Kāpiti Water Supply Project

Potential Ecological Impacts on Wetlands associated with the River Recharge with Groundwater Option (RRwGW)

Prepared for Kāpiti Coast District Council

31 October 2012

Document Quality Assurance

Bibliographic reference for citation: 2012. *Kāpiti Water Supply Project: Potential Ecological Impacts on Wetlands associated with the River Recharge with Groundwater Option (RRwGW)*. Report prepared for Kāpiti Coast District Council.		
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Status: FINAL	Version: 3 (revised groundwater modelling)	Issue date: 31 October 2012
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Template revision: 20120608 000020120608 0000

File ref:
U:\2012\W12082_MCP_KCDC_WaterSupply\Documents\W12082_Kapiti Water Supply Project_Wetland_Ecology_Report_20121029_REVISED.docx

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1.0 Executive Summary

This report considers the potential effects of the proposed Kāpiti Water Supply Project known as the River Recharge with Groundwater Option (RRwGW). Specifically, it considers the worst case scenario for this project known as Scenario 4. This option will result in lowering of groundwater levels during peak demand by up to 1.5 m, though typically it will be in the order of 0.1 m to 0.5 m.

Under average conditions, the groundwater level of the RRwGW Zone is either very close to (<0.3m below ground level) or at the surface in a number of areas. This situation of high groundwater has resulted in the formation of many of the wetlands in this area and has also influenced the current vegetation and habitat values that make these wetlands ecologically significant.

While detailed research has been undertaken on the biological and ecological values of the wetlands of the Kāpiti Coast, there is very little information on the relationship between these systems and the groundwater upon which they rely. Most notably, the interaction between groundwater and surface water in the Kāpiti Coast wetlands is not well understood due to a paucity of longer term monitoring data.

In order to determine which wetlands are likely to be affected by the proposed water supply project, the drawdown contours developed for the RRwGW process were combined with a recent map of known wetlands that will be affected by this proposal.

This process identified 47 wetlands which are potentially affected by the RRwGW Scenario 4. Of these wetlands, 17 are nationally or regionally significant, 15 are locally significant, and a further 15 wetlands are of lower or unknown value.

For each wetland the maximum modelled extent of potential drawdown is identified together with the known depth of peats the characteristics of the wetland. For this stage we conservatively assumed, based on published and unpublished information, that any drawdown exceeding 100 mm was likely to have a significant adverse effect. The number of wetlands where this level of drawdown was likely to occur was 21. This proposed drawdown trigger is based on limited information. It may be conservative or inadequate and monitoring is needed to confirm it.

Our assessment of likely changes to these wetlands was determined based on wetland type; swamp, fen, saltmarsh and ephemeral. Each wetland type is characterised in large part by its relationship with the groundwater and so will respond differently to the modelled changes.

A range of recommendations and options are provided for monitoring of wetland change, and the types of methods and monitoring intensity that would be needed to determine whether an adverse effect was occurring. This considers the monitoring of wetland hydrology, wetland extent, community composition rarity and weediness.

Finally, this report discusses what tools might be available to allow for adaptive management of affected wetlands to limit or reverse effects if they occur.

2.0 Introduction

Boffa Miskell was engaged by CH2M BECA on behalf of Kāpiti Coast District Council to prepare a desktop report which considers the potential effects on the wetlands of the Kāpiti Coast of the River Recharge with Groundwater (RRwGW) Scheme. This scheme proposes to use groundwater from the KCDC well field to recharge the Waikanae River during periods of low river flow when abstraction from the river is limited due to minimum residual flow requirements. This project is described in detail in the Aquifer Testing and Groundwater Modelling report prepared by CH2M Beca.

This report was commissioned to consider whether this groundwater abstraction would depress groundwater levels to the extent that it would have associated impacts on wetlands. Accordingly a focus of this report has been the identification of those wetlands that may be affected by the RRwGW Scheme, describing their ecological and biodiversity values, and quantifying the extent of potential groundwater change for each wetland.

Drawdown effects have been considered in the context of: what ground water changes are known to occur to wetlands naturally (including existing groundwater takes); and what would occur under that worst case drought scenario and with the RRwGW scheme.

This report concludes with recommendations for a monitoring and adaptive management approach to appropriately manage the potential effects of the RRwGW Scheme on the wetlands identified by this report.

This report has been prepared as a desktop exercise using information on wetlands from a combination of sources, including most recently groundwater studies carried out for the MacKay's to Peka Peka Expressway Alliance, and an inventory and significance assessment undertaken for Greater Wellington Regional Council (GWRC) in 2011 to update the schedule of wetlands to be protected in the upcoming revision of the Regional Freshwater Plan. We appreciate the approval from GWRC to utilise this background information and the GIS databases prepared for this project.

3.0 Background Information

3.1 Scenario 4

In October 2012, CH2M Beca provided Boffa Miskell with a worst case scenario of the potential drawdown effects on the Holocene Sand Aquifer. The map provided identified a number of wetlands that would potentially be affected (refer Appendix 1 and the CH2M Beca report for more detail on this scenario).

The ‘worst case scenario’ as provided by CH2M Beca (Scenario 4) was modelled on a constant population at 2060 (assumption of high population growth) with a simulated 50 year low flow (drought). Under this scenario, the maximum combined pumping rate, averaged of the peak week was 29,700 m^3/day. This scenario was intended to provide a scientific basis for a conservative assessment of possible environmental effects over the 50 year planning horizon or the RRwGW that includes a drought with a 50-year return period (refer Appendix 1).

We note that this report has considered the effects modelled by Scenario 4 as being over and above what might typically occur naturally during a drought period as wetlands go through their natural wet and dry cycles.

3.2 Wetland Data

Wetland data used as the basis for this report was provided by Greater Wellington and was based on the Wetland Delineation Project (‘the GWRC Wetland Delineation Project’), a project undertaken for GWRC by Boffa Miskell in 2011. For the GWRC Wetland Delineation Project, wetlands on the Kāpiti Coast were identified in GIS from a compilation of desktop analysis and identification of sites, using existing sources of information and recently flown, high resolution, aerial photography of the Wellington Region. A number of data sets were used for the Greater Wellington Regional Council study, based on studies carried out by a range of organisations over a number of decades as follows:

- GWRC_Wet (n=263 wetland sites);
- GWRC_Hydro (n=284);
- GWRC_Extent (n=359);
- PCC EcoSites (n=211) & Recommended (n=117);
- KCDC Ecosites (n=189) & Recommended (n=172);
- DOC Ecosites (Wellington Sites, n=2,125);
- DOC PNAP Reports (Wellington Sites, n=257);
- DOC Conservation Units (Wellington Sites, n=191);
- QEII Covenants (Wellington Sites, n=274);
- DOC Freshwater Environments of New Zealand FENZ (n=359).
- GWRC Aerial Photography (Flown Jan 2010)
- GWRC Lidar 1 m contour information (Parts of Kāpiti, Lower Hutt, Southern Wairarapa)

The Wetland Delineation Project also included information from the following other sources:

- AUSSEIL et al. Wetlands of National Importance (Wellington Sites, n=34);
- Todd et al, DOC River mouths and Estuaries (Wellington Sites, n=45);
- DOC Conservation Management Strategy CMS (Wellington Sites, n=30).

- GWRC Tender Document (n=41);
- Cromarty & Scott A directory of wetlands in NZ (Wellington Sties, n=2)

An assessment of ecological significance was undertaken as part of the GWRC Wetland Delineation Project using Policy 22 of the proposed Regional Policy Statement and the significance of each wetland has been utilised as the basis for this Kāpiti Water Supply Project report.

Given the reliance on the GWRC Wetland Delineation Project as the basis for this report, it is also important to reiterate the limitations on the quality of data in this report:

- No sites were verified by field survey. For many sites almost no information was given in the source inventory, so any judgement made regarding their value or importance which is based on aerial photography and GIS interpretation must be considered incomplete.
- Some inventories were considerably out of date. Some sites may have been degraded since their original survey, others may no longer exist. Some sites appear to have been "enhanced" through excavation and revegetation.
- Swamp forest: The accuracy of wetland delineation is doubtful where a wetland merges into forest. As a result, a number of small forest fragments which are included in some of the datasets may no longer be true swamp forest.

Similar to the GWRC Wetland Delineation Project, this RRwGW Report has been prepared as a desktop exercise only. No site visits have been undertaken for this project.

We have not assessed potential ecological effects on wetlands from salt intrusion into groundwater.

We have not considered potential adverse effects of Scenario 4 drawdowns on the native fauna of these wetland systems as part of this assessment e.g. mudfish at Nga Manu Wetlands.

4.0 The importance of wetland hydrology

"….hydrology is probably the single most important determinant in the establishment and maintenance of specific types of wetlands and wetland processes." (Mitsch & Gosselink, 2000)

4.1 Introduction

While much is known about the indigenous flora and fauna of the wetlands of the Kāpiti Coast, less is known about their hydrological values and relationship with groundwater. The hydrological regime of a wetland determines the level and extent of many of the wetland ecosystem and its associated functions. The hydrological conditions also affect many abiotic factors such as soil anaerobisis and nutrient availability, thereby determining the biota of the wetland (Mitsch and Goselink, 2007).

Variations in the wetland hydrological regime are generally cyclic and are determined by the timing and presence of the following:

- Surface water;
- Frequency and duration of inundation and drying cycles;
- Depth of surface water;
- Depth to the water table;
- Water sources; and
- Variability of water levels; including depth and extend both seasonally and between years (Mitsch and Gosselink, 2007).

4.2 Existing Knowledge

On the Kāpiti Coast there are five broad wetland types (as defined by Johnson and Gerbeaux, 2004). Two wetland types predominate; fens (typically discharge wetlands[1]) and swamps (typically recharge wetlands[2]). The others are shallow water wetlands, ephemeral wetlands, and saltmarsh wetlands. These types are not mutually exclusive and a single wetland may have elements of several types, for example many swamps also contain open water and have ephemeral wetland margins. These types are discussed in detail in Section 6.0.

A small number of wetlands on the Kāpiti Coast have been the subject of detailed hydrological and groundwater studies, particularly Te Hapua Wetlands (Allen, 2010) and Te Harakeke Wetland (Law, 2008). In general, the shallow groundwater systems of the Kāpiti Coast interact rapidly and directly with climatic factors such as rain fall and evaporation as well as variation in the water levels of adjacent water bodies (Ward 1967). Short-term climatic fluctuations, such as storm events, can cause large, rapid changes to shallow groundwater systems (Ward, 1967).

However, during summer months, the evapo-transpiration rate can exceed the rate of groundwater inflow or discharge into wetlands (Ward, 1967). In general, vegetated wetlands have lower evaporation rates than open wetland areas (Campbell & Williamson, 1997).

1 A discharge wetland is one that contributes or discharges water, typically rainwater, to the aquifer.

2 A recharge wetland is one that receives or is recharged by water from the aquifer.

Critically, there is a strong link between soil moisture content and water table. When the water table is shallow, such as in the case of many of Kāpiti Coasts' wetlands, water lost through evaporation is usually rapidly replaced from the ground water by capillary rise (Campbell and Jackson, 2004, & Ward, 1967). However, when the water table drops to lower than normal levels due to a drought, drainage or abstraction, surface soil can dry out. When this occurs the 'matric' potential (a measure of the capillary action of thin films of water through soils) deceases dramatically, further accelerating drying. GWRC (2005) wetland studies on the Kāpiti Coast demonstrated that groundwater discharge was an important factor in keeping wetland soils moist during the drier parts of the year.

Research undertaken for the MacKay's to Peka Peka Expressway suggests that groundwater reacts differently in areas of peats, sands and gravels (Williams, 2011). Groundwater levels in peats upon which most wetlands lie, tend to be 0.05 m to 0.2 m higher than that found in the underlying sand. Groundwater levels in the sand are however also elevated being just 0.1 m to 0.3 m below the ground surface (Williams, 2011).

Peat soils are widespread across the Kāpiti Coast, but are typically relatively thin. Peatland soils are normally able to retain soil moisture as high as 90% given the soils hydraulic properties and shallow water table (Campbell & Jackson, 2004; Thompson, et al., 1999).

Further, the low permeability of the peat that underlies many Kāpiti wetlands acts as a confining layer that limits water movement to deeper layers. Research also suggests that wetlands do not lose a significant amount of water to groundwater outflow (Campbell & Jackson, 2004).

Being wet, anaerobic and usually acid – peat is a good preservative (Johnson and Gerbeaux, 2005). However, where the groundwater drops and peats dry this can lead to accelerated decomposition, and associated peat loss, and changes to the nutrient status of some wetlands

In addition to hydrology, nutrients have a strong influence on which plants are dominant in wetland vegetation. The two nutrients most likely to be limiting for plant growth in wetlands are phosphorus (P) and nitrogen (N). Typically the wetlands on the Kāpiti Coast are highly infertile, resulting in slow or restricted plant growth that favours only a few seasonally-wet tolerant species.

It is within this shallow groundwater-dominated context that we consider the potential effects of the RRwGW Scenario 4 drawdown.

4.3 Existing Abstraction

While discharge wetlands are buffered against seasonal fluctuations in water levels and may be able to withstand small variations in hydrology, large or long-duration changes may affect the viability of the wetland system. However, we also note that the large range of shallow bores (<6m) in the area means it is impossible to determine how much water is abstracted from the area's shallow bores (Law, 2008) and fully understand the historical hydrological patterns that influence wetlands. According to Jones & Gyopari (2005), during dry summers, total irrigation abstraction increases up to about 6ML/day on the Kāpiti Coast (about 35% of the recharge to the aquifer which is solely riverbed leakage). The abstraction during dry periods is largely supported by water released from aquifer storage causing the water table to seasonally decline by about 1m.

Jones and Baker (2005 cited in Law, 2008) modelled the shallow groundwater on the Kāpiti Coast and assessed the effects of garden irrigation abstractions from the shallow sand aquifer on groundwater dependent ecosystems. Their modelling showed that stream and wetland levels should be unaffected by the large number of groundwater users pumping at the rate typical of narrow (25mm) diameter wells. However, if pumping rates exceeded 100m3/day near a wetland, this may adversely affect these features. Modelling undertaken by Jones and Gyopari (2005) of water levels in Te Harakeke Wetland showed little difference in wetland water levels under three different abstraction scenarios: no abstraction; current level of abstraction, plus additional abstraction for a proposed subdivision to the west of the wetland; and at twice the current level of abstraction. This is notable, given Law's (2008) thesis that groundwater inflow provides the major contributor to the Te Harakeke Wetland water balance (supplying an estimated 65% of inflows).

This was evidenced in a study by Phreatos (2002) that found from assessing the water level in two monitoring bores on the Kāpiti Coast that there was a decline in groundwater level of around 0.5m within the shallow dunes and aquifer between 1997 and 2002. Given the correlation between the groundwater wetlands and the water tables in studies such as Jones & Gyopari (2005), Law (2008), Allen (2010) and GWRC (2005), we consider that the plant communities in many of the wetlands on the Kāpiti Coast have naturalised to the current levels of anthropocentric changes when the water levels are in deficit (i.e. summer months).

However, Law's 2008 thesis on the Te Harakeke Wetland suggests that increased groundwater abstraction during the drier periods of the year could have a detrimental effect on wetland extent. Overall, Law (2008) noted that while the water balance for Te Harakeke was positive, the water balance in the summer months is negative with outflows greater than the inflows (decreasing the amount of water in storage for several months). Increased pressures on the system, especially during drier months of the year, could cause the system to move to longer periods of deficit. With a predicted RRwGW Scenario 4 drawdown of 200 mm in Te Harakeke Wetland, this could have significant adverse effects.

Finally, our assessment for the MacKays to Peka Peka Expressway stated that *"In our view localised reductions in groundwater levels of 20 cm would have a significant adverse effect on wetlands. A reduction of 5 cm is less likely to have a measureable effect".* We note that this was in relation to interrupting groundwater flows and potential effects of the Expressway on wetland systems.

4.4 Summary

Overall, we consider there is sufficient research to suggest that while the wetland ecosystems of the Kāpiti Coast are adapted to the current levels of change, they are highly vulnerable to any significant change to their hydrological regime. Kāpiti Coast-specific research suggests that a significant change is likely to be in the order of 200 mm drawdown, although smaller changes are still likely to have an effect. Given the modelled drawdown that is proposed under Scenario 4 we consider that adverse effects are likely to occur in at least some of the wetlands discussed.

5.0 Wetlands Potentially Affected by RRwGW

Section 4.0 of this report discussed the general nature of wetlands on the Kāpiti Coast in terms of their current values and the importance of the natural hydrological regime for the wetlands of the Kāpiti Coast. In this section, we list each of the wetlands identified as being potentially at risk of drawdown, outline their ecological characteristic - and where there is sufficient background information on these wetlands, we consider the potential effects of the RRwGW Scheme as described in the Aquifer Testing and Groundwater Modelling Report. Section 6 then considers the more specific effects on the individual wetlands potentially affected by the RRwGW Scheme.

Appendix 1 (CH2M BECA) overlays the modelling of the potential drawdown of the Holocene Sand Aquifer (groundwater model of the worst case RRwGW Project) with the wetlands on the Kāpiti Coast based on the GWRC Wetland Delineation Project. The figure presents a range of drawdown contours from no change in groundwater, to a maximum worst-case of 1.5 m groundwater reduction.

Table 1 below lists and describes those wetlands that fall within the maximum drawdown contours seen in Appendix 1. We have assumed that any changes in the Holocene Sand Aquifer will be reflected in the wetlands within these drawdown zones. Where known, we have included information on hydrological class, wetland class and other hydrological information (open water modifications, drainage, weirs etc.). We have also included peat depth information gathered for the MacKay's to Peka Peka Expressway project with the permission of NZTA.

Table 1: Wetlands Located within the RRwGW Zone of Influence (ranked as ranked in the GWRC Wetland Delineation Project). Note: Predicted maximum drawdowns under high population growth to 2060 during the summer of the 50-year drought (mm)

Name	Size (ha)	Ecological characteristics	Hydrological Class (other info)	Wetland Class (if known)[3]	Peat depth (mm) if known	Predicted max draw down (mm)
Likely to be nationally or regionally significant						
Muaupoko Swamp Forest	6.12	Moderately sized headwater wetland, somewhat isolated. An example of ecological sequence between wetland, swamp forest and dry forest. Kohekohe forest and mahoe forest is uncommon in the Foxton Ecological District. Provides habitat for brown mudfish (Department of Conservation 1996) and kereru. This site contains a relatively large area of mahoe forest. Partly protected by Scenic Reserve (Paraparaumu SR).	Terrestrial, Transition to dryland forest. Railway line on edge	Fen		110
Nga Manu Wetland	26.14	Very large dune wetland, part of wetland complex. Open ponds created. One of largest and best examples of swamp forest within Foxton Ecological District. Good example of sequences between wetland, swamp forest and dry forest. Provides habitat for brown mudfish and kereru. Nga Manu Nature Reserve protected under Private Trust.	Palustrine. Causeway within wetland & stormwater feed. Unusually large fluctuations in water levels	Wetland, swamp forest, kohekohe forest, tawa forest		140

[3] Based on substrate, water regime, nutrient status, pH.

Name	Size (ha)	Ecological characteristics	Hydrological Class (other info)	Wetland Class (if known)[3]	Peat depth (mm) if known	Predicted max draw down (mm)
		Protected in part by QEII Covenant, with further area in the process of becoming protected.				
Raumati South Peatlands B	4.96	Moderate sized dune wetland, one of several adjacent. Little information on database.	Palustrine	Fen		10
Te Hapua Swamp Complex A	37.97	Very large dune wetland, part of wetland complex. Landowners trying to create a wetland buffer. Large representative example of habitat that was formally characteristic of the area. Provides habitat for spotless crake. Also *Ranunculus macropus*, *Carex dipsacea*, *Potentilla anserinioides*, (Enright & John 2001). and other species becoming uncommon in the Wellington Region including *Gratiola sexdenta*, kapungawha and *Baumea articulata*. Protected in parts by QEII Covenant - with a further area under negotiation.	Palustrine. Some open water. Northern end of wetland is drained. Artificial water bodies. Will deteriorate slowly unless water table is managed. Buffered by wetness and density.	Swamp. Open water-wetland flaxland on sand plain		90
Te Hapua Swamp Complex D	11.99	Large dune wetland, part of wetland complex. Large representative example of habitat that was formally characteristic of the area. Provides habitat for spotless crake. Also *Ranunculus macropus*, *Carex dipsacea*, *Potentilla anserinioides*, (Enright & John 2001) and other species becoming uncommon in the Wellington Region including *Gratiola sexdenta*, kapungawha and *Baumea articulata*. Protected in parts by QEII Covenant - with a further area under negotiation.	Palustrine. Will deteriorate slowly unless water table managed. Buffered by wetness and density.	Swamp. Open water-wetland / / flaxland on sand plain.		100
Te Hapua Wetland Complex D	?	?	?	Fen		100
Te Harakeke Wetland	80.18	Very large dune wetland/part of wetland complex. A moderately sized area of harakeke flaxland and raupo reedland - the second largest of its type in the Kāpiti District. An important representation of habitat formally common in the area. Protected under QEII Covenant.	Palustrine	Swamp		170
Waikanae Saltmarsh	19.50	Large estuarine wetland, part of wetland complex. Good sequences between salt marsh, fresh water wetlands, dune lakes and dune systems (although degraded and modified). Linkages to Kāpiti Island via Kāpiti Marine Reserve. Provides habitat for numerous fauna species including Australasian bittern, Caspian tern and rare visits from reef and white heron. *Carex litorosa*, *Pimelea* aff. *arenaria*, *Coprosma acerosa*, *Spinifex sericeus*, and	Estuarine. River mouth is cut every 5 years approx, Stock-banks in Waikanae River.	Saltmarsh/		10

Name	Size (ha)	Ecological characteristics	Hydrological Class (other info)	Wetland Class (if known)[3]	Peat depth (mm) if known	Predicted max draw down (mm)
		Leptinella dioica ssp. *monoica* present (Department of Conservation 1996). Also habitat for kapungawha and *Baumea articulata*. Protected as a Scientific Reserve.				
Significant at District Level, may be Regionally significant with additional investigation						
El Rancho Wetlands	8.52	Moderately sized dune wetlands / one of several. Extensively modified. Relative large area of manuka dominated wetland with some open water. Buffered by considerable infestation of gorse and blackberry.	Palustrine	Manuka scrub wetland	500	50
Osbournes Swamp	2.42	Small dune wetland, one of several. Wetland is small and modified. Protected under QEII Covenant.	Palustrine. Constructed open water component	Swamp		60
Pekapeka Road Swamp	4.95	Moderately sized dune wetland/ isolated. Moderately sized wetland with small area of open water and harakeke flaxland-Juncus rushland coprosma scrub associations. Protected under DOC Covenant.	Terrestrial palustrine. Historical drainage with drains present?	Swamp		160
Ratanui Swamp	1.52	Small, somewhat isolated. Wetland <500m. Constructed ponds. Riparian vegetation predominantly exotic including invasive pest plant species. Recommend removal of Ecological Site designation from this site.	May be artificial?	?	2,000	90
Raumati South Peatlands A	2.05	Small dune wetland / isolated. Small area of nationally under-represented habitat type. Relatively large area of kanuka-gorse scrub although it is highly fragmented and exotic species are common	?	Kanuka-gorse scrub, manuka scrub wetland	3,000	10
Te Hapua Wetland Complex B	4.34	Moderate sized wetland / part of wetland. Nothing on KCDC database (not recommended).	Palustrine	Fen		110
Te Hapua Wetland Complex C	7.37	Moderate sized dune wetland / part of wetland. Of moderate size in relation to Foxton Ecological District. Provides habitat for bamboo spike-sedge. Contains open water-reedland-sedgeland-scrub wetland associations. Landowners trying to establish a planted buffer.	Palustrine. Northern end of wetland is drained. Artificial waterbodies and open water present.	Fen		100
Tini Bush	1.27	Small wetland in stream/isolated. Some vegetation clearance. These fragments represent the only example of kohekohe-pukatea associations within Foxton Ecological District. Borders both Foxton and Manawatu Plains Ecological District. Good example of the gradation between wetland and dryland forest with small nikau grove. Representative of the former forest diversity likely to have	Palustrine	Kohekohe pukatea forest, kohekohe forest, kohekohe titoki forest, semi-swamp forest		210

Name	Size (ha)	Ecological characteristics	Hydrological Class (other info)	Wetland Class (if known)[3]	Peat depth (mm) if known	Predicted max draw down (mm)
		occurred within the District. Part of a series of fragments providing connection between Kāpiti Island and the Tararua Ranges. Provides habitat for kereru. Protected by DOC Covenant.				
Waimeha Lagoon – Victor Weggery Reserve	4.09	Moderately sized lake and wetland / somewhat isolated. Wetland habitat with moderate area of open water and raupo reedland-coprosma scrub associations. Provides habitat for kapungawha. Protected as Wildlife Refuge.	Palustrine. Open water is artificially maintained. Strong urban stormwater influence to hydrology. Drains maintained through site.	Swamp		80
Limited value, may be significant at the District level						
Andrews Pond	1.34	Small/isolated. A small wetland amongst residential and commercial land use. Provides habitat for kapungawha. Appears to have significant water quality problems and has degraded since RAP recommendation (circa 1990)	Palustrine.	Manuka / Isolepis / sphagnum shrubland	3,000	30
Kaitawa Reserve Swamp Forest	0.41	Very small, very isolated. Very small fragments of under-represented habitat types including swamp forest. Indicative of previous diversity of vegetation type in the area. Provides habitat for kereru. Active restoration plan is in place. Protected in part as Council Scenic Reserve and part Recreational Reserve.	Terrestrial	Pukatea-maire tawake swamp forest, mahoe forest, kohekohe kanuka forest		10
Kāpiti Airfield Wetland A	2.57	Small dune wetland, somewhat isolated. Very small area of greatly modified ephemeral wetland that provides habitat *for Spiranthes novaezelandiae.* This is the only known natural population of this species within Wellington Region. Very degraded ephemeral site. Only included because of presence of rare orchid. Would need active management and restoration for in situ management of this species. At time of survey mowing contractor was mowing some of the site.	Palustrine	Fen		10
Kowhai Stream Mouth (Hadfields)	2.2	Small barren river mouth, isolated.	Estuary / river mouth	?		80
Ngarara Bush	0.89	Very small, somewhat isolated Small fragment of kohekohe forest and a very small area of swamp forest. Protected under QEII covenant.		Kohekohe forest, kahikatea-pukatea forest		190
Ngarara	2.5	Small dune wetland, one of several.	?	?	3,000	150

Name	Size (ha)	Ecological characteristics	Hydrological Class (other info)	Wetland Class (if known)[3]	Peat depth (mm) if known	Predicted max draw down (mm)
Road Wetland D						
Otaihanga Landfill South	1.4	Small dune wetland, one of several	?	Fen?	1,000	90
Poplar Ave Wetland	3.51	Moderately sized dune wetland. Somewhat isolated. Site Description. Manuka scrub dominated wetland (unit 01). Manuka is more sparse in south end of site here wetland is open rushlands with Isolepis prolifer dominant. Dense blackberry is present on in the north end of this site.	Palustrine. Surrounding area has been cleared and drained in the past and more recently developed for residential purposes.	Fen		10
Te Hapua Swamp Complex E	2.71	Small dune wetland, somewhat isolated. Small wetland habitat with constructed pond and exotic species common.	Palustrine. Constructed ponds.	Fen		100
Te Hapua Swamp Complex F	1.56	Small dune wetland, somewhat isolated. Artificial pond in wet pasture	Palustrine. Constructed ponds main change.	Fen		100
Turf Farm Dune Forest	0.18	Very small, somewhat isolated. Lacking understorey. Narrow area of manuka scrub. Both habitat types are underrepresented in the Foxton Ecological District. Part of a series of fragments that jointly indicate the diversity of habitat formally common in the area.	Palustrine	Kahikatea swamp forest, manuka scrub		160
Unsurveyed site 5	3.17	Moderately sized, somewhat isolated	?	?		170
Waimanu Lagoons	0.64	Very small lake and wetland, somewhat isolated. Highly modified, with artificial assemblage of species and some inappropriate enhancement plantings. However, this site has linkages to Waikanae River Mouth and provides continuation of open water habitat. High use by water bird species.	Lacustrine. Flap gates have changed this site significantly	Shallow		20
Waimeha Stream Mouth	?	Large barren river mouth, isolated.	?	?		80
Wharemauku Stream Mouth	2.9	Small, barren river mouth, very isolated	?	Estuary/river mouth		10
May not be significant or insufficient information4.						
Crown Hill Manuka	0.52	Very small, isolated. Very small area of unprotected wetland	?	Manuka scrub wetland		110

[4] Note: for this last category of wetlands, the listed drawdowns were not calculated using modelled observation wells. The listed values are derived only from the contours to 100 m.

Name	Size (ha)	Ecological characteristics	Hydrological Class (other info)	Wetland Class (if known)[3]	Peat depth (mm) if known	Predicted max draw down (mm)
Bush		dominated by manuka scrub.				
Kāpiti Airfield Raupo Swamp	0.27	Very small dune wetland, somewhat isolated.	?	?		10
Kāpiti Airfield Wetland B	0.77	Very small dune wetland, somewhat isolated	?	?		10
Kāpiti Road Wetland A	0.62	Very small dune wetland, somewhat isolated. Constructed ponds. Riparian vegetation predominantly exotic including invasive pest plant species. Recommend removal of Ecological Site designation from this site.	Palustrine. Constructed ponds.	?		10
Lions Down Bush	1.53	Small, somewhat isolated. Small area of nationally under-represented habitat type. Canopy fragmented and exotic species common in the ground layer. Part of a series of fragments that jointly illustrate the diversity of habitat formally common in the area. Protected under QEII Covenant.	Terrestrial	Kahikatea pukatea swamp forest		80
Ngarara Lake (could not find by this name)	1.55	Small dune wetland, one of several adjacent wetlands	Lake	?		20
Ngarara Road Wetland A	1.28	Small dune wetland, one of several adjacent wetlands	?	?		150
Ngarara Road Wetland B	0.70	Very small dune wetland, one of several adjacent wetlands	?	?		150
Ngarara Road Wetland C	0.64	Very small dune wetland, one of several adjacent wetlands	?	?		150
Otaihanga Landfill Central	1.31	Small dune wetland, one of several.	?	?	2,000	90
Otaihanga Landfill North	0.83	Very small dune wetland, one of several.	?	?	500	90
Reikorangi Road Bush D	1.72	Small wetland on river terrace very isolated.	Terrestrial	?		0
Unsurveyed Site 11	0.67	Very small, somewhat isolated.	?	?		150
Unsurveyed site 12	0.63	Very small, somewhat isolated.	?	?		150
Waikanae River Oxbow	0.47	Very small wetland on river terrace, somewhat isolated.	?	?		50

In summary, a total of 47 wetlands fall within the Scenario 4 drawdown contours (Appendix 1). Of these 17 wetlands are considered to be nationally or regionally significant. A further 15 wetlands are locally important. A final 15 are of low value due to small size and modification, or are poorly known.

We note that Table 1 above focuses on those wetlands identified in the Kāpiti Coast District using the GWRC Wetland Delineation Project. We have since identified one additional wetland that was not included in this assessment: Waikanae North Scrubland, KCDC K065 – a 7.68 ha area of kanuka-manuka scrub and sphagnum moss wetland. We have not included this wetland in the above analysis as there is little known about this area.

All the wetlands of the Kāpiti Coast sand country (and likely effected area of drawdown) are classified as Acutely Threatened (LENZ Threat Classification). There may also be areas of remnant forest within the RRwGW area that include a component of swamp forest that may require more detailed consideration.

We note that for a number of the wetlands within the potentially affected area of the RRwGW Scheme, there is little or no information on flora, fauna, wetland hydrology or underlying peat characteristics (as highlighted in Table 1 above). Therefore, for a number of wetlands outside of the MacKays to Peka Peka Expressway alignment, we have made a 'best guess' based on known information – with some general comments based on our knowledge of peat depths and other observations.

In section 6 of this Report, we separate the potential RRwGW Scenario 4 drawdown effect by wetland classes as determined by the GWRC Wetland Delineation Project.

6.0 Potential effects on Kāpiti Coast wetlands

It is with this more general background on the influence of the Kāpiti Coast's shallow water table on wetland hydrology that we now consider the potential effects of abstraction on each of the identified wetlands located within the RRwGW Scheme. Potential effects are considered in the context of natural variations (including existing groundwater takes) under that worst case drought scenario. We reiterate that the CH2M BECA Scenario 4 effects that we have based this assessment on are for a worst case scenario of up to 15 weeks during a 50 yr drought period. We have not assessed the lesser magnitude drawdown effects during lesser droughts modelled.

Potential adverse effects of the proposed RRwGW Scheme on wetlands would occur where the take of water from the Holocene Sand Aquifer results in a drop in the water level of the wetlands of the Kāpiti Coast to such an extent that the area and/or condition of vegetation or habitats of the wetland are adversely affected. Potential effects on each wetland depends on the degree to which groundwater of various depths is connected to the surface waters of individual wetlands. With the exception of Te Harakeke Wetland, most of the wetlands on the Kāpiti Coast have no significant surface water input, so the hydrology relies mostly on groundwater inflow and local rainfall.

Given the lack of information on the hydrological characteristics of most of the wetlands within the RRwGW Scheme, we have broadly considered the potential / anticipated effects on the different wetland classes present[5]. Palustrine wetlands, the dominant hydrological class of the predominantly swamp, fen and ephemeral wetlands typically present on the Kāpiti Coast, are fed by rain, groundwater, or surface water and do not occur within the normal boundaries of estuaries, lakes or rivers (Campbell & Jackson, 2004). Palustrine wetlands accumulate nutrients and form rich, fertile soils as plant material breaks down anaerobically given the high water table. Of these palustrine wetlands, a large number of Kāpiti Coast wetlands include an element of a number of wetland classes, which may include a combination of swamp, fen, bog and ephemeral wetlands. The complexities of these systems and the information required to simply understand wetland class is illustrated by Allen's (2010) detailed surveys of 21 individual wetlands within the Te Hapua Wetland Complex to gather water quality and water regime data to enable an assessment of wetland class. More specific investigations need to be undertaken in a number of the wetlands outlined in Table 1 to determine wetland class. Further, a number of the wetlands outlined in Table 1 include a component of terrestrial vegetation. In the absence of a site visit to these wetlands or other information on wetland class, we have included terrestrial vegetation associations within the swamp or fen wetland category.

Given the lack of specific baseline or background information on the wetlands within the RRwGW Scenario 4 zone of influence, the changes in hydrological parameters associated with the Scenario 4 drawdown presented in Table 1 above have been separated by wetland class for more general assessment of potential effects.

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5 Wetland classes are governed by distinctive combinations of substrate factors, water regime, and the consequent factors of nutrient status and pH. Nine wetland classes are recognised: bog, fen, swamp, marsh, seepage, shallow water, ephemeral wetland, pakihi and gumland, and saltmarsh (wetland classes and descriptions are from Johnson, P. & Gerbeaux, P. 2004. Wetland Types in New Zealand. Department of Conservation).

Using the assumptions presented in section 5 and the Ch2M BECA Report, wetlands with a strong hydrological relationship to the Holocene Sand Aquifer could therefore be affected by the proposed Scenario 4 drawdown through:

- A drop of between 10 mm and a maximum of 210 mm over summer periods for fen wetlands
- A drop of between 10 mm and a maximum of 190 mm over summer periods for swamp wetlands
- A drop of a maximum of10 mm over summer periods for saltmarsh wetlands
- A potential increase in the number of days at lowest water levels to 15 weeks.

6.1 Fen wetlands

A fen wetland comprises predominantly peat substrate that receives inputs of groundwater and nutrients from adjacent mineral soils. The water table is usually close to or just below the peat surface, and relatively constant. Water flow is slow to moderate. Fens have low to moderate acidity and are oligotrophic to mesotrophic.

Typical Examples: Raumati South Peatlands, Eastern Te Hapua Wetlands, El Rancho Wetlands and Muaupoko Swamp Forest.

The fen wetlands present in the RRwGW Zone are typically dominated by sedge, rush, fern or manuka scrub vegetation. Key indicator species include: *Schoenus, Baumea, Gleichenia* and *Leptospermum*. Based on the limited information gathered as part of the MacKay's to Peka Peka peat depth investigations, typical peat depths range from 500 mm to 3,000 mm in the fen wetlands within the RRwGW Zone.

Based on our knowledge of the Kāpiti Coast wetlands and that of other authors, dominant water input to fens is via local rainfall and local through-flow of shallow groundwater, especially from surrounding dunes (Allen, 2010). The water table tends to be high and relatively constant in fen wetlands (Johnson and Gerbeaux, 2004). This conforms with our seasonal observations in those fen wetlands adjacent to the M2PP Expressway and other studies.

As most fen wetlands on the Kāpiti Coast are discharge wetlands, their hydrology in typically more dominated by shallow groundwater inflow, which buffers these wetlands from variations in water level, hence fluctuations are less dramatic than in surface flow wetlands (typically swamps on the Kāpiti Coast) (Law, 2008; White, et al., 2001; Allen, 2010). However, these reduced fluctuations are likely to mean that the wetlands and their associated peats and vegetation associations are less likely to withstand large seasonal changes as modelled – particularly if these are greater than 100 mm and persist for an extended period.

In terms of the potential effects of drawdowns in the fen wetlands between 10 mm (Raumati Peatlands B) and a maximum of 210 mm (Tini Bush), we consider that they are at a moderate to high risk of seasonal drying out and associated effects. Our own observations in Tini Bush this year suggest low levels of peats (10- 20 cm depth) over saturated sands in these low-lying dune depressions. A 210 mm drawdown could have significant effects on the understory species, e.g. loss of wet ground dependent ferns and bryophytes etc.

Our knowledge of the botanical values of a number of the fen wetlands of the Kāpiti Coast illustrates that these areas typically provide habitat for the more ephemeral species that can tolerate narrower bands of wet and dry cycles, particularly the ephemeral edges of wetlands.

For those fen wetlands dominated by remnant swamp forest, the impacts will potentially be masked by a higher tolerance of these canopy species. However, we consider that these effects and the ability of the vegetation to withstand drought-induced stresses will largely depend on underlying peat depths. From the peat depth information gathered as part of the MacKay's to Peka Peka investigations, peat depths in the fen wetlands range between 20 mm at Tini Bush to up to 3,000 mm at the Raumati South Peatlands.

A range of vegetation stresses were observed in the summer of 2010-2011 in a number of the fen wetlands of the Kāpiti Coast, including El Rancho Wetland and the Raumati South Peatlands, where large-scale dieback of broadleaved species such as five-finger was observed in late summer. As outlined above, indigenous species die-back and larger changes in water fluctuations through summer potentially expose fen wetlands to increased competition from exotic plant species, a number of which are fast growing invasive weeds (e.g. gorse, blackberry and other herbaceous pasture weeds). This could lead to weeds taking over wetlands and only those species tolerant of rapidly changing water tables will survive. This would comprise a significant effect, given the high propensity for weed growth in the Kāpiti Coast.

In the absence of both a field survey and detailed understanding of the hydrology of the potentially affected fen wetlands, it is assumed that this reduction may impact on the vegetation composition and could result in invasion by exotic species – particularly if there are extended dry periods during peak growth seasons. It may also result in a reduction of the overall wetland size.

In summary, potential adverse effects on fen wetlands associated with the RRwGW Scenario 4 drawdown are as follows:

- Increased dry periods as peat and wetland substrates dry out.
- Potential peat compaction following extended dry periods, leading to peat breaking down faster;
- Changes in the nutrient and chemical composition in wetlands;
- Wetland vegetation is likely to migrate in towards areas previously inundated at most flows;
- Competitive exotic species (gorse, blackberry, tall fescue and other grasses, willows) are more likely to colonise and potentially dominate at wetland edges given longer periods of dry conditions; and
- Potential effects on adjacent dry forest components of remnants as wetland changes places additional extractive stresses on these areas through peat recharge.

6.2 Swamp wetlands

A swamp wetland receives a relatively rich supply of nutrients and often also sediment via surface runoff and groundwater from adjacent land. Swamps usually have a combination of mineral and peat substrates. Leads of standing water or surface channels are often present, with gentle permanent or periodic internal flow, and the water table is usually permanently above some of the ground surface, or periodically above much of it.

Typical examples: Te Harakeke Wetland, Nga Manu Wetlands, Western Te Hapua Wetlands

The swamp wetlands present in the RRwGW Zone comprise a wide variety of sedge, rush, reed, tall herb, flax and scrub types – often intermixed with swamp and dry forest. Key indicator species include: *Phormium, Carex, Coprosma, Typha, Cordyline, Dacrycarpus, Syzgium and Leptospermum.*

According to Johnson and Gerbeaux (2004) the water table in swamp wetlands tends to be very high (i.e. above parts of the ground surface, but also variable). This conforms with our seasonal observations in those swamp wetlands adjacent to the MacKays to Peka Peka Expressway. It is our understanding that most of the swamps on the Kāpiti Coast are likely to comprise recharge wetlands, where water levels fluctuate more (Allen, 2010). Based on our observations and published information, the dominant water input to swamps on the Kāpiti Coast is via local rainfall, runoff and through-flow from the immediate watershed and adjacent wetlands. By way of example, Law (2008) calculated that groundwater inflow makes up 65% of the total water inflows into Te Harakeke Wetland system (approximately 30 ha in size). Groundwater outflow was calculated by Law 2008 to contribute 9% to the total losses from the Te Harakeke Wetland system.

The hydrological research of Jones & Gyopari (2005) suggest that a drawdown effect of less than 100 mm is unlikely to adversely affect the wetland ecology of Te Harakeke Wetland, given that the natural fluctuations in groundwater level around the wetland appears to be about 200-300 mm. Jones & Gyopari suggest that at a regional-scale the abstraction of shallow groundwater at low rates appears to not pose a threat to wetland systems. However, they did state that at a local-scale the abstraction of greater rates than garden irrigation wells may affect wetland water levels.

With the exception of Ngarara Bush (with predicted maximum drawdown of 190 mm), we consider the drawdown range of between 10 mm (at the Kaitawa Reserve Swamp Forest wetland) and a maximum of 160 mm (Peka Peka Road Swamp) in summer water levels is unlikely to have any detectable effect on the wetland values – unless the drawdown persists for a long time and is subject to more frequent cycles. While such a drawdown is likely to comprise an additional stress on these groundwater fed systems, we consider that swamp wetlands should be able to persist as these predicted drawdown are within range of the natural seasonal variations experienced by these wetlands.

We consider the biggest risk to these swamp wetlands is the potential length of time of the drawdown of 15 weeks. This extended drawdown during a period of other hydrological stresses on wetlands (when they are experiencing high levels of evapo-transpiration and minimal rainfall recharge) may lead to potential effects on vegetation composition at the margins – particularly if these areas are exposed to ongoing or increased drought cycles.

While there have been large-scale changes to wetlands on the Kāpiti Coast over the past 100 years plus associated with swamp drainage, vegetation clearance and the increased use of shallow bores (<6m deep), there is little evidence that changes to the shallow water table have resulted in the loss of primary swamp forest wetlands. Historically, during drought situations, seepage to dune swale wetlands from groundwater is generally sufficient to maintain the wet root zone conditions required by wetland plants (Phreatos, 2002). Peat depths are also likely to be one of the reasons for the survival of these wetlands, although there is little information from historical studies on peat depth of swamp wetlands of the Kāpiti Coast.

There is also evidence from other swamp wetlands within the Foxton Ecological District that a gradual lowering of approximately 1 m has not led to a massive die-back in vegetation (e.g. the kahikatea of Round Bush, Foxton). The approximately 400 year old remnant swamp forest of Nga Manu also illustrates that these systems are capable of withstanding extended droughts and rapid hydrological changes. For these swamp forest wetlands, we consider the forest canopy should assist with minimising seasonal hydrological stresses of the drawdown predicted.

In summary, potential adverse effects on swamp wetlands associated with drawdown are as follows:

- Areas of open water and shallow water wetland components are likely to decrease during maximum drawdown;
- Increased dry periods as peat and wetland substrates dry out;
- Potential peat compaction following extended dry periods, leading to peat breaking down faster;
- Changes in the nutrient and chemical composition in wetlands;
- Wetland vegetation is likely to migrate in towards areas previously inundated at most flows;
- Competitive exotic species (willows, blackberry, tall fescue) are more likely to colonise and potentially dominate at wetland edges given longer periods of dry conditions; and
- Potential effects on adjacent dry forest components of remnants as wetland changes places additional extractive stresses on these areas through peat recharge.

6.3 Shallow water wetland

These wetlands comprise aquatic habitats, generally less than a few metres deep, having standing water for most of the time. This wetland class accommodates the margins of lakes, rivers and estuary waters with open bodies of water further from the shore. The dominant unifying determinant is the presence of standing water. Nutrient and water chemistry factors are basically those of the water, rather than the substrate.

The shallow water wetlands present in the RRwGW Zone comprise submerged, floating or emergent aquatics. Key indicator species include: *Myriophyllum, Potamogeton, Azolla, Bolboschoenus, Baumia, Schoenoplectus* and *Isolepis.*

For this report, this wetland class has been incorporated into the open water or lake components of the larger wetlands of other classes above, primarily swamp wetlands.

6.4 Saltmarsh wetland

Saltmarsh wetlands embrace estuarine habitats of mainly mineral substrate in the intertidal and sub-tidal zones, but also include those habitats in the supra-tidal zone and in the inland saline hydro system. Water source is from groundwater and adjacent saline or brackish estuary waters.

Typical examples: Waikanae Saltmarsh

The Waikanae Saltmarsh is the only saltmarsh wetland present in the RRGW Zone.

Overall, we do not consider the modelled worst case drawdown of 10 mm is likely to have a significant effect on the Waikanae Saltmarsh, given the likely range in tidal influences on both this river mouth and shallow aquifer in this area. The tidal reach of the Waikanae River extends some distance upstream beyond the Waikanae Saltmarsh – and the tidal fluctuations and regular alternation of ebb and d flood flow are considered likely to have a greater and more regular effect than a potential 10 mm lowering of water levels in this area. Further, the regular opening up of the Waikanae River mouth approximately every 5 years illustrates that this saltmarsh wetland is able to withstand regular perturbations and disturbances that are likely to exceed 10 mm. The Waikanae Estuary, of which the Waikanae Saltmarsh is a component, is the ultimate receiving environment for the Waikanae River and much of the east-west groundwater flow.

However, given the saltmarsh vegetation present is unique in the Wellington Region and the value of the area as habitat for a number of native bird species, adaptive management could focus on ensuring there are no impacts on these habitat values. Any effects of the proposal on saltmarsh wetlands will be negligible.

In summary, potential adverse effects on saltmarsh wetlands associated with worst case drawdown are as follows:

- Areas of open water and shallow water wetland components may decrease during maximum drawdown;
- Increased dry periods as peat and wetland substrates dry out;
- Competitive exotic species (willows, blackberry, tall fescue) may be more likely to colonise and potentially dominate at wetland edges given longer periods of dry conditions; and
- Potential effects on shellfish and flow-on habitat effects for avi-fauna.

6.5 Ephemeral wetlands

Ephemeral wetlands comprise a distinctive wetland class most frequently found in closed depressions lacking a surface outlet, in climates where seasonal variation in rainfall and evaporation leads to ponding in winter and spring and with fluctuations so pronounced that it can lead to complete drying in summer months or in dry years (Johnson & Rogers, 2003 cited in Johnson and Gerbeaux, 2004). The water source is groundwater or an adjacent water body. Substrates are usually wholly mineral, upon an impervious underlying horizon. Water flow is slow to nil, nutrient status moderate and pH neutral.

In terms of the Kāpiti Coast wetlands, ephemeral wetlands are more likely to comprise the smaller wetlands and the outer edges of the swamp and fen wetlands. For the purposes of this report, it was not possible to identify specifically which of the wetlands are ephemeral and they have been more broadly defined into swamp and fen wetlands.

6.6 Summary of potential effects

Effects on shallow groundwater beneath key identified wetlands as predicted by the worst-case modelled drawdowns in the Holocene Aquifer could be up to 210 mm (Tini Bush). As noted in the CH2M BECA report, these predicted water level change effects do not translate directly to changes to water levels in the wetlands – as these areas can have sources of water other than the underlying groundwater (e.g. surface water runoff and direct rainfall can create a wetland in areas with low permeable substrates – a “recharge” or “through-flow” wetland). In other situations where a wetland is fed by groundwater (a “discharge” wetland), a lowered groundwater level beneath the wetland may or may not, result in a lowered water level in the wetlands. If a discharge wetland has an elevation-controlled outlet, then a lowered groundwater level may not change the level in the wetland, as long as the groundwater discharge to the wetland remains sufficient to maintain the wetland water level to the elevation of the outlet. It is important to reiterate that the predicted changes in water levels beneath the wetland serve as an indicator of the “worst-case” changes that could occur.

While the modelled changes are less than the normal variations in water levels of 1 to 2 m observed in wells completed in the shallow aquifers as presented in the CH2M BECA report, our knowledge of many of the wetland systems of the Kāpiti Coast suggests the effects on some wetlands have the potential to be significant under this worst case scenario. As outlined in Table 2, the potential effects of a maximum 210 mm drawdown could be significant, particularly if this maximum drawdown occurs during periods of prolonged droughts. However, determining at what stage drawdown will have an adverse effect depends on the ecological and hydrological characteristics of the individual wetlands present.

The level of research and monitoring undertaken to date on the Kāpiti Coast wetlands is insufficient to determine whether Scenario 4 would result in adverse effects on wetland surface levels. We do not consider a broad aggregation based on ecological significance, wetland or hydrological class provides sufficient detail to determine either effects or monitoring.

However, there are good indications that despite their groundwater dependency, the wetland water levels are not likely to be affected by groundwater abstraction for the following reasons:

- The main input of water for the wetlands is from local rainfall, local runoff, and shallow groundwater from nearby dunes;
- There are multiple confining layers between the surface and the deepest confined aquifers which would almost certainly limit surface water exchange with deep groundwater;
- It appears that the pressure heads of deeper aquifers are higher than those of shallower aquifers, creating a hydraulic gradient that would, if conditions allowed, induce upward leakage, not downward leakage. Downward leakage is a threat to wetland water levels, not upward leakage.
- The estimated transmissivity, specific yield and hydraulic gradient of the aquifers that underlie the wetlands are particularly low.

Overall, very few wetlands potentially affected by the RRwGW Scheme Scenario 4 drawdown have direct hydrological inputs other than groundwater. Accordingly, peat depth, scale of surrounding peat deposits and dune landforms will be the primary influencing factors on the ability of each wetland system to tolerate potential drawdown effects. While groundwater remains the principal effect of concern, the scale and depth of peat will determine the time lag of potential effects, with more extensive and deeper peats more likely to withstand large and long-term drawdowns.

There is some evidence that the larger wetlands are likely to be better able to withstand hydrological effects, as they are more insulated from effects. Further, evapo-transpiration is likely to be less from forested wetlands. Answering this question definitively, however, requires more monitoring and testing of groundwater in bores of various depths close to the potentially affected wetlands that may experience the greater drawdowns.

Wetlands, by their nature are also highly tolerant of environmental stresses and are generally capable of adapting to variations of hydrology. A review of historic high-resolution aerial photographs from 1956, 1966 and 1987 (NZ Aerial Mapping) of the Kāpiti Coast demonstrate the degree of change in wetland character over the short and long term. While a large proportion of wetlands have disappeared from the Kāpiti Coast since historic patterns, it is notable that a number of wetlands have developed over the last 20 – 30 years, e.g. the Raumati Peatlands B was not visible in aerial photographs dating from 1987. Similarly, the majority of today’s regionally significant El Rancho Wetland complex was absent from 1966 aerials. Recent research suggests that the future viability of the Kāpiti Coast wetlands appears promising, for example the historical groundwater declines within the Te Hapua wetland complex appear to be minimal and show signs of reversing (Allen, 2010). However, once a wetland system has been severely modified, it is almost impossible to return the system to its natural state (e.g. 400 year old swamp forest such as Nga Manu).

Overall, as long as Scenario 4 of the RRwGW drawdown is not permanent and does not substantially exceed 15 weeks before aquifer recharge, we consider these predicted drawdowns are unlikely to have a major effect on most of these wetlands, with any effects being short-term. However, in the absence of detailed hydrological and wetland class information and long-term monitoring of this uncertainty over the extent and magnitude of potential hydrological effects, a monitoring and adaptive management approach is required and this is discussed in Sections 7.0 and 8.0 of this report.

There are also a number of potential positive benefits to consider, particularly for those wetlands that have been the subject of artificial control structures and excavation. Wetland vegetation diversity increases as water levels within the wetland decrease, creating opportunity for dry land plants to colonise the area (GWRC, 2005). Permanently flooding a wetland decreases plant diversity, as fewer species are adapted to deepwater and the wetland habitat becomes more homogenous (Sorrell et al, 2004), resulting in dominance by a few plant species (GWRC, 2005). The decrease in habitat homogeneity also decreases the diversity of animals present in a wetland system (Laws, 2008).

7.0 Wetland monitoring

Given the lack of wetland-specific ecological and hydrological monitoring to date and the potentially significant range in adverse effects on wetland systems associated with the RRwGW Scenario 4 drawdowns, we recommend that KCDC implement a comprehensive monitoring and adaptive management approach to appropriately understand and manage the potential effects of the RRwGW Scheme on the identified wetlands.

The Monitoring Plan will need to establish a detailed baseline for water levels, wetland extent and plant communities. From this ecological and hydro-geological monitoring triggers can be determined. This approach is broadly consistent with the MacKays to Peka Peka monitoring regime and the Waikanae Borefield Monitoring Manual, which use monitoring information and triggers developed by URS from historical GWRC and KCDC bore information.

Wetland monitoring has been designed to focus on the full range of nationally or regionally significant wetlands (including wetland class) within the RRwGW Scenario 4 drawdown area – and includes those wetlands with a long history of wetland and/or water table monitoring. Wetland monitoring is recommended to ensure any effects can be picked up in sufficient time to implement adaptive management approaches for other wetlands potentially at risk. Groundwater monitoring within and adjacent to wetlands will also improve understanding of peat depths in potentially at-risk wetlands, which will provide additional baseline information on the potential ability of each wetland to tolerate drought-induced stresses.

The recommended monitoring framework is discussed in more detail below:

7.1 Groundwater monitoring

Most studies of groundwater dependent wetlands on the Kāpiti Coast have recommended additional environmental monitoring in the form of continuous recording of selected wetland water levels and spring flows (refer for example Jones and Gyopari (2005), Law (2008), Allen (2010) and Williams (2011)). Consistent with this research and our knowledge of the groundwater dependent wetlands of the Kāpiti Coast, we recommend that stringent monitoring requirements should be undertaken within the surface water and shallow aquifers of the RRwGW area to consider those ecologically significant wetlands outlined as having potential worst case drawdowns of 100 mm or more in Scenario 4.

The selection of 100 mm as a trigger for potential effects is based on a few studies carried out at specific sites. It may be conservative and over-estimate effects. Equally it may underestimate effects and some wetlands may be impacted by a groundwater drawdown of less than 100 mm. An objective of this monitoring should be to confirm this trigger level.

This monitoring needs to also provide data to assess the hydraulic connection between the wetland and groundwater to determine adaptive management triggers and/or approaches. This information will be critical to the management and conservation of these areas. Such monitoring will allow the water level variation in the wetlands to be quantified and provide data to assess the hydraulic connection between the wetland and groundwater – and develop an adaptive management approach (discussed in Section 8 of this report).

We recommend that if a trigger level is exceeded, the data is reviewed to see why triggers are breached and whether it could have been caused by water abstraction as part of the RRwGW Scheme. The monitoring should also be reviewed to determine whether additional data should be gathered to enable further review. On the basis of that review, action may be taken to remedy or mitigate any effects that maybe occurring as a result of the abstraction.

As outlined above, piezometer installation will inform peat depth information which should assist with assessing risk to wetland health associated with drying out (i.e. shallower peat is assumed to be subject to more rapid peat drying – and may in turn influence rehydration rates).

Recommended groundwater monitoring locations

Table 2 outlines the recommended groundwater monitoring locations based on the expected maximum drawdown range of RRwGW Scenario 4 and the ecological significance / potential effects on identified wetlands. We have also recommended groundwater monitoring at a small number of control wetlands beyond the modelled the influence of RRwGW Scenario 4. We have not included saltmarsh wetlands or estuarine systems.

Monitoring of these control wetlands will provide information to ensure that in the event any wetland trigger levels are exceeded, only those changes attributable to the RRwGW scheme are addressed and mitigated.

Table 2. Recommended Wetland Monitoring Locations (greater than 100mm drawdown)

Wetland location	Wetland class	RRwGW Scenario 4 Drawdown (mm)	Existing shallow groundwater monitoring well
Wetlands identified as nationally or regionally significant			
Muaupoko Swamp Forest	Fen	110	Locations to be confirmed
Nga Manu Wetland	Fen	140	GWRC Nga Manu, Well Site K5 Nga Manu
Te Hapua Swamp Complex D[6]	Fen	100	WRC Monitoring Bores – locations to be confirmed – refer Allen Thesis.
Te Harakeke Wetland	Swamp	170	Te Harakeke 03, M2PP 2011/BH209, M2PP 2012/BH18
Representative wetlands for each wetland class identified by GWRC as locally significant or insufficient information to determine significance			
El Rancho Wetlands (CONTROL)	Fen	50	Waikanae CHP Shallow, M2PP 2011/HA WM5, 2007/BH-O, 2008/BH205P, 2007/BH-Q
Tini Bush	Fen	210	Location to be confirmed.
Ngarara Bush	Fen?	190	KCDC/K12, M2PP 2012/BH20
Ngarara Road Wetland D	Fen?	150	Well Site K4 – Cooper #1, M2PP 2011/BH210
Otaihanga Landfill South	Fen?	90	M2PP 2012/BH10, M2PP 2011/BH305, M2PP 20112/BH11, M2PP 2011/BH307
Crown Hill Manuka Bush	Fen	110	M2PP 2012/BH09

We recommend KCDC continue to use a combination of the information from the existing permanent shallow monitoring wells as outlined in Table 2 above (refer Table 2.2 of URS report

[6] The Te Hapua and Otaihanga Wetland monitoring locations outlined above should provide a general reference for monitoring of the hydrology of the wider Te Hapua Wetlands (approximately 21).

(2010)) and the programme of water level monitoring that has been established in monitoring bores along the proposed MacKays to Peka Peka Expressway since October 2010.

As outlined in Williams (2011), water levels in a number of shallow wells on the Kāpiti Coast have been monitored since 2005 and the well hydrographs provide a valuable record of long term trends in groundwater levels. Hydrographs from work undertaken by Williams (2011) show a seasonal variation with lowest water levels typically recorded in April (end of summer) and the highest water levels recorded in October (end of winter). Water level trends in the shallow bores also remain generally constant from year to year. Comparisons with rainfall records from Waikanae Treatment Plan indicates that changes in water levels in the shallow unconfined aquifers have a strong correlation with rainfall events, suggesting that the shallow aquifer responds rapidly to rainfall recharge (Williams, 2011).

Wetland alert levels

Given the absence of baseline groundwater information on each of the individual wetlands at risk of the RRwGW Scenario 4 drawdown, we consider there is insufficient information to develop a trigger level for each wetland potentially affected. If consent is sought in the coming months, we consider that groundwater monitoring should be implemented in these wetlands immediately.

For those wetlands with established shallow groundwater monitoring information (e.g. Te Harakeke Wetland, Nga Manu Wetlands, Te Hapua Wetlands, El Rancho Wetlands), we recommend that trigger levels for wetland well monitoring should be set as a reduction below the lowest recorded naturally occurring low level for the standpipe piezometers as determined by historical data (M2PP) as follows:

Alert level	0.2 m variation outside the naturally occurring range for the piezometers.
Action level	To be set when the alert level is reached, relative to the potential for effects at that location.

In the absence of specific monitoring information to develop well-specific water level triggers in the wetlands outlined in Table 2 above, we recommend that the groundwater information gathered by URS (2010) based on analysis of 31 months of well data (October 2005 to April 2008) should be used to develop a 50% trigger level for shallow groundwater and wetlands based on the lowest historical level minus 50% of the historic variation. These triggers should then be refined for each wetland following gathering of sufficient monitoring information.

The Wetland Management Plan should provide for groundwater abstraction monitoring to be increased to weekly intervals once drought triggers are reached to ensure any potential effects are picked up in time to develop, agree and implement an adaptive management response.

The Wetland Management Plan should also allow for those cases where post-groundwater abstraction mitigation is implemented – and should provide for monitoring specific to such mitigation to be continued for a longer period if the collected data does not indicate a return to pre-abstraction groundwater levels or establishment of a new equilibrium.

Given the large range in seasonal variations in wetland water levels, and the relative unique hydrology of each wetland, it will be essential that a component of monitoring ensures that any changes in shallow groundwater or wetland levels are assessed relative to regional changes i.e. if water level in a monitoring wetland falls well below its trigger level, the first action should be to review the water level trend in the control locations / adjacent wetlands.

7.2 Wetland Condition Monitoring Plots

Wetland Monitoring Locations

To ensure the hydrological monitoring outlined above is coupled with ecological monitoring of wetlands, we recommend that Wetland Condition Monitoring[7] be undertaken at a number of at-risk wetlands within the RRwGW Zone to provide an ecological baseline condition as part of assessing vulnerability of individual wetlands to a decline in water levels.

The National Wetland Monitoring System is a Landcare research project developed specifically for New Zealand wetlands (Clarkson et al. 2003). This approach involves a systematic comparison and evaluation process integrating data gathered from small-scale permanent plots, fauna stations, hydrological stations, etc., as well as whole wetland assessments, e.g., extent of willow coverage, proportion remaining of the original wetland area and species lists. The overall ecological condition of the wetland is compared against an assumed natural state, such as pre-settlement. It is scored using five indicators to reflect the extent and impact of the modification where a high degree of modification = low score. The indicators relate to the major threats known to damage wetlands and are based on changes in:

- • Hydrology
- • Soils/nutrients
- • Ecosystem intactness
- • Native animal dominance (‘pest-free’ measure)
- • Native plant dominance (‘weed-free’ measure)

The sum of the indicator scores provides an “index” for the ecological condition of the wetland, known as the Wetland Condition Index (WCI). These indicator scores, combined with photo points and aerial photography, should be used to determine ecological baselines of wetland condition.

Table 3 Recommended Wetland Condition Monitoring Locations within the RRwGW Scenario 4 drawdown of greater than 100mm:

Wetland location	Wetland class	RRwGW Scenario 4 Drawdown (mm)	Wetland Condition Monitoring undertaken?
Wetlands identified as regionally significant			
Muaupoko Swamp Forest	Fen	110	No
Nga Manu Wetland	Fen	140	No
Te Hapua Swamp Complex D	Fen	100	No
Te Harakeke Wetland	Swamp	170	No
Representative wetlands for each wetland class identified by GWRC as locally significant			
El Rancho Wetlands	Fen	50	Yes – in El Rancho (Weggery) Wetland
Tini Bush	Fen	210	No

7 Clarkson, B.R., Sorrell, B.K., Reeves, P.N., Champion, P.D., Partridge, T.R, and Clarkson, B.D. 2003 (rev. 2004) Handbook for Monitoring Wetland Condition. Landcare.

Ngarara Bush	Fen?	190	No
Ngarara Road Wetland D	Fen?	150	No
Otaihanga Landfill South	Fen?	90	Yes – M2PP in Otaihanga Central, Southern and Northern
Crown Hill Manuka Bush	Fen	110	No

Wetland Condition Monitoring has been undertaken to date in a number of wetlands on the Kāpiti Coast as part of the National Wetland Monitoring System, Wetland condition monitoring has already been undertaken – and is proposed – as part of the MacKay's to Peka Peka Expressway Project at a number of wetlands within the RRwGW Zone.

In addition to those wetlands above, Poplar Ave Wetland has had Wetland Condition Monitoring undertaken (by GWRC/DOC) and Wetland Condition Monitoring is also proposed in the Raumati South Peatlands B as part of the MacKay's to Peka Peka Expressway pre-construction monitoring programme.

At each of the wetlands in Table 3 above, we recommend wetland condition monitoring be undertaken along a permanent transect within each of the eco tones present within the wetland. This will ensure that different components of the wetlands are monitored for baseline values (e.g. Nga Manu Wetlands contain a range of deep and shallow fen wetlands with areas of open water and vegetation communities ranging from swamp forest through to manuka scrub, flaxland and more ephemeral *Carex* sedgeland).

To assist with developing adaptive management responses, the Wetland Management Plan should include Wetland Condition Monitoring during winter conditions during periods of inundation and high water tables - and late summer conditions during dryer conditions to ensure seasonal variations in water levels and corresponding changes in vegetation communities are established. This would ensure any monitoring or triggers included existing drought and high water table induced stresses within the existing baseline.

As part of the wetland condition monitoring for each wetland, a number of photo points should be established within each wetland in Table 3 above to assist with visual comparisons of wetland condition.

7.3 Trigger levels

As outlined above, Wetland Condition Monitoring is not an appropriate tool for setting of triggers for adaptive management. Its primary use is for establishing a baseline measure of long-term trends in wetland condition to assist with adaptive management measures.

8.0 Adaptive management

If groundwater level changes reach alert or action levels, then there are a number of potential methods that could be considered for minimising or reversing effects before the wetland is deleteriously affected. However, given the 'leaky' nature of the shallow groundwater aquifer systems an adaptive and iterative management approach will be needed which relies on continuous monitoring of groundwater and wetland health to confirm the effectiveness or otherwise of any methods being used.

Where an alert trigger level is exceeded, KCDC and the consenting authority should be notified and potential actions undertaken as outlined below.

- Increase frequency of piezometer monitoring to daily for each wetland with trigger exceedences.
- Review control monitoring piezometers to improve understanding of localised or wider effects on shallow groundwater.
- Piezometer monitoring should continue to daily until recovery of the groundwater level at that monitoring bore to above the trigger level; or a trend of increasing groundwater level of at least three consecutive weeks.
- Analysis of the monitoring data indicates that adverse effects on wetlands are not anticipated, in which case revised trigger levels for each wetland would be established with the approval of KCDC and the consenting authority.

Where an action trigger level for a wetland monitoring bore is exceeded, a range of adaptive management techniques could be investigated or applied as follows:

Installation of weirs in stream outlets

For wetlands that are traversed by streams, the installation of adjustable weirs could form an important component of adaptive management. For example, an adjustable weir in the Ngarara Creek could assist with maintaining higher water levels in Te Harakeke Wetland. Similarly, an adjustable weir installed in the Kakariki Stream could minimise adverse effects on Nga Manu Wetlands by raising the stream level in the vicinity of the wetlands.

Adjustable weirs and setting of water levels in surface waterbodies would be subject to separate GWRC consent and would also require the addressing of matters such as flood control, fish passage, and groundwater effects on adjacent residential areas. Each weir would also require its own monitoring regime.

Weirs may have a greater benefit in larger wetlands with deeper peat layers. For smaller wetlands, groundwater decline would have a more rapid impact and weirs may be less effective.

> *We recommend that KCDC undertake a review of the potentially affected wetlands with outlets capable of management by weirs, and determine whether this would be an effective approach for any.*

Infilling and/or modification of existing drains

Linked to the option of installing temporary seasonal weirs to raise water levels of wetlands with surface water influences, the infilling of drains in close proximity to important wetlands is another potential adaptive management option. A number of wetlands within the RRwGW Zone have man-made drains adjacent to or within them, for example El Rancho Wetland (Weggery).

In addition to infilling drains, another potential method could include the development of additional meanders in existing channels within at-risk wetlands. Additional meanders or similar restrictions would also mean that water would have a longer residence time, and therefore more time to penetrate wetlands[8].

We recommend that KCDC investigate each of the wetlands in Table 1 that are subject to a greater than 100 mm RRwGW Scenario 4 drawdown for potential options for drain infilling or modification.

Season restriction on residential groundwater bores

Consistent with the recommendations of Jones & Gyopari (2005), KCDC could obtain a greater understanding of more detailed information on those existing private bores within 150 m of recognised wetlands outlined in Table 1 that may be subject to more than 100 mm of drawdown. Within this buffer zone for each wetland, all groundwater abstractions, drainage and surface water diversions would be controlled e.g. through seasonal restrictions on use of private bore abstraction in the event established wetland triggers are exceeded.

Use of temporary bores to provide surface water

Water from deep groundwater bores could also be used to temporarily re-saturate peat within identified wetlands subject to observed changes in wetland health/hydrological triggers. This approach could use temporary bores specifically for this purpose, or the reconfiguration of existing bore use during drought periods.

We note that this adaptive management option is unproven and may require additional investigation to ensure potential adverse effects are not caused (e.g. flooding of rare ephemeral flora species such as orchids).

Other mechanisms

- Replanting areas of vegetation die-back with suitable indigenous species.
- Weed control of ephemeral wetland sections
- Digging out deeper open water areas to ensure peat stays saturated (in areas of deep peats).
- Extended buffer planting in exotic vegetation or pasture surrounding the wetland to assist retention of water.
- Undertake a more comprehensive wetland restoration programme.

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8 Refer Laws (2008) for more information on the potential effects of drains on water levels in Kāpiti Coast wetlands.

Other Considerations

While groundwater dependent discharge wetlands are likely to be less affected by drought conditions due to having a base flow maintained by groundwater (and are therefore more likely to retain water in the lowest areas), they remain at risk of changing aquifer levels. Accordingly, ensuring aquifer levels are maintained above a minimum level and establishing wetland-specific trigger levels are important to maintaining wetland health. Further, adaptive management responses (and trigger levels if possible) must take into account the potential for rainfall during any season to cause regular minor fluctuations upon any general annual pattern. For example, unusually heavy rains, wet seasons, or wet years can fully recharge wetlands irrespective of time of year (Johnson and Gerbeaux, 2004).

Monitoring

Each of the above methods, if implemented would require continuous monitoring, the results of which would feedback into the management of the site.

9.0 Summary and conclusions

The wetlands of the Kāpiti Coast are maintained by complex interactions between rainfall, surface water and groundwater (Jones and Gyopari, 2005; Law, 2008; Jones and Baker, 2005) and groundwater is particularly important in maintaining water levels during the summer. Hydrology is therefore the primary influencing factor of wetland health (flora and fauna).

The worst case drawdown scenario in the shallow Holocene Sand Aquifer modelled as part of the CH2M BECA Updated Aquifer Testing and Groundwater Modelling suggests that some regionally significant wetlands may be subject to up to 210 mm of drawdown during extended drought conditions. A large number of other wetlands are expected to experience a worst case drawdown of between 10 and 150 mm.

As the main water input for most wetlands on the Kāpiti Coast, groundwater has a vital role in maintaining the moisture levels of these systems during drier summer months. Accordingly, and on the basis of published and unpublished reports on specific wetlands on the Kāpiti Coast, we consider that wetlands subject to drawdowns of 100 mm or greater are likely to be adversely affected. This cut-off level needs to be confirmed by ongoing monitoring.

Potential effects on these wetland systems relate to temporary drying out of peats and associated die-back of existing wetland vegetation and over time - to changes to the wetland status, the plant communities that occur there, and associated habitat effects on obligate and facultative species of flora and fauna.

Reductions in water table and associated changes in species composition are also likely to open up the wetland to increased colonisation by invasive exotic species leading to changes to their ecological values.

A number of specific wetland monitoring requirements are recommended to ensure there is sufficient background information on wetland hydrology and ecological condition to set monitoring and triggers to determine when each wetland may experience adverse effects.

We have also discussed a number of potential adaptive management approaches that could be used for adaptive management of affected wetlands to limit or reverse effects if they occur.

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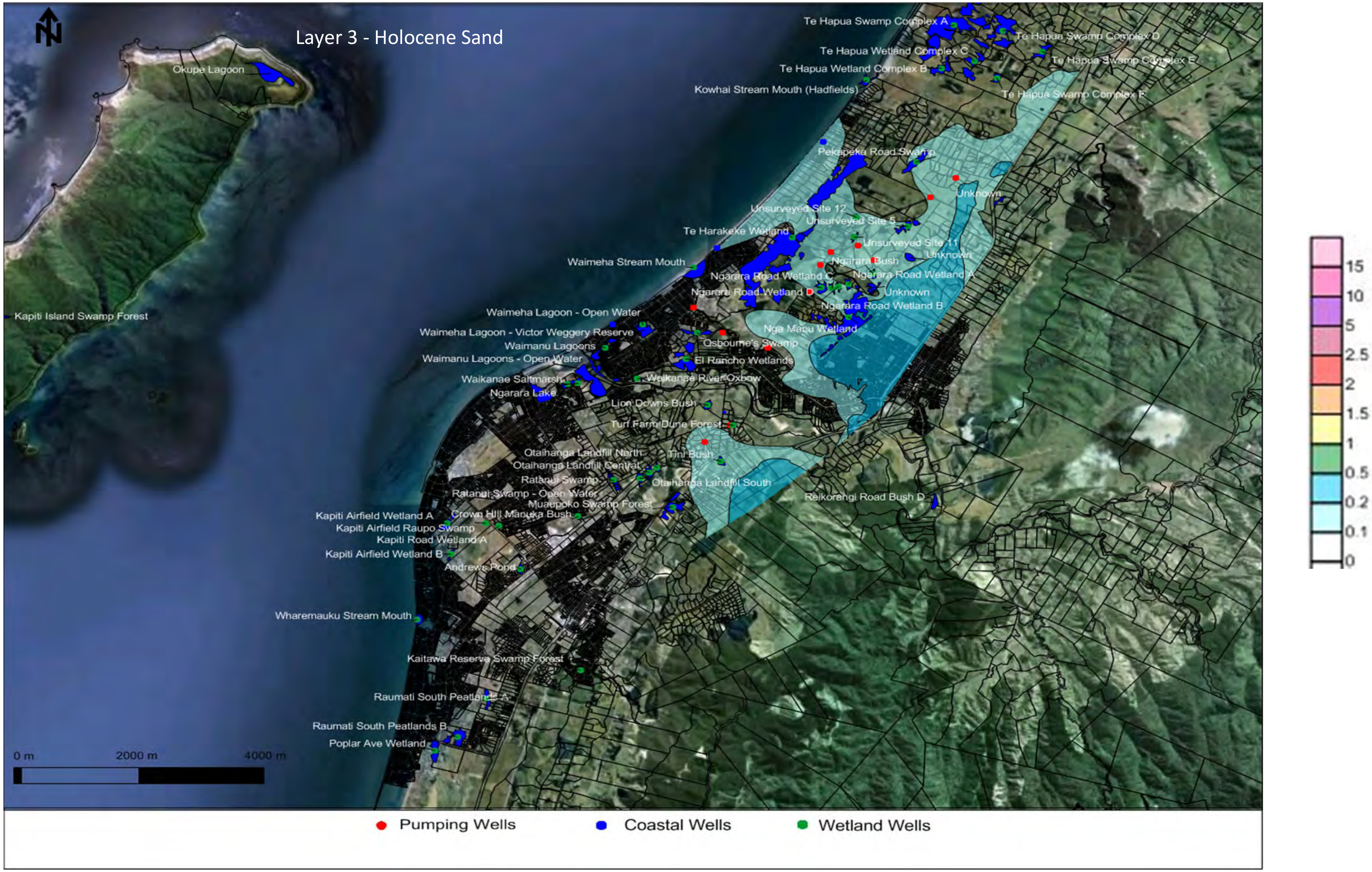
Appendix 1: CH2M Beca RRwGW Scenario 4 Modelled Drawdowns in the Holocene Sand Aquifer with GWRC Wetlands



Scenario 04 - Drawdown - Holocene Sand - 27.8 yrs

CH2M Beca