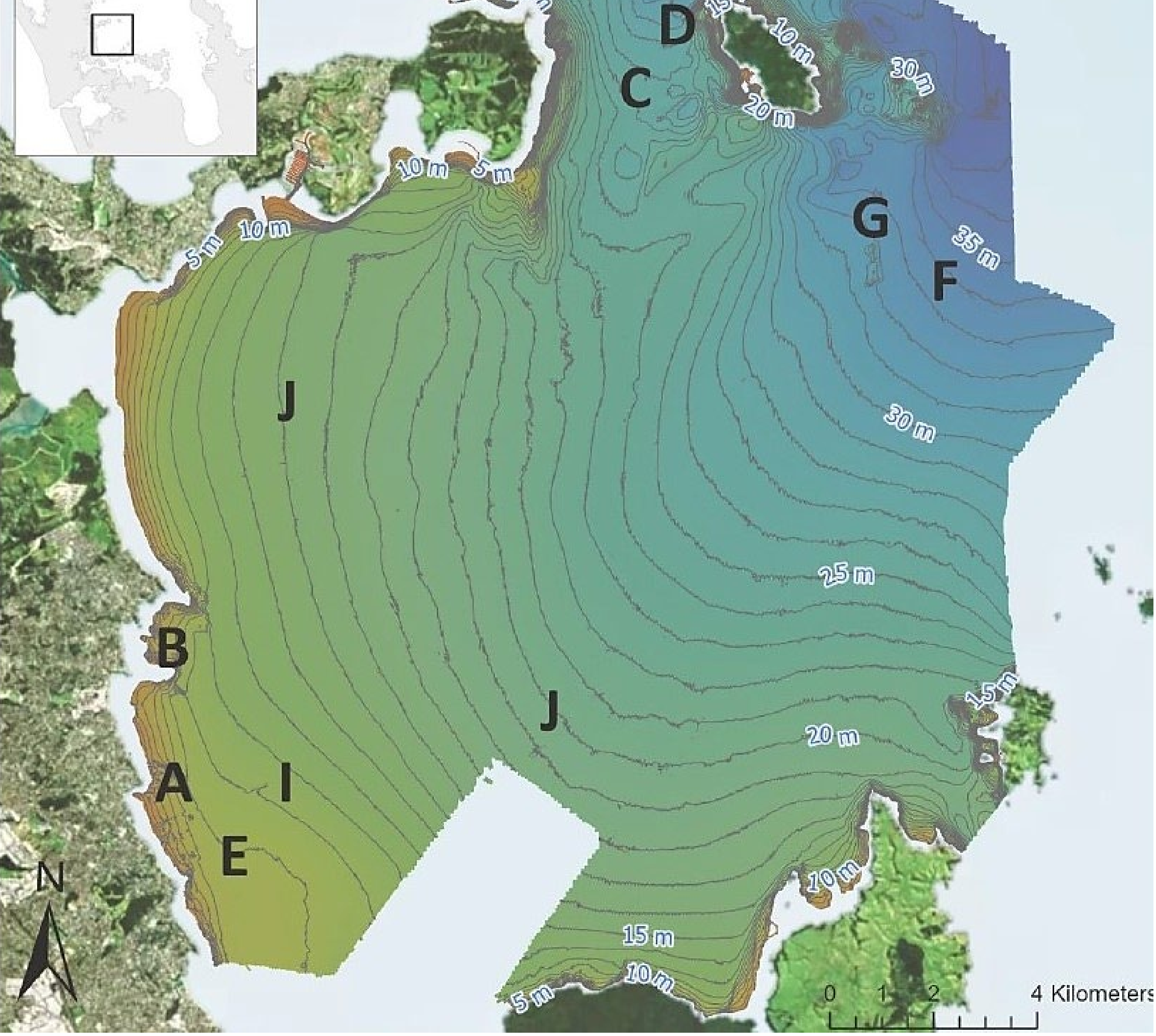

Benthic Habitat Analysis of Approaches to Auckland

National Institute of Water and Atmospheric Research, NIWA

December 2022 Technical Report 2022/23

aucklandcouncil.govt.nz

Research and Evaluation Unit RIMU

Benthic habitat analysis of approaches to Auckland

Desktop classifications using multibeam bathymetric data collected from hydrographic survey HS52

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Cover image: Figure 3-1: HS52 – Approaches to Auckland bathymetry data showing locations of key features described within the text and Table 3-1 (page 14)

Benthic Habitat Analysis of Approaches to Auckland

Desktop classifications using multibeam bathymetric data collected from hydrographic survey HS52

Prepared for Air, Land and Biodiversity Team Research and Evaluation Unit (RIMU) Te Kaunihera o Tāmaki Makaurau / Auckland Council

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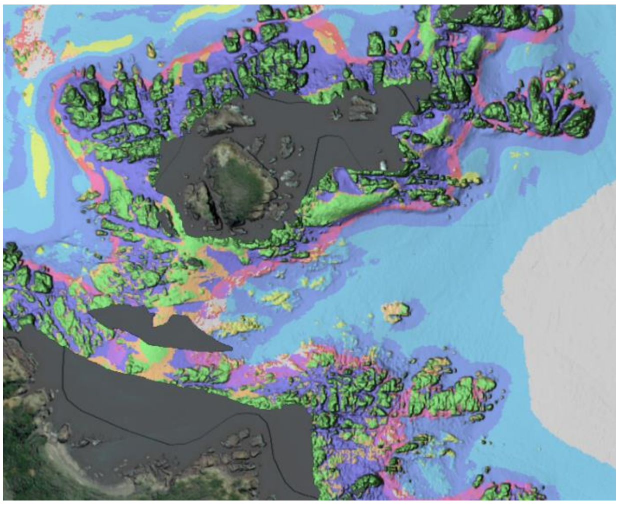

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Contents

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Executive summary

NIWA has been tasked by Te Kaunihera o Tāmaki Makaurau / Auckland Council to produce a desktop habitat study of data collected for the Land Information New Zealand (LINZ) hydrographic survey *HS52 – Approaches to Auckland* from 2016/17. This habitat analysis makes use of existing multibeam echosounder (MBES) data collected for hydrographic purposes, highlighting the multiuse nature of these data . There are key differences in acquisition and processing of multibeam data for hydrographic standards and those for scientific use. To achieve the best outcome for scientific interpretation, NIWA has partially reprocessed the bathymetry and seafloor backscatter information from data provided to LINZ. This has improved the data for the purpose of scientific interpretation, especially the seafloor backscatter data.

Bathymetry, seafloor backscatter, derived products, and segmentation were used to classify the seafloor. Expert-driven interpretations led to a series of areas/features of interest, based on morphological structure and backscatter signatures. Areas of interest for future work have been identified and include natural features such as isolated rocky reefs, areas of high seafloor backscatter, rugosity, and those identified by classification, as well as anthropogenic features such as the large areas of anchor dredge marks. These interpretations may inform future focused research and sampling to verify the acoustic data interpretations. Suggested further work includes seafloor sediment sampling, video transects, acoustic water-column data collection and analysis, and direct water-column sampling.

1 Project Scope

For this study NIWA has been tasked by Te Kaunihera o Tāmaki Makaurau / Auckland Council to partially reprocess and to analyse pre-existing multibeam echosounder (MBES) data. These data were collected by Discovery Marine Limited (DML) for Land Information New Zealand (LINZ) as part of the *HS52 – Approaches to Auckland* hydrographic survey in central parts of the Hauraki Gulf in 2016/2017 (DML, 2017). This desktop study reuses existing data and did not involve any new data collection, sampling, or laboratory analyses.

Analysis of existing data is focused on building derivatives and classifying the bathymetry data, processing the seafloor backscatter data in a qualified way for feature detection and classification, and creating scientifically justified interpretations of the seafloor bathymetry and backscatter data. These outputs may be used to identify areas of potentially high ecological value and highlight areas for more detailed surveys and targeting sampling.

2 Methods

2.1 Data collation

Land Information New Zealand (LINZ) holds the delivered survey data for each hydrographic survey. At a minimum, these hydrographic survey data contain processed soundings, backscatter images, and final processed shoal-biased bathymetry grids. The *HS52 – Approaches to Auckland* hydrographic survey covers an area of 280 km^2 between Auckland's Northshore, Rangitoto and the Whangaparāoa Peninsula. These data were delivered by LINZ in the raw acquisition project in QPS QINSY format. The combined project data contained 2.41 TB of seafloor backscatter information and processed soundings.

The *HS52 – Approaches to Auckland* hydrographic survey was conducted by Discovery Marine Ltd (DML) in 2016/17 using two vessels and three distinct MBES acquisition systems: R2Sonic 2020 and a Teledyne Reson SeaBat 7125, and combined single-beam and side-scan-sonar data in very shallow areas. Only the MBES data are represented in the dataset used here. Bathymetry and seafloor backscatter data in this dataset have been gridded to a 1 m cell size and are delivered in TIFF format with geographic information (GeoTIFF), allowing easy integration in GIS systems. For a comprehensive evaluation of these multibeam echosounder data, refer to NIWA Client report 2021243WN (Pallentin and Watson, 2021).

In this project, NIWA completed additional post-processing on *HS52 – Approaches to Auckland* hydrographic survey data. Data providing additional contextual information was incorporated from NIWA's data holdings (e.g., NIWA's National Invertebrate Collection (NIC) and sediment sample database), GIS databases, and the LINZ data service (LDS), as appropriate.

2.2 Data processing

The dataset for *HS52 – Approaches to Auckland* contains ~4800 individual lines of raw MBES data, with a total volume of raw data of 1.86 TB. Two types of data were processed from these MBES data – bathymetry soundings of the seafloor depth, and backscatter acoustic reflectivity. Because the *HS52 – Approaches to Auckland* survey was acquired using QPS QINCY software, processed data (.qpd format) and raw backscatter data (.db format) were directly imported into QPS QIMERA processing software (v2.4.8), which NIWA uses to process MBES data.

2.2.1 Bathymetry

An initial median-based bathymetry grid was used for visual inspection to detect differences between the hydrographic processing and scientific processing methods. For example, data collected for hydrographic purposes will be gridded using a shoal-biased method for safety of navigation, therefore some shallow erroneous pings may remain within the dataset. To generate geomorphological imagery of the seabed for scientific purposes, these shallow pings need to be cleaned to avoid propagation of error through the interpretation process. A more homogenous representation of the seafloor is needed for benthic habitat classification studies than for hydrographic purposes. A CUBE-based (Combined Uncertainty Bathymetry Estimate) (Calder & Wells, 2006) surface was then generated and, after a final inspection, 50 cm and 2 m resolution surfaces were exported as bathymetry grids (.tiff format) for interpretation in ArcPro software.

2.2.2 Backscatter

Seafloor backscatter data represent the acoustic reflectivity of the seafloor area insonified by each acoustic beam. This reflectivity is measured in decibels (dB) as the return of emitted acoustic energy, considering transmission loss in the water-column due to physico-chemical effects (e.g., salinity, temperature, and pressure).

NIWA used the QPS Fledermaus Geocoder Toolbox (FMGT) for seafloor backscatter processing. Processed .qpd files and their associated raw .db files were loaded into FMGT, integrating all processing steps and adjustments (e.g., tide, navigation, removal of bad pings). The data was geo-rectified, the backscatter signal extracted and filtered, and a backscatter grid produced. FMGT estimates the best possible resolution on several factors, however manual adjustment of the produced grid size is possible. Often the possible resolution of the seafloor backscatter grid is the same or better than that of the bathymetry grid.

Initial attempts to process a continuous backscatter grid from the two MBES systems used by DML for acquisition delivered unsatisfactory results, mainly due to the different system artefacts and strongly different source levels. To counter this, two individual grids were produced and merged in ArcGIS. The MBES systems differ in that the R2Sonic, used in shallow waters along the shorelines, has a clear 'beam pattern' (across swath differences in the return signal) that can be controlled using a beam pattern correction curve, whereas the Reson7125, used in the bulk of the open area, has a clear across swath return signal, but suffers from acquisition setting changes along lines and between days. The contract for *HS52 – Approaches to Auckland* occurred prior to changes to the LINZ HySpec (LINZ, 2020), that specifies best practices for seafloor backscatter acquisition, including consistent acquisition settings for the MBES.

The final backscatter mosaics were tiled in FMGT, due to the size of the survey area and the high resolution of the backscatter grid. Tiling is necessary as backscatter data processing is computer memory intensive and integration of processed and filtered data into a final grid is lengthy. The resulting mosaic datasets were then exported (.tiff format) and displayed in ArcPro.

2.3 Processed data analytics

Spatial analysis of the seafloor bathymetry and backscatter data was performed using ESRI ArcMap (v10.8.2) and ESRI ArcPro (v2.9.3). Visual representation and inspection of data was done using ArcPro (v2.9.3) as this provides direct connectivity into NIWA's ESRI ArcEnterprise environment, supporting the StoryMap deliverable.

2.3.1 Bathymetry derivatives and classification

To generate bathymetry derivatives and classification, the exported GeoTiff grids were loaded into ESRI ArcGIS (v10.8.2), both as native GeoTiff and ESRI FileGeoDataBase (FGDB) format – as different ArcGIS tools are optimised for different input formats.

Two main ArcGIS tools were used to generate bathymetric derivatives and seafloor classification. NIWA's in-house scripts generated a standard suite of bathymetric derivatives based on ESRI tools, including slope, aspect, curvature, and rugosity (roughness). Additionally, we used the Benthic Terrain Modeller (BTM, v3) tool in ArcGIS (v10.8.2) for bathymetric classification based on the method developed by Lundblad (2006) and Walbridge et al. (2016). The principles behind BTM are described in section 2.3.2. The NIWA classification schema are now becoming more generally used in

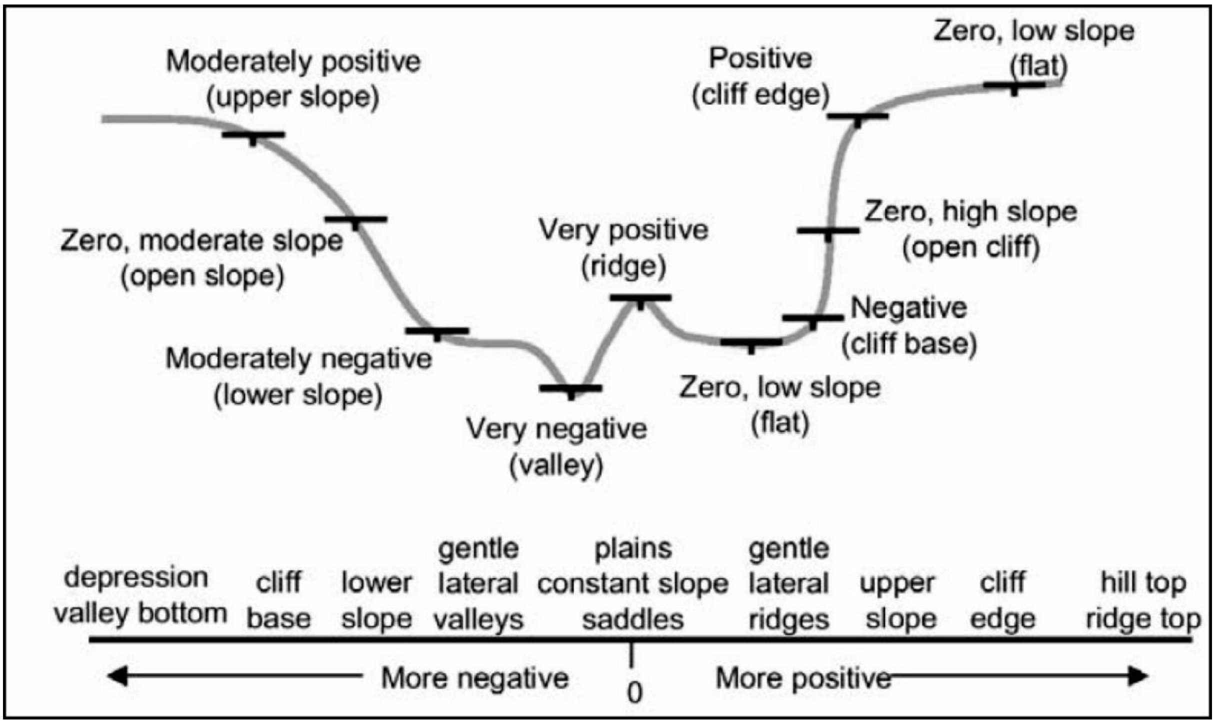
Aotearoa New Zealand and have been used by Te Papa Atawhai Department of Conservation (DOC) for its current work on a national scale bathymetry classification (DOC, 2022).

2.3.2 Benthic Terrain Model classes

The Benthic Terrain Model (BTM) classes are based on several derivatives of the bathymetry, including the bathymetric position index (BPI), slope, and depth. The BTM classes are based on a prescribed set of values from the input layers and are defined in a classification dictionary.

2.3.3 Bathymetric Positions Index

The Bathymetric Positions Index (BPI) is a means of quantifying geomorphic relief relative to surrounding information. The BPI is based on the onshore equivalent, known as Topographic Positions Index (Weiss, 2001). The product is a raster format with values ranging from positive through to negative, that correspond to seafloor terrains (Figure 2-1). A negative BPI value represents a cell that is lower than its neighbouring cells (valleys). A positive value represents a cell that is higher than its neighbouring cells (ridges). Larger numbers represent benthic features that differ greatly from surrounding areas (such as sharp peaks, pits, or valleys). Flat areas or areas with a constant slope produce near-zero values.



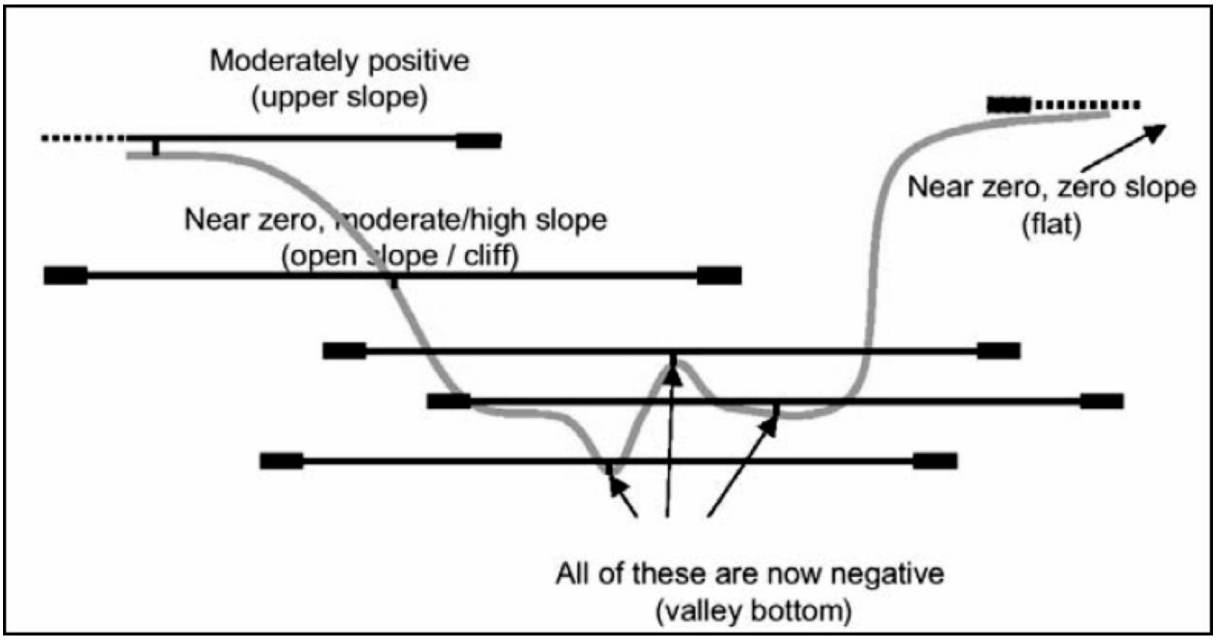


Figure 2-1: An illustration of how bathymetric position index (BPI) values are derived from bathymetry. These are based on the topographic position index by Weiss (2001). The top figure describes fine scale BPI values; the bottom describes broad scale BPI values. (Reproduced from Weiss, 2001).

2.3.4 Classification scheme

The BTM classification scheme provides a surficial characteristic for each area of the seafloor based on slope values and a BPI value range combining fine scale and broad scale. Classification categories include:

1. Flat plains – variable BPI, but slopes no larger than 5°
2. Broad slopes – like 1, but with higher slope values between 5° and 20°
3. Steep slopes – like 2, but with higher slopes between 20° and 35°
4. Broad depression – Broad BPI is low, so wider neighbourhood (broad BPI) is shallower
5. Lateral mid-slope depression – the wider neighbourhood can be deeper or shallower, but the closer neighbourhood is preferentially deeper. A slight slope is present.
6. Scarp, cliff – very high slope values dominate this class (<35°)
7. Depressions – the wider and closer neighbourhood (broad and fine BPI) are shallower.
8. Crevices, Narrow Gullies over elevated terrain – The wider neighbourhood (broad BPI) is deeper, but closer neighbourhood (fine BPI) is shallower.
9. Flat Ridge Tops – High positive broad BPI indicates that wider area is deeper
10. Rock Outcrop Highs, Narrow Ridges – Broad and fine BPI high positive, indicating wider and closer neighbourhoods are deeper
11. Local Ridges, Boulders, Pinnacles in Depressions – Broad BPI high negative (wider neighbourhood) is shallower, fine BPI (closer neighbourhood) high negatives values (small local highs as in boulders)
12. Local Ridges, Boulders, Pinnacles on Broad Flats – negative to positive broad BPI with small (up to 5°) slope describing a wider/broad slope (similar to class 1 and 2), but with high positive fine BPI describing local ridges, boulders, and pinnacles.
13. Local Ridges, Boulders, Pinnacles on Slopes – like class 12, but higher slope values
14. Local Depressions, Current Scours – Similar to class 12, but the local/closer neighbourhood values are deeper (fine scour marks, dredge marks).

2.3.5 Seafloor backscatter and bathymetry segmentation

Backscatter grids generated in FMGT were exported into GeoTiff image files with grid cell values representing decibels (dB). These grids were loaded into ArcPro and merged to generate seafloor backscatter and bathymetry grids covering the same extent of seafloor.

For segmentation of bathymetry and seafloor backscatter data, we used the RSOBIA tools (Le Bas, 2015). This tool offers Object Based Image Analysis (OBIA), a technique originating from aerial and satellite image analysis. The advantage over pixel-based classification is that it generates repeatable, semi-automated segments, identifying 'real world' areas that resemble manual digitisation. An added advantage is that it is less affected by noise or artefacts common in MBES data.

The OBIA algorithm equally weights two input layers: bathymetry, which the tool uses to generate slope and rugosity derivatives, and a seafloor backscatter layer of the same area. The process first segments (splits) the area into objects or areas of maximum homogeneity within the segments. In a second phase the process classifies the areas and assigns them to either a given number of classes or determines the 'best' number automatically. Due to the large size of the survey area, the bathymetric grid was down-sampled to 4 m resolution, with a 20,000 object pixel size limit (area) and a maximum of 10 classes selected. The higher resolution data generated (up to 50 cm grid cell size) for the bathymetry and seafloor backscatter were used for manual observations and features of interest selection.

2.4 Data presentation

For the *HS52 – Approaches to Auckland* habitat project, an ESRI StoryMap was developed. This StoryMap is an online tool to present the work and findings in this study to a wider audience in a distilled format including visual aids such as images and online maps that show the presented key data layers. These online maps allow zooming and panning in the project area and investigation of the generated data in more detail than is possible in a print format. The URL for this StoryMap can be provided upon request (contact Auckland Council's Research and Evaluation Unit at Environmentaldata@aklc.govt.nz)

3 Analysis

3.1 General description of the area and features of interest

The *HS52 – Approaches to Auckland* hydrographic datasets (also known as sonar data) presented in this report provide information about the shape, depth, and nature of the seafloor in an area covering 280 km^2 between Auckland's Northshore, Rangitoto and the Whangaparāoa Peninsula (Figure 3-3 and Table 3-1).

The water depth within the survey ranges from less than 1 m near the coastal region, to approximately 40 m in the northeastern portion, east of Tiritiri Matangi Island. Bathymetry data reveal the variability of the seafloor from the near coastal rocky reefs to the broad flat seabed within the Hauraki Gulf channels. The complex coastal geometry is lined with uniquely stratified and tilted sedimentary sequences in water depths up to ~10 m. Onshore, these strata form the rock platforms within the swash zone and are particularly prominent offshore adjacent to headlands and coastal promontories. The rock platforms that extend offshore likely represent the Waitemata Group (Upper Oligocene to Lower Miocene) that outcrops within Auckland's coastal regions (Ballance et al., 1976). The Waitemata Group predominantly comprises highly deformed sequences of interbedded mud and sandstones.

Channels between the Hauraki Gulf islands within the survey area are characterised by distinctive higher seabed backscatter signatures compared to the surrounding lower backscatter areas, indicative of a different, likely harder or larger grain-size sediment on the seabed within the channels (Table 3-1, feature C). The channels between the Hauraki Gulf islands also host evidence for sediment mobility, including sediment waves on the eastern side of the channel between Tiritiri Matangi Island and Whangaparāoa Peninsula (Table 3-1, Feature D). Larger grain-size sediment and bedforms may indicate higher current speeds within this channel than outside the channel.

Fluid escape features including circular seafloor depressions and pockmarks were visible across the *HS52 – Approaches to Auckland* survey (Table 3-1, features E/F) in water depths between ~15 to 40 m. Sites of fluid escape are recommended for follow-up surveys to evaluate seep activity and abundance of organisms in any benthic ecological communities.

Isolated rocky reefs are observed in the northwestern portion of the survey area (Table 3-1, feature G), and these may represent important habitats for benthic communities. Similarly, rough seabed is observed across many locations within the survey area (Table 3-1, feature H), characterised by increased rugosity and textured seafloor backscatter. These rough seabed regions may be important habitats and may be associated with specific benthic communities.

The impact of human activities is observable on the seafloor within the *HS52 – Approaches to Auckland* survey region. A nearshore pipeline manifests in both bathymetry and in seafloor backscatter as a high intensity stripe on the seabed and is detected more than 2 km from the coast (Table 3-1, feature I). The central flat plains in the survey area show evidence of anchoring impacts (Table 3-1, feature J), likely relating to high tonnage vessel anchoring. These features are sites of seabed disturbance and potential degradation due to the nature of anchoring practices and the associated anchoring gear (Watson et al, 2022).

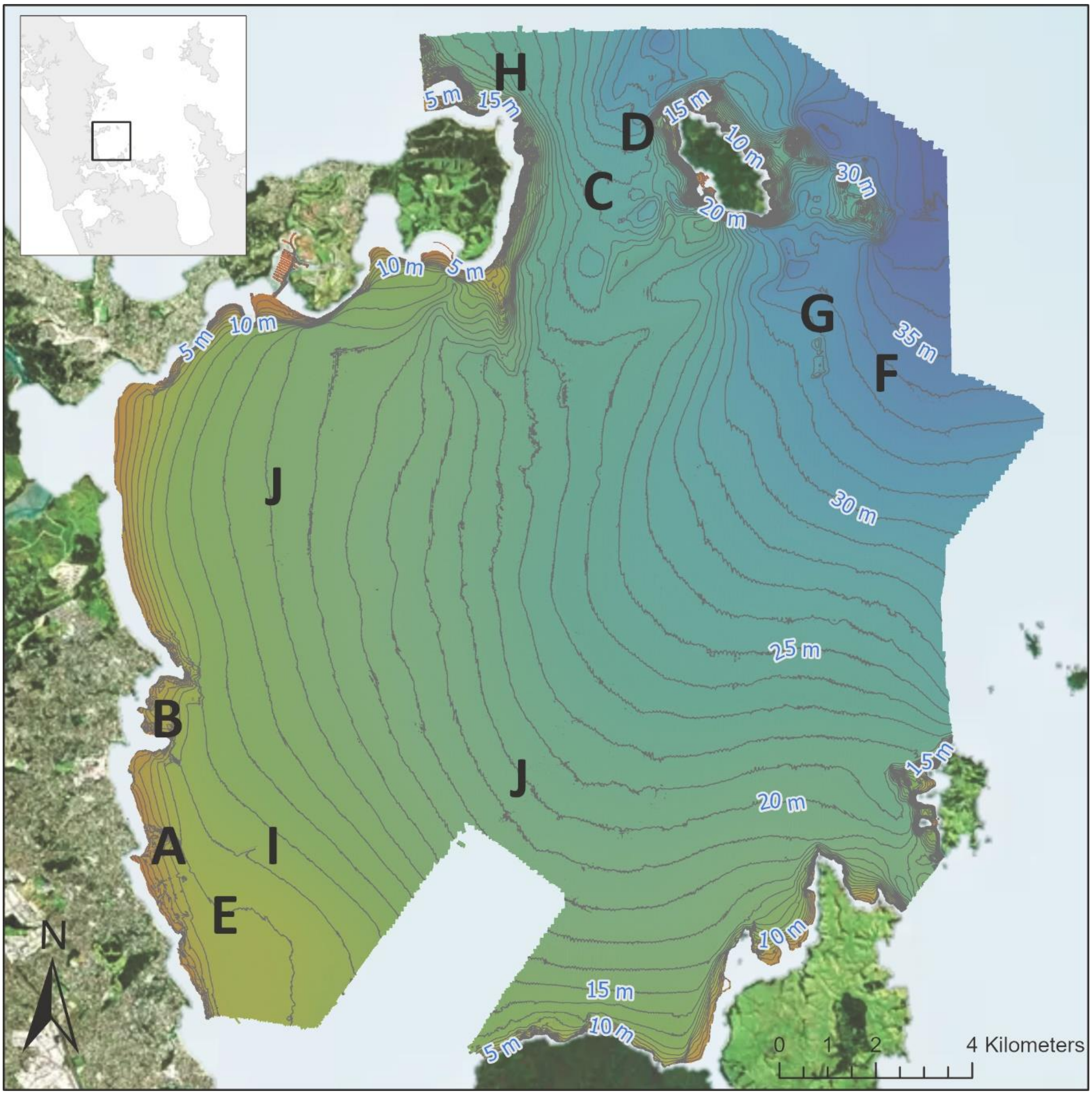
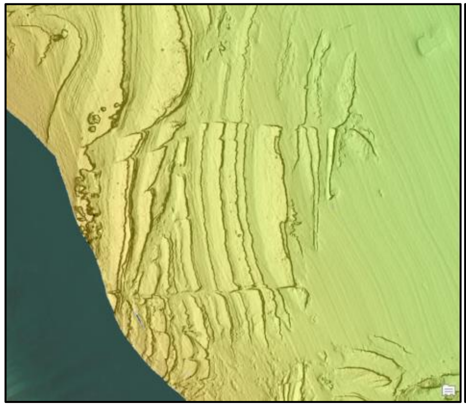
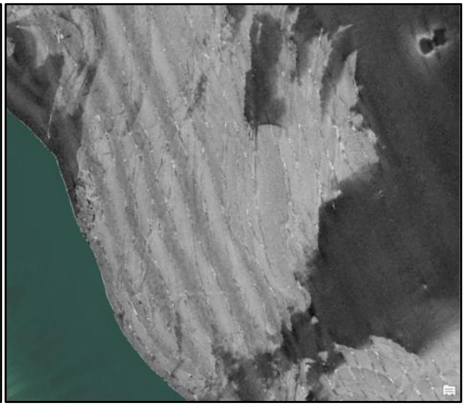
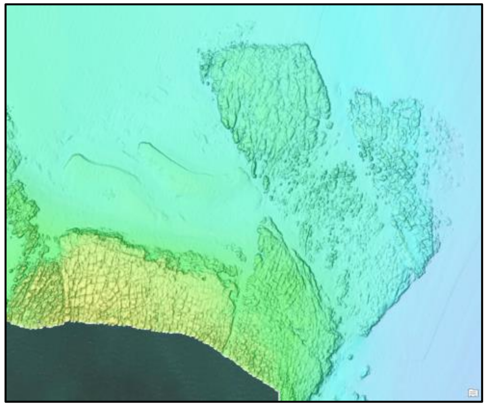
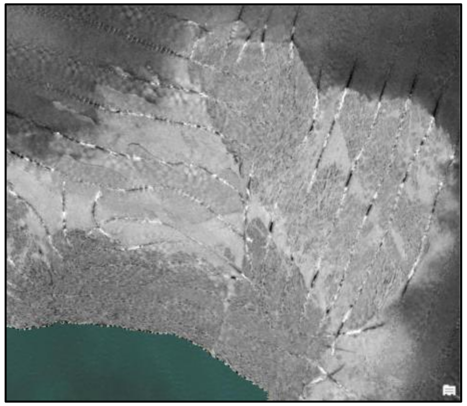
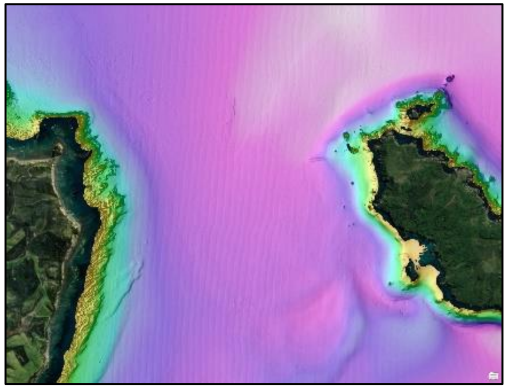


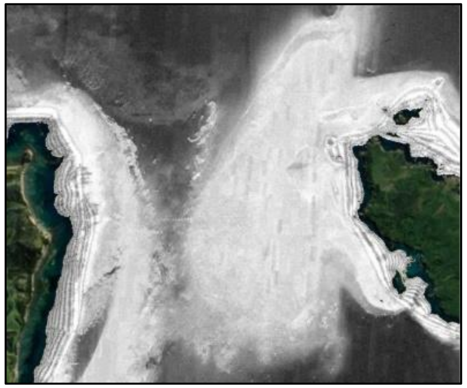
Figure 3-1: *HS52 – Approaches to Auckland* bathymetry data showing locations of key features described within the text and Table 3-1.

Table 3-1: Table showing examples of key features observed within the *HS52 – Approaches to Auckland* survey region. For locations of each feature (A-J) see Figure 3-1.

Feature ID	Example images (bathymetry and/or backscatter) of key features observed within the *HS52 – Approaches to Auckland* survey		Description of key features observed within the *HS52 – Approaches to Auckland* survey
A			Nearshore rocky outcrop showing tilted parallel rock units dipping to the west and offset by faults. These outcrops are likely the offshore extension of Late Oligocene Early Miocene-age deep water mud and sandstones of the Waitemata Group. Backscatter imagery highlights the boundary between the hard rocky substrate (lighter) compared to the deeper and likely soft sediment substrate (darker)
B			Tessellated rocky reef possibly representing a more textured, highly fractured, unit of the Waitemata Group. Backscatter imagery highlights the more textured hard rocky reef substrate (lighter) compared to the deeper and smoother soft sediment substrate (darker).

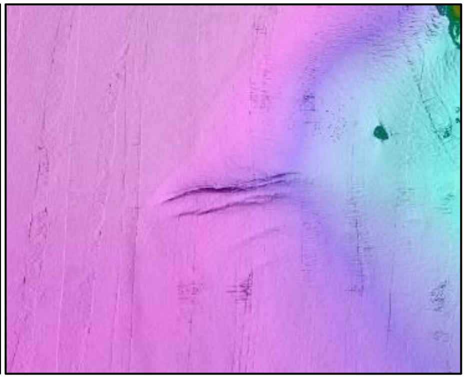
C





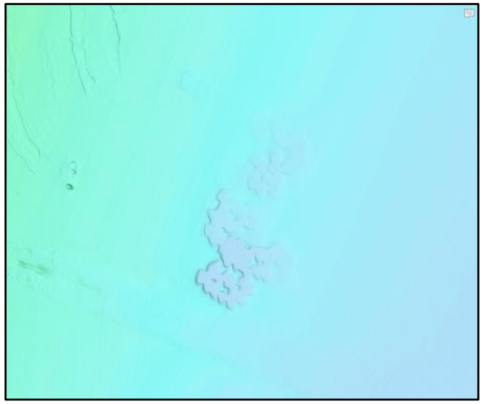
Channels between the mainland and Hauraki Gulf Islands display a unique seabed backscatter signature compared to adjacent seafloor. Varying backscatter is indicative of a substrate boundary. For example, lighter regions near the coast and within the channel may be indicative of larger sediment grains such as sand, compared to the flat plains with darker backscatter which could be dominated by muddy sediment.

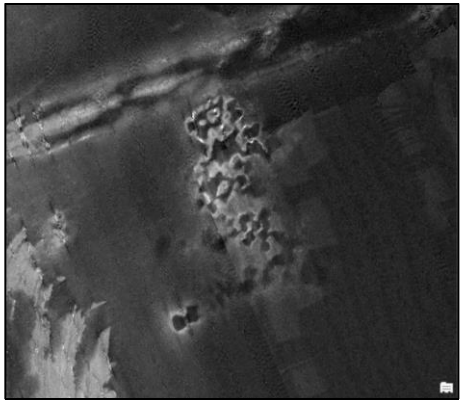
D



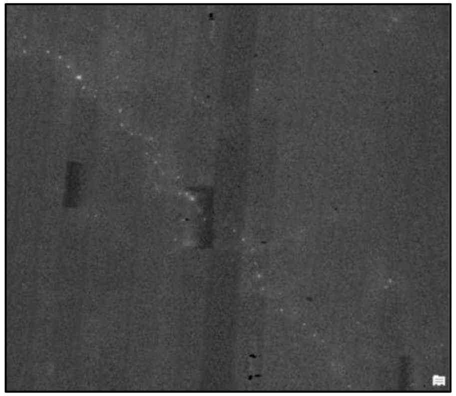
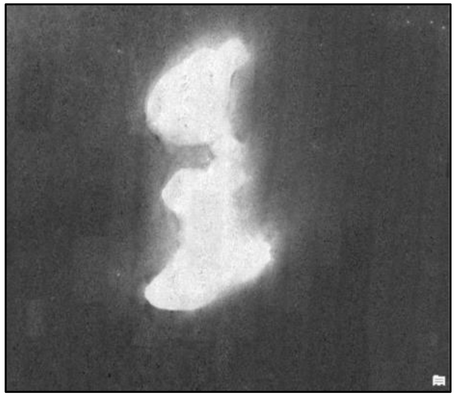
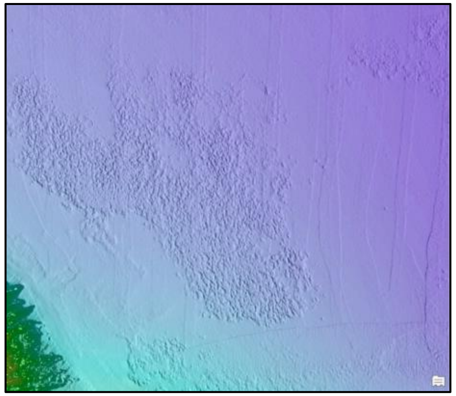
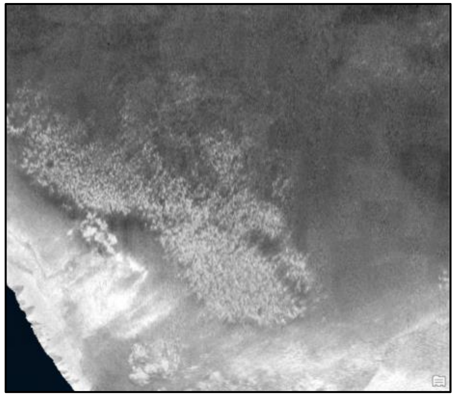
Linear sediment waves on the eastern side of the channel between Whangaparāoa Peninsula and Tiritiri Matangi Island. Sediment wave crests are oriented approximately east-west and may be related to currents between the coast and the Hauraki Gulf Islands.

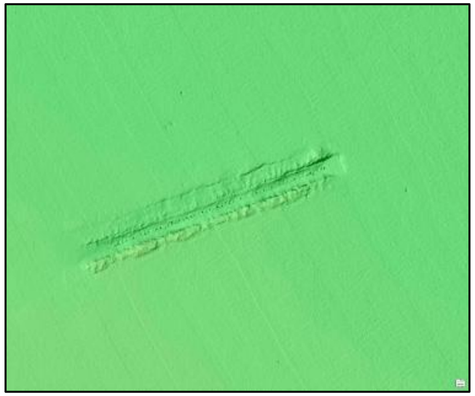
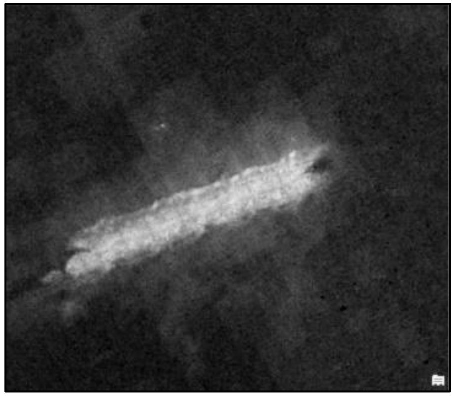
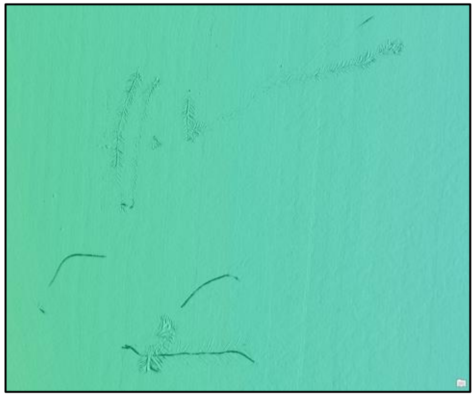
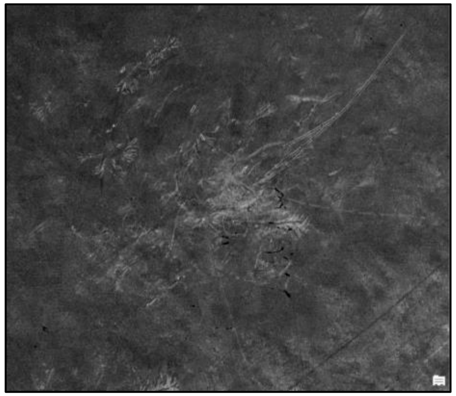
E





A cluster of rounded depressions may be indicative of relict or active seabed seepage and potential sites of sensitive ecosystems. Seafloor backscatter reveals the sloping rim of these features may have a harder substrate compared to their base.

F			Pockmarks following distinctive linear arrangement, oriented NW-SE. This provides evidence of seafloor fluid seepage, possibly along faults. The pockmarks are well expressed in seafloor backscatter as light circular dots on the darker seabed background.
G			Rocky reef patch located in ~30 m water depth. Possible important habitat for benthos that require hard/rocky substrate for community building. This feature is a distinctive high backscatter region, surrounded by lower backscatter seafloor.
H			Rugose and textured seafloor characterised by higher backscatter return compared to surrounding seafloor, possibly formed via current winnowing and/or may represent important habitats for hard substrate benthos.

I			Bathymetric imprint of pipeline from Mairangi Bay. Expression extends over 400 m in length and 60 m width. Seafloor backscatter highlights pipeline well, showing it as a high-intensity feature (indicative of a harder substrate) relative to surrounding seafloor.
J			Anchoring footprint on the seabed. Linear scours caused by anchor deployment and feathering marks caused by gauging of the anchor chain scope whilst vessel swings. Regions with anchoring impacts have a lighter backscatter return compared to the surrounding seabed.

3.1.1 Human impact – wrecks

Minato Maru 102

Identified in the hydrographic survey report (DML 2017), the 30 m long fishing vessel Minato Maru 102 is the most significant shipwreck in the *HS52 – Approaches to Auckland* survey area. The ship sunk in 1983, and the hull shows significant degradation in the acoustic sounding data (Figure 3-2). The shipwreck may function as an artificial deep reef, making it worthwhile for further investigation. Its presence also may be significant to the local community.

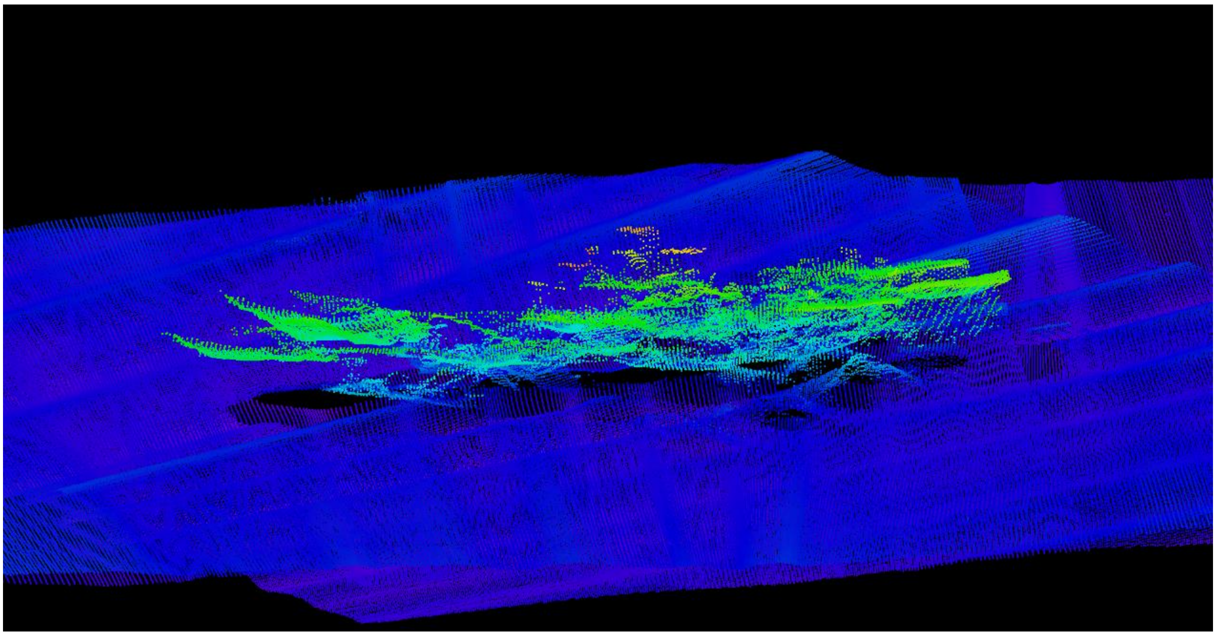


Figure 3-2: Minato Maru 102. 3D view from port side.

3.2 Specific description of processed data

3.2.1 Bathymetry

Bathymetry (shape and depth of seafloor) is illustrated as a sun-illuminated digital elevation model (DEM). The DEMs were produced from 50 cm and 2 m resolution gridded surfaces and overlain on hill-shaded relief to improve depth visualisation. The two resolutions allow greater detail close in and easier display in wider views. Bathymetry data provide baseline information about the physical structure of the seabed. From bathymetry data, other layers (often referred to as derivatives) can be produced to assist in understanding key features of interest within the survey region.

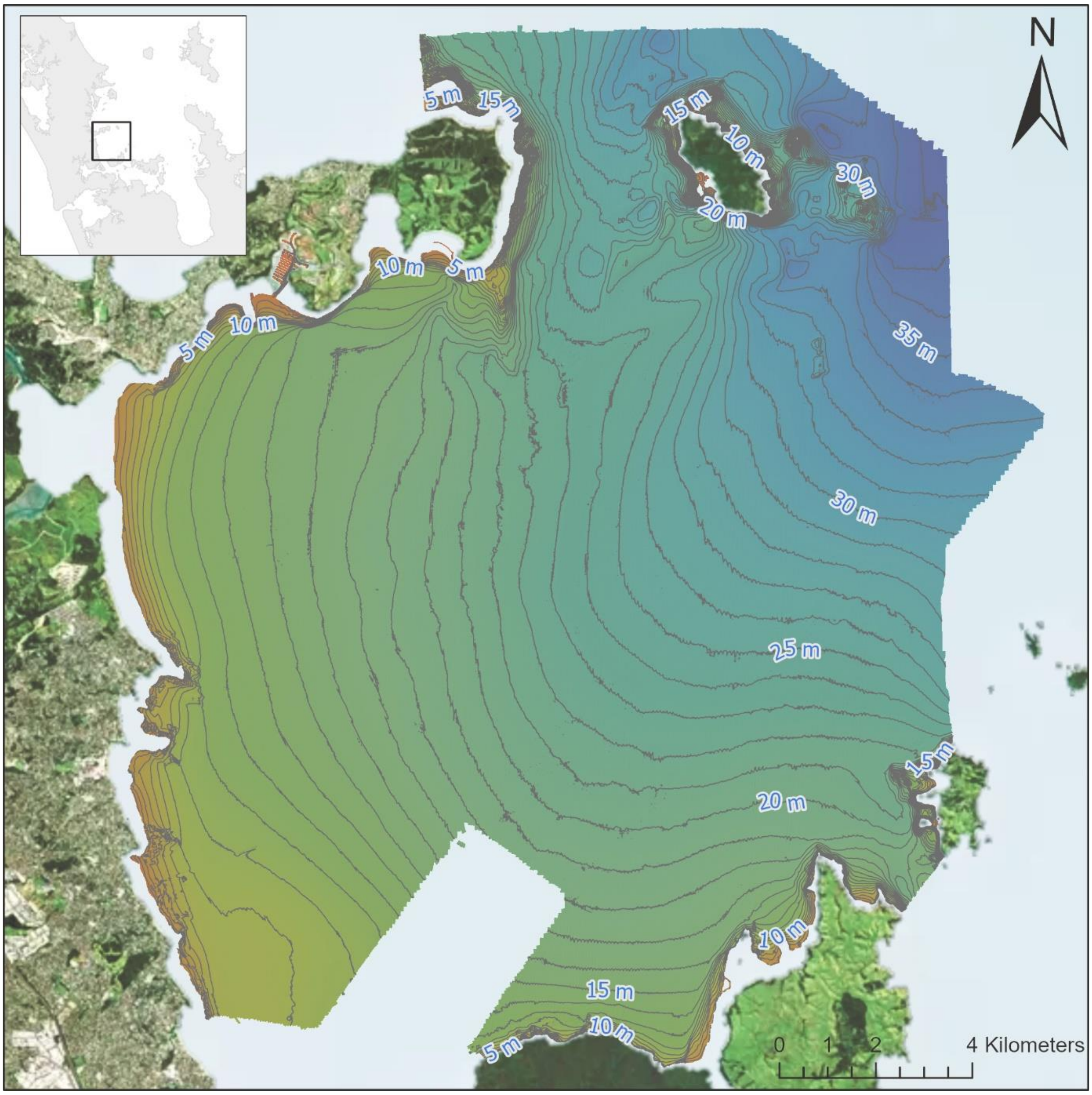


Figure 3-3: Colour shaded bathymetry. Depth shown by contours.

3.2.2 Hillshade

Hillshades are a useful visual aid when illustrating bathymetric data as they aid depth perception. A hillshade was generated with the sun illumination from the northwest (315°) at an altitude of 45° above an artificial horizon. Images in this report are underlain by a 50 cm resolution gridded hillshade with 3 times vertical exaggeration, unless stated otherwise.

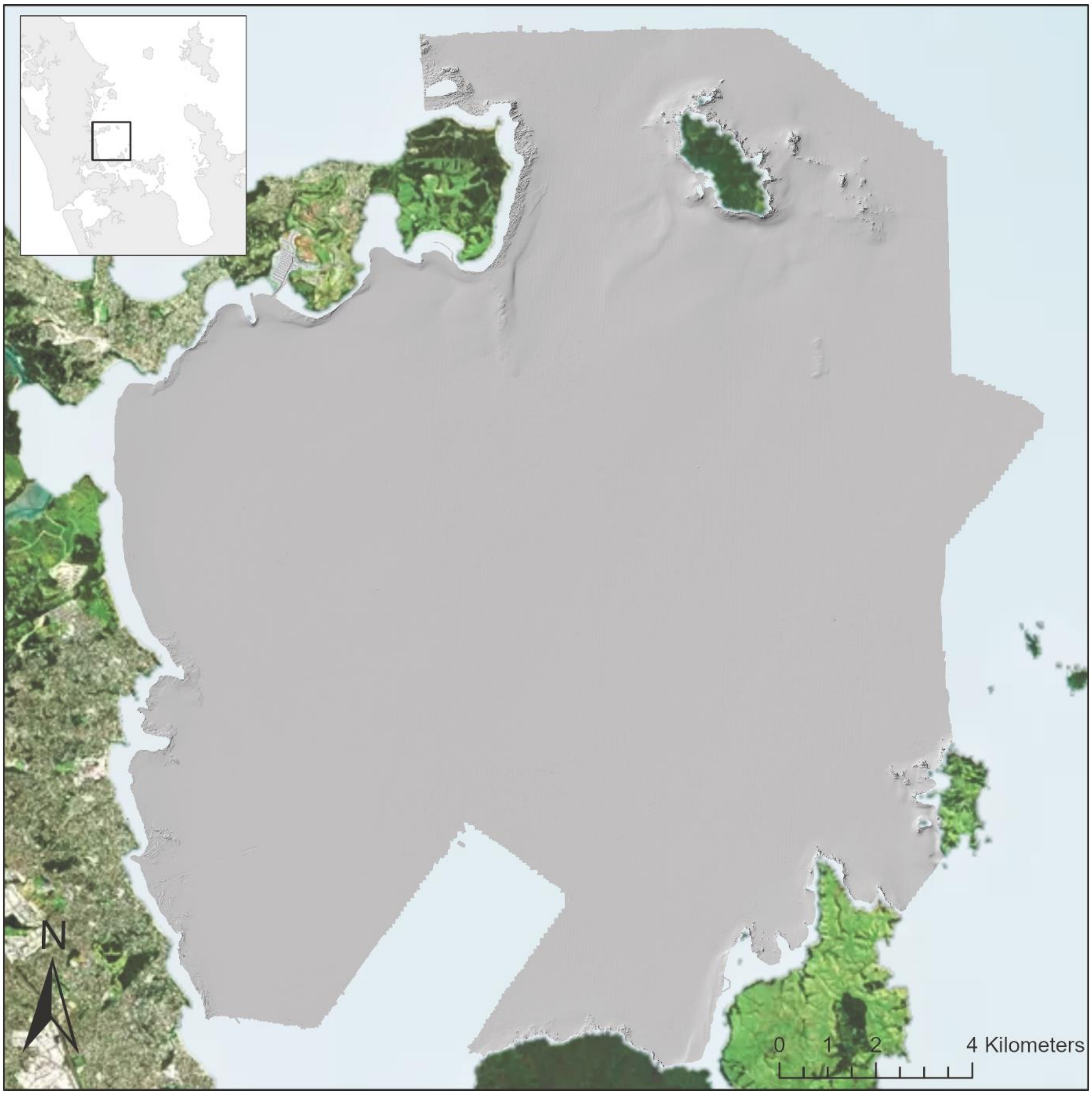


Figure 3-4: Hillshade of bathymetry. Contours omitted to make smaller features visible.

3.2.3 Slope

Slope is the steepness of the seafloor gradient, attributed according to the angle (in degrees) from the horizontal. Values near zero (blue) are flat areas, while higher values (green and yellow) are areas that are increasingly steep (up to 75°) (Figure 3-5: Slope of Bathymetry.). Most of the *HS52 – Approaches to Auckland* area has low slope (Mean < 0.5°), with higher slopes concentrated at nearshore areas and isolated reefs. The stratigraphic layering of the offshore Waitemata Group outcrop is well expressed in the slope derivative, appearing as lineations nearshore. Human impacts such as the pipeline and anchoring footprints are also more easily identified using the slope derivative, as they appear as high slope regions on otherwise flat seabed. The slope derivative also reveals linear striping across the survey area, due to data acquisition artefacts.

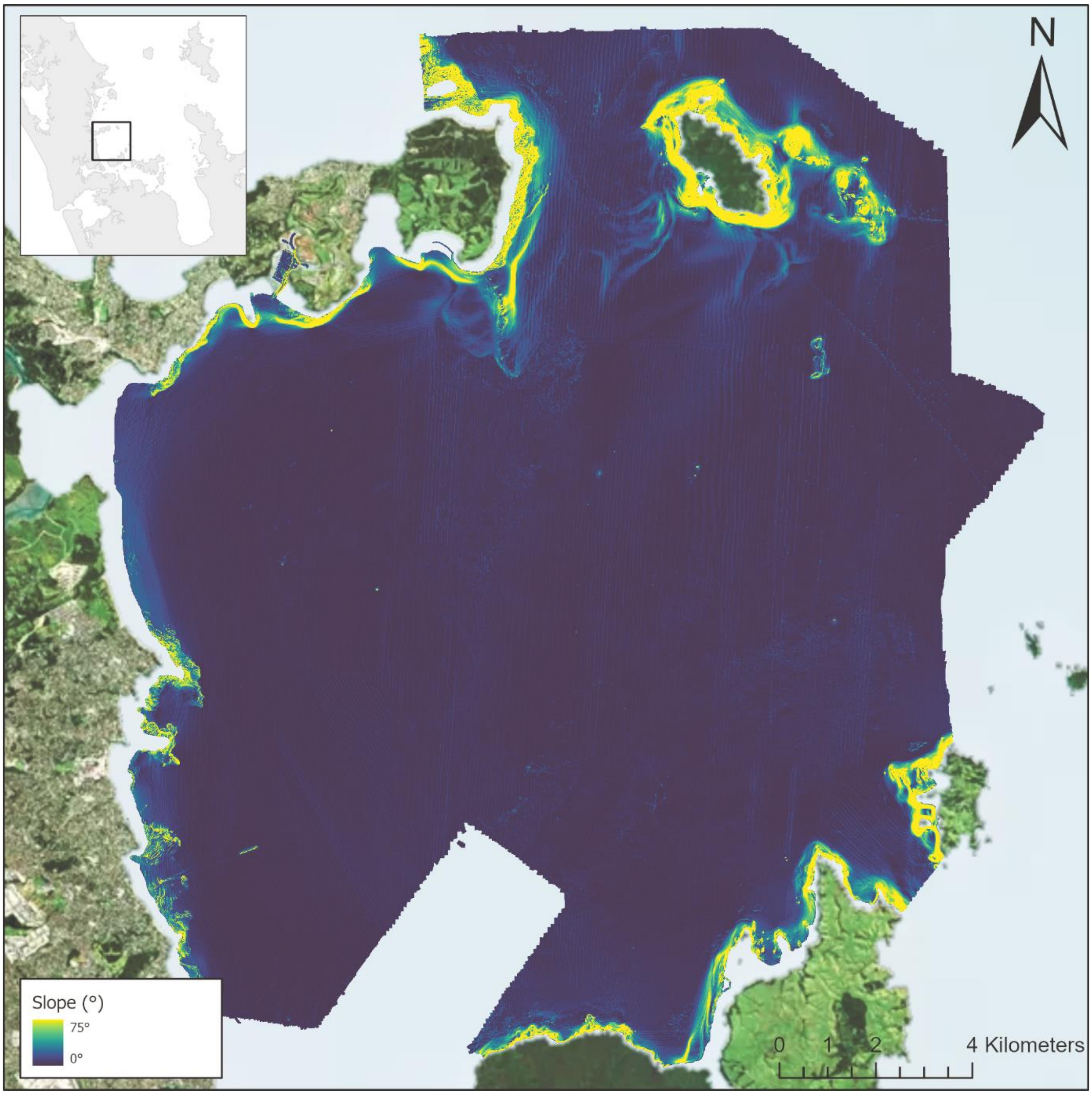


Figure 3-5: Slope of Bathymetry.

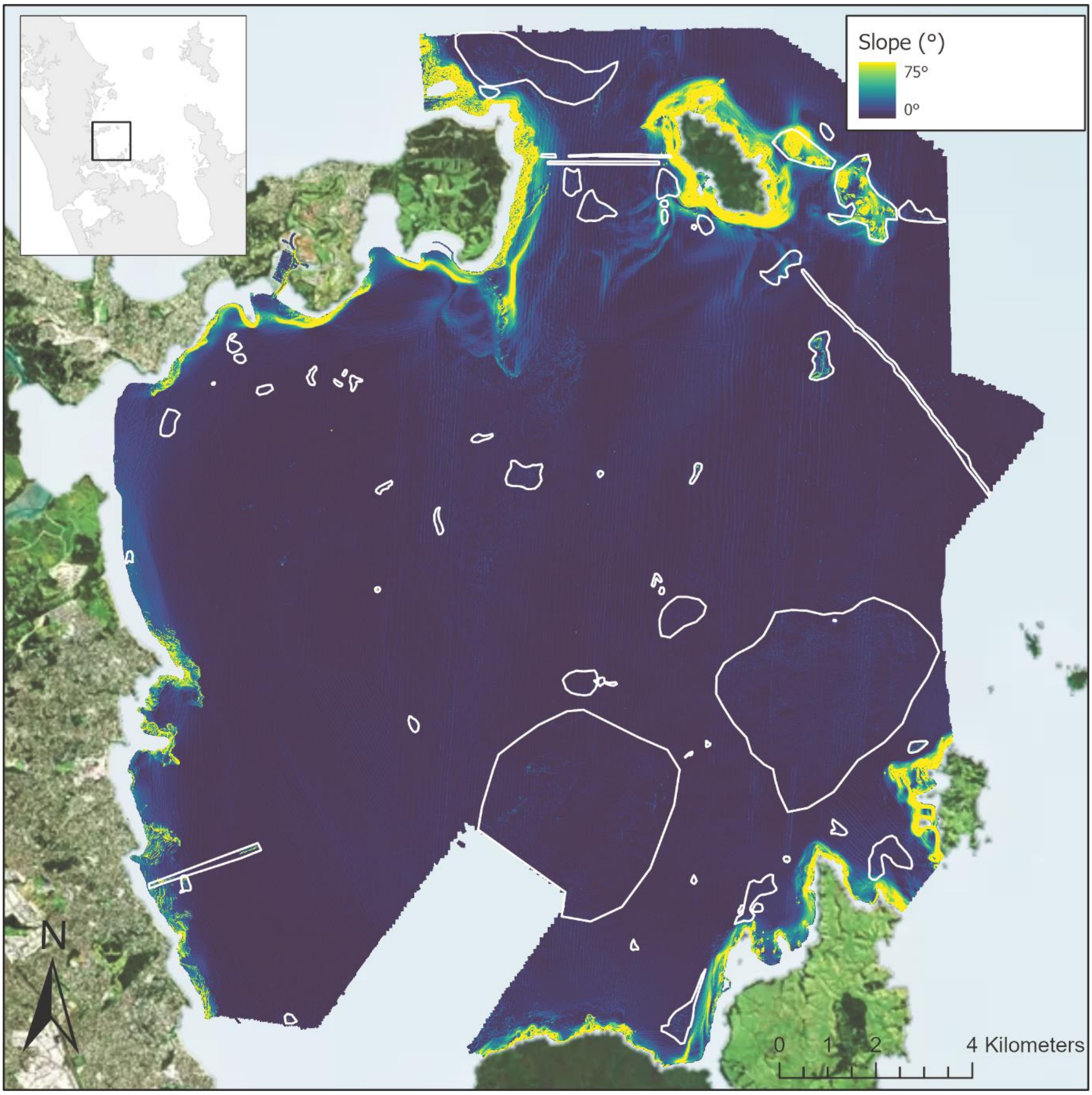


Figure 3-6: Slope of bathymetry. Areas of interest (available in the GIS).

3.2.4 Rugosity

Rugosity is a measure of roughness and terrain complexity and is captured as bathymetric variation in three dimensions. In the benthic environment, ecological diversity can generally be correlated with the complexity of the physical environment. As such, rugosity can help identify areas where high biodiversity may exist on the seafloor. Most of the *HS52 – Approaches to Auckland* area displays low rugosity, and high rugosity is concentrated in nearshore areas, isolated reefs, and pockmarks. Two large areas in the shipping lane and a region north of Whangaparāoa Peninsula also show elevated rugosity.

Figure 3-7: Rugosity of seafloor.

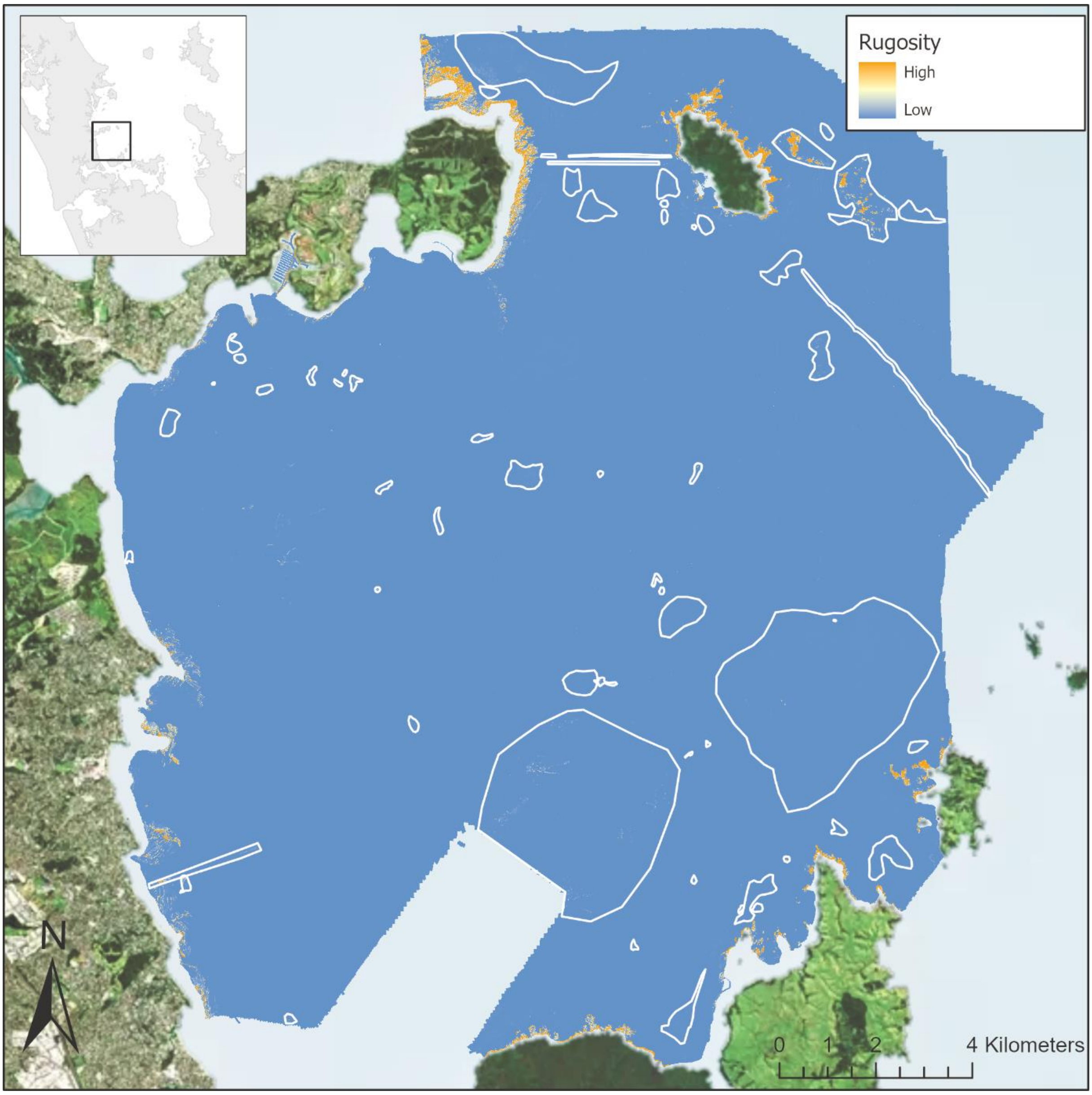


Figure 3-8: Rugosity of seafloor. Areas of interest (available in the GIS).

3.2.5 Aspect

Aspect is the direction of down-slope dip, with north at 0° (green) and south at 180° (red). Aspect can also be thought of as the slope direction. A striped appearance in some areas is a result of artefacts in the data. Aspect shows slope directions generally towards the main 'basin' of the Hauraki Gulf, and in rocky areas can emphasise the layering of the Waitemata Group rocks.

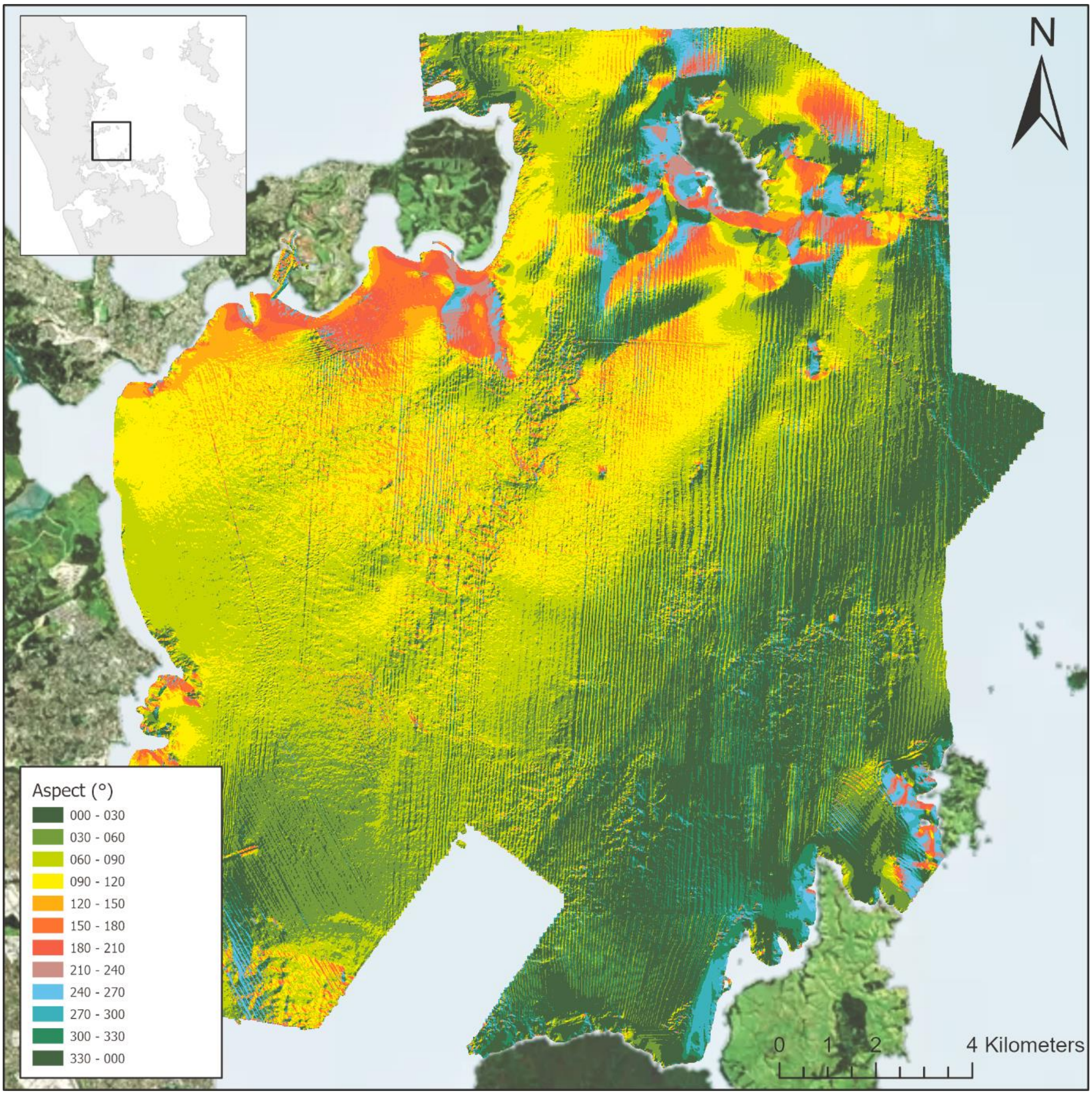

N
Aspect (°)
000 - 030
030 - 060
060 - 090
090 - 120
120 - 150
150 - 180
180 - 210
210 - 240
240 - 270
270 - 300
300 - 330
330 - 000
0 1 2 4 Kilometers

Figure 3-9: Aspect (direction of slope) of the seafloor.

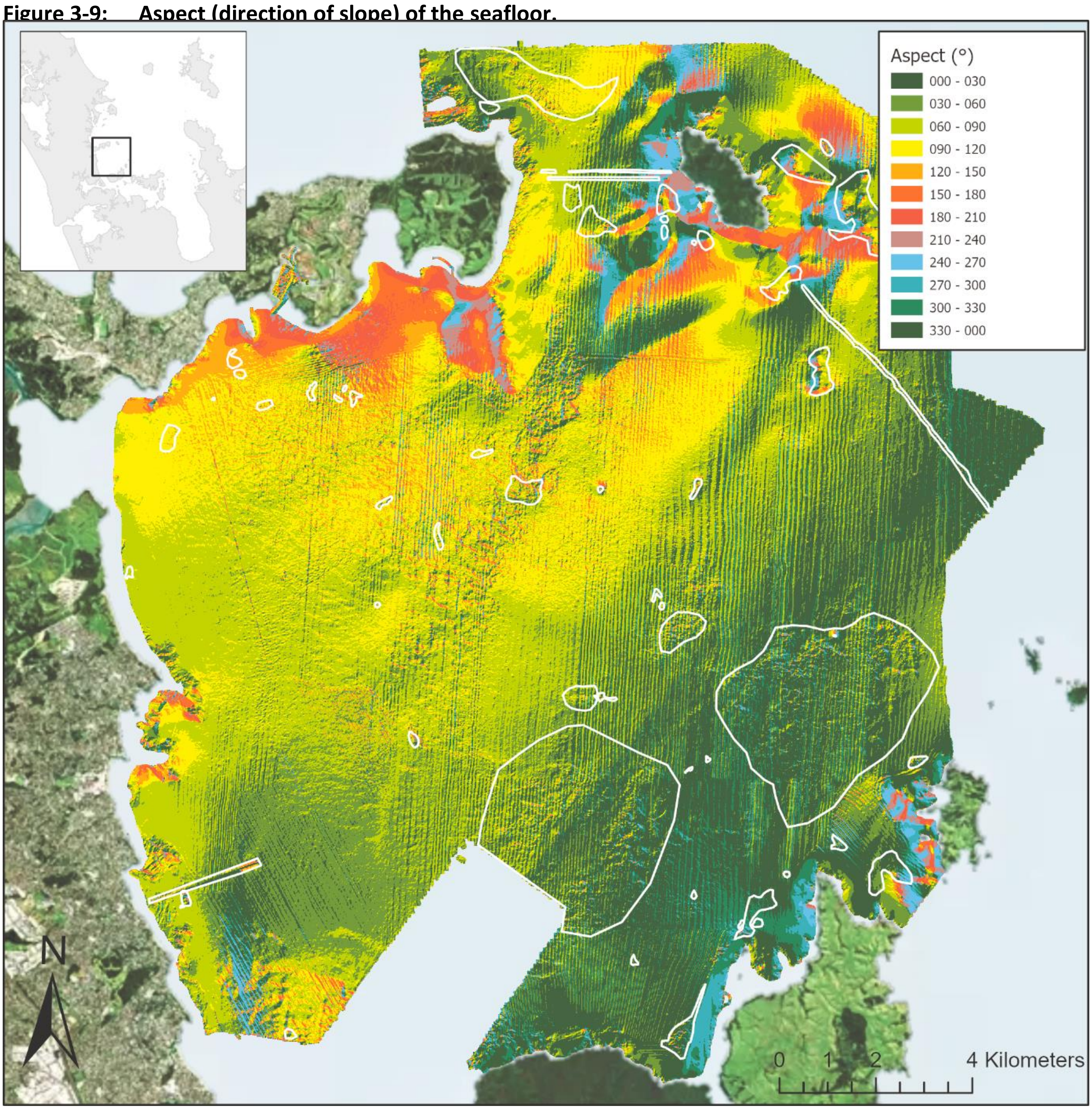


Figure 3-10: Aspect (direction of slope) of the seafloor. Areas of interest (available in the GIS).

3.2.6 Curvature

Curvature is the change of slope. Positive curvature at a location indicates that the surface is upwardly convex, e.g., a mound. Negative curvature indicates that the surface is upwardly concave, e.g., a depression. A neutral value of 0 (blue) indicates that the surface is flat. The colour gradient is symmetrical about zero curvature to emphasise curved versus flat seafloor. Most of the *HS52 – Approaches to Auckland* area seafloor shows neutral curvature (flat), with greatest curvature occurring along the nearshore rocky reefs, at pockmarks, anchor footprints, and along edges of local depressions.

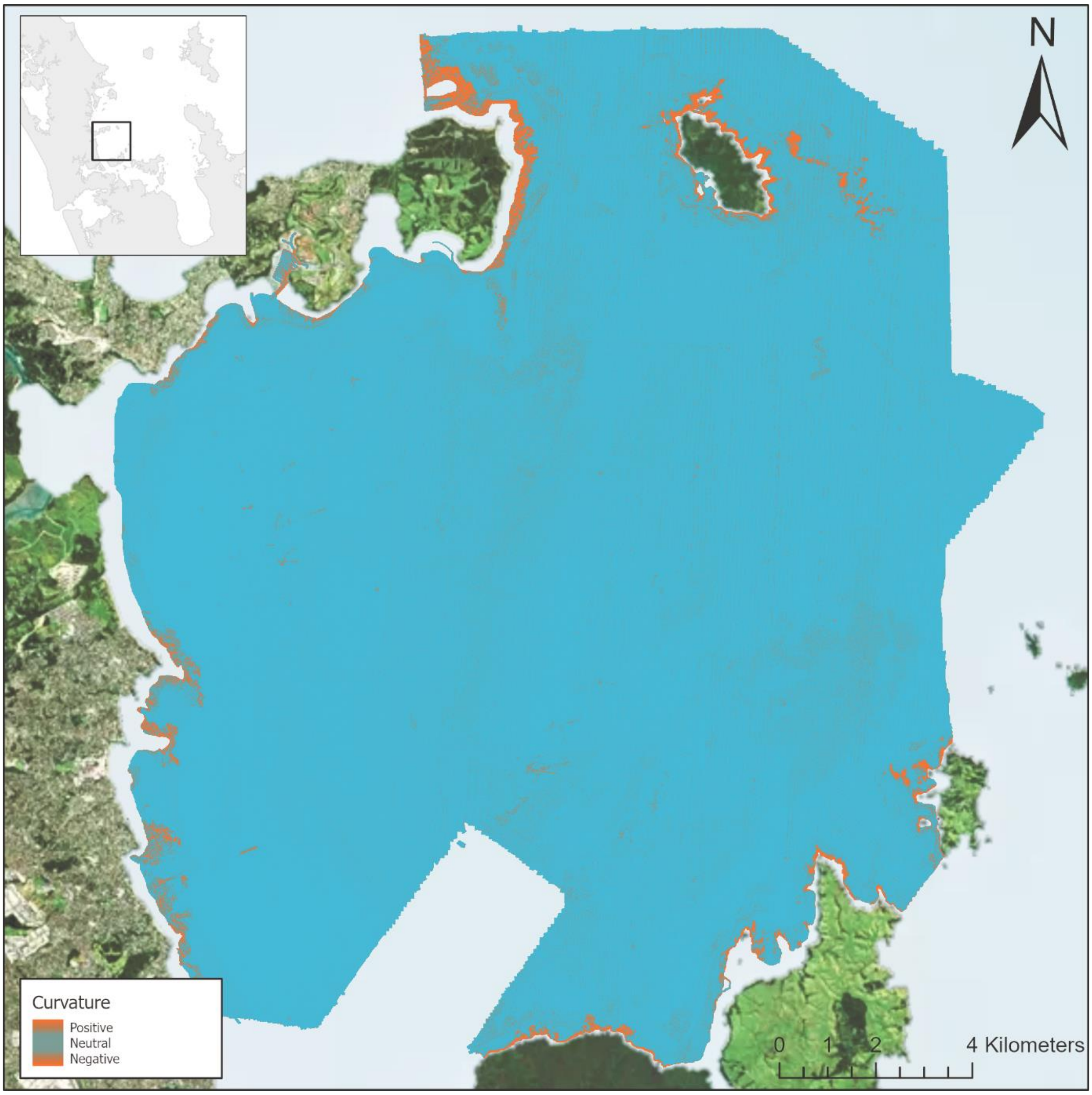


Figure 3-11: Curvature of the seafloor.

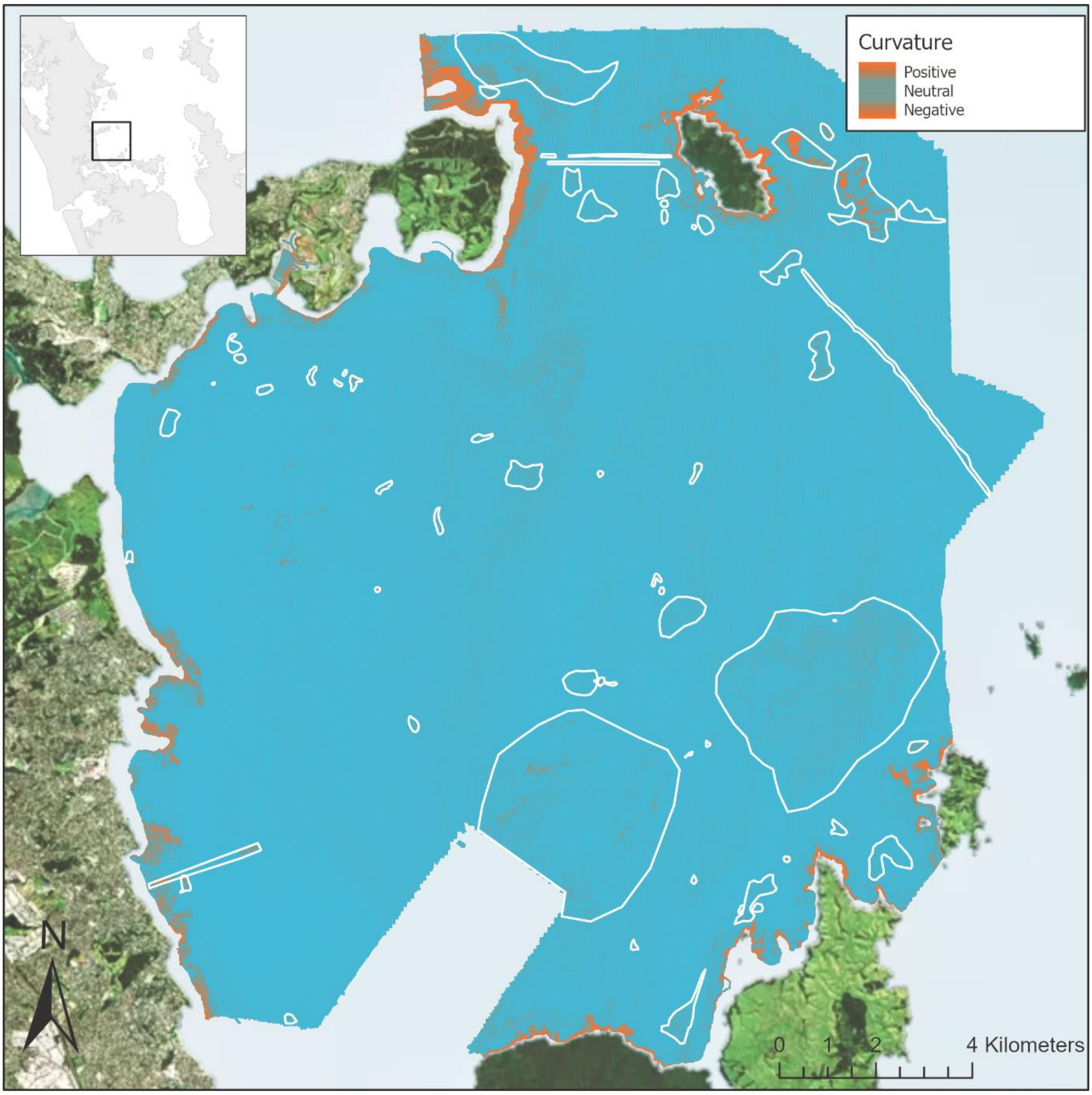


Figure 3-12: Curvature of the seafloor. Areas of interest (available in the GIS).

3.2.7 Seafloor Backscatter

Seafloor backscatter is the returned energy of the transmitted acoustic wave after adjusting for transmission losses due to physico-chemical effects in the water and variable incidence angles due to swath direction and seafloor morphology. The reflectance of the seafloor substrate is very complex and not a simple relationship between grain size and returned energy. Seafloor backscatter is able to show substrate boundaries, however, and often reveals structures not shown by the bathymetry or bathymetric derivatives. For example, higher backscatter is observed within the channels compared to the flat seafloor within the central survey region (Table 3-1 Feature C).

Figure 3-13: Seafloor backscatter (dB).

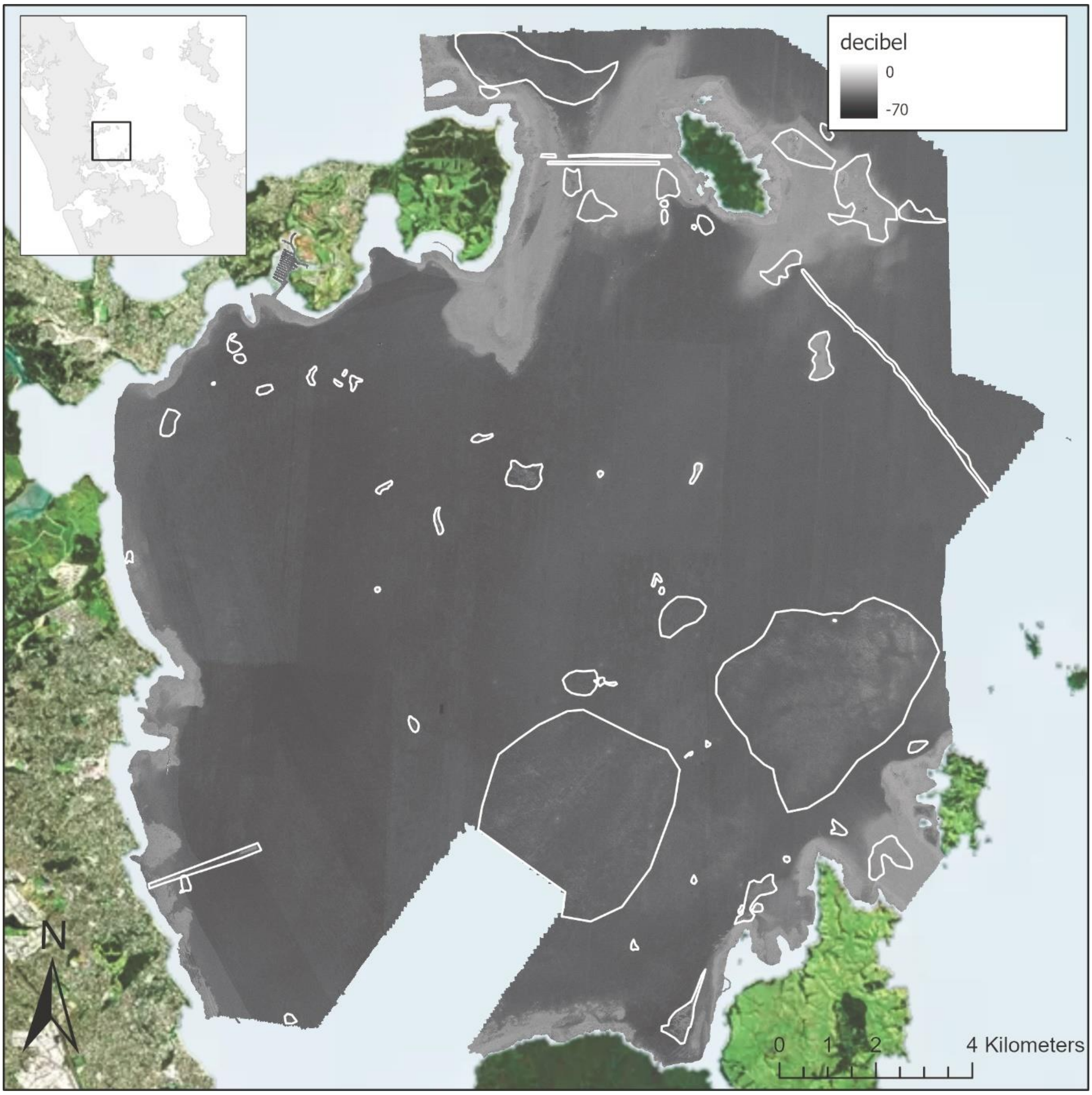


Figure 3-14: Seafloor backscatter (dB). Areas of interest (available in the GIS).

3.2.8 Benthic Terrain Model

Based on NIWA's National Benthic Terrain Classification, the surveyed area of *HS52 – Approaches to Auckland* is largely comprised of flat plains (94.79% of the seafloor). Other significant classes are flat ridge tops (1.89%), broad depressions (0.91%), and depressions (0.77%) (Table 3-2). These classifications are in accordance with a national standard and can be used to compare with other regions.

Table 3-2: Area percentage of BTM classes

Zone	%
Flat Plains	94.79
Broad Slopes	0.18
Steep Slopes	0.00
Broad Depressions	0.91
Lateral midslope depression	0.06
Scarp, Cliff	0.00
Depressions	0.77
Crevices, Narrow Gullies over elevated terrain	0.02
Flat Ridge Tops	1.89
Rock Outcrop Highs, Narrow Ridges	0.50
Local Ridges, Boulders, Pinnacles in Depressions	0.37
Local Ridges, Boulders, Pinnacles on Broad Flats	0.26
Local Ridges, Boulders, Pinnacles on Slopes	0.12
Local Depressions, Current Scours	0.10

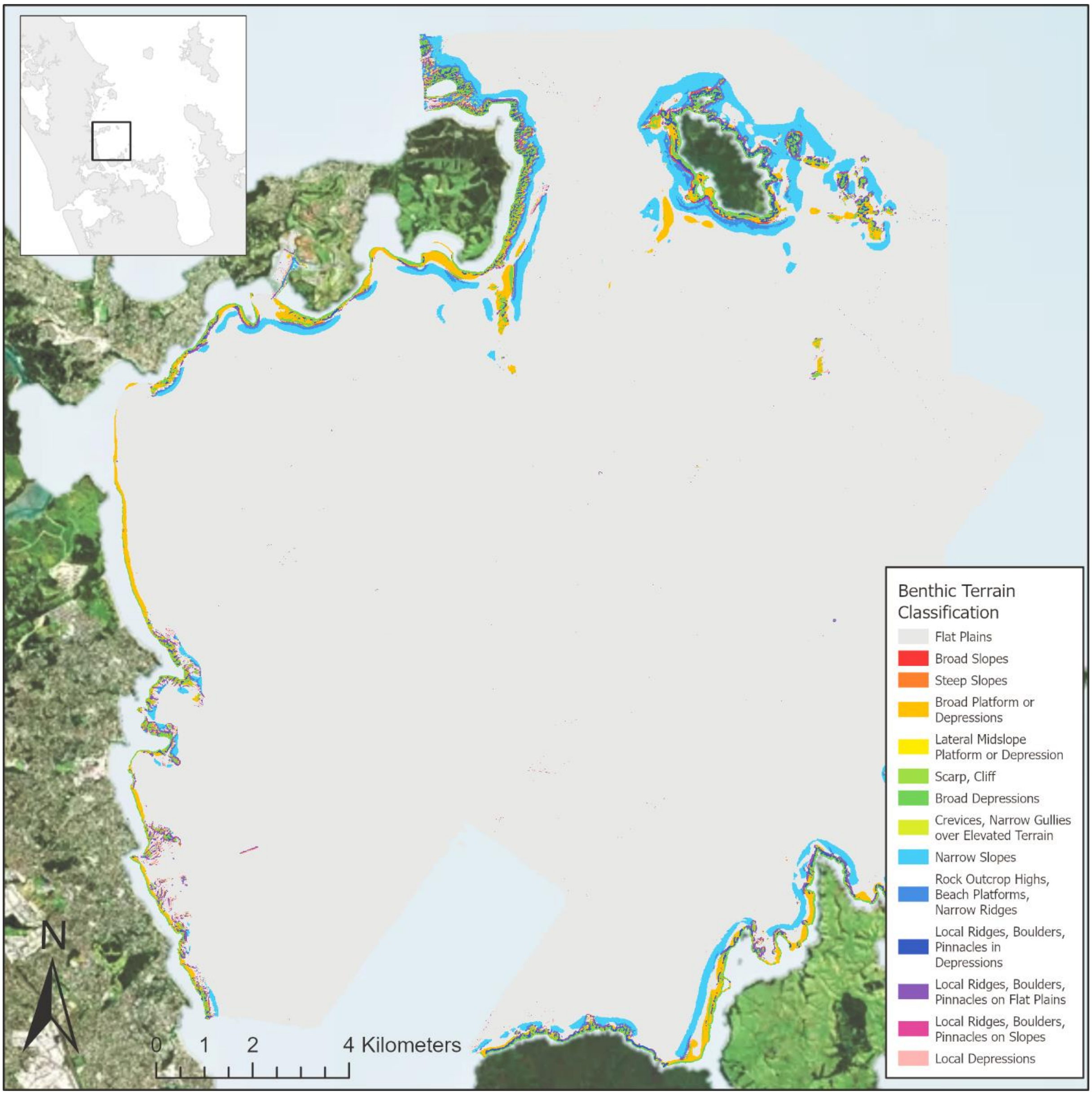


Figure 3-15: BTM classification.

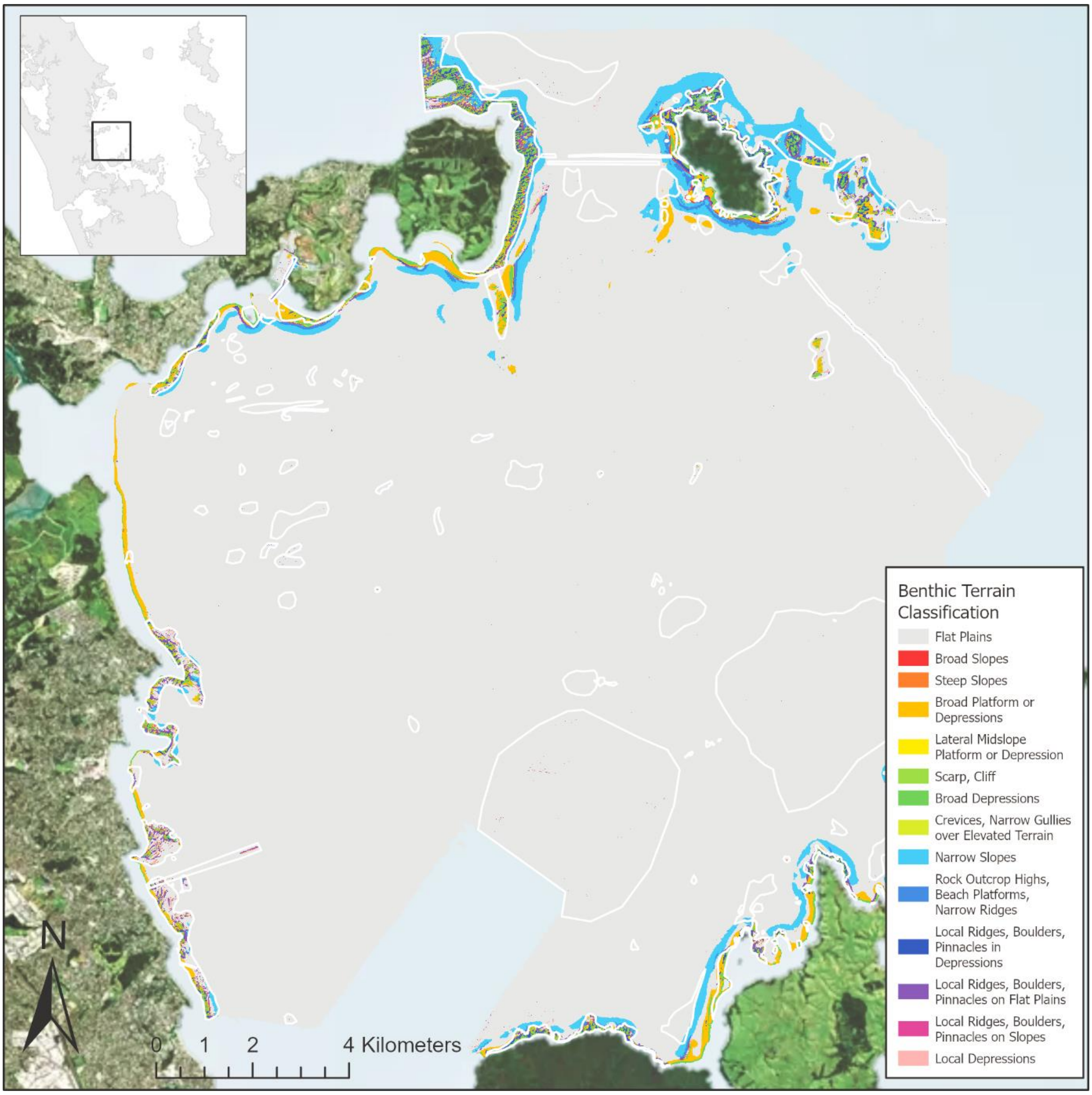


Figure 3-16: BTM classification. Areas of interest (available in the GIS).

3.2.9 Existing physical samples

NIWA's National Invertebrate Collection (NIC; https://niwa.co.nz/our-services/online-services/nic) and sediment sample database hold very few samples in the project area. Often these are also older (>10 years), from various sampling methods, and as such not necessarily representative of the current surface sediments and faunal composition of the area (Figure 3-17 and Figure 3-18).

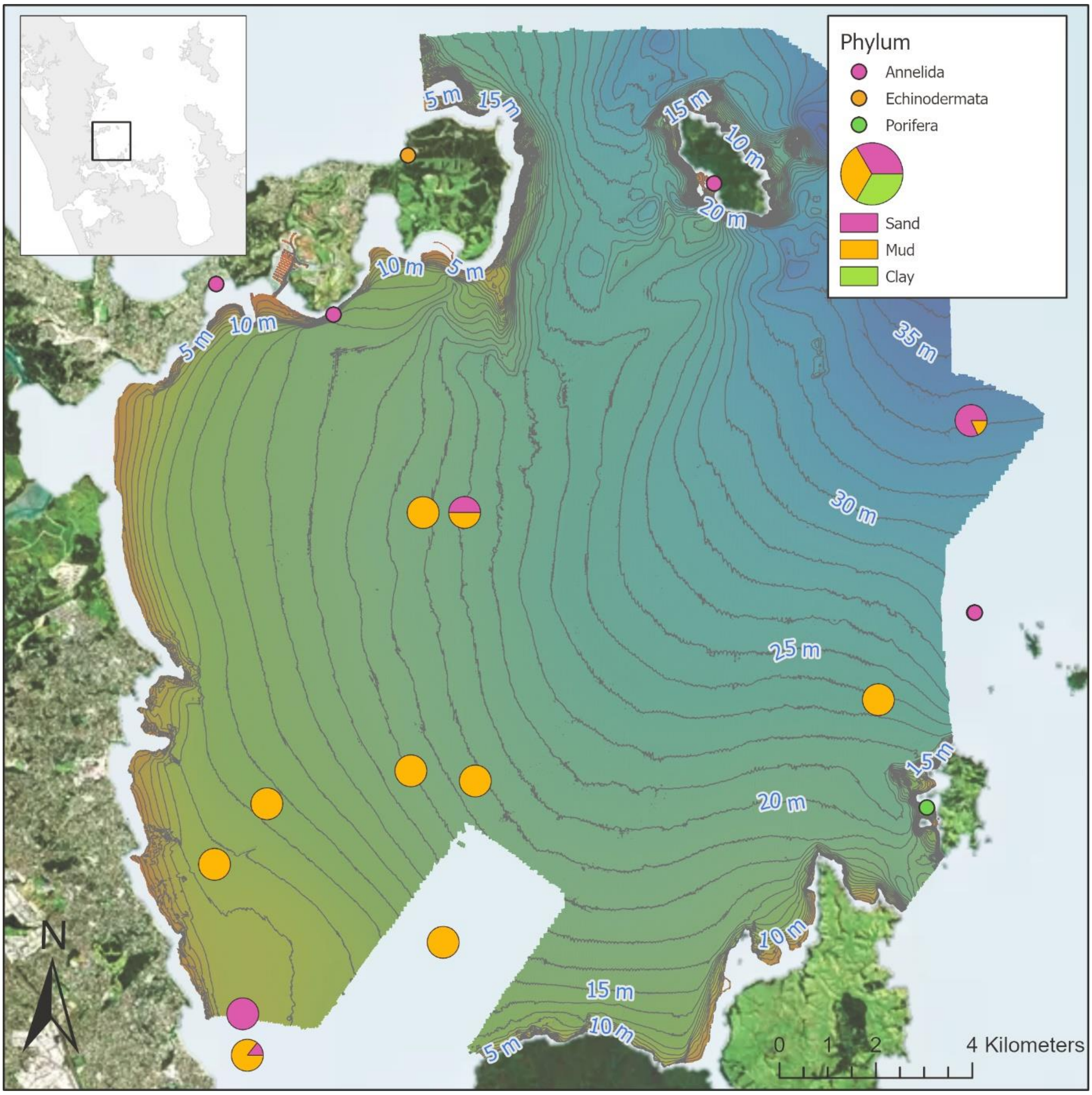


Figure 3-17: NIWA NIC and sediment samples.

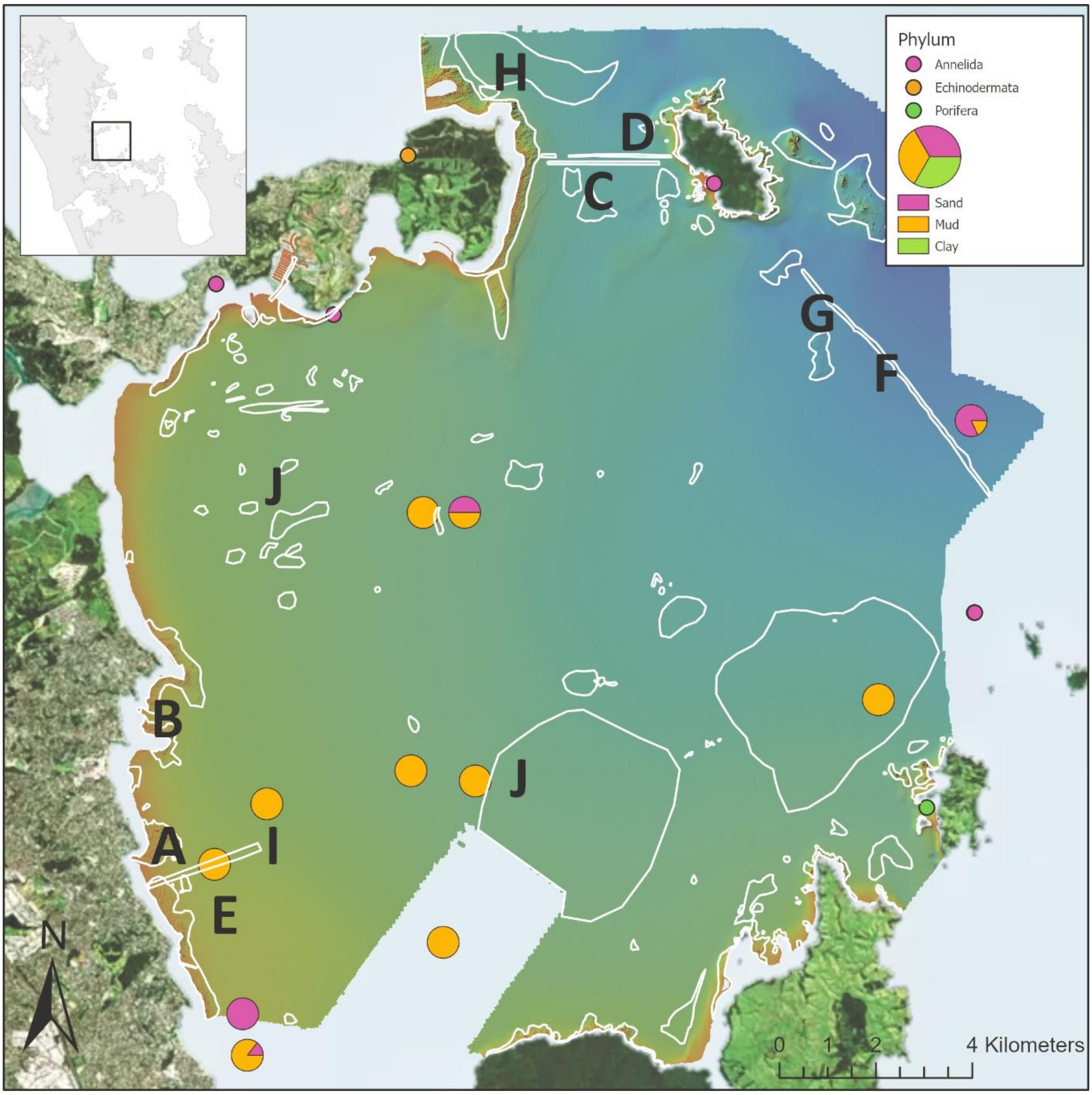


Figure 3-18: NIWA NIC and sediment samples with areas of interest. Areas of interest available in the GIS.

4 Conclusions

The collection of these data for hydrographic purposes and subsequent reprocessing for scientific interpretation demonstrates the range of potential end-uses for multibeam bathymetry and backscatter data, in line with the “map once – use multiple times” approach. The *HS52 – Approaches to Auckland* survey of the “Approaches to Auckland” region provides an excellent basis for understanding seafloor structure and identifying key locations where further research could be focused. Some highlights include:

- the offshore extension of the Waitemata Group formation, likely also representing an important shallow reef habitat,
- evidence for seafloor seepage (activity unknown) in the form of pockmarks, that may host unique benthic fauna that rely on the expelling fluids,
- extensive regions of increased rugosity, mottled backscatter and textured seabed which would benefit from visual inspection via video camera to verify their origins,
- locations where the physical human footprint (seafloor infrastructure or anchoring) has been preserved on the seabed, potential signifying habitat degradation,
- isolated rocky reef structures that may host sessile and ecologically important invertebrates
- near shore seabed with diverse seafloor morphology

The near shore seabed has, as can be expected, the highest amount of diverse seafloor morphology, containing most of the high backscatter, rugose, high slope, and BTM classes of seafloor. As such we suggest this area warrants further detailed work. In this report, we have highlighted many near shore areas of interest for further detailed investigation.

Datasets presented in this report now enable a highly detailed view of the seabed. This represents foundational information to understand the geological, ecological, oceanographic, and anthropogenic processes that coexist within these waters. A GIS layer of the areas of interest identified is included in the accompanying ArcPro project and shown in the maps in section 3.

5 Recommendations for further work

In the preceding project (Pallentin & Watson, 2021) several recommendations were given for possible future work. Below, we expand on these considering the learnings from this study. One suggestion was to augment the analysis with existing sediment and biological sample data. However, the extremely low number of samples currently held by NIWA in the area, and lack of any additional samples being accessible, allows no conclusions to be drawn from these for a habitat study. As such we suggest to:

1. **Extend habitat analysis with essential ground-truthing fieldwork:**
    a. Collect seafloor reference data, such as sediment grab samples and seafloor video data, to ground truth the generated bathymetry and backscatter data products.
    b. Resurvey high priority areas identified in the analysis described following the GeoHab BSWG recommendations and including backscatter compensation lines, regular oceanographic measurements, and sufficient spatial coverage of sediment samples for grain-size analysis. This will allow full, quantitative habitat analysis using the latest automated methods for these priority areas.
    c. Deliverables including a report incorporating all new backscatter data, quantitative analysis comparing old and new data products to validate the approach for future sites, and updates to the online story map.
2. **Complete detailed habitat analysis with extensive fieldwork:**
    a. Resurvey all areas using methods following GeoHab BSWG recommendations, including backscatter compensation lines, regular oceanographic measurements, and sufficient spatial coverage of sediment samples for grain-size analysis. This will result in quantitative habitat analysis for the resurveyed areas.
    b. Change detection analysis to determine any quantitative changes in bathymetry since the last survey.
    c. Deliverables include area report incorporating all new data, quantitative analysis of new survey data and qualitative comparison of existing and new data products, updates to the online story map, a map portfolio of significant derivative layers and changes detected, and NIWA 'Beneath the Waves' poster series products for the areas analysed.
3. **Investigate the numerous types of pockmarks in the survey area:**
    a. Collect acoustic water-column data, both calibrated scientific splitbeam echo sounder (SBES) and MBES data
    b. Collect water-column physical and chemical data (CTD rosette sampling).
    c. Collect targeted video and grab samples near and across these pockmarks.

The work completed in this study and suggested further work above could also be extended into other parts of the Auckland Regional Council area of interest.

6 Data delivery

Reprocessed and analysed *HS52 – Approaches to Auckland* hydrographic survey data are collated in an ArcPro .aprx project (v2.9.3) and an ESRI file geodatabase (FGDB) with associated metadata for each layer. Additionally, a folder ("TIFF") containing source imagery for the seafloor backscatter mosaic datasets (see below) has been included.

The ArcPro project contains:

- Features of Interest
  - Polygons of all features of interest (4 Conclusions);
- Seafloor Physical Samples
  - NIWA sediment sample locations (from Bostock, et al., 2019), with compositional pie charts (3.2.9 Existing physical samples);
  - NIWA Invertebrate Collection biological sample locations, classified by phylum (3.2.9 Existing physical samples);
- Seafloor Segmentation
  - Results of the backscatter and bathymetry RSOBIA segmentation (2.3.5 Seafloor backscatter and bathymetry segmentation);
- Benthic Terrain Model
  - BTM output, based on NIWA's classification dictionary (2.3.2 Benthic Terrain Model classes);
- Backscatter (50 cm)
  - Individual Reson 7125 50 cm resolution backscatter mosaic;
  - Individual R2Sonic 50 cm resolution backscatter mosaic;
- Backscatter (2 m)
  - Combined (Reson 7125 and R2Sonic) 2 m resolution backscatter mosaic;
  - Individual Reson 7125 2 m resolution backscatter mosaic;
  - Individual R2Sonic 2 m resolution backscatter mosaic;
- Bathymetry Derivatives (50 cm)
  - Aspect 50 cm resolution grid, with a focal window of 25;
  - Curvature 50 cm resolution grid, with a focal window of 05;
  - Rugosity 50 cm resolution grid, with a focal window of 01;
  - Slope 50 cm resolution grid, with a focal window of 15;
- Bathymetry Derivatives (2 m)

    - Aspect 2 m resolution grid, with a focal window of 15;
    - Curvature 2 m resolution grid, with a focal window of 05;
    - Rugosity 2 m resolution grid, with a focal window of 01;
    - Slope 2 m resolution grid, with a focal window of 05;
- Bathymetry (50 cm)
    - Bathymetric contours, at 1 m intervals;
    - Digital bathymetric model (DBM), of 50 cm resolution;
    - Hillshade from the 50 cm DBM, sun illumination at 315°, altitude of 45, vertical exaggeration of 3;
- Bathymetry (2 m)
    - Bathymetric contours, at 1 m intervals;
    - Digital bathymetric model (DBM), of 2 m resolution;
    - Hillshade from the 2 m DBM, sun illumination at 315°, altitude of 45, vertical exaggeration of 3;
- Basemap
    - LINZ aerial photography combined image (LINZ 2022);

The FGDB provided includes all the above layers, as well as additional derivative layers, with 01, 05, 15, and 25 focal windows. These layers can provide further information of seafloor characteristics at layer scales than the native 01 focal window. Further information for each layer is contained within the metadata, accessible through Catalog in ArcPro.

7 Acknowledgements

We would like to acknowledge the Hydrographic Authority team at LINZ, in particular Mr Bradley Cooper, for providing the extensive *HS52 – Approaches to Auckland* dataset and additional assistance. DML and their team of hydrographers are acknowledged for the initial MBES data collection.

8 Glossary of abbreviations and terms

backscatter	Seafloor backscatter (as used in this report). The acoustic return signal from an echosounder
BTM	Benthic Terrain Modeller
dB	decibel
DML	Discovery Marine Limited, Tauranga
GeoHab	GeoHab (Marine Geological and Biological Habitat Mapping) is an international association of marine scientists studying biophysical (i.e., geologic and oceanographic) indicators of benthic habitats and ecosystems as proxies for biological communities and species diversity
HS	LINZ Hydrographic Survey
insonified area	Area of seafloor affected by an acoustic beam. Critical to correctly calculate the seafloor backscatter intensity
LINZ	Toitū Te Whenua Land Information New Zealand
DOC	Te Papa Atawhai Department of Conservation
MBES	Multibeam echosounder
SBES	Single beam echosounder
SSS	Side Scan Sonar
TIFF	Tagged Image File Format

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