
			BioVeg	

The ‘aerial imagery’ category was used when kauri could be seen and/or ecosystem types could be accurately assessed using Google Earth imagery. The expert opinion category was used when no direct evidence was available, or the mapper considered that the evidence was sufficiently unreliable that they should use their own judgement to assess attributes. ‘Field observation’ was used when Wildlands staff had first-hand knowledge of the site from site visits.

During the initial mapping period the ‘oblique photo’ category generally referred to the use of Google Street View to observe the vegetation adjacent to roads. In these instances the second evidence field was defined as ‘Google Street View’. Mapping carried out in 2019 using oblique aerial images provided by MPI (see Section 8 for details) also used the ‘oblique photo’ category in the first evidence field and the region the image was taken in was included in the second evidence field, e.g. ‘Waikato Oblique Images’ or ‘Auckland Oblique Images’.

The ‘Reports/Publications’ category referred to the use of other reports, including PNAP survey reports and internal Wildland reports about specific sites. The ‘other mapping’ category was used for the ‘Presence’ attribute, and included GIS layers that specifically identified the location of kauri trees (such as the Kauri Dieback layer).

For the ‘Ecosystem’ attribute, three commonly-used GIS layers were included as evidence categories. These were:

- Kauri Distribution layer, which showed the predicted historical locations of kauri within the landscape.
- Auckland Council Ecosystems layer, which provided a combination of expected and verified ecosystem types across the Auckland Region.
- BioVeg layer, which provided expected vegetation types mapped from aerial photography.

Within each ecological district, different evidence sources proved to be most useful for identifying the presence of kauri and defining the ecosystem types present. A summary of the key evidence sources used is provided in Section 9.2 below.

4.9 Likelihood values

4.9.1 Kauri present

Each 'kauri present' polygon was allocated a likelihood score of 1, 2, 3, or 4 (Table 4) to represent the likelihood that kauri was present within the polygon. Likelihood scores were also allocated to the ‘Abundance’, ‘Maturity’, ‘Distribution’, ‘Ecosystem’ and ‘Anthropogenic’ attributes.

4.9.2 Kauri absent

Where attributes were recorded for 'kauri absent' polygons (as per the initial method described in Section 4.1.1), polygons were allocated a likelihood score of 1, 2, 3, or 4 (Table 4) to represent the likelihood that kauri was absent within the polygon. Likelihood scores were also allocated to the 'Ecosystem' and 'Anthropogenic' attributes.

Table 4: Likelihood scores applied to key attributes, and associated rationales.

Likelihood - Text	Numeric	Key	Likelihood Rationale
Virtually Certain	>99%	1	Physically Sighted
Very Likely	>90%	2	Reputedly documented
Likely	>66%	3	Expert Opinion
More likely than not	>50%	4	Best guess
Not Assessed	N/A	5	Not Assessed

5. GOOGLE EARTH MAPPING: APRIL 2016-FEBRUARY 2017

5.1.1 Delineation of polygon boundaries

Mapping staff used the aerial imagery available on Google Earth Pro to define polygon boundaries. As the primary object of this mapping project was the identification of kauri presence or absence, the boundaries of polygons were primarily defined by visible changes in kauri abundance, as detectable in aerial photographs available on Google Earth Pro at the time. This could, for example, include a change from an area with no kauri present to an area with a low percentage cover, or from low percentage cover to a dense stand.

The second driver of polygon boundaries was ecosystem type, which is often related to percentage cover of kauri. This could include a change from kānuka scrub with occasional rickers to broadleaved scrub/forest with occasional rickers. PNAP survey site boundaries were also frequently used when aerial imagery quality was poor, such as for Great Barrier Island and the Coromandel Peninsula.

Lastly, topography was also considered, which can also relate to kauri presence and/or ecosystem type. For example, kauri forest is often present on ridges, with gullies being more commonly dominated by broadleaved species.

There was no maximum size for a polygon, so the extent of a polygon was based on kauri abundance, ecosystem type, and in some cases, topography.

Where appropriate, polygons from existing GIS layers were adopted. However, if the existing polygons did not accurately define the boundaries identified by the mapper they were modified, or new polygons would be created. Polygon modifications or additions were made using the Google Earth Pro 'Add Path' and 'Add Polygon' tools, and were later digitised by the GIS team.

5.1.2 Scale

The mapping scale included all areas of kauri forest, or vegetation with kauri as a component, that were over one hectare in extent. However, discretion was used to include smaller polygons where this was regarded as worthwhile and efficient. For example, if all kauri in a forest area occur within a discrete stand less than one hectare in extent, it was more efficient to map this stand as a small polygon, rather than to include the stand within a larger polygon, and then spend time estimating the percentage of kauri for the larger polygon as a whole. Conversely, if kauri was present as a few trees scattered widely amongst pasture, a large polygon encompassing all of this pasture provided useful information that was time-efficient.

5.1.3 Polygon codes

During the mapping process, each polygon was assigned a polygon code that related to a specific set of attributes. These polygon codes were assigned to polygons using the 'Add Placemark' tool in Google Earth Pro. Polygons with the same combination of attributes were assigned the same code at the time of mapping. These were then converted into unique polygon ID numbers during the digitisation process.

5.1.4 Coverage

Most of the target area was assessed using the Google Earth mapping methodology described above (Appendices 8 and 9). However, in December 2016, seven key areas were identified by MPI to be subject to aerial surveillance during the 2015/2016 financial year (Appendix 10). It was expected that kauri within these areas would be identified as a result of the surveillance work and that this information would supersede the mapping carried out using Google Earth Pro. Any Google Earth-based mapping within these areas was therefore halted.

5.1.5 Limitations

The quality of the Google Earth imagery available at the time this work was being carried out (2016-2017) was highly variable. In some areas (such as Omahuta Forest) image quality was very poor (Appendix 11). In these areas even old-growth kauri could not be identified using the aerial images, so presence was usually assessed using other resources. Omahuta Forest, for example, was mapped as one large 'kauri present' polygon based on the information provided in the PNAP survey report.

As discussed above, the 'Extensive Forest Tract - Information Poor' ecosystem type was added to the attributes table for sites where kauri forest was very likely to be present in a mosaic, but where the aerial imagery was too poor to be able to accurately delineate areas of kauri from the surrounding ecosystem type.

In other areas, such as the Rodney District, high quality aerial imagery (Appendix 12) resulted in high confidence values and more precise mapping of smaller areas of kauri at varying densities, as shown by the yellow polygon boundaries in Appendix 12.

As most of the target area was mapped using Google Earth imagery, this variability in image quality is reflected in variable mapping precision and confidence values within the geodatabase.

6. AERIAL DATA VALIDATION: FEBRUARY-JUNE 2017

6.1 Prioritisation

Due to the extensive area covered by the project, aerial validation was not possible for all areas. Validation work was prioritised to maximise confidence in the resulting geodatabase. In order to prioritise key areas, a map was produced that highlighted polygons within the geodatabase (as of early 2017) that were larger than 100 hectares and showed low confidence in the 'Presence' attribute. Specifically, this included polygons that showed as kauri present 'likely', or kauri present 'more likely than not', or had been classified as 'Extensive Forest Tract - Information Poor' under the ecosystem type attribute (Appendix 13). This map showed seven key areas where confidence was low:

- Herekino Forest.
- Warawara Forest.
- Ratea/Maungataniwha Forest.
- Russell Forest.
- Northern Waitakere Ranges.
- Hunua Ranges.
- Central Coromandel.

Following consultation with MPI, four forest tracts were selected for aerial validation (Appendices 8 and 9):

- Herekino Forest.
- Warawara Forest.
- Ratea/Maungataniwha Forest.
- Northern Waitakere Ranges.

6.2 Aerial validation method

A pilot flight was flown over the northern Waitakere Ranges in order to test and refine the flight methodology. For the Herekino, Warawara, and Ratea/Maungataniwha Forests, a series of transects were flown. These transects ran east-west across the forest areas, two kilometres apart (Appendix 14). The start and end points of the transects were predetermined and loaded into the aircraft GPS unit to aid navigation, and to ensure that transects were flown as accurately as possible.

The aircraft (a four-seater Cessna) allowed for two observers who were both seated on the left side of the aircraft. Both of the observers, Tim Martin and Sarah Budd, were mappers for the desktop component of the mapping exercise. One observer was responsible for taking georeferenced photographs of areas of kauri trees, while the other took notes and mapped key areas of kauri on printed A3 aerial photographs.

As observations could only be made out of the left side of the plane, each transect was flown in both an easterly and westerly direction to ensure that both sides of each transect were viewed. During the survey the pilot aimed to maintain a height of approximately 700 feet (214 metres) and an airspeed of 70 knots (130 kilometres/ hour). This altitude and height allowed for the passenger window to be opened, which then allowed photographs to be taken without the window glass affecting the quality of the photograph. Photographs could then also be taken with views more directly towards the ground.

The georeferenced photographs, maps and notes were then used to create digital polygons and to populate the associated attributes table. Seventy-two polygons were created as a result of the aerial validation work. The aerial validation provided valuable insight regarding both the strengths and limitations of desktop mapping using aerial photographs. The consistent pattern for the three Northland forest tracts that were flown was the omission of some small stands of kauri, usually of ricker age, by the desktop methods. However, the boundaries of larger polygons of kauri forest were normally confirmed as accurate by the aerial validation, with only minor boundary changes needed following aerial validation. This was particularly the case for tracts of kauri that contained old-growth trees, as these are readily identifiable during desktop mapping if the quality of aerial photographs is reasonable. The likelihood of kauri presence and the correct maturity class for these polygons was then increased to 'virtually certain'. An example of kauri mapping in the Maungataniwha-Raetea Range, before and after aerial validation, is presented in Figures 1 and 2.

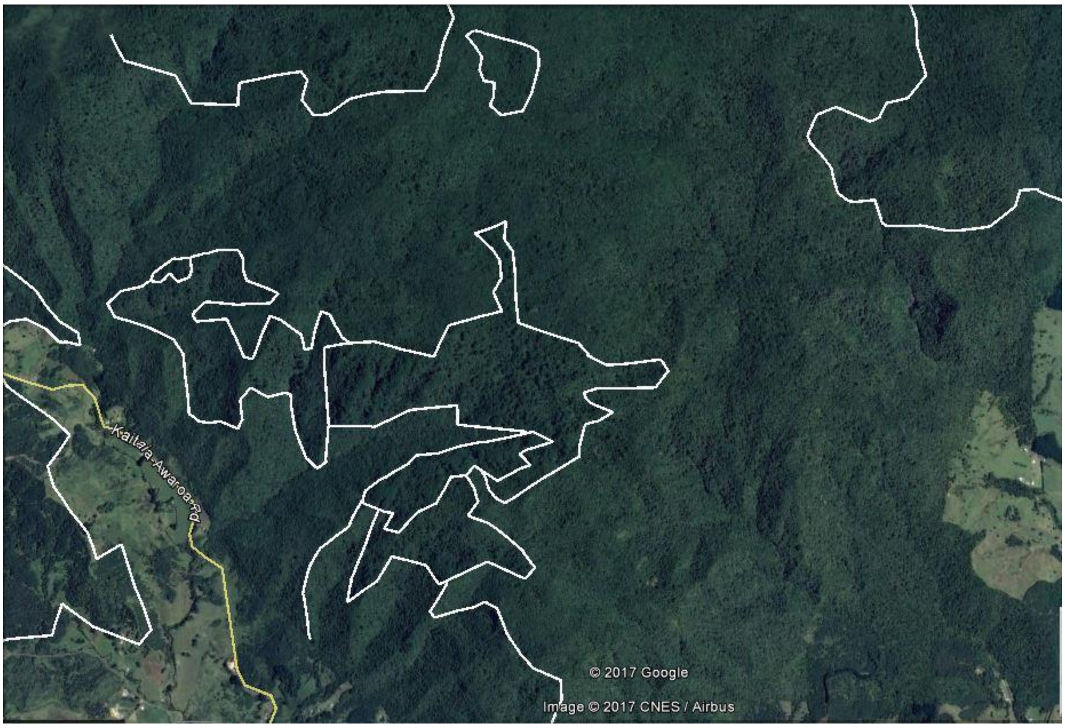

Figure 1: Kauri present polygons on the eastern edge of the Maungataniwha-Raetea forest derived from desktop mapping using Google Earth imagery.

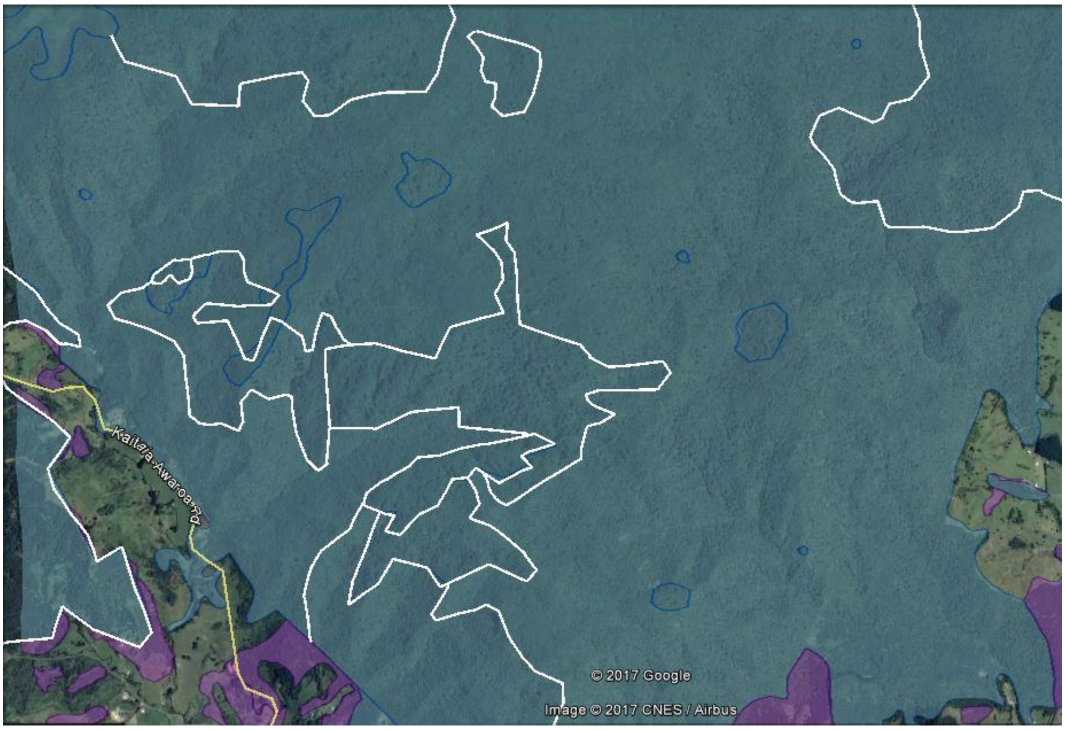

Figure 2: Kauri present polygons on the eastern edge of the Maungataniwha-Ratea forest derived from Google Earth mapping and aerial validation. Note the minor changes to polygon boundaries mapped during the desktop phase, and the inclusion (thin blue lines) of additional stands of kauri, or single trees. The mauve polygons are the seedling-sapling presence areas generated by GIS analysis and have been removed from the geodatabase.

7. DIGITISATION OF DRAFT GEODATABASE

On completion of the first stage of mapping (including the aerial validation work described above), the Google Earth files were saved to secure GIS folders to ensure that no further changes were made to the files. The Google Earth (.kml) files were converted within ArcMap 10.3 to a shapefile (.shp) file.

If an ecologist had determined that there was an existing layer that closely matched the vegetation polygons they required, the polygons from that layer file were copied and used as the basis for the kauri mapping in the area. Polygon boundaries were altered as necessary and coded as marked by the ecologist.

If multiple data sources were used, the appropriate layers were loaded into ArcMap 10.3 and traced as and when required to form a composite layer. Where adjacent polygons from different layers where used, and formed an overlap, the polygon boundary was digitised by eye from the most recent aerial photography, and then checked by the ecologist.

If there was no appropriate polygon layer, the polygons were digitised directly off the aerial photography as mapped by the ecologists.

Once digitisation of an area was complete, the section was converted back to .kml and sent to the ecologist for checking. Any changes to either polygon boundaries or codes were noted on a new .kml file and sent back to the GIS team for correction.

The scales used for digitisation varied depending on what was required to recreate the polygons produced by the ecologists. In most cases where kauri was present this was 1:10,000. However, where necessary this was decreased to ensure that the boundary was digitised correctly. These cases included long, narrow areas of gully vegetation and small areas of kauri where larger scale would not have accurately depicted the polygon boundary. If and where existing layers (e.g. LCDB4.1, Waikato biovegetation database, Auckland SEAs) were used as the basis for polygons in an area, and the boundaries of the polygons were not corrected, the scale can be assumed to be that of the original layer. The minimum scale used in any case was 1:25,000.

Once all the areas were digitised, they were merged into one file. The attribute tables and the completed polygon layer were combined to create the layer file.

The draft geodatabase was then provided to MPI for review.

8. ADDITIONAL MAPPING AND VALIDATION TO PRODUCE FINAL GEODATABASE: JANUARY-JUNE 2019

8.1 Extent

Following the review of the draft geodatabase by MPI, Wildlands was commissioned to provide mapping of four priority areas (Appendix 15). These areas were sites that had been left unmapped in the draft geodatabase to allow information resulting from the MPI surveillance work (carried out during the 2015/16 financial year) to be incorporated (Section 5.1.4).

The areas included in this stage of mapping were:

- Area 1: From Hihi to Mahinepua Bay on the east coast of Northland and inland to the edge of the Puketi and Maungataniwha Forests (*c.*59,530 hectares).
- Area 2: From the Hokianga in the north, to Dargaville in the south and as far eastwards as Kawakawa. (*c.*337,810 hectares).
- Area 3: A large proportion of the Rodney District, north Auckland. The west coast limits were South Head in the North to Waimauku in the South (*c.*138,520 hectares).
- Area 4: A section of the Coromandel Peninsula, form Ngohitanu Bay and Kennedy Bay in the north, to Manaia and Hot Water Beach in the south (*c.*72,750 hectares).

In addition to mapping the areas described above, further work was requested to incorporate the Waikato Point Data for kauri within the Waikato Region. This work focused on several high priority areas on the Coromandel Peninsula and the Kaimai Ranges in order to maximise the value of the map revisions that could be completed within a limited time frame.

8.2 Oblique aerial imagery

Mapping carried out in the identified areas was based on the oblique aerial images captured during surveillance work carried out by MPI in 2015/2016 (Appendices 8 and 9). These images were taken using three cameras aboard a fixed-winged aircraft that were angled to capture oblique aerial images in three directions (to port, forward, and to starboard). The aircraft was flown along flight lines one kilometre apart and all three cameras were programmed to take one photograph every 250 metres along these lines. Each photo was coded individually and the location of each photo was provided in a separate .kml file.

The oblique aerials were used to identify the location of kauri trees within the target areas. When kauri trees were identified in the images, ‘kauri present’ polygons were mapped (using the Google Earth Pro ‘Add Path’ and ‘Add Polygon’ tools) and assigned a polygon code. Google Earth imagery was also used to assist with the delineation of the polygon boundary, while the attribute classifications were assessed solely from the oblique aerial images. The resulting polygons were then digitised and incorporated into the final geodatabase by the GIS team (as described in Section 7) using ArcMap 10.7.

The flight lines allowed the ecologist carrying out the mapping to work up and down the lines systematically. This ensured that no areas were missed and that the vegetation was viewed and assessed from several angles. Photographs that contained few trees (such as large areas of pasture) were able to be scanned rapidly, while photographs of indigenous forest were scrutinised more thoroughly.

The quality of the images varied and was influenced by factors such as the time of day, height of the plane and the amount of salt spray in the atmosphere (Figure 3). However, the overall image quality was significantly better than those available in Google Earth Pro at the time of the initial mapping work. The resulting mapping in these areas is therefore more precise and has increased confidence values associated with the attributes of each polygon. For example, almost all of the polygons featured a confidence level of ‘virtually certain’ for the ‘kauri presence’ attribute.

Figure 3: Aerial oblique image with a white haze that reduced the clarity of the image.

8.3 Waikato point data validation

Aerial surveillance images obtained during 2015/2016 are currently being analysed to produce a GIS file that indicates the location of individual kauri trees across the Waikato Region. The partially completed data set was provided to Wildlands in late April and is referred to in this report as the 'Waikato Point Data'.

Due to time constraints and the delayed availability of this data set it was not possible to incorporate all of the points identified in the Waikato Point Data into the geodatabase. However, key areas of kauri presence (defined as areas that contained more than five points within a one hectare area) that had not yet been identified within a 'kauri present' polygon were prioritised and mapped using the MPI oblique aerial methodology described above. These key areas were clustered in the vicinity of Coromandel Peninsula and the Kaimai Range, and as such these two areas became the focus of the validation work (Appendices 8 and 9).

As the creation of the Waikato Point Data data set is a work in progress it still contains some gaps and errors. Appendix 16 provides an example of an area where new 'kauri present' polygons were added to the geodatabase. Some of these areas were identified in the Waikato Point Data, while others were not and were identified from the oblique aerial images.

9. GEODATABASE OUTCOMES

9.1 Area mapped

The final geodatabase contains a total of 8,899 polygons that cover a total of 540,948 hectares. The mapping encompasses the full natural range of kauri, from Te Paki in the north, to Kawhia in the southwest and the Bay of Plenty in the southeast.

9.2 Evidence sources

A summary of the primary evidence sources used to establish the presence of kauri trees within the mapped 'kauri present' polygons is provided in Table 5. 'Oblique photo' was the most common primary evidence source used to determine kauri presence and includes three main secondary sources; Google Streetview, fixed wing flight surveys, and the MPI oblique aerial images. The MPI oblique aerial images were used to map kauri in 92% of the 'oblique photo' polygons, and 44% of all of the polygons mapped.

Table 5: Evidence sources used in the geodatabase.

Evidence Source	Number of Polygons	Percent of Polygons	Mapped Area (ha)	Percent of Mapped Area
Oblique photo (MPI oblique aerial images)	3,959	44%	148,946	28%
Oblique photo (Google Streetview)	241	3%	19,728	4%
Oblique photo (fixed wing flight surveys)	101	1%	4,006	1%
Report/Publication	1,677	19%	68,503	13%
Aerial imagery	1,108	12%	62,284	12%
Expert opinion	1,092	12%	170,947	32%
Other mapping	617	7%	60,796	11%
Field observation	104	1%	5,730	1%
Total	**8,899**		**540,940**	

While the MPI oblique aerial images are the best source of information available for mapping using the methods described in this report, and were used to map nearly half of all polygons in the geodatabase, they account for only 28% of the total area mapped as 'kauri present'[1]. The difference between percentage of polygons mapped and percentage of area mapped is due to the higher degree of mapping precision that could be achieved within the relatively small areas where these images were used (Appendix 15).

[1] 28% of the mapping area had MPI oblique imagery available at the time it was mapped. Since completion of this mapping work, MPI oblique imagery has become available for most of the northern North Island.

‘Expert opinion’ was the primary source used to classify polygons as ‘kauri present’ across the largest area, accounting for 32% of the total area mapped but only 12% of polygons. This is likely due to the relatively poor aerial imagery available across most of the assessed area at the time of the initial mapping work was carried out. This limited the precision of the mapping, and in many cases required mappers to use their best judgement to define relatively large areas as either ‘kauri present’ or ‘kauri absent’.

All other evidence sources account for 43% of polygons and 41% of the total area mapped as ‘kauri present’.

9.3 Likelihood

The likelihood values associated with the mapping indicate a high level of confidence in the quality of the data. A summary of the proportion of polygons with each likelihood value is provided in Table 6. Nearly two thirds (64%) of the mapped polygons have a kauri presence likelihood value of ‘virtually certain’; an increase from 42.2% in the draft geodatabase submitted to MPI in October 2017. These ‘virtually certain’ polygons account for half (50%) of the area that has been mapped as ‘kauri present’.

This increase in confidence relates to two key factors:

- Firstly, the seedling/sapling analysis that was included in the draft geodatabase contained large numbers of polygons classified as ‘kauri present’ using only the two lowest likelihood categories (‘likely’ and ‘more likely than not’). This included some large areas of forest that contain kauri trees, but where mapping work had been put on hold until MPI’s surveillance flights had been completed. As such, the removal of the seedling/sapling analysis resulted in the removal of a large number of low confidence polygons.

- Secondly, the use of the high quality oblique aerial images provided by MPI allowed mappers to produce precise maps of kauri distribution with a high degree of confidence. Many of these high confidence polygons occur in areas that had previously been classified as ‘kauri present’ with low confidence under the seedling/sapling analysis.

Only 15% of the polygons in the final geodatabase were mapped with the lowest likelihood value of ‘more likely than not’ for the kauri presence attribute. These polygons account for 9% of the mapped area.

Table 6: Summary of likelihood values for the kauri presence attribute.

Likelihood	Percent of Polygons	Percent of Area
1 - Virtually certain	64%	50%
2 - Very likely	10%	10%
3 - Likely	11%	31%
4 - More likely than not	15%	9%

9.4 Kauri forest

A total of 756 polygons have been identified as containing ecosystem type WF10: kauri forest, as defined in Appendix 7. Of these, 179 have been assessed as containing old-growth kauri trees. Kauri forest polygons cover a total of 8,504 hectares, of which over half (4,855 hectares) is thought to contain at least some old-growth trees.

9.5 Old-growth kauri

The mapping work has resulted in old-growth kauri trees being mapped in 582 polygons within 13 ecosystem types:

- VS2: Kānuka scrub/forest.
- VS3: Manuka-kānuka scrub.
- VS5: Broadleaved species scrub/forest.
- WF8: Tōtara, mataī, pūriri forest.
- WF10: Kauri forest.
- WF11: Kauri-podocarp-broadleaved forest.
- WF12: Kauri-podocarp-broadleaved-beech forest.
- MF6: Tānekaha forest locally with Nothofagus.
- MF24: Rimu-tōwai forest.
- Indigenous vegetation (other than the types listed here).
- Indigenous scrub and/or forest with Wilding Conifers.
- Urban areas.
- Exotic forest - wilding conifers.

Using the estimated percent cover of kauri, the proportion of old-growth kauri trees, and the area of each polygon, old-growth kauri trees cover approximately 1,459 hectares.

9.6 Seedling and Sapling analysis

The seedling and sapling analysis resulted in the creation of 47,438 polygons that were not identified in the main geodatabase as containing kauri trees, but which are considered 'likely' or 'more likely than not' to contain kauri seedlings or saplings. This equates to a total area of 314,589 hectares.

As mentioned above, refinements to the boundaries of 'kauri present' polygons has resulted in the creation of many small seedling and sapling polygons around the edges of some 'kauri present' polygons. Although all polygons smaller than 1,000 m^2 were removed from the seedlings and saplings layer, some seedling and sapling polygons that occur on the edge of 'kauri present' polygons are still likely to be an artefact of differences between the main geodatabase and the LCDB (Figure 4). In total, nearly half (46%) of the polygons created by the seedling and sapling analysis are smaller than one hectare.

A summary of the number and total area of seedling and sapling polygons across the key land cover types is provided in Table 7.

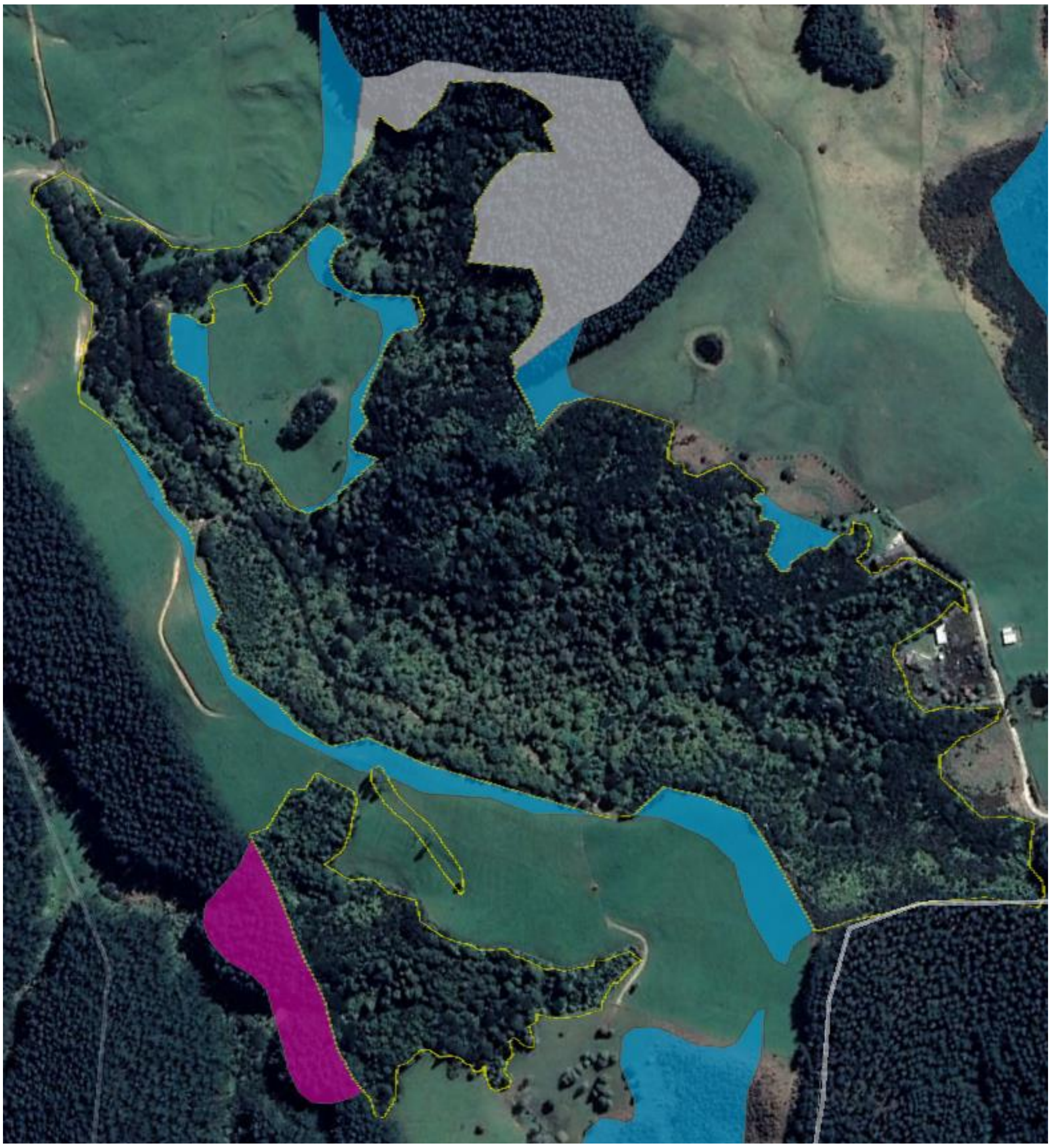

Figure 4: An example of a site where the potential seedlings and saplings polygons (blue, pink and white) are an artefact of refinements to the kauri present polygon boundaries (yellow lines).

Table 7: Summary of results from seedling and sapling analysis.

Landcover Type (as per the LCDB)	Likelihood of Kauri Seedlings and Saplings	Number of Polygons	Total Area (ha)
Broadleaved Indigenous Hardwoods	More likely than not	5,843	112
Fernland	More likely than not	24	119,146
Indigenous Forest	Likely	24,545	58,367
	More likely than not	3,779	85,982
Mānuka and or Kānuka	Likely	11,259	23,873
	More likely than not	1,975	43
Matagouri or Grey Scrub	More likely than not	13	112
Total		**47,438**	**314,589**

10. POTENTIAL USES FOR THE GEODATABASE

The geodatabase has a number of valuable functions that can be used to inform kauri management. Outlined below are a few examples of how the database can be interrogated to provide information regarding the distribution of kauri within key life stages and ecosystem types.

10.1 Identification of where kauri occurs in association with particular ecosystem types

Kauri occurs in association with a wide range of vegetation types and is an important determinant of structure and function in some ecosystems, e.g. kauri forest and kauri-podocarp-broadleaved forest. Identification of the ecosystem types that contain kauri will allow managers to ensure that future kauri management areas are representative of the full range of ecosystems within which kauri occur.

The geodatabase identifies where kauri occurs in highly modified ecosystem types, such as pasture and urban areas. These ecosystems may be environments where kauri is more vulnerable to Kauri Dieback infection

The geodatabase allows the user to identify which ecosystem types in an area of interest contain kauri, as illustrated in Appendix 17. If it is found that other tree species can act as potential hosts for kauri dieback, this information could be used to assess where carrier species may occur in association with kauri trees.

10.2 Mapping of kauri in varying levels of abundance

The geodatabase could be used to produce a map of kauri at varying levels of abundance:

- High kauri abundance (≥50% cover)
  - Kauri forest (WF10)

- Medium kauri abundance (≥20% and <50% cover)
  - Kauri-podocarp-broadleaved forest (WF11)
  - Kauri-podocarp-broadleaved-beech forest (WF12)

- Low kauri abundance (<20% cover)
  - All other ecosystem types

At a broad level this can be achieved by colour coding polygons according to the relative proportion of kauri within their assigned ecosystem types, as described below and illustrated in Appendix 18.

Alternatively, a map of kauri abundance could be created at a greater level of resolution using the '% cover' attribute. This would allow kauri that are present at a particular density (e.g. >90% cover) to be identified and mapped.

10.3 Identification of areas of old-growth kauri

Old-growth kauri is of very high ecological value and as such is of significant interest. Geodatabase users may therefore wish to identify where old-growth kauri occurs.

A map of old-growth kauri can be produced quickly and easily from the geodatabase. If required, such a map could also be refined to show the percentage cover of old-growth trees within each polygon. This function could aid the prioritisation of resources to areas of special significance and potentially inform the location of kauri sanctuaries (e.g. areas with significant cover of old-growth kauri).

10.4 Identification of regenerating kauri in early successional vegetation

Kauri regeneration is crucial to the long term sustainability of kauri forests. As such, users of the geodatabase could choose to identify areas where kauri occur in association with early successional ecosystem types. Appendix 19 illustrates the distribution of kauri occurring within polygons that have been classified as:

- Kānuka scrub/forest (VS2).
- Mānuka-kānuka scrub (VS3).
- Mānuka scrub (VS4).

Maps such as this may also be of interest as they provide an indication of areas where kauri occur in vegetation types that are more vulnerable to fire.

Areas of regenerating kauri could also be identified based on the assessed cover of kauri ricker within the polygons in a particular area. The seedling and sapling layer also provides an indication of where kauri may regenerate in the future.

10.5 Identification of potential vector pathways

The geodatabase provides information regarding the anthropogenic impacts on kauri present polygons. This may provide an indication of potential vector pathways for the introduction or spread of kauri dieback (such as logging operations, restoration activities, or plantation forestry).

10.6 Baseline for future decision making

The geodatabase can be used to set the baseline for future decision making as other GIS layers (such as risk intelligence, vector pathways, environmental layers, and disease status layers) are developed and can be overlaid or built in to the platform. This geodatabase will therefore be an important tool for decision making and can be updated over time as new information becomes available.

10.7 Information sharing

The geodatabase can easily be shared with stakeholders who have interest in particular parts of the region. To do this, the relevant part of the geodatabase can be exported as a .kml file, which can be viewed on most computers with access to Google Earth Pro. Providing small sections of the geodatabase to interested parties will facilitate improved information sharing as the file sizes will be smaller, making them easier to share around (e.g. via email) and to navigate in Google Earth.

11. CONCLUSIONS

In 2009 a partnership programme was established to promote the effective management of Kauri Dieback and to aid collaboration between interest groups. Key groups within the partnership are tāngata whenua, Ministry for Primary Industries (MPI), Department of Conservation, and district and regional councils within the natural range of kauri. To achieve the goals of the partnership programme it was identified that more information was required regarding the current distribution, abundance and maturity of kauri and kauri-dominated ecosystems. As such, in 2015 MPI engaged the services of Wildland Consultants to develop a geodatabase of kauri throughout its naturally-occurring range.

Wildland Consultants has carried out extensive mapping work throughout the entire natural range of kauri using a number of information sources (Appendix 1). These resources included reports, herbarium records, Google Earth imagery, and where available, high resolution oblique aerial photographs provided by MPI. The mapping methodology has been refined and adjusted throughout the project as new resources have been made available.

The result of this work is a comprehensive geodatabase that provides the first high resolution map of kauri distribution, age structure, and species associations throughout the natural range of kauri. A total of 8,899 'kauri present' polygons have been created across a total of 540,940 hectares. The seedling and sapling analysis also resulted in the creation of a further 47,438 polygons across 314,589 hectares, which provide an indication of where kauri may regenerate in the future.

This geodatabase is also the first systematic assessment of the current extent of kauri forest and old-growth kauri. Kauri forest (WF10) covers *c.*8,504 hectares, and old-growth trees cover *c.*1,459 hectares.

The accuracy of the database, as reflected in the confidence attributes for each polygon, is determined by the accuracy and coverage of the contributing imagery and databases. If the geodatabase was further revised using the increased coverage of high quality aerial imagery now available, further aerial surveillance work, and ground-truthing, this would lead to further refinement of the geodatabase in terms of both the spatial extent of kauri, and knowledge of the associated attributes.

The completed geodatabase will be a powerful tool for stakeholders hoping to contribute to the effective management of the Kauri Dieback Programme. The mapped polygons and their associated attributes provide important information that should be used to inform kauri management planning and prioritisation. This includes information on the ecosystems kauri are associated with, as well as the distribution of kauri at key life stages and levels of abundance.

ACKNOWLEDGMENTS

Travis Ashcroft (MPI), Kim Brown (MPI), Kim Parker (Waikato Regional Council), and Phil Hancock (formerly MPI, now Department of Conservation) provided technical liaison and sourcing of data sets from Kauri Dieback Programme partners, and other agencies. Auckland Museum, Scion, Te Papa, and Landcare Research provided kauri herbarium records. Auckland Council staff provided useful discussion of the use of Singers and Rogers to classify ecosystem types. Andrew McDonald (Biospatial Ltd) provided access to the MPI oblique aerial images.

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APPENDIX 1

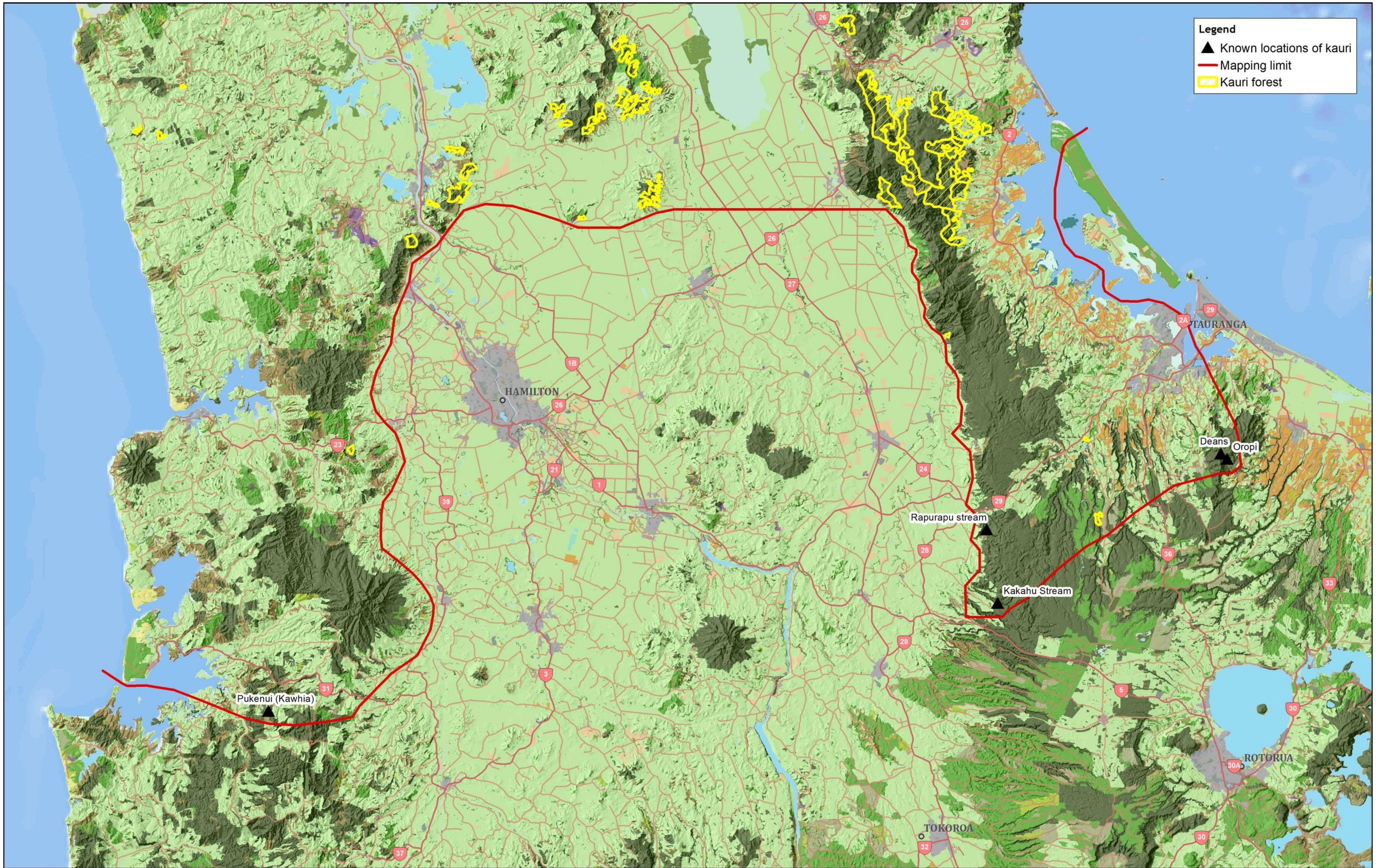
SUMMARY OF DATA SETS RECEIVED

Data Type	Viewed?	Useful?	Used in Pilot?	Information	Areas Covered	Confidence in Data (Very high, High, Moderate, N/A)	Comment
Forest service maps	Yes	Yes	No	Historic modification, vegetation.	Glenbervie, Omahuta, Puketi, Russell, Trounson, Waipoua	Moderate	Will be useful for assessing anthropogenic modification.
Waikato potential ecosystems	Yes	Yes	No		Waikato Region	Moderate	Maps Singers and Rogers classification across Waikato Region, useful.
Kauri plantation maps and associated documents	Yes	Yes	No	Kauri plantation locations.	Kauri extent	High	None in pilot area, will be useful elsewhere.
Spatial distribution	Yes	Yes	Yes	Merged layer likely to be used as base layer.	Kauri extent	Moderate	Large number of polygons already mapped, need to assess for kauri presence, maturity, cover. Seedlings and saplings not mapped. Some inaccuracies noted during the pilot mapping phase. Use with caution.
Singers and Rogers	Yes	Yes	Yes			Moderate	Have it in Auckland, Waikato and Northland Regions. Need it for BoP.
Auckland potential vegetation	Yes	Yes	Yes		Auckland Region	Moderate	Maps Singers and Rogers classification across Auckland Region, useful.
Waikato bioveg	Yes	Yes	No		Waikato Region	High	Detailed veg polygons classed by LCDB categories.
NVS databank	Yes	Yes	No		Kauri extent	High	Will be useful for improving confidence and determining seedling and sapling distribution and abundance.
Fundamental soils layer	Yes	Yes	No		Kauri extent	Moderate	Will be used as required.
Land use map (output of LUCAS)	Yes	Yes	No		Kauri extent	Moderate	Will be used as required.
LENZ	Yes	Yes	No		Kauri extent	Moderate	Will be used as required.
Predicted Potential vegetation	Yes	Yes	No		Kauri extent	Moderate	Will be used as required.
LCDB4.1	Yes	Yes	No		Kauri extent	Moderate	Will be used as required.
Tane's Tree Trust	Yes	Yes	No		Kauri extent	High	Useful to increase confidence for selected polygons.
Herbarium data	Yes	Yes	Yes		Kauri extent	Very high	Herbarium data has been used to determine the southern limit. Will be used to identify offshore islands where kauri is present (e.g. Poor Knights), and to verify presence of kauri identified in aerials. Some herbarium records also contain useful information on stand age, extent, and associated species. Herbarium data has been obtained from Auckland Museum, Landcare Research, Te Papa, and Scion.
PNAP reports	Yes	Yes	No		Kauri extent	High	Have hard copy reports only. Useful for increasing confidence of polygons, and identifying seedling and sapling distribution and abundance.
Aerial survey of Waitakeres and Hunuas looking for kauri	No	Yes	No		Auckland Region	N/A	Have not received this.
Natural areas within forestry blocks and other areas (Wildlands reports)	Yes	Yes	No		Northland, Auckland	Very high	Useful for increasing confidence of polygons.
NZDF ecological surveys (Wildlands reports)	Yes	Yes	No		Auckland Region	Very high	Useful for increasing confidence of polygons.
SEA ground truthing and other Auckland Council reports (Wildlands)	Yes	Yes	No		Auckland Region	Very high	Useful for increasing confidence of polygons.
BOP SNA layer and attributes	No	Yes	No		Bay of Plenty	N/A	Not received yet but likely to be useful.
Natural areas in structure plan for Far North District	yes	Yes	No		Northland Region	Moderate	Useful for increasing confidence of polygons.
Waipoua Forest Vegetation Map	Yes	Yes	No		Waipoua Forest	High	Useful for increasing confidence of polygons.
Waikato SNA layer and attributes	Yes	Yes	No		Waikato Region	Moderate	Will be useful if have attribute data for polygons.
DOC Northland Region SNAs	Yes	Yes	No		Northland Region	High	Useful for increasing confidence of polygons.
Known kauri forests	Yes	Possibly	No	pdf maps of kauri extent.	Kauri extent	Moderate	Limited use as hard copy information.
QEII covenants	Yes	No	No			N/A	If we had attributes for polygons could be useful.
Auckland Ecosystems	Yes	Yes	Yes	Kauri forest polygons useful for locating dense kauri.	Auckland Region	Moderate	Very useful.
Significant ecological areas (SEA's)	Yes	Partly	No		Auckland Region	Moderate	Need the site reports that go with site polygons.
DOC Ecosystems (EMU layer)	Yes	Yes	Yes		Nationwide	Moderate	Note that this uses an older version of Singers and Rogers, which needs to be taken into account, e.g. WF11 is now labelled WF10.
Auckland Councils Park extent	Yes	No	No		Auckland Region	N/A	Other layers more useful.
Whangarei Harbour 1942-1950 aerial images	Yes	Limited	No			High	Very small area covered.
1950s aerial photographs	Yes	Yes	No	Aerial imagery.	Far North, Matawhai, Matakana	High	Useful to increase confidence for selected polygons.
Ad hoc flights	Yes	Yes	No			High	Useful to increase confidence for selected polygons.
Historic Northland imagery	Yes	Yes	No	Aerial imagery.	Aupori	High	Useful to increase confidence for selected polygons.
Kiwimage	Yes	Yes	No	Aerial imagery.	Extent	High	Useful to increase confidence for selected polygons.
SPOT imagery	Yes	Yes	No	Aerial imagery.	Extent	High	Useful to increase confidence for selected polygons.
Kauri Dieback Programme Field Data	Yes	Yes	No	Locations of known trees.	Extent	Very high	Useful to increase confidence for selected polygons.
Northland Aerial Oblique Images	Yes	Yes	No	Oblique photos covering large amounts of Northland.	Northland	Very high	Used to map two previously unmapped areas in Northland to a high level of accuracy.

Data Type	Viewed?	Useful?	Used in Pilot?	Information	Areas Covered	Confidence in Data (Very high, High, Moderate, N/A)	Comment
Auckland Aerial Oblique Images	Yes	Yes	No	Oblique photos covering a large area of Rodney, Auckland.	Rodney, Auckland	Very high	Used to map previously unmapped section of Rodney, Auckland.
Waikato Aerial Oblique Images	Yes	Yes	No	Oblique photos covering entire Waikato Region.	Waikato Region	Very high	Used to map previously unmapped section of the Coromandel Peninsula.
Waikato Point Data of kauri tree locations (unvalidated)	Yes	Yes	No	Point data showing individual kauri tree locations.	Waikato	Moderate	Large amounts of kauri were missed, but most of the trees identified as kauri were accurate. Used to map some high priority areas.

APPENDIX 2

SOUTHERN DISTRIBUTIONAL LIMIT OF KAURI



Data Acknowledgment
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N

Report: 3886
Client: MFPI
Ref: 06 0723
Path: E:\gis\Kauri\mxd\figs\
File: Kauri_Southern_Limit.mxd

Southern distribution limit of naturally occurring stands of kauri, North Island

0 10 20 km

Scale: 1:400,000
Date: 1/04/2016
Cartographer: RPB
Format: A3R

FINAL ATTRIBUTE TABLE

Presence/Absence	Primary Classification	Secondary Classification	Guide
Presence 1,2,3,4 (Extent of Kauri)	**Abundance** 1,2,3,4	Rare <1% Occasional 1-19% Common 20-49% Abundant 50-74% Dominant >75%	For all Abundance Secondary Classifications; - Old-growth and Mature - based on estimated Canopy Cover - Rickers - based on estimated Canopy Cover - Seedlings/saplings - based on estimated stem counts
	Maturity 1,2,3,4	Old-growth >20m canopy diameter Mature 5-20m canopy diameter Rickers <5m canopy diameter Seedling/Sapling	- We have given a proportion (cover %) for each maturity type within each polygon, rather than mapping each maturity type as separate polygons. Most polygons contain a mixture of these classes. - These specifications were revised to be suitable for determining from aerial photographs.
	Distribution 1,2,3,4	Single tree	When only single specimen are known within a polygon
		Random	Distribution of trees where individuals are spaced at unpredictable distances from each other with no visible aggregation (clustering or clumped) of trees
		Random - mixed	Random distribution but with some aggregation of trees and individual trees
		Clumped	Aggregation of trees as a group/s of trees with joined canopies
		Cluster	Aggregation of trees as a group/s of trees whose canopies are not touching
	Ecosystem 1,2,3,4	WF4: Pōhutukawa-pūriri-broadleaved forest	Other Secondary Classifications from Singers & Rogers can be added if evidence based
		WF5: Tōtara-kānuka-broadleaved forest [dune forest & scrub]	Other Secondary Classifications from Singers & Rogers can be added if evidence based
		WF8 Tōtara, mataī, pūriri forest	Other Secondary Classifications from Singers & Rogers can be added if evidence based
		WF10: Kauri forest	Other Secondary Classifications from Singers & Rogers can be added if evidence based
		WF11: Kauri-podocarp-broadleaved forest	Other Secondary Classifications from Singers & Rogers can be added if evidence based
		WF12: Kauri-podocarp-broadleaved-beech forest	Other Secondary Classifications from Singers & Rogers can be added if evidence based
		MF4: Kahikatea forest	Other Secondary Classifications from Singers & Rogers can be added if evidence based
		MF24: Rimu-tōwai forest	Other Secondary Classifications from Singers & Rogers can be added if evidence based
		MF25: Kauri-tōwai-rata-montane podocarp forest	Other Secondary Classifications from Singers & Rogers can be added if evidence based
		MF6: Tānekaha forest locally with *Nothofagus*	Other Secondary Classifications from Singers & Rogers can be added if evidence based
		WL1: Mānuka-Gumland grass tree-Machaerina scrub/sedgeland [gumland]	Other Secondary Classifications from Singers & Rogers can be added if evidence based
		VS2: Kānuka scrub/forest	Other Secondary Classifications from Singers & Rogers can be added if evidence based
		VS3: Mānuka-kānuka scrub	Other Secondary Classifications from Singers & Rogers can be added if evidence based
		VS4: Mānuka scrub	Other Secondary Classifications from Singers & Rogers can be added if evidence based
		VS5: Broadleaved species scrub/forest	Other Secondary Classifications from Singers & Rogers can be added if evidence based
		Exotic/Indigenous Treeland-TL	
		Exotic Forestry - conifers	
		Exotic Forestry - other	
		Exotic forest - wilding conifers	
		Exotic Forest - other	
		Exotic Scrub-ES	
		Exotic Scrub and/or Forest with Wilding Conifers	
		Indigenous scrub and/or forest with Wilding Conifers	

Presence/Absence	Primary Classification	Secondary Classification	Guide
		Grassland/Herbfield-GH	
		Grassland/Herbfield -GH with trees	
		Indigenous Wetland	
		Exotic Wetland-EW	
		Planted native vegetation-PL	
		Open Water body	Water bodies larger than 1 hectare, so it doesn't look like a 'missed area'
		Indigenous vegetation (other than the types listed here)	
		Urban areas	
		Exotic grassland/urban areas	
		Exotic forestry/grassland	For use when mapping small areas of fragmented forestry amongst pasture/grassland
		Dune/sandfieldExtensive Forest Tract - Info Poor	
		Extensive Forest Tract - Information Poor	For use when aerial imagery poor
	Anthropogenic 1,2,3,4	Unmodified	
		Clearance - Non-Harvest Removal	
		Logging/Harvest	Where records show that Kauri was historically logged or otherwise cleared, or where the other options are not applicable.
		Plantation	Other Secondary Classifications can be added only with written agreement from MPI Technical Liaison
		Restoration	

Note: The kauri absence data described below was not collected for all sites. See Section 4.1.2 for further explanation.

Presence/Absence	Primary Classification	Secondary Classification	Guide
	Abundance 5	N/A	Nil/ Not Appropriate
	Maturity 5	N/A	Nil/ Not Appropriate
	Ecosystem 1,2,3,4	WF4: Pōhutukawa-pūriri-broadleaved forest	Other Secondary Classifications from Singers & Rogers can be added if evidence based
		WF5: Tōtara-kānuka-broadleaved forest [dune forest & scrub]	Other Secondary Classifications from Singers & Rogers can be added if evidence based
		WF8 Tōtara, mataī, pūriri forest	Other Secondary Classifications from Singers & Rogers can be added if evidence based
		MF4: Kahikatea forest	Other Secondary Classifications from Singers & Rogers can be added if evidence based
		MF24: Rimu-tōwai forest	Other Secondary Classifications from Singers & Rogers can be added if evidence based
		MF6: Tānekaha forest locally with *Nothofagus*	Other Secondary Classifications from Singers & Rogers can be added if evidence based
		WL1: Mānuka-Gumland grass tree-Machaerina scrub/sedgeland [gumland]	Other Secondary Classifications from Singers & Rogers can be added if evidence based
		VS2: Kānuka scrub/forest	Other Secondary Classifications from Singers & Rogers can be added if evidence based
		VS3: Mānuka-kānuka scrub	Other Secondary Classifications from Singers & Rogers can be added if evidence based
		VS4: Mānuka scrub	Other Secondary Classifications from Singers & Rogers can be added if evidence based

Presence/Absence	Primary Classification	Secondary Classification	Guide
Absence 1,2,3,4 (Non-extent of Kauri)		VS5: Broadleaved species scrub/forest	Other Secondary Classifications from Singers & Rogers can be added if evidence based
		Exotic/Indigenous Treeland-TL	
		Exotic Forestry - conifers	
		Exotic Forestry - other	
		Exotic forest - wilding conifers	
		Exotic Forest - other	
		Exotic Scrub-ES	
		Exotic Scrub and/or Forest with Wilding Conifers	
		Indigenous scrub and/or forest with Wilding Conifers	
		Grassland/Herbfield-GH	
		Indigenous Wetland	
		Exotic Wetland-EW	
		Planted native vegetation-PL	
		Open Water body	Water bodies larger than 1 hectare, so it doesn't look like a 'missed area'
		Indigenous vegetation (other than the types listed here)	
		Urban areas	
		Exotic grassland/urban areas	For use when mapping large areas where no kauri are present
		Exotic forestry/grassland	For use when mapping small areas of fragmented forestry amongst pasture/grassland
		Dune/sandfield	
	Anthropogenic 1,2,3,4, or 5	Unmodified	Only to be used with an 'Indigenous' Ecosystem classification
		Removal/harvest	Where records show that Kauri was historically logged or otherwise cleared, or where the other options are not applicable.
		N/A	If attributed a 5 then Not Appropriate or Not assessed to be used

For this project, the term Kauri always means '*Agathis australis*' and always means naturally seeded except when it is classified as 'Plantation' or 'Restoration'.

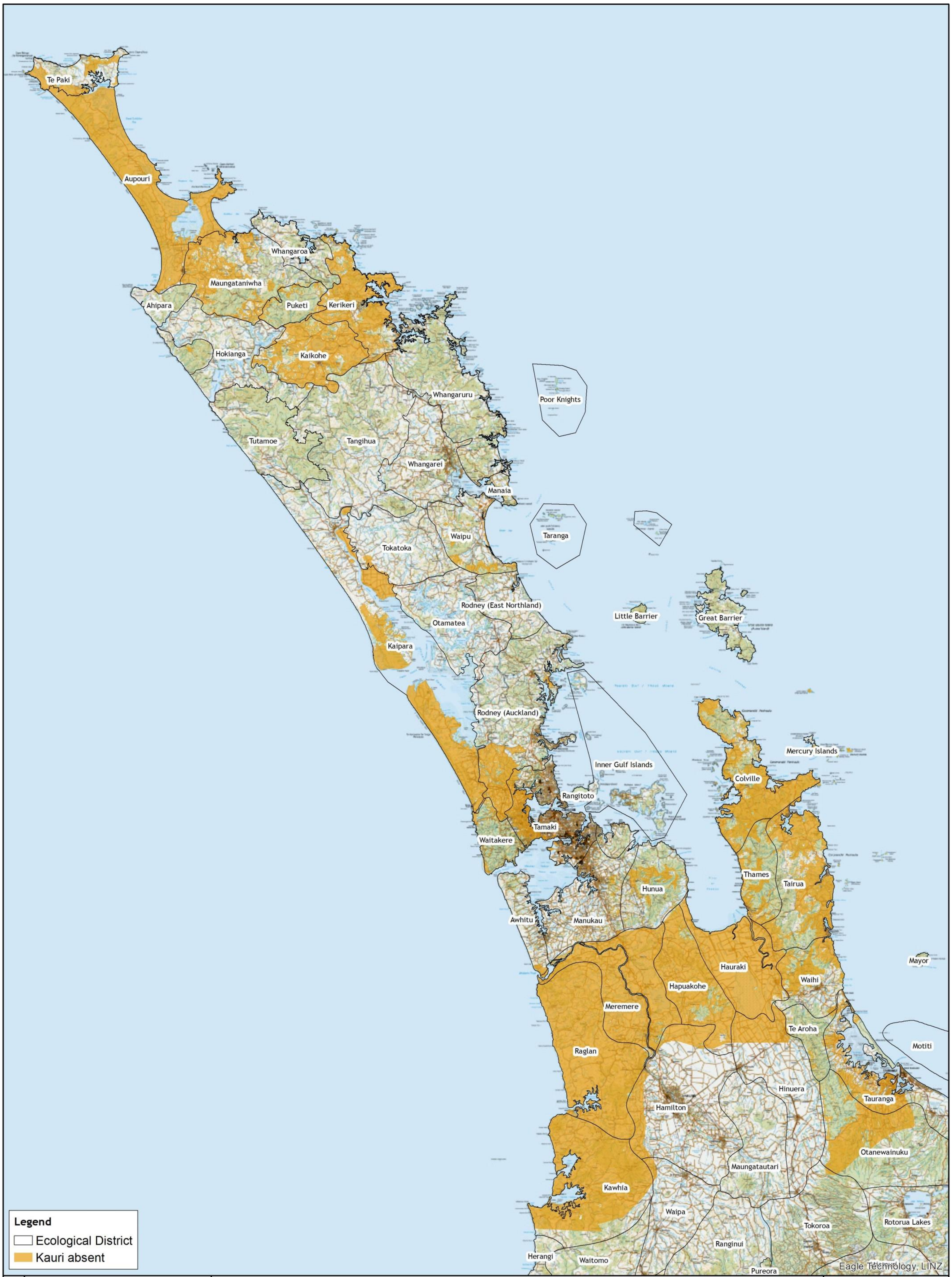
Where kauri is present, or not, for a one-hectare area it is defined by a polygon.

If kauri (including isolated specimens) is present in a polygon then by definition this is a 'Kauri Present' polygon.

A 'kauri absent' polygon implies there are no kauri trees within this polygon.

APPENDIX 4

AREAS WHERE 'KAURI ABSENT' POLYGONS WERE MAPPED



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Data Acknowledgment

Maps contain data sourced from LINZ
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Report: R3886
Client: MFPI
Ref: 06 0723
Path: E:\gis\Kauri\mxd\
File: Kauri_absent.mxd

Areas where 'kauri absent' polygons were mapped

0 50 100 km

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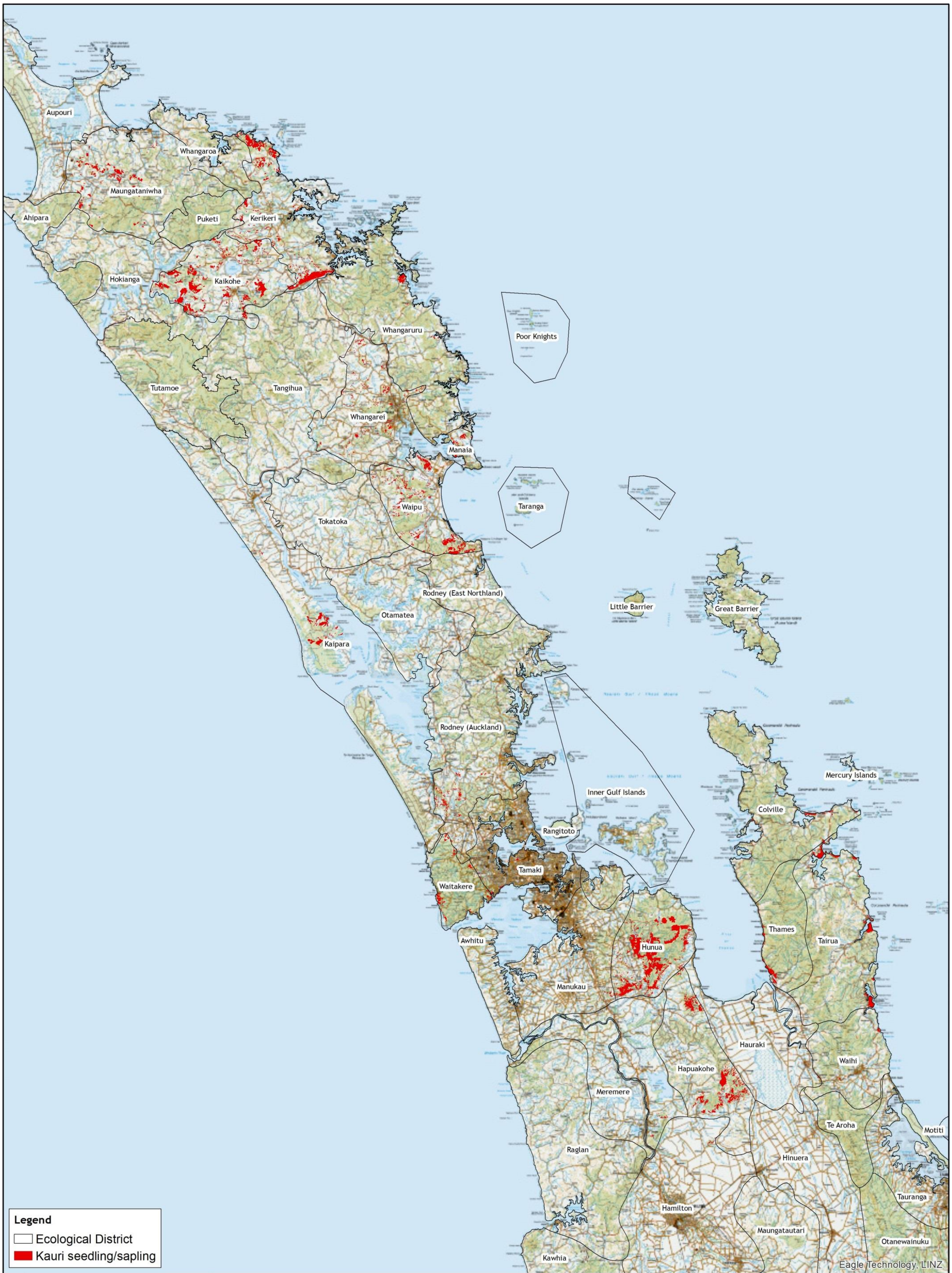
Scale: 1:1,250,000
Date: 25/08/2017
Cartographer: RPB
Format: A3

APPENDIX 5

AREAS MAPPED MANUALLY USING PRELIMINARY SEEDLINGS AND SAPLINGS DECISION MATRIX



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Data Acknowledgment
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Report: R3886
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File: Kauri_seedsapling_manual.mxd

Areas mapped with seedlings and saplings as evidence

0 50 100 km

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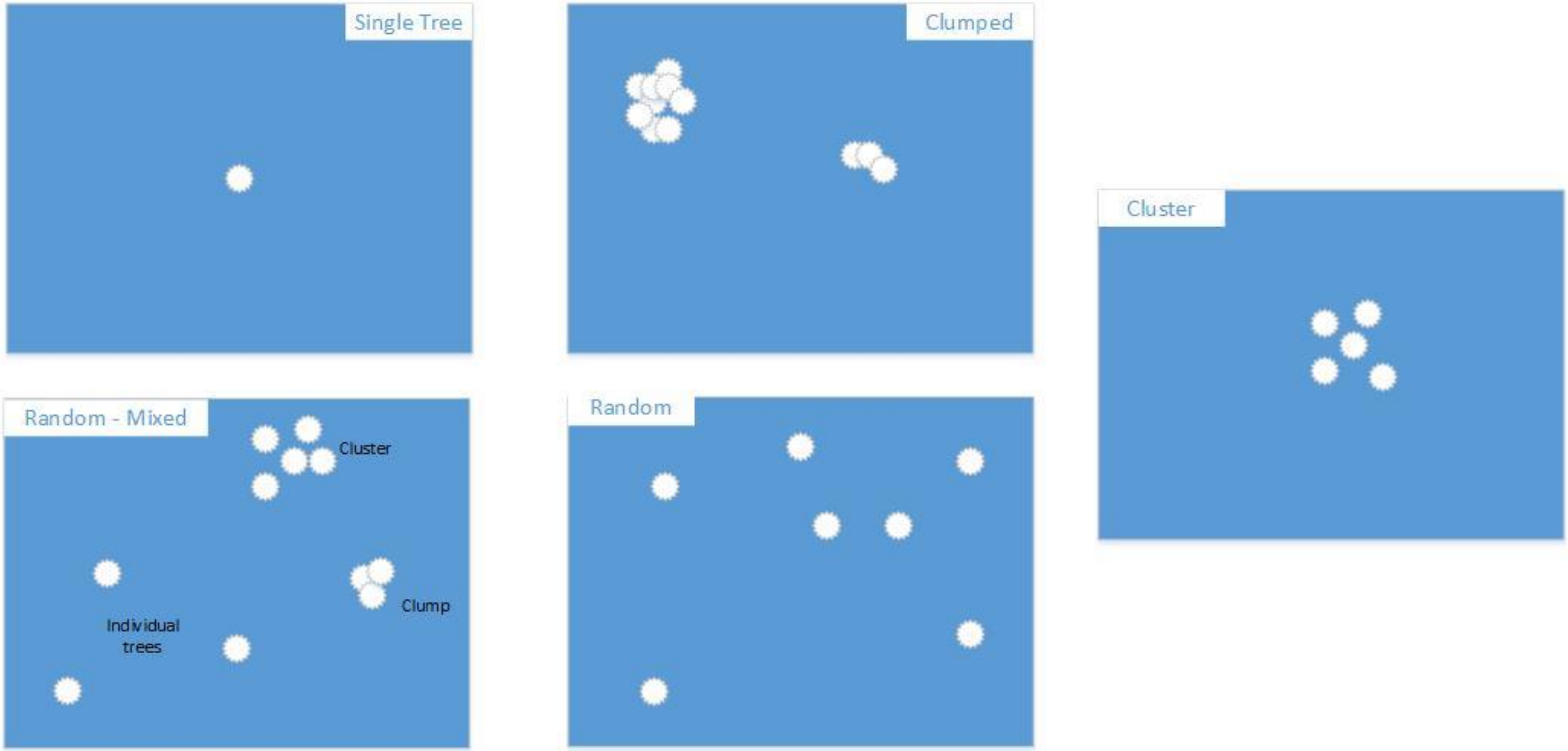
Cartographer:	RPB
Format:	A3

APPENDIX 6

SCHEMATIC EXPLANATION OF DISTRIBUTION CLASSES



Single Tree – when only single specimen are known within a polygon
Random – Random distribution of individual trees, no visible aggregation (clustering or clumped) of trees
Random - Mixed – Random distribution with some aggregation of trees and individual trees
Clumped – Aggregation of Kauri as a group/s of trees with **joined** canopies.
Cluster – Aggregation of Kauri as a group/s of trees whose canopies are not touching.

APPENDIX 7

QUANTITATIVE INTERPRETATION OF ECOSYSTEM CLASSES

Type	Ecosystem Unit Code and Name	Quantitative Thresholds	Additional Guidelines	Ecosystem Description (as per Singers and Rogers)
Forest - warm	WF4: Pōhutukawa-pūriri-broadleaved forest	Coastal broadleaved species collectively comprise the greatest component of the canopy and kauri comprises <20% of canopy. If kauri ≥20% cover, classify as kauri-podocarp-broadleaved forest.	Coastal, normally but not always with pōhutukawa. Kauri not dominant or co-dominant. Occurs with kauri as a component on Mahurangi coastline and Little Barrier Island. Possibly also on offshore islands such as Poor Knights	Broadleaved forest of several variants with pōhutukawa, pūriri, karaka, kohekohe locally with tītoki, mangeao, rewarewa, tawa, puka, tawāpou, ngaio, nīkau, taraire, and occasional tānekaha and kauri in northern part of range and locally hard beech along the Bay of Plenty coast and East Cape (also with black beech). Kānuka and kōwhai locally occur on dry, steep ridges. Where present on some northern offshore islands, especially Three Kings includes local endemic species and varieties
Forest - warm	WF5: Tōtara-kānuka-broadleaved forest [dune forest & scrub]	Forest on dunes. Tōtara, kānuka, and broadleaved species collectively comprise the greatest component of the canopy and kauri comprises <20% of canopy. If kauri ≥20% cover, classify as kauri-podocarp-broadleaved forest.	Always on dunes. Often kānuka dominant. Occurs at Woodhill and possibly elsewhere on west coast dunes. Kauri if present likely to be occasional rickers.	Podocarp, broadleaved forest of mosaics of kānuka on younger (Holocene) dunes, grading into tītoki, tōtara, māhoe, karaka, kohekohe, tawa, pūriri, hīnau and locally pōhutukawa, narrow leaved maire and taraire on older dunes
Forest - warm	WF8 Tōtara, mataī, pūriri forest	Tōtara, mataī, and pūriri collectively comprise the greatest component of the canopy and kauri comprises <20% of canopy. If kauri >20% cover, classify as kauri-podocarp-broadleaved forest.	Natural occurrence of kauri on volcanic loams/ lava-flow forests unlikely. Note that secondary derivatives can have kānuka as co-dominant. If kānuka more common than any other species, use VS2 (kānuka scrub forest).	Two variants determined by landform and soil type with i.) tōtara, mataī, pūriri, tītoki forest locally with kōwhai and taraire on alluvial free draining soils and i.) tōtara, mataī, abundant pūriri, taraire, occasional pukatea, rewarewa, karaka, kohekohe, tawa, tītoki, Northern rātā and abundant nīkau on fertile basaltic volcanic loam soils. Youngest basaltic examples (occurring on more recent basaltic lava flows in the Auckland volcanic field) are colloquially described as "lava forests" (Lindsay et al 2009). Largely only secondary/ modified derivatives of kānuka and scattered tōtara, pūriri, taraire now remain.
Forest - warm	WF10: Kauri forest	Kauri comprise ≥50% of the canopy. Note that kauri forest over 600 m above sea level is classified as MF25.	Kauri is the dominant species (a greater component of the canopy than any other species)	Kauri forest with occasional podocarp (miro, rimu, toatoa, Hall's tōtara, tānekaha) and broadleaved trees (northern rātā, tawa, taraire, hīnau, rewarewa, kohekohe and tōwai)
Forest - warm	WF11: Kauri-podocarp-broadleaved forest	Kauri comprises ≥20% and <50% of canopy, in association with podocarps and broadleaved species which collectively comprise 50-79% of the canopy. Note that kauri forest over 600 m above sea level is classified as MF25.	Kauri is co-dominant with podocarps or broadleaved species. Beech is absent. Widespread kauri forest type from Auckland northwards.	Kauri, podocarp, broadleaved forest with occasional rimu, miro, kahikatea, kauri, taraire, tawa, tōwai, kohekohe, pūriri, rewarewa. Altitude variants occur with taraire more abundant at lower altitude while tōwai at higher altitudes
Forest - warm	WF12: Kauri-podocarp-broadleaved-beech forest	Kauri comprises ≥20% and <50% of canopy, in association with beech species, and sometimes podocarps, which collectively comprise 50-79% of the canopy. If beech not present in canopy use WF11. Note that kauri forest over 600 m above sea level is classified as MF25.	Kauri is co-dominant with beech, and other canopy species, if present, are podocarps or broadleaved species. Occurs at Omahuta (Northland), locally on North Shore, Hunua Range, Coromandel, Kaimai Range, and western Waikato.	Kauri, podocarp, broadleaved and hard beech forest with occasional tānekaha, Hall's tōtara/ lowland tōtara, rimu, miro, tawa, hīnau, rewarewa and locally narrow-leaved maire, tāwari, and hard beech —generally confirned to ridges
Forest - mild	MF4: Kahikatea forest	Kahikatea comprises the greatest component of the canopy and kauri comprise <20% of canopy. If kauri ≥20% and <50% cover, classify as kauri-podocarp-broadleaved forest.	Occurs on well-drained alluvium (river side flats). Kauri is present but not dominant or co-dominant. Examples in Rodney Ecological District (especially around Warkworth). Almost all secondary.	Podocarp forest of abundant kahikatea locally with mataī and a sparse sub-canopy of ribbonwood, houhere spp., locally kōwhai, pōkākā, māhoe, tarata and divaricating shrubs on alluvial Holocene flood plains. Ribbonwood and houhere are locally absent while often pōkākā is can be more abundant
Forest - mild	MF24: Rimu-tōwai forest	Rimu and tōwai collectively comprise the greatest component of the canopy and kauri comprises <20% of canopy. If kauri are ≥20% cover classify as kauri-podocarp-broadleaved forest.	Secondary forest at mid to high altitudes (450-600 m) in Northland, Hunua, and Coromandel dominated by tōwai. Can have old-growth kauri e.g. Kauaeranga Valley	Podocarp, broadleaved forest with occasional emergent rimu, miro and northern rātā and with abundant tōwai, locally tawa, swamp maire and occasional hīnau, rewarewa, tāwari, pukatea, mangeao, raukawa, narrow leaved maire, makamaka and hutu.
Forest - mild	MF25: Kauri-tōwai-rātā-montane podocarp forest	Presence of any species listed in description with kauri present in the canopy at any percentage cover.	Forest >600 metres altitude with kauri. Occurs in Coromandel, Kaimai Range, Little Barrier Island, Great Barrier Island. Normally on ridges/summits. Often unmodified due to remoteness.	Kauri, podocarp, broadleaved low forest of kauri, yellow silver pine, rimu, Kirk's pine, toatoa and locally Hall's tōtara, tāwari, hīnau, tōwai, southern and Parkinson’s rātā and tāwheowheo
Forest - mild	MF6: Tānekaha forest locally with beech	Tānekaha comprises the greatest component of the canopy. If kauri is more than ≥20% and beech is more than ≥20%, then classify as kauri-podocarp-broadleaved beech forest.	Secondary forest on low altitude hillslopes. Often post-fire. Northland, Auckland, Coromandel, inland Waikato. Nurse crop for kauri. Seedlings/saplings may be present even if kauri not in canopy.	Abundant tānekaha, with stunted tōtara, Hall's tōtara, rimu, rewarewa, kāmahi and hard beech locally on Mamaku Plateau. On very steep sites grades into scrub of stunted tānekaha, kānuka, *Olearia furfuracea*, *Dracophyllum strictum*, mingimingi and *Gaultheria* species.

Type	Ecosystem Unit Code and Name	Quantitative Thresholds	Additional Guidelines	Ecosystem Description (as per Singers and Rogers)
Forest - mild	MF20: Hard beech forest	Hard beech comprises the greatest component of the canopy. If kauri is more than ≥20% classify as kauri-podocarp-broadleaved-beech forest.		Beech forest and beech, podocarp, broadleaved forest of at least three local variants all with abundant hard beech. i.) northern with ocassional rimu miro, Hall's tōtara, tāwari, northern rātā, tānekaha, toatoa, tāwheowheo, kāmahi, rewarewa; ii.) central with black beech and locally kāmahi, rimu, northern rātā, hīnau and rewarewa and iii.) southern with occasional rimu, miro, Hall's tōtara, southern rātā, tāwheowheo and locally kāmahi, black, red and silver beech.
Wetland	WL1: Mānuka-Gumland grass tree-*Machaerina* scrub/sedgeland [gumland]	The following species collectively comprise the greatest percentage cover: mānuka, *Dracophyllum*, *Schoenus, Gleichenia*, *Ghania*, *Machaerina*, *Tetraria*, *Lepidosperma*. Kauri comprises <50% cover.	Occurs in eastern Hunua Range, and as clearings in Waipoua Forest. Kauri usually present as seedlings/saplings if soils are well-drained.	Low scrub, sedgeland of two broad types (poor draining and seasonally dry), dominated by mānuka with Gumland grass tree, tall mingimingi with species of *Machaerina*, *Schoenus*, *Gahnia*, *Tetraria* and *Lepidosperma* sedges, tangle fern and locally
Vegetation - Successional	VS2: Kānuka scrub/forest	Kānuka comprises the greatest component of the canopy. Includes kānuka-kauri associations where cover of kānuka exceeds cover of kauri. Note: if on dunes, classify as WF5 (tōtara-kānuka-broadleaved forest on dunes.	Kānuka more common than any other canopy species. Kauri often present as rickers. Can include associations of kānuka with pōhutukawa, pūriri, kahikatea etc. Well drained soils below 500 m altitude.	Kānuka scrub/forest of a range of variants. Later succesional transitions include a wide range of broadleaved and podocarp trees (includes abundant tōtara in secondary forest)
Vegetation - Successional	VS3: Mānuka-kānuka scrub	Mānuka and kānuka collectively comprise the greatest component of the canopy. Includes mānuka-kānuka-kauri associations where cover of mānuka-kānuka exceeds the cover of kauri.	Mānuka and kānuka are co-dominant. Kauri, if present, are usually seedlings/saplings or rickers.	Mānuka-kānuka scrub of a range of variants. Later successional transitions include a wide range of broadleaved and podocarp trees and tree ferns
Vegetation - Successional	VS4: Mānuka scrub	Mānuka comprises the greatest component of the canopy. If kauri is present, cover of kauri is less than the cover of mānuka.	Mānuka is dominant. Kauri, if present, are usually seedlings/saplings or small rickers.	Mānuka scrub of a range of variants. Later successional transitions include a wide range of broadleaved and podocarp trees and tree ferns
Vegetation - Successional	VS5: Broadleaved species scrub/forest	Indigenous broadleaved species not listed above collectively comprise the greatest percentage of the canopy. If kauri ≥20% and <50%cover then classify as kauri-podocarp-broadleaved forest.	A 'catch-all' category for scrub/forest not dominated by any of the above species. Some seral species e.g. māmāngi (*Coprosma arborea*) can also act as a nurse species for kauri. Use this category for areas close to kauri forest which are not covered in the categories above, but may support kauri seedlings/saplings.	Scrub/ low forest of a wide range of variants including species of *Coprosma*, *Coriaria*, *Pittosporum*, *Pseudopanax*, *Melicytus*, *Olearia*, *Hebe*, *Myrsine*, wineberry, and locally kōtukutuku, kāmahi, rewarewa, northern rātā and tree ferns
	Exotic Forestry - conifers.	Forest with planted conifers comprising the greatest percentage of the canopy	Most areas of this type will be plantations of *Pinus radiata*	
	Exotic Forestry - other	Forest with planted exotics (other than conifer spp) comprising the greatest percentage of the canopy	A catch all category for plantations of exotic species other than *Pinus* sp, inclusive of *Eucalyptus*, *Picea*, *Acacia* etc.	
	Exotic forest - wilding conifers	Wilding conifers comprise the greatest proportion of the canopy. If wilding conifers are <50% cover, classify as the vegetation type according to the dominant species (e.g. mānuka scrub).	Wilding pines (within the range of kauri typically *Pinus pinaster*) can form forests which can be intermixed with indigenous seral species (especially mānuka, kānuka, tānekaha, and sometimes kauri).	
	Exotic Forest - other	Non-planted forests (e.g. self sown) dominated by exotics other than conifier spp.)	A catch all category for non-planted forests of exotic species (e.g. tree privet, grey willow, black wattle)	
	Exotic Scrub	Exotic species with woody stems <10 cm diameter collectively comprise the greatest component of the vegetation.	In the natural range of kauri most likely to be dominated by gorse or woolly nightshade.	
	Exotic Scrub and/or Forest with Wilding Conifers	Exotic species with woody stems collectively comprise the greatest component of the vegetation. Some wilding conifers are also present in the canopy		
	Indigenous scrub and/or Forest with Wilding Conifers	Indigenous species with woody stems collectively comprise the greatest component of the vegetation. Some wilding conifers are also present in the canopy		
	Grassland/Herbfield - GH	Exotic grass species collectively form the greatest component of the vegetation. Using an aerial mapping system, will include areas of pasture dominated by herb species e.g. clover, pennyroyal, buttercup	Exotic grasses (inclusive of taller species e.g. pampas, bamboo) and herbs (e.g. clover, creeping buttercup),	
	Grassland/Herbfield - GH with trees	Exotic grass species collectively form the greatest component of the vegetation. Using an aerial mapping system, will include areas of pasture dominated by herb species e.g. clover, pennyroyal, buttercup. Occasional trees or groups of trees <1ha are also present		

Type	Ecosystem Unit Code and Name	Quantitative Thresholds	Additional Guidelines	Ecosystem Description (as per Singers and Rogers)
	Indigenous Wetland - IW	Wetland ecosystems with >50% indigenous plant cover.		
	Exotic Wetland - EW	Wetland ecosystems with >50% exotic plant cover.		
	Exotic/Indigenous Treeland - TL	Exotic and indigenous trees forming 20-80% cover amongst non-woody vegetation in the ground tier (e.g. pasture).	Often occurs along stream and river margins where it includes willow (*Salix* sp.), poplar (*Populus* sp.) and scattered indigenous trees such as tōtara and kānuka.	
	Planted Indigenous Vegetation - PL	Native restoration plantings with <50% exotic biomass		
	Indigenous vegetation (other than the types listed here)	Indigenous vegetation (more than 50% cover of indigenous species) which does not fit any of the other ecosystem types described in this table (or for which ecosystem type cannot be accurately determined with the imagery or data available).		
	Open Water Body			
	Urban Area			
	Exotic forestry/exotic grassland			
	Exotic grassland/urban area			
	Extensive Forest Tract - Info Poor	For use when aerial imagery is too poor to delineate areas of kauri forest		

APPENDIX 8

AREAS ASSESSED USING EACH OF THE KEY MAPPING AND VALIDATION METHODS

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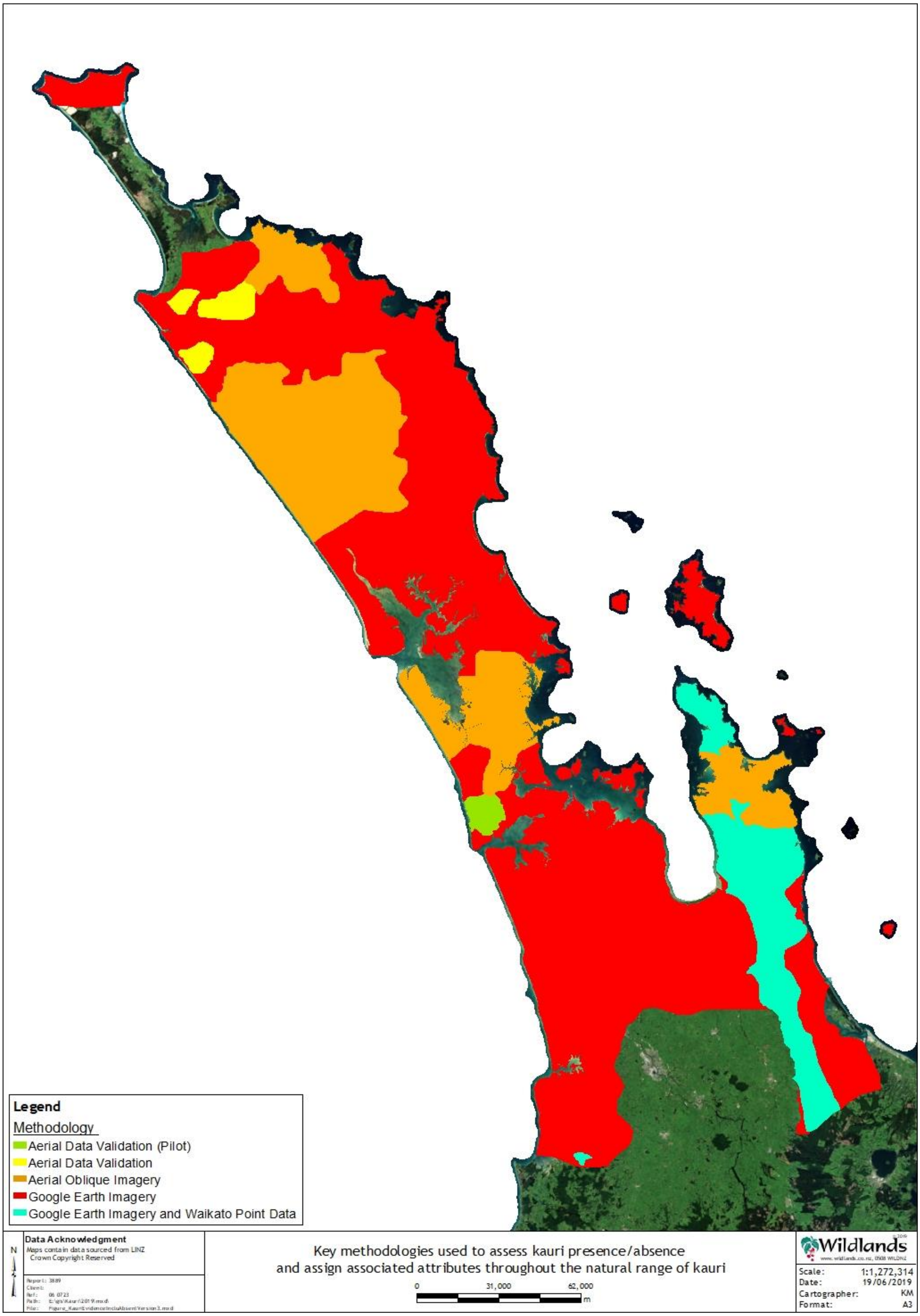
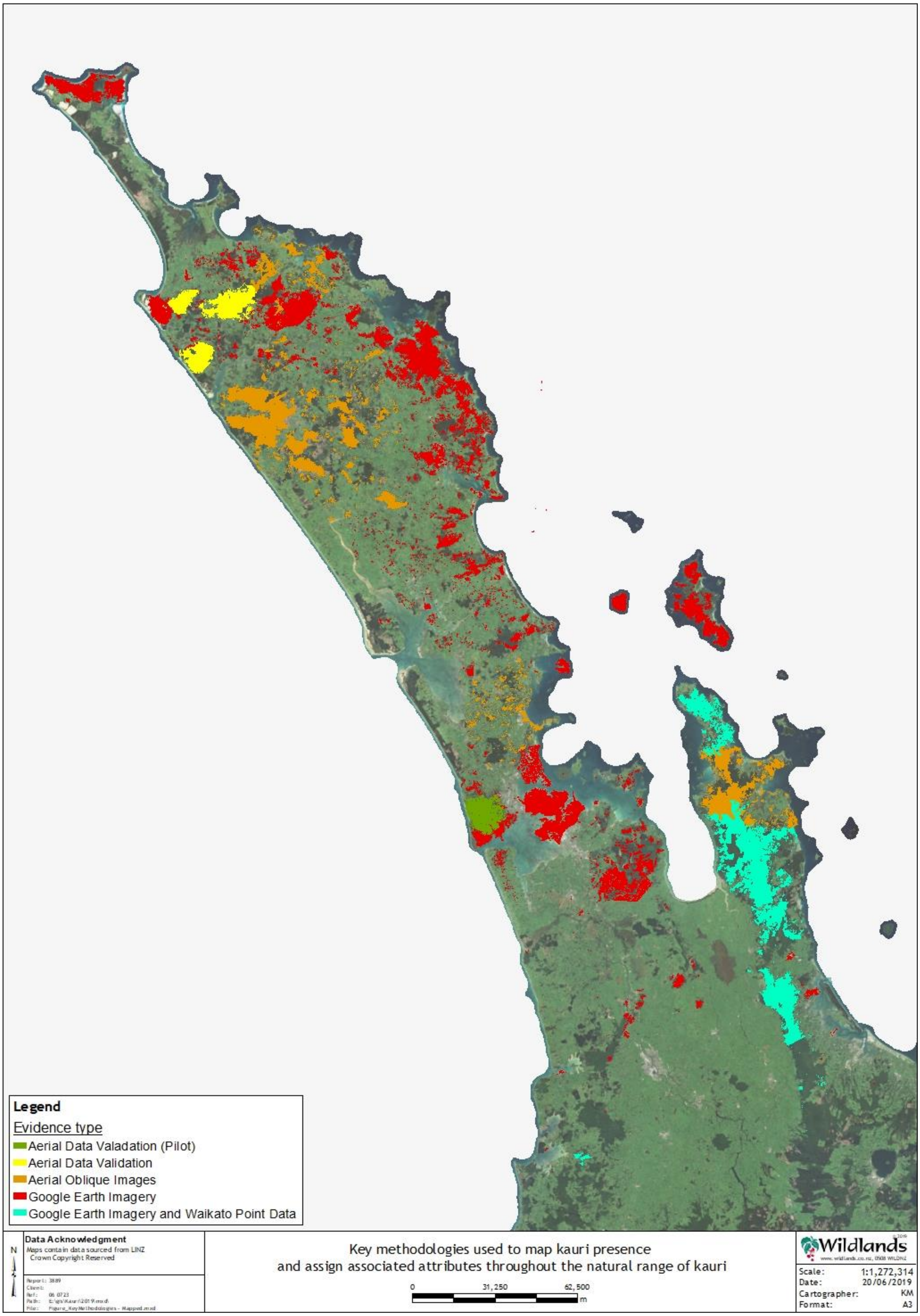

Legend
Methodology
Aerial Data Validation (Pilot)
Aerial Data Validation
Aerial Oblique Imagery
Google Earth Imagery
Google Earth Imagery and Waikato Point Data
N
Data Acknowledgment
Maps contain data sourced from LINZ
Crown Copyright Reserved
Report: 3889
Client:
Ref: 06 0723
Key methodologies used to assess kauri presence/absence
and assign associated attributes throughout the natural range of kauri
0
31,000
62,000
m
Wildlands
Scale: 1:1,272,314
Date: 19/06/2019
Cartographer: KM
Format: A3

APPENDIX 9

‘KAURI PRESENT’ POLYGONS MAPPED USING EACH OF THE KEY MAPPING AND VALIDATION METHODS


Legend
Evidence type
Aerial Data Valadation (Pilot)
Aerial Data Validation
Aerial Oblique Images
Google Earth Imagery
Google Earth Imagery and Waikato Point Data
N
Data Acknowledgment
Maps contain data sourced from LINZ
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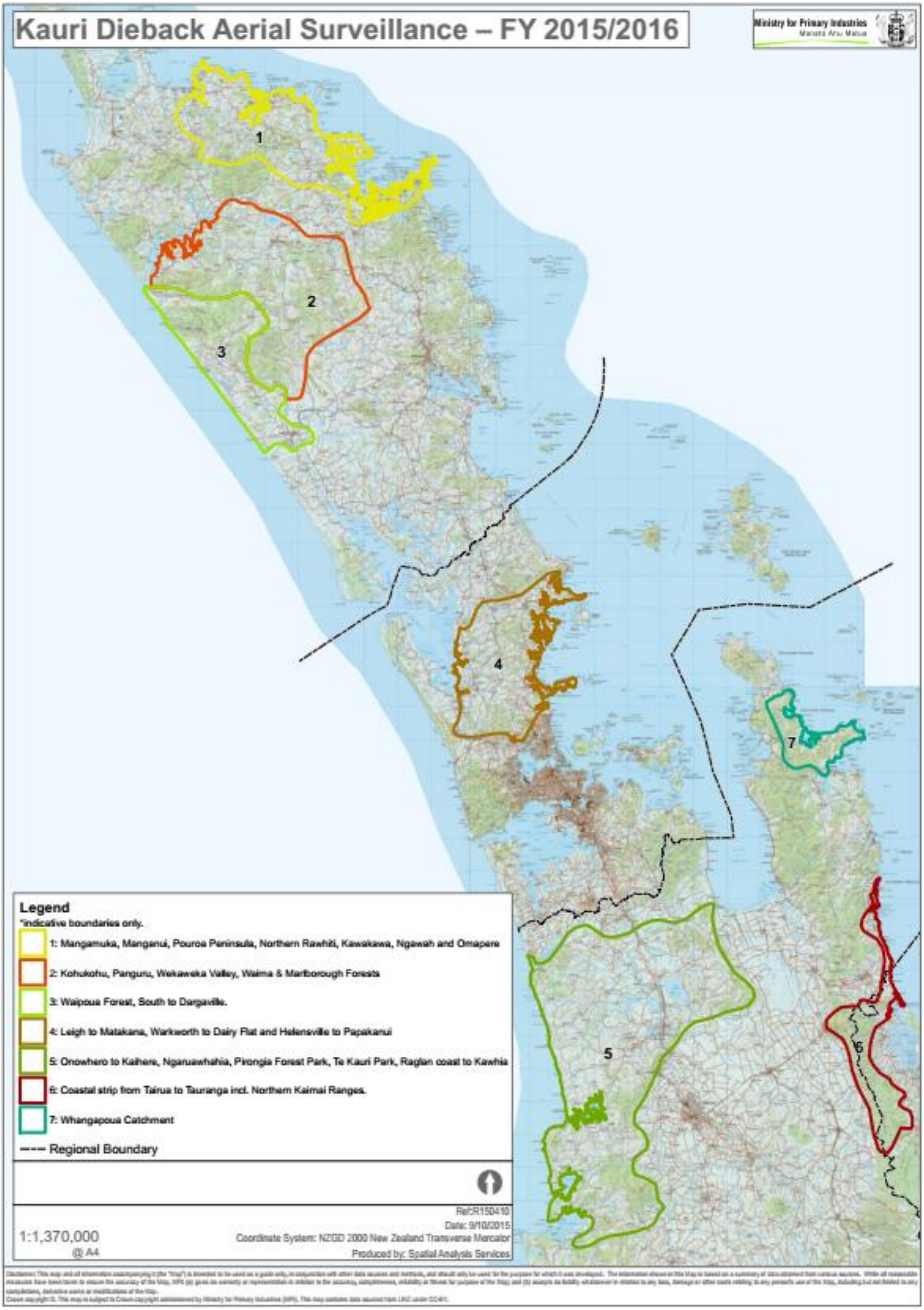
Report: 3889
Client:
Ref: 06 0723
Path: E:\gis\Kauri\2019\mxd\
File: Figure_KeyMethodologies - Mapped.mxd
Key methodologies used to map kauri presence
and assign associated attributes throughout the natural range of kauri
0
31,250
62,500
m
Wildlands
www.wildlands.co.nz, 0508 WILDNZ
Scale: 1:1,272,314
Date: 20/06/2019
Cartographer: KM
Format: A3

APPENDIX 10

MPI AERIAL

SURVEILLANCE AREAS


Kauri Dieback Aerial Surveillance – FY 2015/2016
Ministry for Primary Industries
1
2
3
4
5
6
7
Legend
*indicative boundaries only.
1: Mangamuka, Manganui, Pouroa Peninsula, Northern Rawhiti, Kawakawa, Ngawah and Omapere
2: Kohukohu, Panguru, Wekaweka Valley, Waima & Marlborough Forests
3: Waipoua Forest, South to Dargaville.
4: Leigh to Matakana, Warkworth to Dairy Flat and Helensville to Papakanui
5: Onowhero to Kaihere, Ngaruawhahia, Pirongia Forest Park, Te Kauri Park, Raglan coast to Kawhia
6: Coastal strip from Tairua to Tauranga incl. Northern Kaimai Ranges.
7: Whangapoua Catchment
Regional Boundary
Ref:R150410
Date: 9/10/2015
1:1,370,000
@ A4
Coordinate System: NZGD 2000 New Zealand Transverse Mercator
Produced by: Spatial Analysis Services

LOW QUALITY GOOGLE EARTH AERIAL IMAGERY FOR OMAHUTA FOREST, NORTHLAND

Low quality Google Earth imagery from the Omahuta Forest, kauri mapped as present using the PNAP.

0 50 100 m

N

Data Acknowledgment
Maps contain data sourced from LINZ
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Google Earth Imagery

Report: 3889
Client:
Ref: 06 0723
Path: E:\gis\Kauri\2019.mxd
File: Figure3_LowQualityImageryVersion3.mxd

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www.wildlands.co.nz, 0508 WILDNZ

Scale:
Date: 18/06/2019
Cartographer: KM
Format: A3

APPENDIX 12

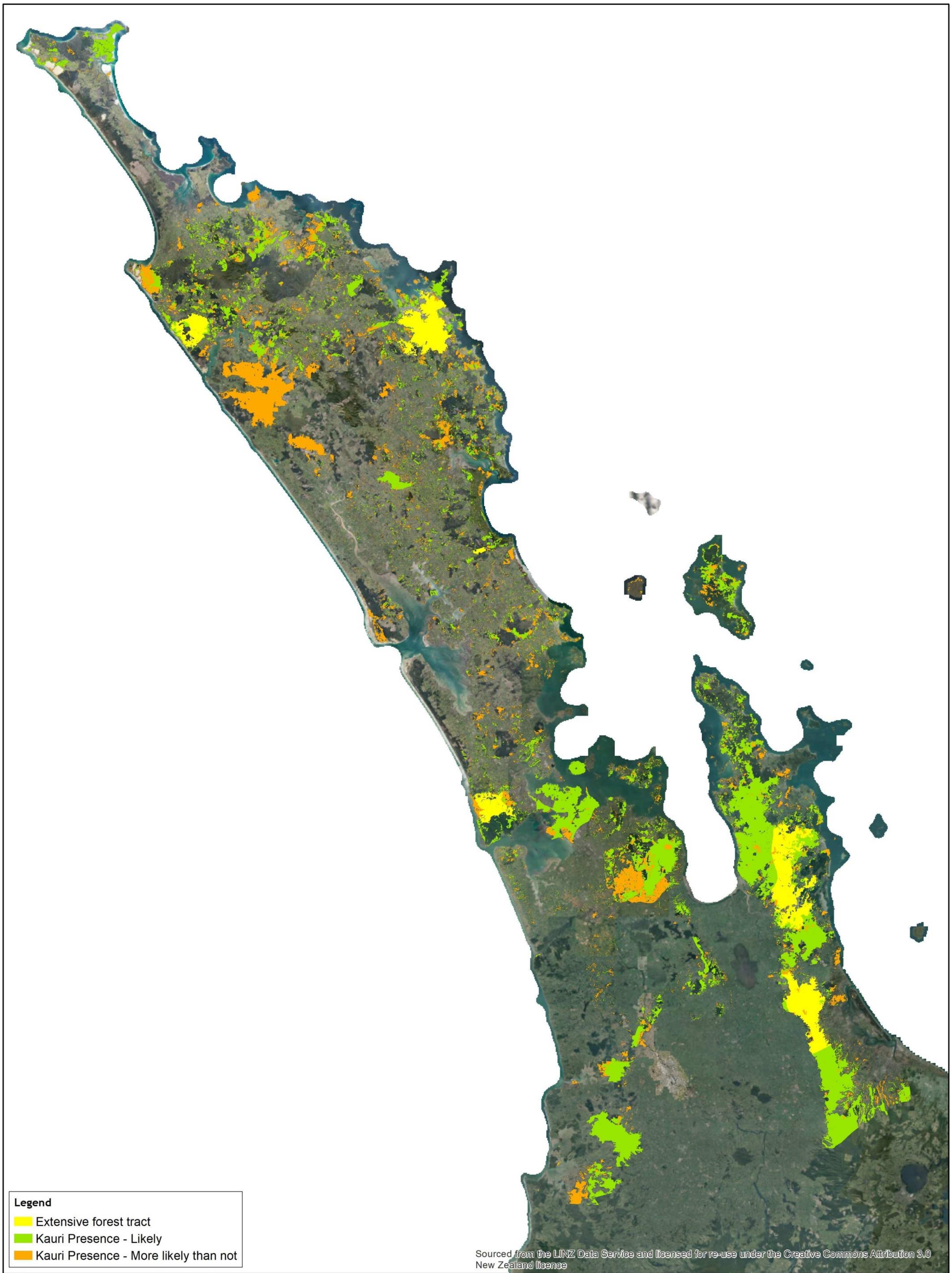
HIGH QUALITY GOOGLE EARTH
AERIAL IMAGERY FOR
RODNEY DISTRICT


N
Data Acknowledgment
Maps contain data sourced from LINZ
Crown Copyright Reserved
Report: 3889
Client:
Ref: 06 0723
Path: E:\gis\Kauri\2019\mxd\
File: Figure4_HighQualityImagery.mxd
High quality google earth imagery from
the Rodney District, North Auckland.
0
37.5
75
m
Wildlands
www.wildlands.co.nz, 0508 WILDNZ
Scale: 1:1,500
Date: 18/06/2019
Cartographer: KM
Format: A3

APPENDIX 13

VALIDATION

PRIORITISATION MAP



N

Data Acknowledgment
Maps contain data sourced from LINZ
Crown Copyright Reserved

Report: R3886
Client: MFPI
Ref: 06 0723
Path: E:\gis\Kauri\mxd\
File: KauriPresense.mxd

Kauri present 'likely', kauri present 'more likely than not' and 'extensive forest tract' polygons

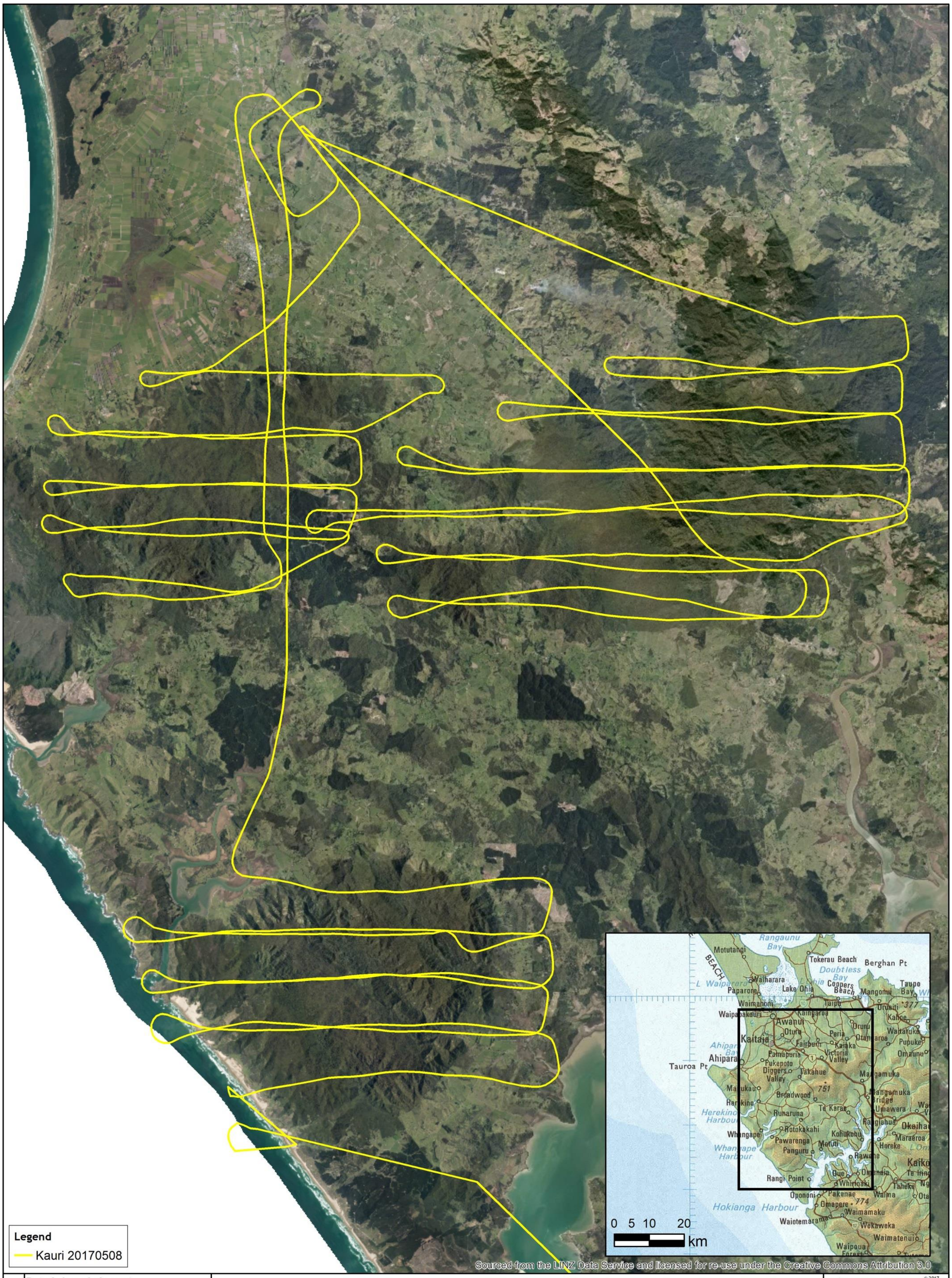
0 25 50 km

Wildlands © 2017
www.wildlands.co.nz, 0508 WILDNZ

Scale: 1:1,250,000
Date: 24/08/2017
Cartographer: RPB
Format: A3

APPENDIX 14

VALIDATION FLIGHT PATHS



N

Data Acknowledgment
Maps contain data sourced from LINZ
Crown Copyright Reserved

Report: R3886
Client: MFPI
Ref: 06 0723
Path: E:\gis\Kauri\mxd\
File: FlightPath.mxd

Aerial mapping flight path for Herekino, Warawara and Ratea/Maungataniwha Forests

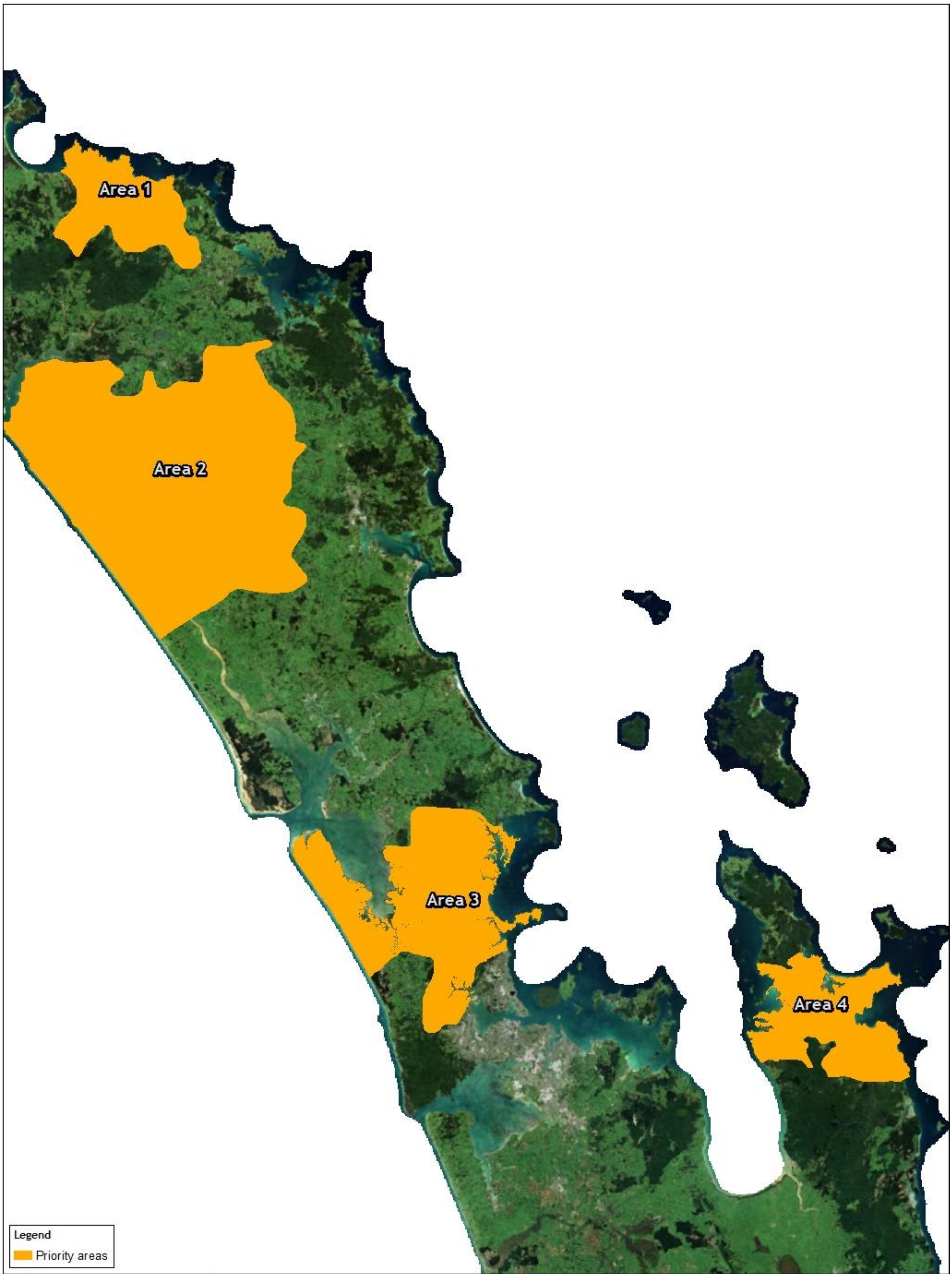
0 5 10 km

© 2017 Wildlands www.wildlands.co.nz, 0508 WILDNZ

Scale: 1:141,469
Date: 24/08/2017
Cartographer: RPB
Format: A3

APPENDIX 15

AREAS PRIORITISED FOR ADDITIONAL MAPPING FOLLOWING MPI AERIAL SURVEILLANCE



Data Acknowledgment
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Report: 3889
Client:
Ref: 06 0723
Path: E:\gis\Kauri\2019\mxd\
File: Figure_MPI_Priority.mxd

Areas prioritised for additional mapping following MPI aerial surveillance

0 | 20,500 | 41,000 m

Wildlands
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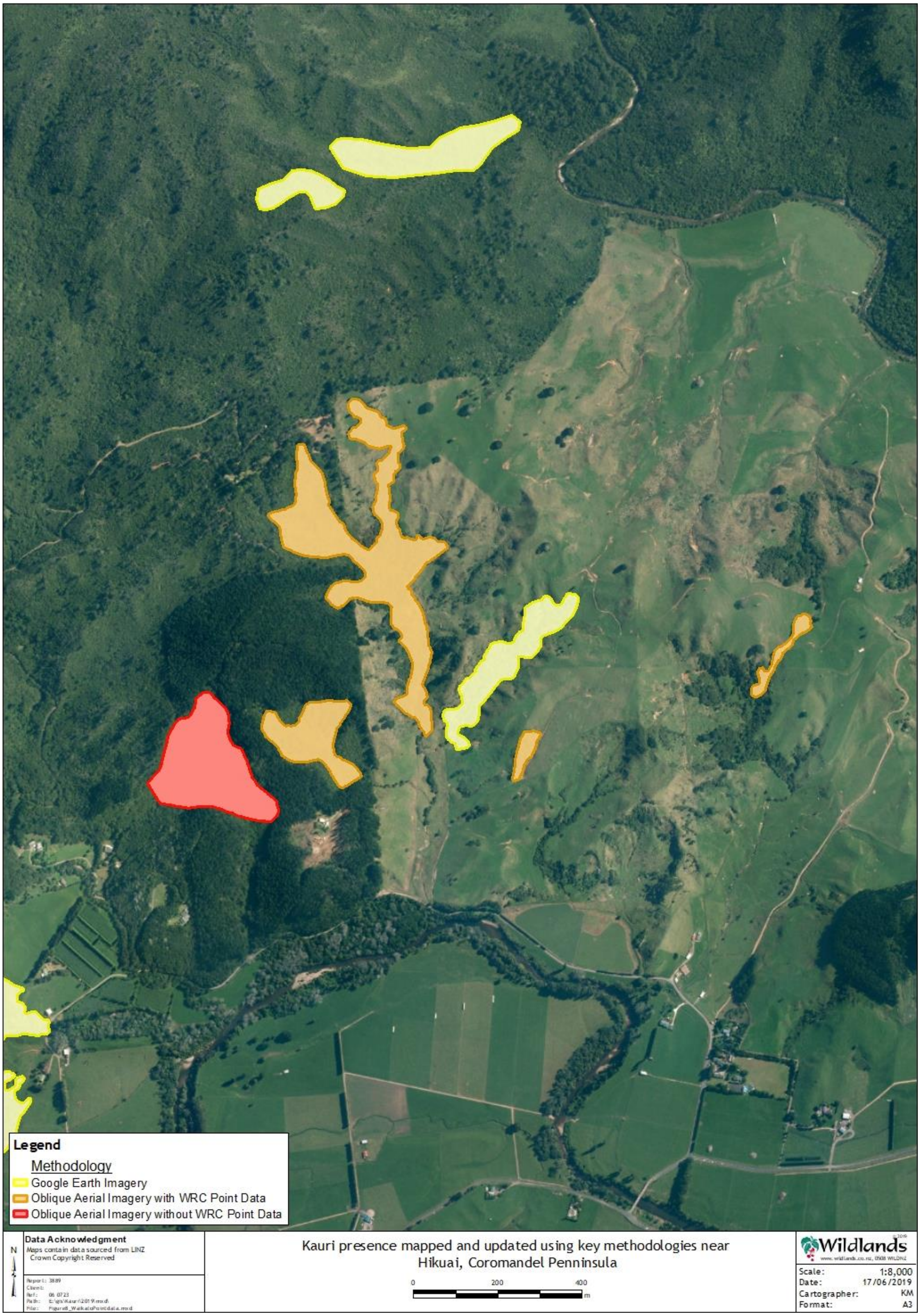
Scale: 1:850,000
Date: 18/06/2019
Cartographer: KM
Format: A3

APPENDIX 16

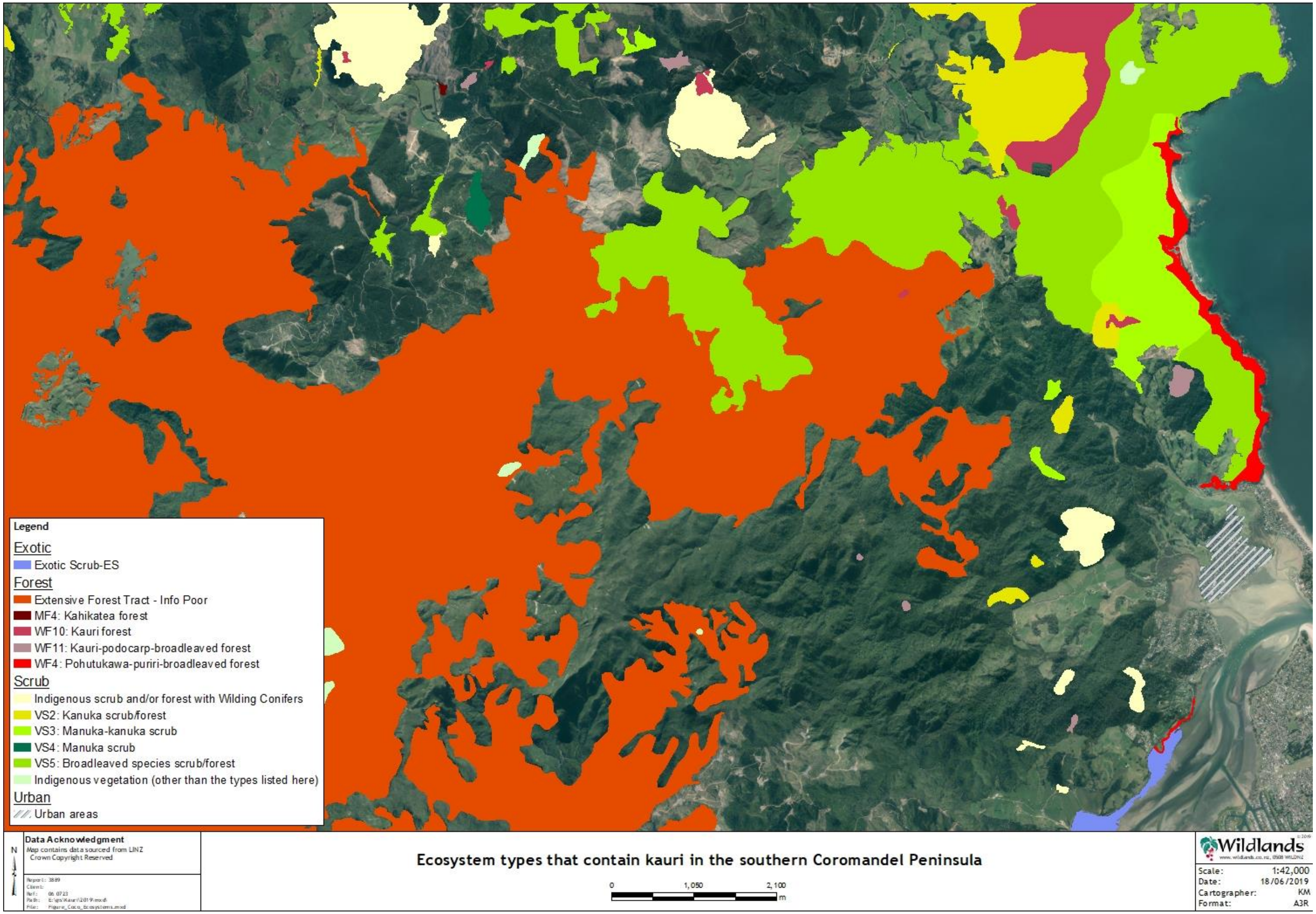
KAURI PRESENCE MAPPED AND UPDATED USING KEY METHODOLOGIES NEAR HIKUAI, COROMANDEL PENINSULA



Legend
Methodology
Google Earth Imagery
Oblique Aerial Imagery with WRC Point Data
Oblique Aerial Imagery without WRC Point Data
N
Data Acknowledgment
Maps contain data sourced from LINZ
Crown Copyright Reserved
Report: 3889
Client:
Ref: 06 0723
File: Figure8_WaikatoPointdata.mxd
Kauri presence mapped and updated using key methodologies near
Hikuai, Coromandel Penninsula
0
200
400
m
Wildlands
Scale: 1:8,000
Date: 17/06/2019
Cartographer: KM
Format: A3

APPENDIX 17

ECOSYSTEM TYPES THAT CONTAIN KAURI IN THE SOUTHERN COROMANDEL PENINSULA


Legend
Exotic
Exotic Scrub-ES
Forest
Extensive Forest Tract - Info Poor
MF4: Kahikatea forest
WF10: Kauri forest
WF11: Kauri-podocarp-broadleaved forest
WF4: Pohutukawa-puriri-broadleaved forest
Scrub
Indigenous scrub and/or forest with Wilding Conifers
VS2: Kanuka scrub/forest
VS3: Manuka-kanuka scrub
VS4: Manuka scrub
VS5: Broadleaved species scrub/forest
Indigenous vegetation (other than the types listed here)
Urban
Urban areas
N
Data Acknowledgment
Map contains data sourced from LINZ
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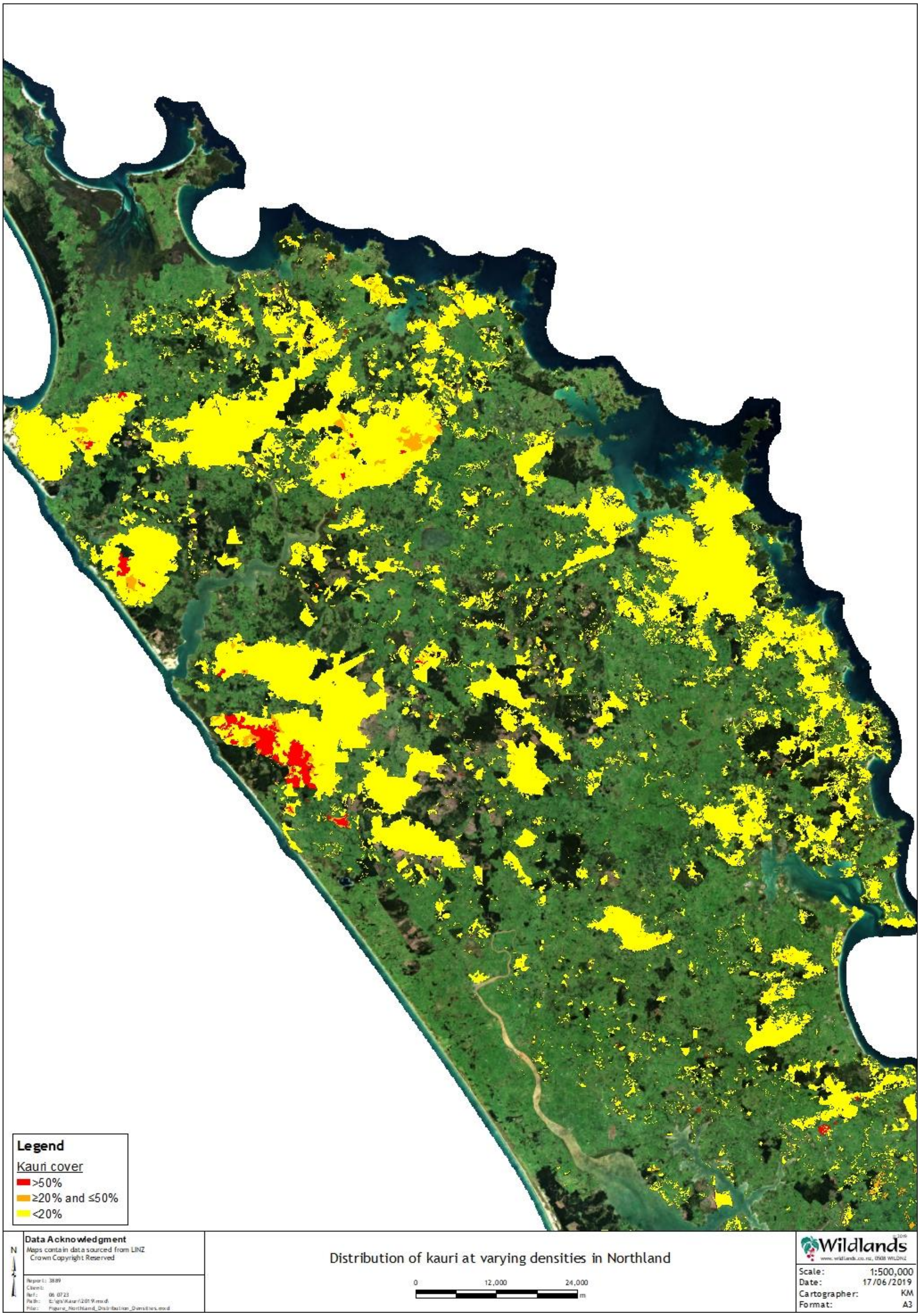
Ecosystem types that contain kauri in the southern Coromandel Peninsula
0
1,050
2,100
m
Wildlands
Scale: 1:42,000
Date: 18/06/2019
Cartographer: KM
Format: A3R

DISTRIBUTION OF KAURI IN VARYING DENSITIES IN NORTHLAND



Legend
Kauri cover
>50%
≥20% and ≤50%
<20%
N
Data Acknowledgment
Maps contain data sourced from LINZ
Crown Copyright Reserved
Distribution of kauri at varying densities in Northland
0
12,000
24,000
m
Wildlands
Scale: 1:500,000
Date: 17/06/2019
Cartographer: KM
Format: A3

APPENDIX 19

KAURI PRESENT WITHIN REGENERATING ECOSYSTEMS THROUGHOUT THE NATURAL RANGE OF KAURI


Legend
Regenerating ecosystem types
Kānuka scrub/forest (VS2)
Mānuka-kānuka scrub (VS3)
Mānuka scrub (VS4)
N
Data Acknowledgment
Maps contain data sourced from LINZ
Crown Copyright Reserved
Report: 3889
Client:
Ref: 06 0723
Path: E:\gis\Kauri\2019\mxds
File: Figure_Regenerating.mxd
Kauri present within regenerating ecosystems
throughout the natural range of kauri
0
31,250
62,500
m
Wildlands
Scale: 1:1,272,314
Date: 17/06/2019
Cartographer: KM
Format: A3

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