BEFORE A BOARD OF INQUIRY
MACKAYS TO PEKA PEKA EXPRESSWAY PROPOSAL

UNDER	the Resource Management Act 1991
IN THE MATTER OF	applications for resource consents and a notice of requirement in relation to the MacKays to Peka Peka Expressway Proposal
BY	New Zealand Transport Agency

STATEMENT OF EVIDENCE OF BRYDON NICHOLAS HUGHES ON BEHALF OF THE KAPITI COAST DISTRICT COUNCIL

Groundwater

DATE: 5 October 2012

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1. INTRODUCTION

1.1 My full name is Brydon Nicholas Hughes.

1.2 I am currently Director of Liquid Earth Limited, an independent hydrogeological and water resource management consultancy I own and operate.

1.3 I hold a Master of Science degree with first class honours in engineering geology from the University of Canterbury, conferred in 1992. I have 18 years' experience in groundwater resource management and investigations both while employed by Regional Councils, and more recently in private consultancy. I have presented evidence at a number of Council and Environment Court Hearings. I am an accredited hearings commissioner under the Ministry for the Environment's Making Good Decisions Programme.

1.4 Between 1995 and 1999 I was employed as Groundwater Scientist by the Wellington Regional Council. This role involved the development and implementation of groundwater monitoring and investigation programs across the Kapiti Coast area as well as input to the groundwater management provisions of the Regional Freshwater Plan (**RFP**).

1.5 At the current time I am involved with a project for the Greater Wellington Regional Council updating the conceptual groundwater model for the Kapiti Coast as part of a project to review groundwater allocation and management for the upcoming review of the RFP. During 2005/06 I also provided input on groundwater impacts for a review of land development impacts on stormwater management for the Kapiti Coast District Council (**Council**) (SKM, 2006).

1.6 I am authorised by the Council to present this evidence on its behalf.

1.7 I have read and am familiar with the Code of Conduct for Expert Witnesses in the Environment Court Practice Note 2011. I agree to comply with that Code. Other than where I state that I am relying on the advice of another person, this evidence is within my area of expertise. I have not omitted to consider material facts known to me that might alter or detract from the opinions that I express.

2. SCOPE OF EVIDENCE

2.1 My evidence will address the following matters:

(a) the overall nature of the hydrogeological setting including the occurrence of groundwater-dependant ecosystems;

(b) issues raised in the Council's submission regarding the effects of the proposed Expressway on the shallow groundwater resource and hydraulically connected surface water bodies (wetlands and streams);

(c) comments on the proposed Groundwater Level Management Plan (**GLMP**) including proposed monitoring and mitigation options;

(d) issues raised in the Council's submission relating to contaminated land; and

(e) measures to avoid or mitigate potential adverse effects associated with contaminated land during Expressway construction and operation.

3. EXECUTIVE SUMMARY

3.1 The proposed Expressway alignment traverses the coastal plain between MacKays Crossing and Peka Peka. This area is underlain by a shallow, spatially extensive unconfined aquifer system hosted in Holocene sand deposits along the coastal margin. The Holocene sand aquifer is primarily recharged by infiltration of local rainfall and is hydraulically connected to numerous small streams and wetlands on the coastal plain. The aquifer system is also utilised extensively for small scale abstraction to provide garden water supplies for residents in Paraparaumu and Waikanae.

3.2 Construction of the Expressway has the potential to result in localised changes in groundwater level and flow paths in the Holocene sand aquifer. Construction of the Expressway may result in changes to the natural hydraulic properties of the Holocene sand aquifer, potentially disrupting the natural flow of groundwater towards the coast. Where permeability of the natural aquifer materials is reduced, ponding may occur to the east of the Expressway alignment accompanied by a corresponding reduction in groundwater levels on the downgradient (west) side. Conversely an increase in permeability may result in a more widespread decline in groundwater levels. Groundwater levels may also be affected by activities such as dewatering or the construction of stormwater treatment and attenuation structures.

3.3 While the potential magnitude of changes in natural groundwater levels and flow paths resulting from expressway construction is relatively minor, the expressway alignment passes close to several significant wetland areas which are potentially sensitive to small changes in groundwater level under both 'average' and 'extreme' conditions.

3.4 While extensive investigation and modelling has been undertaken to quantify potential effects arising from Expressway construction, due to the heterogeneity of the hydrogeological environment an element of uncertainty remains regarding the absolute magnitude of effects likely to result. To address this uncertainty and enable an adaptive management approach to construction, a Groundwater Level Management Plan has been developed which outlines a monitoring regime intended to quantify actual effects. This document includes triggers for initiating various management interventions if actual effects exceed those predicted.

3.5 Overall, I support the GLMP approach as a pragmatic approach to enable Expressway construction to occur in a manner which ensures adverse effects on groundwater are appropriately mitigated. However, I propose some amendments to the proposed monitoring and mitigation options to ensure potential effects can be adequately characterised, particularly in terms of significant wetland areas.

3.6 The proposed Expressway alignment crosses a number of sites where soil or groundwater contamination has been identified. I support the management approach proposed for these sites in the Contaminated Soils and Groundwater Management Plan to ensure risks to human health and the environment are appropriately mitigated. However, I recommend that additional monitoring is undertaken downstream of the Otaihanga Landfill to ensure that Expressway construction does not result in any changes to existing groundwater or surface water quality.

4. MATTERS RAISED IN SUBMISSION

4.1 The Council's submission raised a number of issues related to the potential impacts of the proposed Expressway on the groundwater resource including:

(a) potential hydrological disturbance of groundwater-dependent ecosystems in close proximity to the Expressway alignment due to changes in the natural hydrogeological environment associated with construction and operation of the Expressway; and

(b) the adequacy of proposed baseline monitoring and characterisation of wetlands to enable reliable assessment of potential short and long-term effects on wetlands through the GLMP.

4.2 The submission also raised concerns relating to the management of Land and Groundwater Contamination effects including the potential for construction activities to alter the existing treatment system utilised at the Otaihanga Landfill increasing the potential for offsite effects.

5. HYDROGEOLOGICAL ENVIRONMENT

5.1 The groundwater resources of the Kapiti Coast form an integral component of the overall hydrological system and have a significant role in sustaining freshwater ecosystems in riverine and wetland habitats. Due to the heterogeneous geological environment, the nature and extent of hydrological interaction between groundwater, streams and wetlands is typically complex and often location-specific. The following section provides a summary of the key considerations in terms of the hydrogeological environment of relevance to the proposed project.

5.2 These geological materials host a spatially extensive groundwater resource which can be subdivided into three basic hydrogeological settings:

(a) a shallow unconfined Holocene (Q1[1]) sand aquifer along the seaward margin of the coastal plain;

(b) shallow, moderate to highly permeable unconfined aquifers hosted in recent (Q1) alluvium adjacent to rivers and streams draining the Tararua Range; and

(c) semi-confined and confined aquifers occurring within the late Quaternary fluvioglacial outwash gravel deposits (Q2 to Q8) underlying a majority of the coastal plain.

5.3 The proposed Expressway alignment primarily overlies the Holocene sand aquifer, although it crosses the Quaternary gravel (Q1) aquifer as it traverses the Waikanae River floodplain. Potential interaction with deeper semi-confined and confined aquifers is primarily restricted to abstraction from the Parata (Q4) gravel deposits for construction water supply.

[1] The Q1, Q2 etc notations relate to oxygen isotope stages which are utilised to define geological timescales over the late Quaternary Period.

Holocene Sand Aquifer

5.4 The Holocene sand aquifer underlies a majority of the proposed Expressway alignment. This aquifer system consists of fine to medium sand and organic material (peat) with occasional gravel layers. These materials extend to the west of the prominent postglacial marine terrace which can be traced from Otaki to Paraparaumu and reflect accumulation of sediments along the coastal margin over the Holocene Period (last ~6,500 years). The materials comprise a heterogenous mix of coarser sand and gravel accumulated along the coastal margin, aeolian (dune) sand and organic materials accumulated in poorly drained interdune and back dune areas.

5.5 The Holocene sand materials host a spatially extensive unconfined aquifer which exhibits low permeability due to the fine-grained texture of the sand and organic materials. Typical hydraulic conductivity values in the sand deposits are less than 2 m/day and may be significantly lower in organic materials. In contrast, the recent (Q1) alluvial materials underlying the Waikanae River floodplain exhibit hydraulic conductivity values in excess of 200 m/day.

5.6 The water table typically occurs within 1 to 2 metres of the land surface across the coastal plain, although it may vary locally reflecting the topography of larger dunes toward the seaward margin of the coastal plain. Piezometric survey data show groundwater flows in a westerly direction across the coastal plain approximately perpendicular to the coast.

5.7 The aquifer system is predominantly recharged by rainfall infiltration. **Figure 1** shows groundwater level hydrographs from two piezometers monitored by Greater Wellington Regional Council (**GWRC**) located north of Waikanae at the Nga Manu and Te Harakeke wetlands respectively. The plot shows groundwater levels respond rapidly to recharge following individual rainfall events then recede more slowly as water is progressively drained from the aquifer system. The overall seasonal variation of between 0.4 and 0.5 metres appears to track the frequency and magnitude of rainfall events with maximum levels generally occurring in late winter or spring and minimum levels in autumn. This hydrograph response is similar to that observed in other monitoring sites screened in the Holocene sand aquifer along the Kapiti Coast.

5.8 A different hydrograph response is observed in the shallow alluvial (Q1) gravel materials underlying the Waikanae River floodplain. As shown in **Figure 2**, groundwater levels in this area respond rapidly to variations in stage height in the Waikanae River indicating a high level of hydraulic connection with surface water. The rapid decline in groundwater levels following each recharge event is interpreted to reflect discharge back to the Waikanae River or to the Waimeha Stream through the permeable gravel materials.

Wetland Hydrology

5.9 Wetlands form a highly valued hydrological environment on the Kapiti Coast and occur along, or in close proximity to, the proposed expressway alignment.

5.10 Allen (2010) undertook a hydrological investigation of the Te Hapua wetland which lies to the north of Peka Peka Road. This wetland complex is similar in nature to those occurring in the vicinity of the proposed Expressway alignment. The study identified two characteristic types of wetlands:

(a) Fens - low-lying areas where the water table occurs above the surrounding land surface forming areas of standing water. These wetlands are characterised as 'discharge' wetlands which receive throughflow from the surrounding unconfined aquifer and lose water via direct evaporation and transpiration from vegetation. Water levels in fens tend to be similar or slightly lower than the surrounding water table and fluctuate rapidly in response to groundwater level variations.

(b) Swamps - low-lying areas between larger dunes which collect runoff from the surrounding land. Due to the accumulation of organic material and fine sediment these areas tend to have low (vertical) permeability allowing water to pond following significant rainfall events. Water levels in swamps are typically perched above the surrounding water table and show a different pattern of temporal variation in response to rainfall.

5.11 Data collected by Allen (2010) showed groundwater levels are typically 35 to 150 millimetres higher than the water table in swamps (although groundwater levels may rise above standing water levels for a short period following heavy rainfall). Standing water levels in fens were observed to range between 5 and 90 millimetres lower than the surrounding water table. The study also noted that the recharge/discharge characteristics may vary spatially within individual wetlands and also in response to temporal changes in groundwater levels.

5.12 The difference in hydraulic response between individual wetland areas is illustrated in **Figure 3**. This figure shows a plot of water levels recorded in four shallow piezometers installed in separate wetland areas in Queen Elizabeth Park near MacKays Crossing. The data exhibit temporal water level variation in two piezometers (R26/6520 and R26/6920) which follows the general pattern observed in the Holocene sand aquifer across much of the Kapiti Coast. In contrast, the remaining two piezometers show relatively stable levels punctuated by rapid, short-terms increases following significant rainfall events.

5.13 The differences in temporal water levels response observed in closely spaced wetlands are interpreted to reflect the presence of both recharge and discharge wetlands in close proximity (within a 250 metre radius at the MacKays Crossing site). The potential occurrence of both recharge and discharge wetlands along the proposed Expressway alignment is noted in the Assessment of Groundwater Effects (Technical Report 21). The differences in hydrology between these wetland types means the potential response to changes in groundwater levels cannot be assumed to be the same in all individual wetlands.

5.14 Overall, available data suggest the hydrology of individual wetland areas on the Kapiti Coast is complex, reflecting the influence of topography as well as the hydraulic properties of underlying soil materials. Of particular note is the potential for wetland areas to be affected in different ways by construction and operation of the Expressway. Discharge wetlands are hydraulically connected to the surrounding unconfined aquifer and so are susceptible to changes in local changes in groundwater levels resulting from activities which alter the local aquifer water balance (e.g. dewatering, compaction or replacement of peat, stormwater drainage etc). In contrast, recharge wetlands are more likely to be affected by changes to surface drainage patterns resulting from alteration of natural landforms (e.g. reductions in catchment area or topographical modifications).

5.15 As a consequence, care needs to be taken to ensure that assessment of potential effects takes into account both the heterogeneity of the geological environment as well as the potential local-scale variability of natural interaction between groundwater and surface water resources.

6. EFFECTS ON GROUNDWATER

6.1 The Assessment of Environmental Effects (**AEE**) identifies a number of aspects of the project which have the potential to result in localised changes to groundwater levels and flow paths. These include:

(a) cuts below the water table requiring short-term dewatering;

(b) loss of recharge due to an increase in impervious area;

(c) excavation and replacement of sand with peat (thereby altering the rate of natural groundwater throughflow);

(d) surcharging of peat to accelerate ground settlement (with a consequent reduction in the permeability of the peat material);

(e) abstraction of groundwater for construction-related activities; and

(f) alteration of natural groundwater levels associated with construction of stormwater attenuation/treatment wetlands, swales and flood storage areas.

6.2 Additional activities which have the potential to effect groundwater include:

(a) Realignment of natural stream channels; and

(b) Changes in the contributing catchment area for recharge wetlands

6.3 These activities have the potential to:

(a) alter water levels in hydraulically connected waterbodies (particularly wetlands) and existing bores utilised for water supply;

(b) reduce baseflow discharge to rivers and streams; and

(c) divert or alter natural groundwater flow paths potentially changing the nature of groundwater throughflow and contaminant migration pathways.

6.4 Technical Report 23 of the AEE outlines an assessment of potential effects on groundwater associated with Expressway construction. This assessment is primarily based on the application of numerical modelling to predict potential effects on groundwater. While I largely support the approach adopted by the applicant to assess potential effects on groundwater, I note the following aspects that warrant further attention:

(a) The assessment relies extensively on the application of numerical modelling to predict the likely impacts on Expressway construction. Due to the heterogeneous nature of the geological environment and limitations of the spatial resolution of data available to construct and calibrate the model(s) there is an element of uncertainly in overall model predictions which is not necessarily reflected in the certainty of conclusions regarding the overall magnitude of potential effects.

For example, Technical Report 21 (Appendix F, Figure F4) outlines calibration statistics for the various models utilised in the assessment. With the exception of the Otaihanga Landfill model, the standard (RMS) error of the remaining models is listed at between 0.3 to 0.9 metres, which in many cases is larger than the predicted magnitude of effects and of a similar order to the observed seasonal variation in groundwater levels.

(b) The hydrology of individual wetlands is not well characterised, particularly with regard to their interconnection with shallow groundwater levels and the likely impact of changes in groundwater levels (in the case of discharge wetlands) or contributing catchments (in the case of recharge wetlands) on wetland ecology. As noted in the Ecological Impact Assessment (Technical Report 26):

> '*While specialist investigations have been undertaken.......there remains some uncertainty as to the hydrological interconnectedness of peat and thus the nature and scale of any associated effects of construction on wetlands in close proximity to the proposed expressway route*'.

In particular, there is a degree of disconnection between the predicted magnitude of changes in groundwater levels (Technical Report 21) which is described as '*less than minor*' or '*negligible*' and the Ecological Impact Assessment, which characterises the predicted drawdown as potentially having an effect ranging from '*low*' to '*very high*' in terms of aquatic habitat loss and modification (Technical Report 26, Table 40).

6.5 Given the acknowledged uncertainties inherent in numerical groundwater modeling at a local scale, and the incomplete knowledge of wetland hydrology, I consider it appropriate that a precautionary approach is adopted to managing potential adverse effects associated with Expressway construction. This should include hydrological characterization and monitoring of wetlands identified in the Ecological Impact Assessment as potentially susceptible to changes in groundwater level.

6.6 In order to address uncertainties inherent in the assessment of effects on groundwater, the Applicant has developed a GLMP (Proposed Condition G.29). This document outlines a water level and discharge monitoring program intended to:

(a) establish baseline groundwater level and baseflow conditions prior to commencement of Expressway construction; and

(b) quantify effects on groundwater levels and baseflow resulting from Expressway construction.

6.7 The GLMP specifies a maximum departure from 'natural' groundwater level conditions in terms of 'alert' and 'trigger' levels which, if exceeded, initiate various management actions ranging from an increased frequency of monitoring to changes in construction methodology.

6.8 I support the proposed GLMP approach as an appropriate means to ensure environmental effects are consistent with predictions made in the AEE and to enable adaptive management of the project during the construction and post-construction phases. However, I recommend some modifications/amendments to the GLMP to address specific issues including:

(a) NZTA should undertake investigations to improve resolution of the hydrological function of individual wetlands, particularly in terms of natural water level variation and hydraulic connection to the water table (i.e. identification of recharge/discharge characteristics). The hydrological regime of each high-value wetland needs to be characterised in order to set critical thresholds to trigger mitigation actions, and to design effective mitigation methodologies.

(b) The need to establish an adequate baseline to differentiate natural variation in water levels from changes associated with Expressway construction. This may require regular monitoring of groundwater levels for a period in excess of the period (1 year prior to construction) specified in the GLMP and be assisted by continuous (automated) monitoring of groundwater levels at key locations along the Expressway alignment. Monitoring should be extended to include standing water levels in wetlands.

(c) The need to continue water level monitoring for an extended period following Expressway construction to adequately characterise medium to long-term effects on groundwater levels. For example, while effects on 'average' levels may become apparent over a relatively short period, variations during more extreme climate conditions that may be of particular significance in terms of wetland ecology may only occur over the medium term.

(d) Further development of proposed mitigation options in the GLMP to address the potential for long term post-construction hydrological disturbances to wetlands in addition to the current focus on the construction phase effects. Mitigation options should be further developed to ensure construction methodologies adjacent to vulnerable wetlands are designed to avoid wetland disturbance and adverse effects on hydrology (including recharge wetlands).

6.9 I note conditions GD.1 to GD.8 contained in the evidence of Ms Williams go some way to addressing issues related to the duration of monitoring and the potential for effects on wetland ecology. However, I still consider it necessary that provision be made in the GLMP for the hydrological characterisation of individual wetlands prior to construction and the automatic monitoring of groundwater level and/or stage height in or adjacent to high value wetland areas. I also recommend that provision be made for input from Council into the development and review of the monitoring program.

6.10 While acknowledging uncertainties inherent in modelled groundwater level changes associated with Expressway construction and abstraction of groundwater for construction-related activities, I concur with the conclusion reached in the Assessment of Groundwater Effects that Expressway construction is unlikely to have an adverse effect on existing groundwater users due to the relatively small magnitude of drawdown compared to the overall saturated aquifer thickness.

7. STREAM REALIGNMENT

7.1 The proposed construction involved realignment of several streams which cross the Expressway alignment. In a majority of cases the proposed channel modifications would appear to present a relatively low potential to significantly alter stream hydrology and surrounding groundwater levels. However, in the case of the Waimeha Stream (which crosses the Expressway alignment adjacent to Te Moana Road, Waikanae), the potential exists for excavation of the channel to alter stream hydrology, at least on a temporary basis. This effect is not specifically addressed in the AEE.

7.2 The Waimeha Stream originates along the former channel of the 'Waimeha River', a channel of the Waikanae River which flowed in a north-west direction across the coastal plain prior to being diverted into the Waikanae River by channel works during the late 1890s (Welch, 2004). Discharge in the Waimeha Stream is inferred to represent drainage of groundwater throughflow from the Waikanae River occurring within permeable gravels along the course of this historical river channel.

7.3 Available gauging data indicate an increase in flow in the Waimeha Stream of approximately 150 L/s between Park Avenue and Te Moana Road. As with a majority of spring-fed streams of this type, the rate of flow varies according to the head difference between stream stage and surrounding groundwater level and is moderated by the accumulation of fine sediment (referred to as the 'clogging layer') which restricts the rate of groundwater inflow through the stream bed.

7.4 Construction of the Expressway requires both temporary and permanent diversion of sections of the Waimeha Stream into a new (excavated) channel while construction is undertaken to provide optimum alignment in terms of the proposed Expressway layout. Due to the absence of clogging layer materials the excavated channel, at least during the initial period following diversion, will have a different hydraulic connection to the surrounding aquifer, potentially increasing baseflow discharge with a consequent reduction in surrounding groundwater levels.

7.5 While effects of stream realignment may be short-term (until the streambed clogging layer re-accumulates) I recommend that regular gauging of Waimeha Stream and monitoring (possibly automatic) of groundwater levels in nearby piezometer 2010/BH07 be specifically included in the GLMP along with identified mitigation options should effects be of a significant magnitude and/or extended duration.

8. CONTAMINATED LAND

8.1 As part of the Assessment of Land and Groundwater Contamination Effects (Technical Report 23) an investigation was undertaken to identify and characterise areas of potential soil and groundwater contamination along the proposed Expressway route.

Results of this investigation identified four sites which showed contaminant concentrations in soil or groundwater exceeding background concentrations and the relevant environmental or human health guideline values. It will be important to ensure that during construction and operation of the proposed Expressway these sites are managed in an appropriate manner to ensure risks to human health and the environment are appropriately mitigated.

8.2 NZTA proposes to manage construction activities which may impact on contaminated land in accordance with a Contaminated Soils and Groundwater Management Plan (Proposed Condition G.32) and undertake specific investigations on four areas of land that are proposed to be utilised for stormwater treatment (Condition 33).

8.3 Overall, I support the proposed approach to managing potential soil and groundwater contamination with the exception of that proposed for the Otaihanga Landfill site.

Otaihanga Landfill

8.4 At the current time discharge from the Otaihanga Landfill is collected by a drain which runs around the toe of the landfill. This drain intercepts shallow groundwater flow and conveys surface runoff via a wetland area before final discharge off-site. Construction of the Expressway will reduce the size of the wetland area potentially reducing the effectiveness of this feature in terms of treating runoff from the landfill site, particularly during periods of high flow. Changes in groundwater level as a result of Expressway construction may also alter the position of the water table underlying the landfill. Such changes could potentially alter the chemical characteristics of drainage water as well as the volume of water flowing in the toe drain.

8.5 While recognising that there may be existing effects on groundwater and surface water quality associated with the Otaihanga Landfill, the Council seeks to ensure that any such existing effects are not exacerbated as a result of changes to local hydrology and groundwater flow or loss of existing 'wetland treatment' areas resulting from Expressway construction.

8.6 The amended Contaminated Soils and Groundwater Management Plan included in evidence of Dr Kerry Laing proposes to undertake limited surface and groundwater quality monitoring at the Otaihanga Landfill. While I support this monitoring, I recommend the following additions/amendments:

(a) That an additional surface water monitoring site is added downstream of the Expressway alignment to ensure construction activities do not materially alter overall surface water quality draining from the site.

(b) Groundwater sampling from the two bores (BH306 and BH307) located near the toe of the landfill should be undertaken from the shallower screened interval as the deeper piezometers proposed for sampling (7 to 10 metres bgl) may not be ideally situated to determine representative effects on groundwater quality in the absence of a strong vertical hydraulic gradient, particularly in response to localised variations in groundwater throughflow and flow paths occurring at shallow depths. Samples should be analysed for a representative range of cations, anions, nutrients and (dissolved) metals.

(c) Monitoring should commence sufficiently in advance of construction (recommended 2 years) to provide a reliable baseline to determine any post-construction effects and continue for a period of at least two years following construction or until any trends identified post-construction can be reliably determined.

(d) If sampling indicates any significant departure from the baseline (particularly parameter concentrations approaching relevant guideline values or consent limits) which can be attributed to Expressway construction, provision should be made to provide additional treatment to surface runoff or shallow groundwater throughflow before exiting the landfill site.

9. CONCLUSION

9.1 Construction of the proposed Expressway has the potential to alter groundwater levels and flows in the unconfined aquifer on a local scale. While the magnitude of these changes is likely to be relatively small, they may be sufficient to result in changes to the hydrology and ecology of high value wetlands along the proposed alignment.

9.2 In order to ensure effects on the nature environment are appropriately mitigated, some relatively minor amendments to the proposed GLMP are sought. These amendments primarily relate to adequate characterisation of the existing environment, the duration, frequency and location of monitoring and the inclusion of appropriate mitigation options.

Brydon Hughes
Hydrogeologist
5 October 2012

References

Allen, W.C., 2010; *Hydrological characteristics of the Te Hapua wetland complex: The potential influence of groundwater level, bore abstraction and climate change on wetland surface water levels*. MSc Thesis, Victoria University of Wellington, April 2010.

SKM, 2006; *Review of Development Impacts on Stormwater Management*. Report prepared for Kapiti Coast District Council, February 2006.

Appendix: Figures 1-3

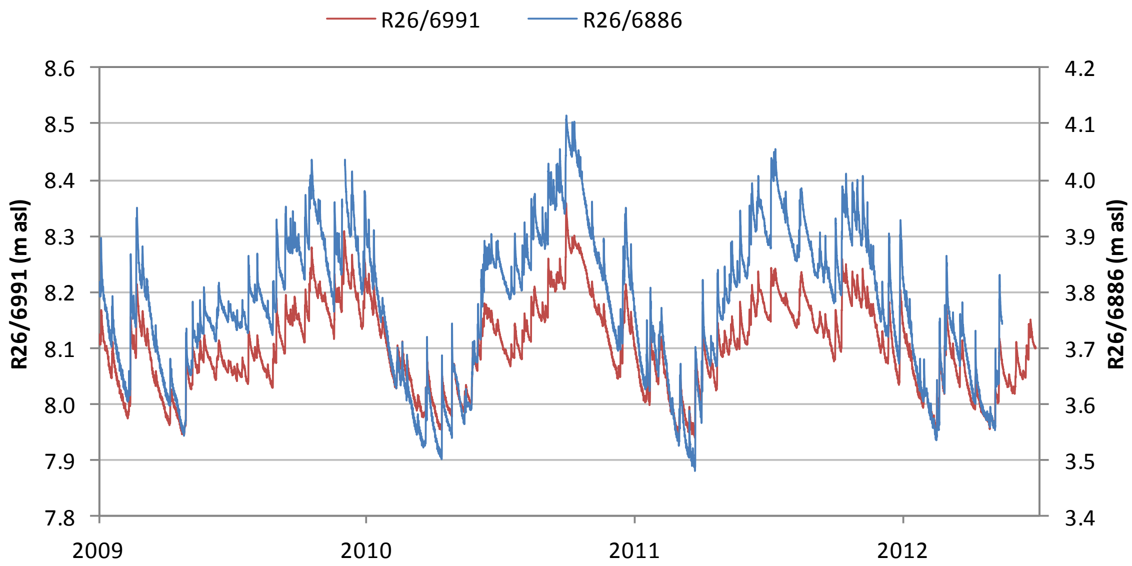

Figure 1. Groundwater levels recorded in two bores screened in the Holocene sand aquifer in the Waikanae area, 2009 to 2012.

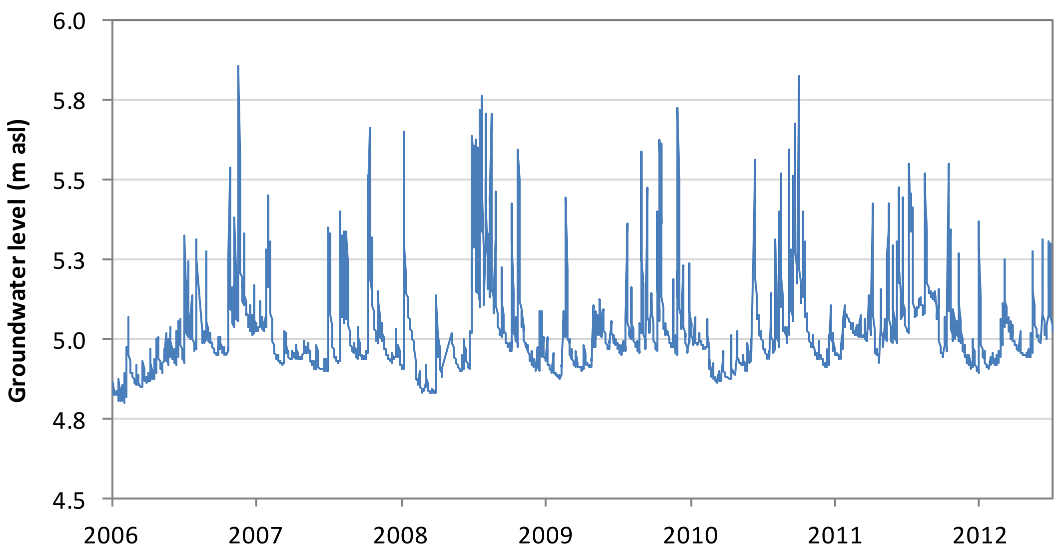

Figure 2. Groundwater levels recorded in recent (Q1) gravels underlying the floodplain of the Waikanae River, 2006 to 2012.

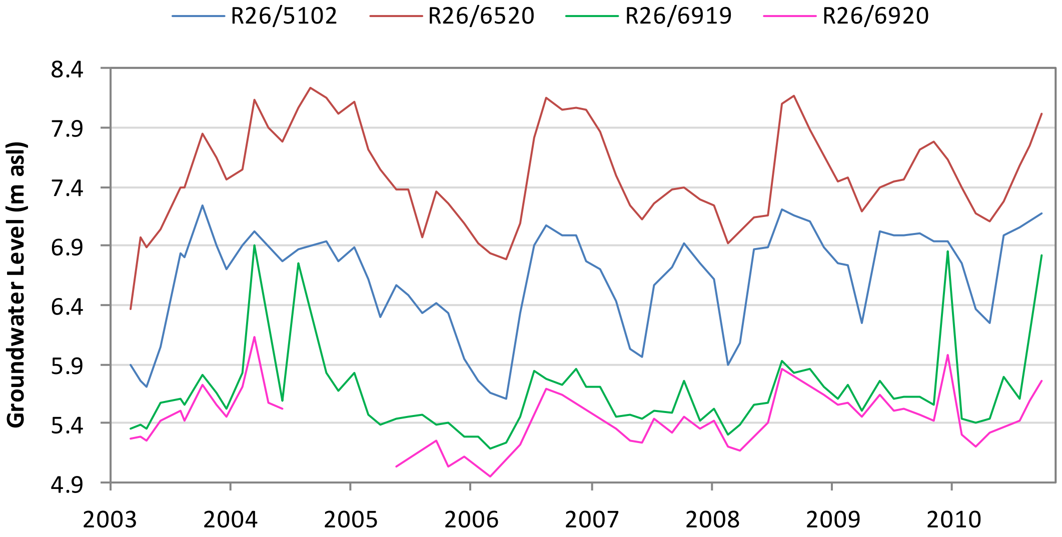

Figure 3. Groundwater levels recorded in shallow piezometers in four separate wetland areas in QE Park, 2003 to 2012. Note the difference in seasonal response between discharge wetlands (R26/5102 and R26/6520) and recharge wetlands (R26/6919 and R26/6920)