Environment Committee Meeting

8 October 2020

This Report relates to Item 5 in the Agenda

“Wairau Aquifer Discharge to Cook Strait”

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Marlborough District Council
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5 March 2020

Attention: Peter Davidson

Dear Peter

Re: Wairau Offshore Groundwater Geological Assessment - Marlborough

Background

You have requested that Beca provides a high-level summary of available information on the offshore geology of Cloudy Bay and the geological evidence for a possible Wairau Aquifer discharge to Cook Strait.

Council are interested in understanding the possibility of offshore groundwater discharge into Cloudy Bay and the possibility of offshore springs. This work assists in the understanding of the aquifer as a complete system. An understanding of the geology offshore is also key to understanding of the risks related to sea water intrusion into the aquifer.

Scope

The scope of our work is as outlined in your instructions to us on 5 December 2019 and includes the review of the geology of the Cloudy Bay Area based principally on a NIWA geophysical study carried out in 2005.

The possibility of an aquifer sea discharge is being re-examined by MDC based on the young age and relatively dilute nature of moderately deep groundwater at the Cloudy Bay coast.

Our scope includes review of geological maps and published scientific papers relevant to Cloudy Bay and Cook Strait marine geology.

We have also spoken to compilers of Geological Q-Map 10 (John Begg and Mike Johnston) and to Joshu Mountjoy of NIWA to discuss the offshore geology and possibility of groundwater discharge on the seabed.

Regional Geology and Faulting

The published geology map of the area is GNS Science's Q Map 10 Geology of the Wellington Area compiled by Begg and Johnston, 2000. The map is part of the national 1:250,000 series geological maps and provides the currently known geology and geological formations. Several concealed active faults inferred from seismic data are shown in Cloudy Bay and the geology offshore is recorded as "*thick (>1000m) deposits of Oligocene-Miocene sedimentary rock identified offshore from seismic interpretation.*"

The onshore geology is well known and is visible in outcrops and exposures as well as the younger formations being recorded from numerous wells on the Wairau Plains. A study by Brown (1981) provided descriptions of the main geological formations that were recognised from correlations between groundwater wells. A 3D geological model of the Wairau Plains geology was developed by GNS Science in 2009 (White

and Tschritter). The geological sequence for the Wairau Plains and elsewhere in Marlborough gives an indication of the geology that can be expected to exist offshore in Cloudy Bay.

White and Tschritter (GNS, 2009) describe the following onshore geological sequence in the Wairau Plains area:

Table 1: Geological Sequence in Onshore Wairau Basin

Formation	Geological Era	Description
Dillon's Point	Holocene	Beach deposits, beach ridges with sand and marine gravel, estuarine mud and silt deposited since post - glacial sea level rise
Rapaura	Holocene	Well sorted terrestrial gravels with sand/silt matrix forming the Wairau Aquifer
Speargrass	Late Pleistocene	Poorly sorted outwash gravels of the Last Glaciation (Otiran) with clay/silt matrix (forms terrace at Renwick)
Wairau Gravels	Late Pleistocene	Terrestrial gravels of Last Glaciation filling the bottom of Wairau Valley
Hillersden Gravel	Late Pliocene	Poorly sorted clay-bound greywacke gravels
Wairau Conglomerate	Early- mid Pliocene	Poorly sorted clay-bound greywacke conglomerate
Upton	Miocene	Poorly bedded greywacke conglomerate and sandstone and siltstone

The inferred thickness of Hillersden Gravels beneath the Wairau Plains is approximately 1000m (shown on cross section A-A, Q Map 10, GNS Science), although this has not been confirmed by drilling.

The offshore geology of Cloudy Bay is less well known than the onshore geology of the Wairau Plains, however seismic reflection data are available from several seismic surveys, the most detailed being the seismic surveys carried out by NIWA in 2005. Geological interpretation has been carried out by Uruski (1992), Barnes and Pondard (2013) and Holdgate and Grapes (2015), however there has been no offshore drilling in Cloudy Bay to provide calibration of the seismic data. The geological interpretation of the seismic profiles are based on correlation with known sedimentary sequences on the East Coast of the North Island and Marlborough.

Uruski and Holdgate/Grapes have examined the seismic data and have interpreted a deep basin (Wairau Basin) extending out into Cook Strait with up to 4 km thickness of sediments. This basin is bounded by the Wairau Fault on the west, the Mt Vernon/Cloudy Bay/Awatere faults on the east and Fault C on the northern edge of the Cook Strait Canyon.

The offshore Wairau Basin likely contains the full sedimentary sequence reaching back in geological time to late Cretaceous age at the base of the sequence. Seismic reflection data also indicates that hard Oligocene limestone is present within the sequence of Tertiary sedimentary rocks. Basement under this basin is likely to be indurated sedimentary rocks (greywacke and argillite) of the Torlesse Group (Pahau Terrane). The

Wairau Basin originated as a half graben rift basin due to crustal extension that began during the Cretaceous and became a depo-centre for sediments accumulating offshore throughout the Tertiary period. The basin has more recently become compressional with uplift occurring on the northwest side of the Wairau Fault.

Holdgate and Grapes (2015) have carried out a comprehensive data review and reinterpretation of all available seismic reflection profiles within Cloudy Bay – Cook Strait (from 1969 – 2005) and have inferred the following geological sequence in offshore Cloudy Bay:

Table 2: Geological Sequence in Offshore Cloudy Bay

Formation	Geological Era	Description
Dillons Point	Holocene	Beach deposits, beach ridges with sand and marine gravel, estuarine mud and silt deposited since post - glacial sea level rise. Forms a confining layer (aquiclude) for the underlying Wairau Aquifer. (shown in green in Fig. 2b)
Rapaura	Holocene	Well sorted terrestrial gravels with sand/silt matrix forming the Wairau Aquifer. Groundwater generally less than 6 years old. (shown in blue in Fig. 2b)
Speargrass/ Wairau Gravels	Late Pleistocene	Poorly sorted outwash gravels of the Last Glaciation (Otiran) with clay/silt matrix. Contains older groundwater due to low permeability and slow recharge. (shown in blue in Fig. 2b)
Unnamed Marine Deposits	Late Pleistocene	Marine deposits laid down between last interglacial and glacial stages (120-30 ka) with prominent foreset beds (shown in yellow in Fig. 2b)
Unnamed Marine and Fluvial Deposits	Late Pleistocene	Marine deposits and gravels laid down during penultimate glaciation stage (140-125 ka) (shown in red in Fig. 2b)
Hillersden Gravel	Late Pliocene	Poorly sorted clay-bound greywacke gravels
Wairau Conglomerate	Early- mid Pliocene	Poorly sorted clay-bound greywacke conglomerate
Upton	Miocene	Poorly bedded greywacke conglomerate, sandstone, siltstone and mudstone
Marlborough Limestone and Weber Formation	Eocene -Oligocene	Limestone and sandstone
Whangai	Late Cretaceous	Black shales

Fault C is an inferred NW-SE orientated fault along the northern edge of the canyon in Cook Strait that separates the Wairau Basin sediments from uplifted Torlesse Group greywacke basement of Rakaia Terrane exposed in the lower North Island.

The Wairau Fault has been active throughout the development of the Wairau Basin and seismic reflection profiles shows 700m of vertical offset has occurred where basement rocks have been uplifted on the north side of the fault. The most recent study of the Wairau Fault by Nicol and Van Dissen (2018) reveals that the mean earthquake recurrence interval on the onshore part of the fault is approximately 1,000 years over the past 6,000 years i.e. 6 earthquakes. A longer earthquake recurrence interval is indicated for the offshore part of the fault in Cloudy Bay, with up to 8 earthquakes having occurred in the past 18,000 years i.e. mean EQ recurrence interval of 2,250 year (Pondard and Barnes, 2010).

The major faults likely penetrate deeply into the crust which is approximately 20-25km thick above the Australian- Pacific Plate Boundary subduction zone dipping gently (approximately 8 degrees) to the west beneath Cook Strait.

NIWA Seismic Survey 2005

NIWA carried out detailed high resolution seismic reflection surveys of Cloudy Bay and Cook Strait in 2005 as part of a study of active faults in the offshore region of Marlborough. The study enabled the paleo-earthquake history and timing and co-seismic vertical displacements to be calculated. This survey provides the most up to date data on the underlying geology in Cloudy Bay and Cook Strait.

Beca has previously supplied you with an A1 poster which summarises the results of this NIWA seismic survey.

On the south side of the Cook Strait Canyon the seismic survey located the position of the following active faults: Wairau, Cloudy, Vernon, Awatere, Kekerengu/ Needles, Tako, Campbell Bank and Chancet Faults.

On the north side of the Cook Strait Canyon the following active faults were located: Shepherds Gully, Ohariu, Wellington, Nicholson Bank, Wharekauhau /Wairarapa and Boo Boo Faults.

None of the above listed faults could be positively connected across Cook Strait Canyon and it is thought that the predominant gravel cover in the canyon and the steep topography has made it difficult for the fault features to be identified on seismic profiles. Holdgate and Grapes (2015) have reviewed the seismic, geological and earthquake history of the Cook Strait faults and have concluded that the Wairau Fault connects to the Shepherds Gully Fault, whilst the Cloudy/Vernon/Awatere Faults connect to the Ohariu/Wellington faults.

The Wairau Fault offshore in northern Cloudy Bay has a pronounced offset of the seabed in a prominent curved fault scarp at water depths 100 –140m (approximately 25-30 km offshore of Cloudy Bay), and rupture of the seabed here is very likely to have produced tsunamis. The seismic profiles show splinter faults off the main Wairau Fault on its northern side and it is likely that these converge with the main fault zone at depth (Holdgate and Grapes, 2015). Additionally two new faults (named New Fault A and New Fault B) were located south of Wairau Fault and these two faults appear to trend towards the Ohariu Fault west of Wellington in the North Island.

Figure 1: Plan of NIWA seismic survey lines in Cloudy Bay with bathymetry of Cook Strait Canyon (in grey shade).

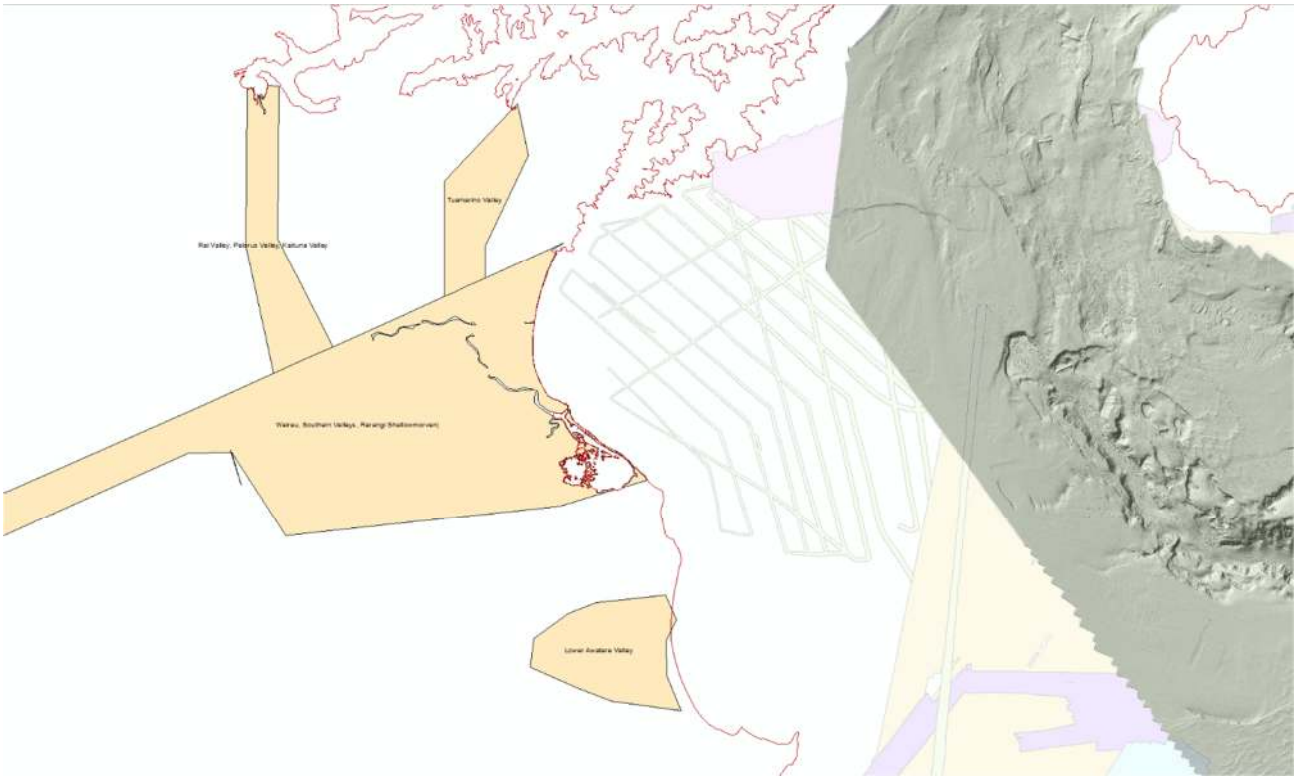
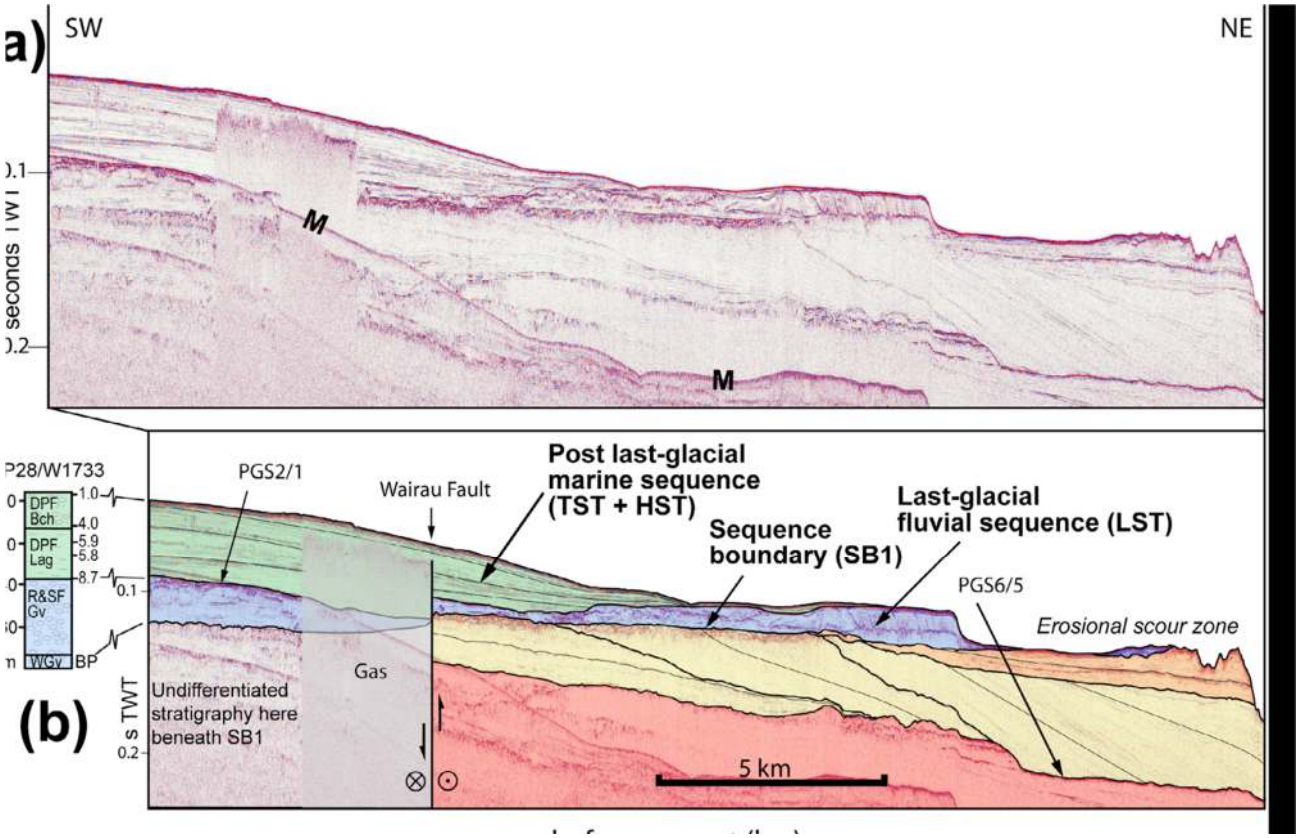


Figure 2: Seismic reflection line and geological interpretation across Wairau Fault trace in outer Cloudy Bay from Figure 4, Pondard and Barnes 2010.

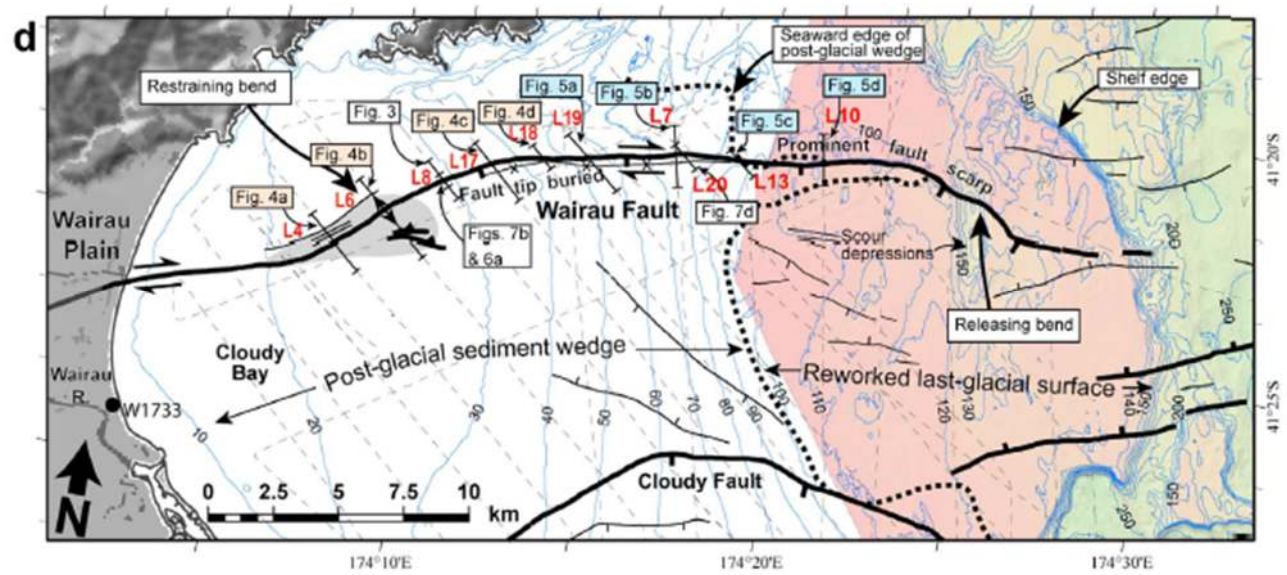


The geological interpretation of Pondard and Barnes 2010 shown in Figure 2 is based on correlation with onshore well P28/W1733 (a 84m deep well located near the coast) and shows the outer limit of marine Dillons Point Formation (in green) overlapping the last glacial fluvial sequence of lower Rapaura Formation and Speargrass Formation (in blue) with older sedimentary units beneath showing large fore-set bedding structures (in yellow and red). An ""*erosional scour zone"* near the edge of the continental shelf and inshore of the edge of the Cook Strait Canyon appears to have stripped away the outer part of the Rapaura Formation.

The profile shown is a 23km long transect (Profile L16) from 10km offshore of Rarangi (at 30m water depth) out to the southern edge of Cook Strait Canyon (at approximate water depth 140m). The Wairau Fault has offset the sedimentary sequence with uplift on the north side of the fault which has a normal sense of movement. The diffuse signal response near the fault indicates natural gas leaking out of the fault zone.

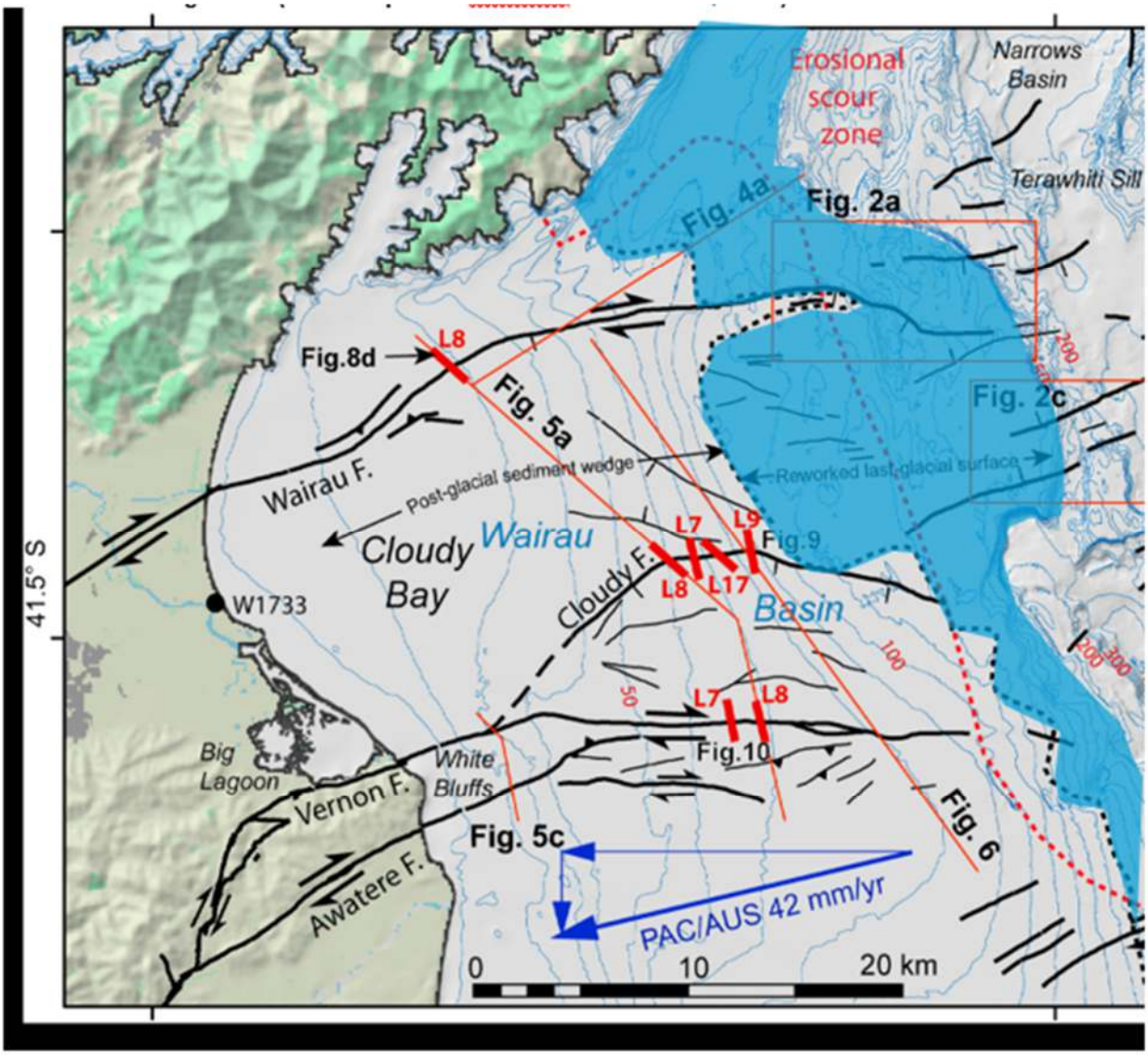
Barnes and Pondard (2010) have plotted the outer extent of the Holocene fluvial deposits (Rapaura Formation) shown as a dotted line in Figure 3 below.

Figure 3: Cloudy Bay Bathymetry with Wairau Fault, post glacial sediment wedge and reworked glacial surface (from Figure 2 in Barnes and Pondard, 2010).



Red numbers in the figure are seismic profiles across Wairau Fault. The post glacial sediment wedge is the offshore Dillon's Point Formation (shown in white). Groundwater discharges could occur in the vicinity of the dotted line where the Rapaura Formation fluvial gravels (shown in pink) become exposed on the seabed. Correlation well W1733 shown near mouth of the Wairau River. Faint dashed lines are the locations of seismic reflection lines.

Figure 4: Active faults of Wairau Basin and Cook Strait Canyon and plotted overlay of likely extent of exposed terrestrial gravels (base map from Pondard and Barnes, 2010).



Plotted overlay in blue represents the approximate area where terrestrial gravels (such as Rapaura Formation) are likely to be exposed on the sea floor on the shelf above Cook Strait Canyon. The black dotted line is the eastern limit of the wedge of overlying Holocene marine cover sediments (Dillons Point Formation). Note that terrestrial gravels have been eroded away in the Cook Strait Canyon, although reworked gravels form the present substrate in the floor of the canyon. The Cook Strait Canyon is east of the blue overlay where water depth is >140m.

Base map taken from Pondard and Barnes, 2010.

Offshore Groundwater Assessment

As far as we aware there are no known groundwater discharges or springs that have been documented in Cloudy Bay.

Near the shoreline of Cloudy Bay groundwater wells have shown that there is groundwater flow in the Rapaura Formation (Wairau Aquifer) with more groundwater in the middle section of the aquifer and less on the fringes (Brown, 1981) and artesian flows are present in some wells.

The seismic surveys of Pondard and Barnes (2010) indicate that the Rapaura Formation extends out as far as the erosional scour zone near the edge of Cook Strait Canyon. The lower Rapaura Formation is likely to have been deposited as a braided plain of fluviatile gravels when sea level was lower during the early Holocene period. The formation is likely to have permeability within well sorted gravels within former river channels, based on the inferred depositional environment.

A similar analogue to the Wairau Offshore Aquifer exists in Wellington Harbour where recent drilling by Wellington Water has encountered the offshore aquifer of the Hutt Valley alluvial gravels extending out into the harbour beneath shallow marine cover sediments at least as far as Miramar Peninsula (pers.comm. John Begg). The groundwater was found to have elevated iron and manganese and concept plans to pipe the groundwater direct to Wellington City via a seabed pipeline were abandoned due to the high costs of treatment.

The geological evidence suggests that it is possible that the Wairau Aquifer groundwater extends well out into Cloudy Bay and may be discharging near the erosional scour zone where the Rapaura Formation is exposed at the seabed.

The NIWA seismic survey shows that the Wairau Fault is leaking gas and does not form an effective seal, so it is also possible that groundwater is leaking out on the seabed at the fault zone.

Additionally, there may be freshwater springs where the overlying Dillon's Point Formation becomes sandy near the early Holocene shoreline. Such springs would likely cause pocking (craters) on the seabed due to sediment disturbance from upwelling groundwater as was discovered by the recent Queen Charlotte Sound bathymetric survey carried out by NIWA. A detailed bathymetry survey of the seabed in Cloudy Bay would likely reveal the locations of pockmarks indicating freshwater springs. NIWA are currently trialling new ship-based geophysical technology in Wellington Harbour that can detect freshwater springs (Joshu Mountjoy pers. comm.) and if this is successful this could be another method to define offshore groundwater discharges in Cloudy Bay.

Geologists John Begg and Joshu Mountjoy agree that groundwater discharge in Cloudy Bay and at the edge of Cook Strait is a realistic possibility.

A review of offshore fresh groundwater in New Zealand by Leanne Morgan and Joshu Mountjoy (2019) assessed a high likelihood of groundwater offshore of the Wairau Valley.

Additional marine surveys and geophysical imaging may be able to provide further evidence of presence of offshore groundwater and groundwater discharge. Drilling would provide more direct information but at much higher cost.

Applicability

This report has been prepared by Beca on the specific instructions of our Client. It is solely for our Client's use for the purpose for which it is intended in accordance with the agreed scope of work. Any use or reliance by any person contrary to the above, to which Beca has not given its prior written consent, is at that person's own risk.

Should you be in any doubt as to the applicability of this report and/or its recommendations for the proposed development as described herein, and/or encounter materials on site that differ from those described herein, it is essential that you discuss these issues with the authors before proceeding with any work based on this document.

Yours sincerely

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On behalf of

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