NIWA
Taihoro Nukurangi

Offshore framework of the Heretaunga Aquifer in Hawke Bay

A desktop study into the likely offshore extent of freshwater aquifers in Hawke's Bay and the relationship to mapped seeps

Prepared for Hawke's Bay Regional Council

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Prepared by:
Joshu J. Mountjoy

For any information regarding this report please contact:

Dr Joshu Mountjoy
Programme Leader
Marine Geology
+64-4-386 0336
joshu.mountjoy@niwa.co.nz

National Institute of Water & Atmospheric Research Ltd
Private Bag 14901
Kilbirnie
Wellington 6241

Phone +64 4 386 0300

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Executive summary

Hawke's Bay Regional Council commissioned NIWA to undertake a screening report of existing data and interpretations relevant to the offshore Heretaunga Aquifer. We have compiled all available data and reviewed relevant elements of it. We have also compiled relevant literature and synthesised existing interpretations for this report. The area of interest is specifically focused around a region where features termed *"Springs in seafloor"* have been mapped on LINZ chart *NZ 56 Table Cape to Blackhead Point*. It has been proposed that these might be related to submarine groundwater discharge from the Heretaunga Aquifer, so we have assessed existing data and interpretations in the context of this potential relationship.

The results indicate that the last glacial fluvial gravel deposits that form the Heretaunga Aquifer geological unit extends offshore from the Heretaunga Plains in a north easterly direction towards Mahia Peninsula. The offshore basin is bound on the seaward side by Kidnappers Ridge, a structural feature buried beneath the seafloor, and extending north east from Cape Kidnapper. Seismic facies interpretations indicate that gravel units thin out about half way across Hawke's Bay but may extend close to Mahia Peninsula where they transition to sandy units. The mapped *"Springs in seafloor"* occur seaward of the last glacial gravel unit and above older units interpreted to be Quaternary glacial sequences aged 340-710 kyrs, i.e. several glacial cycles older than the Heretaunga gravel unit. We see no evidence for fluid expulsion in terms of seafloor features in the area of mapped *"Springs in seafloor*" in the available 10 m resolution multibeam bathymetry data, nor in acoustic water-column backscatter data.

The data and interpretations we have compiled and screened provide an excellent framework for the offshore Heretaunga Aquifer but do not provide any evidence for submarine groundwater discharge.

To provide a robust framework for the Heretaunga Aquifer and to determine if submarine groundwater discharge occurs in the area we recommend that further studies are carried out.

It is recommended that

1. A regional project be undertaken to understand the offshore extent of the Heretaunga Aquifer. This could include:

    1.1 Acquisition of additional high-resolution seismic reflection data to provide higher density coverage of the inner shelf which would be interpreted in conjunction with existing data.

    1.2 Acquisition of Controlled Source Electromagnetic Data (CSEM) that can map resistivity anomalies related to the salinity of sub-seafloor fluids.

    1.3 Drilling of offshore test boreholes to both constrain stratigraphic models and to undertake water sampling and permeability measurements.

    1.4 Integration with onshore aquifer stratigraphic architecture and hydrogeological modelling.

2. New survey data be acquired to determine if freshwater seepage is occurring, potentially including:

    2.1 A focused water column acoustic backscatter survey over the area that may reveal features related to freshwater seeps.

    2.2 Ocean temperature and salinity data surveys. Other geochemical tracers indicating fresh water such as radium isotopes

1 Background

The Hawke's Bay Regional Council (HBRC) faces the challenge of sustainably managing critical groundwater resources that are subject to increasing user pressure. The limit of aquifers beyond the coastline and the magnitude of leakage to the ocean is critical information for aquifer management models yet this aspect is currently unconstrained. HBRC require a compilation and review of existing geophysical datasets to define a stratigraphic model for the shallow (upper ~200 m) sediments beneath the Hawke Bay continental shelf. This framework is needed to provide a model for offshore units to better understand aquifer geometry. This understanding of the aquifer would underpin future work to identify submarine groundwater seepage (freshwater springs on the seafloor) in the Hawke Bay, Springs Box vicinity.

1.1 Services to be provided

NIWA was specially engaged to provide the following Services and deliverables:

1. A collation and review of existing geophysical and geological research, literature and data.
2. Package together existing interpretations of continental shelf stratigraphy based on seismic reflection data with any other relevant data to provide a framework for understanding the offshore aquifer and potential for freshwater springs in the area identified by HBRC.
3. The compiled information provided as a short report and presented in a seminar to HBRC.

2 Migrating sedimentary systems during former sea level cycles

The last glacial maximum (c. 20-18 ka) was associated with global eustatic lowstand sea level of about -120 m relative to present day. At this time, the Hawke Bay continental shelf was exposed, widening the coastal plain by >60 km, and the shoreline lay close to the edge of the continental shelf (Figure 1 and Figure 2) (Barnes et al., 2002; Lewis, 1973; Paquet et al., 2009). River systems across the wider Hawke Bay catchment are interpreted to have coalesced in the inner part of the modern bay and been forced to flow north east by the former topographic high of Kidnappers Ridge and towards Mahia Peninsula. It can be broadly assumed that the migrating sedimentary systems that developed during and since the last glacial maximum were repeated during former glaciations and this is supported by work of Paquet et al. (2011).

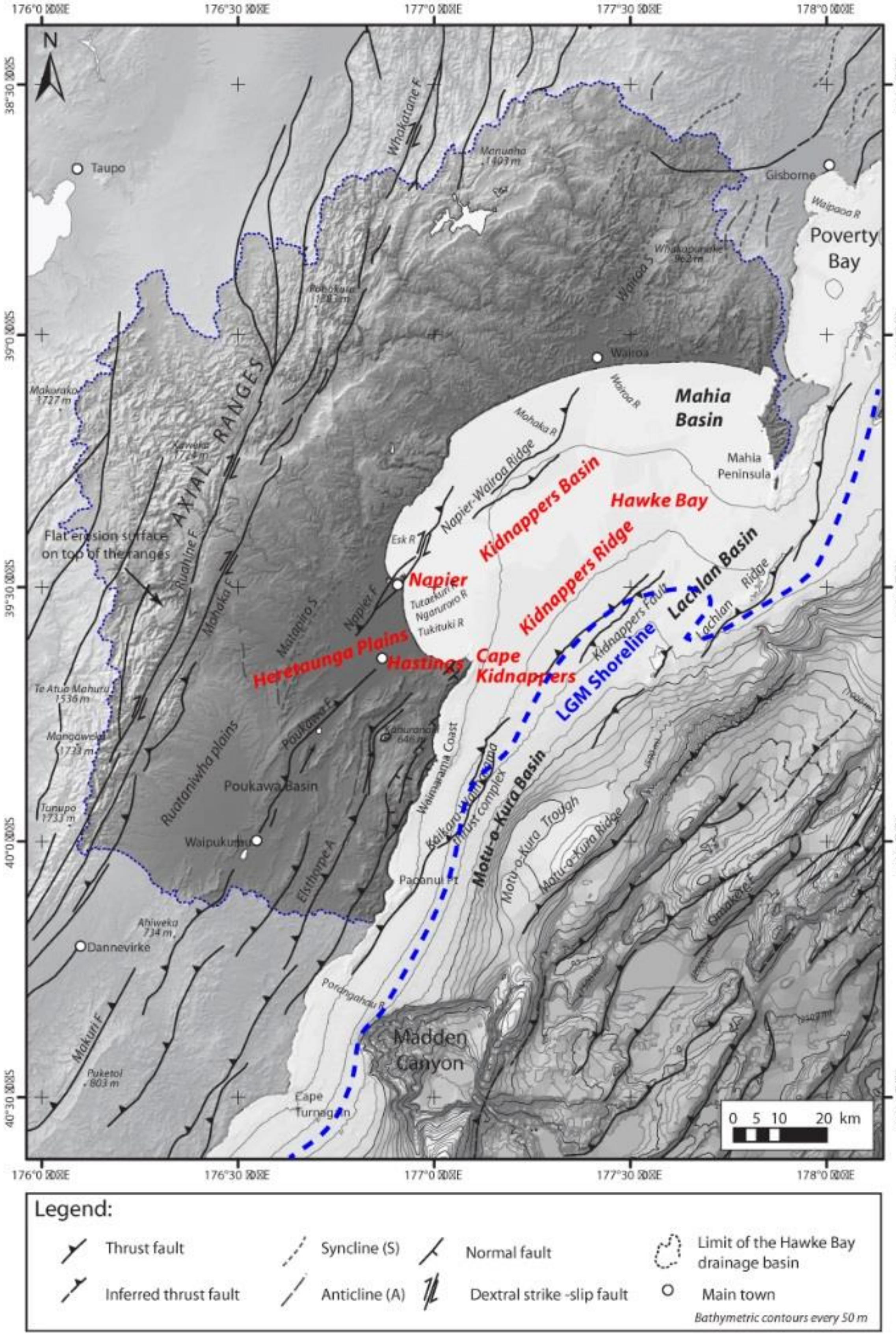

Figure 1: Hawke Bay region showing the larger catchment area and the shoreline during the last-glacial maximum (LGM, 18 ka).Modified from Paquet et al. (2011).

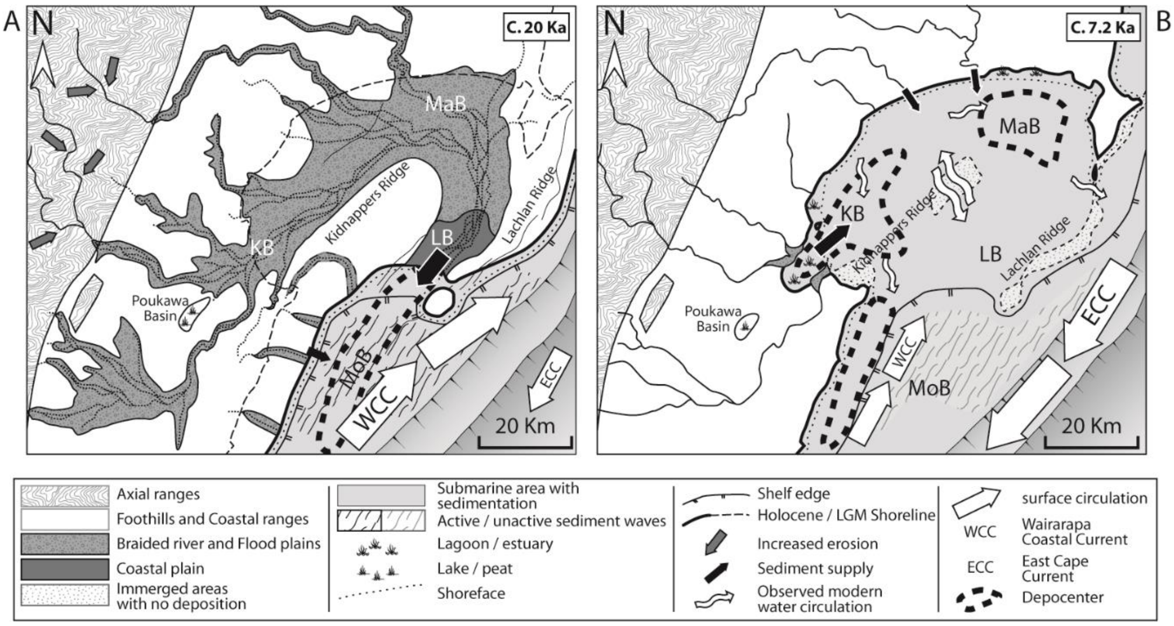

Figure 2: Schematic model of the Hawke's Bay margin sediment transport from Paquet et al. (2009). (A) Last glacial maximum (~20 ka) sea level lowstand (~-120 m), exposing coastal plain to shelf break. (B) Sedimentation following transgressive sea level when the shoreline reached its current position at the beginning of the Holocene ~7.2 ka.

2.1 Current model of gravel-rich aquifers beneath the Heretaunga Plains

Knowledge of the Heretaunga Plains aquifer primarily comes from consultancy reports prepared for the HBRC (Dravid and Brown 1997; Lee et al. 2014; Morgernstern et al. 2017).

The Quaternary material underlying the Heretaunga Plains occupies a fault-bounded depression 900-1600 m deep (Dravid and Brown 1997; Beanland et al. 1998). Adjacent hills are underlain by predominantly marine Eocene (~40 ma) to Late Pliocene/early Quaternary (2-3 Ma) sediments. Correlation of Early to middle Quaternary conglomerate, pumiceous sandstone and carbonaceous mudstone preserved at Cape Kidnappers and as isolated remnants on the hilltops west of Napier has been made beneath the Heretaunga Plains based on seismic reflection profiles and sparse borehole data (Morgernstern et al. 2017).

Younger middle to late Quaternary (<1 Ma) deposits present beneath the Heretaunga Plains are of alternating fluvial and marginal marine origin (Brown and Dravid 1997). Borehole data indicate that across the Heretaunga Plains area, deposition during the low sea level stands of the Last Glaciation (71,000 to c. 12,000 years ago) was dominated by alluvial gravels accumulated from the bed load of the braided river systems of the Ngaruroro, Tutaekuri and Tukituki rivers. These materials make up the primary aquifer of the Heretaunga Plains. An aquitard confining the gravel aquifer material is formed of overlying fine-grained materials deposited across much of the eastern Heretaunga Plains.

3 Data and literature compilation relevant to offshore systems

3.1 Published information

Stratigraphy offshore Hawke's Bay comprises an almost complete middle Cretaceous to Holocene sedimentary section (Barnes et al., 2002; Field et al., 1997; Pettinga, 1982). Deep-marine deposits from Cretaceous through Miocene are overlain by shallow-marine shelf and subaerial Pliocene–

Holocene cyclothemic strata. Ongoing tectonic deformation has resulted in significant uplift and folding and many of the older units are exposed at the seafloor along with Holocene sequences. For example, seafloor mapping of the exposures of the unconformities reveal extensive exposures of Pliocene–Pleistocene strata on the southern crest of Lachlan Ridge and inshore west of Portland Island (Barnes et al., 2002). Seabed samples can be tied to unconformities mapped in seismic reflection data to validate the last 1.2 Ma (Quaternary) stratigraphy.

Paquet et al (2009; 2011) used the Quaternary sequence stratigraphy to analyse the recent sedimentary development and paleoenvironment of Hawke Bay. Their findings are particularly useful in terms of understanding offshore sedimentary units relevant to the Heretaunga Aquifer. The 3.5 kHz sub bottom profile shown in Figure 3 is characteristic of the high-resolution data interpreted. A schematic of the tectonically deformed depositional units in Hawke Bay are shown in Figure 4, which illustrates the strong SW-NE strike of the Kidnappers Basin offshore of the Heretaunga Plains. The basin is narrow (<20 km) in the NW-SE direction and pinches out up onto the buried Kidnappers Ridge tectonic structure to the SE (Figure 4B). Depositional units are inferred to exhibit more lateral continuity in the NE direction along the axis of the basin (Figure 4C).

The primary aquifer beneath the Heretaunga Plains is the last glacial fluvial gravel unit aged 71,000 – 12,000 years (Lee et al., 2014) indicated as T1 in Figure 4C, D. The offshore continuation of this unit, represented offshore by units U3 and U4 in Figure 4. Deeper units likely include other fluvial gravel sequences that may function as aquifers but, as little is known about these onshore, correlation to specific units and surfaces offshore would be difficult.

Submarine Groundwater Discharge (SGD) can mark the offshore extent of confined aquifers that cross the coastal zone and is an important piece of information for managing coastal aquifers (McCoy and Corbett, 2009). Eleven features referred to as “spring in seabed” are charted in LINZ Chart *NZ 56 Table Cape to Blackhead Point* as shown in (Figure 5). The Source Data for the region of the chart where the seeps occur is attributed to HMNZS Lachlan 1954-1957 at 1:75000 scale. No further information about the origin of these features or the accuracy of the locations has been available to this study.

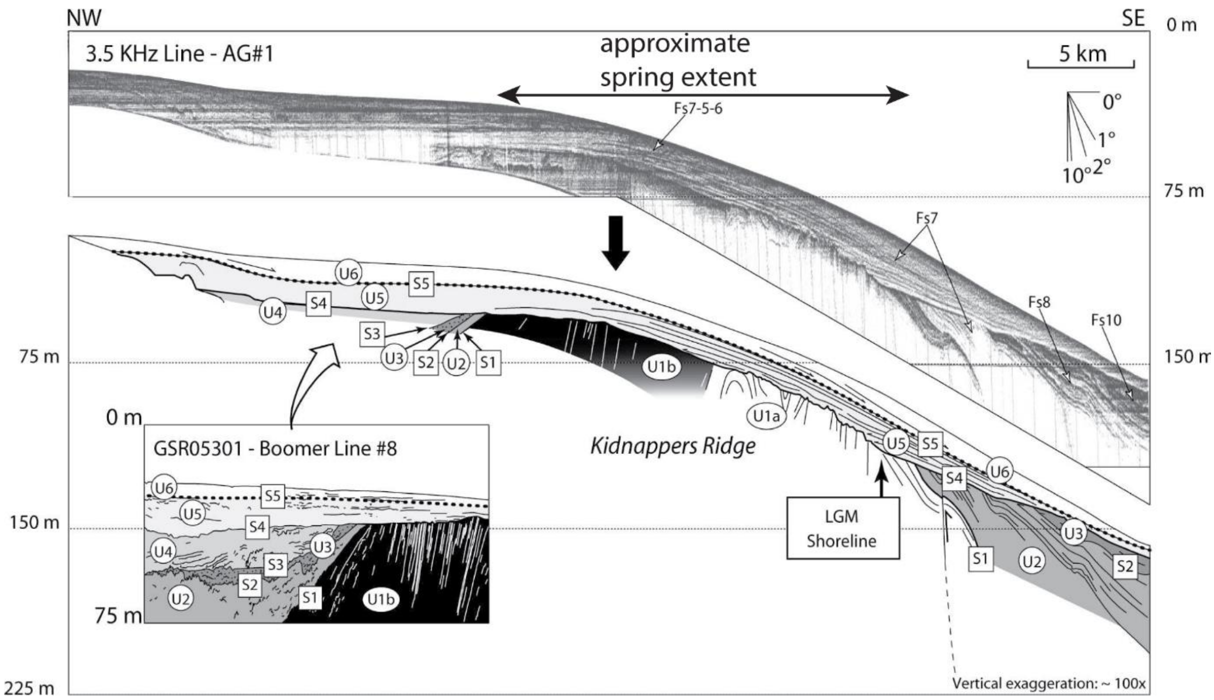

Figure 3: Interpretation of the inner-shelf to outer-shelf 3.5 kHz profile after Paquet et al. (2009). This type of data has been used to map the units relevant to the Heretaunga Aquifer. Approximate Spring Extent relates to the mapped "Springs in seafloor" from the LINZ chart *NZ 56 Table Cape to Blackhead Point* and shown on Figures 5,6,7, and 9.

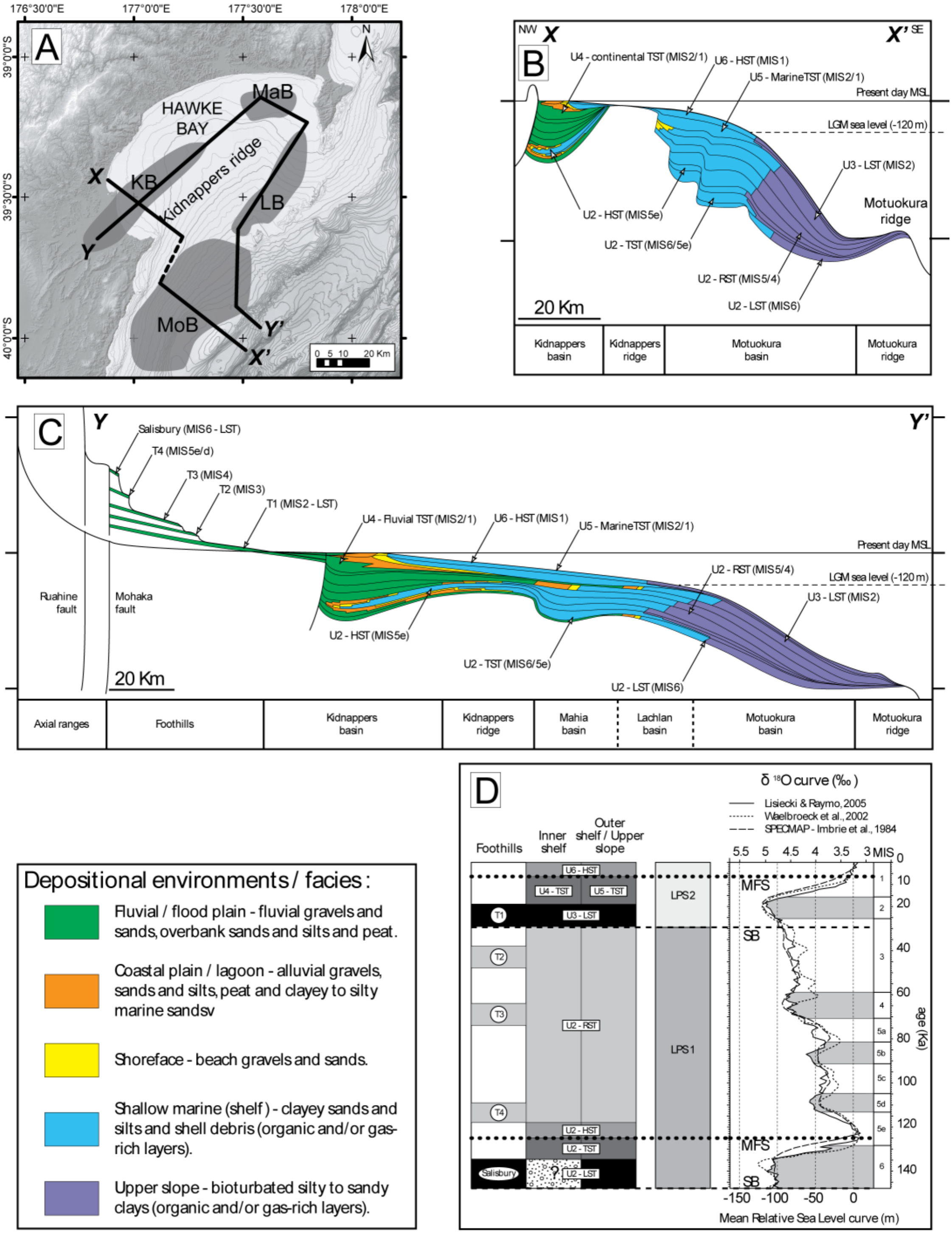

Figure 4: Schematic sections through Hawke Bay with facies interpretation tied to depositional periods of sea level after Paquet et al. (2009). A) Section locations. B&C) Sections X-X' and Y-Y'. The legend for depositional environment/facies is shown bottom left. D) Age model for the various units with respect to the global Mean Relative Sea Level Curve.

3.2 Data compilation

A marine data compilation for the inner Hawke's Bay area has been completed and is summarised below by data category.

3.2.1 Multibeam bathymetric data

Multibeam bathymetric data from four separate surveys has been collated for this report. The distribution of the data is shown in Figure 5 and the survey specifications listed in Table 1.

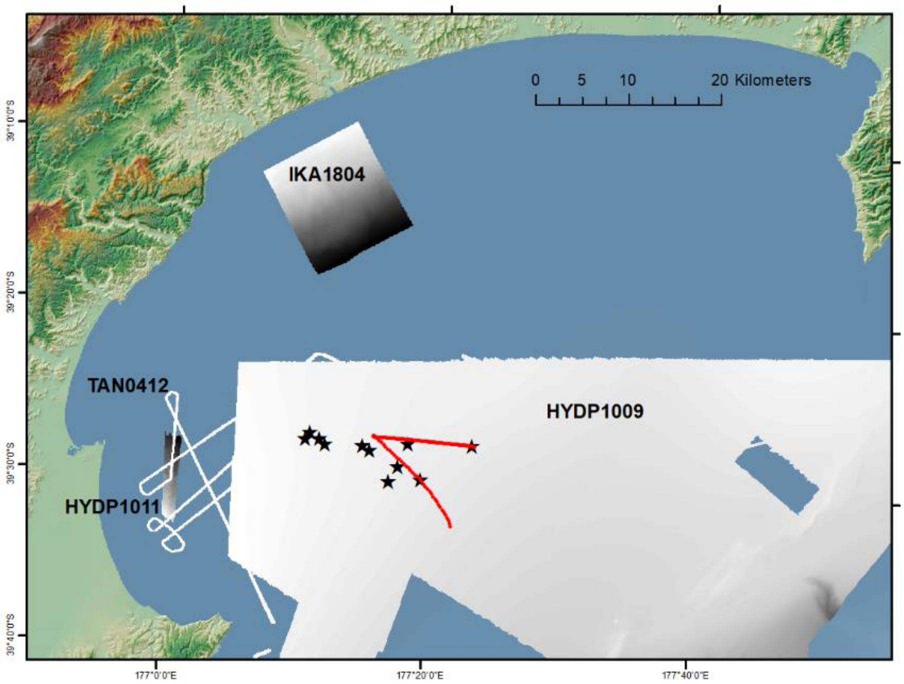

Figure 5: Distribution of multibeam bathymetric grid data held at NIWA. Grey polygons show where bathymetric grid data exist. Red line shows a single pass with the multibeam system to collect acoustic water column data. Black stars are mapped "Springs in seafloor" from the LINZ chart *NZ 56 Table Cape to Blackhead Point.*

Table 1: Multibeam Bathymetric surveys in the Hawke's Bay region.

Survey ID	Year	Instrument	Grid Resolution
HYDP 1009	2010	Atlas Hydrosweep MD-2/30	10 m
TAN0412	2004	Simrad EM300	25 m
HYDP1011	2010	Atlas Hydrosweep MD-2/30	10 m
IKA1804	2018	Kongsberg EM2040	2 m

3.2.2 Acoustic water column data

Water column data exist for survey IKA1804 (Figure 5 and Table 1). In addition, a single line of water column data was collected over the area of "Springs in seabed" in 2018 (Figure 5).

3.2.3 High resolution seismic reflection data (sub bottom profiler)

Sub bottom profiler data held at NIWA as either digital or analogue files is shown in Figure 6. Data collected specifically for Fabian Paquet's PhD project (Paquet, 2007; Paquet et al., 2009; Paquet et al., 2011) is not held in any form by NIWA.

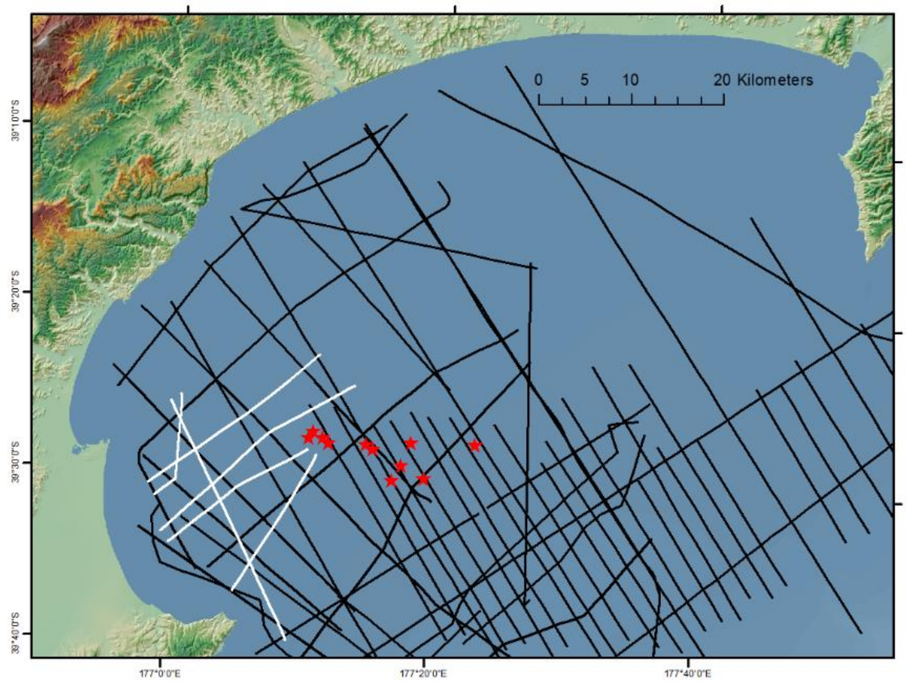

Figure 6: Sub bottom profiler data navigation. White lines indicate data that is held digitally Black lines indicate data that was collected with an analogue system and is held as paper copies and scanned sections. Red stars are mapped "Springs in seafloor" from the LINZ chart *NZ 56 Table Cape to Blackhead Point.*

3.2.4 Multichannel seismic reflection data

A large volume of seismic reflection data exists in Hawke's Bay. We have added two NIWA surveys to the existing data compilation that is available from the New Zealand Petroleum and Minerals Datapack https://www.nzpam.govt.nz/maps-geoscience/petroleum-datapack/. The datapack predominantly includes offshore data but also a certain amount of onshore data (Figure 7). These data include a varied range of age and data quality. The two NIWA surveys are 48 channel seismic data from voyages TAN0313 and TAN0412.

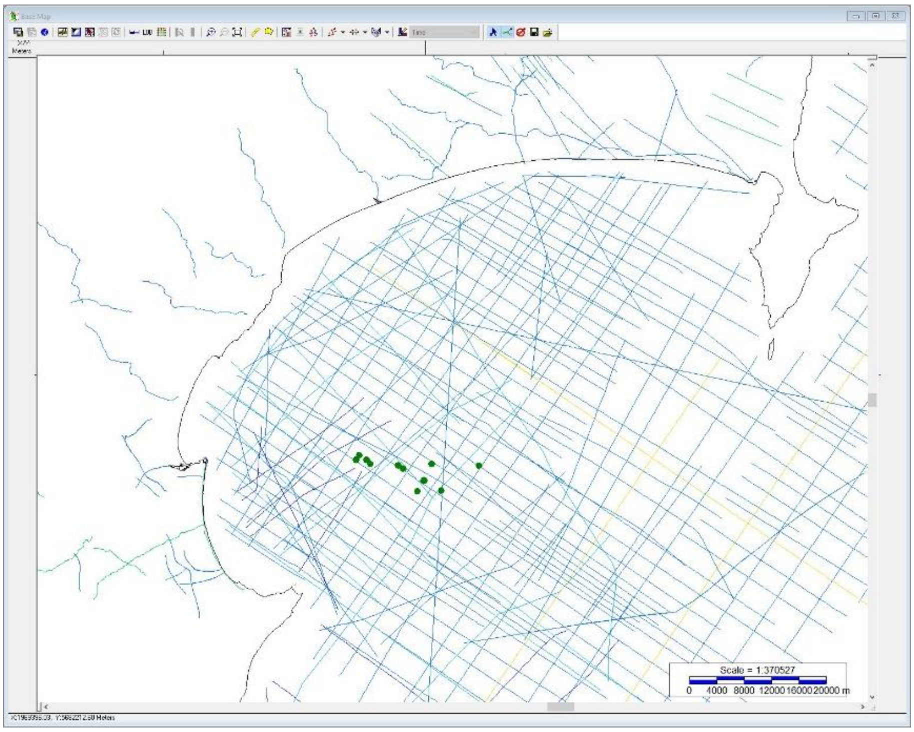

Figure 7: Available digital format multi-channel seismic reflection data compiled in a project in the software Kingdom Suite. Yellow and blue lines show location of 2D data. Green dots are mapped "Springs in seafloor" from the LINZ chart *NZ 56 Table Cape to Blackhead Point*

3.2.5 Surface sediment samples

Samples have been compiled all around the coast of New Zealand and are published in Bostock et al. (2019). This dataset covers the relative grainsize component of mud vs sand vs gravel, and the percentage carbonate (Figure 8). Hawke's Bay surface sediments are dominated by sandy material within 10 km of the coast and mud in the middle of the bay.

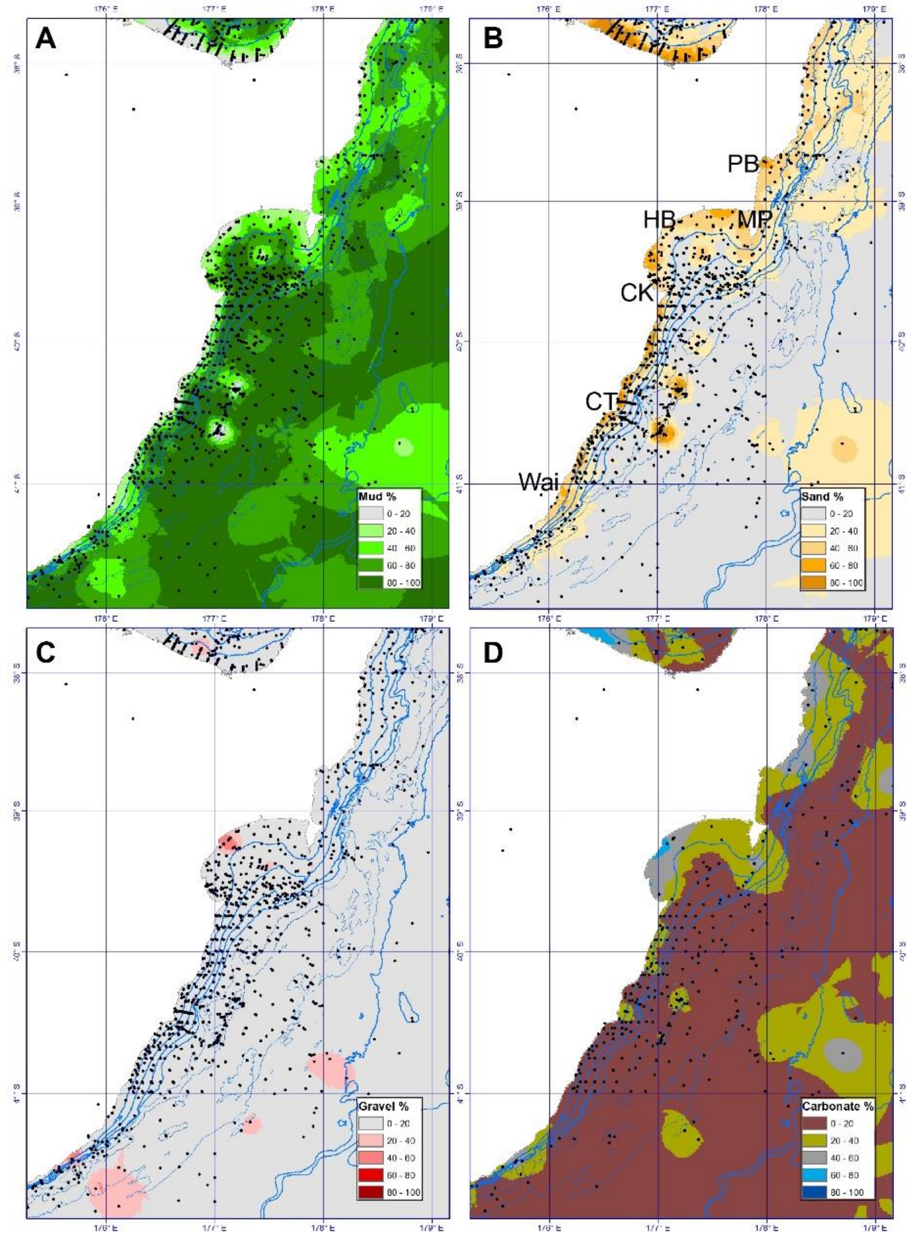

Figure 8: East Coast of the North Island. A) Mud %, B) Sand %, C) Gravel %, D) Carbonate %. Station locations are shown by black dots. Place names are labelled: MP - Mahia Peninsular, PB – Poverty Bay/Turanganui-a-Kiwa, HB – Hawke Bay, CK – Cape Kidnappers, CT - Cape Turnagain, Wai – Wairarapa. After Bostock et al. (2019).

4 Discussion

The objective of this study is to better characterise the offshore extent, lithological composition, and hydrostratigraphic attributes of the Heretaunga aquifer beneath Hawke's Bay to improve management of freshwater resources. Specifically an area of identified "springs in seabed" suggest Submarine Groundwater Discharge (SGD) may be occurring. A primary aim of the study is to determine if the springs could be related to discharge from the main Heretaunga aquifer.

Onshore the main Heretaunga Aquifer unit is the last glacial fluvial gravels. Published stratigraphic interpretations and paleoenvironmental reconstructions, primarily after Paquet et al. (2009; 2011), indicate that the equivalent offshore units to those underlying the Heretaunga Plains occur in a narrow SW-NE trending, elongated basin with a similar width to the plains themselves (Figure 4). This basin geometry is a result of the major fluvial systems being directed north east by the Kidnappers Ridge former topographic high (Figure 2). Seismic reflection data clearly show units within the basin pinching out to the seafloor in an erosive unconformity as they approach this structural ridge. The data and interpretations indicate that there should be connectivity of the Heretaunga Aquifer beyond the coastline in a NE direction (Paquet et al., 2009). Based on seismic stratigraphic facies analysis, the model in Figure 4 suggests that the last glacial fluvial gravel units may extend over half way across Hawke Bay. In Figure 9 the inferred extent of the equivalent offshore unit to the Heretaunga Aquifer Gravels (Seq 1) is shown by the gravel symbology. As the mapped extent of this unit is based on seismic facies interpretation it remains an inferred extent requiring direct sampling (e.g. by drilling) to be confirmed. The Seq 1 unit is likely to be a combination of gravel, sand and mud facies.

4.1 Relationship between mapped springs and equivalent offshore aquifer units

The inferred extent of the last glacial fluvial gravels offshore does not overlap with the area of mapped springs (Seq 1 Figure 9). The mapped springs are positioned above stratigraphically lower and therefore older sequences, that dip NW on the landward flank of the Kidnappers Ridge and can be expected to include gravel. Based on the mapping of Paquet et al. (2011) the units underlying the springs include Seq 4-7, considered to be 340-710 kyrs. An approximately 10 m-thick post glacial (Holocene) sediment drape caps the angular unconformable strata at the seabed (e.g. Figure 3). This is a fine grained unit that, at the seabed, is predominantly mud with some sand in inner and central Hawke's Bay (Figure 7) (Bostock et al., 2019).

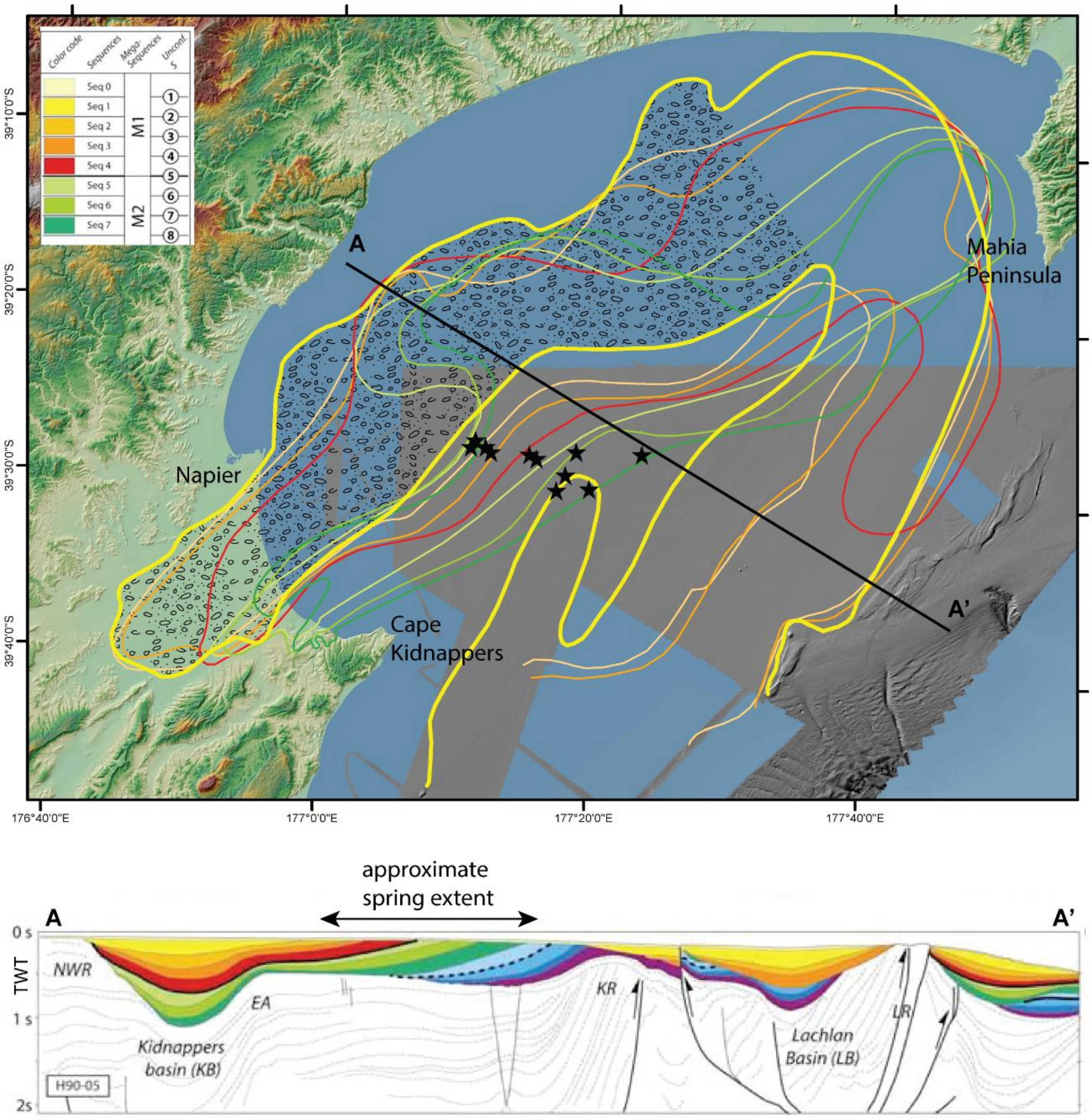

Figure 9 : Summary figure showing mapped units form Paquet et al. (2011) and a corresponding interpreted seismic reflection line A-A'. The mapped "*springs in seafloor*" are shown as black stars and fall completely outside Seq 1 which correlates to the Heretaunga Aquifer. The contour colours in the map correspond to the units (Seq1-7) in the seismic profile A-A'. Seq 1 has a gravel texture over the region where it is interpreted that fluvial gravels exist, along with possible sandy and muddy units (refer Figure 4). Approximate Spring Extent relates to the mapped "Springs in seafloor" from the LINZ chart *NZ 56 Table Cape to Blackhead Point* and shown on top panel.

A single reconnaissance survey line of acoustic water column backscatter exists over the area (Figure 5). The only observed features in the water column most likely related to schooling fish. Multibeam bathymetry covers the entire area of the springs at 10 m resolution and shows no seafloor expression for them (e.g. negative or positive relief indicating pockmarks or mounds).

We have no indication as to what data were used to determine that "Springs in Seafloor" exist as they have been mapped on the chart, so it is difficult to be certain of the veracity of the features. None of the data we have available indicates the presence of springs at the location mapped. The data and interpretations we have screened suggest that if these are freshwater springs they are not related to the Heretaunga Aquifer (e.g., note extent of unit U3 on Figure 3).

5 Recommendations

Our collation and synthesis of data and interpretations of the near surface geology in offshore Hawke's Bay in the context of the offshore Heretaunga Aquifer indicate that the gravel unit that host the aquifer onshore likely continues offshore as a SW-NE trending basin 11-18 km wide that extends across Hawke Bay to the west of Mahia Peninsula. This interpretation is based on facies analysis of seismic reflection (MCS and Boomer) data. New data have been collected since these interpretations were done that have not been interpreted for this project. We cannot confirm the presence of freshwater springs in Hawke's Bay, however interpretations suggest the mapped springs are not related to the offshore Heretaunga Aquifer unit as they sit outside the mapped extent of it. The existing interpretations provide a robust framework for understanding the offshore aquifer and we make the following recommendations for further work to characterise it better.

1. A more regional project be undertaken to understand the offshore extent of the Heretaunga Aquifer. This could include:

    1.1 Acquisition of additional high-resolution seismic reflection data to provide higher density coverage of the inner shelf which would be interpreted in conjunction with existing data.

    1.2 Acquisition of Controlled Source Electromagnetic Data (CSEM) that can map resistivity anomalies related to the salinity of sub-seafloor fluids.

    1.3 Drilling of offshore test boreholes to both constrain stratigraphic models and to undertake water sampling and permeability measurements.

    1.4 Integration with onshore aquifer stratigraphic architecture and hydrogeological modelling.

2. New survey data be acquired to determine if freshwater seepage is occurring, potentially including:

    2.1 A focused water column acoustic backscatter survey over the area that may reveal features related to freshwater seeps.

    2.2 Ocean temperature and salinity data surveys. Other geochemical tracers indicating fresh water such as radium isotopes.

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