March 2014

MIRANDA HIGH TIDE ROOSTING AREAS

Initial Hydrological Assessment

Submitted to:
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Report Number. 1378610548-003

REPORT

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FIGURES

1.0 BACKGROUND

The Miranda coastline, on the western side of the Firth of Thames (Figure 1), and the nearby wetlands are 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. The Miranda Naturalists' Trust (MNT) was formed in 1975 to encourage people to visit the coastline and appreciate its wide range of flora and fauna. MNT established and maintains the Miranda Shorebird Centre and “the hide” which together receive over 20,000 visitors a year. Together the MNT and the Department of Conservation (DoC) work closely to manage the area. Efforts are being made to develop a co-ordinated management plan for the coastal strip covering MNT land, the crown owned Miranda Taramaire reserve, the privately owned Dalton Block, the privately owned Robert Findlay Wildlife Area, which is protected by a QE II National Trust Covenant and other nearby blocks, which are either privately owned or conservation areas.

As part of ongoing enhancement of the area, DoC, in conjunction with Fonterra Co-operative Group Limited (Fonterra) are looking at options for extending the high tide roosting zone for shore birds in the Miranda area. One option is to 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. The MNT and DoC has developed a conceptual plan for the area, as shown in Figure 2. To identify issues and risks with establishing the area as a high tide roosting area, DoC requires a hydrological assessment of the site and DoC has commissioned Golder Associates (NZ) Limited (Golder) to carry out this work.

This report[1] summarises the initial assessment undertaken to gather information on how appropriate the site and hydrological conditions are for the proposed ponds. Surface water movements are reviewed, including the potential for flushing of the ponds, saltwater intrusion and potential effects on pastureland beyond the proposed area being considered for purchase and/or covenant.

2.0 SCOPE

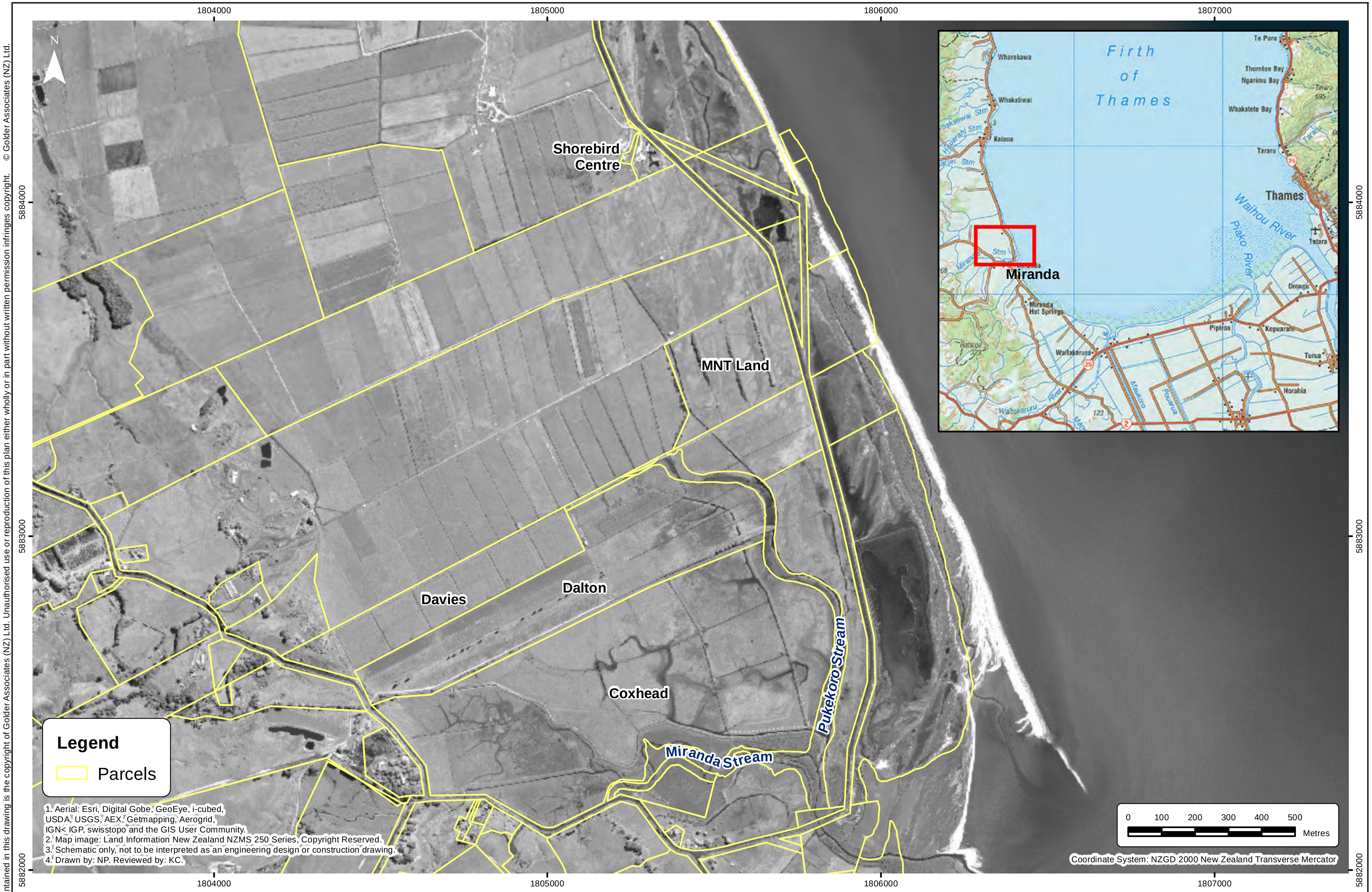
The initial assessment has involved gathering background information on topography and geology of the location, a site visit on 4 December 2013 and a simple pre-feasibility desktop analysis of the hydrology of the site. The objective is to assess the feasibility of constructing high tide roosting ponds and the potential for flushing the ponds based on existing topographic information.

The project covers the private land adjacent to lower reaches of the Miranda Stream and the Pukorokoro Stream and East Coast Road (i.e., the Coxhead and Dalton properties).

3.0 REQUIREMENTS OF THE PROPOSED NEW ROOSTING AREA

During high tide much of the coastal shell banks and tidal flats are inundated. The wading and shore birds tend to congregate during this time on roost areas situated on the higher sections of the shell banks and inland ponds. These congregation areas include the “Stilt Ponds” within the Robert Findlay Wildlife Area and the ponds within the Miranda Taramaire reserve. The proposal under investigation is to provide additional inland ponds and wetland areas to increase the space available for high tide roosting.

[1] This report is subject to the limitations outlined in Section 8.0 and attached.



Golder Associates

TITLE SITE LOCATION

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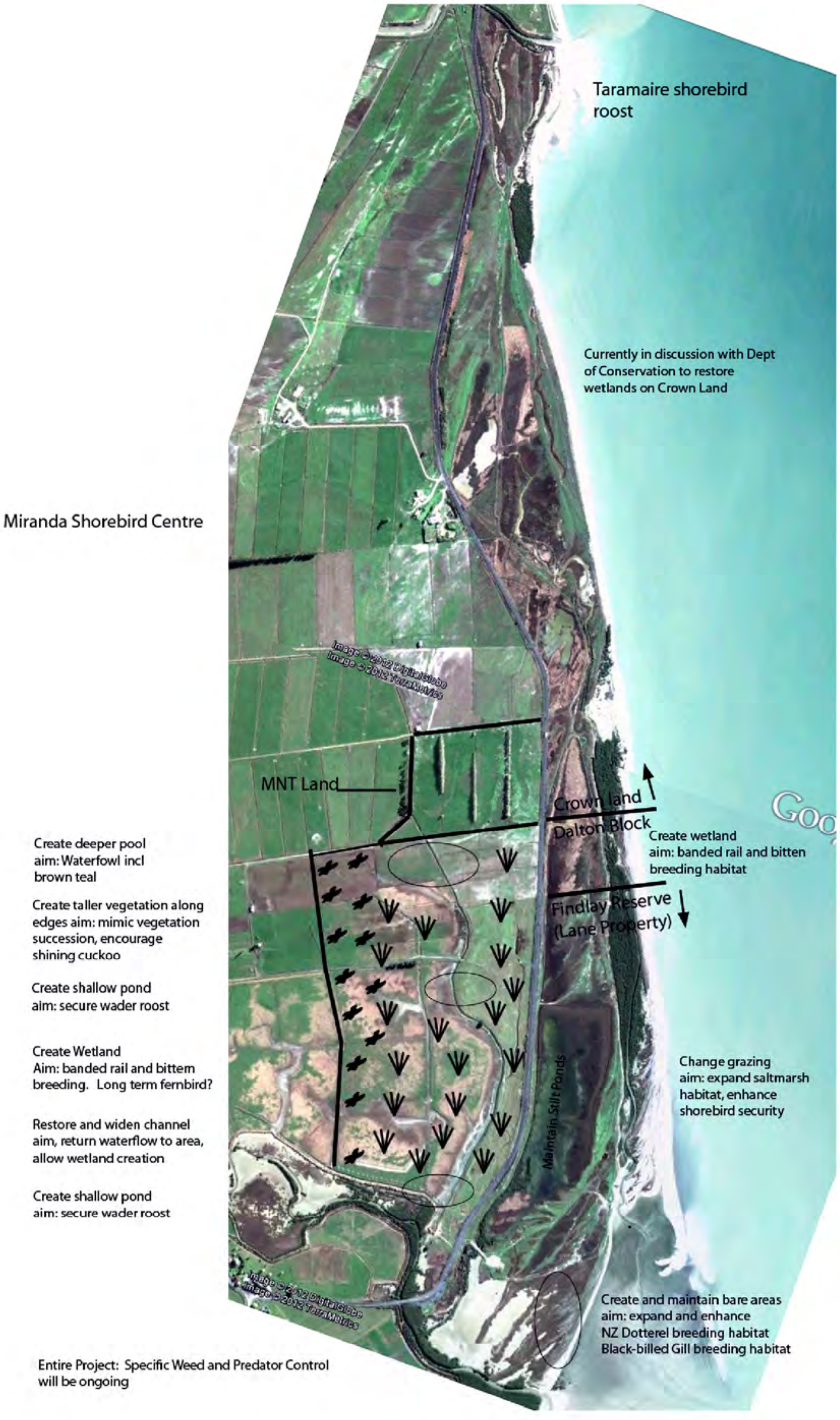

1. Schematic only, not to be interpreted as an engineering design or construction drawing.
2. Drawn by: XX. Reviewed by: XX.

TITLE CONCEPTUAL PLAN MIRANDA ROOSTING AREA

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The proposed new high tide roosting area is mainly intended to be a summer time roost site, from September to April, although it is anticipated that it would be used by birdlife throughout the year. The roost site would predominantly be used during high tide when the tidal mudflat and shell bank areas are inundated. It is not anticipated that the roost site would be a significant feeding or breeding area. Other than restricting the risk of predation by controlling vegetation to maintain at least 50 m of open visibility around the roost site maintaining specific consideration of breeding requirements is not required.

DoC and members of the Miranda Shorebird Centre consider that the ideal high tide roosting area would have shallow pooled water approximately 75 mm deep and be subject to periodic flushing and replacement of the water. Birds would roost around and within the shallow pooled water. A less ideal option is for a deeper pond with an island in the middle for roosting. It is acknowledged that during larger flood events the area would be more deeply inundated and the wading and shore birds would need to find an alternative temporary roosting site.

To reduce the risk of predation, DoC indicates there is need to limit the growth of surrounding vegetation so as to allow open visibility for at least 50 m around the roost area. This could be achieved through the use of grazed pasture provided grass growth did not become long and rank. The substrate is not considered to be important for the roosting area except in ensuring that the water level is maintained between inundations. If an island is built, it would need to have an upper layer of shell or be regularly sprayed to ensure that weed growth did not occur.

Old aerial photos available in the Shorebird Centre, especially one dated 1977 (Figure 3), indicate that the lower section of Pukorokoro Stream was previously tidal with extensive tidal flats and wetland areas inland of East Coast Road. It is likely that this area was previously used as a roost site during periods when the more coastal and lower elevation tidal flats and shell banks were inundated. Essentially the conceptual plan proposed by DoC and MNT is to recreate the hydraulic system and roosting area that existed in 1977. The difficulty in designing and operating the proposed roosting ponds will be controlling/managing the size of the tidal flats/wetland and managing the effects on the surrounding productive land.

4.0 SITE VISIT

A site visit was carried out on 4 December 2013. Golder met with DoC staff member John Gumbley and local farmers Gary Dalton and Noel Coxhead.

The following notes with regards to the current flood control system were made during the site visit.

- There is a farmer built and run flood control system, based on the use of stop-banks and flap gates on culverts to prevent seawater inundation. This system works well, for current land use, requiring little maintenance at low cost, is subject to little bureaucracy and prevents salt water inundation of a large area. Any new system is likely to be subject to more regulation, and possibly higher maintenance and running costs than the current system.
- There are five land holders (C Views Ltd, MNT, Davis, Coxhead and Dalton) who currently use the flood control system to protect their land from sea water inundation through normal tidal fluctuations and reduce land inundation periods of high flow in Miranda Stream. The scheme has been upgraded, expanded and enhanced over time. The flood control gates are 40 to 50 years old in the current position. Previously another gate and control system was used approximately 600 m to the north.
- The flood gates currently consist of three concrete pipes: two pipes of approximately 1,200 mm diameter with wooden flap gates and one pipe of approximately 900 mm diameter with a metal flap gate (Figure 4). The gates are simple gravity-based gates, which are hinged at the top and have no automation or springs attached. The weight of the gates ensures that their normal position is closed; they open in response to increasing the pressure difference between upstream and downstream.

- The farmers commented that they would expect a spring tide to inundate three properties without the use of the flood gates. They also commented that two to three times a year about 50 ha of their farm land is under water (fresh water) for a short time. During the site visit, Mr N. Coxhead indicated that for his land within the Maranda Stream stop-banks (i.e., outside the flood control scheme) and immediately upstream of the flood gates, the frequency of saltwater inundation and flooding has meant some pastureland is of reduced productivity and accordingly does not merit the risk and expense of applying fertiliser, regrassing or other land development attention. This area has some saltwater tolerant species which are less palatable to stock and require “hard grazing” by adult cattle to control.

- There is a build-up of mangroves and sediment in the lower sections of Miranda Stream. This has changed local channel bed elevations. The elevation of the current drainage system is expected to be significantly different to the system what was present in the 1977 photo. The stream bed of the lower sections of Miranda Stream (i.e., the area inside the stop-banks) may now be perched above surrounding land.

- To create the proposed wetland in the identified area while ensuring that adjacent areas maintain their current level of protection against salt water inundation is likely to require the construction and maintenance of additional stop-banks and new flood gates.

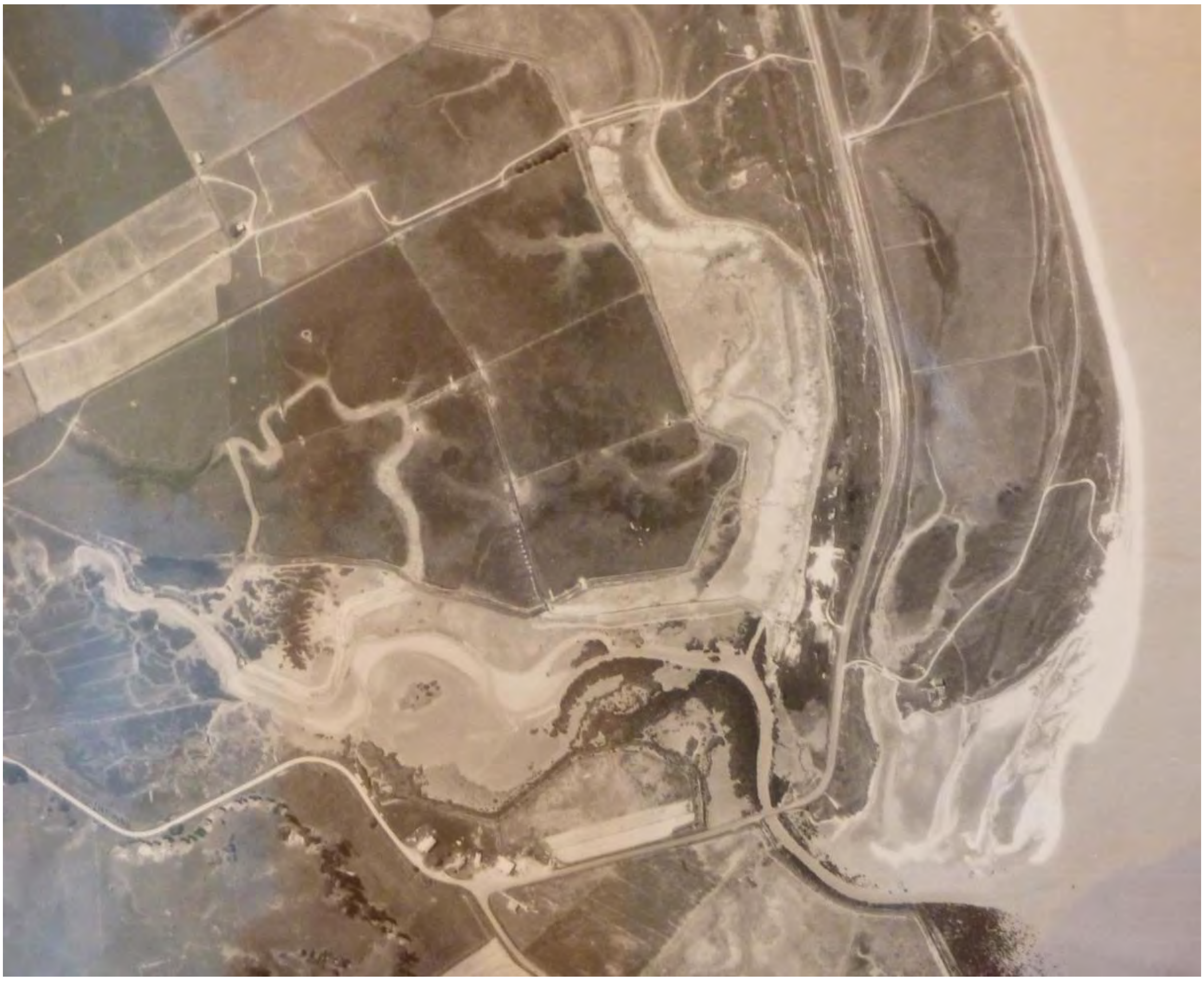


Figure 3: Aerial photo of the Miranda Stream mouth dated 1977 (sourced from Miranda Shorebird Centre).

Figure 4: Existing flood control gates and Pukorokoro Stream upstream of the gates. Photos taken on an incoming tide. Note mangroves in Miranda Stream (top left photo).

5.0 AVAILABLE INFORMATION AND TECHNICAL CONSIDERATIONS

5.1 Existing Flood Control Scheme

The existing flood control scheme achieves two primary functions:

1) It significantly reduces salt water inundation during high tides.

2) It significantly reduces the potential for flood flows in Miranda Stream from backing up into Pukorokoro Stream.

A consequence of achieving the functions outlined above, is that the flood control structures influence and restrict flood flows from Pukorokoro Stream to Miranda Stream and ultimately to the sea.

The area protected by the flood control scheme consists of grazed pasture. Pasture species require some air around their roots and cannot survive extended periods of water logged conditions. Similarly, the majority of pasture species are not salt tolerant and will quickly die if exposed to salt or brackish water. The existing flood control scheme protects an area of 50 ha to 100 ha. Much of this area has been developed into pasture, which would be severely affected by any inundation by salt water. During the site visit Mr Coxhead described a large flood event that had resulted in considerable storm surge and sea water overtopping some of the flood control works and parts of East Coast Road. This event resulted in considerable inundation over a number of days. Subsequently pasture dies due to contact with salt water and/or smothering by deposited silt and debris required re-grassing of affected areas.

When considering options for development of the high tide roosting site the implications on the current flood control works need to be carefully considered, including consideration of both functions (salt water inundation control and local fresh water flood control) of the existing scheme.

5.2 Tidal Assessment

The National Institute of Water and Atmospheric Research (NIWA 2007) identifies mean high water spring tide (MHWS) as 1.6 m above mean sea level (amsl) and the mean high water perigean-spring tide (MHWPS) as 1.87 m amsl. This occurs when the tide coincides with the moon's perigee (when it's closest to the earth) and produces a higher tide. This calculation was based on the sea level recorder at Tararu (Site No.9415). At this monitoring site, the level of the water is expressed as a height above a local datum which was Moturiki Vertical Datum. This is the same datum as used for the local topographical data. The tidal estimates in NIWA (2007) do not consider storm surge which will cause higher water levels.

Waikato Regional Council (WRC) monitors tidal water levels at Tararu on the Firth of Thames. Water level information for this site is available since May 1990 (Figure 5 and Figure 6). Analysis of the recorded data suggests that the high tide level regularly exceeds 1.5 m 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.

The reported spring high tide levels above are based on historical data. In the future sea levels may rise due to climate change. Ministry for the Environment (MfE 2008) recommends that sea-level rise estimates be based on the Intergovernmental Panel for Climate Change (IPCC) Fourth Assessment Report, which for timeframes out to 2099 indicates:

a) A base value sea-level rise of 0.5 m relative to the 1980-1999 average should be used, along with

b) 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.

Climate change will exacerbate existing coastal hazards through sea-level rise, range and frequency of high tides, storms, wave patterns, and coastal sediment supply (MfE 2008). This may lead to landward intrusion of seawater, inundation, changes in water quality and erosion or sedimentation issues.

Given the very low lying topography of the area, any sea-level rise associated with climate change will increase inundation under high tide conditions unless the current flood control system is maintained and the height of the stop-banks increased as sea level rises.

Hayward (2013) has identified southward migration of the shell chenier ridges over the last 1,000 years. This indicates that long shore sediment movement is slightly from the north although there is not expected to be significant long shore movement of sediment.

NIWA (2007) found that the rapidly colonisation of the intertidal areas of the southern Firth of Thames by mangroves during the last 50 years has influenced sedimentation patterns.

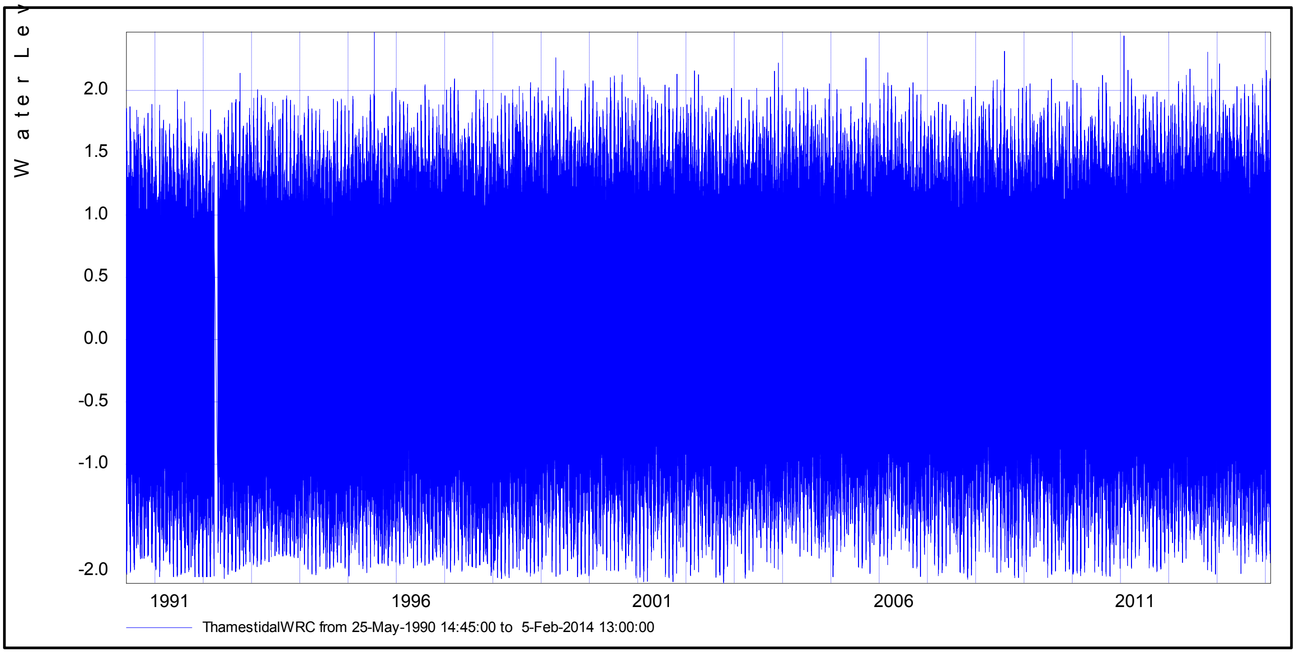


Figure 5: Tidal fluctuations at Tararu in the Firth of Thames (Site No.9415).

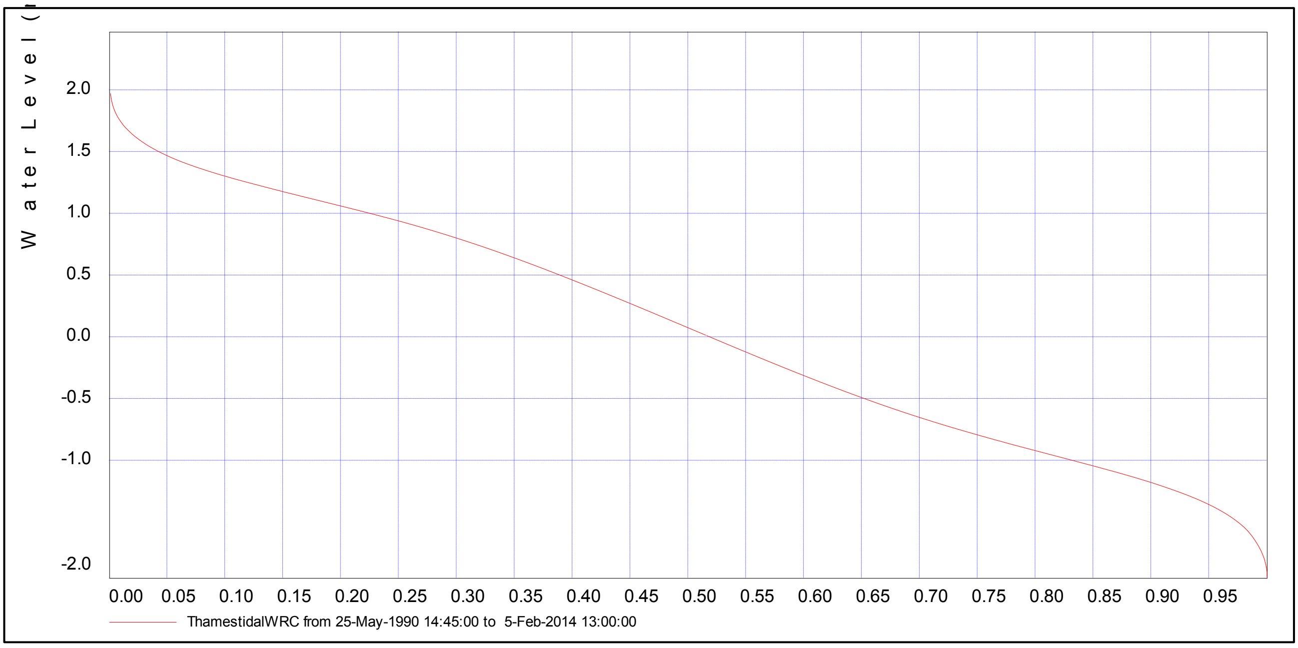


Figure 6: Exceedance curve for water level recorded at Tararu in the Firth of Thames (Site N0. 9415).

5.3 Hydrogeological Setting

The area under investigation is dominated by Quaternary age fine grained sediments. Geological logs indicate bores drilled in this area (bores numbered 72_618, 72_4091) intersected silts and clays to 140 m and 83 m, respectively. These thick deposits of fine material are considered to have low permeability. Surface sediments observed during the site visit were very fine silts and muds with some shells. This is consistent with the bore log descriptions.

There are three bores (numbered 72_5159, 72_5157, 72_5156) on the WRC database to the north of the proposed site with unknown depth or shallow depth. These bores may tap thin shelly layers within the muds from past chenier ridges. It is presumed that bore 72_5159 is an unused bore identified during the site visit close to the position of the earlier flood gate. This bore could be used for groundwater monitoring purposes if development of the roosting ponds in the area were to proceed.

The nearby shallow bores could potentially be connected to a buried shell layer which may extend as far as the area of interest. The area is, however, not highly used for groundwater abstraction and pumping pressure from nearby bores is considered to be low. This means that there is low potential for the salt water to be drawn into the shallow system due to pumping. Given the generally low permeability of the sediments, groundwater resources in this area are unlikely to be affected by a small increase in salt water surface inundation.

5.4 Hydrological Assessment

There is no hydrological information available for either the Miranda Stream or the Pukorokoro Stream. The closest 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. Both records indicate that large flood flows do occur but these are usually of relatively short duration.

During the site visit, Mr Coxhead indicated that the area near the intersection of Miranda and Findlay roads regularly floods. He also indicated that during large floods, water from Pukorokoro Stream ponds upstream of the flood gates and can take many days to dissipate due to high water levels in Miranda Stream. Such comments are consistent with the fact that the catchments of both Miranda and the Pukorokoro streams are relatively small and therefore more prone to rapid short duration flooding associated with localised high intensity rainfall events rather than long duration flooding which is more characteristic of large catchments.

Given the lack of flow information from either the Miranda Stream or the Pukorokoro Stream, it is necessary to consider local rainfall and climate information in order to assess the potential flooding risk posed by the two watercourses.

The national climate database cliflow (http://cliflo.niwa.co.nz/) indicates that rainfall is measured daily at the Hot Springs Miranda rainfall site (Site Number C75233), which is located approximately 4 km south of the mouth of Miranda Stream. Measurements commenced in October 1978 and are on-going (Figure 7). The records indicate a mean annual rainfall of 1,140 mm to 1,150 mm (calendar years 1979 to 2013). The maximum daily rainfall recorded was 158 mm for the 24 hour period up to 9am on 23rd May 1985. Daily rainfall greater than 50 mm has been recorded on 54 occasions, three of which had daily rainfall greater than 100 mm. The rainfall record suggests that large storm events can occur throughout the year but are usually of relatively short duration. The maximum recorded seven day rainfall was 268 mm for the seven day period beginning on 22 January 2011. Seven day rainfall totals of greater than 150 mm were recorded on only four occasions.

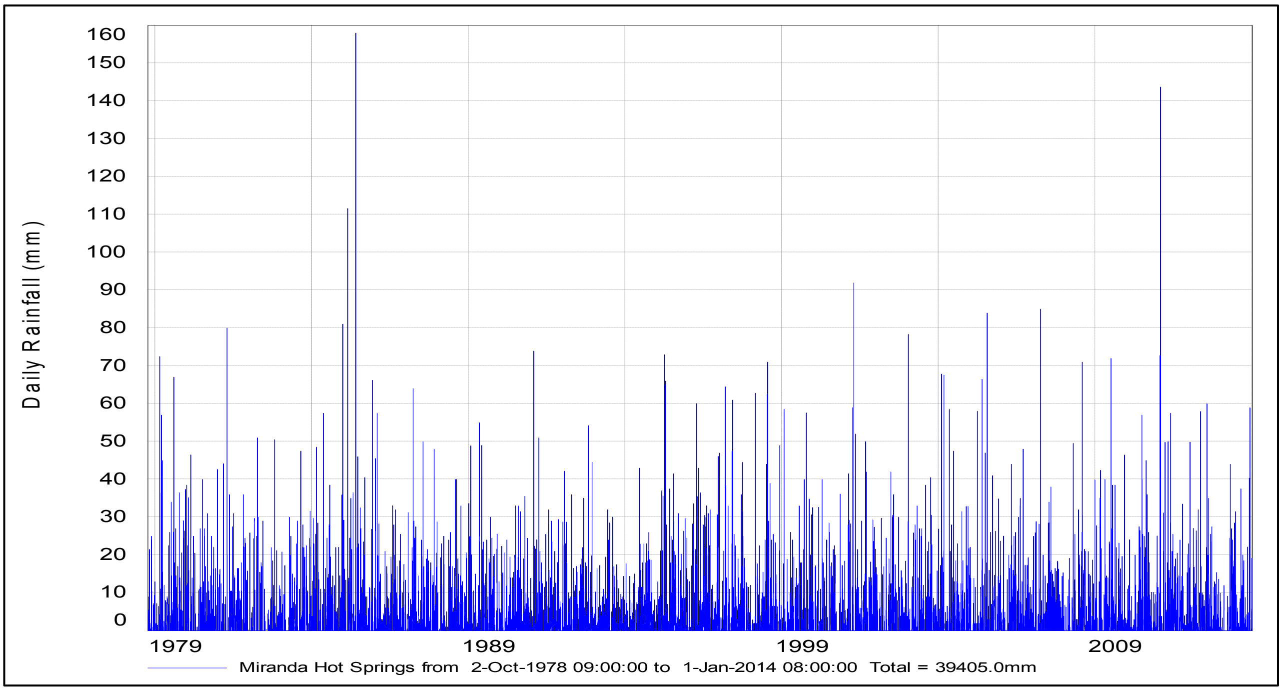


Figure 7: Daily rainfall recorded at the Hot Springs Miranda rainfall station.

The closest full climate station where evaporation is either measured or calculated is located in Thames (site name Thames 2, Site Number B75152), which is 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.

NIWA has established a virtual climate station network which extends across the country in a 5 km grid. For each virtual climate station, NIWA has developed long term synthetic climatic records (daily rainfall since 1960, daily temperature and evapo-transpiration since 1972). 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. The rainfall and Penman potential evapotranspiration (PET) record for virtual climate station 29232 has been obtained and a monthly summary is presented in Figure 8. The data indicates that on average PET will exceed rainfall over the summer months of November to February, PET and rainfall will be roughly even during the months of March and October and rainfall will significantly exceed PET for the remainder of the year, April to September. Therefore, any ponds that are developed (assuming they are perfectly sealed) will on average tend to dry over the summer months unless additional inflow is provided and water will need to be discharged from the ponds over the winter months.

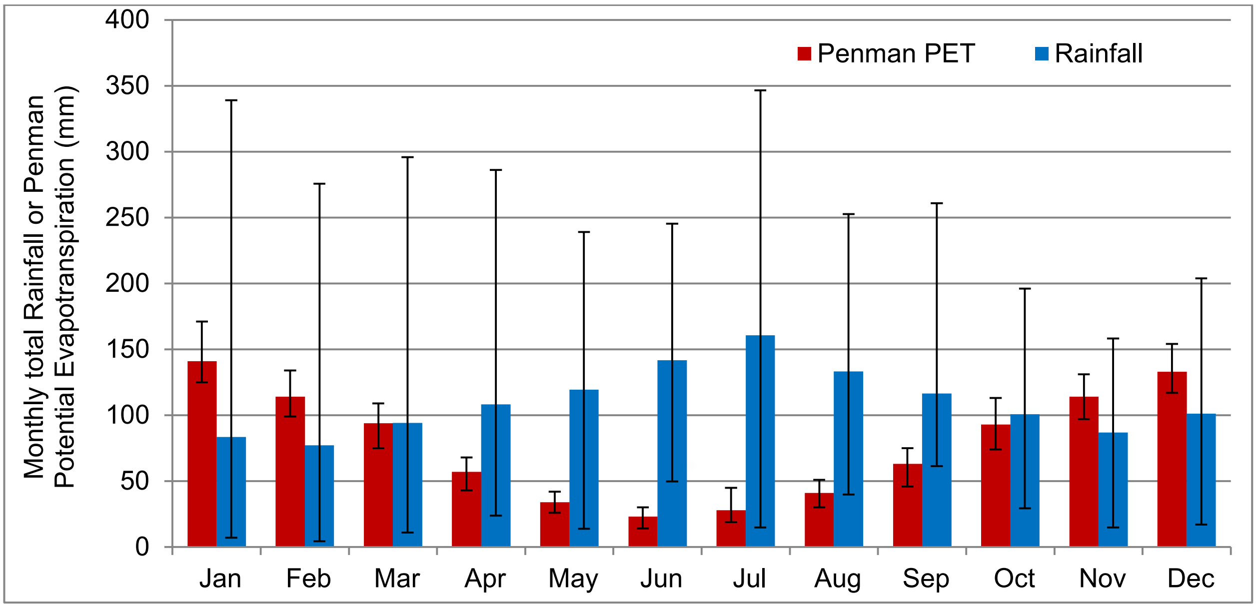


Figure 8: Average, maximum and minimum monthly rainfall and Penman PET from the NIWA virtual climate station 29232 from January 1972 to December 2013.

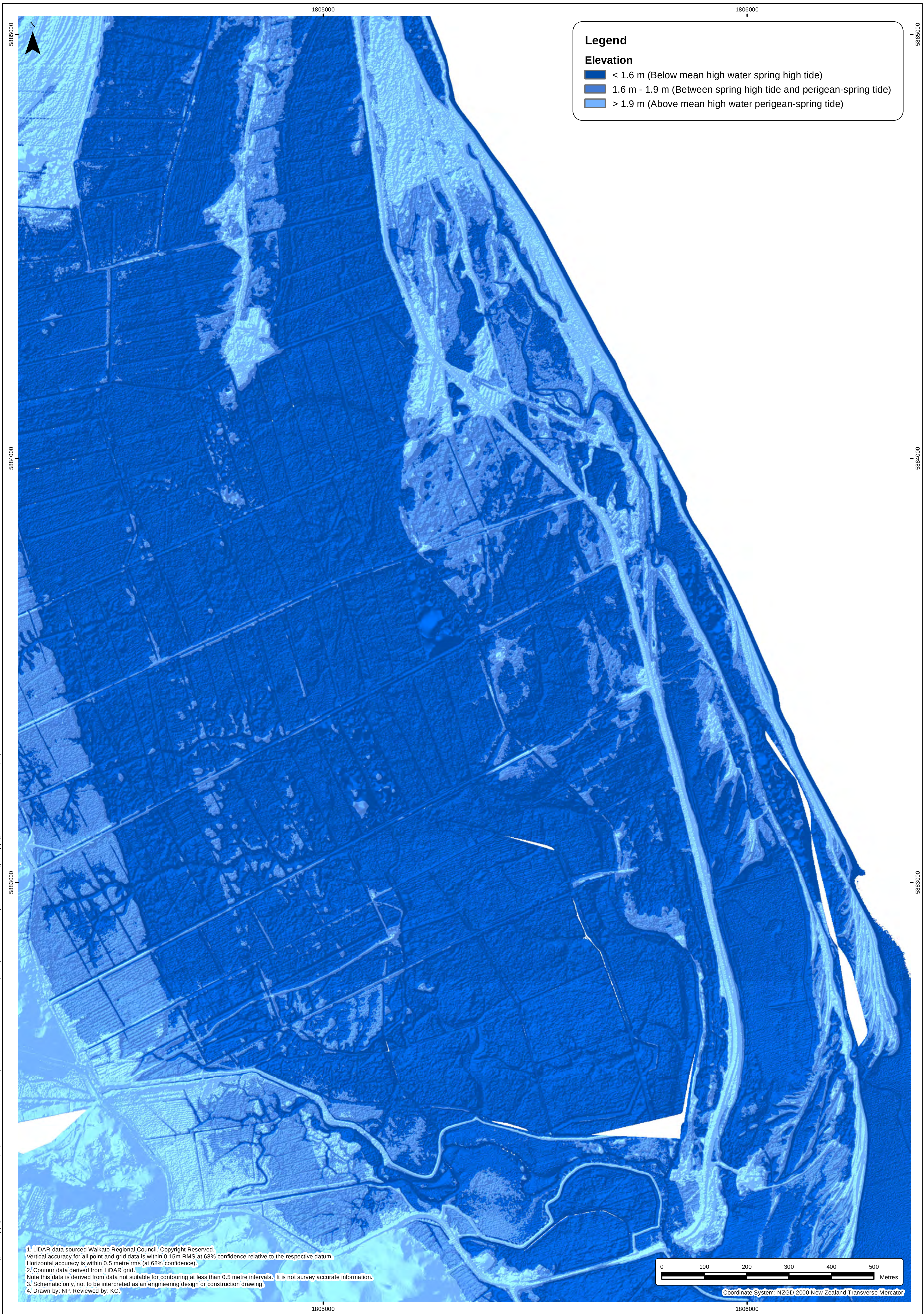
It is clear from the limited available data that both the Miranda and Pukorokoro streams have experienced and will continue to experience significant flooding associated with localised high intensity rainfall events. Floods tend to be of short duration with flood waters draining fairly rapidly over a few days although exceptions have been experienced. Any new roosting sites that are developed in the lower sections of these streams will therefore be subject to periodic inundation by flood water, which will tend to last for a few days. Inundation lasting longer than a week is not expected. The lack of available flow data for the Miranda and Pukorokoro streams will mean some field monitoring will be required to obtain data to support detailed design of any roosting ponds or redevelopment of the flood control system.

5.5 Topographical Assessment

The topographic data presented in Figure 9 show a large extent of land below spring high tide level (1.6 m amsl) and an even greater area below the perigean-spring tide (1.9 m amsl). This land extends well beyond the properties that are being assessed for their potential as high tide roosting areas.

Topographic data were provided by WRC as grid data for the Miranda area. The grid data are relative to the Taratu datum. WRC note that the accuracy estimates for terrain modelling refer to the terrain definition on clear ground. Ground definition in vegetated terrain may contain localised areas with systematic errors or outliers which fall outside this accuracy estimate. Any points interpolated from a primary data set have the potential to downgrade the accuracy of a terrain definition. Also 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.

The extent of tidal inundation would be controlled by the rate of flow through any proposed opening of the flood gates, rather than being limited by the current topography. The low lying (dark blue) area is shown to be reliant on the current stop-banks surrounding Miranda Stream to prevent inundation.



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The modelled road level is just over 2.5 m amsl (Figure 9). This elevation is consistent with comments made by local farmers during the site visit that they remember a high tide event combined with storm surge that resulted in sea-water flowing over the road level in some places.

The elevation of the culverts that make up the flood control gates cannot be accurately identified from the available topographic information. The site visit indicated that the culverts are set well below high tide level, at an estimated invert elevation of approximately 1 m amsl. The tidal data presented in Section 5.2 indicates that water level is above 1 m for about five hours every tidal cycle (i.e., roughly from mid tide to full tide).

If open, the two approximately 1,200 mm diameter and one 900 mm diameter flood gates would convey an estimated 0.5 m^3/s at the peak of a 1.6 m tide and allow an estimated volume of up to approximately 5,000 m^3 to pass during a tidal cycle. For a 1.9 m tide it is estimated that up to approximately 7,000 m^3 could pass during a tidal cycle with an estimated peak flow of 0.75 m^3/s.

Assuming the shallow high tide roosting ponds that are proposed are approximately 75 mm deep and cover an area of 10 ha (i.e., approximately the same size as the existing Stilt Ponds) then they will contain a volume of approximately 7,500 m^3. Comparing this volume with the potential flow that could pass through the existing flap gates if opened indicates that considerable flushing or inflow could be achieved through opening of the flap gates during a high tide cycle.

6.0 SUGGESTED OPTIONS

6.1 Background

Golder has identified three potential options for development of additional high water roosting sites, which are described below along with an assessment of advantages and disadvantages. Golder has not assessed the resource consent requirements of the three options.

6.2 Development within Existing Flood Control System

This option is focused on utilising the flood control system and developing ponds in Pukorokoro Stream upstream of the flood control gates. The concept revolves around re-contouring the area upstream of the existing gates to make a series of ponds.

Advantages

- No change to flood control scheme and there will continue to be a high level of flood protection for the upstream properties.
- Is generally consistent with the conceptual plan developed by MNT and DoC.
- The flat topography and rectangular shape of the land where the ponds will be created will facilitate the provision of an area of clear visibility around the ponds, with vegetation management.
- The water level in the ponds is unlikely to fluctuate significantly and will be relatively stable.

Disadvantages

- Ponds will be predominantly fresh water. The ponds could be made more brackish through controlled opening of one of the flood gates during high tide to allow salt water to flow back up to the ponds. Any controlled opening of the floods gates would need to be undertaken with the approval of the existing farmers that are serviced by the flood control system. The controlled opening of the gates would require active flow management and monitoring.

- During the summer months the ponds will tend to dry out although this could be addressed through periodic controlled opening of the flood gates.
- The ponds will slightly reduce the storage within the flood control works and will result in a slightly larger area being inundated during floods in Pukorokoro Stream.
- If the ponds are made more brackish through the introduction of salt water there will be an increased risk of pasture die back following flooding as the pond water will mix with the flood waters and extend over a larger area.
- Proximity to East Coast Road may result in disturbance of roosting birds by vehicle traffic.
- The area will periodically be inundated due to flooding of Pukorokoro Stream. Silt deposited during such events could gradually infill any ponds that are created, requiring ongoing maintenance.

6.3 Alteration of Flood Control Scheme

This is an extension of the option outlined above (Section 6.2) to create a fully tidal roosting location. To do this would require removal of the existing flood control gates, which would result in much of the planned roosting area being inundated during high tides. To ensure continued flood protection of the areas outside the proposed roosting site the existing stop-banks would need to be extended and the flood gates shifted upstream.

Advantages

- Is generally consistent with the conceptual plan developed by MNT and DoC.
- The flat topography and rectangular shape of the land where the ponds will be created will facilitate the provision of an area of clear visibility around the ponds, with vegetation management.
- Will create a fully tidal environment so any ponds will be brackish although the water level in the developed ponds may fluctuate beyond the depths ideal for shorebirds.

Disadvantages

- Proximity to East Coast Road may result in disturbance of roosting birds by vehicle traffic.
- Shifting the stop-banks up-gradient will shift the flooding that currently occurs from Pukorokoro Stream further up-gradient.
- The area will periodically be inundated due to flooding of Pukorokoro Stream. Silt deposited during such events could gradually infill any ponds that are created, requiring ongoing maintenance.
- Will involve significant changes to the existing flood control system. Resource consents are likely to be required to shift the flood gates and construct the additional stop-banks. The upgraded flood control system is likely to face far more bureaucracy, and possibly maintenance and running costs than the current system.
- The costs associated with shifting the existing gates and constructing additional stop-banks are expected to be high. Detailed engineering design of the new stop-banks and flood gates will be difficult. The lack of flow data from the Miranda and Pukorokoro streams is likely to result in an overly conservative design which would exacerbate construction costs.
- Ongoing vegetation clearance will be required to ensure that mangroves do not spread in to the new roosting area.
- There is a slight potential for increased salt water intrusion of localised coastal aquifers. Monitoring of groundwater quality may be required.

6.4 Existing Flood Plain of Miranda Stream

This option is focused on developing the tidal flats and low lying areas adjacent to the Miranda Stream between Miranda Road and the existing flood control stop-banks. Golder understands that this area is a combination of conservation areas and land owned by Mr Coxhead. The lower parts of this area are tidal and during larger flood events much of the area becomes inundated. Thick mangrove forest covers the lower tidal sections and mangroves are colonising upstream. The upper parts of the area are relatively poor pasture which is periodically grazed.

Advantages

- No change to flood control scheme.
- No significant loss of productive land.
- Direct contact to tidal influences so any ponds will be brackish. Natural elevation difference means a series of ponds could potentially be created, with the upper ponds being predominantly fresh and the remaining ponds becoming progressively more brackish closer to the stream mouth. This progression could provide a series of different habitats.
- Limited re-contouring of the land required.
- No specific inflow management required in that natural tides will flush the area.
- Adjacent to Miranda Road so potentially good access and public viewing.

Disadvantages

- Shape – the area is long and narrow, being approximately 1.5 km long and 0.4 km wide, which is not ideal given the requirement to maintain 50 m clear visibility around the roost site.
- Lower sections are already heavily invested with mangroves. Clearing the existing mangroves and/or preventing the further spread of mangroves will be difficult. The existing mangroves will be trapping sediment, resulting in an increase in the Miranda Stream bed elevation. In order to maintain the same level of flood protection, the stop-banks need to be raised as the elevation of the stream bed increases. Removal of the mangroves is likely to reduce the need to continually raise the stop-banks.
- Proximity to Miranda Road many result in disturbance of roosting birds by vehicle traffic.
- There is considerable vegetation along Miranda Road where potential predators could live which would require management to control.
- The area will periodically be inundated due to flooding in the Miranda Stream. Silt deposited during such events could infill any ponds that are created, requiring ongoing maintenance.

7.0 FURTHER WORK

The coastal environment is very dynamic and extremely difficult to model accurately. That coupled with the lack of flow data from either the Miranda or Pukorokoro streams means that Golder does not consider it appropriate to undertake detailed hydraulic modelling of the proposed alterations to the flood control system at this stage.

To allow feasibility level design of the proposed high tide roosting ponds additional information is required to assess the flow rates and flooding potential. This information would include:

- Dimensions and plans of the existing flood gates.

- Detailed topographical information of the area surrounding the flood gates, the stop-banks, the lower section of Pukorokoro Stream near the flood gates, the topography of the bed of the Miranda Stream (i.e., within the existing stop-banks) and the topography of the area identified for the roost site is recommended.
- Measurement of water levels at the flood gates through a series of tidal cycles would improve understanding of the operation of the flood gates and allow a more detailed assessment of the potential to flush any ponds that are constructed upstream of the gates.
- An assessment of the expected consenting requirements associated with each of the three identified options.

8.0 LIMITATIONS

Your attention is drawn to the document, “Report Limitations”, as attached in Appendix A. The statements presented in that document are intended to advise you of what your realistic expectations of this report should be, and to present you with recommendations on how to minimise the risks to which this report relates which are associated with this project. The document is not intended to exclude or otherwise limit the obligations necessarily imposed by law on Golder Associates (NZ) Limited, but rather to ensure that all parties who may rely on this report are aware of the responsibilities each assumes in so doing.

9.0 REFERENCES

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APPENDIX A

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