June 2015

HYDROLOGICAL AND WATER QUALITY REVIEW

Miranda/Pukorokoro - Hydrological and Water Quality Review

Submitted to:
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Report Number: 1523545_7410-002-R-Rev0

REPORT

Golder Associates

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1.0 INTRODUCTION

The Department of Conservation (DOC) has commissioned Golder Associates (NZ) Limited (Golder) to assist with compiling hydrological and water quality data in the Miranda/Pukorokoro area as part of the Living Water Programme.

The Living Water project (the Project) is a joint project between DOC and Fonterra Limited (Fonterra) and involves working with local communities, dairy farmers and other stakeholders.

For the Firth of Thames/Tikapa Moana area the Project is focused on the Miranda-Kaiaua shoreline,which is a seasonal home to thousands of wading and shore birds. The area is the largest example of a chenier plain ecosystem in New Zealand and is listed as internationally important under the International Union for Conservation of Nature and Nature Resources Ramsar Convention.

As part of ongoing enhancement of the area, the Living Water project is investigating opportunities for both ecological restoration and providing additional high tide roosting for shorebirds. To support the project, and to identify issues and risks with establishing the area as a high tide roosting area, an assessment of currently available hydrological and water quality data for the area is required.

This report[1] has been prepared for DOC and presents the following:

- Project Background.
- Scope of work including the desired outcomes of this assessment.
- Details and results of the data collection, compilation and review.
- A gap analysis to identify where information may be missing.
- A proposed monitoring plan to help fill the information gaps.
- Recommendations for future work.

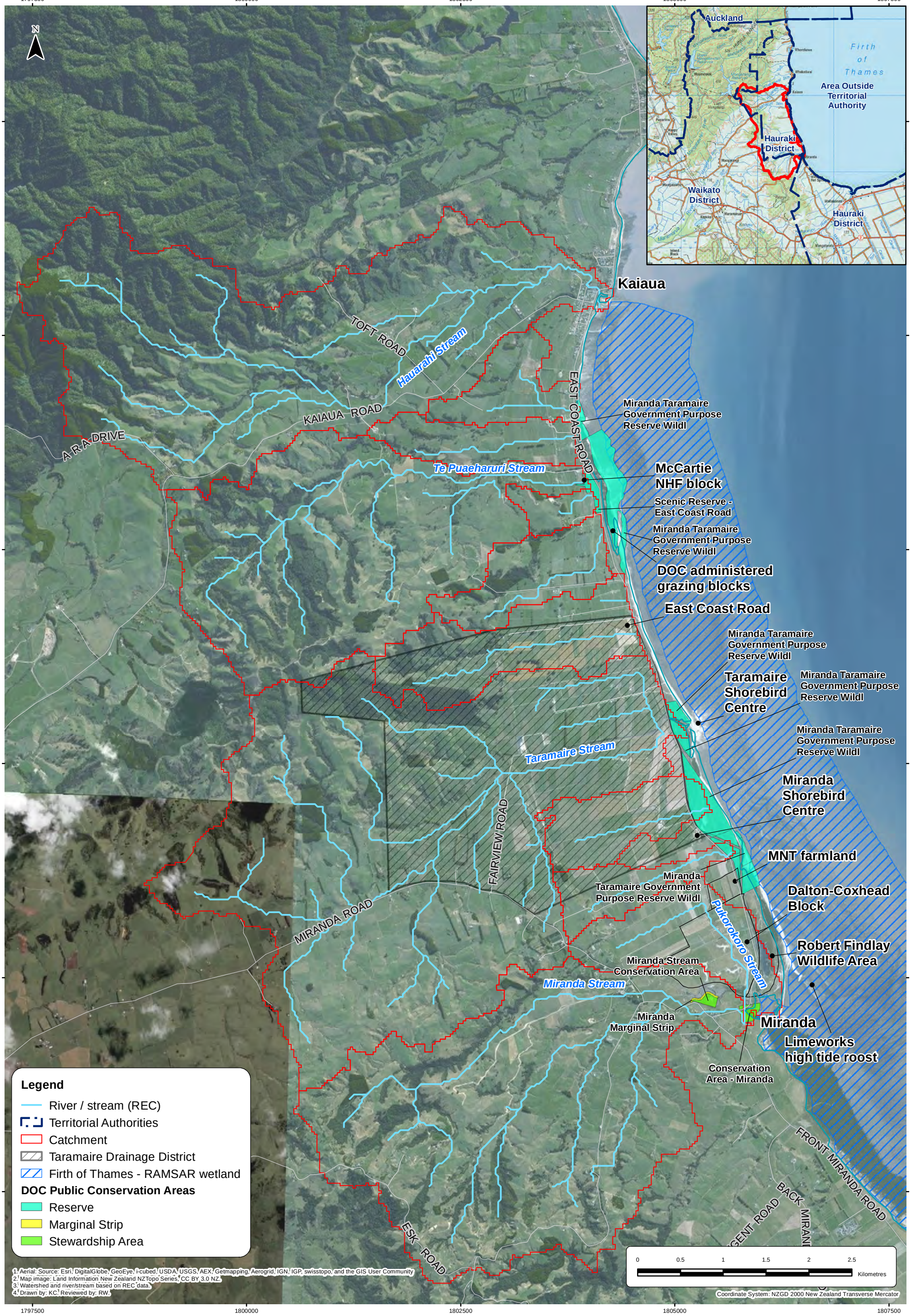
2.0 BACKGROUND

The Miranda coastline, on the western side of the Firth of Thames (Figure 1) is part of the Miranda chenier plain, which extends from approximately Miranda, to near Whakatiwai, around 17 km to the north. Chenier plains are sandy or shelly beach ridges built up over time by wave action. At Miranda a number of these shelly ridges have formed over time. The formation of these ridges, especially the most seaward ridge, leads to wetland areas forming behind and between older ridges.

Management of the Project area falls across multiple agencies including regional and district councils. Management agency boundaries are provided in Figure 1 and include the Auckland Council, Waikato Regional Council, Hauraki District and Waikato District Councils. The area also falls under the DOC Northern North Island Partnership Region and the Coromandel District Partnership District.

In 1975 the Miranda Naturalists' Trust (MNT) was formed to encourage people to visit the coastline and appreciate its wide range of flora and fauna. The MNT established and maintains the Miranda Shorebird Centre and “the hide,” which together receive over 20,000 visitors a year. The MNT and DOC work closely to manage the area and have developed a conceptual management plan for the coastal strip. This plan covers MNT land, the crown owned Miranda Taramaire reserve, the privately owned Dalton Block, the privately owned Robert Findlay Wildlife Area (protected by a QE II National Trust Covenant), and other nearby blocks that are either privately owned or conservation areas.

[1] This report is subject to Golder's standard report limitations attached in Appendix A.



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As part of ongoing enhancement of the area, DOC, in partnership with Fonterra, is looking at options for extending the high tide roosting zone for shore birds in the Miranda area. The initial focus for DOC is to develop what is referred to as the Rangipo Reserve. This 1 ha block is located near the corner of Rangipo and East Coast Road (Figure 1). Planting native species together with vegetation and pest management are proposed. A number of additional options have been considered and include:

- Purchase low lying land bordering Pukorokoro Stream, (i.e., inland of East Coast Road and close to the current roosting areas) and construct a series of shallow tidal ponds in this area (Dalton-Coxhead Block).
- Restoration of a number of DOC administered grazing blocks on the seaward side of East Coast Road north of Taramaire. These were historically infilled and developed/reclaimed for grazing. DOC intends to return these to indigenous "glass pond" wetland areas.

The MNT and DOC have developed a conceptual plan for the area (presented in Golder 2014). Areas of interest from this figure are also presented in Figure 1.

3.0 SCOPE OF WORK

Golder prepared a hydrological review in 2014. This assessment focused on the Pukorokoro Stream area and provided a data review of climate, tidal, hydrogeological, hydrological, topographical and brief details of the existing flood scheme.

As part of this contract Golder has been tasked with updating the Pukorokoro Stream area information, extending the study area north up to Kaiaua, and to include a review of available freshwater quality data and coastal data. The Project area for this data review includes the surface water catchments between Miranda and Kaiaua and associated wetland and estuarine areas.

4.0 DATA REVIEW – AVAILABLE INFORMATION

4.1 Data Review Methodology

Data was reviewed through desktop analysis and stakeholder engagement. A broad review of publicly available documents was undertaken online, including Auckland University and Waikato University thesis searches.

A brainstorming session was undertaken during the Project start-up meeting on 12 March 2015 with DOC and Fonterra staff. This session identified key stakeholders and likely information sources, who were subsequently contacted. A summary table of the key stakeholders, information sources and the information obtained is included in Appendix B.

4.2 Climate

Rainfall

The national climate database CliFlo[2] indicates that rainfall is measured daily at the Miranda Hot Springs rainfall site (Site Number C75233), which is located approximately 4 km south of the mouth of Miranda Stream. Measurements have been made since October 1978 and are on-going (Figure 2).

[2] (http://cliflo.niwa.co.nz/)

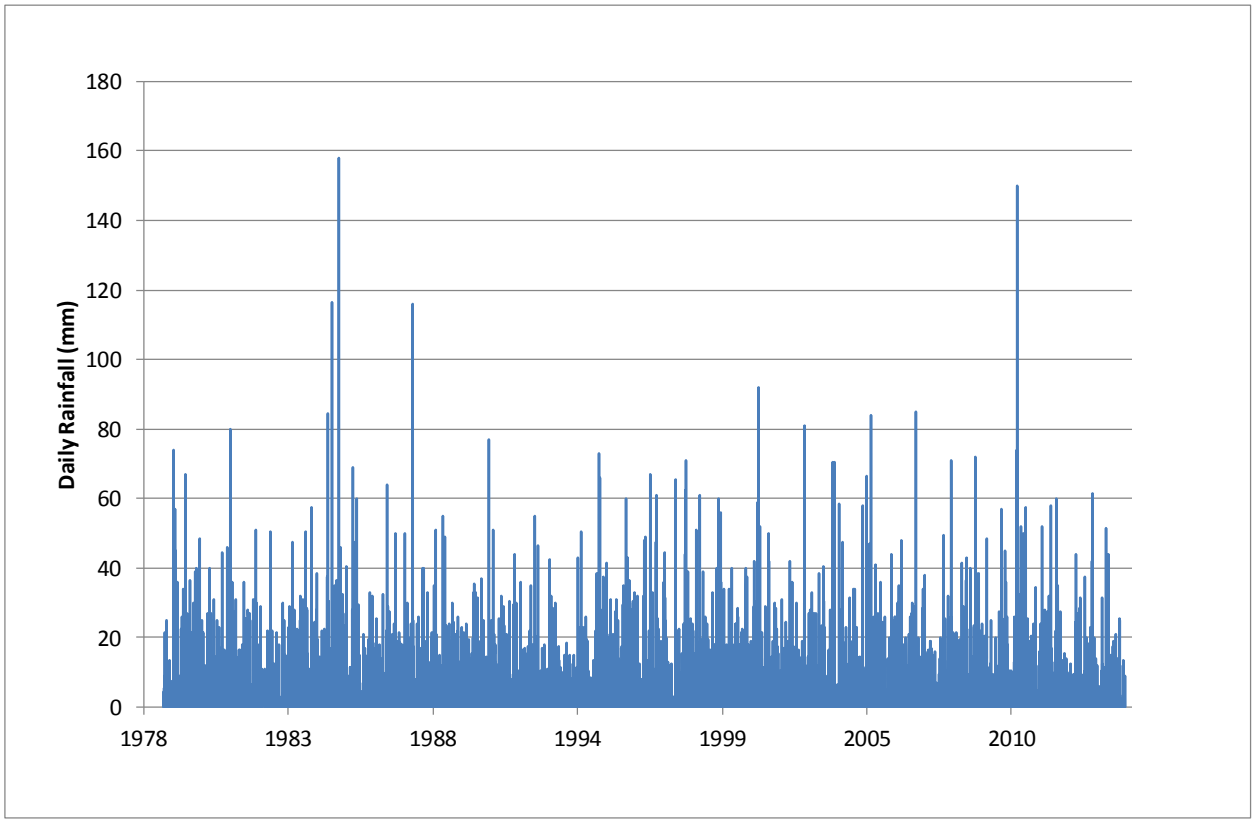

Figure 2: Miranda Hot Springs (Site Number C75233) rainfall record.

According to the Miranda Hot Springs gauge, average annual rainfall is around 1,120 mm. The maximum daily rainfall recorded was 158 mm for the 24 hour period up to 9am on 23 May 1985. Daily rainfall greater than 50 mm has been recorded on approximately 50 occasions, three of which had daily rainfall greater than 100 mm.

Other nearby rainfall recording sites include:

- The Mangatangi Dam, administered by Waikato Regional Council (WRC) located approximately 8 km west of Kaiaua in the Hunua Ranges
- Waharau Regional Park administered by Auckland Regional Council (ARC), located 19 km north of Kaiaua near Wharekawa.

NIWA's high intensity rainfall design system (HIRDS)[3] provides rainfall intensity data for given return periods for the Project area. This can be sourced from the HIRDS online calculator (http://hirds.niwa.co.nz/).

Evaporation

The closest full climate station where evaporation is measured is located in Thames (Thames 2, site number B75152), located approximately 22 km east of the outlet of Miranda Stream. The Thames 2 climate station was opened in January 1971 and measurements are on-going.

[3] http://hirds.niwa.co.nz/

Daily Penman potential evapo-transpiration (PET) recorded at the Thames 2 site varies between 0 mm and 9.8 mm and monthly evaporation varies between 0 mm and 170 mm.

A rainfall and Penman PET plot (Figure 3) indicates that:

- PET will on average exceed rainfall over the summer months of November to February,
- PET and rainfall will be roughly even during the months of March and October
- Rainfall will significantly exceed PET for the remainder of the year, April to September.

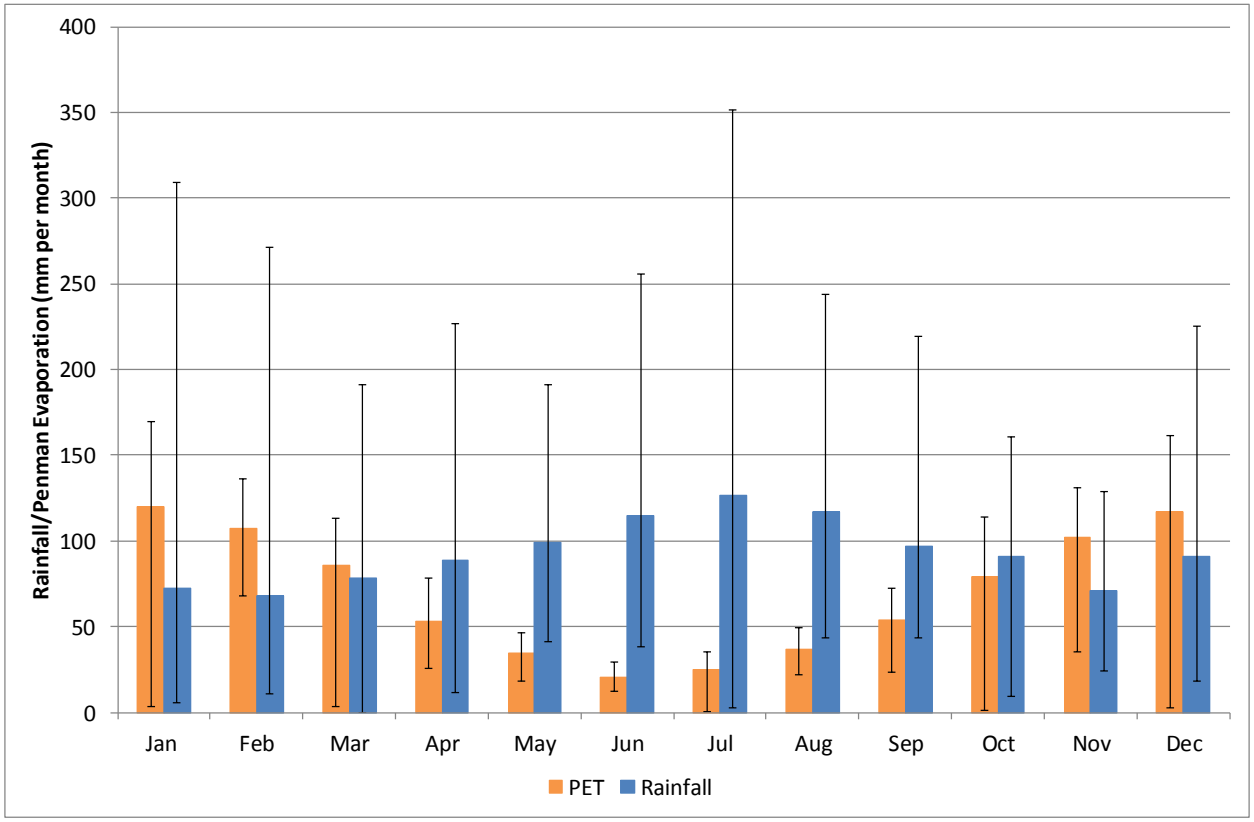

Figure 3: Rainfall (Miranda Hot Springs) and evaporation (Thames 2) data.

Other climate data

The Thames 2 climate station also records daily air temperature, sunshine hours, wind speed/direction and cloud cover.

Figure 4 presents the wind speed and direction at Thames in the form of a wind rose. The data from the Thames 2 site is not likely to be applicable to the Project area for all climate measurements given its location. For example, wind data may be influenced by the Coromandel Ranges to the east and may therefore not reflect the Project area precisely.

Wind data used for hydrodynamic modelling in the Firth of Thames (NIWA 2003) utilised wind data from Auckland, Onehunga , Paeroa and others from north of Auckland. Worst case wind data was sourced from the Mokohinau Islands.

Virtual climate data

NIWA has established a virtual climate station network which extends across the whole of New Zealand in a regular 5 km grid. Virtual climate station (VCS) data are estimates of daily rainfall, potential evapotranspiration, air and vapour pressure, maximum and minimum air temperature, soil

temperature, relative humidity, solar radiation, wind speed and soil moisture for each node on the grid. The estimates are updated every day, based on spatial interpolation of observations made at climate stations located around the country. Data from the virtual climate network is not freely publically available and requires negotiation with NIWA.

The closest virtual climate station to Miranda is site 29232, which is situated near the intersection of Miranda and Fairview roads approximately 4 km inland from the mouth of Miranda Stream.

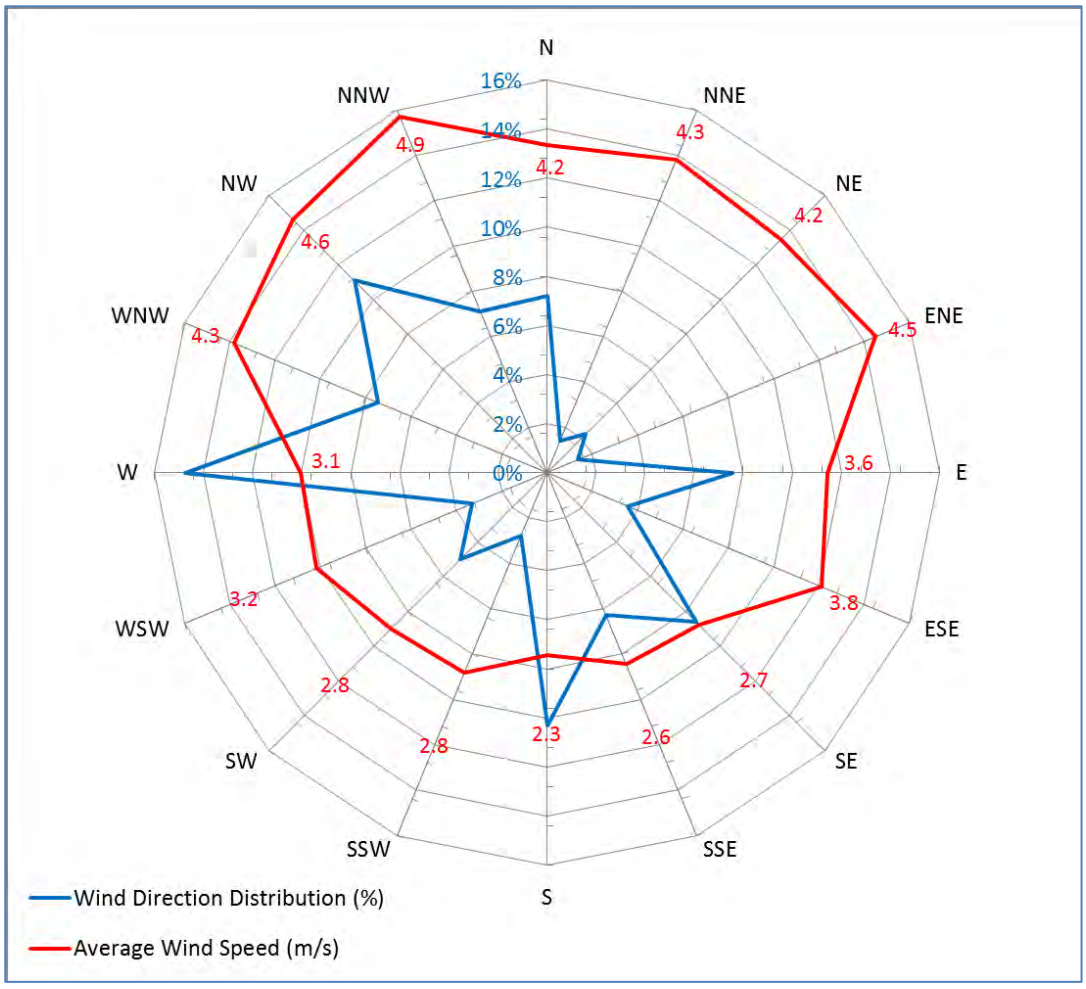

Figure 4: Wind data (Thames 2).

Climate change

It is widely accepted that climate change is occurring due to a warming atmosphere. This will lead to changes in rainfall patterns and temperatures across the country. Current projections as per the Intergovernmental Panel for Climate Change (IPCC) Fifth Assessment Report (IPCC 2013) predict lower annual average rainfall in the northern and eastern districts of the North Island, with higher annual average rainfall elsewhere. Drought periods in eastern and northern New Zealand are projected to double or triple by 2040. The report also highlights that the uncertainty in projected rainfall changes remains large for many parts of New Zealand.

For the Project area, projected changes in annual average rainfall are fairly minimal and are likely to have minimal impact on the Project. However, extreme rainfall depths that are potentially flood generating are predicted to increase by 8 % for every degree of warming. Further information of potential flooding in relation to climate change is provided in Section 4.3.

Climate change research work is currently underway through the CCII[4] (Climate Changes, Impacts & Implications) research project. This is a targeted project that will update and improve projections of climate trends, variability and extremes across New Zealand out to 2100, based on the latest global projections. NIWA are currently heading up the CCII - Firth of Thames (and contributing catchments) coastal study. The Firth of Thames is the coastal focus of the project. The research is expected to provide understanding of the impacts associated with climate change on estuaries and coasts including:

- Groundwater salinization of coastal aquifers.
- Changes in tide range.
- Enhanced upstream saline intrusion affecting portability of water supplies and suitability for irrigation.
- Changes in estuarine ecosystems (e.g., through drowning of intertidal reefs).
- Changing temperature and aquatic plant habitat effects on kaimoana.
- Changes in estuarine sedimentation and consequent effects on ecosystem health.
- Changing underwater light regimes.
- Impacts on intermittently closed and open lakes and lagoons (ICOLLs) and river mouths.
- Land drainage and stormwater management in low-lying land.
- Shoreline erosion.
- Microbial water quality changes (effects on public health).
- Drainage and stormwater systems.
- Bank erosion.
- River flood control measures (e.g., willow management, outflanked by sea level rise).
- Changing effect on river cuts or partial diversions (e.g., Kaituna, Heathcote), bridges and road/rail infrastructure.

This work is currently underway and is a jointly managed by a number of agencies. No published data is available at this time (Pers Comm. G McBride, NIWA, 29 May 2015).

4.3 Hydrology

Hydrological data

There is very little hydrological information available for streams within the Project area.

The closest continuous flow monitoring sites are on the Mangatangi Stream and Mangatawhiri River, located at least 15 km inland and west of the mouth of Miranda Stream. Both flow records are influenced by upstream reservoirs.

[4] http://ccii.org.nz/research-aims/ra2/coastal/

WRC uses data from a flow monitoring site on the Orere River, at Orere Point Road Bridge, to estimate low flow statistics for the streams along the Kaiaua Coast. The Orere River monitoring site is located 17 km to the north of Kaiaua. The Orere River drains a catchment containing a mixture of native forest and farmland.

WRC has undertaken low flow gauging's at six locations within the Project area. These include two locations on the Miranda Stream (five gaugings), two location on the Haurahi Stream (13 gaugings), Te Puaeharuri Stream (five gaugings) and another un-named tributary off Fairview Road (four gaugings). Most of the data relates to low flow periods during 2014 and 2015.

Vegetation and land cover

Vegetation and land cover can affect hydrological processes. Information regarding land cover and natural stream cover is available from DOC's GIS portal[5] and has been presented in Appendix C. Natural stream cover relates to the indigenous vegetation cover in the upstream catchment and is displayed as a proportion of the upstream catchment area.

Firth of Thames hydrological model

NIWA has developed a hydrological model for catchments draining to the Firth of Thames. Catchments of the Project area are included and are based on the River Environment Classification[6] (or REC for short). The model couples with the hydrodynamic model of the Firth of Thames developed by NIWA.

The hydrological modelling will provide information on hydrological fluxes including groundwater. NIWA is also planning to start work on a sediment module to help predict sediment fluxes. Currently the model and results are unpublished but data may be available from NIWA on request (Pers. Comm. C Zammit, NIWA, 8 May 2015).

Modelling is based on the TopNet model[7]. The model is a 2D hydrological model and provides continuous simulation of stream and river flows on 1 hour time-step (1972 – 2015). Key inputs to the model include; rainfall, temperature, humidity, solar radiation, wind speed, sea level air pressure, topography via a digital elevation model (DEM), river network, soil maps, landuse and cover (LCDB)(Pers. Comm. C Zammit, NIWA, 9 June 2015). This data is available from NIWA on request.

Flows for the Project area catchments are calibrated using data from a number of continuously measured flow sites in the Auckland and Waikato regions, including (but not limited to) the following stream and rivers: Waitoa, Tapu, Ohinemuri, Waihou (2 locations),and Piako rivers.

Climate change and impact on flooding

Climate change and the increase in extreme rainfall on the project area is a project risk. IPCC 2013 predicts an increase in extreme rainfall depth by as much as 8 % for every degree of warming. This is likely to lead to increased flooding and erosion in low lying parts of the Project area.

Drainage schemes

Understanding the modified drainage schemes in the Project area is important as these have a significant influence on the hydrology/hydraulics and to a lesser extent the ecology (via fish passage, etc.) of the area.

To the north of the Miranda Shorebird Centre is a 720 ha area called the Taramaire Drainage District (TDD). This district is administered by the Hauraki District Council (HDC). This water management scheme includes 4 km of drains, 5 km of stop banks and 14 culverts/flood gate assets (Pers. Comm. I McLeod, HDC, 28 May 2015). Information relating to the drainage assets was provided by HDC in

[5] http://maps.doc.govt.nz/mapviewer/index.html?viewer=docmaps

[6] maps rivers that have a similar character across New Zealand's landscape

[7] http://tools.envirolink.govt.nz/dsss/topnet-/

the form of a scanned marked up drawing. This information has been digitised into Figure 5. Golder also holds an informal asset register for the scheme (email from I McLeod, HDC, 28 May 2015) but no locations are included. No other formal asset information is readily available. The TDD scheme is also briefly summarised in a report by HDC (2011).

Drainage works in the Project area (south of the Miranda Shorebird Centre) and north of Miranda are undertaken by landowners only and not administered by HDC. HDC has no formal land drainage responsibilities. The drainage system in this area includes a number of stop banks and flood gates on the Miranda and Pukorokoro Stream. Limited details from a site visit and anecdotal evidence are provided in a previous report by Golder (2014). Known drainage assets in the Project area based on the information readily available are presented in Figure 5. No documented information on these assets is available.

4.4 Geology, Hydrogeology, Tectonics and Soils

Geology

The coastal corridor of the project area is dominated by Quaternary age fine grained sediments including generally unconsolidated shell, mud, sand, gravel and peat. Quaternary sediments uncomfortably overlie faulted and fractured Waipapa Group greywacke basement rocks which outcrop to in the west of the Project area. Faulting in the area has led to outcropping of Miocene lavas of the Kiwitahi Volcanic Group and sandstones, siltstones and mudstones of the Waitemata Group in the Project area and outcropping of Te Kuiti Group sediments to the west. Geology maps on the 1:250 000 scale are available as QMaps on the GNS Science website. The geology of the project area is presented in Appendix D, Figure D1.

Hydrogeology

Geological logs indicate bores drilled on the coastal plains intersect quaternary deposits of silts, shells and clays to depths between 20 m and 140 m. These thick deposits of fine material are generally considered to have low permeability. Lenses of buried shell beds constitute local aquifers of limited extent. Surface sediments observed during Golder's site visit were fine silts and muds with some shells layers (Golder 2014). This is consistent with local bore log lithology descriptions.

Groundwater occurs in the coastal shallow shell beds, as covered briefly in Strahan 1997, Bryce 1997 and Cheatley 2000. They found that general groundwater flow direction in the shell beds was toward the Firth of Thames. The water table is shallow (average 1.2 m above mean sea level (amsl)) within the coastal aquifer and fluctuates with the tide (measured 1.56 m amsl). Therefore, there is potential seawater movement through this shallow coastal aquifer. This shallow localised coastal aquifer is considered to be a few meters deep and extends along the coastal strip. Based on the available information, the shallow coastal shell bed aquifer it is not considered to be highly connected to the deeper lensoidal shell bed layers that are buried beneath low permeability sediments and targeted by local bores.

The hydraulic conductivity of the greywacke bedrock is not high however the significant thickness and extent of the unit means it is the largest aquifer in the area. The hydraulic conductivity of the greywacke is dependent on fracture density and as such is highly variable. Groundwater-fed springs are evident at the base of the greywacke hills in Mangatangi, which is 10 km to the west of the Project site (Golder 2012). Although Golder has not found written evidence of springs in the Project area, it is expected that many of the streams originating in the greywacke hills to the north of the catchment will be spring fed.

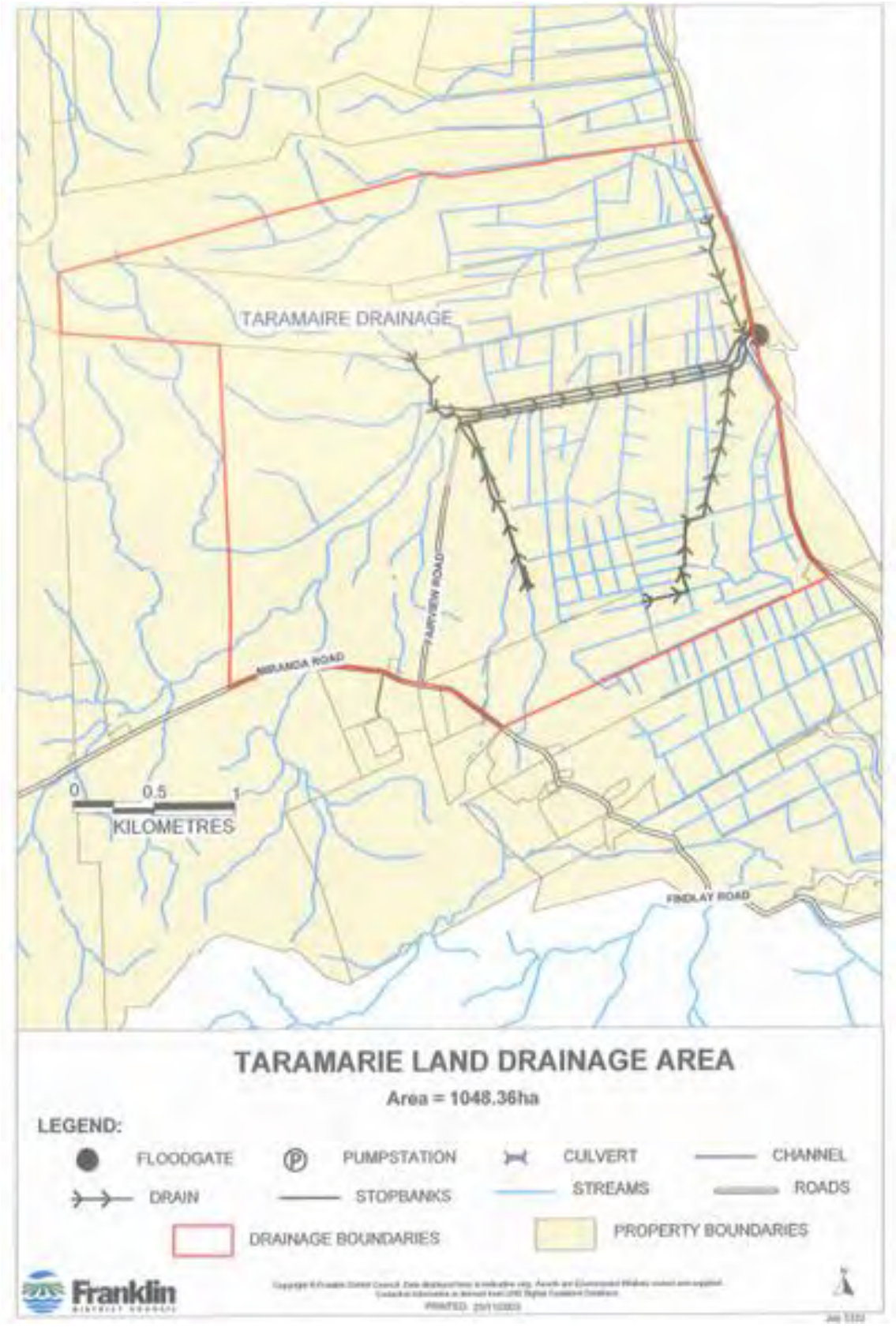

Figure 5: Taramaire Drainage District map.

There are 24 groundwater bores on the WRC bores database within the project area (Figure 6 and Table 1). The current use of each bore is not recorded in the database but it is assumed that many of them are used for domestic and stock water supply purposes. Available bore logs indicate most bores target water bearing layers in the deep fractured basement greywacke or sandstones.

One bore (numbered 72_152) is drilled to 3.2 m and is screened in a thin shelly layer buried within the muds from past chenier ridges. This bore is consented as a monitoring bore. Within the Project area there are six bores (numbered 72_5157, 72_5158, 72_5159, 72_5160, 72_5162, 72_5164) on the WRC database with unknown or shallow depths. These shallow production bores in the coastal plains area are assumed to be connected to thin buried shell lenses which are generally localised.

The area is not highly used for groundwater abstraction and pumping pressure from bores is considered to be low due to the lower permeability of the more prominent muds and silts of the quaternary sediments, compared to the buried shell bed layers. This indicates that there is low potential for salt water to be drawn into the buried shell bed lens system due to pumping. Given the generally low permeability of the sediments and the discontinuous nature of the shell lenses, groundwater resources utilised in this area are unlikely to be affected by a small increase in salt water surface inundation.

Table 1: Bores located within the Project area.

Bore ID	Depth (m)	Casing depth (m)	Assumed targeted geology[(1)]
61_1136	35	26	Waipapa Group basement greywacke
61_1188	112.6	101	Waipapa Group basement greywacke
61_291	132.67	-	Waitemata Group sandstone
61_350	103	40	Waitemata Group siltstone
61_354	72	52	Waitemata Group sandstone
61_667	80	58.5	-
61_922	121.74	104.6	-
72_152	3.2		Quaternary Alluvium – shell bed
72_2165	45	28.5	Waipapa Group basement greywacke
72_2924	135		Kiwitaki volcanics
72_4091	88	73	Waitemata Group mudstone
72_4101	70	47	Waipapa Group basement greywacke
72_4196	80.2	47.5	Waipapa Group basement greywacke
72_4363	97.3	56.7	Waipapa Group basement greywacke
72_5157	-	-	-
72_5158	-	-	-
72_5159	-	-	-
72_5160	-	-	-
72_5161	180	-	-
72_5162	-	-	-
72_5164	-	-	-
72_618	160	142	Waipapa Group basement greywacke
72_7118	72	58	Waipapa Group basement greywacke
72_7136	114	88	Waipapa Group basement greywacke

Notes 1) Assessment made by Golder based on bore position, local geology and bore depth.

1797500 1800000 1802500 1805000

5892500 5890000 5887500 5885000 5882500 5880000

N

Waharau Regional Park rainfall site

Mangatangi rainfall site

Firth of Thames

Thames 2 evaporation site

Miranda Hot Springs rainfall site

161_4

Kaiaua

72_152

61_1136

Hauarahi Stream

161_1

61_922

72_4196

61_1188

72_7118

Te Puaeharuri Stream

3152_2

72_5164

61_667

3100_1

Taramaire Stream

72_4091

72_5157

72_2924

72_2165

61_350

72_5159

61_291

61_354

Pukorokoro Stream

72_5160

552_1

552_2

Miranda Stream

72_5162

72_4101

72_618

Miranda

1256_1

Miranda Hot Springs rainfall site

72_7136

72_4363

Legend

- Study area
- River / stream (REC)
- Groundwater bores
- Flow monitoring (gaugings)
- Miranda Rainfall sites

Type and status of consent

- Farm effluent to land [Current]
- Groundwater monitoring well [Current]
- Groundwater take [Application]
- Groundwater take [Current]
- Surface water take [Application]
- Surface water take [Current]
- Treated farm wastewater to water [Current]
- Treated wastewater to ground [Current]
- Treated wastewater to land [Current]
- Truck wash discharge to water [Current]

0 0.5 1 1.5 2 2.5 Kilometres

1. Aerial: Source: Esri, DigitalGlobe, GeoEye, i-cubed, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community
2. Map image: Land Information New Zealand NZTopo Series, CC BY 3.0 NZ.
3. Watershed and river/stream based on REC data.
4. Drawn by: KC. Reviewed by: RW.

Coordinate System: NZGD 2000 New Zealand Transverse Mercator

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Some of the bores are located in low lying areas and if these areas become inundated by tidal conditions they could allow ingress of saline water if not properly capped. Any disused bores in areas of potential surface inundation should be capped or sealed with grout as per New Zealand drilling standards (NZS 4411:2001).

Tectonics

Tectonics and earth movement in the Project area is important to understand as ground movements may have implications for flooding (via tsunami) and general ground level or drainage changes when considering longer timeframes. The tectonic setting in the Firth of Thames is documented in GNS 2001. The Firth of Thames is interpreted as being part of the Hauraki Rift, an active continental rift structure, extending more than 250 km from a concealed junction with the Taupo Volcanic Zone (TVZ) to the northern Hauraki Gulf. The Hauraki Rift is bounded by Firth of Thames Fault to the west and the Hauraki Fault to the west. The rift structure is infilled with tertiary and Quarternary sediments to a maximum thickness of 2.5 km.

North – south trending faults are associated with the Hauraki Rift. The only known active faults in the area are the Wairoa Fault in the Hunua Ranges and the NNW trending Kerepehi Fault located down the central axis of the Firth of Thames. The Wairoa Fault dips 60 to 70 degrees to the west and has a low vertical slip rate of about 0.1 mm/year. Given the limited movement associated with the faults and their location the risk of significant locally generated tsunami or extensive tectonic induced ground level or drainage changes within the project area is considered minimal.

Soils

Soil maps for the Project area are available online. S-map (latest digital online national soil database) is yet to map the Project area however the fundamental soil layers for the Project area is available. The fundamental soil layers[8] provide detail on chemical attributes, physical attributes, drainage properties, soil moisture properties and soil environment parameters. These layers are presented in Appendix D, Figure D2.

4.5 Water Quality

Only limited freshwater and marine/estuary water quality data exists in the Project area.

Current water quality data provided in WRC 2011 for adjacent (similar landuse) catchments draining to the Firth of Thames (Piako, Waitoa) indicate that water quality issues in these catchments are predominantly related to sediment, nutrient and biological inputs. It is likely that similar water quality issues will arise in the lower reaches of the Project catchments and ultimately the Firth of Thames.

Surface Water Quality

Sediment associated with flooding in Project catchments and re-suspension and deposition within the Firth of Thames, the tidal stream mouths and low lying areas is expected to be the largest management problem for the Project area.

Farming is the predominant landuse in the area and a number of consented effluent discharges were identified on WRC's online GIS mapping tool in the Miranda Kaiaua catchments. Nutrient runoff associated with farming practices will likely influence background water quality within the Project area.

Figure 7 provides the locations of current WRC freshwater monitoring sites. A number of catchments drain to the Firth of Thames (Hauraki Catchment) and may be used to determine general background water quality estimates for the Project area. WRC have also undertaken a limited

[8] From Landcare Research https://soils.landcareresearch.co.nz/contents/SoilData_FSL_Maps.aspx?currentPage=SoilData_FSL_Maps&menuItem=SoilData.

number of discrete surface water samples in the area. Locations include one sample at the Findlay Road Bridge and 2 samples from Miranda Stream.

NIWA are planning to start work on a sediment module that will couple with the hydrological and hydrodynamic model for the Firth of Thames. When this module becomes available, it will help predict sediment fluxes from the Project area catchments.

Groundwater Quality

Groundwater studies and limited monitoring have been undertaken in the Project area.

The shallow coastal groundwater around the Firth of Thames was studied by Bryce 1997 and Cheatley 2000. This work is well summarised in a report by EcoQuest (2004). Studies found that shallow groundwater in the project area have elevated levels of nitrates and phosphorus. Grazed areas had relatively higher levels than non-grazed areas. General groundwater flow direction was towards the Firth of Thames and this could impact wetland vegetation at the coast (especially elevated nitrates). Leaching of nutrients into very shallow groundwater lenses was enhanced by the high water table and porous substrate (shell layers).

Geochemical processes in the local shallow groundwater have been studied by analysing concentrations of major anions and cations. Porous shell layers with an abundance of organic matter and high water table was found to generate anerobic conditions. The geochemical processes found to dominate the estuarine environment were mixing of sea water with shallow groundwater, weathering reactions, oxidation/reduction mechanisms, chemical precipitation, ion exchange and the input of fertiliser. Carbon dissolution was the dominant weathering reaction in sample waters resulting in increased concentrations of calcium and bicarbonate. Concentrations of zinc, aluminium and silica were enriched relative to seawater as a result of the weathering of parent rock material, predominantly silicate materials (EcoQuest 2004).

WRC have limited sampling results from two bores in the project area (61_667 and 72_5158). Both bores were sampled in 2010.

Coastal water quality

Data is available from NIWA and WRC for sampling sites within the Firth of Thames. No specific data is available for the Project area. Generally, nutrients and sedimentation are the main risk to the Firth of Thames, especially re-suspension of sediment in the southern shallow waters. Metals analysis of sediment show elevated levels of some contaminants from historical landuses such as mining. This is more applicable to the eastern shores (Coromandel side) and the main river outlets (e.g., Waihou).

Sea Change (2014) has undertaken a comprehensive review of coastal water quality in the Firth of Thames. General issues outlined in this document are associated with sediment accumulation within estuaries, nutrient runoff from land (especially nitrogen) and localised heavy metals (generally from runoff from urban areas).

WRC (2002) provides water quality information (relevant to aquaculture) in the Firth of Thames as part of research into aquaculture sustainability. This draws extensively from previous NIWA work in the area.

NIWA have been surveying water quality parameters within the Firth of Thames for a number of years. The purpose of the research is to understand the seasonal patterns of productivity and nutrients in the Firth. Parameters including depth, salinity, temperature, density, oxygen, nitrate, phosphorus, ammonia and chlorophyll a were monitored. The results have been published by WRC (2013) and include GIS layers and depth integrated water quality plots. Recent monitoring which is yet to be published includes additional parameters such as turbidity, pH, CDOM and pCO_2 and is associated with NIWA's hydrodynamic modelling currently underway in the Firth of Thames. Data is generally only available seaward of the 5 m depth mark because of the depth limitations of the research vessel (pers comm. John Zeldis, NIWA, 23 April 2015).

Figure 7: Regional water quality monitoring sites (source: WRC 2011).

WRC undertook monthly monitoring at three sites in the southern Firth of Thames between November 2006 and December 2007 (WRC 2011). Results indicated that the Firth of Thames water quality was generally reasonably good with moderate concentrations of the plant nutrients N and P and low concentrations of faecal bacteria (WRC 2011). Because of this a long term monitoring programme was not developed.

DOC has commissioned a report from NIWA that looks at sediment transport and deposition in the Hauraki Gulf (DOC 2015). The document provides results from sediment transport modelling. Of the 19 main rivers modelled, the Waihou and Piako Rivers (both drain to the Firth of Thames) have the highest sediment input rate. This report is not yet publicly available but is expected to become available in late 2015.

Other relevant studies

A number of water quality, ecological and biodiversity studies and reports (Wildlands 2014, EcoQuest 2004, Strahan 2007) have been and are currently underway in the Project area. Much of the information will be of limited value for ascertaining specific background water quality in the Project area.

Wildlands are currently undertaking a biodiversity assessment, including fish identification and some basic macroinvertebrate identification (pers comm. J. Roxborough, QEII National Trust. 22 April 2015), which will provide a good indication of overall stream health and water quality. Once completed, the Wildlands assessment will provide a review of restoration options relevant to water quality including suggestions for revegetation work and riparian planting in the Project area catchments. This is specifically relevant to the Taramaire and Miranda Streams, as the mouths of these streams are the predominant high tide shorebird roosts.

EcoQuest have undertaken a number of fish surveys in intertidal areas of the Project area. This information is however not publicly available (Pers. Comm. R Brejaart, EcoQuest, 22 April 2014).

Strahan (1997) reviewed the plant ecology of the Miranda wetland and looked at restoration options. He included information regarding pH and electrical conductivity on selected number of shallow groundwater piezometers and surface pools (tidal and non-tidal). The documented pH varied little while conductivity was found to be highest in areas influenced by the tide. Conductivity varied between 5 – 36 ms/cm depending on location. The lowest conductivity results were measured from well drained chenier ridges and non-tidal pools.

4.6 Water Use

A number of consents to either take water or discharge water to streams were identified in the Project area. These were identified from WRC's GIS mapping website[9] and are presented in Figure 6.

Currently there are two surface water takes consented in the Project area (one on Miranda Stream and the other on Taramaire Stream) with a further two applications pending (one on Miranda Stream and the other on Te Puaeharuri Stream).

According to the WRC database there is only one current resource consent to take groundwater in the Project area (Figure 6). Consent number AUTH127320 authorises the taking of groundwater from bore numbered 72_5157. This consent authorises abstraction of 60.3 m^3/day, however, the bore depth is not known. There are three further applications pending to take groundwater in the Project area.

[9] http://giswrcmaps.waikatoregion.govt.nz/WRCMaps

There are eight current resource consents authorising discharges of farm effluent to land and a further number of treated wastewater/farm effluent discharges to both land, surface water and groundwater within the project area.

4.7 Coastal Processes

Coastal processes and evolution are important to the study as they help with interpreting how past, present and future coastal evolution may impact or be impacted by proposed changes associated with the Project. The sections below review data available in the key areas of coastal processes.

Coastal evolution and geomorphology

The Miranda chenier plain coastal evolution has been studied in detail at least twice over the last 50 years. Information and data has been gathered to describe and characterize the following:

- Morphology of the modern chenier or spit.
- Morphology, stratigraphy, sedimentology of the chenier plain and the cheniers themselves leading to development of a 3D morphostratigraphic model (Dougherty and Dickson, 2012; Woodroffe et al., 1983). Hypotheses concerning the evolution of the chenier plain in response to sediment supply, sea level change and coastal processes.
- Construction of sea level proxies and relative sea level change curve.
- Southward migration and extension of the modern chenier from 1969 to present.

This information has been derived from:

- Elevation surveys of the chenier plain (Schofield, 1960).
- Historical aerial photos analysis and interpretation (e.g., Woodroffe et al., 1983; Dougherty and Dickson, 2012) used to derive the decadal-scale behavior of the active (modern) chenier and to characterize the depositional environments: foreshore (beach face), shell (storm) ridge and embayed tidal flat in the lee of shell ridge and the general patterns of longshore and cross-shore transport patterns leading to accumulation of shell ridges, onshore migration and north to south alongshore extension of the cheniers – data on migration rate and shoreline progradation rates through time since 1969.
- Sub surface data from sedimentological studies using traditional facies methods of trenching, sampling and sediment size analysis, interpretation, vibra-coring (Hutcheon, 2006), and 7 km of GPS referenced high frequency ground penetrating radar along 2 cross-shore profiles (Dougherty and Dickson, 2012).
- Sea level proxies have been derived from facies relationships delineating the boundary between the chenier beach face and foreshore sediments, and by plotting the range of beach face – nearshore elevations of each numbered chenier against the radiocarbon ages of the corresponding dated chenier (radiocarbon dates derived from preserved shell fragments).

Dougherty and Dickinson 2012 provide the most recent interpretation of the development of the Miranda chenier plain. They have used ground penetrating radar and aerial photo surveys to extend previous interpretations of its formation. They conclude that historical sea level fluctuations helped to form chenier ridges and the plain of the Project area itself. Sea level has retreated to the current level in the past 1000 and 4000 years. The chenier ridge formations associated with storm events have built a series of shell banks as sea level steadily declined. The shell ridges were formed generally parallel to one another across the plain.

LiDAR data and aerial photos may be helpful for understanding coastal evolution in the area. LiDAR data showing shoreline profiles and changes over time are available for the Project area. This is only limited to 2007/2008 with a smaller addition to the Project area added in 2010/2011 (further information in Section 4.8). WRC hold aerial photos of the Project area as part of estuary monitoring as entire region photography. These are limited to the years 2002, 2006, 2007 and 2012. The next data capture is expected in 2017. WRC also hold historical photos of the region in archives. These are not geo-referenced.

WRC monitors changes in the extent and distribution of different intertidal vegetated habitats in selected estuaries in the Waikato region. WRC 2006 provides estuarine vegetation survey data for the Southern Firth of Thames. This was completed using aerial photography and on the ground mapping.

A review of WRC GIS database suggests that no coastal elevation profiles are available in the Project area. Nearby profiling in the southern Firth of Thames, as presented in the Firth of Thames State of the Environment Report (Hauraki Gulf Forum 2011) (Figure 8), indicate that since 1944 bed elevations have increased significantly (> than 1.5 m in places).

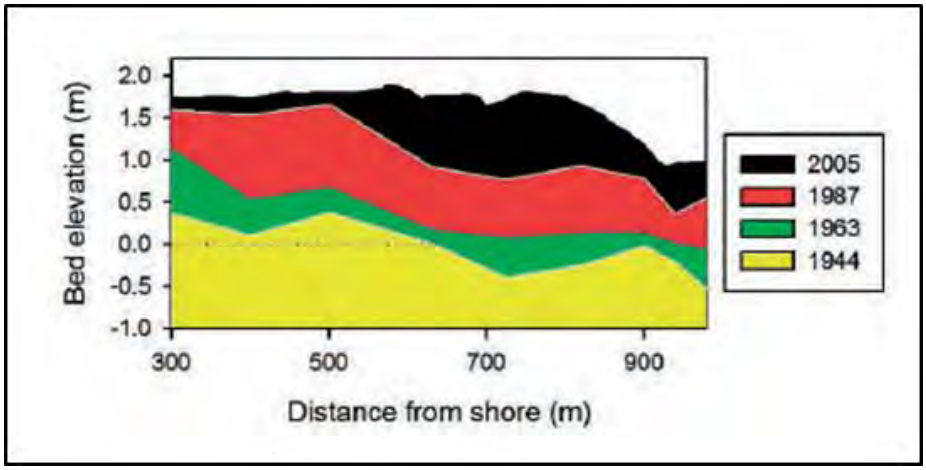

Figure 8: Bed elevation plot for southern Firth of Thames (Source: Hauraki Gulf Forum 2011).

Tidal dynamics

No specific data is available for the estuaries of the Project area however a large amount of data is available for the Firth of Thames. NIWA 2003, NIWA 2007 and WRC 2002 provide a good summary of tidal information for the Firth of Thames. Tidal ranges are typically 2 m to 3 m and tidal currents in the Firth of Thames are generally low (< 0.3 m/s).

Net tidal movement is largely wind driven and stronger currents can be generated by winds. Circulation within the Firth of Thames is dependent on the persistent wind direction and can cause clockwise and anticlockwise circulation. Residual wind pattern in the Firth of Thames is clockwise for all strong wind events above 15 m/s with the southern flanks of the Firth of Thames observing an east to west movement (as summarised in NIWA (2007) and originally produced in Bell et al. (2004)).

NIWA (2003) provides a good overview of tidal movements and mixing within the Firth of Thames and its interaction with the rest of the Hauraki Gulf.

Habitat types around the coastal fringe of the Project area are summarised in Appendix E. The vegetation communities provide some indication of local hydrodynamic conditions.

Sea level data

WRC monitors tidal water levels on the Firth of Thames at Tararu (3 km north of Thames). Water level information for this site is available since May 1990. Analysis of the recorded data suggests

that the high tide level regularly exceeds mean high water spring tide (MHWS) level of 1.6 m above mean sea level (amsl). The maximum recorded water level is 2.47 m amsl, which was recorded on 14 July 1995. The record indicates that between 25 May 1990 and 5 February 2014 there were over 100 tides exceeding 2.0 m amsl (Golder 2014).

NIWA 2007 identifies the mean high water perigean-spring tide (MHWPS) as 1.87 m amsl.

Sea level rise

Sea-level rise estimates based on the IPCC Fifth Assessment Report (IPCC 2013), which for timeframes out to 2099 indicates a base value sea-level rise of 0.3 m to 0.6 m relative to the 1986-2005 average. For a high carbon scenario, this could be as much as 0.5 m to 1 m.

The Ministry for the Environment (MfE 2008) suggest that an assessment of the potential consequences from a range of possible higher sea-level rises (particularly where impacts are likely to have high consequence or where additional future adaptation options are limited). At the very least, all assessments should consider the consequences of a mean sea-level rise of at least 0.8 m relative to the 1980 - 1999 average.

Wave action

Waves are the primary agent for coastal sediment remobilization, erosion, transport and deposition.

General wave climate information is available for the Firth of Thames and is summarized in NIWA 2007. Northerly winds generate short-period waves, typically < 1 m high (NIWA 2007). A 20-year wave-climate hindcast for the Firth of Thames (Kaiaua at 5 m depth) was developed by Gorman & Heydenrych (2004). Extreme significant wave heights do not exceed 1.25 m, with the predominant wave direction being from the N and NNE.

NIWA (2007) suggests that wave heights are likely to be attenuated in the southern Firth due to bed friction as the waves propagate over the intertidal mud flats. Wave periods indicate the sea state is mostly due to local wind-sea interaction, with occasional penetration of swell from the Hauraki Gulf during large cyclonic storms.

Storm surge

Anecdotal evidence dating back to 1938 (1938, 1978, 1995, 1997, 1999, 2005) provides evidence of storm tide events in the Firth of Thames with some direct evidence of damage in the Project area (i.e., 1938). NIWA (2007) provides a review of these events and estimated peak storm tide level. HDC (2011) provides evidence of two January 2011 events, both of which peaked over 2 m amsl. Storm surge is amplified in the Firth of Thames due to bed friction and further exacerbated under northerly wind conditions (NIWA 2007). Storm surge has breached the Pukorokoro Stream flood control works and the eastern highway in the Project area on a number of occasions (Golder 2014).

Sedimentation rates and sediment quality

Sediments smother the intertidal flats that wading birds are foraging on, and are a key driver of the recent expansion of mangroves, which reduces feeding and roosting habitat for many birds (WRC 2008).

There is a large amount of research currently being implemented by NIWA in the area of sedimentation in New Zealand estuaries and specifically in the Firth of Thames. Much of this research focuses on large rivers such as the Waihou River (river mouth located near Thames).

No specific information is available for sedimentation rates of the Project area estuaries and intertidal flats. General information from research in the southern areas of the Firth of Thames suggests sedimentation rates vary spatially and temporally. Pre-1950 vertical sedimentation rates were around 20 mm/yr. Following mangrove colonisation rates increased markedly. NIWA (2007) found deposition rates of 30 mm/yr to 100 mm/yr with variations based on location and mangrove cover/maturity. Much of the sedimentation is due to re-suspension of sediment already delivered to

the Firth of Thames. New research on mangrove expansion and the effect of mangroves on sedimentation is expected to be published by NIWA in 2015 (Pers. Comm. A Swales, NIWA, 8 May 2015).

Sediment quality data has been collected from sites offshore Miranda and Kaiaua and presented in WRC (2007), WRC (2014) and Hauraki Gulf Forum (2011). The monitoring sites are located offshore at Kaiaua and Miranda. Sediment dwelling organisms and sediment grain size, nitrogen and carbon content and algal biomass were measured and are provided in WRC (2014).

Metals analyses are included in WRC (2007). Generally the Firth of Thames sediments are enriched in mercury, lead, cadmium, copper, zinc and arsenic when compared to Raglan Harbour (assumed to be background levels). Miranda and Kaiaua however showed levels consistent with background levels. It is likely that eastern shores of the Firth of Thames have been impacted by historical mining and other high risk land uses.

4.8 Topography and Bathymetry

Topographic Data

LiDAR data is available for the majority of the project area and is available from WRC as grid data. The grid data are relative to the Taratu datum. The accuracy of the data is approximately +-0.5 m. Golder obtained LiDAR covering the lower reaches on the Miranda, Pukorokoro and Taramaire streams in 2014 as part of the initial hydrological review (Golder 2014). The analysis undertaken in Golder 2014 shows a large extent of land in the Miranda area below the spring high tide level (1.6 m amsl) and an even greater area below the perigean-spring tide (1.9 m amsl).

Upper parts of the Miranda and Taramaire stream have not been mapped but it is unlikely that this would impact flood modelling on the coastal fringe in the areas of interest.

WRC note in the metadata that the data is not suitable for contouring at less than 0.5 m intervals or gridding at less than 1 m. The topographic data should be used as an indication only as to the extent of low lying land in the area of interest. More accurate surveying would be required for detailed design work. More information can be found in Golder (2014).

The full dataset can be purchased on request from WRC. The extent of the dataset is provided in Appendix F, Figure F1.

Bathymetric Data

Bathymetric data was utilised in a hydrodynamic model of the Firth of Thames (NIWA 2003). The model has been adapted and further refined with some catchments of interest. It is understood the initial model data is based on marine charts of the Firth of Thames with further refinements made in areas of interest (pers comm Mark Pritchard, NIWA 4 May 2015). The data has a 0.5 km^2 horizontal grid resolution. Bathymetry for the model is available on request from NIWA. NIWA (2003) provides more information on this data.

Bathymetric data for the coastal areas adjacent to the Project area is available to view digitally from the SeaChange project website (SeaSketch - http://www.seasketch.org/) and by request from NIWA. The SeaSketch website will only be available for a limited time and there is currently no permanent database for this information.

5.0 GAP ANALYSIS

5.1 Summary

As indicated by the data review, there is generally fairly limited data available within the Project area. Table 2 provides a summary of current data gaps and these are further expanded in the sections below.

Table 2: Gap analysis summary for the Project area

Discipline	Sub-discipline	Data	Gaps	Description
Climate	All	✓	No	■ Available from a number of nearby climate stations. NIWA virtual climate and HIRDS data also available.
Hydrological	Flows	×	Yes	■ Hydrological model developed by NIWA has some flow information for Project catchments. This will provide an indication of the flow regime of Project area catchments however it is not suitable to be used for design purposes. ■ Some limited low flow data but no other data or assessments of average or flood flows. Very limited data on potential spatial or temporal changes.
	Surface water levels	×	Yes	■ No surface water mapping or assessment is available to identify and understand wetland locations and connectedness to surface water bodies (streams) and the Firth of Thames. Specifically those water bodies behind the shell ridges. ■ No water level data for rivers or wetlands. Especially those influenced by the flood scheme. Water levels and flows are critical to wetland development. ■ Very limited data on potential spatial or temporal changes. ■ No documented information on the levels and extent of the Pukorokoro Stream flood control scheme.
Hydrogeology	Groundwater levels	✓	Yes	■ Some limited information from a range of bores. No specific groundwater level assessment across the Project area.
Water Quality	Surface water	×	Yes	■ Very little information available. Characterisation of general water quality (sediment, nutrients, biological)

Discipline	Sub-discipline	Data	Gaps	Description
				for the Project area is not available.
	Groundwater	✓	Yes	■ Some limited information from some shallow bores.
Coastal	Tidal information	✓	No	■ Good understanding of tides and hydrodynamics in the Firth of Thames.
	Sea level	✓	No	■ No gaps identified. Tararu gauge, Firth of Thames
	Sea level rise	✓	Yes	■ MfE estimates (MfE 2008) available to quantify sea level rise. There is currently no analysis of the impact of sea level rise on the Project area, wetland areas and current drainage scheme.
	Wave climate	✓	No	■ General wave climate data is available for the Firth and specifically Kaiaua. It is deemed acceptable.
	Storm surge	✓	No	■ Reasonable anecdotal evidence available.
	Evolution and geomorphology	✓	Yes	■ Reasonably well studied (2 in last 50 years) ■ No correlations between storms and alongshore migration of the chenier spit has been undertaken. Alongshore sediment movement rates have not been quantified.
	Sedimentation	✓	Yes Yes	■ Information available for the Firth of Thames – localised sediment inputs not verified.
Topographical	All	✓	Yes	■ LiDAR data only. Not available for entire Project area. Vertical resolution is limited to approximately ± 0.5 m and is unlikely to be suitable for detailed localised modelling or construction level design.
Bathymetrical	All	✓	Yes	■ Good coverage of the Firth of Thames. Based on chart data but digitised for the hydrodynamic model (NIWA 2003). ■ No information on bathymetry of stilt ponds glass ponds or other

Discipline	Sub-discipline	Data	Gaps	Description
				permanent water bodies. LiDAR would not be accurate as LiDAR cannot survey past waterbody/pond surfaces.

Notes: × - limited information available, ✓ - some information available, ✓ - good information available.

5.2 Climate

The project area is relatively small with limited elevation changes and climate is not expected to vary significantly across the project area. No specific climate monitoring sites exist within the catchments of interest however climate data from nearby sites (e.g., Miranda Hot Springs and Thames 2) are sufficient to predict the climate of the Project area.

5.3 Hydrology

Limited data exists for the Project area. A small number of low flow gaugings provide information about low flows during the dry summer periods. No other measured flow data is available. Hydrological modelling by NIWA (See Section 4.3) may provide some flow information, however it is unclear if and when this may come available. Flow data is important to determine water levels during typical flow conditions and those during flood events. A brief hydrological assessment should be completed on catchments such as the Miranda and Pukoroko Stream that are tagged for restoration following the collections of background data. This should include collection of some continuous flow data to assess temporal changes and a flood assessment.

No water level data exists for any of the streams and wetlands within the Project area. Streams are heavily influenced by the flood scheme in the area, especially flap gates and stop banks. When specific restoration areas have been identified, continuous[10] background water level data should be collected. This applies to both streams and wetland/pond areas to understand how they function under various tidal and flow conditions.

Limited information is available for the TDD flood management scheme and only anecdotal (from farmers and photos) information is available for the Miranda Pukorkoro private flood scheme. A survey of stopbanks, flap gates and drainage lines including invert levels may be required for detailed flood assessments. The level of details would depend on the assessment. LiDAR data (available from WRC) would provide an indication of stopbank height but flapgate and culvert configurations would likely be required. Golder (2014) provides some general information on stopbank and flood scheme configuration of the Miranda-Pukoroko Stream.

5.4 Water Quality

No long term water quality data exists for streams in the Project area. Water quality impacts in the Project waterways are likely to include sediment inputs (especially from flood events and re-suspension of sediment from the Firth of Thames) nutrients from landuse practices and biological inputs. Water quality data from streams, estuarine areas and selected wetland areas should be collected to determine baseline conditions within the Project area. Site locations would depend on the proposed developments but may concentrate on the Miranda, Pukoroko and Taramaire Streams as well as some ponds such as the bittern ponds and stilt ponds. As a minimum, water sampling and testing under both low flow and high flow conditions is recommended.

[10] Automated equipment available that can be programmed to take samples at fixed or variable time intervals.

5.5 Coastal/Estuarine

The coastal and estuarine areas of the Firth of Thames have been under investigation for some time. Although no site specific information is available, general tidal and sea level data currently being measured is deemed acceptable.

No specific sea level rise investigation has been undertaken in the Project area, specifically an assessment of the impact of this on the exiting wetlands and the current drainage scheme. It is likely that sea level rise will impact the area and be a major risk in the future. Increases in the bed levels of the Firth of Thames may offset this somewhat.

The evolution and geomorphology of the chenier spit is important to shorebird habitat. No historical record of storm events and the correlation of significant NE storm events with episodes of alongshore migration of the modern chenier/spit have been undertaken. Additionally the quantity of sediments transported alongshore/across-shore in response to storms is poorly understood. Each of these would provide further understanding of the chenier formation in the Project area.

Sedimentation rates within the Project area have not been verified. Sediment deposition in the Project stream mouths/estuaries may be similar to that in the Firth of Thames due to the predominant driver for this being re-suspension of sediment. There may be some catchment inputs that may influence this also. The sedimentation rates within the less connected (or unconnected) wetland areas such as those behind the most seaward chenier ridge are not well understood. The impact of sea level rise may also lead to more frequent overflows of the ridge and higher rates of sedimentation.

5.6 Topography/Bathymetry

Current topographic information for the Project area is available from WRC in LiDAR form. Catchment areas in the headwaters are missing for much of the Project area; however topographic data in these areas may not be critical for any flood/tidal modelling. Topographic information is accurate to 0.5 m vertical and a detailed topographic survey will be required to confirm the LiDAR data and support any design work.

Bathymetric data for the Firth of Thames is available. It is not thought that detailed estuarine bathymetry will be required for any assessments in the Project area. Bathymetric data of specific areas of stilt ponds, glass ponds and any other permanent water features may be required if these are highlighted for specific work. LiDAR elevation data will only provide levels to the pond surfaces.

6.0 PRELIMINARY MONITORING PLAN

The Project is focussed on developing and enhancing the Miranda-Kaiaua shoreline. The primary focus is both ecological restoration and providing secure roosting sites for shorebirds. The monitoring plan recommended in this section is intended as a general plan only and presents concepts and ideas for monitoring rather than a specific plan targeted at an agreed proposed project. Consideration has been given to the costs associated with monitoring programmes and the likely benefits of the monitoring for the programme itself.

Monitoring for the Project as a whole should include ecological assessments (i.e. bird counts, stream walks, habitat assessments, vegetation surveys etc.) to understand how any development or enhancement of the Project area affects the ecology.

The monitoring recommended in this section focuses on the hydrological and water quality aspects of the overall Project only and is designed to fill the knowledge gaps identified in this report. Table 3 provides a general overview of monitoring that may be implemented for the Project. Particular monitoring would depend on areas of development/enhancement which is yet to be determined.

Table 3: Suggested monitoring plan.

Parameter	Timing/Frequency	Notes
Water Level	Continuous logging with 2 monthly visits by staff for data download, calibration and maintenance.	Use of water level sensors to measure surface water and groundwater levels. Examples are: ■ Measuring shallow groundwater levels to determine how groundwater levels are affected by floods and tides in the Project area. Shallow piezometer. ■ Measurement of surface water levels upstream and downstream of the Pokorokoro flood scheme stopbanks to understand how tides and floods influence water levels in the Pokorokoro Stream area.
Flow	Continuous logging with quarterly visits by staff for data download, calibration and maintenance.	Use of flow monitoring equipment Examples: ■ Measure flow into and out of the Pokorokoro flood scheme. Instrument is located within the flood scheme outlet pipe and continuously measures water velocities and calculates instantaneous flow rates. ■ Measure flow into and out of a pilot trial Equipment may need to be specialised due to complex flow environment (i.e. tidal). WRC hydrological technicians could potentially be available to provide assistance.
Surface water quality	Quarterly baseline samples, 4 per annum.	Baseline water quality analysis. Examples are: • Nutrient suite (Nitrogen and Phosphorus based analysis), TSS and physiochemical (temp, pH, D.O, turbidity, conductivity). Targeting of high flow and low flows would be required. Use of automatic samplers to sample during flood events are a possibility but likely cost prohibitive.

Surface water quality	Continuous logging with quarterly visits by staff for data download, calibration and maintenance.	Baseline continuous water quality monitoring from in-situ water quality sonde equipment. Measurement of temperature, pH, D.O, turbidity and conductivity on a 15 minute basis.
Groundwater quality	Quarterly baseline samples, 4 per annum	Shallow groundwater bore located in the project area. Example: Nutrient suite (Nitrogen and Phosphorus based analysis) and physiochemical (temp, pH, D.O, turbidity, conductivity).
Aerial Photos	3 - 5 yearly	Aerial photos would assist in monitoring physical changes from development of the Project area. WRC currently undertake 5 yearly flyovers as part of the REMP (see Section 4.7). The area could be expanded to include the Project area. Would require collaboration with WRC.
Survey	Annually	Elevation transects should be established at the site of the proposed restoration projects. These transects would run from the coastal margin and extend a short way inland. It is likely that surveyors will be required onsite to obtain detailed ground elevation data as part of the monitoring programme and any subsequent design phase. A simple coastal elevation transect should be set up where surveyors can quickly and easily take elevations from known locations. This will help to understand how ground levels are changing over time in the Project area.
Stream walks	Annually	Qualitative assessment of restoration/enhancement areas including photo documentation of hydrological, water quality and coastal aspects of the project. Can be incorporated into ecological assessments.

There will be ongoing annual operational requirements associated with any monitoring programme. These include data download, calibration and maintenance of equipment and reporting.

7.0 RECOMMENDED FUTURE WORK

Recommendations for further work including prioritising further investigations and assessments have been carefully considered. The coastal environment is very dynamic and potentially difficult to both model and monitor.

7.1 Monitoring

Golder recommends some basic cost effective baseline monitoring of areas identified for enhancement and restoration (Section 6.0). The purpose of the monitoring would be to establish a baseline to enable measurement of improvements in the area and to also fill some information gaps highlighted in this report.

Monitoring of any recent or proposed development areas such as the potential development (excavation and linking with the Taramaire Creek mouth) near Rangipo Road would be recommended to help measure any changes to hydrology, water quality and coastal processes in the area.

7.2 Suggested Investigations

Sea level is predicted to rise significantly over the next 100 years. An investigation into how this will affect the Project area, and how this might be managed should be undertaken. Currently storm surge is known to overtop East Coast Road. With projected sea level rise this will likely be more frequent and of longer duration meaning high volumes of seawater entering the Project area. This will also be exacerbated by predicted increase in flooding due to climate changes.

A study to gain a detailed understanding of the current flood control system on the Miranda and Pukorokoro Stream. A survey of stopbanks extent and levels, flap gate configuration and invert levels should be undertaken as well as an investigation on how the drainage system is managed. The flood control system is one of the major influences of the hydrology in the Project area and it is poorly documented.

7.3 Modelling

Any modelling undertaken should be simple and cost effective. Basic modelling of the Pokorokoro stream should be undertaken to understand how this functions in relation to floods and tides and to identify areas currently inundated by flooding and the duration of floods. Monitoring data would be required to help with calibration of any model.

Basic modelling should also be undertaken to understand inundation levels of the Dalton and Coxhead properties if:

- Flapgates on the Pokorokoro stream flood scheme were removed or partially forced open, and
- A new pipe linking the Dalton and Coxhead property to the Miranda Stream (linked to sea level fluctuation) was installed. Modelling of vertical elevation and/or automation (both mechanical and electrical).

7.4 Pilot Trials

Golder recommends some small scale trials or pilot studies are undertaken in areas of particular interest. It is understood some small scale development (excavation and linking with the Taramaire Creek mouth) is potentially proposed for the DOC administered grazing blocks near Rangipo Road. This could be used as a pilot trial to both increase understand the hydrological response to wider proposed changes and bring communities and interested parties together to observe the results of changes to local hydrology.

Another potential pilot trial could include opening the flap gate to Miranda/Pokorokoro Stream. Partially or fully opening the flood scheme flap gate during a tidal cycle would allow a better understanding of the levels of potential inundation adjacent to Pokorokoro Stream. This would need to be well organised with local landowners and well monitored. Additional pipe configurations outlined in Section 7.3 could also be trialled. Any trial of this nature would follow some basic hydrological modelling. The purpose of the trial would be to see if the flap gate configuration and or automation could be manipulated to help develop and restore the appropriate parts of the Dalton and Coxhead properties and return it to estuarine conditions.

7.5 Catchment Management

Catchment management within the project area should be ongoing. Landowners and land users in the area should be contacted and educated on catchment wide issues, especially sedimentation and eutrophication of waterways.

WRC should be engaged and asked to become more active in the area and a relationship established to enable research to be undertaken collaboratively. On site workshops to discuss the data gaps, design potential pilot trials and monitoring strategies could facilitate better inclusion within the project.

8.0 CONCLUSIONS

The Living Water project has been established to investigate opportunities to provide additional high tide roosting for shorebirds. Hydrology, water quality and coastal processes will all influence the success of any enhancement within the Miranda Kaiaua area.

This review has outlined and identified a number of data gaps for the area. Golder has made recommendations into further work and monitoring in the catchment aimed at addressing the identified data gaps. Golder considers that workshops to design pilot trials and monitoring programmes would provide a good platform to bring interested parties together. Pilot trials can provide focus and direction to the project.

9.0 REFERENCES

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WRC 2006: Estuarine vegetation survey: Inner Firth of Thames. Environment Waikato Technical Report 2006/40. Prepared by Meg Graeme for Waikato Regional Council, June 2006.

WRC 2007. Trace elements in sediments of the lower eastern coast of the Firth of Thames. Environment Waikato Technical Report 2007/08 . Prepared by Nick Kim for Waikato Regional Council, May 2007.

WRC 2011. Water quality of the Hauraki Rivers and Southern Firth of Thames, 2000–09. Technical Report 2011/06. Prepared by Waikato Regional Council, May 2011.

WRC 2013. Visualising nutrients and phytoplankton in the Hauraki Gulf Marine Park using GIS July 2013. NIWA Client Report No. CHC2013-080. NIWA Project: WRC13503. Prepared by Zeldis J, Bind J, Roulston H, Sykes J, Walkington M for Waikato Regional Council, July 2013.

WRC 2014. Regional estuary monitoring programme 10 year trend report: April 2001 to April 2011. Prepared by Hazel Needham, Nathan Singleton, Hilke Giles, Hannah Jones for Waikato Regional Council, June 2014.

APPENDIX A

Report Limitations

Report Limitations

This Report/Document has been provided by Golder Associates (NZ) Limited ("Golder") subject to the following limitations:

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vi) Where data supplied by the client or other external sources, including previous site investigation data, have been used, it has been assumed that the information is correct unless otherwise stated. No responsibility is accepted by Golder for incomplete or inaccurate data supplied by others.

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APPENDIX B

Contacts and Publications

Living Water Contacts					
Organisation	**Organisation/person**	**Role**	**Email**	**Phone Number**	**Contact**
Auckland Council	Nick Holwerda	Senior Environmental Technician (RIMU)	Nicholas.Holwerda@aucklandcouncil.govt.nz	-	Discussion on 17 March 2015. Referred to Doug Stewart of WRC
	Megan Carbines	Manager Environmental Science (RIMU)/Senior Marine Scientist	megan.carbines@aucklandocuncil.govt.nz	09 484 6237	Emailed enquiry on 14 April 2015. Received reply on 16 April. Referred to SeaChange data layers and Hilke Giles.
	Tim Higham	Manager Hauraki Gulf Forum	tim.higham@aucklandcouncil.govt.nz	-	Emailed enquiry on 21 April 2015. Received reply with relevant info.
Auckland University	Sam Trowsdale	School of Environment	s.trowsdale@auckland.ac.nz	-	Emailed enquiry on 14 April 2015. Replied 14 April 2015, no information. Suggested a thesis search on the Auckland University website
Catchment to Coast	Shane Kelly	Environmental Consultant (HGF report author)	shane@coastandcatchment.co.nz	09 5366238	Emailed enquiry on 21 April 2015. Replied, no new information.
DOC	Greg van Der Lee	Ranger Partnerships - Kaitiaki Manutātaki Hauraki Office	gvanderlee@doc.govt.nz	03 371 3781, 0275681336 , 07 867 9283	Project Manager. Provided input at start up meeting. Generally not a technical information source
	Helen Kettles	Technical Advisor - Marine Ecosystems	hkettles@doc.govt.nz	04 471 3202	Emailed enquiry on 14 April 2015. Provided a list of information. See info links.
	Ben Woodward	Technical Advisor, Freshwater	bwoodward@doc.govt.nz	07 858 1047	Emailed enquiry on 14 April 2015. Replied to email on 20 April 2015, no information.
EcoQuest Education	Ria Berjaart	Academic Director	ria@ecoquest.co.nz	027 435 9179, 09 2322501	Email forwarded by Jono on 17 April 2015. Received information on 22 April.
	Lynette Benson	Part time lecturer	lbenson@openspace.org.nz	09 232 2898	Emailed an enquiry on 16 April 2015. Emailed back to say they had no information relevant to the project.
	Jono Clarke	Director	jono@ecoquest.co.nz	-	Called the office and then emailed an enquiry on 16 April 2015. Returned email to refer me to Ria Berjaart
Fonterra	Tim Brandenburg	North Island Project Manager for living water	tim.brandenburg@fonterra.com	+64 096350029, mobile +64 0278893099	Provided input at start up meeting. Generally not a technical information source
Franklin District Council	Check, probably not, cross over with ARC.	Now Auckland Council		-	See Auckland Council
Golder Associates	Phil Osborne	Principal, Coastal & Offshore Practice Leader	Phil_Osborne@golder.com	-	Provided guidance and review on Coastal sections
HDC	Adrian De Laborde	Tech Services	adrian@hauraki-dc.govt.nz	-	Awaiting contact. Back 12 May
HDC	Ian McLeod	Drainage Manager	mac@hauraki-dc.govt.nz	-	Emailed general enquiry on 14 April 2015. Emailed back to say not available until 12 May. Provided drainage information.
Landcare Research	Linda Lilburne	S-map Project contact	-	-	Discussion with Linda on 18 March 2015. S-map not complete, only fundamental soil layer exists online. LRIS portal - download GIS files for analysis
Miranda Naturalists Trust	Gillian Vaughan	current chair	gillianv@actrix.co.nz	09 298 2500	Emailed general enquiry on 16 April 2015. Called on 1 May 2015, Replied late in Project. Information provided already covered.
NIWA	Kathy Walter	Data Manager - Hydrology	Kathy.Walter@niwa.co.nz	-	Emailed enquiry on 21 April 2015. Followed up on 1 May 2015. No data available in the Project area.
	Andrew Swales	Mangrove study Firth of Thames	Andrew.Swales@niwa.co.nz	07-856-1761	Emailed enquiry on 21 April 2015. Discussed further work to the mangrove study on 2007. Provided two recent papers on mangrove seedling recruitment and mangrove development in the Firth of Thames.
	John Zeldis	Lead author - Firth nutrient loadings and sediment, Principal Marine Scientist.	John.Zeldis@niwa.co.nz	-	Emailed enquiry on 22 April 2015. Replied with nutrient information of the Firth area. Limited offshore of Project area due to depth limitations of vessel. Provided plots of temp, salinity, density, CDOM, chl-a, turbidity, CO2, pH
	Mark Pritchard	Coastal Modeller		-	Called on 4 May 2015. Discussed the bathymetric data and origins and availability,
	Murray Hicks	Sediment Delivery to the Firth	Murray.Hicks@niwa.co.nz	03 343 7872	Emailed general enquiry on 29 April 2015. Referred to Reece Hill at WRC for more information.
	Scott Stephens	Coastal Hydrodynamics	Scott.Stephens@niwa.co.nz	07-856-1745	Called on 4 May 2015. Discussed the bathymetric data Referred to Mark Pritchard.
	Christian Zammit	Hydrologist	Christian.Zammit@niwa.co.nz	03 343 7879 , 027 510 3984	Emailed enquiry on 21 April 2015. Replied 22 April 2015. He developed the hydrologic model that feeds into the hydrodynamic model (A. Swales) for the Firth. Called on 1 May 2015 - left a message. Contact made on 8 May, discussed model and model development.
QEII	Jason Roxburgh	Coromandel Regional Representative for the QEII National Trust	jroxburgh@openspace.org.nz	07 868 2401, 027 535 8327	Discussion with Jason on 22 April 2015. He is undertaking high level biodiversity assessment. Minimal crossover.
Bogman Ecological	Keith Thompson	Director	keith@bogman.co.nz	021 945 252	Made contact on Thursday 2 April. No information. Suggested I contact Chris Hendy formerly of UoW as he had undertaken some WQ sampling.
University of Waikato	Library	-	-	-	Contacted on 4 May, awaiting Info. Available in storage. Need to access it in the Library. Document is well summarised in EcoQuest 2004.
	Dave Campbell	Surface water hydrology and ecohydrology	davec@waikato.ac.nz	-	Made contact on Friday 27 March - no information. Suggested Earl Bardsey did not work it that area either.
Waikato District Council	Parvarti Patel	Asset Engineer	-	07 824 5638	No information, contact WRC

Living Water Contacts					
Organisation	**Organisation/person**	**Role**	**Email**	**Phone Number**	**Contact**
WRC (formerly EW)	Ed Brown	Hydrologist	Ed.Brown@waikatoregion.govt.nz	-	Contacted 22 April 2015, referred WQ to Bill Vant
	Howard Ettema	LiDAR info	Howard.Ettema@waikatoregion.govt.nz	-	Emailed on 16 April 2015. Received info on 17 April 2015.
	Peter Singleton			-	Contacted on 21 April.
	Tracie Dean-Spears	Lakes etc.	Tracie.Dean-Speirs@waikatoregion.govt.nz	-	Contacted 19 March 2015, referred back to Ed Brown.
	Bill Vant	Water quality scientist	-	0800-800-401	Contacted 22 April 2015, referred WQ SOE sites Waitakaruru, (No Suggestions) and Mangatangi. Also SOE reports online.
	Hannah Jones	Coastal Scientist	Hannah.Jones@waikatoregion.govt.nz	-	Provided information mostly covered by report to date. Some further information on FoT coastal data review currently underway.
	Hilke Giles	Marine		-	Suggest talk to Hannah Jones
	Heather Braybrook	Information	Heather.Braybrook@waikatoregion.govt.nz	-	Provided GIS data layers and information on a regular basis
	Reece Hill	Marine Sediment	Reece.Hill@waikatoregion.govt.nz	-	Sent email on 29 April regarding river and marine sediment in the Firth of Thames. No reply. Covered by Heather Braybrook.
	Doug Stewart	Senior Technical Lead	doug.stewart@waikatoregion.govt.nz	0800-800-401	Contact 18 March 2015, Out of the office. Sent email. Made contact again on Friday 27 March - provided some hydrology information.
Waikato District Council	Parvarti Patel	Asset Engineer	-	07 824 5638	No information, contact WRC
Watercare	Andrew Lester	Hydrologist	-	-	Contact on 2 April 2015. No Information available for the catchments of interest.
Wildlands	William Shaw	Ecologist	willie.shaw@wildlands.co.nz	-	Contact on 16 April 2015. Hold an ecology report for the area. Requested from Richard Gillies on 16 April 2015
Wildlands	Richard Gillies	Ecologist	Richard.Gillies@wildlands.co.nz	07 343 9017, 021757522	Contact on 16 April 2015. Requested report. Obtained report.

Publications

Citation	Link	Held by Golders?	Project site specific data?	Comments
Coastal				
Bell, R.G.; Goodhue, N. (2007). Mean level of the sea at Tararu: 1993–2006. NIWA Client Report HAM2007-084 prepared for Environment Waikato.		No	FoT	Sea level data review
Dougherty, A. J. , Dickson, M. E. (2012). Sea level and storm control on the evolution of a chenier plain, Firth of Thames, New Zealand. Marine Geology, 307-310 58-72.	Must be purchased online	No	Yes	Coastal development
Hauraki Gulf Forum 2011: State of our Gulf - Tıkapa Moana, Hauraki Gulf State of the Environment Report Prepared for the Hauraki Gulf Forum, August 2011.	http://www.aucklandcouncil.govt.nz/EN/AboutCouncil/representativesbodies/haurakigulfforum/Documents/hgfstateoftheenvreport2011.pdf	Available online	FoT	Provides overview of some sediment quality monitoring locations offshore (Miranda and Kaiaua)
NIWA 2003: Ecological sustainability assessment for Firth of Thames shellfish aquaculture: Task 1 – Hydrodynamic modelling. Prepared for Auckland Regional Council (Technical Publication No. 252,) and Waikato Regional Council (Technical report 05/05) by NIWA (Client Report: HAM2003-113), July 2003.	http://www.aucklandcity.govt.nz/council/documents/technicalpublications/FoT_Hydro_modelling_TP252.pdf	Available online	FoT	Bathymetry data for the Firth of Thames
NIWA 2007: Mangrove-habitat expansion in the southern Firth of Thames: sedimentation processes and coastal-hazards mitigation. Swales A, Bell RG, Ovendun R, Hart C, Horrocks M, Hermanspahn N, Smith RK. NIWA Client Report HAM2006-138 prepared for Environment Waikato, June 2007.	http://www.waikatoregion.govt.nz/PageFiles/9926/tr0813-1.pdf	Available online	FoT	Provides general overview of the Firth of Thames, no project area specific data.
WRC 2002: Factors Related to the Sustainability of Shellfish Aquaculture Operations in the Firth of Thames: a Preliminary Analysis. NIWA Client Report: EVW02243. Prepared for Environment Waikato and Auckland Council, February 2002.	http://www.waikatoregion.govt.nz/PageFiles/1634/aquaculturereport1to3.pdf	Available online	FoT	
WRC 2006: Estuarine Vegetation Survey: Inner Firth of Thames. Environment Waikato Technical Report 2006/40. Prepared by Meg Graeme for Waikato Regional Council, June 2006.	http://www.waikatoregion.govt.nz/PageFiles/5096/tr06-40.pdf	Available online	FoT	Estuarine vegetation survey of the project area. Discsses riparian management, land drainage, resoration activities.
WRC 2007: Trace Elements in Sediments of the Lower Eastern Coast of the Firth of Thames. Environment Waikato Technical Report 2007/08 . Prepared by Nick Kim for Waikato Regional Council, May 2007.	http://www.waikatoregion.govt.nz/PageFiles/9587/tr0708.pdf	Available online	FoT	Some sediment metals information for Miranda and Kaiaua (offshore)
WRC 2013: Visualising nutrients and phytoplankton in the Hauraki Gulf Marine Park using GIS July 2013. NIWA Client Report No. CHC2013-080. NIWA Project: WRC13503. Prepared by Zeldis J, Bind J, Roulston H, Sykes J, Walkington M for Waikato Regional Council, July 2013.	http://www.waikatoregion.govt.nz/PageFiles/27976/TR201350.pdf	Available online	FoT	Nutrients, phytoplankton, salinity etc.
WRC 2014: Regional Estuary Monitoring Programme 10 year trend report: April 2001 to April 2011. Prepared by Hazel Needham, Nathan Singleton, Hilke Giles, Hannah Jones for Waikato Regional Council, June 2014.	http://www.waikatoregion.govt.nz/tr201441/	Available online	FoT	Sediment monitoring offshore at Miranda and Kaiaua
Water Quality				
SeaChange 2014: Water Quality and Catchments - collation of information. WRC Doc # 3030353. Prepared for WRC by P Singleton, July 2014.	http://www.seachange.org.nz/PageFiles/365/Water%20Quality%20and%20Catchments%20RT%20-%20Technical%20Report%201%20-%20Collation%20of%20Information.pdf	Available online	None	Provides a good review of water quality and catchment overview. A lot of information regarding sediment, nutrients and contaminants in both the streams and coastal areas.
WRC 2011: Water Quality of the Hauraki Rivers and Southern Firth of Thames, 2000–09. Technical Report 2011/06. Prepared by Waikato Regional Council, May 2011.	http://www.waikatoregion.govt.nz/PageFiles/19426/TR2011-06.pdf	Available online	None	
Hydrogeology				
Bryce, A. (1998). The chemistry of shallow groundwater's at Miranda, Firth of Thames. Unpublished master's dissertation, University of Waikato, Hamilton, New Zealand.	University of Waikato Library archives	No	Yes	Available from the University of Waikato Library. Not sighted. Review available in SeaChange 2014.
Hydrology and Drainage				
Eco quest 2004: Muddy Feet, Firth of Thames Ramsar Site Update, 2004. EcoQuest Education Foundation Report Series No. 1 . Prepared by EcoQuest Education Foundation for Waikato Regional Council, Thames Coromandel District Council and Hauraki District Council, 2004	http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.130.2421&rep=rep1&type=pdf	Available online	Limited	General review of Firth of Thames catchments, history of drainage and reclamation. Provides some groundwater quality information and general review of hydrology.
Golder 2014: Miranda High Tide Roosting Areas – Initial Hydrological Assessment. Report No. 1378610548-003. Prepared by Golder Associates for Department of Conservation, Hamilton.	\\AKL2-V-FILE01\AKL-DUN-FILES\Projects-Numbered\13786x\10xxx\1378610_548_DepartmentOfConservation_MirandaHydrologyWetland\Reports (Golder)\1378610548-003-R-Rev0-Initial hydrological assessment.pdf	Yes	Yes	
HDC 2011: Drainage Manager's Report on Kaiaua Issues. Prepared by Drainage Manager and District Engineer, October 2011	http://www.hauraki-dc.govt.nz/files/council_documents/minutes/council/2011/October%2026/819756-Drainage-Kaiaua.pdf	Available online	Limited flooding evidence	Information on drainage scheme in project area and some flood events.
Low flow gauging data for Miranda to Kaiaua	Spreadsheet supplied by WRC	Yes	Yes	
General				
Merrett, M.; Clarkson, B. (1997). Vegetation survey of the foreshore from Miranda to Kaiaua. Prepared for Department of Conservation, Auckland Conservancy by Waikato Botanical Society. 28 p.	http://docs.niwa.co.nz/library/public/EWTR2006_40a.pdf	Available online	Limited	
Muddy Feet, Phase II	http://www.arc.govt.nz/albany/fms/main/Documents/Environment/Coastal%20and%20marine/Muddy%20Feet%20Phase%20II%20Firth%20of%20Thames%20Ramsar%20Site%20Gap%20Analysis%20-%20Working%20Paper.pdf	Available online	None	Gap analysis of information relevant to the Firth of Thames. Provides overview of key risks to the Firth of Thames and identifies the gaps in information around the key risks.
Muddy Feet, Phase III	http://www.basecampfoundation.org/documents/Muddy%20Feet%20Phase%203%20-%20restoration%20action%20plan.pdf	Available online	None	Restoration and action plan for the Firth of Thames and ecotourism plan. Relevant but of little use.
Plant Ecology of Miranda Wetlands, Restoration Options - Dougal Strahan	http://researchcommons.waikato.ac.nz/bitstream/handle/10289/8532/thesis.pdf?sequence=1	Available online	Yes	
SeaChange 2014b :Biodiversity and Biosecurity: collation of information. Prepared by SeaChange 2014.	http://www.seachange.org.nz/PageFiles/393/Biodiversity%20and%20Biosecurity%20RT%20-%20Technical%20Report%201%20-%20Collation%20of%20Information.pdf	Available online	Limited	
Wildlands 2014: Evaluation of Restoration Management Requirements At Miranda – Pukorokoro. Contract Report No. 3156. Prepared by Wildlands Consultants for Department of Conservation, March 2014.	\\AKL2-V-FILE01\AKL-DUN-FILES\Projects-Dynamics\2015\7410\1523545_MirandaHydrologyReportofConservation\Data\Golder Data (Current)\From Wildlands 16 April 2015\3156 Miranda Pukorokoro Evaluation of Restoration Options.pdf	Yes	Limited	
WRC 2008: Priorities and Related Actions for the Sustainable Management of the Firth of Thames Ramsar site Muddy Feet Phase II: Keep the Birds Coming. Prepared for WRC by B. Brownell, J. Dahm and M. Graeme, March 2008.	http://www.waikatoregion.govt.nz/PageFiles/6182/tr0815.pdf	Available online		

APPENDIX C

Landcover Types

1797500 1800000 1802500 1805000 1807500

5892500 5890000 5887500 5885000 5882500 5880000

N

Firth of Thames

Legend

Catchment

River and stream pressures - natural cover

- 0.9 - 1.0
- 0.8 - 0.9
- 0.7 - 0.8
- 0.6 - 0.7
- 0.5 - 0.6
- 0.4 - 0.5
- 0.3 - 0.4
- 0.2 - 0.3
- 0.1 - 0.2
- 0.0 - 0.1

Land Cover Database version 4.0

Artificial Surfaces

- Built-up Area (settlement)
- Surface Mines and Dumps

Bare or Lightly Vegetated Surfaces

- Sand and Gravel

Water Bodies

- Lake or Pond

Cropland

- Orchard Vineyard and Other Perennial Crops

Grassland, Sedge and Saltmarsh

- High Producing Exotic Grassland
- Low Producing Grassland
- Herbaceous Freshwater Vegetation
- Herbaceous Saline Vegetation

Scrub and Shrubland

- Gorse and/or Broom
- Manuka and/or Kanuka
- Broadleaved Indigenous Hardwoods

Forest

- Forest - Harvested
- Deciduous Hardwoods
- Indigenous Forest
- Exotic Forest
- Mangrove

1. Aerial: Source: Esri, DigitalGlobe, GeoEye, i-cubed, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community
2. Map image: Land Information New Zealand NZTopo Series, CC BY 3.0 NZ.
3. River and landcover data sourced from FENZ and LENZ,
4. Drawn by: KC. Reviewed by: RW.

0 0.5 1 1.5 2 2.5 Kilometres

Coordinate System: NZGD 2000 New Zealand Transverse Mercator

Golder Associates

TITLE | LANDCOVER TYPE AND NATURAL COVER OF RIVERS

JUNE 2015

PROJECT | 1523545

C1

K:\GIS\Projects-Dynamics\2015\7410\1523545_MirandaHydrologyReportofConservation\MapDocuments\AppC1_LandcoverType_NaturalCoverOfRivers _A3P_GIS.mxd

APPENDIX D

Geology and Soils

1800000 1802500 1805000 1807500

5892500 5890000 5887500 5885000 5882500 5880000

N

Kaiaua

Miranda

Legend

- Accurate fault
- Approximate fault
- Concealed fault

NZL GNS 1:250K geological units (Key Name)

- Amokura Formation of Warkworth Subgroup (Waitemata Group)
- Late Miocene to Middle Pleistocene river deposits
- Manaia Hill Group sandstone and siltstone (Waipapa terrane)
- Mangakotuku Formation of Lower Te Kuiti Subgroup (Te Kuiti Group)
- Mercer Sandstone of Meremere Subgroup (Waitemata Group)
- Miranda unit basaltic andesite (Kiwitahi Volcanic Group)
- OIS1 (Holocene) ocean beach deposits
- OIS1 (Holocene) river deposits
- OIS5+-OIS2 (Middle Pleistocene - Late Pleistocene) river and hill slope deposits
- Waikato Coal Measures of Lower Te Kuiti Subgroup (Te Kuiti Group)
- Waipapa Group chert (Waipapa terrane)
- Waipapa Group sandstone and siltstone (Waipapa terrane)

1. Aerial: Source: Esri, DigitalGlobe, GeoEye, i-cubed, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community
2. Map image: Land Information New Zealand NZTopo Series, CC BY 3.0 NZ.
3. QMAP GIS, CC-BY-3.0-NZ.
4. Drawn by: KC. Reviewed by: RW.

0 0.5 1 1.5 2 2.5 Kilometres

Coordinate System: NZGD 2000 New Zealand Transverse Mercator

Golder Associates

TITLE | GEOLOGY MAP (QMAP) AROUND KAIAUA AND MIRANDA

JUNE 2015

PROJECT | 1523545

D1

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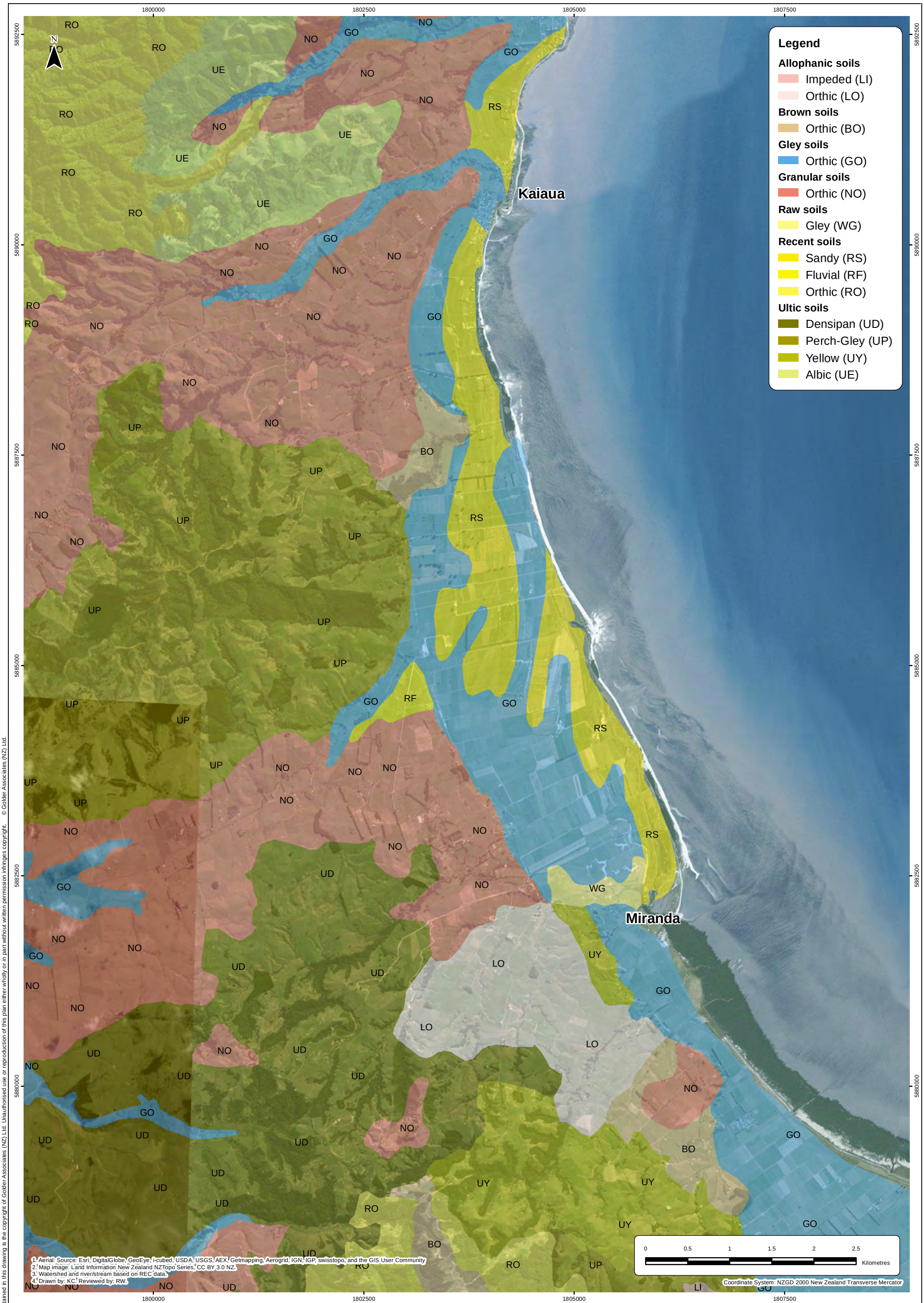

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TITLE | SOIL MAP AROUND KAIAUA AND MIRANDA

JUNE 2015

PROJECT | 1523545

D2

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APPENDIX E

Habitat Types

1797500 1800000 1802500 1805000 1807500

5892500 5890000 5887500 5885000 5882500 5880000

N

Kaiaua

Kaiaua

Sheltered Shallow Reef

Mudflat

Biogenic Mangrove

Biogenic Mangrove

Biogenic Saltmarsh

Biogenic Saltmarsh Above MHW

Biogenic Saltmarsh Above MHW

Mudflat

Biogenic Saltmarsh Above MHW

Miranda

Miranda

Biogenic Saltmarsh

Biogenic Saltmarsh Above MHW

Biogenic Mangrove

Mudflat

High Current Shallow Mud

Shallow Mud

High Current Shallow Gravel

Sheltered Shallow Gravel

Sheltered Shallow Sand

Shallow Mud

Legend

Catchment boundary

0 0.5 1 1.5 2 2.5

Kilometres

Coordinate System: NZGD 2000 New Zealand Transverse Mercator

1. Aerial: We acknowledge the contributions of data and advice from many sources including: the Ministry of Fisheries Spatial Information Management Team; the Marine Conservation Team and Marine Technical Support Officers f ; the National Institute
Copyright: ©2013 Esri, DeLorme, NAVTEQ
Source: Esri, DigitalGlobe, GeoEye, i-cubed, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community
2. MPA data sourced from Arcgis server SeaSketch hauraki gulf project.
3. Drawn by: KC. Reviewed by: RW.

1797500 1800000 1802500 1805000 1807500

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TITLE | MARINE PROTECTED AREA POLICY HABITAT 2011

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E1

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APPENDIX F

LiDAR Data Extent

1797500 1800000 1802500 1805000 1807500

5892500 5890000 5887500 5885000 5882500 5880000

N

Kaiaua

Hauarahi Stream

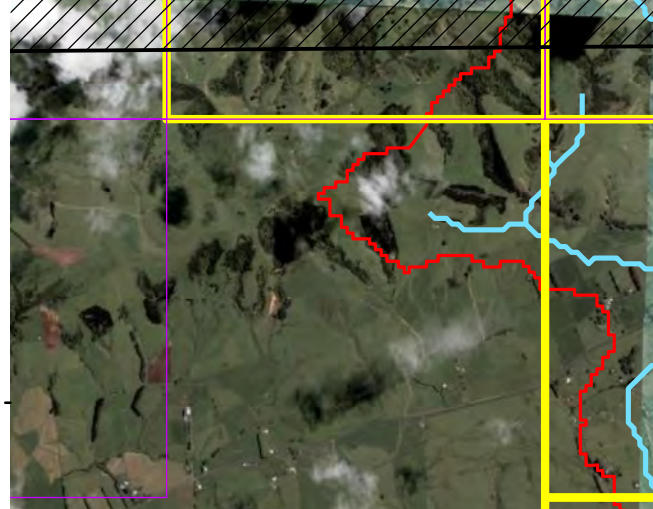
Te Puaeharuri Stream

Taramaire Stream

Pukorokoro Stream

Miranda Stream

Miranda



Legend

- WRC LiDAR Extent
- LiDAR 2010-2011 tiles
- LiDAR 2007-2008 tiles
- River / stream (REC)
- Catchment

1. Aerial: Source: Esri, DigitalGlobe, GeoEye, i-cubed, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community
2. Map image: Land Information New Zealand NZTopo Series, CC BY 3.0 NZ.
3. Watershed and river/stream based on REC data.
4. Drawn by: KC. Reviewed by: RW.

0 0.5 1 1.5 2 2.5 Kilometres

Coordinate System: NZGD 2000 New Zealand Transverse Mercator

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TITLE | LIDAR EXTENTS

JUNE 2015

PROJECT | 1523545

F1

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