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Wetland mapping in northern New Zealand using LiDAR and Machine learning

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Authors / Contributors:

Andrew Macdonald

Pania Te Whaiti

Edin Goldberg

For any information regarding this report please contact:

Andrew Macdonald, Director of Biospatial Ltd

andrew@biospatial.co.nz

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Executive Summary

This report outlines the methodology and outputs of a project to develop indicative wetland layers for the Northland region, and the Kaipara Moana (harbour) catchment, which spans part of both Northland and Auckland regions. This project deployed innovative aerial imagery and classification methodologies to map and classify wetlands within the targeted regions.

These layers have been developed for Northland Regional Council (NRC) in collaboration with the Kaipara Moana Remediation (KMR) Programme. The layers are intended to inform understanding and management of wetlands, and the regional council's approach to identify and map natural inland wetlands 500m² in extent or greater by 2030 and to establish an inventory of natural inland wetlands, as required under the National Policy Statement for Freshwater Management (NPS-FM).

Key deliverables for this project included:

- Wetland polygons to identify wetlands over 500m², to show (as a minimum) at a scale of 1:1000:
 - Wetland type:
 - i. Combined freshwater wetlands (excluding gumlands)
 - ii. Mangrove habitat
 - iii. Saltmarsh habitat
 - iv. Waterbodies
 - v. Gumland/wet heathland wetlands
- Historic imagery basemap
- Coastlines (saline and terrestrial extent lines)

The wetland datasets were delivered as both wetland polygon extents and geo-segments. Geo-segments represent small, segmented polygons (approximately 100-200m² in size) which collectively define each wetland extent. Geo-segments were provided to NRC for ease of ongoing analysis and validation using in-house improvement processes. The wetland polygon extents were created by merging the geo-segments into one extent and applying a smoothing algorithm for aesthetic purposes.

All wetland polygon datasets were provided as predictive output layers generated through machine learning processes which facilitated the recognition of complex patterns and relationships among landscape data. The wetland polygons have not been fully assessed against the wetland definition in the Resource Management Act due to limitations on the ability to assess hydrological and soil conditions and presence or absence of fauna adapted to wet conditions in the field. The predictive layers are therefore primarily based on an assessment of slope, vegetation type and height using LiDAR data and aerial imagery (historic and current).

More than 99,000 combined freshwater wetland extents (excluding gumland) were identified in the Northland area and over 49,000 were greater than 500m². The wetlands greater than 500m² spanned an area of 42,325ha in Northland (or 3.33% land area).

More than 21,000 combined freshwater wetland extents were identified in the Auckland area and over 7,000 were greater than 500m². The wetlands greater than 500m² covered an area of 4,028ha in Auckland (or 2.72% land area).

There has not been any substantive 'ground-truthing' or field validation of wetland data. Furthermore, the current tools available for validation and ongoing attribution of wetland polygon datasets were not suitable for this project. This was due to the size and complexity of datasets created using LiDAR and high-resolution remote sensing data. Previous mapping of wetlands greater than 500m² in Northland in 2021 has also highlighted errors and challenges mapping large numbers of wetland polygons.

The outcomes of this project are expected to significantly support the NRC and the Kaipara Moana Remediation Programme in their environmental management and policy implementation efforts.

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1. Introduction

Wetlands are critical to New Zealand’s biodiversity, water quality objectives, flow and flood control, and carbon sequestration efforts. However, accurate mapping and classification have been challenging due to varied regional expertise, methodologies, and data quality. Responding to the NPS-FM requirements (MfE, 2020)¹, this project sought to standardize wetland mapping across Northland and the Kaipara Moana catchment, providing crucial data to support a range of council activities (such as land management and biodiversity programmes) and the KMR objectives.

1.1. Earlier Wetland Mapping Data Available

Northland Protected Natural Area Programme (PNAP) reports for the 19 Ecological Districts of mainland Northland and published between 1998 and 2012 are available on the Department of Conservation website (DOC, 2024): survey-reports included many mapped wetlands throughout the region. Since then, Northland Regional Council have developed a number of wetland layers (Table 1). Some of these layers are incomplete and contain significant inaccuracies. Figures 1-4 below show examples of inaccuracies within these existing wetland datasets. Only the layer created by Ministry of Environment in 2021 (MFE, 2021)⁷ was developed to meet NPS-FM specifications of identifying wetlands 500m² or greater (Figure 4). Validation of this layer highlighted errors and challenges associated with mapping wetlands at 500m² scale.

Table 1: Existing wetland mapping datasets held by Northland Regional Council and their development data.

Year	Layer name	Reference	Number of features	Area (ha)
2011 ²	Top 150 wetlands	Figure 1	245	25,580
2013 ³	MfE wetlands	-	3,373	14,456
2016 ⁴	Known wetlands	Figure 2	1,051	32,398
2018 ⁵	Northern heathlands/gumlands	-	812	6,905
2020 ⁶	Mangrove and saltmarsh	Figure 3	6,000	18,640
2021 ⁷	MfE wetlands	Figure 4	22,009	74,597

¹ Clause 3.23 of the NPS-FM requires regional councils to map natural inland wetlands >500m² by 2030 and to establish an inventory of natural inland wetlands. Ministry for Environment. (2020). National Policy Statement for Freshwater Management.

² <https://www.nrc.govt.nz/media/244bkjfe/northlands-top-ranked-wetlands-as-at-july-2021.pdf>

³ <https://data.mfe.govt.nz/layer/52676-current-wetland-extent-2013/attachments/11939/view/>

⁴ <https://www.arcgis.com/sharing/rest/content/items/a235e3e75b684dab8637c75d8789570f/info/metadata/metadata.xml?format=default&output=html>. Combination of DOC PNAP, top 150, farm plan data collected through efund data, farm planning, and aerial photo identification.

⁵ <https://catalogue.data.govt.nz/dataset/heathlands2>

⁶ <https://www.nrc.govt.nz/media/1grl5ko5/northland-intertidal-vegetation-mapping-methodology-2020.pdf>

⁷ <https://environment.govt.nz/assets/publications/Wetland-mapping-methods-review-discovery-approach.pdf>



Figure 1. Example of inaccuracies within the NRC Top150 wetland layer (2011), red indicates an inaccurately mapped wetland.



Figure 2. Example of the inaccuracies of the NRC known wetland layer (2016), red indicates inaccurately mapped wetland on a hillslope adjacent to a wetland.



Figure 3. Example of the inaccuracies of the NRC mangrove and saltmarsh layer (2020). Red indicates saltmarsh, green indicates mangroves. A large area of freshwater wetland has been inaccurately mapped as saltmarsh, and terrestrial vegetation around the edge of the freshwater swamp has been incorrectly mapped as mangrove.



Figure 4. Example of inaccuracies within the MfE wetland layer (2021), red indicates inaccurately mapped wetland.

2. Methodology for Mapping Biospatial Wetlands

The general wetland mapping methodology used for this project is shown below in Figure 5.

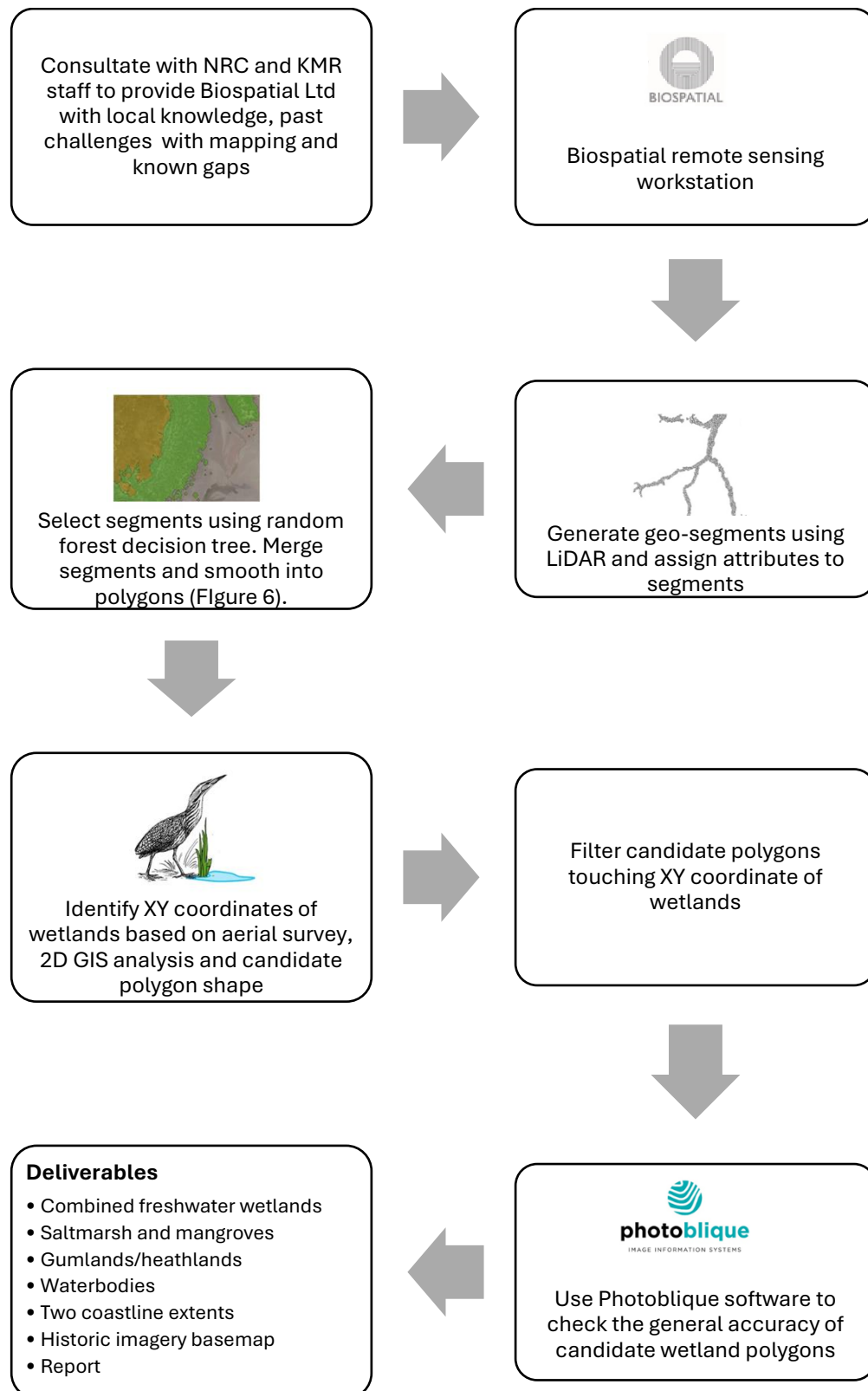


Figure 5. General methodology used for mapping Northland/KMR wetlands.

An example of the wetland delineation methodology and terminology used in this project is provided in Figure 6.



Figure 6. Example of wetland extent and geo-segment delineation approach.

3. Data Delivered to Northland Regional Council and KMR

A list of the wetland layers delivered to NRC and KMR is provided in Appendix 1. A map depicting the project areas is provided in Figure 7. All wetland datasets were provided as predictive output layers generated through machine learning processes. Wetland condition attributes, forest swamps and constructed wetlands were not delivered as part of this project. This is because the current tools available for the attribution of wetland datasets were not suitable for this project due to the size and complexity of datasets created using LiDAR and high-resolution remote sensing data. Biospatial Ltd and Photoblique Ltd are in the process of creating new tools to carry out this task and this is an area of potential further work.

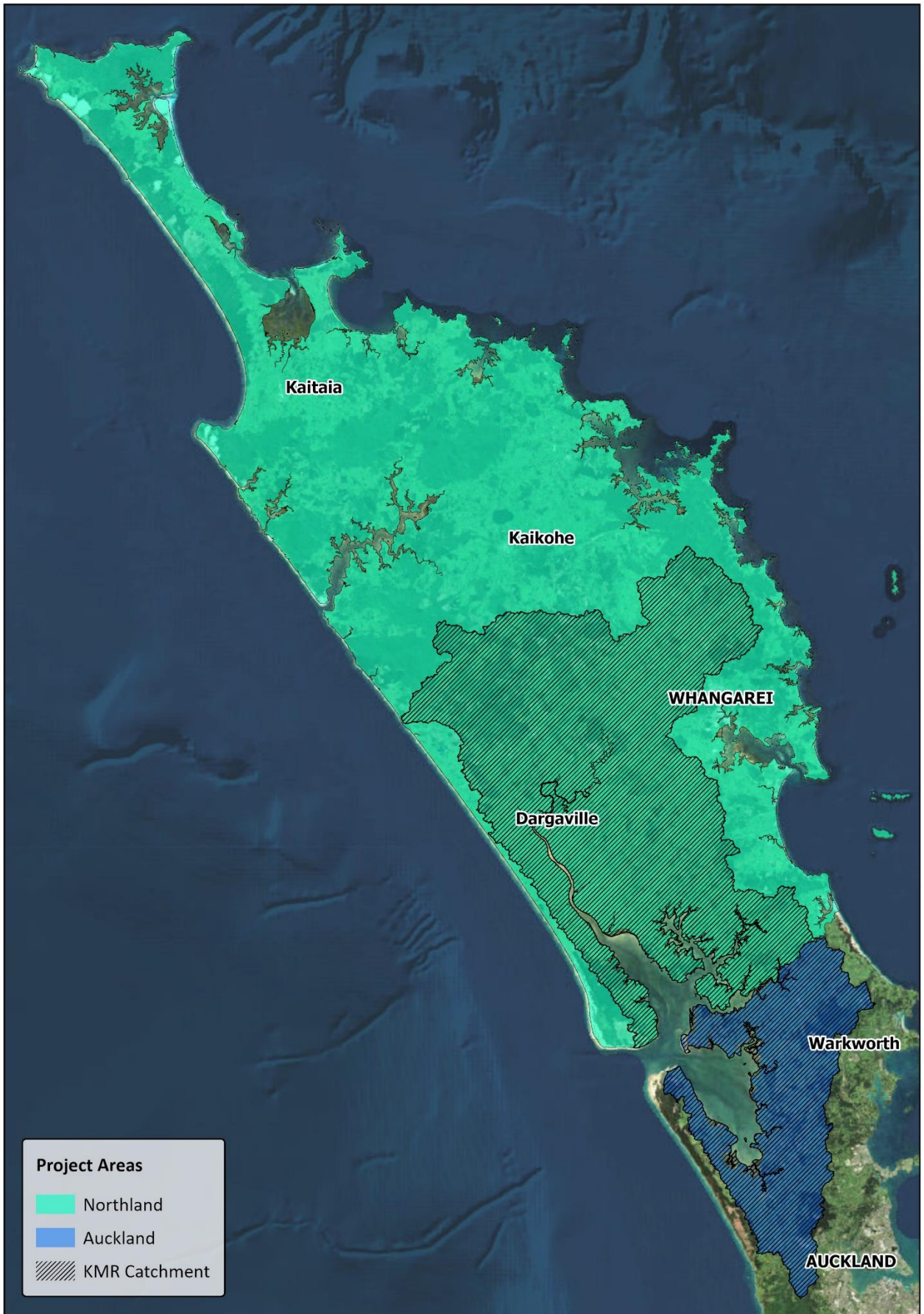


Figure 7. Project areas.

3.1. Summary of Results

A summary of the wetland dataset extent layers and their corresponding statistics is provided in Table 2.

Table 2: Summary of Biospatial Ltd wetland layer 2024 statistics. NB the land area used for calculations was 1,269,881ha in Northland, 148,225ha in Auckland and 595,534ha in the KMR catchment area. These figures will change, especially gumland, as improvements to the validation and attribution process is achieved.

Wetland type	Total number	Area (ha)	% Land area	Number above 500m ²	Area (ha)	% Land area
NORTHLAND						
Combined FW Wetland Extents	99,526	43,253	3.41	49,429	42,325	3.33
Mangrove Extents	80,653	13,395	1.06	4,041	13,155	1.04
Saltmarsh Extents	10,072	3,121	0.25	2,850	3,044	0.24
Waterbody Extents	52,443	6,457	0.51	9,834	5,853	0.46
Gumland Extents	5,376	21,163	1.67	3,304	21,111	1.66
AUCKLAND						
Combined FW Wetland Extents	21,349	4,150	2.80	7,023	4,028	2.72
Mangrove Extents	22,193	4,175	2.82	904	4,051	2.73
Saltmarsh Extents	38,007	808	0.55	1,405	684	0.46
Waterbody Extents	7,229	344	0.23	1,345	260	0.18
KMR CATCHMENT						
Combined FW Wetland Extents	59,454	13,622	2.29	25,758	13,131	2.20
Mangrove Extents	39,005	6,387	1.07	1,775	6,215	1.04
Saltmarsh Extents	38,072	1,058	0.18	1,772	921	0.15
Waterbody Extents	30,062	2,067	0.35	6,635	1,709	0.29

3.2. Biospatial Combined Freshwater Wetland Layer (Northland and Auckland)

Pastoral wetlands are typically found in agricultural landscapes, often modified or degraded, and may include areas with wet pasture or rush-dominated grasslands. These wetlands are usually seasonally inundated and maintain a vegetative cover that is often grazed. Swamps in New Zealand are characterized by their lush, dense vegetation dominated by tall sedges, flax, and sometimes swamp forest species like kahikatea and pukatea, thriving in areas with permanent water. Fens are less common and are distinguished by their peat-forming processes, fed by surface or groundwater with a higher mineral content than bogs, supporting a diverse array of grasses, rushes, and herbs. Bogs are typically ombrotrophic (rain-fed), with low nutrient levels and highly acidic conditions, supporting a specialized range of plants adapted to these conditions, such as sphagnum moss, sundews, and bladderworts. Marshes are shallow-water ecosystems primarily sustained by rivers, streams, or groundwater. Dominated by herbaceous plants like rushes.

The Biospatial combined freshwater wetlands layer consists of swamps, fens, bogs and marshes (Figure 8). Most of these combined freshwater wetlands are likely to be classified as pastoral wetlands and swamps. To map these wetlands emphasis was placed on training geo-segments under canopy cover less than 8m in height.

99,526 combined freshwater wetland extents (excluding gumland) were identified in the Northland area and 49,429 were greater than 500m². The wetlands greater than 500m² covered an area of 42,325ha in Northland (or 3.33% land area). A total of 21,349 combined freshwater wetland extents were identified in Auckland and 7,023 were greater than 500m². The wetlands greater than 500m² covered an area of 4,028ha in Auckland (or 2.72% land area) (Table 2).

Three methods of wetland validation/selection techniques were used for this project: aerial survey (wetland locations captured using a handheld camera from a plane), Photoblique desktop interpretation with imagery captured in 2017, 2021 and 2023, and 2D GIS desktop interpretation using Northland/Auckland 2014-16 imagery. The latter method was only adapted as a validation method later in the contract due to time restraints and inefficiencies of Photoblique desktop to support and process large numbers of wetlands.

Over 250,000 GIS point data were manually created to assist with the identification and selection of predictive wetland output datasets in a 2D GIS environment. More than 90,000 GIS point data were created using Photoblique desktop.

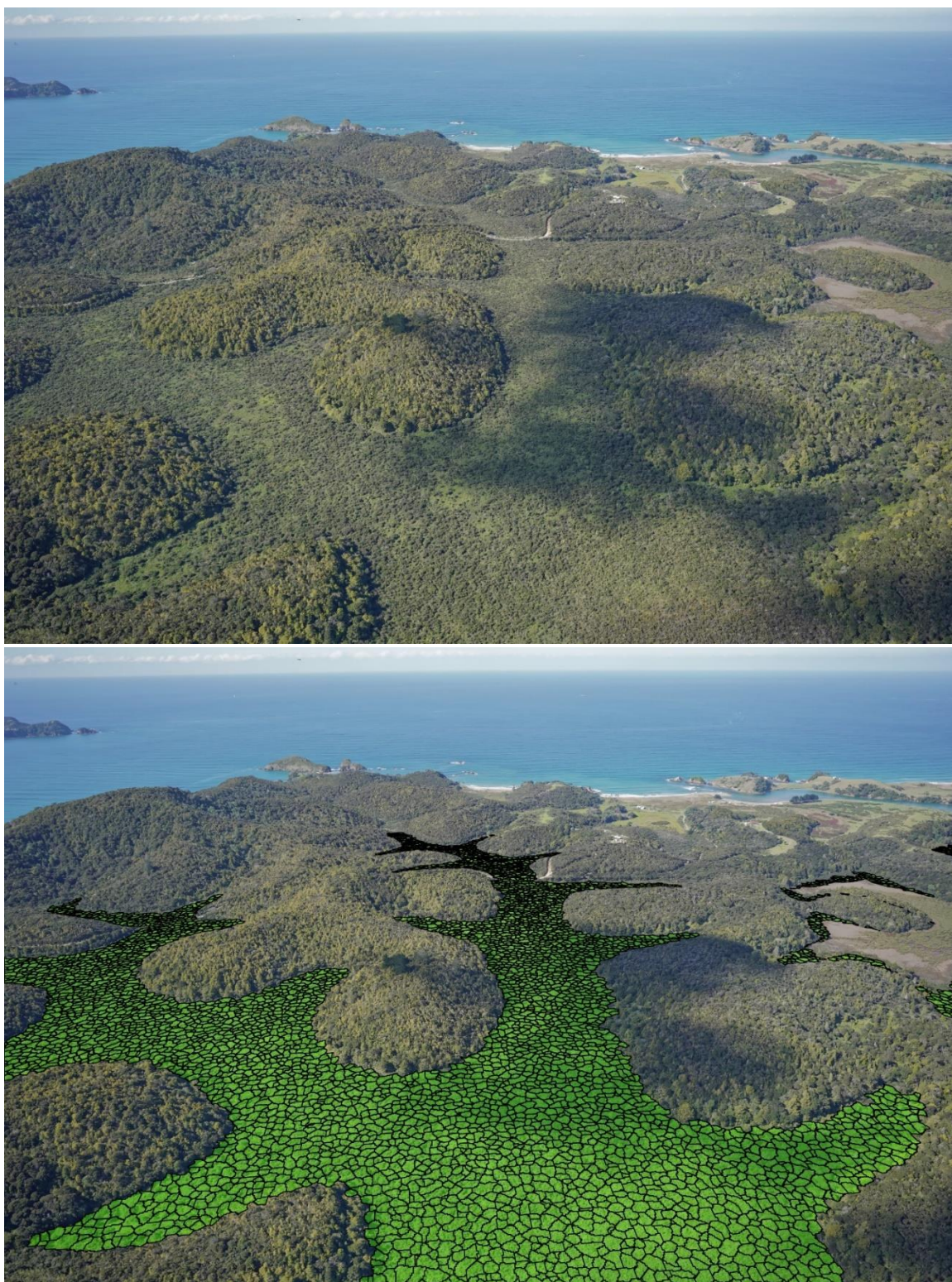


Figure 8. Individual wetland landscape geo-segments mapped for this project, before (top image) and after (bottom image) mapping.

3.2.1. Methodology and Limitations

Supervised classification

A supervised classification method based on raster layers was initially employed to delineate the combined freshwater wetland areas. The method accurately delineated wetland extents in certain locations, particularly where distinct spectral signatures were present.

Limitations of supervised classification

Despite its effectiveness in some areas, the implementation of supervised classification on raster datasets did not consistently produce accurate wetland extents across varied landscapes (Figure 9). This inconsistency can be attributed to the complex nature of the combined freshwater wetland ecosystems, which often exhibit gradual transitions and mixed vegetation types.



Figure 9. Results using the supervised classification method.

Implementation of landscape segmentation

To overcome these limitations, the methodology evolved to segmenting the landscape into smaller, manageable polygons (approximately 100-200m² each) (Figure 10). This approach allowed for a more nuanced analysis of the terrain, as each segment could be individually analysed and assigned specific metrics related to wetland likelihood, such as terrain wetness index, vegetation height, and slope.



Figure 10. Geo-segmented wetland.

Machine learning integration

A random forest machine learning model was then employed to assess these segments, identifying those likely to represent wetland areas. The use of machine learning facilitated the recognition of complex patterns and relationships among the data points that traditional methods might miss, thus enhancing the accuracy of wetland identification.

Cluster interpretation for wetland confirmation

The aggregation of selected geo-segments into clusters significantly enhanced the confidence in identifying actual wetlands. When multiple adjacent geo-segments were classified as wetlands by the machine learning model, this clustering strongly indicated the presence of a wetland, confirming the model's predictions.

Model refinement and manual adjustments

Continuous refinement of the machine learning model, incorporating feedback and observations from field validations (Figure 11), could further increase the accuracy of the wetland mapping. This iterative process allows for the model to adapt to new data and improve over time.

Over 250,000 GIS point data were manually created to assist with the identification and selection of predictive wetland output clusters in a 2D GIS environment. More than 90,000 GIS point data were created using Photoblique desktop and oblique imagery captured in 2023. Due to time constraints, other GIS point datasets delivered to NRC for this project were created with less accurate but more efficient methods, such as LINZ aerial imagery 2016.

This approach also facilitated manual corrections where necessary. Experts in wetlands without a background in remote sensing could easily observe and rectify errors, attributable to the

segment-based structure of the data, which was intuitively understandable even to those without extensive GIS training.

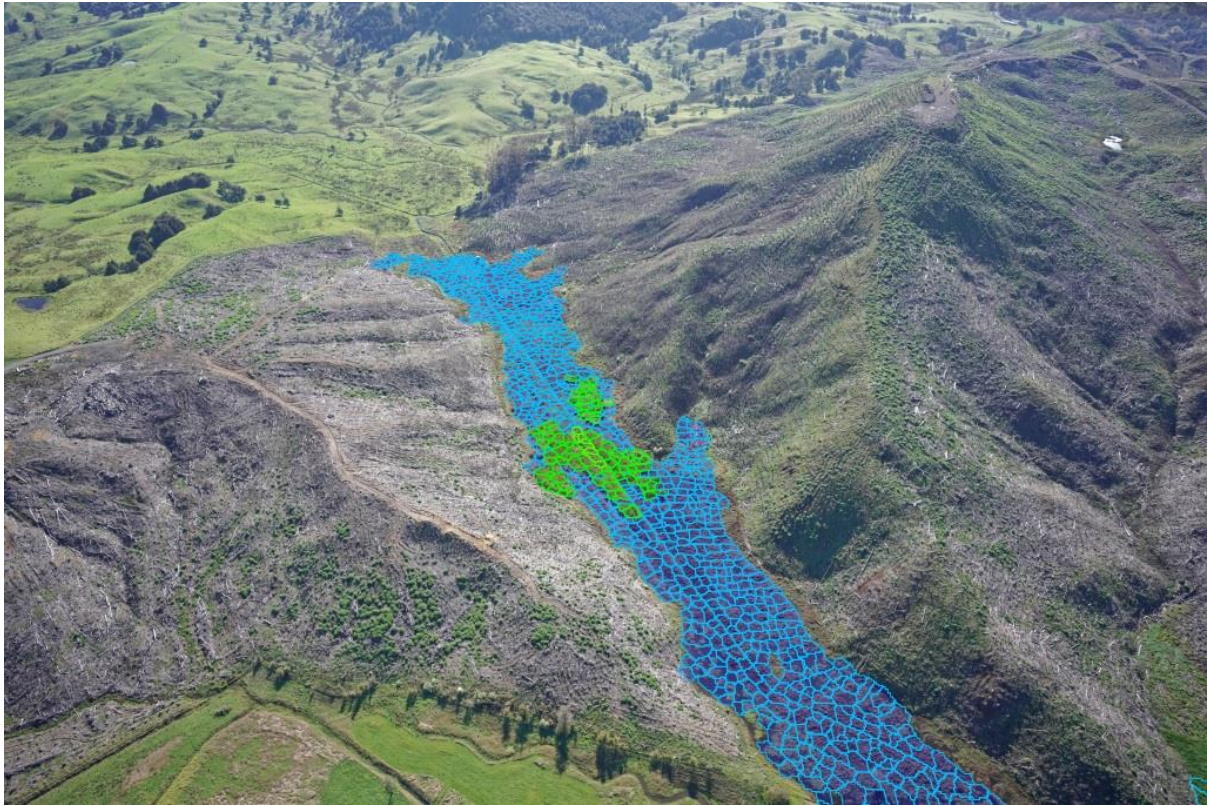


Figure 11. Geo-segmented wetland where in green, an ecologist has identified a different vegetation type within the wetland complex and attributed this area accordingly.

Dynamic attribute updating and aesthetic considerations

The segmented approach means wetland maps can continue to be refined as it enables easy updates to attributes as more information and data became available (through freshwater farm plans/consent applications/KMR site visits for example), or as environmental conditions change, ensuring the combined freshwater wetland layer remained current and reflective of actual conditions on the ground.

While the segmented approach might generate some visually unappealing extents due to their granular nature, these can be smoothed in the final presentation layer to enhance visual coherence and interpretability for stakeholders and decision-makers.

3.3. Biospatial Mangrove Layer (Northland and Auckland)

Mangroves in Northern New Zealand mangrove (*Avicennia marina* subsp. *australis*) typically occupy intertidal zones. These are areas that are flooded at high tide and exposed at low tide, forming dynamic habitats that vary significantly in salinity, temperature, and moisture levels throughout the day. Mangroves can grow to considerable heights in Northland, typically reaching up to 10 meters, though most commonly, they are seen around 3 to 5 meters tall.

3.3.1. Mangrove Mapping Data Created by Biospatial Ltd in 2020

Earlier mangrove data created in 2020 by Biospatial Limited (Biospatial NRC Mangrove and Saltmarsh Layer 2020) included some errors, particularly near the saline/freshwater interface. Terrestrial vegetation such as macrocarpa, pōhutukawa, and manuka dominated freshwater wetland were identified inaccuracies in previous mapping. These non-mangrove vegetations were previously misclassified due to terrestrial areas mapped as intertidal areas prior to LiDAR availability.

3.3.2. Mangrove Mapping Data Created by Biospatial Ltd in 2024

A Biospatial mangrove layer was created for this project (Figure 12). The Biospatial 2024 layer leveraged the elevation of the digital elevation model and vegetation data obtained from a canopy height model, significantly improving the specificity of mangrove identification. This method provided refined control over the selection of mangrove canopies, effectively reducing the inclusion of irrelevant vegetation.

To further enhance accuracy and consistency in mapping, supervised training datasets generally consisted of mangroves over 50cm in height where the mangrove covered greater than 50% of the canopy area. The mangrove dataset excludes areas of small sparse mangroves and recently expanded areas of mangroves.

More than 80,000 mangrove polygon extents were identified in the Northland area and over 4,000 were greater than 500m². The mangrove polygon extents greater than 500m² spanned an area of 13,155ha in Northland (or 1.04% land area). More than 22,000 mangrove polygon extents were identified in Auckland and around 900 were greater than 500m². The wetlands greater than 500m² spanned an area of 4,051ha in Auckland (or 2.73% land area) (Table 2).



Figure 12. Individual mangrove canopy polygons mapped in 2024 for this project, before (top image) and after (bottom image) mapping.

3.4. Biospatial Saltmarsh Layer (Northland and Auckland)

Saltmarshes in Northern New Zealand are coastal ecosystems that occur in the intertidal zones where saltwater and freshwater mix, creating a unique habitat for a range of fauna. Saltmarshes play a crucial role in coastal protection and water quality improvement by buffering storm surges and trapping sediment.

Common saltmarsh species used to identify saltmarsh layer

- *Juncus australis*, commonly known as Austral rush, is a perennial herbaceous plant characterized by its tufted, cylindrical stems and preference for wet, swampy environments in New Zealand.
- *Isolepis nodosa*, commonly known as knobby club-rush or knotted club-rush, is a perennial sedge with tufted, cylindrical stems and small, clustered flower heads, typically found in coastal and wetland areas of New Zealand.
- *Apodasmia similis*, commonly known as oioi or jointed wire rush, is a perennial, reed-like plant with slender, jointed stems and is native to coastal wetlands and saltmarshes in New Zealand.

A Biospatial saltmarsh dataset was created (Figure 13) using the same methodology developed to create the Biospatial Combined Freshwater Wetland dataset. However, the trained model was only used on geo-segments contained within the intertidal area defined by the area between the saline extent line and the terrestrial mapping extent line (Figure 20).

More than 10,000 saltmarsh polygon extents were identified in the Northland area and over 2,500 were greater than 500m². The saltmarsh polygon extents greater than 500m² spanned an area of 3,044ha in Northland (or 0.24% land area). More than 38,000 saltmarsh polygon extents were identified in Auckland and around 1,400 were greater than 500m². The saltmarsh extents greater than 500m² spanned an area of 684ha in Auckland (or 0.46% land area) (Table 2).



Figure 13. Individual saltmarsh landscape geo-segments mapped for this project, before (top image) and after (bottom image) mapping.

3.5. Biospatial Waterbody Layer (Northland and Auckland)

Some larger wetlands include shallow lakes and open water areas less than two metres deep, often with marsh wetlands around the edges.

The Biospatial waterbody layer identifies constructed and open waterbodies (Figure 14). The same methodology that was used to create the Biospatial Combined Freshwater Wetland dataset was used to identify both constructed and open waterbodies. Further refinements have been identified to improve this layer.

More than 52,000 waterbody polygon extents were identified in the Northland area and over 9,000 were greater than 500m². The waterbody extents greater than 500m² spanned an area of 5,853ha in Northland (or 0.46% land area). More than 7,000 waterbody extents were identified in Auckland and around 1,300 were greater than 500m². The waterbody extents greater than 500m² spanned an area of 260ha in Auckland (or 0.18% land area) (Table 2).



Figure 14. Individual waterbody landscape geo-segments mapped for this project, before (top image) and after (bottom image) mapping.

3.6. Biospatial Gumland Layer (Northland)

Gumlands are the least fertile and most acidic of the wetlands mapped and are normally found on sloping ridges where ancient kauri forests once grew. Over thousands of years the kauri dropped acid litter causing nutrients and organic material to leach out of the soil. This left behind a hard silica pan (base) which is a barrier to water draining away. Gumlands are often not recognised as wetlands because they are on hilltops. In summer they can dry completely and in winter they may be waterlogged. They receive water from rain. In hollows, wet peat bogs can form. Manuka (*Leptospermum scoparium*) and Tangle fern (*Gleichenia dicarpa*) were predominantly used as indicators of gumland for mapping and training purposes (<https://www.nrc.govt.nz/resource-library-summary/publications/wetlands/gumlands-factsheet/gumlands/>)

A Biospatial gumland/wet heathland predictive layer was created for this project (Figure 15). More than 5,000 gumland polygon extents were identified in the Northland area and over 3,000 were greater than 500m². The gumland extents greater than 500m² spanned an area of 21,111ha in Northland (or 1.66% land area). Gumlands were not mapped in the Auckland area.

The gumland data was derived from a machine learning process trained using a combination of LiDAR data, RGBI data and SPOT5 imagery. This methodology resulted in many false positives due to mānuka being present in regenerating scrub which presented similar visual characteristics to gumlands making it difficult to distinguish the two apart.

Historic imagery was used to validate and filter some of the false positives from the output (Figure 16). Further validation and corrections are necessary using Photoblique web viewer.



Figure 15. Individual gumland canopy polygons mapped for this project, before (top image) and after (bottom image) mapping.

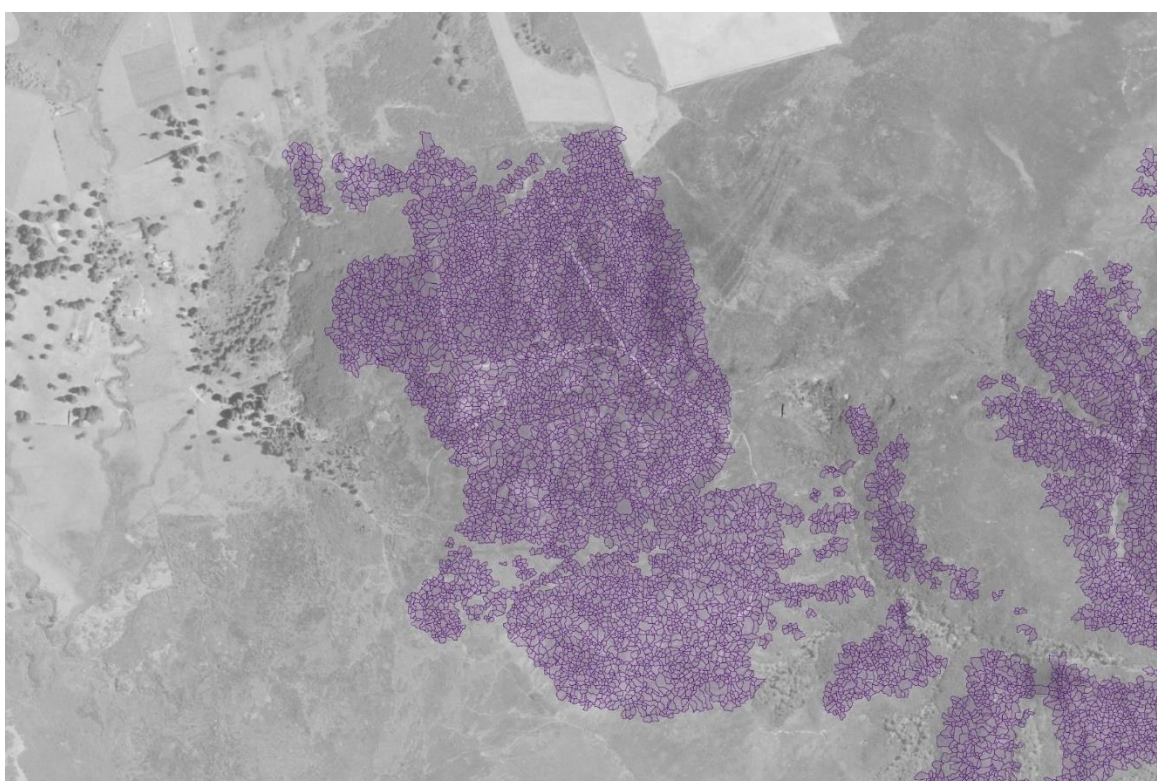


Figure 16. Individual gumland canopy polygons mapped for this project overlaid onto historic imagery captured in 1957, before (top image) and after (bottom image) mapping.

3.7. Biospatial Historic Imagery Basemap (Northland and Auckland)

A comprehensive composite imagery orthomosaic of the Northland and Auckland area was created at a resolution of 1 meter per pixel (Figure 17). This standardized resolution facilitated an easier analysis and integration with other spatial data layers, allowing for more effective historical comparisons and landscape analysis.

The historic imagery layers were provided as individual orthomosaics based on survey numbers (Appendix 2), maintaining the native resolution of the imagery, which varied between 50 cm/pixel to 150 cm/pixel. The range in resolution reflects the technological capabilities and aerial survey methods used during the respective periods. This resource was instrumental in creating a layer that provides a unique historical perspective on landscape changes, particularly focusing on gumlands and other wetlands.

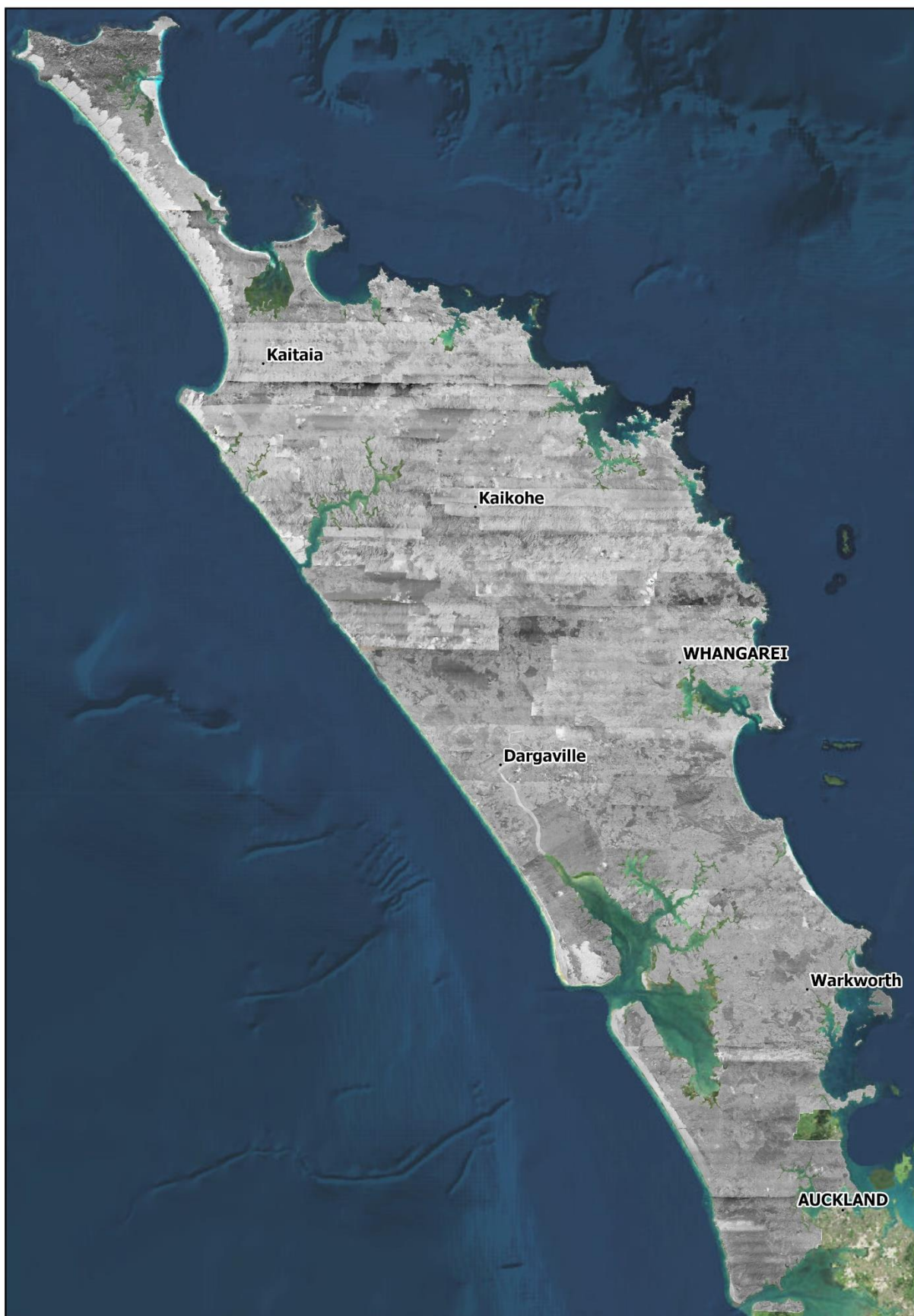


Figure 17. Merged historic imagery orthomosaic of Northland and Kaipara Moana Catchment @ 1 metre per pixel resolution.

3.7.1. Source

Historic images were sourced from the Retrolens website <https://retrolens.co.nz/> and licensed by LINZ CC-BY 3.0. Retrolens is a valuable digital archive that houses historical aerial photographs of New Zealand, captured from as early as the 1930's. The platform offers a comprehensive resource of the available scanned historic imagery captured in New Zealand.

3.7.2. Purpose of the Historic Imagery Layer

The primary purpose of the historic imagery layer was to serve as an additional source of validation for identifying gumlands and other wetlands within the landscape. This is because gumlands/wet heathlands can easily be confused with areas of regenerating mānuka due to their similar visual characteristics in contemporary imagery.

Wetlands are typically enduring features in the landscape, and are therefore consistently visible throughout the imagery archive, making historical aerial photographs an invaluable resource for confirming their persistence over time. Therefore, the historic imagery offers a unique and useful reference for wetland mapping.

3.7.3. Historic Imagery Processing and Methodology

The earliest images available on the Retrolens website were selected for the project, with an emphasis on compiling the images to create a layer reflecting the earliest captured dates possible, ranging from 1938 to the 1970's. The majority of the imagery utilized was flown during the 1940's, 1950's, and 1960's.

Images were accessed and downloaded using Photoblique image information software v 2.1.8. Images were then geotagged in Photoblique Sync and inspected and assessed for quality and coverage in Photoblique.

A photogrammetry stitching process was used to achieve seamless stitching of the imagery and orthorectified for elevation and terrain variations. The images were orthorectified to within 5m accuracy over flat terrain. Orthorectification removed the effects of image perspective from camera tip/tilt and displacement caused by terrain relief from raw imagery. Each frame was draped over the Digital Terrain Model (DTM) and the image was scaled and levelled in terms of true ground coordinates. Ground control was obtained by comparing identifiable features between current and historic imagery.

3.8. Biospatial Saline Extent Line (Northland and Auckland)

The Biospatial saline extent line was created using 1 metre resolution Digital Elevation Models (DEM). It was used to accurately define the inland extent where there is a noticeable change in vegetation from salt-tolerant species to terrestrial species that have a lower tolerance to saline conditions (Figure 18).

3.8.1. Methodology

The saline extent line was manually created by selecting specific elevation contours that best represent the transition in vegetation. This involved detailed analysis and selection of contours that vary with proximity to the open ocean. In areas far from the open ocean, within the reaches of a harbour, the selected elevation is generally higher compared to areas near the harbour mouth depending on the location's propensity for storm surges and wave run-up. This approach recognizes the influence of saline water intrusion which diminishes further up rivers.

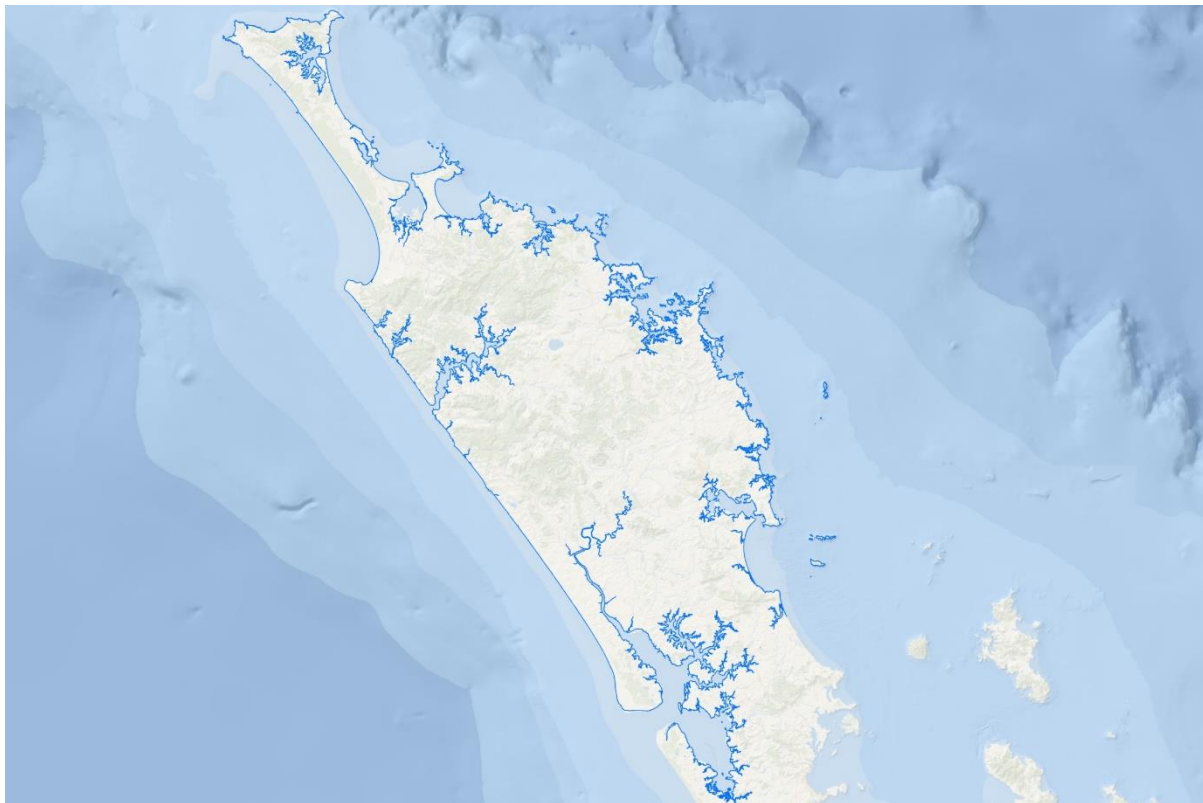


Figure 18. Biospatial saline extent line of Northland, offshore Islands and Kaipara harbour (blue).

3.8.2. Limitations of other coastline data available

- LINZ Coastline: The LINZ coastline provides a baseline of the New Zealand coastline, however, this line rarely intersects freshwater terrestrial swamps and saltmarsh with accuracy.
- NRC Natural Character Coastline: This coastline was derived from Northland Regional Council's natural character mapping created in 2012. It was manually digitised using a stylus and tablet from interpretation of satellite imagery. This coastline was used for the

development of the 2020 mangrove and saltmarsh layer, but a number of inaccuracies have since been identified

- NIWA Coastline: The NIWA coastline does not adequately delineate the boundary of saltmarsh and freshwater swamps and subsequently this layer was not used.

3.8.3. Proxy for Mean High Water Mark (MHWM):

Currently the Biospatial Saline Extent Line serves as the best available proxy for the mean high-water mark, providing a vital tool for coastal management and planning (Figure 19).

By combining elevation data with precise contour analysis and vegetation interpretation, this line offers a nuanced delineation of the transition from saltmarsh to terrestrial ecosystems. The Biospatial Saline Extent Line is also a means to distinguish between natural ‘inland’ wetlands and ‘coastal’ wetlands, which is a distinction made in the NPS-FM (the NPS-FM provisions only apply to natural inland wetlands).

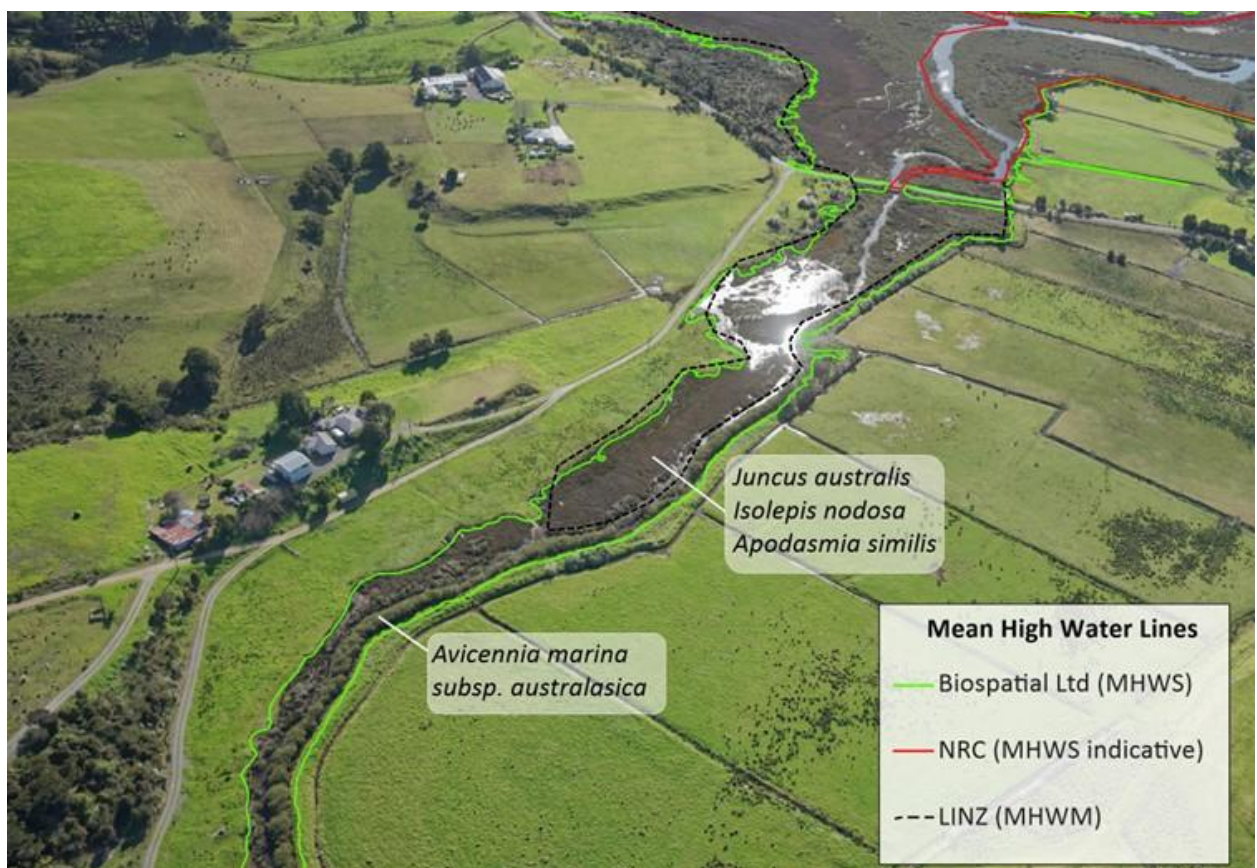


Figure 19. Comparison of Biospatial saline extent line (green) to other coastlines in use.

3.9. Biospatial Terrestrial Extent Line (Northland and Auckland)

The Biospatial terrestrial extent line (Figure 20) represents the seaward limit of the mangrove canopy as captured on 1 metre resolution Digital Surface Models (DSM). The terrestrial extent line was manually derived by selecting contour lines that best match the observable limits of mangrove vegetation on the DSM. This line is not intended to represent the low water line and loosely aligns with the $\frac{1}{4}$ to $\frac{1}{2}$ tide mark.

The terrestrial extent line was fundamental to define the boundary where terrestrial vegetation predominantly ends. It was used to create a mask to specifically delineate the terrestrial extent of mangrove and saltmarsh habitats.

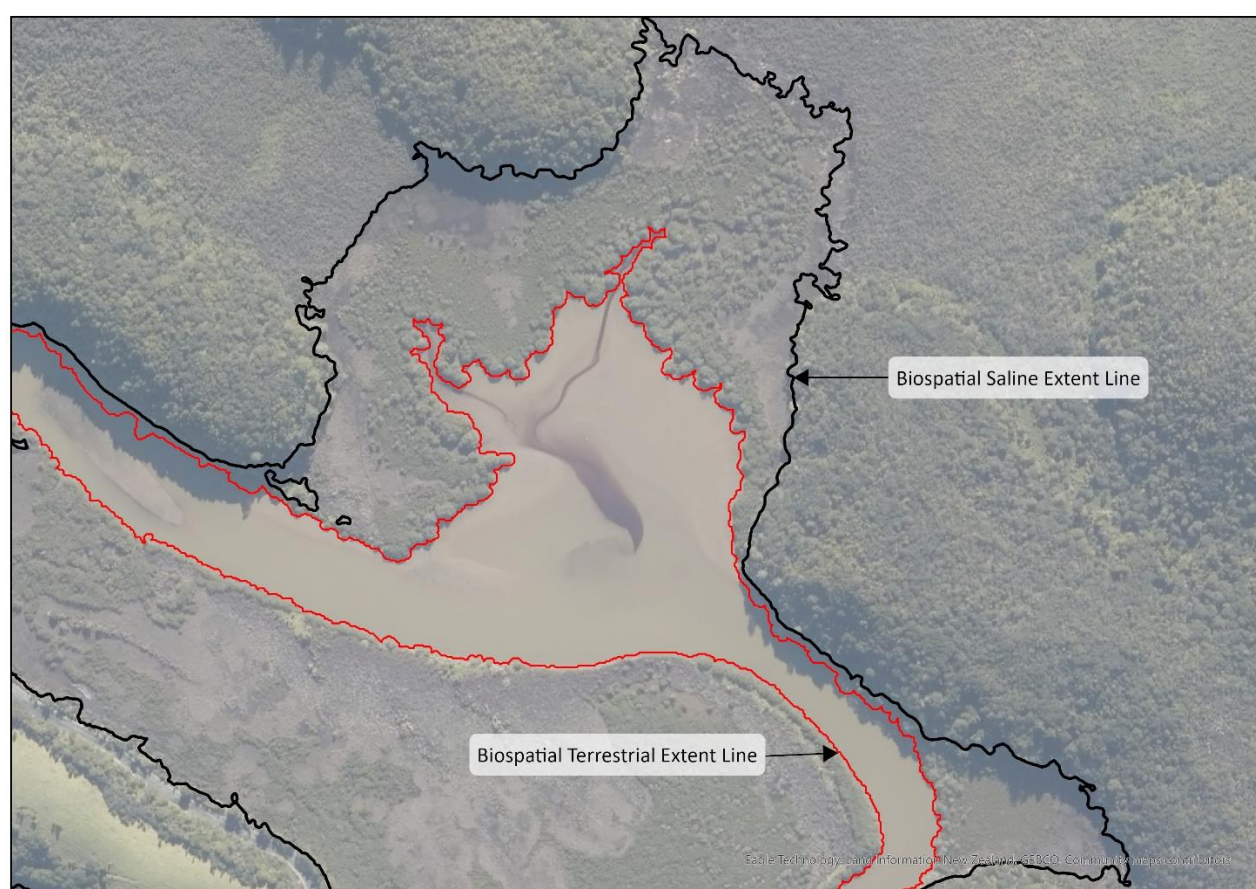


Figure 20. Red line depicts the Biospatial terrestrial extent line. The area between the saline extent line (black) and terrestrial extent line (red) represents the intertidal area.

4. Discussion

The Northland Biospatial combined freshwater wetland extents were compared to Northland Regional Council's 1051 known wetlands mapped manually in 2016⁵. Ninety or 8.6% of the known wetlands did not have a corresponding predicted wetland extent. Further breakdown of the missed wetlands indicated 52 were a forest type wetland not yet mapped for this project, 22 appeared mapped in error and 12 were missed by the predictive algorithm. Of the wetlands missed by the predictive algorithm, 0.6ha was the average size, with 3 hectares being the largest and 0.08 ha being the smallest. The missed wetlands mostly represented very minor or marginal

wetlands. It is likely that the predictive algorithm identified these wetlands, but the selection process failed to identify them as wetlands.

The Auckland Biospatial combined freshwater wetland extents were compared to Auckland Regional Council's 1,961 known wetlands mapped manually in 2013⁴. These wetlands consisted of wetlands classified as swamp, seepage, marsh and gumland vegetation. The gumlands classified by Council were similar to swamps mapped for this project. Of the known wetlands, 1,198 (or 61.1%) corresponded to 1,036 Biospatial wetland extents. The remaining 763 (or 38.9%) did not have a corresponding Biospatial predicted wetland extent. Of the known wetlands that did not correspond to freshwater wetland extents, 76 were classified as Biospatial Waterbody extents, 11 as Biospatial Mangrove extents and 11 as Biospatial Saltmarsh extents. The Biospatial combined freshwater wetland extents layer provided for this project identified 20,313 wetlands that had not been mapped previously by Council.

The methodology that was ultimately used to map wetlands was developed late in the contract. The full potential of the methodology has not been explored. The level of confidence in the wetland data can be improved by reprocessing the LiDAR data and creating more layers using the LiDAR dataset which may help distinguish wetlands in the landscape. Furthermore, all wetland training data was created using vegetation below 8m in height. Therefore, any wetlands identified consisting of vegetation greater than 8m will be unreliable.

The datasets used for generating wetlands in Northland was LiDAR and RGBI. SPOT5 imagery was also used for generating predictive gumland layers. The imagery used for generating wetlands in Auckland was LiDAR, RGB 2012 and RGB 2017-2022. An alternative method of improving the level of confidence in the dataset is re-running the process when new imagery becomes available. This is because more datasets will generate a higher level of confidence.

The Biospatial gumlands dataset has a large number of false positives and currently has the lowest level of confidence out of all of the wetland extents. The gumlands mapping was predicted using vegetation attributes. However, gumlands are found on a wide variety of slopes, and the main canopy vegetation type is mānuka which is a ubiquitous vegetation type throughout Northland and Auckland. A more appropriate indicator of gumlands is soil type. The soil type is not yet mapped accurately enough to delineate gumlands.

The segmented machine learning methodology of delineating wetlands that was applied to the other wetland datasets was not suitable for mapping swamp forests accurately. The predicted output produced a large number of false positives and false negatives. An alternative methodology is being developed. Biospatial has trained a neural network model in Photoblique to classify multiple tree species (Figures 21 & 22). The results appear promising and could be used to map swamp forest in future.



Figure 21. Aerial view of kahikatea stand representing likely swamp forest.

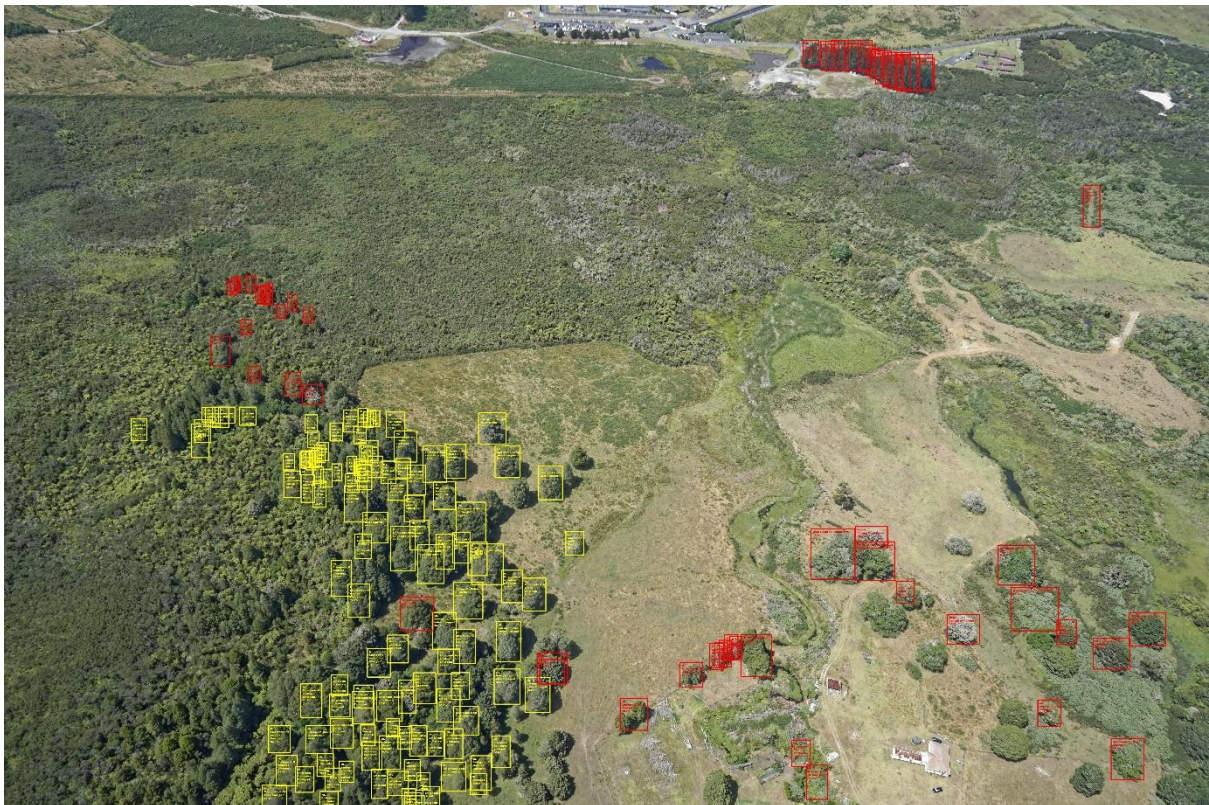


Figure 22. The neural network method is able to accurately identify kahikatea (yellow). A number of different tree species are also identified (red).

5. Conclusion

The adapted methodology for mapping combined freshwater wetland layers represents a significant advancement in wetland delineation techniques compared to historic field mapping, Wildland surveys, desktop-based GIS efforts and the Ministry for Environment (MfE) feasibility study in 2021 using machine learning and LiDAR datasets. By integrating machine learning with landscape segmentation and enabling manual refinements, this approach not only improves the accuracy and reliability of wetland mapping but also ensures the data remains flexible and adaptable over time. This methodological evolution underscores the dynamic and innovative strategies utilised to meet the challenges of accurately mapping complex wetland systems.

6. Limitations

The wetland extent and geo-segment layers are predictive outputs. There has not been any substantive desktop validation or field validation of wetland layers as part of this project. Some of the predictive wetland extents overlap, such as ponds, combined freshwater wetlands and gumlands. These need to be further distinguished from each other. The accuracy of wetland mapping could also be progressed through various means including resource consents, freshwater farm plans and KMR site visits for example.

Accurately mapping and validating large numbers of wetland polygons using the current tools available is cumbersome and time-consuming. The number of polygon extents generated in this project ranged between 5,000 and 100,000 polygons. In a traditional GIS 2D view using the current tools available, it is difficult to consistently and accurately assess large feature count datasets. The attribution process becomes very onerous once 10,000-100,000 polygons are generated. Therefore, only a small proportion of polygons can be accurately validated using 2D GIS.

2D GIS is suitable for smaller wetland datasets generated prior to NPS-FM requirements, such as the Northland Regional Council's known wetland layer generated in 2016 which consisted of approximately 1000 polygons. The 2022 MfE wetland layer for Northland was developed to meet NPS-FM specifications of wetlands 500m² or greater and had 22,000 polygons and it did not appear to be accurate or validated. The large number of wetlands above 500m² in the landscape mapped using machine learning techniques is problematic for current attribution methods.

Photoblique desktop was used as a generic validation method of the wetland datasets. Photoblique desktop enables users to accurately overlay GIS data. However it requires a high level of GIS proficiency to do so, the layers are not able to be edited easily and navigating 50,000-100,000 wetlands proved to be slow.

7. Recommendations

The wetland datasets have been delivered in a raw geo-segmented form and a simplified extent layer where the segments have been merged into one polygon and a smoothing algorithm applied for aesthetic purposes. The geo-segment layer is best viewed at a scale less than 1:10,000 whereas the wetland extent datasets are suitable for general viewing at all scales. It is recommended that the geo-segment layers are used for ongoing corrections and monitoring.

Photoblique Ltd is developing a specialised web viewer application for ongoing corrections and monitoring of large wetland datasets (Figure 23). This will address the inability to adequately and easily validate the wetland polygons by supporting a collaborative approach to wetland validation across multiple disciplines including GIS analysts, ecologists and land management advisors. Early adoption trials of the web viewer suggests users will be capable of viewing large datasets on aerial imagery and oblique imagery that will overcome limitations experienced during this project.



Figure 23. Smoothed wetland polygons overlaid in Photoblique web viewer.

8. Acknowledgements

We thank James Griffin (NRC), Duncan Kervell (KMR), Justin Murfitt (NRC), Katrina Hansen (NRC), Lisa Forester (NRC), Stephanie Versteeg (KMR) and Manas Chakraborty (NRC) for their assistance with wetland identification and/or for reviewing and improving an earlier draft of this report.

9. References

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10. Appendix 1 Summary of Data Delivered

DELIVERABLES	DESCRIPTION	DATA LIMITATIONS	SCALE RANGE
NORTHLAND			
Northland Combined FW Wetland Extents	This dataset maps the extent of wetlands defined by the national policy statement for freshwater management. Additional to wetlands as defined by NPSFM, areas suitable for wetland restoration are identified for consideration in developing farm environment plans to trap sediment. Wetlands were mapped using a combination of LiDAR (2018) and RGBI (2014-2016) imagery captured by Northland and Auckland Councils. Wetlands were validated using a combination of Photoblique and Biospatial_KMR Historic Imagery layer derived from Retrolens. Slope, Spectral signatures, Topographic wetness index and vegetation structure were used to identify and delineate Wetlands. Information is current to the datasets available. Data was derived using a combination of AI model training and manual output validation. Wetlands have been manually selected using a combination of aerial surveys, GIS desktop surveys and Photoblique validation. As such data is limited to wetlands which have been manually validated and may not be representative of all wetlands present. Data is presented using a polygon approach for ease of display. Elevation data has been attached for data overlay in Photoblique.	Data may be subject to false positive and/or false negative results. The spatial extents can be used as a guide for where wetlands exist. Data is a representation of the capture date of the imagery and LiDAR.	The data was derived from 1 metre resolution LiDAR and aerial imagery data and validated using 5cm oblique imagery and approx. 50cm Historic Imagery.
Northland Combined FW Wetland Geo-Segments	This dataset maps the extent of wetlands defined by the national policy statement for freshwater management. Additional to wetlands as defined by NPSFM, areas suitable for wetland restoration are identified for consideration in developing farm environment plans to trap sediment. Wetlands were mapped using a combination of LiDAR (2018) and RGBI (2014-2016) imagery captured by Northland and Auckland Councils. Wetlands were validated using a	Data may be subject to false positive and/or false negative results. The spatial extents can be used as a guide for where wetlands exist. Data is a representation of the capture date of the imagery and LiDAR.	The data was derived from 1 metre resolution LiDAR and aerial imagery data and validated using 5cm oblique imagery and approx. 50cm Historic Imagery

DELIVERABLES	DESCRIPTION	DATA LIMITATIONS	SCALE RANGE
	combination of Photoblique and Biospatial_KMR Historic Imagery layer derived from retrolens. Slope, Spectral signatures, Topographic wetness index and vegetation structure were used to identify and delineate Wetlands. Information is current to the datasets available. Data was derived using a combination of AI model training and manual output validation. Wetlands have been manually selected using a combination of aerial surveys, GIS desktop surveys and Photoblique validation. As such data is limited to wetlands which have been manually validated and may not be representative of all wetlands present. Data is presented using a segmented approach for ease of prolonged iterative monitoring, editing and annotating. Elevation data has been attached for data overlay in Photoblique.		
Northland Mangrove Extents	This dataset maps the extent of mangroves along the Northland coastline. Coastline used to delineate the extent of this data is the Biospatial_SalineInfluenceExtent_Northland. Mangroves were mapped using a combination of LiDAR (2018) and RGBI (2014-2016) imagery captured by Northland and Auckland Councils. Data was derived using a combination of AI model training and manual output validation. Validated was conducted using a combination of Photoblique and GIS desktop surveys. Slope, Spectral signatures, Topographic wetness index and vegetation structure were used to identify and delineate Mangroves. Mangrove height of 0.5m and vegetation cover of 50% were used as guides for mapping.	Data may be subject to false positive and/or false negative results. The spatial extents can be used as a guide for where mangrove exists. Scale is created to a 1m resolution. Data is representation of the capture date of the imagery and LiDAR.	The data was derived from 1 metre resolution LiDAR and aerial imagery data and validated using 5cm oblique imagery and approx. 50cm Historic Imagery.

DELIVERABLES	DESCRIPTION	DATA LIMITATIONS	SCALE RANGE
	Data is presented using a polygon approach for ease of display. Elevation data has been attached for overlay in Photoblique.		
Northland Mangrove Geo-Segments	This dataset maps the extent of mangroves along the Northland coastline. Coastline used to delineate the extent of this data is the Biospatial_SalineInfluenceExtent_Northland. Mangroves were mapped using a combination of LiDAR (2018) and RGBI (2014-2016) imagery captured by Northland and Auckland Councils. Data was derived using a combination of AI model training and manual output validation. Validated was conducted using a combination of Photoblique and GIS desktop surveys. Slope, Spectral signatures, Topographic wetness index and vegetation structure were used to identify and delineate Mangroves. Mangrove height of 0.5m and vegetation cover of 50% were used as guides for mapping. Data is presented using a segmented approach for ease of prolonged iterative monitoring, editing and annotating. Elevation data has been attached for overlay in Photoblique.	Data may be subject to false positive and/or false negative results. The spatial extents can be used as a guide for where mangroves exists. Scale is created to a 1m resolution. Data is representation of the capture date of the imagery and LiDAR.	The data was derived from 1 metre resolution LiDAR and aerial imagery data and validated using 5cm oblique imagery and approx. 50cm Historic Imagery.
Northland Saltmarsh Extents	This dataset maps the extent of Saltmarsh along the Northland coastline. Coastline used to delineate the extent of this data is the Biospatial_SalineInfluenceExtent_Northland. Saltmarsh was mapped using a combination of LiDAR (2018) and RGBI (2014-2016) imagery captured by Northland and Auckland Councils. Data was derived using a combination of AI model training and manual output validation. Saltmarsh was validated using a combination of Photoblique and GIS desktop surveys.	Data has a high accuracy rate but may be subject to some false positive and/or false negative results. The spatial extents can be used as a guide for where saltmarsh exists. Scale is created to a 1m resolution Data is representation of the capture date of the imagery and LiDAR.	The data was derived from 1 metre resolution LiDAR and aerial imagery data and validated using 5cm oblique imagery and approx. 50cm Historic Imagery.

DELIVERABLES	DESCRIPTION	DATA LIMITATIONS	SCALE RANGE
	Slope, Spectral signatures, Topographic wetness index and vegetation structure were used to identify and delineate Saltmarsh. Data is presented using a polygon approach for ease of display. Elevation data has been attached for data overlay in Photoblique.		
Northland Saltmarsh Geo-Segments	This dataset maps the extent of Saltmarsh along the Northland coastline. Coastline used to delineate the extent of this data is the Biospatial_SalineInfluenceExtent_Northland. Saltmarsh was mapped using a combination of LiDAR (2018) and RGBI (2014-2016) imagery captured by Northland and Auckland Councils. Data was derived using a combination of AI model training and manual output validation. Saltmarsh was validated using a combination of Photoblique and GIS desktop surveys. Slope, Spectral signatures, Topographic wetness index and vegetation structure were used to identify and delineate Saltmarsh. Data is presented using a segmented approach for ease of prolonged iterative monitoring, editing and annotating. Elevation data has been attached for data overlay in Photoblique.	Data has a high accuracy rate but may be subject to some false positive and/or false negative results. The spatial extents can be used as a guide for where saltmarsh exists. Scale is created to a 1m resolution. Data is representation of the capture date of the imagery and LiDAR.	The data was derived from 1 metre resolution LiDAR and aerial imagery data and validated using 5cm oblique imagery and approx. 50cm Historic Imagery.
Northland Gumland Extents	This dataset maps the extent of wetlands gumlands within Northland region. Gumlands were mapped using a combination of LiDAR (2018) and RGBI (2014-2016) imagery captured by Northland and Auckland Councils. Gumlands were validated using a combination of Photoblique and Biospatial_KMR Historic Imagery layer derived from retrolens. Slope, Spectral signatures, Topographic wetness index and vegetation structure were used to identify and delineate Wetlands.	Data may be subject to false positive and/or false negative results. The spatial extents can be used as a guide for where gumlands exists. Scale is created to a 1m resolution. Data is representation of the capture date of the imagery and LiDAR.	The data was derived from 1 metre resolution LiDAR and aerial imagery data and validated using 5cm oblique imagery and approx. 50cm Historic Imagery

DELIVERABLES	DESCRIPTION	DATA LIMITATIONS	SCALE RANGE
	Information is current to the datasets available. Data was derived using a combination of AI model training and manual output validation. Data is presented using a polygon approach for ease of display. Elevation data has been attached for data overlay in Photoblique.		
Northland Gumland Geo-Segments	This dataset maps the extent of wetlands gumlands within Northland region. Gumlands were mapped using a combination of LiDAR (2018) and RGBI (2014-2016) imagery captured by Northland and Auckland Councils. Gumlands were validated using a combination of Photoblique and Biospatial_KMR Historic Imagery layer derived from retrolens. Slope, Spectral signatures, Topographic wetness index and vegetation structure were used to identify and delineate Wetlands. Information is current to the datasets available. Data was derived using a combination of AI model training and manual output validation. Data is presented using a segmented approach for ease of prolonged iterative monitoring, editing and annotating. Elevation data has been attached for data overlay in Photoblique.	Data may be subject to false positive and/or false negative results. The spatial extents can be used as a guide for where gumlands exists. Scale is created to a 1m resolution. Data is representation of the capture date of the imagery and LiDAR.	The data was derived from 1 metre resolution LiDAR and aerial imagery data and validated using 5cm oblique imagery and approx. 50cm Historic Imagery.
Northland Waterbody Extents	This dataset maps the extent of waterbodies identified within Northland Region. Waterbodies were mapped using a combination of LiDAR (2018) and RGBI (2014-2016) imagery captured by Northland and Auckland Councils. Waterbodies were validated using a combination of Photoblique and GIS desktop techniques. Slope, Spectral signatures, Topographic wetness index and vegetation structure were used to identify and delineate waterbodies.	Data may be subject to false positive and/or false negative results. The spatial extents can be used as a guide for where waterbodies exist Data is a representation of the capture date of the imagery and LiDAR	1m resolution

DELIVERABLES	DESCRIPTION	DATA LIMITATIONS	SCALE RANGE
	Information is current to the datasets available. The spatial extents can be used as a guide for where a waterbody exists Data was derived using a combination of AI model training and manual output validation. Elevation data has been attached for data overlay in Photoblique. Data is presented using a polygon approach for ease of display.		
Northland Waterbody Geo-Segments	This dataset maps the extent of waterbodies identified within Northland Region. Wetlands were mapped using a combination of LiDAR (2018) and RGBI (2014-2016) imagery captured by Northland and Auckland Councils. Waterbodies were validated using a combination of Photoblique and GIS desktop techniques. Slope, Spectral signatures, Topographic wetness index and vegetation structure were used to identify and delineate waterbodies. Information is current to the datasets available. The spatial extents can be used as a guide for where a waterbody exists Data was derived using a combination of AI model training and manual output validation. Elevation data has been attached for data overlay in Photoblique. Data is presented using a segmented approach for ease of prolonged iterative monitoring, editing and annotating.	Data may be subject to false positive and/or false negative results. The spatial extents can be used as a guide for where waterbodies exist. Scale is created to a 1m resolution Data is a representation of the capture date of the imagery and LiDAR.	Scale is created to a 1m resolution
Northland & Auckland Combined FW Wetland Validation Points	This dataset was manually created to identify and verify locations of wetlands as defined by the national policy statement for freshwater management. Additional to wetlands as defined by NPSFM, areas suitable for wetland restoration are identified for consideration in developing farm environment plans to trap sediment. Wetlands have been manually selected using a combination of aerial surveys, GIS	Data is limited to wetlands which have been manually validated and may not be representative of all wetlands present. Information is current to the datasets available. This data can be used as a guide for where a wetland exists.	Northland

DELIVERABLES	DESCRIPTION	DATA LIMITATIONS	SCALE RANGE
	desktop surveys (utilising GIS satellite imagery) and Photoblique validation (utilising areal imagery). Points have been categorized based on their validation process.	Data indicates wetlands which have been validated using GIS desktop, Areal and Areal Imagery observations. Validated wetlands were not checked on site for wetland indicators/native vegetation growth percentage. Validated wetlands include wetlands able to be identified using the described methods and is not an indicator of all wetlands present.	
Northland & Auckland Saltwater Extent Line	Detailed coastline of Northland delineated using evidence of saline influenced vegetation. 2018-2020 Northland LiDAR 1m DEM and Northland 0.4 rural Aerial Photos (2014-2016) were used to create the Saline influence extent. Multiple contour lines were generated from the DEM and those which best delineated the difference between the saline tolerant vegetation and terrestrial freshwater vegetation were selected for the saline influence extent. Saline tolerant plant species, <i>Juncus australis</i>, <i>Isolepis nodosa</i>, <i>Apodasmia similis</i> and <i>Avicennia marina</i> subspecies <i>australasica</i> were used as indicators of frequent inundation during tidal events.	Scale is created to a 1m resolution. Data has high accuracy and high detail, however, may be subject some inaccuracies in isolated locations. Layer should be used as an indication of likely saline influence. Data is representative of the capture date of the imagery.	The scale range that the data was created at was 1m resolution DEM
Northland & Auckland Historic Imagery Basemap 1m	The earliest images available between 1938 - 1982 were downloaded from Retrolens https://retrolens.co.nz/. Images were accessed and downloaded using Photoblique image information software v 2.1.8 A photogrammetry stitching process was used to stitch the imagery and orthorectified for elevation and terrain variations. The images were orthorectified to within 5m accuracy over flat terrain. Each frame was draped over the DTM and the image was scaled and levelled in terms of true ground coordinates. Ground control was obtained by comparing identifiable features between current and historic imagery. Orthomosaics were exported in .tif image format.		Variable: 30cm to 100cm/pix.
AUCKLAND (KMR)			
	This dataset maps the extent of wetlands defined by the national policy statement	Data may be subject to false positive and/or false negative	The data was derived from 0.5

DELIVERABLES	DESCRIPTION	DATA LIMITATIONS	SCALE RANGE
Auckland Combined FW Wetland Extents	for freshwater management. Additional to wetlands as defined by NPSFM, areas suitable for wetland restoration are identified for consideration in developing farm environment plans to trap sediment. Wetlands were mapped using a combination of LiDAR (2018) and RGBI (2014-2016) imagery captured by Northland and Auckland Councils. Wetlands were validated using a combination of Photoblique and Biospatial_KMR Historic Imagery layer derived from retrolens. Slope, Spectral signatures, Topographic wetness index and vegetation structure were used to identify and delineate Wetlands. Information is current to the datasets available. Data was derived using a combination of AI model training and manual output validation. Wetlands have been manually selected using a combination of aerial surveys, GIS desktop surveys and Photoblique validation. As such data is limited to wetlands which have been manually validated and may not be representative of all wetlands present. Data is presented using a polygon approach for ease of display. Elevation data has been attached for data overlay in Photoblique	results. The spatial extents can be used as a guide for where wetlands exist. Data is a representation of the capture date of the imagery and LiDAR.	metre resolution LiDAR and aerial imagery data and validated using 5cm oblique imagery and approx. 50cm Historic Imagery.
Auckland Combined FW Wetland Geo-Segments	This dataset maps the extent of wetlands defined by the national policy statement for freshwater management. Additional to wetlands as defined by NPSFM, areas suitable for wetland restoration are identified for consideration in developing farm environment plans to trap sediment. Wetlands were mapped using a combination of LiDAR (2018) and RGBI (2014-2016) imagery captured by Northland and Auckland Councils. Wetlands were validated using a combination of Photoblique and Biospatial_KMR Historic Imagery layer derived from retrolens. Slope, Spectral signatures, Topographic wetness index and vegetation structure	Data may be subject to false positive and/or false negative results. The spatial extents can be used as a guide for where wetlands exist. Data is a representation of the capture date of the imagery and LiDAR.	The data was derived from 0.5 metre resolution LiDAR and aerial imagery data and validated using 5cm oblique imagery and approx. 50cm Historic Imagery.

DELIVERABLES	DESCRIPTION	DATA LIMITATIONS	SCALE RANGE
	were used to identify and delineate Wetlands. Information is current to the datasets available. Data was derived using a combination of AI model training and manual output validation. Wetlands have been manually selected using a combination of aerial surveys, GIS desktop surveys and Photoblique validation. As such data is limited to wetlands which have been manually validated and may not be representative of all wetlands present. Data is presented using a segmented approach for ease of prolonged iterative monitoring, editing and annotating. Elevation data has been attached for data overlay in Photoblique.		
Auckland Mangrove Extents	This dataset maps the extent of mangroves along the Northland coastline. Coastline used to delineate the extent of this data is the Biospatial_SalineInfluenceExtent_Kaipara. Mangroves were mapped using a combination of LiDAR (2018) and RGBI (2014-2016) imagery captured by Northland and Auckland Councils. Data was derived using a combination of AI model training and manual output validation. Validated was conducted using a combination of Photoblique and GIS desktop surveys. Slope, Spectral signatures, Topographic wetness index and vegetation structure were used to identify and delineate Mangroves. Mangrove height of 0.5m and vegetation cover of 50% were used as guides for mapping. Data is presented using a polygon approach for ease of display. Elevation data has been attached for overlay in Photoblique.	Data may be subject to false positive and/or false negative results. The spatial extents can be used as a guide for where mangroves exist. Scale is created to a 1m resolution. Data is representation of the capture date of the imagery and LiDAR.	The data was derived from 1 metre resolution LiDAR and aerial imagery data and validated using 5cm oblique imagery and approx. 50cm Historic Imagery.
Auckland Mangrove Geo-Segments	This dataset maps the extent of mangroves along the Northland coastline. Coastline used to delineate the extent of this data is	Data may be subject to false positive and/or false negative results.	The data was derived from 1 metre resolution LiDAR and aerial

DELIVERABLES	DESCRIPTION	DATA LIMITATIONS	SCALE RANGE
	the Biospatial_SalineInfluenceExtent_Kaipara. Mangroves were mapped using a combination of LiDAR (2018) and RGBI (2014-2016) imagery captured by Northland and Auckland Councils. Data was derived using a combination of AI model training and manual output validation. Validated was conducted using a combination of Photoblique and GIS desktop surveys. Slope, Spectral signatures, Topographic wetness index and vegetation structure were used to identify and delineate Mangroves. Mangrove height of 0.5m and vegetation cover of 50% were used as guides for mapping. Data is presented using a segmented approach for ease of prolonged iterative monitoring, editing and annotating. Elevation data has been attached for overlay in Photoblique.	The spatial extents can be used as a guide for where mangroves exist. Scale is created to a 1m resolution Data is representation of the capture date of the imagery and LiDAR.	imagery data and validated using 5cm oblique imagery and approx. 50cm Historic Imagery.
Auckland Saltmarsh Extents	This dataset maps the extent of wetlands defined by the national policy statement for freshwater management. Additional to wetlands as defined by NPSFM, areas suitable for wetland restoration are identified for consideration in developing farm environment plans to trap sediment. Wetlands were mapped using a combination of LiDAR (2018) and RGBI (2014-2016) imagery captured by Northland and Auckland Councils. Wetlands were validated using a combination of Photoblique and Biospatial_KMR Historic Imagery layer derived from retrolens. Slope, Spectral signatures, Topographic wetness index and vegetation structure were used to identify and delineate Wetlands. Information is current to the datasets available. Data was derived using a combination of AI model training and manual output validation.	Data may be subject to false positive and/or false negative results. The spatial extents can be used as a guide for where saltmarsh exist. Data is a representation of the capture date of the imagery and LiDAR.	The data was derived from 0.5 metre resolution LiDAR and aerial imagery data and validated using 5cm oblique imagery and approx. 50cm Historic Imagery.

DELIVERABLES	DESCRIPTION	DATA LIMITATIONS	SCALE RANGE
	Wetlands have been manually selected using a combination of aerial surveys, GIS desktop surveys and Photoblique validation. As such data is limited to wetlands which have been manually validated and may not be representative of all wetlands present. Data is presented using a polygon approach for ease of display. Elevation data has been attached for data overlay in Photoblique		
Auckland Saltmarsh Geo-Segments	This dataset maps the extent of Saltmarsh along the Northland coastline. Coastline used to delineate the extent of this data is the Biospatial_SalineInfluenceExtent_Kaipara. Saltmarsh was mapped using a combination of LiDAR (2018) and RGBI (2014-2016) imagery captured by Northland and Auckland Councils. Data was derived using a combination of AI model training and manual output validation. Saltmarsh was validated using a combination of Photoblique and GIS desktop surveys. Slope, Spectral signatures, Topographic wetness index and vegetation structure were used to identify and delineate Saltmarsh. Data is presented using a segmented approach for ease of prolonged iterative monitoring, editing and annotating. Elevation data has been attached for data overlay in Photoblique.	Data has a high accuracy rate but may be subject to some false positive and/or false negative results. The spatial extents can be used as a guide for where saltmarsh exists. Scale is created to a 1m resolution. Data is representation of the capture date of the imagery and LiDAR.	The data was derived from 1 metre resolution LiDAR and aerial imagery data and validated using 5cm oblique imagery and approx. 50cm Historic Imagery.
Auckland Waterbody Extents	This dataset maps the extent of waterbodies identified within Auckland Region. Wetlands were mapped using a combination of LiDAR (2018) and RGBI (2014-2016) imagery captured by Northland and Auckland Councils. Waterbodies were validated using a combination of Photoblique and GIS desktop techniques. Slope, Spectral signatures, Topographic wetness index and vegetation structure were used to identify and delineate waterbodies.	Data may be subject to false positive and/or false negative results. The spatial extents can be used as a guide for where waterbodies exist. Scale is created to a 0.5m resolution. Data is a representation of the capture date of the imagery and LiDAR.	Scale is created to a 0.5m resolution.

DELIVERABLES	DESCRIPTION	DATA LIMITATIONS	SCALE RANGE
	Information is current to the datasets available. The spatial extents can be used as a guide for where a waterbody exists Data was derived using a combination of AI model training and manual output validation. Elevation data has been attached for data overlay in Photoblique. Data is presented using a polygon approach for ease of display.		
Auckland Waterbody Geo-Segments	This dataset maps the extent of waterbodies identified within Auckland Region. Wetlands were mapped using a combination of LiDAR (2018) and RGBI (2014-2016) imagery captured by Northland and Auckland Councils. Waterbodies were validated using a combination of Photoblique and GIS desktop techniques. Slope, Spectral signatures, Topographic wetness index and vegetation structure were used to identify and delineate waterbodies. Information is current to the datasets available. The spatial extents can be used as a guide for where a waterbody exists. Data was derived using a combination of AI model training and manual output validation. Elevation data has been attached for data overlay in Photoblique. Data is presented using a segmented approach for ease of prolonged iterative monitoring, editing and annotating.	Data may be subject to false positive and/or false negative results. The spatial extents can be used as a guide for where waterbodies exist. Scale is created to a 0.5m resolution. Data is a representation of the capture date of the imagery and LiDAR.	Scale is created to a 0.5m resolution.

11. Appendix 2 Historic Imagery Data Delivered

YEAR	SURVEY NUMBER	COMMENTS
1938	SN91	
1938	SN138	
1940	SN143	
1940	SN147	
1941	SN143	
1942	SN209	Hokianga
1942	SN209	Whangarei
1942	SN209	
1942	SN212	
1944	SN350	
1945	SN350	
1947	SN350	
1947	SN390	
1947	SN390	
1947	SN390	B
1948	SN350	
1950	SN209	Mid North
1950	SN212	
1950	SN350	
1950	SN727	
1950	SN209	
1951	SN209	
1951	SN209	A
1951	SN209	B
1951	SN209	C
1951	SN350	
1952	SN212	
1953	SN209	
1953	SN212	
1955	SN209	A
1955	SN209	B
1957	SN212	
1957	SN1046	
1957	SN209	
1958	SN1071	
1960	SN1312	
1961	SN212	
1963	SN212	
1963	SN1543	
1964	SN1581	A
1966	SN1811	Waipoua

YEAR	SURVEY NUMBER	COMMENTS
1967	SN2016	
1970	SN1876	
1977	SN5091	
1979	SN5091	
1981	SN5782	
1981	SN5783	A
1982	SN8104	A