Report

Kapiti Coast - Revised Aquifer Testing and Groundwater Modelling

Prepared for Kapiti Coast District Council (Client)

By CH2M Beca Limited

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Overview and Background

As part of the Kapiti Water Supply Review and Options project for the Kapiti Coast District Council (KCDC), CH2M Beca (Beca) has been commissioned to provide an assessment of the feasibility of using groundwater pumped from the Council's well field at Waikanae. The well field currently comprises six on-line production wells, two completed but not-yet-connected production wells, one newly drilled and almost-completed production well and two back-up wells located between 600 m and 2000 m from the coast in three groups. Three additional wells are planned for future installation. The lateral distance between the wells in each group ranges from about 300 m to 800 m. Overall, the KCDC well field extends from Peka Peka Road in the north to approximately 1 km south of the Waikanae River. The project vicinity assessed in this report extends three to 4 km north and south of the well field area.

Following three stages of investigations, evaluation and consultation, Council agreed to proceed with *River Recharge with Groundwater* as the top-ranked solution and to take further steps to confirm the feasibility of this option. The *River Recharge with Groundwater* solution involves discharging groundwater to the Waikanae River, immediately downstream of the existing Water Treatment Plant intake, during periods of low river flow when abstraction from the river is limited due to minimum residual flow requirements. The groundwater will replace extracted river water downstream of the water treatment plant when more water is taken from the river during periods of low flows, thereby maintaining natural flow rates in the river. Groundwater will be abstracted from the Parata, Pleistocene Sand, and Waimea aquifers via the wells within the Council's existing well field in Waikanae (constructed in 2004/2005) as well as new wells constructed during 2011 and 2012. Additional wells are planned to provide design yield to meet the forecasted 2060 peak day demand (with headroom) of 32,700 m^3/day (equivalent to about 380 L/s).

This updated report summarises results from pumping tests, investigation drilling, electrical conductivity surveying and subsequent groundwater modelling with the objective of simulating the drawdown and interference effects that might be associated with abstraction, in order to more fully evaluate the long-term feasibility of the *River Recharge with Groundwater* option. This report follows on from the previous report issued on 25 March 2011. This updated report describes and uses the additional information derived from the drilling and testing of investigation wells N1, N2, N3, S1 and S2, and production well N2.

Pumping Tests and Hydrogeology

A total of fifteen constant rate pumping tests have been analysed to better understand the properties of the various aquifers and aquitards underlying the project area. The analyses were made using data collected from six "long-term' tests conducted for periods of 6 to 14 days, followed by a recovery period and nine "short-term" tests conducted for periods of 6 to 9 hours followed by recovery periods of one to one and one half hours. The long-term tests included water level observations from two to 11 wells during each test while the short-term tests were generally recorded only in the pumped investigation well. Simplified analyses of data from some of the long-term tests were presented in the 2011 report but have been updated using the more-sophisticated analysis techniques possible with Aqtesolv. A total of 62 individual Aqtesolv analyses (Appendix C) were completed to generate a range of aquifer parameter values for the three water bearing zones, (the Parata, Pleistocene Sand and Waimea aquifers), as well as some limited estimates of the properties of the intervening, lower-permeability, Pleistocene silt layers that act as leaky aquitards within the groundwater system. KCDC production well N2 was reconstructed during June 2012, and retested from 20 July through 4 August 2012 with the results included in Appendix G.

The results of the analyses indicate that groundwater is derived from three major aquifers that are hydraulically inter-connected. Pumping from any of these three aquifers results in water level changes (drawdowns) in overlying and/or underlying zones. Previous investigations indicated that the Waimea and Parata terrestrial gravels were the dominant aquifers underlying the project area and that these aquifers were hydraulically isolated from the shallowest surficial aquifers. However, the additional hydrogeological characterisation conducted as part of this investigation indicates that many of the KCDC production wells are completed in the lower Pleistocene sand aquifer, and that yields from this aquifer can be as high as those from wells completed in the Waimea or Parata terrestrial gravels. The Pleistocene sands are “cleaner” (containing less silt and clay) than the terrestrial gravels that are often clay-bound. (Cross-sectional diagrams showing the subsurface geology of the study area and the positioning of these aquifers are presented in Appendix A).

The silt layers that lie between these aquifers are “leaky” allowing pumping effects to be passed on to adjacent aquifers. In addition, the silt layers are not always present in significant thickness between the identified (named) aquifers. All three aquifers are relatively high yielding with pumping rates of 20 to 70 L/s possible from properly designed and completed wells at most locations. Some vertical leakage occurs from the shallow unconfined aquifer when pumping from the three deeper aquifers. This “leaky” aquifer system is an update from the previous understanding that the Parata and Waimea aquifers were hydraulically isolated from shallower, more surficial aquifers and that the Pleistocene sand between these two aquifers was not also a significant aquifer.

Saline intrusion into the KCDC supply wells and domestic wells located near the coast is a potential risk from increased pumping in the future. The lowering of aquifer water levels (which always occurs during pumping) will allow the interface between the salt water (entering the aquifers off shore) and fresh water (recharged inland from rainfall and river loss) to move landward. There is also the potential risk of lowered water levels in wetlands and streams caused by the increased production from the Council’s water supply wells.

In order to obtain a preliminary base line for understanding the existing salinity in shallow coastal wells a survey was carried out in December 2010. The survey comprised in-situ recordings of electrical conductivity in some 100 domestic wells and water quality analysis of samples from 25 wells distributed along the coast from Raumati South to Peka Peka. The testing confirms that all of the waters sampled are classified as “fresh water.”

Groundwater Flow Modelling and Pumping Scenarios

An updated three dimensional groundwater flow model has been used to assess the likely effects of different pumping regimes on groundwater and river levels in the vicinity of the well field. The model was developed as part of an adaptive management programme that includes modelling, monitoring and mitigation if needed. Uncertainty in model results (inherent in any model) would be offset by monitoring to measure actual effects and assess the need for mitigation. The model was also used to evaluate the aquifer budget (water flowing into and out of the model). The groundwater model was developed using the USGS model code MODFLOW (Harbaugh et al, 2000), and the Schlumberger pre- and post-processor Visual Modflow Pro 2010. The modelling work incorporates recommendations made by GNS Science who were commissioned by Council to peer review an earlier conceptual model developed by Beca. Their comments and our resolutions are included in Appendix E. The model was calibrated using existing aquifer and well data which included the revised stratigraphy and test analyses derived from the new investigation wells and aquifer tests.

Four possible pumping scenarios were simulated in order to provide an assessment of the likely effects on existing groundwater users and surface water bodies. The results of the simulations are included in Appendix D. These scenarios were based on 36 years of historical Waikanae River flows (to define river flow levels) plus 36 years of historical climate data and four population estimates (to define water supply demand from the river). A 50-year drought was incorporated within the historical records. Whenever demand exceeded the river's ability to supply water without causing the river level to drop below mandated minimum flow levels, pumping was simulated from the model, to supply the supplemental water needed to maintain minimum flows through direct discharge of the pumped water to the river.

The supplemental flows will be pumped from existing and future KCDC production wells. A hierarchy was developed to indicate which wells would be used, when they would be pumped and what pumping rates would be likely. The hierarchy was based on water chemistry, well yield (and associated pumping costs) and distance from each well to the point where water would be pumped into the river. This hierarchy was employed to limit adverse effects on the river while keeping costs to an acceptable level.

Each scenario assumed a constant population throughout the 36-year period of simulation. Four possible populations were calculated by assuming moderate or high growth rates over a projection timeframe to 2049 or 2060. The assumption of a constant population equal to the endpoint population (2049 or 2060) over the entire 36-year simulation is conservative (over-estimates demand) because the actual population during all but the last year of the 36-year simulation will be less than that of the 36th year. It does allow, however, a worst-case analysis, were a drought (such as that of 2003) to occur at any time during the 35-year consent or 50-year planning periods[1].

Each scenario consists of a time series that begins in "Year 0" and ends after the completion of "Year 35" (ie, a 36 year simulation). Actual rainfall and river flow data from July 1975 through July 2011 were assumed to represent rainfall and river flow from Year 0 through 35, and includes the inclusion of a synthesised one-in-50-year drought. By using historical data, the four scenarios represent simulation of the environmental effects that could occur under four possible demand and population growth scenarios from moderate (Scenario 1) to more extreme (Scenario 4) . These simulations do not strictly represent conditions from 2014 through 2049 (the period requested for consent) as future rainfall and river flows cannot be known and the population will not be at the assumed end-point levels over the entire simulation period. None-the-less they provide a scientific basis for four conservative assessments of possible environmental effects.

The following four scenarios were simulated:

- Scenario 1: A constant population equal to that at 2049, under an assumption of moderate growth. Under this scenario the maximum combined pumping rate[2], averaged over the peak week was 23,500 m^3/day from a total of up to eight wells, all of which are existing
- Scenario 2: A constant population equal to that at 2049, under an assumption of high population growth. Under this scenario the maximum combined pumping rate, averaged over the peak week was 28,000 m^3/day from a total of up to ten wells, eight of which are existing with two additional wells planned for future construction
- Scenario 3: A constant population equal to that at 2060, under an assumption of moderate population growth. Under this scenario the maximum combined pumping rate, averaged over the peak week was 24,000 m^3/day from a total of up to eight wells, all of which are existing or; and
- Scenario 4: A constant population equal to that at 2060, under an assumption of high population growth. Under this scenario the maximum combined pumping rate, averaged over the peak

[1] The 35-year planning period represents the length of the consent sought beginning in 2014. Fifty years is the planning period addressed by Beca for KCDC, from 2010 to 2060.

[2] Total daily pumping rates are rounded to the nearest hundred m^3/day.

week was 29,700 m^3/day from a total of up to eleven[3] wells, eight of which are existing or with three additional wells planned for future construction.

Modelled Groundwater Effects

The results of 3D groundwater modelling indicate that the extended well field can be operated as planned over the 36-year period of planned river flow augmentation at short-term (15 week), peak rates of up to 29,700 m^3/day.

Drawdown effects on shallow groundwater in the Holocene Sand Aquifer beneath nationally ranked wetlands[4] (eg. Te Harakeke or Muaupoko Swamp Forrest) as predicted by the model could be up to 170 mm greater than without the KCDC well field. Drawdowns beneath wetlands of district level value (eg. Tini Bush) are predicted to be larger, up to 210 mm. Predicted drawdowns of up to 150 mm occur beneath wetlands that are either not rated as being of significance, unnamed and/or with insufficient information. The changes are less than the normal variations in water levels of 1 m to 2 m observed in wells completed in the shallow aquifers. Because the predicted changes are in most cases much less than the actual water level variations that naturally occur, the effects on those wetlands of national or district significance are unlikely to be noticeable and are considered to be minor in terms of a water level change.

Modelled maximum changes to water levels in coastal wells under the worst-case pumping of Scenario 4 results in a drawdown of 5+ m in the deeper Pleistocene Sand and Waimea aquifers. A drawdown of 5 m is equivalent to a deep aquifer water level about 2 m below mean sea level based on water level data collected from Sentinel Well 1. Drawdowns below sea level over a period of weeks may allow saline water to begin to move inland. However water level recovery occurs relatively quickly in these aquifers after pumping ceases such that groundwater returns to its “normal” off-shore flow direction within weeks of the cessation of pumping. Therefore, the long-term risk of intrusion of marine (saline) water is considered to be low for the operating system proposed as it can be adequately managed through monitoring and mitigation. The potential for saline intrusion will be further assessed through the implementation of a Saline Water Intrusion programme planned for 2013 and through the on-going monitoring of water levels.

Modelling showed that the worst case pumping of the KCDC wells under Scenario 4 might result in drawdowns of up to 2+ m in the Parata aquifer in two wells located in the northeast portion of the study area.

Under the worst-case pumping of Scenario 4 a total of 49 wells completed to depths of 20 m or less (completion in the Holocene Sand or Upper Pleistocene Sand aquifers) could potentially be affected by summer-long water level reductions of up to 0.5 m. We understand that all except three consented wells in the affected area are more than 18 m deep[5] (The remainder are permitted). The expected drawdowns in wells completed in the shallowest aquifer (the Holocene sand) are less than recorded natural variations in groundwater level and are likely to be unnoticed.

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[3] Well K13 was included as a possible source in the four scenarios but was not needed to meet the required peak combined pumping rates.

[4] Wetlands were ranked by Boffa Miskell (2012) based on their previous work in the greater project area.

[5] Greater Wellington Regional Council Key Issues Report. Notice of Requirement and Resource Consent Applications for the Mackays to Peka Peka Expressway Proposal NZTA, 11 June 2012. Report commissioned by the Environmental Protection Authority under Section 149G(3) of the Resource Management Act.

Such drawdowns could cause existing wells with shallow pumps or surface mounted pumps reliant on vacuum lift, to stop producing water, requiring lowering of pumps or in extreme cases where the wells are too small in diameter for use of a submersible pump, well replacement. If these wells are properly constructed and completed with submersible pumps placed near the bottom of the well, we expect that they would still be capable of their permitted or consented yields. In other words, the adverse effects on these wells (should they occur) can be sufficiently managed by way of conditions of consent.

Wells completed in the Pleistocene Sand and Waimea aquifers may be affected by pumping of the KCDC wells with drawdowns of 15+ m near the pumping centres of Kb4 to K6. Some 18 deeper wells completed to depths greater than 40 m and not owned by KCDC could be affected by drawdowns of greater than 5 m (although it is noted that these public supply wells have already been operational and such effects would already have been experienced to some extent). Such wells may experience a small decline in yield. However, wells of this depth are more likely to be properly constructed and completed with pumps placed deep enough such that the predicted maximum drawdown effects may be unnoticed. An understanding of the depth screened in each individual well and pump location would be required to assess whether deterioration of well yield might be caused by KCDC pumping. The overall adverse effects on these wells are therefore considered to be low; where pumps are of insufficient depth, they can be readily lowered in affected wells.

The actual numbers of wells identified as potentially being affected is likely to be smaller than indicated above. A survey conducted in August 2012 by Beca of the wells identified as being potentially affected indicated that 41% were either no longer in operation or duplicate entries in the database. This suggests that the actual number of affected wells may be only 60% of the numbers identified in the modelling analysis.

Potential mitigation scenarios were modelled to investigate the viability of injection of river water during the winter and spring months when an estimated 10,000 m^3/day could be available. Three possible injection locations (coastal, central and eastern) were modelled with injection before and after model Year 27 which includes the 50-year drought. The results indicated that injection could significantly reduce drawdowns in the Holocene Sand Aquifer underlying the wetlands but that water level rises above the “natural” wetland water levels during injection would occur. The injection scenarios indicate that injection can be considered as a mitigation option. Further modelling would be needed to optimise pumping and injection volumes, locations and schedules.

The modelling indicated that injection could also partially mitigate saline intrusion risks. The analyses suggested that the injection scenario run started and ended too early to optimally mitigate saline intrusion. As with injection to mitigate drawdowns beneath wetlands, further modelling would be needed to optimise injection as a possible mitigation for saline water intrusion risks.

In summary, the testing and modelling indicate that the *River Recharge with Groundwater* option can operate for the requested 35-year consent period with relatively small effects that can be mitigated through adaptive management. Monitoring is recommended to quantify these effects and as a trigger for implementation of mitigation. Revised pumping schedules, altered well pumping hierarchy or injection during high river-flow periods may help to mitigate the environmental effects, should the need be indicated by monitoring.

1 Introduction

1.1 Context

CH2M Beca Ltd (Beca) has been commissioned by the Kapiti Coast District Council (KCDC) to assist in identifying the most suitable solution for providing water to the communities of Waikanae, Paraparaumu and Raumati for the next 50 years.

As part of the water supply review and options study for KCDC, Beca has been asked to provide an assessment of the sustainable yield from the existing well field at Waikanae. The well field currently comprises nine production wells and two back-up wells located between 600 m and 2000 m from the coast in three groups (including the back-up wells PW1 and PW5). Two additional groups, the N series and S series, will augment the three existing groups. The lateral distance between the wells in each group ranges from about 300 m to 800 m. Figure 1 shows the project vicinity and locations of KCDC production and investigation wells.

Following three stages of investigations, evaluation and consultation, Council agreed to proceed with *River Recharge with Groundwater* as the top-ranked solution and to take further steps to confirm the feasibility of this option[6].

The *River Recharge with Groundwater* solution involves discharging groundwater to the Waikanae River, immediately downstream of the existing Water Treatment Plant intake, during periods of low river flow when abstraction from the river is limited due to minimum residual flow requirements. The groundwater will bolster river flows downstream of the water treatment plant and thus enable more water to be taken from the river while maintaining the natural level of river flow. Groundwater will be abstracted from the Lower Pleistocene Sand and Waimea aquifers using wells within the Council's existing well field in Waikanae (constructed in 2004/2005) and a new well (N2) drilled and tested during winter 2012 but with no pump yet installed or connection to the system. Additional wells N3, S1 and S2 are planned to be able to provide the forecasted 2060 peak-design-daily-yield-with-headroom of 32,700 m^3/day.

1.2 Overview of Aquifer Testing

A series of pumping tests and analyses were conducted to better characterise the groundwater flow system of the project area. Both long-term and short-term aquifer pumping tests were evaluated to quantify parameters of the three identified aquifers supplying water to the KCDC wells. Long-term constant-rate tests were conducted on:

- K4, K6 and Kb4 (tested March - May 2010)
- K5, K10 and N2 (tested January - August 2012)

The pumping portions of the tests were typically 9 to 12 days in duration, followed by a recovery period of similar length. Exceptions were the initial test of well N2 which was aborted[7] after 7+ days

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[6] Council meeting 19 August 2010.

[7] The first long-term test of N2 was stopped after 10,435 minutes (7.25 days) when a shift in the aquifer near the well screen caused well efficiency to decline. The data collected in the ten other wells monitored during the test was not affected by the changes observed in the pumping well. Recovery data for 30 days following the aborted test was collected in eight of these wells. Well N2 was reconstructed during June 2012 and retested in

of pumping and K10 which was stopped after 6+days of pumping. Water levels in 1 to 10 observation wells in the general vicinity of the pumped wells were monitored throughout each test.

Short-term constant-rate pumping tests were conducted in four investigation wells drilled as part of this programme. These tests consisted of pumping for a period of four to eight hours in screened portions of N2, N3, S1 and S2. Two or three depth intervals were tested in each of these investigation wells for a total of nine tests.

Hydraulic parameters were derived from the pumping test results and used as input for the calibrated, 12-layer, numerical, 3-dimensional groundwater flow model.

1.3 Overview of Groundwater Flow Modelling

An updated 3-dimensional, 12-layer, numerical groundwater flow model has been developed to simulate the drawdown and interference effects that might be associated with abstraction from KCDC wells, in order to better evaluate the long-term feasibility of the *River Recharge with Groundwater* option. This updated model takes on board the results of investigation and testing described above and findings from a groundwater flow model of the Kapiti Coast region between approximately MacKays Crossing and Peka Peka, which is described in Beca Infrastructure Ltd (2012).

The purpose of the model is to identify:

- the *range* of effects on groundwater expected from the River *Recharge with Groundwater* option
- where these effects would occur
- a monitoring programme to measure the actual effects at these locations
- mitigation options and triggers that should be considered as part of an adaptive management approach.

The model is one part of the overall programme of adaptive management. Because of the uncertainty of when future dry and wet periods would occur, how extreme they would be and what the population and associated water demands would be when these wet and dry periods do occur, the model was not designed to predict future conditions with total accuracy. It is understood that the ground and groundwater conditions are inherently variable and that this also means that the model will not be able to predict absolute effects at every location. Rather, the model was designed to consider changes that occur as a result of the *River Recharge with Groundwater* option and is to be used in combination with an adaptive management programme based on monitoring and established triggers to indicate if, when, and where mitigation should be implemented.

The purpose of the initial KCDC groundwater flow model, described in CH2M Beca (2011), was to assess feasibility of the River Recharge option. As such it focused on the effects of pumping from the deeper aquifers using pumping test data mostly derived from previous studies. Calibration of the model focused on effects in the deeper aquifers with less attention placed on effects in the shallowest, surficial zones that include wetlands, streams and shallow domestic wells, about which there was limited data at the time.

The updated KCDC model presented in this report incorporates an improved understanding of the groundwater flow system of the area developed through investigation well drilling and aquifer testing conducted during 2011 and 2012. It also includes an improved understanding of the shallow

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July-August 2012 (results in Appendix H). The long-term test of K10 was also stopped when the data indicated the well was developing during the test. Well K10 will be redeveloped and re-tested at a future date.

groundwater flow system developed as part of an investigation to assess the potential effects of the planned Mackays to Peka Peka ("M2PP") expressway (Beca Infrastructure Ltd, 2012). With its improved hydrogeological characterisation of the deeper aquifers and the improved understanding gained from the M2PP studies, the updated KCDC model better predicts the effects of the proposed pumping scenarios on the deeper *and* shallow flow systems.

The updated model incorporates an extension of the flow system into and beneath off-shore areas. The use of off-shore aquifers in the model and the resulting predictions of water level changes that would occur under various pumping scenarios, allows for an improved understanding of saline water intrusion potential. In support of the understanding of current conditions in near-shore wells, an initial baseline study for understanding the present level of salinity in the shallow aquifer was undertaken in December 2010. This baseline survey consisted of electrical conductivity monitoring in coastal domestic wells. This conductivity survey indicated that marine salt water has not intruded into any of the monitored domestic wells. A lack of a network of deep coastal wells means that a similar survey of salinity in the deeper aquifers could not be carried out. A future salinity study involving drilling of additional salinity monitoring wells is planned for early 2013.

After the model was developed and calibrated allowing it to replicate past conditions using historical water level, rainfall recharge and pumping data, it was used to simulate four pumping scenarios over a 36-year period. The simulation scenarios represent four population forecasts:

- Scenario 1: A constant population for the region equal to that at 2049, under an assumption of moderate growth from today
- Scenario 2: A constant population for the region equal to that at 2049, under an assumption of high population growth from today
- Scenario 3: A constant population for the region equal to that at 2060, under an assumption of moderate population growth from today; and
- Scenario 4: A constant population for the region equal to that at 2060, under an assumption of high population growth from today.

Each scenario was based on a 36-year record of river flows in the Waikanae River to indicate when and how much additional water would be needed to maintain required flows in the river. These supplemental flows would be pumped from existing and future KCDC production wells represented in the model. A simplistic hierarchy was developed to indicate which order the wells would be used in and what pumping rates would be likely. The hierarchy was based on water chemistry, well yield, distance to neighbouring wells and distance from each well to the point where water would be pumped into the river (and associated pumping costs). This hierarchy was employed to limit effects to the river and aquifer while keeping costs to a reasonable level.

Effects on the environment were quantified as changes in water levels caused under each of the pumping scenarios. Emphasis was placed on assessing the effects on existing water users, wetlands and streams, and the intrusion of saline marine waters into the aquifer system. The preliminary modelling indicated that the largest effects occur under Scenarios 2 and 4. Subsequent modelling efforts then focussed on these two scenarios. After the results were reviewed by KCDC and their Technical Advisory Group (TAG), injection of groundwater during winter was modelled to explore and demonstrate the feasibility of injection as part of an adaptive management plan to mitigate drawdowns that might cause unacceptable environmental effects (in particular to high-value wetlands). Injection mitigation was modelled for the highest-pumping rate/50-year drought period of Scenario 4, only. This "worst-case" simulation was chosen for modelling as the effects of pumping (and the need to mitigate) are smaller under the lower-demand Scenarios 1, 2, and 3 and during the lower-demand periods of Scenario 4.

In November 2010 the original conceptual 3D model was peer reviewed by GNS Science, who made a number of recommendations. The original conceptual model was then refined in accordance with these recommendations for development of the first-iteration model. The updated model presented in this report addresses all of the points raised by GNS Science (refer Appendix F).

1.4 Purpose of this Report

The purpose of this report is to document an assessment of the potential effects on the environment from groundwater pumping to maintain flow in the Waikanae River as part of the *River Recharge with Groundwater* option. This report presents the results of an improved understanding of the hydrogeology of the aquifers underlying the coastal areas near Waikanae, details of aquifer testing and subsequent analyses, and development of an updated 12-layer groundwater flow model used to simulate four pumping scenarios and three possible mitigation scenarios (should mitigation be required).

The results and findings from this modelling study will form a key input into the Assessment of Environmental Effects (AEE) for seeking consents for the *River Recharge with Groundwater* option.

2 Geology and Hydrogeology

2.1 Geology

The geology of the Waikanae – Paraparaumu area has been summarised from the following studies and published geological maps:

- Begg, J.G., Johnston, M.R.: 2000: *Geology of the Wellington Area*, 1:250,000 Geological Map
- URS, 2003: *Waikanae/Otaihanga Borefield Drilling Strategy KCDC Contract 401*
- URS, 2005: *Waikanae Borefield Technical Report*
- Pattle Delamore Partners Ltd, 2003: *Waikanae and Otaihanga Emergency Wells – Water Supply Security*
- Greater Wellington Regional Council - KCDC water well database
- CH2M Beca, 2011: *Kapiti Coast Aquifer Testing and Groundwater Modelling*
- Beca Infrastructure, 2012. *Technical Report 21 – Assessment of Groundwater Effects, Mackays to Peka Peka Expressway.*

2.1.1 Regional Geology

The geology of the Waikanae area has been dominated by tectonic activity and glacial and fluvial processes combined with changes in sea level. Significant tectonic activity in the area has resulted in vertical uplift of the greywacke basement rocks forming the hilly greywacke terrain of the Tararua Ranges in the east. Horizontal shifts of these hills have occurred along faults such as the Ohariu fault and associated splinter faults. The hill slopes were then dissected by glacial and inter-glacial fluvial processes that have eroded the greywacke and re-deposited it as sandy, gravely alluvial deposits including channel deposits, over-bank deposits and alluvial fans. These processes, in combination with longshore drift processes, formed large coastal plains. With each large scale tectonic movement, the rivers altered course and slowly migrated north and south across the alluvial fans depositing gravels, sands and silts. Episodic flood events resulted in finer materials such as silts and clays being deposited further away from the river channels, and in between such events, areas of peat developed in swamps. Several phases of sand dunes inter-finger with the swamp deposits and rise up to 20 m in elevation along the coast.

At least twice in the past, major global glaciations have altered sea level resulting in at least two periods of transgression and regression of marine waters over the project area. During these periods of transgression, marine sand was deposited in the near-shore marine environment when the shoreline was nearby. When the glaciers advanced in other parts of the world, sea level dropped and the area once again became terrestrial with associated deposition by rivers, streams and other alluvial processes.

2.1.2 Local Geology and Aquifer Designations

A geological model has been developed from existing water well data records, data from the original borefield development (URS 2005), drilling records from geotechnical investigations conducted as part of the M2PP expressway project, and investigation drilling conducted as part of this project. This geological model comprises up to eleven stratigraphic units of up to 50 m thick. Table 1 lists the elevation range, thickness and hydraulic role of these units as interpreted from the well logs of KCDC production and investigation wells. (Some of the indicated maximum thickness values may be higher than actual where interpretation of the contact between units was difficult or ambiguous.) As indicated in the table (by a thickness of 0 m) the entire sequence of stratigraphic units is not always present at all locations with the result that some water bearing units (the Waimea, Pleistocene Sand and Parata aquifers) are separated by lower-permeability Pleistocene silts at some locations but are in direct contact with each other at others. The variations in thickness and in the hydraulic properties of the silt layers affect the flow of groundwater within the system; where the silts are thin or absent, pumping from one aquifer directly affects water levels in adjacent aquifers (as discussed further in the groundwater modelling section of this report).

The geological nomenclature for the various stratigraphic units has been changed slightly from that of previous reports. We have revised the names of the Parata and Waimea aquifers to Parata Terrestrial Deposits and Waimea Terrestrial Deposits. These names better reflect the fact that some portions of these units consist of clay-bound gravels that cannot supply significant quantities of water to a well. In other words, portions of the Parata and Waimea stratigraphic units act as aquifers while portions act as “leaky aquitards.” In the interest of simplicity when discussing the hydrogeological role of these units, we continue to use the terms Parata and Waimea *Aquifers*, even if portions of these geologic units may not be capable of supply water to wells. In addition, we have changed the names of the Regressional Alluvium and Marine Sands in the URS reports to Pleistocene Silts and Pleistocene Sands.

Investigation drilling has also revealed that permeable units lie below the Waimea Terrestrial Deposits at some locations. These appear to represent older transgressional /regressional deposits. Their extent and properties are not well known and they have not been named in this report.

Geological cross-sections showing the spatial-distribution of these units are attached in Appendix A.

Table 1 – Interpreted Stratigraphic Units

Stratigraphic Unit	Elevation Range – Top of Unit (mRL)	Thickness Range (m)	Dominant Hydraulic Role
Holocene Peat/Alluvium/Fill	0 to +13.2	0 to 5	Aquitard
Holocene Sand	-2.3 to +15. 5	0 to 20	Aquifer
Pleistocene Sand (Upper)	-11.0 to +7.5	0 to 26	Aquifer
Pleistocene Silt (Upper)	-8 (observed in only 1 well)	0 to 18	Aquitard
Parata Terrestrial Deposits	-24.0 to +4.1	9 to 41	Aquifer
Pleistocene Sand (Lower)	-71.0 to -5.9	3 to 50 (likely includes portions of the Waimea)	Aquifer
Pleistocene Silt (Lower)	-62.9 to -47.2	0 to 10	Aquitard
Waimea Terrestrial Deposits	-105.4 to -37.4	4 to 56 (likely includes deeper units)	Aquifer
Deep Unnamed Silt	-65.2 (observed in only 1 well)	0 to 11 to ?	Aquitard
Lowest Unnamed Aquifer	-75.8 (observed in only 1 well)	0 to 7 to ?	Aquifer?
Greywacke Bedrock	-85.7 to -60.7 (most wells not drilled deep enough to reach greywacke)	100s of m	Aquitard/base of flow system

The surficial unit consisting of peat and alluvium (and at some locations, fill) was deposited during recent (Holocene) times when both climate and sea level were similar to today. Underlying these deposits are Holocene sand deposits that formed as dunes in this coastal area. The units lying beneath the Holocene sands were deposited during cyclic glacial and inter-glacial episodes when sea level dropped and terrestrial sands and gravels with interlayered silts and clays were deposited by rivers and streams meandering across what is now the Kapiti coastal plain. As the glacial episode ended, sea level rose, resulting in marine sand being deposited in near-shore areas which had previously been above sea level. With the continued sea level rise, these areas that had once lain near the shore line and its associated higher-energy environment where the marine sands had been deposited now lay further off shore where the lower energy environment resulted in the deposition of marine silts and fine sands. When the next glacial cycle began, sea level dropped again and the cycle was repeated.

This sequence was repeated at least twice in the Kapiti coastal area as indicated by the terrestrial Waimea and Parata sand and gravel deposits. The presence of even deeper coarse-grained and fine-grained units as observed in the log of Investigation well S1 suggest that additional cycles may have occurred prior to the deposition of the Waimea sands and gravels. Additional investigation bores would be needed to further address this issue as few of the wells in the project area have been drilled deep enough to unambiguously penetrate the greywacke basement rock and adequately characterise these deepest units.

Greywacke rock was observed in four of the KCDC wells and is observed in outcrops east of State Highway One (SH1). It is thought to drop steeply beneath the Waimea sands and gravels, as a result of tectonic activity along the NE-SW aligned Ohariu North fault aligned along the foothills of the Tararua Ranges, east of SH1 (Hemi Matenga and Maungakotukutuku parks). Cross-sections constructed from borehole data for the area between Peka Peka Road and Paraparaumu (Appendix A) indicate localised basement highs of greywacke occur in the vicinity of Peka Peka Road, Waikanae, and Paraparaumu. These could be a result of displacements on splinter faults associated with the Ohariu North Fault, or may reflect embayments in the old coastline.

To assist in selection of water well investigation sites, the geomorphology of the area was examined using stereo-pairs of aerial photographs at a scale of 1:9,000 flown in 1952. The aerial photographs were used to identify possible fault traces from stream offsets and spring seepages and other paleo-topographic features. The oldest available photography was used to allow viewing of the landscape with as few as possible of the natural features modified by development.

2.2 Hydrogeology

2.2.1 Groundwater Levels

Groundwater levels in the Waikanae Groundwater Zone are recorded at a number of Greater Wellington Regional Council (GWRC) monitoring stations spread throughout the Waikanae area and within the different aquifers (Figure 1). The depth of the monitoring wells ranges from 5 m to 122 m. The water levels are recorded by GWRC and the hydrographs provide records of long term level trends (Figure 2). A summary of available time-series water-level data is given in Table 2.

The hydrographs show a seasonal variation with the lowest water levels typically recorded in April (end of summer) and the highest water levels recorded in October (end of winter). Water levels in the deeper wells (R26/6566, R26/6284 and R26/6378) appear to be rising slightly, while the water level trend in the shallow wells remains generally constant from year to year.

Comparison with rainfall records recorded at the Waikanae Treatment Plant indicates that changes in water level in the shallow aquifer have a strong correlation with rainfall events, suggesting that the shallow aquifer responds rapidly to rainfall recharge. This is supported by moisture balance modelling carried out for Greater Wellington (Jones and Gyopari, 2005).

Table 2 - Summary of Time-Series Water Level Data

GWRC Well No.	Well Name	Depth (m BGL)	Recording Start Date	Comments
R26/6831	Larch Grove	9	March 2001	
R26/6833	Mclean Park	9	April 2001	
R26/6916	Waikanae CHP shallow	21	August 1994	
R26/6566	Estuary shallow	79	February 2005	
R26/6284	Waikanae Park	90	July 2003	
R26/7025	KCDC W1	5	November 2005	
R26/6886	Te Harakeke 03	6	November 2005	
R26/6287	Rangihiroa Street	6	December 2002	
R26/6673	Taiata Street shallow	38	February 2005	Recordings suggest regular pumping nearby
R26/6991	GWRC Nga Manu	5	November 2005	
R26/6992	KCDC K6 Observation	7	November 2005	
R26/6378	KCDC Rutherford Drive	122	September 2006	General increase in water level since recording started

2.2.2 Marine Water (Saline) Intrusion

The intrusion of marine (saline) water is a potential risk because much of the well field is located close to the coast and abstracts water primarily from the Waimea and lower Pleistocene Sand aquifers, which underlie a system of leaky alluvial aquifers. The deeper Waimea and lower Pleistocene Sand aquifers are believed to extend offshore from the coastline. Their exact positions and depths are unknown as no data is available from the offshore areas. However, projecting these aquifers at the dips indicated in the East - West cross-section (Appendix A) suggest that they do not crop out directly into the marine waters of Cook Strait (or Rauoterangi Channel) within a distance of a few kilometres of the coast. Bathymetry data presented in Maritime Chart NZ00046A1 indicate a maximum depth of 60 m within a distance of 5 km of the Kapiti coast suggesting that units from the Parata upwards are likely to crop out into marine waters and that the deeper, lower Pleistocene Sand and Waimea aquifers do not crop out within 5 km of the coast. Nonetheless, the presence of marine waters in overlying zones makes saline water intrusion possible with increased pumping from these aquifers.

In particular, there is the potential risk that increased pumping from KCDC wells could cause saline intrusion[8] in:

- Near-shore domestic wells screened in the shallow aquifers
- Near-shore wetlands and streams
- KCDC's near-shore water supply wells.

There is also a small risk of saline intrusion into deep wells located further inland, if marine water is present at depth in these areas. Pumping could cause the "up-coning" of deeper water and if saline, deterioration of water quality. Water quality samples analysed as part of the permeability testing of Investigation wells N2, N3, S1 and S2 do not indicate the presence of marine water at depth and neither do the analyses of water samples collected from the KCDC production wells (refer Section 2.2.5). Up-coning, therefore, appears to be a low risk.

In order to obtain a preliminary base line for understanding the existing salinity in shallow coastal wells, a survey was carried out by Beca in December 2010. The survey comprised in-situ recordings of electrical conductivity in some 100 domestic wells distributed along the coast from Raumati South to Peka Peka. The in-situ test results have been contoured in Figure 3, with higher conductivity and TDS being recorded closest to the sea.

In addition, water samples were collected from 25 domestic wells and analysed at the Council's laboratory for electrical conductivity, salinity and total dissolved solids; the results are summarised in Table 3. This testing confirms that all of the waters sampled would be classed as fresh water. The laboratory results are consistent with the field-measured electrical conductivity survey of the 100 domestic wells and are included in the contouring of electrical conductivity shown in Figure 3.

In order to limit the saline intrusion risk, earlier work by Beca recommended new production wells should be located further inland and completed in the Pleistocene Sand or Parata aquifers (where possible). In addition, wells in closest proximity to the coast should be retired. However, because the glacial and fluvial aquifer system is relatively narrow in lateral (west - east) extent and the greywacke basement rock surfaces at the foothills just east of SH1, the new wells will need to be located as far inland as possible but at sites where the depth to the basement rock is still of the order of 80 m or more.

[8] Marine water intrusion is further discussed (including schematic diagrams) in Appendix D.

Table 3 - Water Quality Test Results

Site	Date Sampled	Electrical Conductivity (µS/cm)	Salinity ($^{0}/_{00}$)	Total Dissolved Solids (g/m^3)
34 Olive Terrace, Paraparaumu Beach	13/12/10	587	0	337
8 Goldie Place, Waikanae	13/12/10	453	0	285
13 Toby's Way, Waikanae	13/12/10	738	0.1	408
20 Reeves St, Waikanae Beach	13/12/10	360	0	228
114 Paetawa Rd, Peka Peka	13/12/10	659	0	353
14 Field Way, Waikanae Beach	14/12/10	328	0	190
59 Weggery Drive, Waikanae	14/12/10	212	0	163
24 Eruini St, Waikanae Beach	14/12/10	385	0	190
11 Tutere St, Waikanae	14/12/10	493	0	293
109 Paetawa Rd, Peka Peka	14/12/10	443	0	261
121 Alexander Rd, Paraparaumu	15/12/10	242	0	158
26 Anthony Grove, Paraparaumu Beach	15/12/10	130	0	89
2 Park Rd, Paraparaumu Beach	15/12/10	404	0	257
2 McKenzie Ave, Raumati South	15/12/10	335	0	208
125 Tutere St, Waikanae	15/12/10	289	0	141
5 Aaron Court, Paraparaumu (1)	15/12/10	145	0	87
5 Aaron Court, Paraparaumu (2)	15/12/10	569	0	325

2.2.3 Well Interference

Constant rate aquifer tests carried out in existing wells suggest that the separation distance between wells should be at least 400 m. This spacing does not eliminate drawdown interference effects, but would allow efficient utilisation of the aquifer. In general, the larger the spacing between wells, the smaller the resulting drawdown interference effect. The actual drawdown interference effect can only be known from the results of pumping tests carried out in the individual and combined wells. In order to limit the risk of restricted drawdown due to well interference, well siting was (and in the future, should be) aimed to maximise the distance between new wells with wells aligned parallel to the coastline and perpendicular to the regional groundwater flow direction. This orientation and positioning has been adopted in selecting the locations for new and future production wells N2, N3, S1 and S2.

2.2.4 Existing Wells and the Waikanae River

Pumping testing indicates that some leakage from the shallower aquifers to the deeper aquifers does occur and therefore new wells should be located at least 500 m from the Waikanae River. Where possible, the new wells will also be located away from urban areas where there is a greater density of private shallow groundwater wells abstracting water. This orientation and positioning has been adopted in selecting the locations for new production wells N2, N3, S1 and S2.

2.2.5 Water Quality

Water quality testing has been be carried out in association with the drilling and testing of the investigation wells N2, N3, S1 and S2 to check the quality and likely viability of each of the four aquifers (the upper Pleistocene Sand aquifer, the Parata aquifer, the lower Pleistocene Sand aquifer, and the Waimea aquifer). Water quality testing has also been carried out in the existing production wells.

Sodium and chloride levels from the deepest tested zones indicate higher values than those from the shallower tested zones. The higher levels may be relics of when the area lay offshore beneath marine waters and now represent the near-endpoint of flushing and mixing with fresh groundwater or they may represent the upper portion of a zone of diffusion with higher-concentration saline water at depth.

Phosphorus can be significant to surface waters and can be the "limiting" nutrient such that its addition may cause an increase in biological growth. Investigations have been undertaken by NIWA (Suren et al, 2011) to better understand the effects of the chemistry of the groundwater on the Waikanae River ecology. Phosphorus has been analysed in samples collected from both investigation and supply wells. The results of these analyses (Table 4) were used in the development of the well hierarchy planned for supplementing river flow.

Table 4 - Dissolved Reactive Phosphorus Levels

Well	Dissolved reactive phosphorus (mg/L)
K10	0.063
Kb4	0.022
K4	0.095
K5	0.214
K6	0.059
Kb7	Not tested
K12	Not tested
N2	0.025
N3	0.139
S1	0.071
S2	0.051

3 Pumping Testing

3.1 Test Details

Pumping tests were conducted in wells representative of the KCDC well field, both existing and future-planned, to better assess the hydraulic properties of the aquifers and aquitards comprising the groundwater flow system of the Kapiti coastal area. Six long-term, constant-rate pumping tests were undertaken during 2010 and 2012 in production wells (including the new production well N2). Nine short-term constant-rate tests were also conducted in 2011 and 2012 in four investigation wells. Each of these tests is briefly discussed below with details presented in Table 2. Details of the pumping and observation wells are given in Appendix B.

3.1.1 2010 Production Well Constant-Rate Tests

During the tests conducted in 2010, water levels in the production wells were recorded with the existing SCADA system. The majority of the monitoring wells, however, had been completed with 20 mm diameter PVC piezometers that do not allow installation of typical electronic pressure transducers. Therefore frequent manual monitoring rounds were carried out by KCDC staff in order to collect and record water levels in these observation wells.

K4 The pumping test of K4, screened in the gravel layer within the Pleistocene Sand Aquifer (the aquifer overlying the Waimea aquifer) commenced on 6 May 2010 at 10:00 AM. The pumping rate of 70 L/s was maintained for 11 days while groundwater levels were recorded in 13 observation wells spread across the well field. Pumping was stopped at 18 May 2010 at 9:00 AM. Water levels in the pumping well and the observation wells were recorded until the groundwater level in the pumped well had fully recovered (within 2 days of cessation of pumping).

K6 The pumping test of K6, screened in the Waimea Aquifer, commenced on 31 March 2010 at 8:44 AM. The pumping rate of 58 L/s was maintained for 9 days while groundwater levels were recorded in 19 observation wells spread across the well field. After 9 days the pump was shut down on 9 April 2010 at 9:58 AM and water levels were recorded until full recovery had been achieved in the pumped well (within 5 days of cessation of pumping).

Kb4 The pumping test of Kb4, screened in the Lower Pleistocene Sand and Waimea aquifers, commenced on 16 April 2010 at 1:22 PM. The pumping rate of 35 L/s was maintained for 12 days while groundwater levels were recorded in 24 observation wells spread across the well field. On 28 April 2010 at 2:00 PM, after 12 days the pump was shut down and water levels recorded until full recovery had been achieved in the pumped well (within 2 days of cessation of pumping).

3.1.2 2012 Production Well Constant-Rate Tests

During the tests conducted in 2012, water levels were recorded with a combination of the existing SCADA system, electronic data loggers and manual measurements.

K5: The pumping test of K5, screened in the Lower Pleistocene Sand and Waimea aquifers, commenced on 25 January 2012 at 11:52 AM. The pumping rate of 34.9 L/s was maintained for almost 8 days while groundwater levels were recorded in 14 observation wells spread across the well field. After almost 8 days, the pump was shut down on 1 February 2012 at 10:19 AM. Water levels were recorded until full recovery had been achieved in the pumped well (within 3 days of cessation of pumping).

K10: The pumping test of K10, screened in the Lower Pleistocene Sand and Waimea aquifers, commenced on 10 January 2012 at 10:32 AM. The pumping rate of 15 L/s was maintained for more than 6 days while groundwater levels were recorded in 12 observation wells spread across the well field. After 3 days the water level in the pumping well began to rise. On 16 January 2012 at 4:15 PM, 6 days into the test, the pump was shut down as it appeared that the well was developing and thereby generating misleading data. Recovery was not recorded.

N2: The initial pumping test of N2, screened in the Lower Pleistocene Sand and Waimea aquifers, commenced on 23 April 2012 at 9:00 AM. The well was pumped more than 7 days while groundwater levels were recorded in 11 observation wells spread across the well field. After slightly less than 6 days a shift in the aquifer materials near the well screen occurred and drawdown increased significantly in the pumping well causing the pumping water level to drop below the data logger. The pumping rate was then adjusted downward several times over the day to 31 L/s and then to 28 L/s when the water level decline became severe and the pumping portion of the test was halted on 30 April 2012 at 1:15 PM. Recovery was then measured using data loggers for more than 2 weeks in all but two wells. Data logger failure limited recovery measurement in the N2 and the nearby domestic well (the “Brown well”). The aquifer shifts near the pumping well did not affect the water levels in any of the observation wells. The subsequent adjustments in pumping rate, however, were observable as subtle water level changes in most of the monitored observation wells.

A second pumping test of N2 commenced on 9 July 2012 but was aborted by a generator fault-interrupt circuit that shut down the test after 6 days of pumping. The pumped well was allowed to recover for 5 days and the test was restarted on 20 July 2012 at 10:00 AM. The well was pumped at 26.7 L/s for 15 days while groundwater levels were recorded in 11 observation wells spread across the well field. Pumping continued without incident until 4 August 2012 at 10:00 AM when recovery was then measured until 20 August 2012, as planned. Refer to Appendix H for an analysis of the completed pumping test results.

3.1.3 2011 - 2012 Investigation Well Constant-Rate Tests

Two or three constant-rate pumping tests were conducted in each of four investigation wells drilled during 2011 and early 2012. These tests were made with screens placed in zones identified as promising for potential development of a production well. Each test included 4 to 8 hours of pumping at a constant rate followed by a short period of recovery. The tests were conducted by Richardson Drilling under guidance from Beca.

N2 50.3 - 53.3 m: The pumping test of N2 with a temporary 142 mm diameter, 3 m long temporary screen with 0.25 mm slot openings, placed in the Lower Pleistocene Sand Aquifer between depths of 50.3 and 53.3 m, commenced on 6 July 2011 at 8:00 AM. The pumping rate of 4 L/s was maintained for 6 hours while groundwater levels were recorded in the test well only. The pump was shut down and recovery was recorded for one hour by which time the water level had fully recovered.

N2 67.3 - 70.3: The pumping test of N2 with a temporary 142 mm diameter, 3 m long temporary screen with 0.25 mm slot openings, placed in the Waimea Aquifer between depths of 67.3 and 70.3 m, commenced on 26 July 2011 at 2:00 PM. The pumping rate of 2 L/s was maintained for 6 hours while groundwater levels were recorded in the test well only. The pump was shut down and recovery was recorded for 1.5 hours by which time the water level had recovered to within 0.14 m of its original non-pumping (static) water level.

N3 60 - 69 m: The pumping test of N3 with a temporary 142 mm diameter, 6 m long temporary screen with 0.25 mm slot openings, placed in the Waimea Aquifer between depths of 60 and 69 m, commenced on 18 November 2011 at 8:00 AM. The pumping rate of 3.7 L/s was maintained for 8 hours while groundwater levels were recorded in the test well and a nearby domestic well. The pump was shut down and recovery was recorded for one hour by which time the water level had recovered to within 0.175 m of its original non-pumping (static) water level.

N3 73.2 - 79.5 m: The pumping test of N3 with a temporary 142 mm diameter, 6 m long temporary screen with 0.25 mm slot openings, placed in the Waimea Aquifer between depths of 73.2 and 79.5 m, commenced on 13 December 2011 at 8:00 AM. The pumping rate of 2.8 L/s was maintained for 8 hours while groundwater levels were recorded in the test well only. The pump was shut down and recovery was recorded for one hour by which time the water level had recovered to within 0.055 m of its original non-pumping (static) water level.

S1 17 – 20 m: The pumping test of S1 with a 142 mm diameter, 3 m long temporary screen with 0.25 mm slot openings, placed in the Parata Aquifer between depths of 17 m and 20 m, commenced on 18 May 2011 at 8:00 AM. The pumping rate of 1.3 declining to 1.04 L/s was maintained for 6 hours while groundwater levels were recorded in the test well only. The pump was shut down and recovery was recorded for one hour by which time the water level had recovered to within 0.605 m of its original non-pumping (static) water level.

S1 57.4 - 66.4 m: The pumping test of S1 with a 142 mm diameter, 9 m long screen with 0.25 mm slot openings, placed in the Lower Pleistocene Sand Aquifer between depths of 57.4 m and 66.4 m, commenced on 22 September 2011 at 8:00 AM. The pumping rate of 1.1 to 1.8 L/s was maintained for 9 hours while groundwater levels were recorded in the test well only. The pump was shut down and recovery was recorded for one hour by which time the water level had recovered to within 0.880 m of its original non-pumping (static) water level.

S2 27.5 - 31.5 m: The pumping test of S2 with a 142 mm diameter, 4 m long temporary screen with 0.25 mm slot openings, placed in the Lower Pleistocene Sand Aquifer between depths of 27.5 and 31.5 m, commenced on 28 January 2012 at 7:00 AM. The pumping rate of 1.8 to 1.9 L/s was maintained for 8 hours while groundwater levels were recorded in the test well only. The pump was shut down and recovery was recorded for one hour by which time the water level had recovered to within 0.264 m of its original non-pumping (static) water level.

S2 33 – 39 m: The pumping test of S2 with a 142 mm diameter, 6 m long temporary screen with 0.25 mm slot openings, placed in the Lower Pleistocene Sand Aquifer between depths of 33 m and 39 m, commenced on 9 February 2012 at 7:00 AM. The pumping rate of 2.9 L/s was maintained for 8 hours while groundwater levels were recorded in the test well only. The pump was shut down and recovery was recorded for 70 minutes by which time the water level had recovered to within 0.110 m of its original non-pumping (static) water level.

S2 61.9 - 66.3 m: The pumping test of S2 with a 142 mm diameter, 6 m long temporary screen with 0.25 mm slot openings, placed in the Lower Pleistocene Sand Aquifer between depths of 61.9 and 66.3 m, commenced on 7 March 2012 at 7:30 AM. The pumping rate of 1.7 L/s increasing to 2.0 L/s was maintained for 8.5 hours while groundwater levels were recorded in the test well only. The pump was shut down and recovery was recorded for 70 minutes by which time the water level had recovered to within 3.340 m of its original non-pumping (static) water level.

3.2 Test Results

The full results of the pumping tests including data plots are attached in Appendix C. A summary of test results for the second test of N2 is included in. Appendix H.

The results of the pumping tests indicate that vertical leakage occurs within the groundwater system between the various named aquifers. Leakage appears to occur from over and/or underlying aquifers when the Parata, Pleistocene Sand or Waimea aquifers are pumped. A summary of the results[9] of the pumping tests is given in Table 5.

The results indicate that three deeper aquifers underlie the Kapiti coastal area supplying water to the KCDC wells: the Parata, the Pleistocene Sand (lower), and the Waimea aquifers. These three aquifers are relatively high-yielding with similar hydraulic properties. All three have similar values for the average (geometric mean) values for transmissivity, storativity and hydraulic conductivity. The Pleistocene Sand Aquifer has a hydraulic conductivity that is slightly higher than those of the Waimea and Parata aquifers in spite of the fact that the Parata and Waimea aquifers include more coarse grain sizes (gravels and cobbles). The Pleistocene Sands (both upper and lower) appear to be “cleaner”, containing fewer fine-grained soils (silts and clays) and are therefore more consistently permeable. The tests also indicate that the overall system is “leaky” with pumping in one aquifer causing groundwater to move from overlying and /or underlying aquifers via silt layers with relatively moderate permeabilities.

[9] The results of the second N2 pumping test are not incorporated into the results of Table 5. The test results are close in value, however to those calculated using the data from the first test. The mean transmissivity calculated from the July test data was 21% greater while the mean storativity was 11% smaller, than those calculated from the April test data.

Table 5 - Summary[10] of Pumping Test Results

Hydro-stratigraphic Unit	Aquifer Parameter	Minimum	Maximum	Geometric Mean
Parata Aquifer	Transmissivity (m^2/day)	1.1E+02	1.3E+03	3.2E+02
	Hydraulic Conductivity (m/s)	8.1E-05	5.4E-04	2.1E-04
	Storativity (-)	4.3E-05	6.3E-04	1.6E-05
Pleistocene Sand Aquifer (upper and lower)	Transmissivity (m^2/day)	9.0E+01	2.3E+03	5.1E+02
	Hydraulic Conductivity (m/s)	3.4E-05	8.8E-04	2.4E-04
	Storativity (-)	2.7E-06	1.1E-03	2.0E-04
Waimea Aquifer	Transmissivity (m^2/day)	2.8E+02	9.1E+02	5.7E+02
	Hydraulic Conductivity (m/s)	1.50E-04	3.5E-04	2.3E-04
	Storativity (-)	2.3E-04	9.0E-04	5.2E-04

A significant tidal effect was observed in the monitored coastal wells. Tidally-induced variations in water level are commonly observed in wells located close to the coastline with aquifers extending off shore. Changes in tidal levels cause corresponding changes in the non-pumping (so called “static”) water levels observed in coastal wells. The largest daily tidal variations were observed in K13 (approximately 0.8 m) located close to the coast. However, K6, K5 and K10 located further inland indicated daily tidal variations of about 0.15, 0.25, and 0.5 m, respectively. Tidal variations of this magnitude indicate that the aquifers are connected to marine waters, even if at some offshore distance, although a portion of the response may be the result of pressure loading on the seafloor. The potential for pumping-induced saline water intrusion must be considered in the planned pumping of these and all KCDC wells.

The results from the pumping tests, and the fact that a large number of observation wells have been monitored during the tests, allows a detailed calibration of the groundwater model. Observation wells targeting shallow, mid-depth and deep aquifers have been monitored allowing a reasonable understanding of the aquifer system as a whole. Additional KCDC wells installed in the future should have aquifer tests of similar durations and with monitoring in multiple observation wells to increase the understanding of the aquifers and allow for improved model calibration/ verification in the future.

4 3D Model Set-up and Methodology

Three dimensional groundwater flow modelling has been used to evaluate the aquifer budget (water flowing into and out of the model) and assess the likely effects of different pumping regimes on groundwater and river levels in the vicinity of the well field. This section sets out the methodology used in development of the model. Full details of the model set-up, development and calibration are given in Appendix D.

The groundwater model was developed using the USGS model code MODFLOW (Harbaugh et al, 2000), and the Schlumberger pre- and post-processor Visual Modflow Pro 2010/2011. The model was calibrated to existing aquifer and well data (as detailed in the following sections), and then the proposed pumping regimes were simulated in order to provide an assessment of the likely effects on existing groundwater users and surface water bodies.

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[10] Although the values in the table are presented to two significant figures, it is more realistic to realise that they may only be accurate to only one significant figure.

4.1 Existing Takes

Jones & Gyopari (2005) estimated that approximately 3,000 domestic garden irrigation wells are spread across the populated area of the model. The pumping schemes are not known for these wells and the abstractions are not metered. The wells are generally between 3 m and 5 m deep and abstract approximately 1 - 5 m^3/day. The effect of these takes in the steady state model was simulated by removing 6,800 m^3/day using the evapotranspiration module in Modflow. This method allowed for a general abstraction from the shallowest layers by zone without requiring that an individual well be assigned to each modelled cell of the topmost layer in the model. We have conservatively assumed that each well is pumped at an estimated abstraction rate of 2.25 m^3/day.

Jones & Gyopari (2005) quantified a seasonal demand peaking at 6,000 m^3/day and averaging 2,000 m^3/day. In their analysis they assumed:

- half the properties in the area have garden wells for irrigation,
- irrigation demands are represented by the potential evapotranspiration rate minus precipitation,
- the percentage of each property that receives irrigation water ranges from 5 % to 20 %.

We have used both the higher rate from our analysis and the Jones & Gyopari (2005) seasonally-varied rates in our simulations, as discussed below.

Currently, the KCDC wells are consented to take 23,000 m^3/day, or if pumped to their maximum limit year round, 8.40 million m^3/yr. Actual use is far less. During the 2011-2012 monitoring period (1 April 2011 to 31 Mar 2012) the KCDC wells were only used for testing and maintenance purposes with a maximum daily abstraction rate of 10,400 m^3/day and an annual total of 205,000 m^3/year. This annual extraction represents almost 2.5 % of the annual water abstraction allowed under the current consent. During the 2010-2011 period the system was used for only 3 days for water supply, during 2009-2010 for only 12 days and during and during 2008-2009, the KCDC wells were not used at all for water supply (URS, 2012).

4.2 3D Computer Model

A model area of 15.5 km by 11.5 km was selected (Figure 4). The model extends from approximately 300 m above sea level to 130 m below sea level, and is composed of 12 layers, each 147 rows by 373 columns, representing the individual aquifers and aquitards shown in the geologic cross sections in Appendix A. The spatial distribution of the layers is as mapped on the published geological maps for the area, as discussed in URS (2005) supplemented with borehole data from the Greater Wellington Regional Council (GWRC) database, the on-going investigations at the Mackays to Peka Peka expressway project (M2PP), and investigation wells drilled and tested as part of this project.

In the immediate vicinity of the existing and proposed production wells the grid resolution is 40 m x 40 m. In general, the grid size ranges from 40 m by 40 m over the area being considered for abstraction and recharge, gradually widening to 200 m x 200 m at the outer bounds of the model. This grid layout has been designed to allow scrutiny of changes in the aquifers in the area in which significant changes will take place, while not making the model too unwieldy in terms of calibration and run times.

Natural surface water bodies were modelled using the River Package function of Visual MODFLOW Pro. Significant drains and spring-fed streams have been modelled using the Drain Package function.

For steady-state model calibration, an average annual rainfall of 1311 mm/year (calculated from GWRC records over the period 2003 to 2012) was used dividing the model into a series of recharge zones differentiated by soil type and land use (refer to Appendix D for the assessment method). This method follows that originally employed by Jones and Gyopari (2005) and subsequently adopted in CH2M Beca (2011) and Beca Infrastructure (2012). For the transient calibration, rainfall data was used to generate recharge rates following the method of Jones & Gyopari (2005) and applied at 2-week intervals over the 2004-2012 period. For modelling scenarios, recharge was calculated using the Jones & Gyopari (2005) method and weekly rainfall data from the 36 year record starting July 1975.

4.3 Model Calibration

The steady-state groundwater model was calibrated using an average of: river levels, rainfall rates (used to generate recharge rates), water levels in GWRC monitored wells, and water levels in KCDC wells. The results of constant rate pumping tests undertaken in K4, K5, K6, K10, Kb4, and N2 were also used. The transient model was calibrated to the same data as it varied over the period 2003 - 2011 and described below (ie. It was not averaged).

4.3.1 Steady State Model

The steady state model was initially calibrated to "steady-state" water levels and gauging data from the Waikanae River indicating losses to and from groundwater. Steady state water levels were derived from average (mean) water levels in observation wells in the GWRC monitoring well data base and water levels recorded in KCDC wells. The majority of the GWRC wells (listed in Table 2 and located in Figure 1) are screened in the shallow aquifers and therefore were used mostly to represent steady-state water levels in the shallower zones. The KCDC wells are mostly completed in deeper aquifers and were used to represent steady-state water levels in the deeper aquifers. Non-pumping water levels (so-called "static") levels recorded in the KCDC wells (pumping and observation) at the beginning and end of the pumping tests conducted during March through May 2012 were used to generate representative "steady-state" levels by visually selecting the midpoint of the water level data. The deeper aquifer steady state levels may therefore only be approximations of the long-term average levels.

For the steady state model a calibration to the data was achieved (Appendix D) with an initial normalised root mean square (RMS) of about 11 %. A normalised RMS of 10 % or less is considered to indicate a good calibration. Because there is uncertainty that the parameters calibrated to (water levels that vary seasonally, pumping rates, and rainfall) represent "steady state conditions", and adjustments to hydraulic conductivity need to be made during the transient calibration, the normalised RMS accuracy of the steady state model was considered to be appropriate.

4.3.2 Transient Model

We calibrated the transient model using two methods: 1) "long-term" (multi-year) calibration to recorded rainfall and monitored water level data from GWRC wells and 2) "short-term" calibration to selected aquifer tests lasting 7 to 9 days. The objective was to adjust model parameters to allow satisfactory replication of the GWRC monitoring data (long-term calibration) and observation well response during the pumping tests (short-term calibration).

For the long-term calibration, a recharge and water level time series for the period from March 2004 to March 2012 (8 years) was used. We selected this period because it includes the most comprehensive water level monitoring records that are available from GWRC, including records from deep monitoring wells. In this calibration, the model uses actual rainfall variation (averaged bi-weekly) over the pumping period as the varying inflow to the model. Pumping from KCDC wells was not included because of the infrequency of pumping and the low percentage of actual pumping volumes to maximum consented volumes. River flows were kept constant. The calibration included garden wells pumping at a seasonally adjusted rate based on the method of Jones & Gyopari (2005) which resulted in an average pumping rate of 0.67 m^3/day per well. An acceptable calibration to the rainfall and water level time series was achieved with only minor differences in the resulting hydrograph plots for the calibration wells (Appendix Figure D2-A –D2-E).

The long-term calibration model was then used as the starting point for calibration to the pumping tests. The aquifer tests conducted at N2 and K10 were used to adjust the parameters of the aquifer. These locations were chosen to represent the northern and south-central portions of the KCDC well fields. In theory, a transient calibration should only rely on changes to storage-rated parameters (specific storage and specific yield). However, it is common to adjust hydraulic conductivity as the input values are based on conversion of transmissivity (calculated from aquifer tests) to hydraulic conductivity (calculated based on interpretation of bore logs). Because the actual thickness of the aquifers responding to pumping during the tests is not exactly known, we adjusted hydraulic conductivity as well as storage parameters during the transient calibrations.

The final parameters by hydrogeological unit[11], used to calibrate the model are given in Table 6.

The parameters for the shallow layers including the Waikanae River Gravel have been adopted from those determined for the MacKays to Peka Peka model (Beca Infrastructure, 2012) some of which originated from Jones and Gyopari (2005), who developed a model that focused on the shallow groundwater aquifer in the Waikanae area. The Beca model started with the original Jones and Gyopari values (also employed in the original CH2M Beca KCDC model) adjusting these to replicate monitoring data collected near the planned expressway. The MacKays to Peka Peka model did not rely on calibration to data from deeper aquifer testing.

Table 6 - Adopted Hydrogeological Properties

Hydrogeological Unit	Horizon		Hydrogeological Parameters			
	Layer	Hydraulic Role	K_h (m/day)	K_v/K_h	S_s	S_y
Holocene Peat	1-2	Aquitard	3.63	0.02	0.05	0.50
Waikanae River Gravel/Alluvium	1-5	Unconfined Aquifer	260 – 1296	0 - 0.01	0.03	0.30
Holocene Sand	1-3	Unconfined Aquifer	65	0	0.005	0.15
Pleistocene Sands	4	Unconfined Aquifer	22.5	0.36	0.0025	0.10
Pleistocene Silts	5,7,11	Leaky Aquitard	0.017	0.1	3.66e-5	0.05
Parata Terrestrial Gravel	6,8	Aquifer	0.17	0.1	2.46e-5	0.25
Pleistocene Sands deep	9,12	Aquifer	26	0.06	3.15e-6	NA
Waimea Terrestrial Gravel	10	Aquifer	0.60	0.12	5e-6	NA
Greywacke Bedrock	-	No-flow boundary	0	0	0	0

[11] There are nine hydrogeological units identified in the project area and 12 layers in the model because some of the units, such as the Pleistocene sand, are repeated as “upper Pleistocene sand” and “lower Pleistocene sand.” The greywacke is not included as a layer in the model as it is treated as a “no-flow” boundary.

4.4 Modelling Scenarios

The transient model was developed to simulate the planned programme of using the Waikanae River to supply residents of the area with drinking water and using the KCDC supply wells to maintain the minimum flows required for the river. This would be accomplished by using the KCDC wells to discharge directly to the river rather than to the treatment plant for the reticulated supply. The timing and amounts of water needed for river flow augmentation will depend on population growth and natural climate variations (affecting total demand from the river) and natural variations in river flow (affecting timing and quantities needed to supplement river flow).

Four possible pumping scenarios were simulated to provide an assessment of the likely effects on existing groundwater users and surface water bodies that could occur without mitigation. These scenarios were based on 36 years of historical Waikanae River flows with a simulated 50-year low flow incorporated (to define river flow levels), plus 36 years of historical climate data and four population estimates (to define water supply demand from the river). Whenever demand exceeded the river's ability to supply water without causing the river level to drop below mandated minimum flow levels, pumping was simulated from the groundwater model, to supply the supplemental water needed to maintain minimum flows through direct discharge of the pumped groundwater to the river.

Four possible populations were calculated by assuming moderate or high growth rates over a projection timeframe to 2049 (35-year consent period starting in 2014) or 2060 (50-year project planning period beginning in 2010). The assumption of a constant population equal to the endpoint population (2049 or 2060) over the entire 36-year simulation is conservative (over-estimates demand) because the actual population during all but the last year of the 36-year simulation will be less than that of the 36^{th} year. It does allow, however, a "worst-case" analysis, were a drought (such as that of 2003) to occur at any time during the 35-year consent or 50-year planning periods.

Each scenario begins in "Year 0" and ends after the completion of "Year 35." Actual rainfall and river flow data from July 1975 through July 2011 were assumed to represent rainfall and river flow from Year 0 through 35. By using historical data, the four scenarios represent simulation of the environmental effects that could occur under four possible demand and population growth scenarios from moderate (Scenario 1) to more extreme (Scenario 4) . These simulations are not intended to exactly represent conditions from 2014 through 2049 (the period requested for consent) as future rainfall and river flows cannot be known and the population will not be at the assumed end-point levels over the entire simulation period. They are intended to provide a scientific basis for a conservative assessment of possible environmental effects over the 50 year planning horizon of *River Recharge with Groundwater* that includes a drought with a 50-year return period.

To control model run time, the daily demand data was consolidated to weekly volumes (m^3 of groundwater needed per week to supplement river flow) which was then averaged across 7 days to derive a weekly average demand in m^3/day.

Based on the four growth forecasts, the following scenarios were modelled:

- Scenario 1: A constant population equal to that at 2049, under an assumption of moderate growth. Under this scenario the maximum combined pumping rate[12], averaged over the peak week was 23,500 m^3/day from a total of up to eight wells, all of which are existing
- Scenario 2: A constant population equal to that at 2049, under an assumption of high population growth. Under this scenario the maximum combined pumping rate, averaged over the peak

[12] Total daily pumping rates are rounded to the nearest hundred m^3/day.

week was 28,000 m^3/day from a total of up to ten wells, eight of which are existing with two additional wells planned for future construction

- Scenario 3: A constant population equal to that at 2060, under an assumption of moderate population growth. Under this scenario the maximum combined pumping rate, averaged over the peak week was 24,000 m^3/day from a total of up to eight wells, all of which are existing; and
- Scenario 4: A constant population equal to that at 2060, under an assumption of high population growth. Under this scenario the maximum combined pumping rate, averaged over the peak week was 29,700 m^3/day from a total of up to eleven wells, eight of which are existing with three additional wells planned for future construction.

The wells used to meet the demands of the four scenarios were selected based on a number of factors. The three main factors were:

- Water quality and compatibility with river water (primarily an issue of phosphorous concentration)
- Proximity to other wells (to minimise well interference by spreading drawdown and avoiding concentrated drawdown where sea water intrusion might occur); and
- Overall pumping and delivery costs (to avoid wasteful energy use and unnecessary costs to KCDC).

A hierarchy of wells was determined based on these three factors. In each scenario the well at hierarchy level 1 was pumped (simulated in the model) first at its anticipated long-term sustainable pumping rate. When more water was needed than could be supplied by this one well, the well with hierarchy level 2 was then pumped alongside the first well as long as needed. When more water was needed, additional wells were added to meet the required demand. A total of up to 11 wells are anticipated to fulfil the minimum river flow with hierarchy level 1 (KCDC Kb4) used regularly, hierarchy level 11 (S2) used only occasionally and hierarchy level 12 (K13) not used at all. The planned well-use hierarchy and planned pumping rates are shown in Table 7.

Table 7 – Well Hierarchy and Pumping Planned Rates Used in the Model

Well Rank	Well Number	Planned Pumping Rate (l/s)
1	Kb4	45
2	N2	25
3	K4	80
4	K6	58
5	Kb7	10
6	K10	17
7	K12	8
8	K5	46
9	N3	25
10	S1	25
11	S2	20
12	K13	0
Total Maximum	All	359

5 Results of Modelling / Assessment of Environmental Effects

5.1 Overview of Approach

The general approach to assess the effects of the proposed pumping under the four scenarios was to model 36 years of aquifer response both with and without the planned pumping and then compare the resulting water levels to quantify the differences. Rainfall data, originally supplied at weekly periods for the 36-year simulation period, was consolidated to control model run time for non-pumping periods; the periods beginning one month after pumping stopped through the period one month before pumping started again was reduced to a single time series. During the single consolidated time series, the weekly rainfall data was averaged and applied throughout the entire consolidated period to generate average recharge rates. This process reduced run times and output file size to manageable levels.

Two sets of data files were used for each of the four scenarios, one with pumping wells and one without. In each simulation the calculated water levels were recorded for the locations representing key wetlands (to quantify effects on groundwater beneath wetlands) and along the coast (to help quantify saline water intrusion effects). The differences between the pumping and non-pumping water levels at these key locations were then used to generate drawdown hydrographs indicating the extent and timing of maximum environmental effects. Drawdown contour maps for selected aquifers were then generated using the indicated times of maximum effects to demonstrate the predicted worst-case effects throughout the project area.

The 36-year simulation period used the weekly rainfall and river flow data collected from July 1975 through July 2011 (modified for a 50-year drought in April 2003 and consolidated as described above) to calculate recharge from “Simulation Year 0” through “Simulation Year 35”. These years do not directly represent the expected effects at the indicated times starting from July 2014, the anticipated start of the river flow supplementation programme. Rather, they represent a 36-year period of record in which droughts have occurred that give us an understanding of what could occur at any time within the next 35 to 50 years.

The 36 years of river flow data were used to calculate when supplemental groundwater discharge would be needed to maintain river flow at the required minimum levels (refer CH2M Beca, 2012). The amounts and timing of groundwater pumping were calculated based on the difference between recorded river flows and the required minimum flow to be maintained in the Waikanae River. The flow data were not used directly to generate boundary conditions (levels) in the modelled river cells. Instead we used the average base flow water levels developed as part of the surface water characterisation of the Waikanae River to indicate base flow levels that would interact with water levels in adjacent aquifers[13].

5.2 Edge Effects in the Model

A review of the preliminary results from the model indicated that, along the northern edge of the model, some of the predicted drawdowns appeared to be greater than drawdowns further to the south and closer to the pumping centres actually causing these drawdowns. The higher than expected drawdowns along the northern edge of the model have been interpreted as edge effects

[13] The Modflow river package cannot directly incorporate surface water *flow* data. An indirect application of the flow data to generate water levels at each river cell would require detailed generation of flow vs water level rating curves along every reach of the river, an analysis that currently does not exist.

that are not true representations of actual drawdowns that would have occurred had the boundaries of the model been located several kilometres further to the north.

The northern edge of the figures showing the predicted drawdowns (Figures 9 and 10) lies about 800 m from the model's northern boundary. Ideally, a model is constructed such that pumping effects do not extend to the model's boundaries because the boundary can affect heads (water levels) near the boundary. The type and magnitude of the effect is controlled in part by the type of boundary set within the model. In the case of the KCDC model, the northern boundary consists of "inactive model cells." These operate as "no-flow" boundaries, neither contributing flow into or out of the model (as would constant head or general head boundaries), nor holding the head at a constant value and drawdown at "0" (as would a constant head boundary). Because the no-flow boundary does not allow the effect of the drawdown to spread out further that the model boundary, drawdowns are over-calculated by the model near the boundaries. Therefore, the model-predicted drawdowns in the vicinity of the model boundaries are greater than those that would actually occur were the boundary moved several kilometres to the north of that used in the model. Unfortunately there was limited data from the area north of the boundary. KCDC has drilled no investigation or production wells and conducted no pumping tests in this area. For this reason the model boundary used in the original KCDC model was allowed to remain as it was.

5.3 Model Results

The results of the two highest demand Scenarios: 2 (high growth-rate population of 2049) and 4 (high growth-rate population of 2060) are presented as drawdown hydrographs and as drawdown contour maps for the "worst-case" drawdowns in the four main water-bearing zones (Holocene Sand, Parata, Pleistocene Sand and Waimea aquifers)). Scenarios 1 and 3 were run and preliminary analyses of the results made. Because the drawdowns from these two scenarios parallel, but are less than those of Scenarios 2 and 4, we have not included hydrographs and drawdown contour maps for these scenarios in this report. All further presentation and discussion focusses on Scenarios 2 and 4.

The maximum drawdown contour figures discussed below are temporary drawdowns that would only occur at the peak of water withdrawal at the height of the 50-year drought under the largest population growth scenario. During most years, the drawdowns would smaller and in many years zero as the KCDC wells would only be used to supplement river flow during dry periods when natural flows were too small for water supply and minimum required flows. In addition, it should be noted that such drawdowns are not new effects. Similar (but smaller) drawdowns have been occurring for nearly a decade as the existing KCDC wells have been pumping these four major water bearing zones over that period.

5.3.1 Drawdown Hydrographs

The composite drawdowns at key observation points for each of the two maximum demand scenarios (2 and 4) are shown in Figures 5 to 8. The hydrographs are grouped by 1) wetlands, and 2) coastal wells. Wetland locations and relative significance were identified by Boffa Miskell (Matiu Park, 2012, personal communication of wetland rankings) and are listed in Table 8.

Table 8 – Ranking of Kapiti Coast Wetlands by Boffa Miskell

Likely Nationally or Regionally Significant	Significant at District Level / May Be Regional Significant w/ Additional Investigation	Limited Value / May Be Significant at District Level	May Not Be Significant or Insufficient Information
Muaupoko Swamp Forest	El Rancho Wetlands	Andrews Pond	Crown Hill Manuka Bush
Nga Manu Wetland	Osbournes Swamp	Kaitawa Reserve Swamp Forest	Kāpiti Airfield Raupo Swamp
Raumati South Peatlands B	Pekapeka Road Swamp	Kāpiti Airfield Wetland A	Kāpiti Airfield Wetland B
Te Hapua Swamp Complex A	Ratanui Swamp	Kowhai Stream Mouth (Hadfields)	Kāpiti Road Wetland A
Te Hapua Swamp Complex D	Raumati South Peatlands A	Ngarara Bush	Lions Down Bush
Te Hapua Wetland Complex D	Te Hapua Wetland Complex B	Ngarara Road Wetland D	Ngarara Lake
Te Harakeke Wetland	Te Hapua Wetland Complex C	Otaihanga Landfill South	Ngarara Road Wetland A
Waikanae Saltmarsh	Tini Bush	Poplar Ave Wetland	Ngarara Road Wetland B
	Waimeha Lagoon – Victor Weggery Reserve	Te Hapua Swamp Complex E	Ngarara Road Wetland C
		Te Hapua Swamp Complex F	Otaihanga Landfill Central
		Turf Farm Dune Forest	Otaihanga Landfill North
		Unsurveyed site 5	Reikorangi Road Bush D
		Waimanu Lagoons	Unsurveyed Site 11
		Waimeha Stream Mouth	Unsurveyed site 12
		Wharemauku Stream Mouth	Waikanae River Oxbow

Three sets of coastal observation wells were placed at three locations to represent the effects that could occur at the coast in the northern, central and southern portions of the coastal areas that might be affected by pumping. At each location, water levels were observed and recorded by the model at three depths representing three aquifers: Holocene Sand, Pleistocene Sand and Waimea aquifers. The hydrographs representing each of the wetland and coastal locations show the difference between water levels simulated for the 36-year period with and without the pumping by KCDC wells. They do not show the predicted water levels at these locations. Actual water levels, even without pumping by KCDC, will vary over time as they respond to variations in rainfall.

The hydrographs indicate that the maximum effects (drawdowns) occur in all of the scenarios during year 27, simulated with the lowest rainfall periods and the highest demand on the KCDC wells to supplement river flow. In Scenario 2 (Figure 5) the maximum drawdown[14] effect occurs late in year 27[15] (specifically at "Year 27.8"). The hydrograph shows the largest effect under Scenario 2 is a predicted drawdown of 130 mm in the shallow groundwater of the Holocene Sand Aquifer beneath the Nga Manu wetland (ranked by Mr Park as of National significance) and a drawdown of 120 mm

[14] Model predicted effects are presented to two significant figures: 0.5 m for coastal wells and to the nearest 10 mm for wetland predictions because these effects are small. It is recognised that model result errors may be greater than these amounts.

[15] Year 27 includes the effects of a 50-year drought and the corresponding drought-created water demands.

beneath the Tini Bush wetland (ranked by Mr Park as of district significance) during the same year (27.8 - drought conditions). Figure 6 shows that the largest predicted drawdown in the Holocene aquifer beneath a wetland ranked of limited significance is about 150 mm beneath Ngarara wetland. Figure 6 also shows that the largest predicted drawdown under Scenario 2 along the coast is a drawdown of 4.8 m indicated in the Waimea Aquifer at the “Coastal 2” well location and a drawdown of 3.3 m in the Waimea Aquifer at the “Coastal 3” well location.

Scenario 4 (which represents the “worst-case” of the four modelled scenarios with a high-growth rate to 2060 population) indicates the largest of the predicted environmental effects. These also occur during year 27.8 of the modelled scenario. The hydrograph in Figure 7 shows the largest effect under Scenario 4 is a predicted drawdown of 170 mm in the shallow groundwater of the Holocene Sand Aquifer beneath the Te Harakeke wetland (ranked by Mr Park as of National significance) and a drawdown of 210 mm beneath the Tini Bush wetland (ranked by Mr Park as of district significance) during the same year (27.8 - drought conditions). Figure 8 shows that the largest predicted drawdown in the Holocene aquifer beneath a wetland ranked of limited significance is about 190 mm beneath Ngarara wetland. Figure 6 also shows that the largest predicted drawdown under Scenario 2 along the coast is a drawdown of 4.9 m indicated in the Waimea Aquifer at the “Coastal 2” well location and a drawdown of 3.4 m in the Waimea Aquifer at the “Coastal 3” well location.

The environmental effects under Scenarios 1 and 3 are less than those of Scenarios 2 and 4.

5.3.2 Drawdown Maps

The largest predicted environmental effects (drawdowns) in the four major water-bearing zones are shown in Figures 9 and 10. These maps of the modelled area indicate the maximum calculated drawdowns from Scenarios 2 and 4 at “Year 27.8” of the 36-year simulation in the Holocene Sand, Parata, Pleistocene Sand (lower) and Waimea aquifers. As shown in the hydrograph Figures 5-8, this time period has the largest calculated effects in all the scenarios. Scenarios 2 and 4 at Year 27.8 represent the two highest water demands as calculated based on the 50-year drought inserted at 2003 (Year 27 of the simulations) and the high-growth-rate projected populations of 2049 (Scenario 2) and 2060 (Scenario 4). Drawdowns at other times and under smaller growth scenarios would be smaller and during non-pumping years, zero.

Figures 9 and 10 show the largest cumulative effects in the Pleistocene Sand and Waimea aquifers with the highest drawdowns occurring near the centres of highest pumping rates and duration (near wells Kb4, K4, and K6). Drawdowns in this area are predicted to be of the order of 15+ m during the highest demand period of Scenario 4 with slightly smaller drawdowns under Scenario 2.

The highest drawdowns in the Parata Aquifer are smaller than those of the underlying aquifers. However, in areas where the Parata is more hydraulically connected to underlying aquifers, drawdowns of up to 5 m may occur under the worst case of Scenario 4, Year 27.8 pumping. Maximum drawdowns under the next highest pumping Scenario (2) would be less than 2 metres.

The effects in the shallowest Holocene Sand Aquifer under the highest pumping of Scenario 4 are predicted to be less than 0.5 m in all of the modelled area with the highest drawdowns along the eastern part of the modelled area. In these areas the model indicates drawdowns of 0.2 to 0.5 m. Here, the deeper pumped zones have been modelled with more direct hydraulic connection to deeper aquifers based on investigation drilling at the N1 and N2 sites. Smaller drawdowns are predicted under Scenario 2.

5.3.3 Environment Effects – Wetlands

The modelling of effects on shallow groundwater, as indicated by the worst-case drawdowns in the Holocene Sand Aquifer, suggest that water level changes beneath wetlands identified as nationally significant by Boffa Miskell (Matiu Park, 2012, personal communication of wetland rankings) could be as much as 170 mm. The changes are for the most part much less than the normal variations in water levels of 1 m to 2 m observed in wells completed in the shallow aquifers as shown in Figure 2. Because the predicted changes are less than the actual water level variations that naturally occur in these areas, the effects may be unnoticeable. Higher drawdowns of up to 0.5 m are indicated in the eastern portions of the study area with changes of 210 mm beneath the Tini bush wetland ranked as "of district significance." Table 9 lists maximum modelled drawdowns beneath the known wetlands as included in the GWRC database (GWRC, 2012b) and ranked by Boffa Miskell. The values shown for wetlands of National, District and Limited significance were generated by virtual wells assigned in the model to the Holocene Sand Aquifer directly beneath the wetland. The values for the "May not be Significant" category were derived from the model generated values for nearby wetlands with modelled virtual wells in the Holocene Sand Aquifer. .All values are reported to the nearest 10 mm[16].

Table 9 – Maximum Modelled Drawdown Effects in the Holocene Aquifer Underlying Wetlands Identified by Boffa Miskell

Likely Nationally or Regionally Significant ***Drawdown [m]***	**Significant at District Level / May Be Regional Significant w/ Additional Investigation** ***Drawdown [m]***	**Limited Value / May Be Significant at District Level** ***Drawdown [m]***	**May Not Be Significant or Insufficient Information** ***Drawdown [m]***
Muaupoko Swamp Forest ***110***	El Rancho Wetlands ***50***	Andrews Pond ***30***	Crown Hill Manuka Bush ***110***
Nga Manu Wetland ***140***	Osbournes Swamp ***60***	Kaitawa Reserve Swamp Forest ***10***	Kāpiti Airfield Raupo Swamp ***10***
Raumati South Peatlands B ***10***	Pekapeka Road Swamp ***160***	Kāpiti Airfield Wetland A ***10***	Kāpiti Airfield Wetland B ***10***
Te Hapua Swamp Complex A ***90***	Ratanui Swamp ***90***	Kowhai Stream Mouth (Hadfields) ***80***	Kāpiti Road Wetland A ***10***
Te Hapua Swamp Complex D ***100***	Raumati South Peatlands A ***10***	Ngarara Bush ***190***	Lions Down Bush ***80***
Te Hapua Wetland Complex D ***100***	Te Hapua Wetland Complex B ***110***	Ngarara Road Wetland D ***150***	Ngarara Lake ***20***
Te Harakeke Wetland ***170***	Te Hapua Wetland Complex C ***100***	Otaihanga Landfill South ***90***	Ngarara Road Wetland A ***150***
Waikanae Saltmarsh ***10***	Tini Bush ***210***	Poplar Ave Wetland ***10***	Ngarara Road Wetland B ***150***
	Waimeha Lagoon – Victor Weggery Reserve ***80***	Te Hapua Swamp Complex E ***100***	Ngarara Road Wetland C ***150***
		Te Hapua Swamp Complex F ***100***	Otaihanga Landfill Central ***90***

[16] Acknowledging that this level of accuracy might exceed the model accuracy, but that it gives an understanding of the relative magnitude of effect

Likely Nationally or Regionally Significant *Drawdown [m]*	Significant at District Level / May Be Regional Significant w/ Additional Investigation *Drawdown [m]*	Limited Value / May Be Significant at District Level *Drawdown [m]*	May Not Be Significant or Insufficient Information *Drawdown [m]*
		Turf Farm Dune Forest ***160***	Otaihanga Landifll North ***90***
		Unsurveyed site 5 ***170***	Reikorangi Road Bush D ***0***
		Waimanu Lagoons ***20***	Unsurveyed Site 11 ***150***
		Waimeha Stream Mouth ***80***	Unsurveyed site 12 ***150***
		Wharemauku Stream Mouth ***10***	Waikanae River Oxbow ***50***

The largest predicted drawdowns in the Holocene Sand Aquifer at year 27.8 and the wetlands identified in the GWRC data base are presented in Figure 10.

Suren et al (2011) of NIWA, considered the effects of the existing well field on wetlands. They concluded that invertebrate fauna found in three wetlands investigated were typical of other wetlands in the North Island. While acknowledging that the knowledge of wetland invertebrate communities is in its infancy, they concluded that if reduced water levels did cause a wetland to dry out, much of the fauna is highly mobile and capable of rapidly re-colonising the wetland once water returned. NIWA concluded that it is highly likely that the effects on the fauna communities would be “less than minor”.

It is important to recognise that these predicted water level change effects do not translate directly to changes in water levels in the wetlands. Wetlands can have sources of water other than the underlying groundwater. Surface water runoff and direct rainfall can create a wetland when the near surface soils are of low permeability (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 wetland. 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.

If a more complete understanding of an individual wetland were desired, site-specific analysis would be needed to better quantify how changes in groundwater levels would affect water levels in the wetland. The predicted changes in water levels beneath the wetland serve as an indicator of the “worst-case” changes that could occur. Boffa Miskell (2012b) is conducting a desk-top study of potential environmental effects on the wetlands listed in Tables 8 and 9. They may conclude that a water level change in some wetlands of more than 100 mm could be significant. Their report should be consulted for additional details.

Mitigation to reduce drawdown in the Holocene Sand Aquifer lying beneath the wetlands through injection under three possible scenarios is explored in Section 5.7.

5.3.4 Environment Effects – Marine (Saline) Intrusion

The maximum worst-case changes in coastal water levels, predicted to occur during Year 27.8 (50-year drought) under Scenario 4 is of approximately 5+ m at the coast in the deeper Pleistocene

Sand and Waimea aquifers and 4 m at the Coastal 2 location (Figure 1). Actual water levels at these locations are not accurately known as no monitored wells currently exist at these locations. However, the water level in the GWRC monitoring well R26/6378 (Sentinel 1), which is completed in the Waimea Aquifer, varied over the past three years around an elevation of 3 mRL (Figure 2). A drawdown of 5 m would result in aquifer water levels about 2 m below mean sea level.

Water levels held to this level over a prolonged period would cause saline water to move inland within the deeper aquifers with a resulting deterioration of water quality in coastal wells completed in these aquifers. However, the maximum period of prolonged pumping during the 50-year drought with 2060 population is around 15 weeks, after which water levels quickly recover as shown by the return to drawdowns of less than 3 m for well Coastal 2 deep (the well indicating the largest drawdowns) within about 3 weeks and to less than 2 m within 7 weeks (Figure 8).

After water levels substantially recover, groundwater flow would return to its “normal” flow direction (toward off shore areas). Thus the potential for inland flow of marine waters within the deeper aquifers over the 15 week pumping period would be reversed during the non-pumping periods. Additional analysis planned for the KCDC Saline Intrusion study will help to better define current and future salinity conditions and the need for mitigation through adaptive management. Therefore, the overall effect of saline intrusion is considered to be small as the risk of intrusion occurrence along the coastal interface will be carefully monitored as the *River Recharge with Groundwater* project is staged over time. Should salinity levels be identified above the trigger level specified by way of conditions of consent, appropriate mitigation action will be confirmed and implemented. Mitigation through injection under three possible scenarios is explored in Section 5.7.

5.3.5 Environment Effects – Existing Water Users

The model indicates that 35 wells completed in the Parata, Pleistocene Sand and Waimea aquifers may be affected by pumping of the KCDC wells with drawdowns of more than 5 m. Of these, 17 are owned by KCDC. The maximum worst-case (Scenario 4, Year 27.8) simulation indicates short-term, temporary drawdowns of 15+ m in the Pleistocene Sand and Waimea aquifers near the pumping centres of Kb4 to K6, although it is understood that these existing wells have been pumped in the past and therefore much of this drawdown would already have been experienced.

Two wells completed in the Parata aquifer in the northeast portion of the study area, could be affected by pumping of the KCDC wells with drawdowns of up to 5 m. These Parata aquifer wells are completed near KCDC wells N2 and N3.

Up to 49 wells completed to depths[17] of 20 m or less could potentially be affected by summer-long water level reductions between 200 mm and 500 mm caused by pumping of the KCDC wells. These Holocene Sand and Upper Pleistocene Sand aquifers drawdowns are less than recorded natural variations in groundwater level and are likely to be unnoticed by well users.

Figure 11 shows wells identified that could be affected by drawdown range and well depth/aquifer completion under the maximum drawdown of the 50-year drought. The owners of these wells as

[17] A review of the GWRC database indicates more than 1100 wells in the project area with no listed depth. In our analysis we have included these wells in the shallow “0 to 20 m depth” category. Therefore, it is possible that the number of wells indicated in our analyses as being completed in this shallow category may be too large while the number of wells completed in the deeper categories (the Parata, Lower Pleistocene Sand and Waimea aquifers) may be too small. *All* well owners identified as having wells in any of these depth categories was included in the telephone survey included in Appendix G. Therefore all the wells potentially affected and included in the GWRC database have been identified.

listed in the KCDC database were contacted by telephone. The owners were surveyed on whether the well was still in operation, the performance of the well and other details. A total of 89% of the well owners responded to the survey. They indicated that 41% no longer had operating wells or were duplications of other entries in the data base. Of the remaining 59% (wells in current operation), 43% had surface mounted pumps, 41% had submersibles and 16% did not know. Based on this summary we estimate that only about 60% of the affected well totals listed in the following paragraphs are likely to exist as operating wells and that about 40% of these are likely to have surface-mounted pumps that would be more likely to have their ability to pump affected by large drawdowns than their submersible counterparts. A summary of the results of the survey are included in Appendix F. The details of the survey that include the well owner's name and contact details are held in confidence by KCDC for future contact should monitoring indicate that specific wells might be affected by the pumping proposed by the district.

The ability of these wells to produce at their current rates has the potential to be affected by the pumping of the KCDC wells. Drawdowns caused by KCDC pumping could cause wells with shallow pumps or surface mounted pumps reliant on vacuum lift to stop producing water requiring lowering of pumps or, in extreme cases of wells too small in diameter for use of a submersible pump, well replacement. However, if properly constructed and completed with submersible pumps placed near the bottom of the well, they should still be capable of their permitted or consented yields. The adverse effects to these wells are considered to be low because they can be readily managed by lowering their pumps.

Mitigation to reduce drawdown and therefore the associated potential effects on existing water users through injection under three possible scenarios is explored in Section 5.7.

5.3.6 Environmental Effects – Rivers and Streams

Flows in the Waikanae River will be affected by pumping from the KCDC wells. A zone-budget analysis of changes in flows into the river from groundwater discharge and out of the river to recharge groundwater were modelled for the 35 years of Scenario 4. In this scenario the changes in flow in the river were tracked for each time step of the 35 years modelled in both the unpumped and Scenario 4 simulations. The differences tracked for the generally losing reach (between SH1 and Jim Cooke Memorial Park) and the generally gaining reach (between Jim Cooke Memorial Park and the river mouth) are plotted in Figure 12a.

The graph shows that pumping the KCDC wells causes an increase in recharge to groundwater from the losing reach and a decrease in groundwater discharge to the river in the gaining reach. Typically pumping changes river flow by around 10 L/s with some higher decreases during extreme pumping events. The model predicts that the largest effect of a net decrease in river flow of just under 18 L/s would occur during the peak of the 50-year drought modelled for year 27.8. This net decrease represents about 3% of the river flow in a 50-year drought, and much of the effect would already occur under the current borefield consent. Therefore this effect is considered to be minor. A possible mitigation measure may be for the KCDC wells to recharge an additional amount to the river to offset the river loss caused by pumping, should the available headroom not be required to meet water supply demands.

Pumping may affect other streams and drains in the area. The Mazengarb drain, Waimeha Stream Ngarara Stream, Kakariki Stream and Wharemauku Stream are all included in the model. Other streams in the area such as the Tikotu, the Muaupoko and the un-named stream in the north of the model area are not. There is insufficient flow and level data along various reaches of these streams and drains to properly calibrate the model for groundwater inflow/outflow calculations. Without proper calibration any calculated changes in flow derived from the model would not be meaningful.

Because there is insufficient calibration data, we have assessed the effects on these streams qualitatively. Figure 12b shows the model-predicted maximum drawdown at year 27.8 under Scenario 4. The figure shows that predicted maximum drawdowns are less than 50 mm for the Holocene Sand Aquifer beneath the Waimeha, Wharemauku and Tikotu streams with drawdowns of 50 to 100 mm in the Holocene Sand Aquifer beneath the Ngarara and the unnamed stream in the north of the model area and beneath much of the Mazengarb drain. Higher drawdowns of up to approximately 400 mm are indicated beneath portions of the Kakariki and Muaupoko streams close to the eastern edge of the coastal plain.

The actual effects induced by these drawdowns will depend on river levels, streambed conductances and groundwater levels at the time of pumping. Without detailed knowledge of these factors, effects cannot be meaningfully quantified. However, in areas were the predicted drawdowns are less than 50 mm, we believe that such drawdowns are likely to cause less than minor changes in flow. In addition, based on our experience with streams and rivers in New Zealand, we believe that during the conditions of the 50-year drought simulated under Scenario 4 at 27.8 years, it is likely that portions of these streams, especially the upper reaches where predicted drawdowns are greatest, would already be dry. In dry reaches the additional drawdown caused by the KCDC pumping would have no effect on flow the stream as it would already be dry. The upper reaches of the streams with the highest indicated drawdowns in the Holocene Sand aquifers could be monitored to indicate whether the KCDC pumping had any effects. Such monitoring could be used as part of an adaptive management programme and in conjunction with additional stream gauging to generate the information needed to properly calibrate the model so that it could be used to quantify effects.

5.4 Consideration of the GWRC Safe Aquifer Yield Policy

The Greater Wellington Regional Council (GWRC) has issued a Safe Aquifer Yield Policy that includes the Kapiti Coast area. We have compared the listed quantities of groundwater indicated by GWRC as a “Safe Yield” with the quantities to be pumped by the KCDC wells. Table 6.2 “Aquifer Allocation Limits – Kapiti Coast” (GWRC, 2009) indicates that the safe yield for the entire Waikanae aquifer system is 10.7 million m^3/year with 3.9 million m^3/year allocated from the “Gravel Aquifer > 40 m,” which we interpret as the Lower Pleistocene Sand and Waimea aquifers. The average withdrawal over the 36-year period under the highest growth projections (Scenario 4) is 776 m^3/day or 0.28 million m^3/year. This average withdrawal represents 7.3% of the total GWRC allocation for the Lower Pleistocene Sand and Waimea aquifers and 2.6% of the total safe yield of total Waikanae groundwater zone.

Currently, KCDC has a consent to abstract up to 23,000 m^3/day. This amount would be equivalent to 8.40 million m^3/year or 78.5% of the total “safe yield” of the Waikanae aquifer system, if the KCDC wells were pumping at their full-consented rates year round. In reality, KCDC pumps a far smaller annual total withdrawal. Over the past six years, the greatest annual take has been 0.79 million m^3/year (2005-2006), or less than 10% of the total that could be withdrawn. The planned average withdrawal of 776 m^3/day or 0.28 million m^3/year, the quantity that ultimately affects the long-term safe yield of an aquifer, is far below the current take.

The short-term peak rate of 29,700 m^3/day demand during the 50-year drought represents a 29% increase over the currently consented peak amount. However, the system does not operate near this rate on a continuous basis. Abstraction at the peak rate of 29,700 m^3/day is only anticipated for one week of the 50-year drought.

5.5 Consideration of the GWRC Regional Freshwater Plan

The recently issued GWRC report on the current “state and trends” in freshwater allocation (Keenan et al, 2012) suggests that 86% of the groundwater safe yield from the Waikanae groundwater zone has been allocated. The total allocation appears to include the KCDC take as if it were pumping at its fully consented rate as indicted by the fact that the consented 23,000 m^3/day is equivalent to 78.5% of the 10.7 million m^3/year defined as the safe yield. As discussed above, that actual take is much less. The proposed pumping under Scenario 4 would not increase the annual withdrawal amount. In fact it is likely to be less as groundwater would be replaced by surface water as a drinking water source. It would only be used for direct drinking water supply during emergencies.

This “state and trends” report also indicates that annual rainfall totals are likely to increase by 2.5% to 5% over the next 100 years, with 7.5% to 10% more rain falling during the winter and 0% to 2.5% less falling during the summer, over the next 100 years. These changes have not been directly included in our groundwater model. However, if the relatively small decrease in precipitation does occur during the summer requiring a greater withdrawal, then the increase in winter rainfall may allow for greater recharge to the groundwater system and/or the potential for additional water to be used for mitigation through injection (discussed below) should it be required.

The GWRC report also indicates that one well in the Waikanae groundwater zone has demonstrated a decline in water level. This well (R26/6626), is shallow (15.8 m deep) and surrounded by other shallow wells less than 20 m deep. GWRC calculated the median trend for this well to be 12 mm per year (equivalent to a decline of 1.2 m over 100 years) and that the decline represented an annual rate of change in aquifer storage as a percent of safe yield of 5.8%. It is not known how this trend was calculated or whether a sufficient number of water levels collected at consistent times with no significant well pumping occurring during the measurement periods, allowed for a valid trend analysis. It is also not known whether GWRC assumed that the decline of 12 mm/yr represented an aquifer/area-wide decline in water level, an assumption that seems unlikely. We believe that this decline, if statistically and hydraulically valid, is more likely to be caused by the pumping of nearby wells lowering the groundwater level locally than by a regional decline in the overall levels of the Holocene Sand and/or Pleistocene Sand aquifers, as indicated by the time-series of water levels (mostly from shallow wells) shown in Figure 2. These wells show no apparent decline over the 8+ years shown on the multiple-well hydrograph. Therefore, we conclude that the 12 mm per year trend in this single shallow well does not indicate a 5.8% decline in storage as a percent of safe yield of the entire aquifer. The GWRC report acknowledges “the difficulty in separating localised drawdown from aquifer-scale effects in monitoring data.” Because such a trend is small (1.2 m over 100 years) it is unlikely to be noticed by the well owner as the seasonal variation of the shallow aquifers in this area is typically on the order of 1 m to 2 m per year. Nonetheless, the trend should be monitored.

5.6 Consideration of the Predicted Rise in Sea Level

NIWA in a recent study for GWRC (Bell and Hannah, 2012), assessed the potential changes in sea level in the greater Wellington area, including the Kapiti Coast. They concluded that subsidence of the Kapiti coastal area was about 1 mm/yr and that a base value of 500 mm relative rise should be considered for future planning into the 2090s with an upper bound of 1.0 m to 1.4 m possible. Because the assessment of environmental effects in this modelling study is based on the difference between non-pumping and pumping conditions (in other words, drawdowns caused by pumping) no appreciable differences in these drawdowns are expected.

An overall rise in wetland levels is likely, however. By raising the head (or water level) at the discharge point of the Waikanae groundwater system (the marine waters off the coast), groundwater levels in the region should also rise. Although not quantified in the KCDC modelling study, a sea level rise of 1 m was modelled as part of an assessment of environmental effects that the M2PP Expressway might cause. The predicted rises of 0.5 to 1.0 m in the shallowest aquifer could extend inland up to 2 km with rises of 0.2 m extending up to 4 km inland. Therefore water level rises in the shallow aquifers underlying the wetlands of a similar magnitude to those predicted to be caused by KCDC pumping, might be expected.

5.7 Potential to Mitigate Environmental Effects through Injection

Three scenarios were modelled to investigate the potential for injection to mitigate the drawdown effects that might be caused by the pumping of the KCDC wells. The scenarios were not modelled to develop a mitigation procedure that optimises injection rates, timing and locations. Rather, the scenarios were modelled to indicate whether injection has the potential to mitigate deleterious environmental effects. If modelled drawdown is reduced through one or more of the injection scenarios, then it indicates that injection should be considered as an option if monitoring indicates that adaptive management is needed. At that point (or before) a number of injection scenarios could be modelled to develop an optimised mitigation strategy.

The potential mitigation scenarios were modelled based on the planning assumption that river water would be available during the wetter months of winter and early spring for injection at the rate of 10,000 m^3/day (about 115 L/s). All three mitigation scenarios modelled a four year period beginning with year 27 that includes the 50-year drought with its associated highest demand (pumping withdrawal rates) of Scenario 4. In these mitigation scenarios, water was injected during the winter/early spring for 150 days starting with the first week of July of each year. A total injection rate of 10,000 m^3/day was distributed to a different set of injection wells in each of the mitigation scenarios to assess the feasibility of injection to reduce drawdowns in the Holocene Sand Aquifer and the Lower Pleistocene Sand and Waimea aquifers. Any reduction of drawdown resulting from the mitigation scenarios in these aquifers would result in a reduction of:

- The potential for saline water intrusion,
- Drawdown effects in the aquifers underlying the wetlands, and
- Drawdown effects on existing wells.

The three sets of injection wells and the injection rates used are shown in Table 10. These wells injected into the actual completion zones for existing wells, planned completions zones for wells planned KCDC and into the Lower Pleistocene Sand Aquifer for the coastal injection mitigation scenario.

Table 10 – Mitigation Scenario Wells and Injection Rates

Mitigation Injection Scenario	Injection Well /rate [m^3/day] (L/s)	Injection Well /rate [m^3/day] (L/s)	Injection Well /rate [m^3/day] (L/s)	Injection Well /rate [m^3/day] (L/s)	Injection Well /rate [m^3/day] (L/s)
Coastal	**C1** [3,335] (38.6)	**C2** [3,335] (38.6)	**C3** [3,335] (38.6)		
Central	**K4** [4,000] (46.3)	**K6** [4,000] (46.3)	**K10** [2,000] (23.1)		
Eastern	**N3** [1,771] (20.5)	**N2** [2,160] (25.0)	**Kb4** [3,193] (37.0)	**S1** [2,160] (25.0)	**S2** [1,418] (16.4)

5.8 Potential to Mitigate Drawdowns in Aquifers beneath Wetlands

Composite hydrographs for each of the four injection locations (base case – no injection, coastal, central, and eastern) for each of the top three categories of wetlands as listed in Tables 8 and 9 (national value, district value and limited value) are presented in Figures 13, 14 and 15. These figures show the modelled changes in water levels in the Holocene Sand Aquifer beneath each wetland resulting from injection at the indicated wells, with withdrawal from the KCDC production wells over their highest demand period (Year 27 that includes the 50-year drought). Drawdown maps[18] of the Holocene Sand Aquifer with and without mitigation injection are shown for the coastal injection mitigation option (Figure 16), the central injection mitigation option (Figure 17) and the eastern injection option (Figure 18).

The drawdown maps and hydrographs show that injection has the potential to mitigate drawdown effects in the Holocene Sand Aquifer underlying the wetlands in the project area. Figure 13 shows that without injection, drawdowns in the Holocene Sand Aquifer beneath the nationally ranked wetlands within the modelled area are around 140 to 170 mm in the worst cases (the Harakeke wetland and Muaupoko swamp, respectively) to just a few millimetres in the best cases (Waikanae saltmarsh and the Raumati South wetland). Under the coastal injection scenario, drawdown in the Holocene Sand Aquifer reduces to about 70 mm beneath Te Harakeke wetland, about 110 mm beneath the Nga Manu wetland, and a few tens of millimetres in the shallow aquifer beneath the other wetlands of National significance. Under the eastern injection scenario, the drawdown reductions are even greater. Figure 13 shows that with injection, the largest drawdown is reduced to about 70 mm beneath the Nga Manu wetland. Figure 14 shows that drawdowns beneath wetlands of district significance are also reduced thorough injection with the biggest improvements to wetlands valued at the district level occurring with injection at coastal and eastern well locations. Injection to reduce drawdowns beneath wetlands of limited significance is most effective when injection occurs in the eastern locations, most likely because the low-value wetlands are mostly located in the eastern portion of the project area. Comparison of the potential reductions of drawdowns under the three scenarios indicates that the eastern injection scenario appears to be the most promising for future mitigation of drawdown effects on wetlands.

Figures 16, 17 and 18 visually demonstrate the effectiveness of injection to reduce drawdowns. Each figure compares the 4 years of modelled drawdowns at the time with the generally greatest drawdowns (27.8 years). The upper drawdown contour maps at the top of these figures shows the 27.8 year drawdowns with no injection while the lower part of the figure shows the drawdowns at 27.8 years that would occur with injection under the coastal injection scenarios. Comparison of the resulting maximum drawdowns shown in the three figures indicates that the eastern injection scenario to be most likely mitigation option.

The hydrographs all show that injection will also cause water levels in the Holocene Aquifer to rise. Depending on the location of the wetland and where water is injected, the rise in water levels in the Holocene Sand aquifer before withdrawal begins could range from a high of almost 700 mm (Tini Bush with coastal injection) to as little as a few millimetres (Raumati South Peatlands B and El Rancho). The hydrographs also show that at the end of the modelled period where injection has occurred for two winter/spring periods with no summer pumping in between, water levels in the Holocene Sand Aquifer rise to levels that could be almost 200 mm higher than those that occurred during the year before pumping. An optimised injection system would not inject as much water after a summer of no pumping with the end result that the water level rises could be managed and not allowed to keep rising.

[18] Larger versions of the injection portion of these figures can be found in Appendix D.

The hydrographs and the drawdown maps demonstrate that injection has the potential to mitigate to a large degree, the predicted changes in water levels in the Holocene Sand aquifer that underlies the wetlands in the Waikanae project area. Additional modelling could be used to refine and optimise such mitigation by finding the optimal locations, rates and timing to control water level changes to acceptable levels.

5.9 Potential to Mitigate Saline Intrusion

Composite hydrographs for each of the four injection locations (no injection, coastal, central, and eastern) are presented in Figure 19. The figure shows the modelled changes in water levels in the Holocene Sand, Lower Pleistocene Sand and Waimea aquifers at three coastal locations resulting from the injection at three imaginary wells followed by withdrawal from the KCDC production wells over their highest demand period (year 27 that includes the 50-year drought).

The hydrographs show that the best potential for mitigation of saline intrusion is injection in the eastern areas . Injection at this location results in the smallest drawdown hydrographs during the 50-year drought pumping with the greatest drawdowns occurring at 27.8 years into the simulation. Injection along the coast appears to cause the greatest water level rises with mitigation that is short lived while injection at the eastern locations places more water upgradient allowing water levels to remain elevated (and offsetting the effects of summer withdrawals) for longer. The sharp rise in water levels indicated for coastal injection and the relatively quick arrival at relatively constant water levels (but continuing to rise slightly) and then the sharp decline after injection stops indicates that injection was begun too early and that most of the water likely discharged offshore. The relatively best improvement in reduction of water levels in the Lower Pleistocene Sand Aquifer and the advantage of the eastern injection over coastal or central injection is shown in Figures 20, 21 and 22. These drawdown maps compare the drawdowns without injection (top map) and with injection (bottom map).

Based on the sharp drop and time lag between the higher water levels at the end of injection and the drawdown curves below the “0” level that indicate the onset of withdrawal, it appears likely that the modelled injection began and ended too early in the season to be efficient and effective as a mitigation for salt water intrusion. However, based on our understanding of the hydrogeology of the Waikanae borefield area, we consider that the results are sufficient to show that the risk of saline intrusion can be appropriately monitored and managed, particularly given the staged nature of the *River Recharge with Groundwater* scheme over time. The effects of the current borefield use are well known and have been monitored regularly and reported annually by URS (for example see URS: 2012 Annual Report Waikanae Borefield Monitoring Report). Although the use of the borefield has been limited to date, URS has predicted that the contact interface of the aquifers with seawater is a considerable distance offshore and monitoring results do not indicate a current high risk of saline intrusion. Given this current situation of relatively low saline intrusion risk, it is considered that the staged implementation of the proposed scheme can be comprehensively monitored and responded to through adaptive management measures such as reconfiguring bore use and pumping rates, spreading the use of bores further across the borefield to spread associated drawdown effects and implementing aquifer injection. Based on the modelled highest drawdowns indicated under Scenario 4 pumping, we recommend monitoring for changes in salinity at the locations indicated on Figure 23. Monitoring wells should be completed at three depths at each location: 1) in the Waimea/Lower Pleistocene Sand Aquifer, 2) in the Parata Aquifer and 3) in the Upper Pleistocene/Holocene Sand Aquifer.

Aquifer injection is a method used at many locations internationally to manage saline intrusion. We believe that further exploration through modelling to better optimise injection scenarios would better assess the potential for injection to mitigate saline intrusion. The small improvements shown by the modelled scenarios presented here suggest that injection has the potential to reduce drawdowns. Such an optimisation should be incorporated into an adaptive management programme.

5.10 Potential to Mitigate Changes in River and Stream Flows

Injection as a possible method to mitigate changes to flows in the Waikanae River from the pumping of the KCDC wells was explored by simulating injection at the central well locations during the Scenario 4 year 27-30 simulations and comparing the changes in groundwater recharge from the upper/losing reach and changes in groundwater discharge to the lower/gaining reach. Figure 12 shows a net increase in river flow during the injection periods and a reduction in the net decrease in river flow during the pumping periods. The increases in flow are up to 9 L/s during injection. The model indicates that injection decreases the net reduction in Waikanae River flow from 18 L/s to 11 L/s, resulting in a river flow rate 7 L/s higher during the 50-year drought period than that without injection. Although the changes are relatively small in terms of absolute rates, the simulation does indicate that injection is a possible mitigation option that should be considered.

6 Limitations and Appropriate Use of Modelling Results

This model and its simulation gives a prediction of water level changes that are expected under the assumptions of future hydrological and population conditions, as well as spatial distribution of geological units and hydrogeological properties. Because these assumptions cannot exactly represent actual conditions, the actual response to pumping from the KCDC wells will differ to some extent from those predicted by the model. The model does, however, give our best assessment of what is likely to occur based on these assumptions.

The model was developed to allow assessment of the *range* of effects expected from the River *Recharge with Ground Water* option, where these effects would occur, a monitoring programme to measure the actual effects at these locations, mitigation options and triggers that should be considered, all as part of an adaptive management approach.

Monitoring allows comparison of actual responses with those predicted by the model. If the response of the system differs from that predicted, the model can be used as one of many tools to investigate such differences.

Another limitation of the model is its focus on certain areas (primarily the areas of concern such as near KCDC wells and near the Waikanae River) and less on areas further afield or with sparse data. In such areas where geological information, water level observations and surface water data are limited, the model is likely to be less accurate and its findings should be considered with this understanding in mind.

7 Summary and Conclusion

7.1 Pumping Testing

Constant rate pumping tests were carried out in five existing production wells, one new production well (N2) and four investigation wells in order to provide information about the aquifer characteristics. The tests were undertaken in zones screened in the Parata, lower Pleistocene Sand and Waimea aquifers. In addition, observation wells completed in other zones and monitored during the tests helped to generate information on parameters in intervening leaky aquitards. Constant rate pumping tests carried out in the production wells were carried out for 6 to 12 days followed by recovery periods of up to two weeks. During recovery, the water levels in the pumped wells fully recovered in the four tests that were run as planned. Only a portion of the recovery was measured in the two tests that were shut down earlier than planned (K10 and N2). The details and results of a second test of N2 are presented in Appendix H.

The pumping tests in the investigation wells consisted of pumping for 6 to 9 hours followed by recovery periods of 1 to 1.5 hours. These tests were conducted using temporary screens also placed in the Parata, lower Pleistocene Sand and Waimea aquifers.

Analysis of the pumping test results indicates that the Parata, Pleistocene Sand and Waimea aquifers are productive and capable of localised sustained well yields of up to 80 L/s. The three tested aquifers are confined with average (geometric mean) transmissivities of approximately 320, 500 and 570 m^2/day, respectively. The average (geometric mean) storativities of these aquifers are about 0.02 (Parata Aquifer), 2.0 x 10^{-4} (lower Pleistocene sand aquifer) and 5.0 x 10^{-4} (Waimea aquifer). These values indicate that the Parata aquifer is semi-confined to unconfined and the deeper lower Pleistocene Sand and Waimea aquifers are confined. The test results indicate that the deeper aquifers are “leaky” with confining layers moderately permeable. Leakage coefficients of approximately 2.5 x 10^{-4} day^{-1} were calculated. These aquifer test results were used as the starting point in calibrating the numerical groundwater model.

Rainfall and water level time series data obtained from GWRC were also used to calibrate the model to match the seasonal variation in recharge and water levels. The period from 2007 to 2010 was used as it contains data from the greatest number of water level monitoring stations. Surface water gauging data from the Waikanae River conducted during 2003 (Jones and Gyopari, 2005) was used to identify areas where the aquifer system was losing or gaining river flow and to quantify these gains and losses for model calibration and simulations.

7.2 Assessment of Environmental Effects

The results of 3D groundwater modelling indicate that the extended well field can be operated to meet forecast demands and in a 50 year return period drought to provide river flow augmentation for short-term periods (15 weeks), at peak rates of up to 29,700 m^3/day.

7.2.1 Wetlands

Effects on shallow groundwater beneath nationally ranked wetlands as predicted by the modelled drawdowns in the Holocene Aquifer could be as much as 170 mm with larger drawdowns of 270 mm beneath wetlands of district value and of limited value over the 15 week drought period, than without the KCDC well field. Drawdowns of more than 150 mm were modelled for the aquifer underlying several unknown/ un-named wetlands that have not been rated for significance. The changes are less than the normal variations in water levels of 1 to 2 m observed in wells completed in the shallow aquifers. However, ecological advice is that a change of water level of 100 mm may be significant in some wetlands, depending on a number of factors. The groundwater level changes calculated by the model may not represent changes in water level that would occur in the wetland itself as they are effects recorded in the sand beneath the wetlands. An analysis of each wetland would be needed to understand the relationship between groundwater levels in the underlying aquifer and water levels in the wetland. Even so, because the predicted changes are less than the actual water level variations that naturally occur, the effects may be unnoticeable and masked by natural water level variations.

The changes in water levels in the Holocene Sand Aquifer may be mitigated in part through injection during the winter and spring. A set of three simple injection scenarios indicated a reduction in the drawdown effects caused by pumping of the KCDC wells during the simulation of the 50-year drought. The simulation also indicated that injection would cause a rise in water levels in the Holocene Sand Aquifer during the injection periods. In some wetlands, such a water level rise may be significant. The simulation did not optimize injection location, quantities or timing. Rather, it indicated that injection is one potential mitigation option to reduce the environmental effects of the planned pumping.

7.2.2 Marine (Saline) Intrusion

Modelled maximum changes to water levels in coastal wells have the potential to cause saline water to move inland under the worst-case pumping scenarios. The maximum effect under a 50-year drought in 2060 (Scenario 4) is a short-term drawdown of approximately 5+ m in the deeper Pleistocene Sand and Waimea aquifers. A drawdown of 5 m would result in aquifer water levels about 2 m below mean sea level based on water level data collected from Sentinel 1 which has a water level that centres around 3 mRL after tidal and seasonal fluctuations are removed from the data. Water levels held to this level over a period of several weeks could cause saline water to move inland within the deeper aquifers. A resulting deterioration of water quality in coastal wells completed in these aquifers is possible. However, water level recovery occurs within weeks of pumping ceases such that groundwater returns to its "normal" off-shore flow direction. Therefore, there is a risk of intrusion of saline water, however with monitoring and management, this risk is considered to be low. We note in particular that such drawdown would only be associated with pumping during a "worst case" drought period and might have a duration of perhaps 15 weeks – it is not an annual occurrence. Water quality and water levels can be monitored to check against saline intrusion and mitigation or adaptive management measures can be implemented (such as altered pumping schedules, altered well pumping hierarchy or injection during high river-flow periods), if needed.

The potential for saline intrusion may be mitigated in part through injection during the winter and spring. A set of three simple injection scenarios indicated a small reduction in the drawdown effects caused by pumping of the KCDC wells during the simulation of the 50-year drought. The simulation was far from optimised, however, and additional modelling would be needed to develop an effective and efficient injection mitigation scheme. The simulation also indicated that injection would cause a rise in water levels in the underlying aquifers during the injection periods. The simulation did not optimise injection location, quantities or timing. Rather, it indicated that injection is one potential option to reduce the environmental effects of the planned pumping.

7.2.3 Existing Well Users

The predicted drawdown indicates that the combined interference effects between the KCDC production wells screened in the Pleistocene Sand and Waimea aquifers will be about 10 to 15+ m in the maximum pumping scenarios. Modelling suggests that during a 50-year drought under the maximum weekly average demand of a high-growth rate population of 2060, pumping of up to 27,710 m^3/day for 15 weeks will result in drawdown in privately owned wells screened in the shallow unconfined aquifer, of less than 200 mm with the greatest drawdowns in the eastern portion of the study area near wells N1, N2 and N3. The resulting drawdown in the Parata aquifer is generally less than 1 m, but drawdowns of up to 5 m may occur in the central and northeast portion of the study area where investigation drilling indicates a more direct connection of the Parata Aquifer to deeper aquifers. Pumps in existing privately owned wells may need to be lowered or wells deepened if such water level declines do occur. The cause of such water level declines should be based on monitoring and analyses of individual wells indicating a water level decline. The adverse effects to these wells are considered to be low to moderate but can be readily managed by lowering of pumps (or well deepening).

The actual number of potentially-affected wells is likely to be smaller than number identified in our analysis. A survey conducted in August 2012 by Beca of the wells identified as being potentially affected indicated that 41% were either no longer in operation or duplicate entries in the database.

This suggests that the actual number of affected wells may be only 60% of the numbers identified in the modelling analysis.

7.2.4 Rivers and Streams

The modelled changes in flows in the Waikanae River are small with the greatest reduction in flow of 18 L/s occurring during the peak of the 50-year drought. Although this amount is much lower than the error of flow measurement during low flow conditions, its occurrence at the same time as the low flow of the 50-year drought increases its significance.

This decrease in flow could be mitigated through a combination of both injection (that would also mitigate effects on wetlands, existing well users and saline intrusion) and the discharge of additional groundwater to the river when river recharge is planned. Injection could result in a reduction of the decrease in river flow by almost 40 %. The additional discharge of groundwater directly to the river would represent an increase of about 5 % of the total groundwater pumped to supplement river flow.

8 Further Investigations

A number of further investigations are recommended based on the conclusions of this project. These recommendations may be considered for inclusion into conditions of consent. The recommended activities are related to the development of additional water supply wells and a number of activities to better manage the risk of saline water intrusion.

- An improved algorithm to correct the water level data collected from wells displaying the cyclic variations in water level caused by daily tidal variations should be developed for each well. These algorithms would allow for “correction” of regularly collected water level data to representative levels more suitable for monitoring the potential for marine water intrusion into the aquifer.
- All future production wells drilled in the area at sites N3, S1, S2 and S3 should include 7 to 14 day aquifer tests whereby the well is pumped at its production level and water levels are measured in a number of observation wells.
- The risk of saline intrusion should continue to be managed through the use of saline monitoring wells and regularly reporting and response. The existing groundwater model and aquifer injection scenarios should continue to be optimised over time to improve adaptive management outcomes.
- The suitability and cost-benefit of a time domain electromagnetic survey (TDEM) along the coast and in the vicinity of the existing and proposed production wells should be considered to explore current saltwater intrusion conditions so that future monitoring that might be required in consent conditions has a basis for comparison.
- Dedicated monitoring wells should be installed at locations identified using the modelling studies and the TDEM survey. Salinity should be measured during installation with wells screens installed at key depths. These wells should be incorporated into an on-going saltwater intrusion monitoring programme/adaptive management programme.
- Water level data from GWRC monitored wells along with water level and pumping data from KCDC wells should be reviewed on an annual basis to check actual effects of KCDC pumping. Water levels in shallow, intermediate and deep aquifers should be evaluated in the context of pumping, rainfall and river flow conditions.
- The groundwater model should be refined using the information obtained from these listed recommended activities, within five years of their completion. Modelled water levels and

measured levels should be compared and used to refine the model in an updated calibration/verification.

9 References

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10 Disclaimer

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

Figures

a) GWRC Monitoring Wells Used for Calibration

b) KCDC Wells Used for Pumpng Test Analyses and Locations Used for Model Calibration

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GWRC & KCDC Well Location Plan

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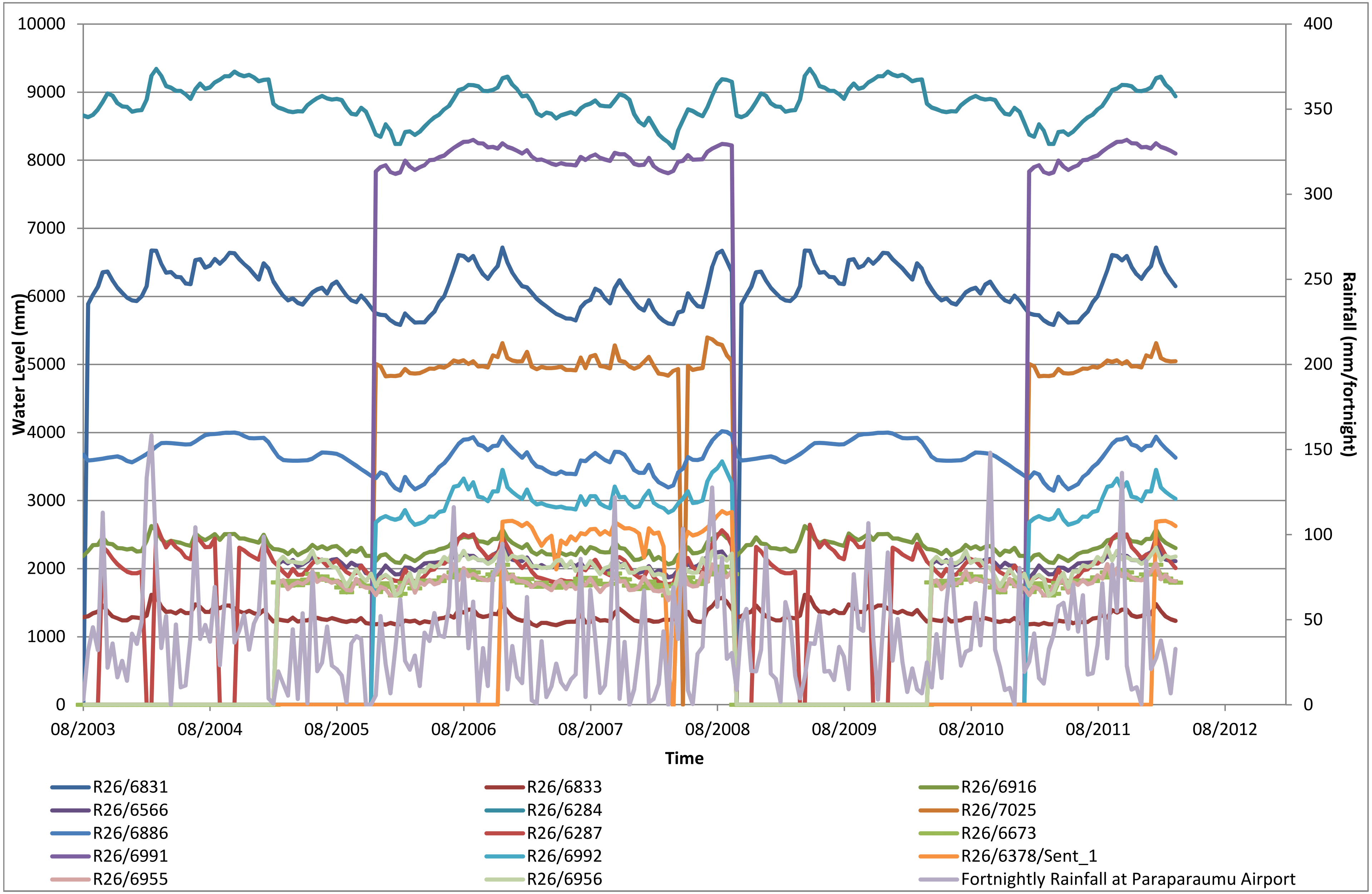
Figure 1



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Water Level Time Series

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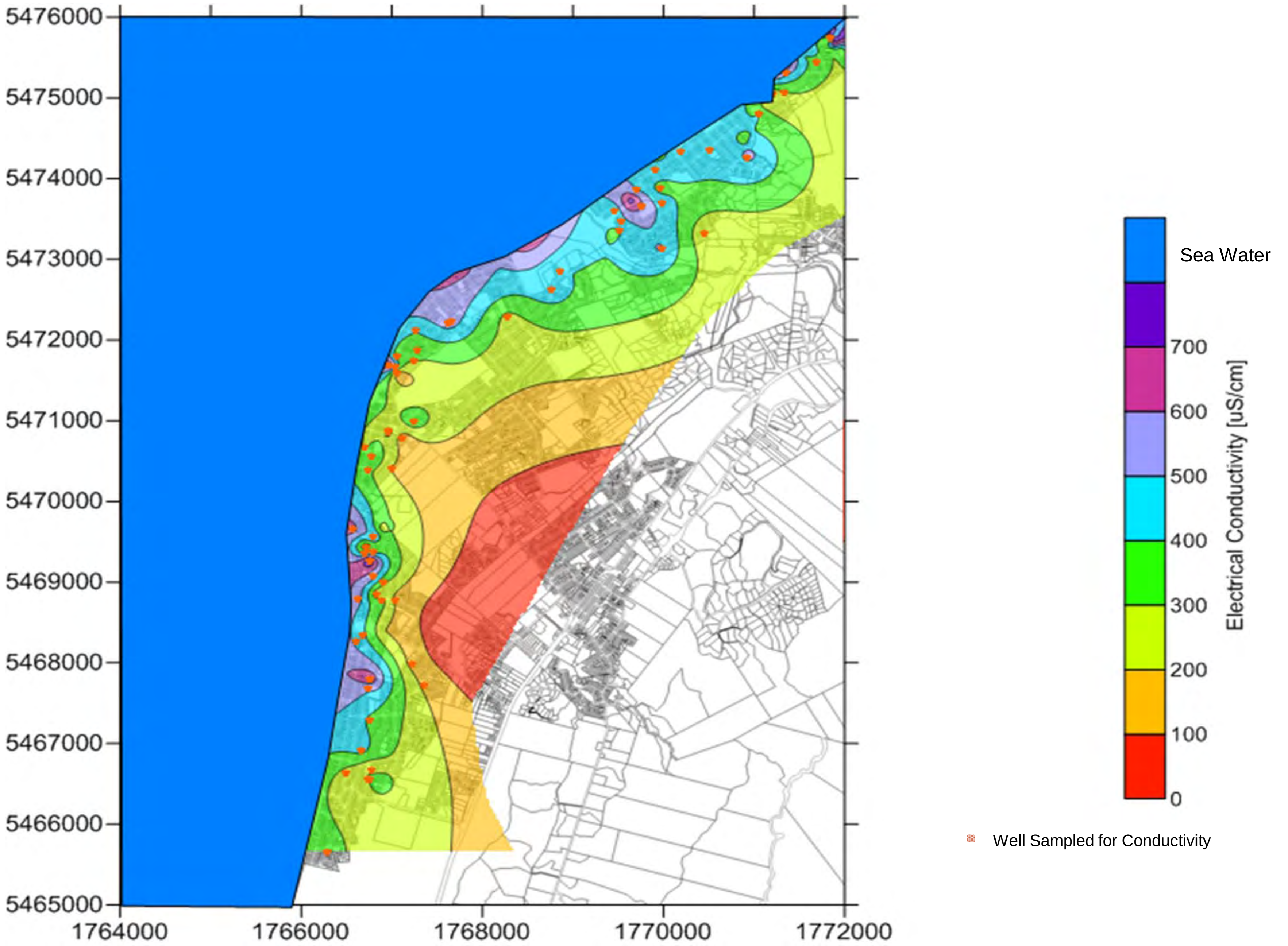
Figure 2



Results of December 2010 Electrical Conductivity Survey

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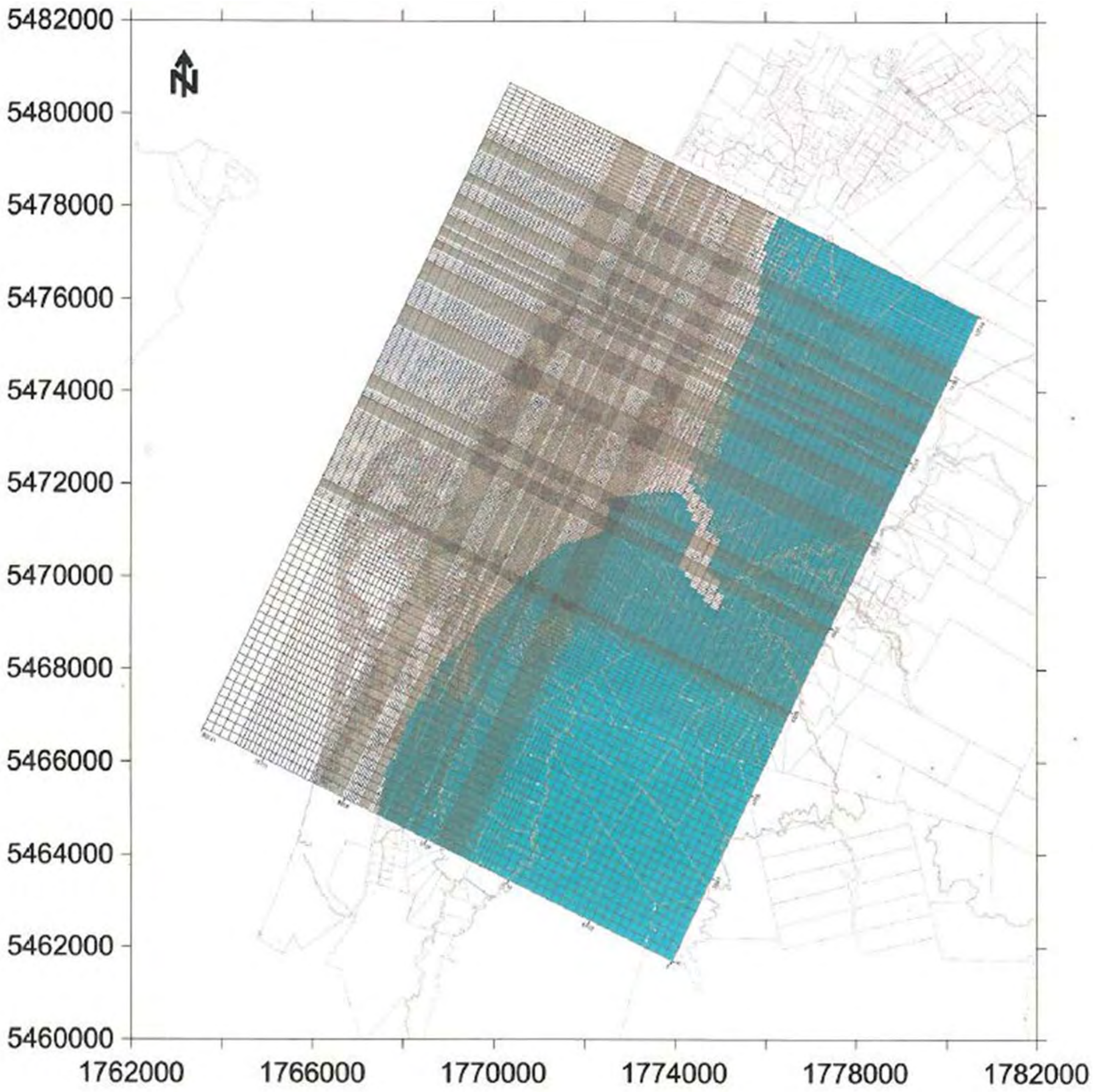
Figure 3



Modelled Area Showing Cell Distribution and Inactive Areas (in blue)

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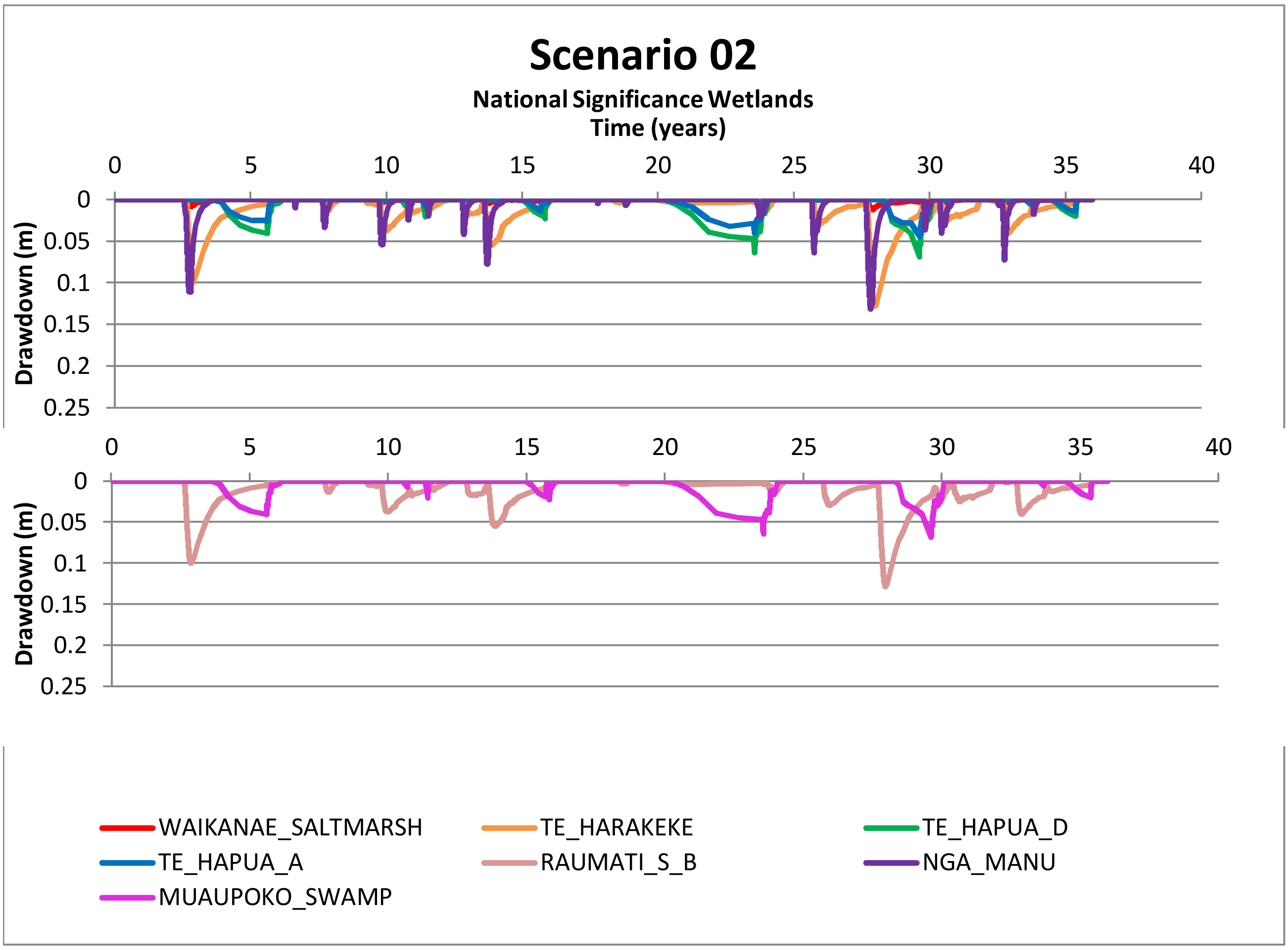
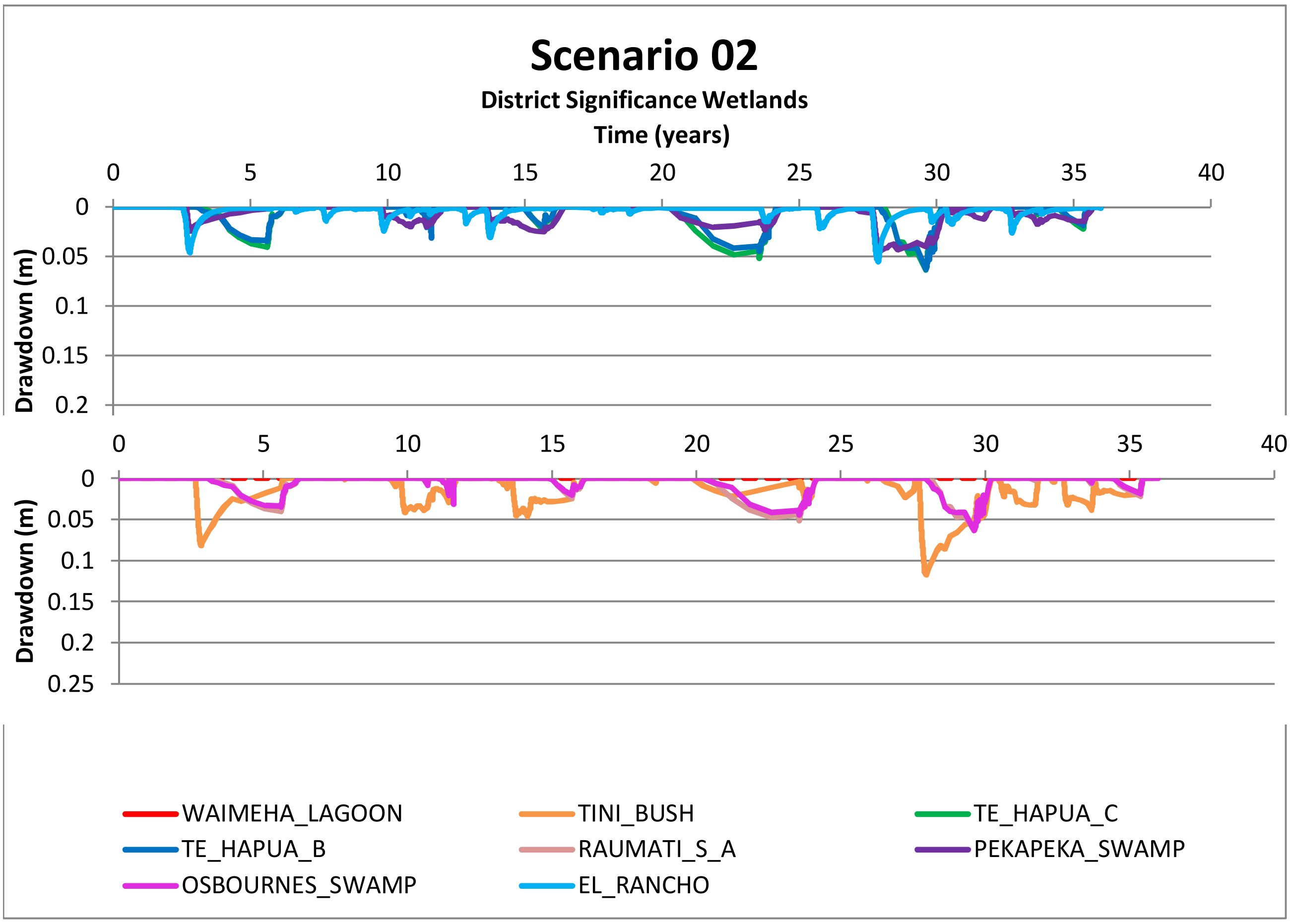
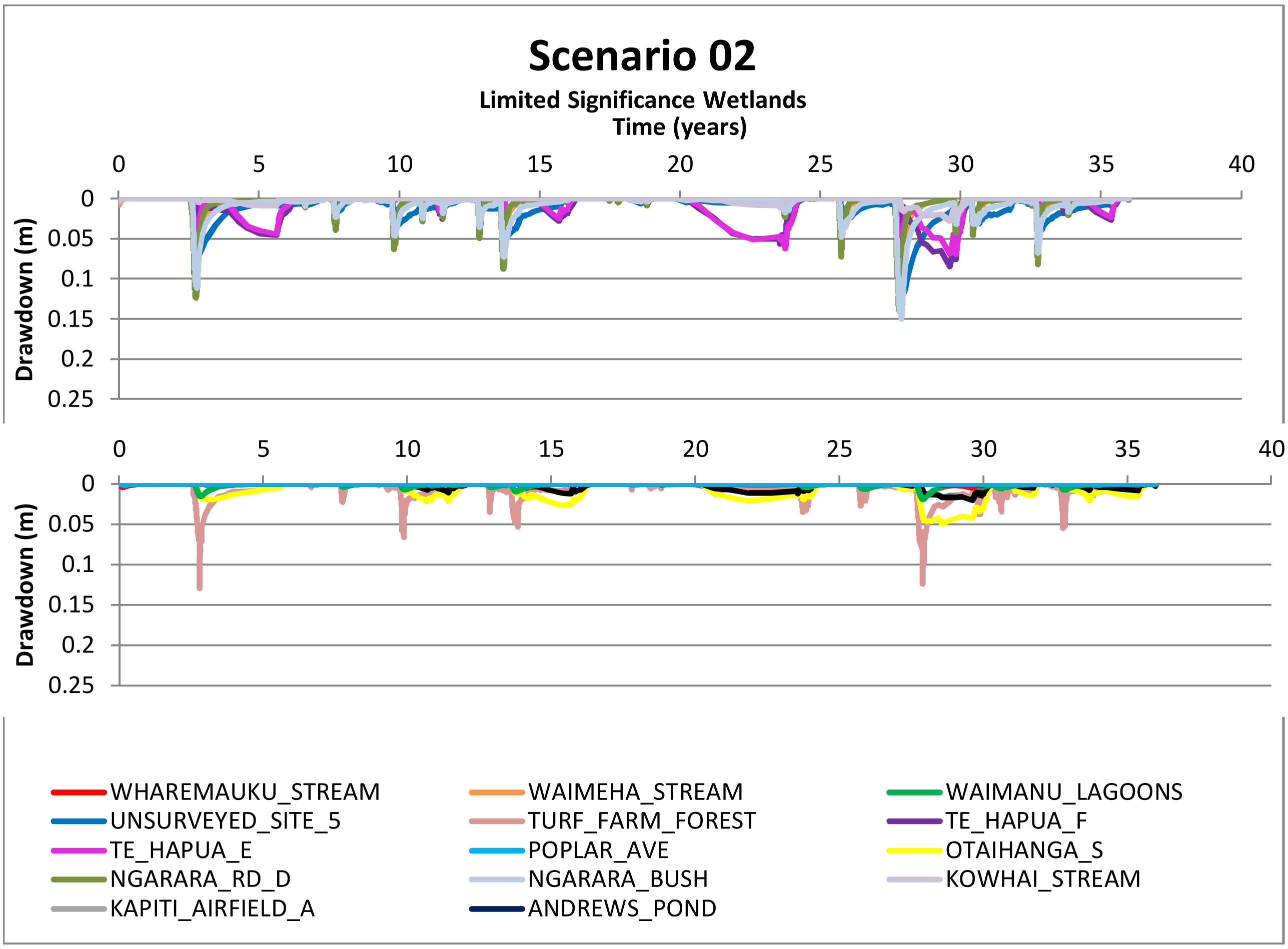
Figure 4


Scenario 02
National Significance Wetlands
Time (years)
0
5
10
15
20
25
30
35
40
Drawdown (m)
0
0.05
0.1
0.15
0.2
0.25
WAIKANAE_SALTMARSH
TE_HARAKEKE
TE_HAPUA_D
TE_HAPUA_A
RAUMATI_S_B
NGA_MANU
MUAUPOKO_SWAMP


Scenario 02
District Significance Wetlands
Time (years)
0
5
10
15
20
25
30
35
40
Drawdown (m)
0
0.05
0.1
0.15
0.2
0.25
WAIMEHA_LAGOON
TINI_BUSH
TE_HAPUA_C
TE_HAPUA_B
RAUMATI_S_A
PEKAPEKA_SWAMP
OSBOURNES_SWAMP
EL_RANCHO



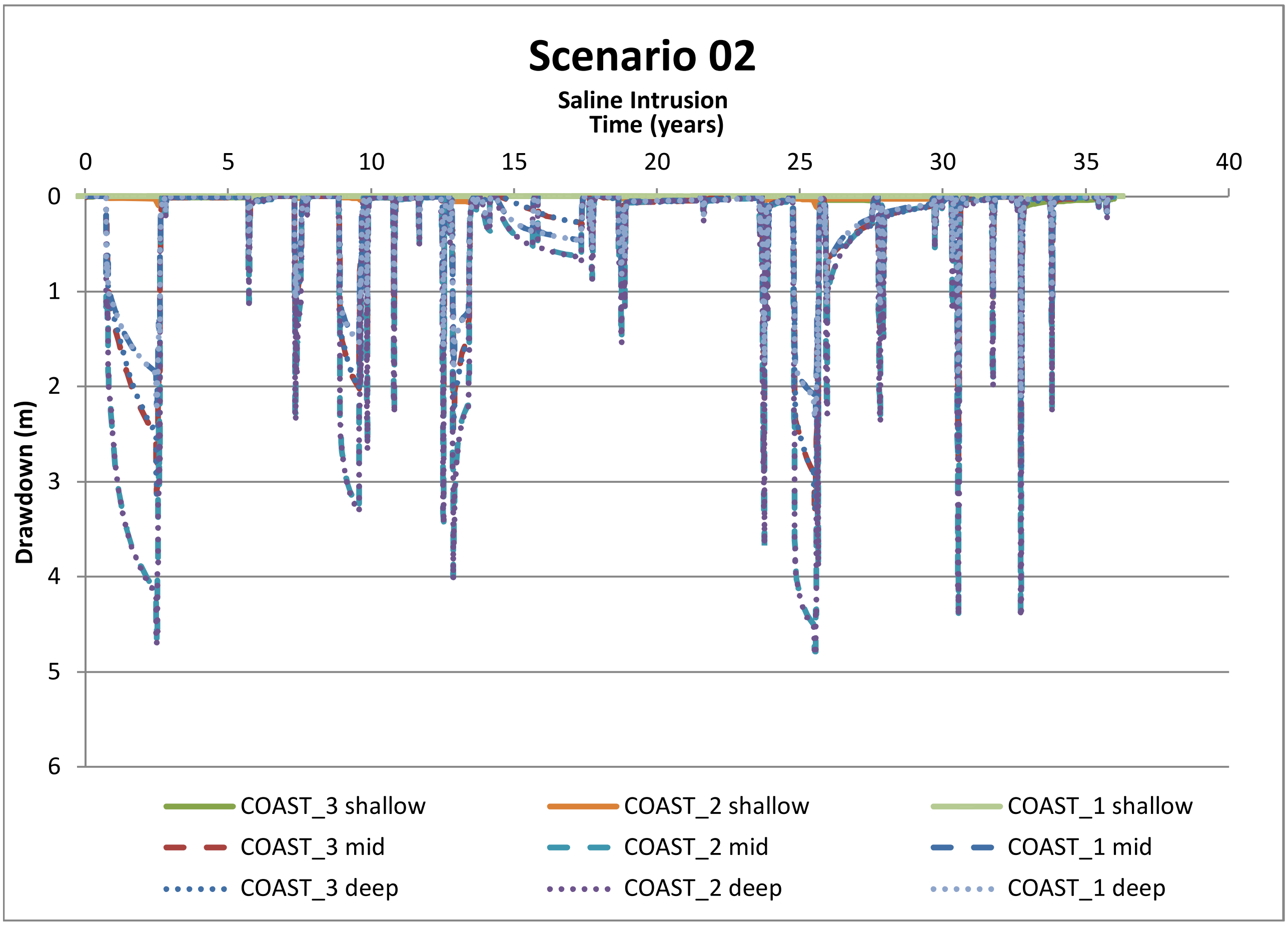


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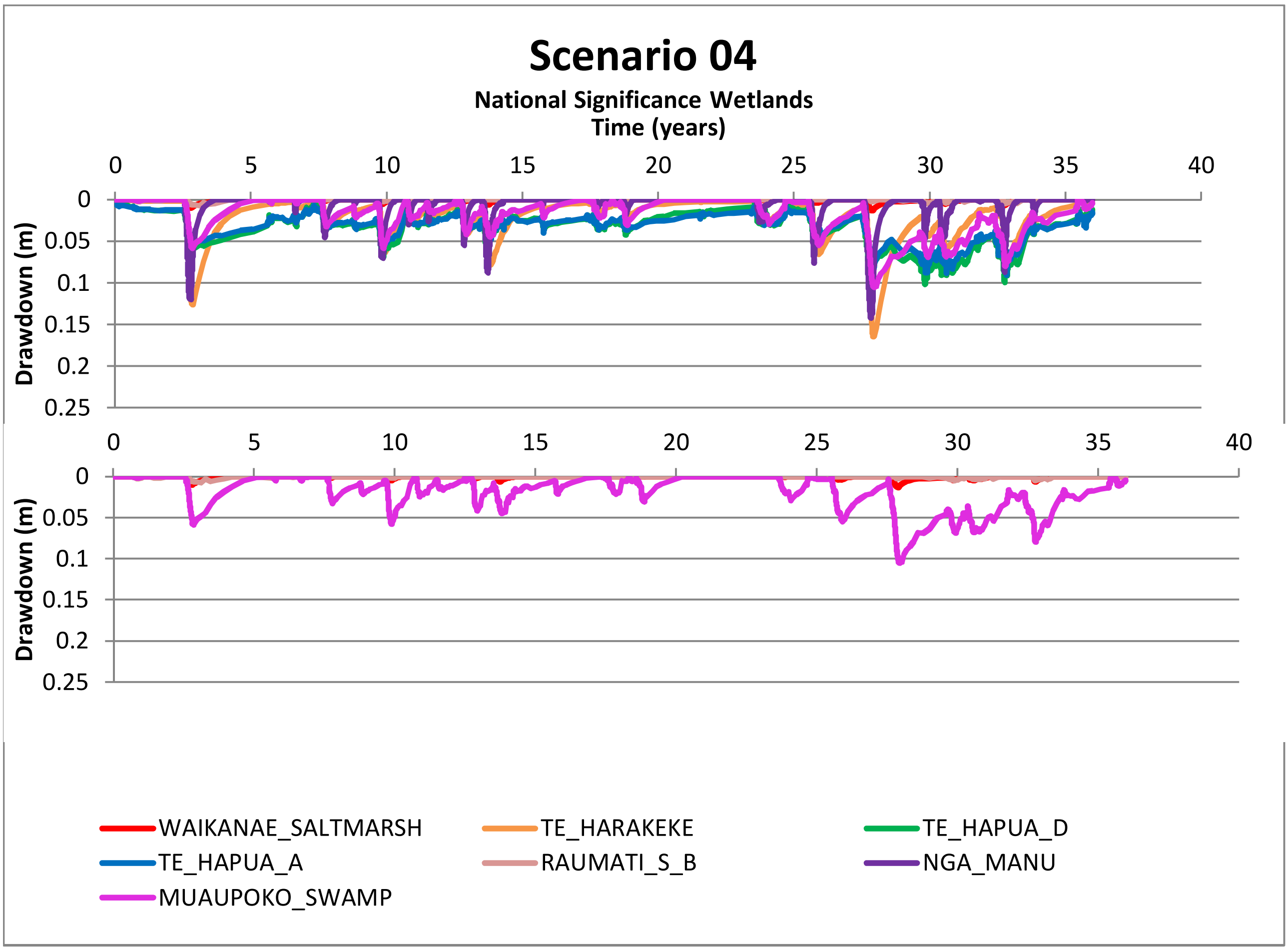
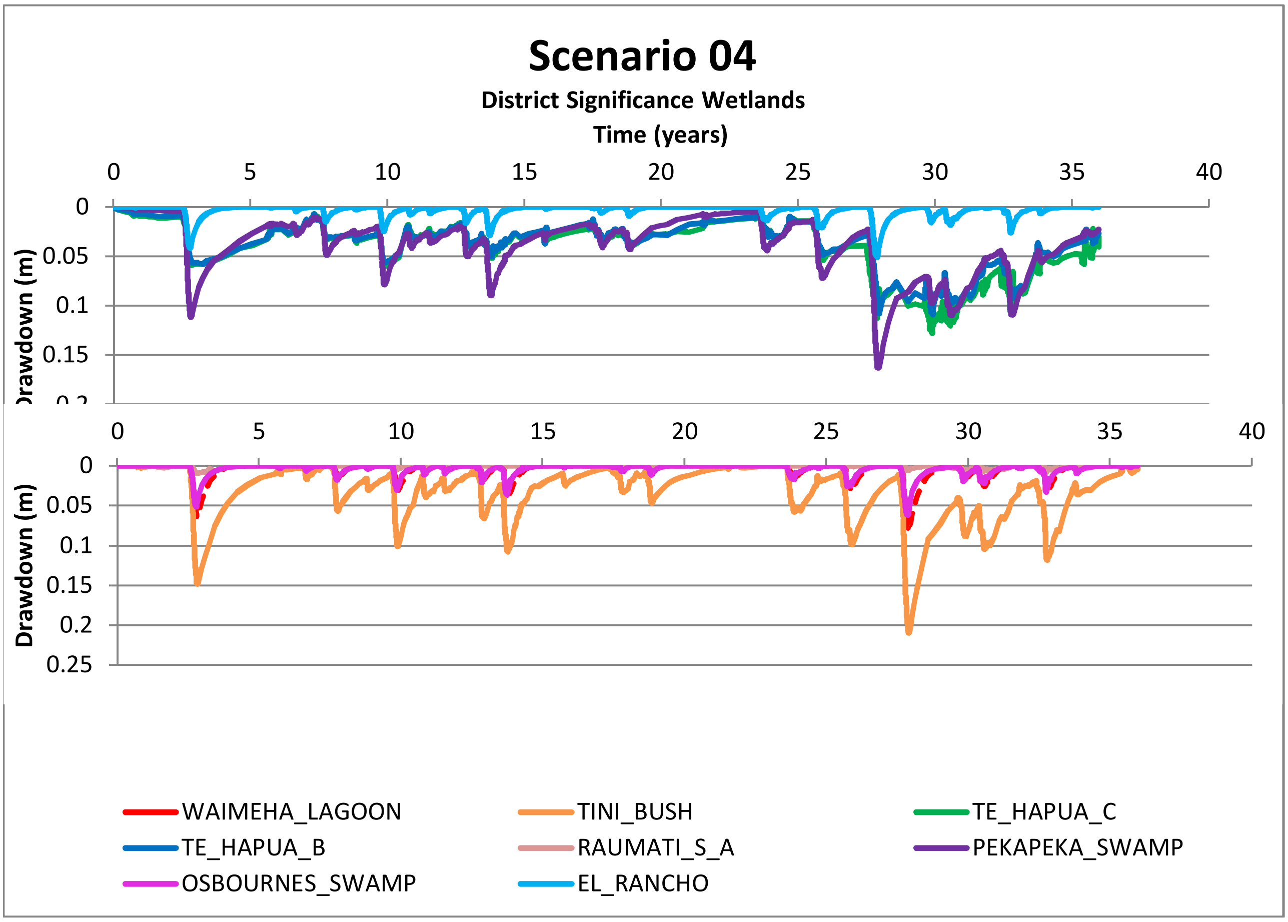
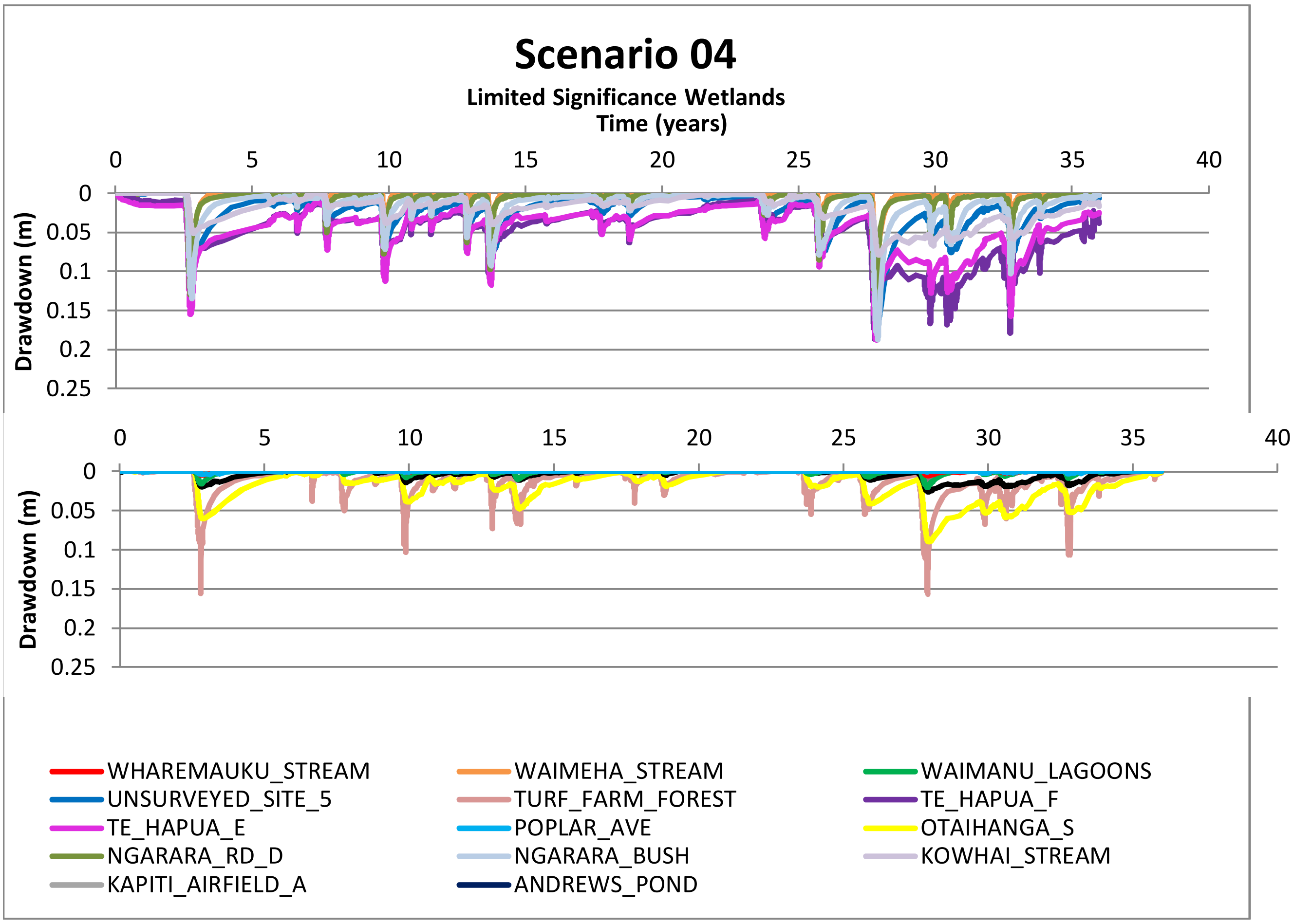
Figure 6

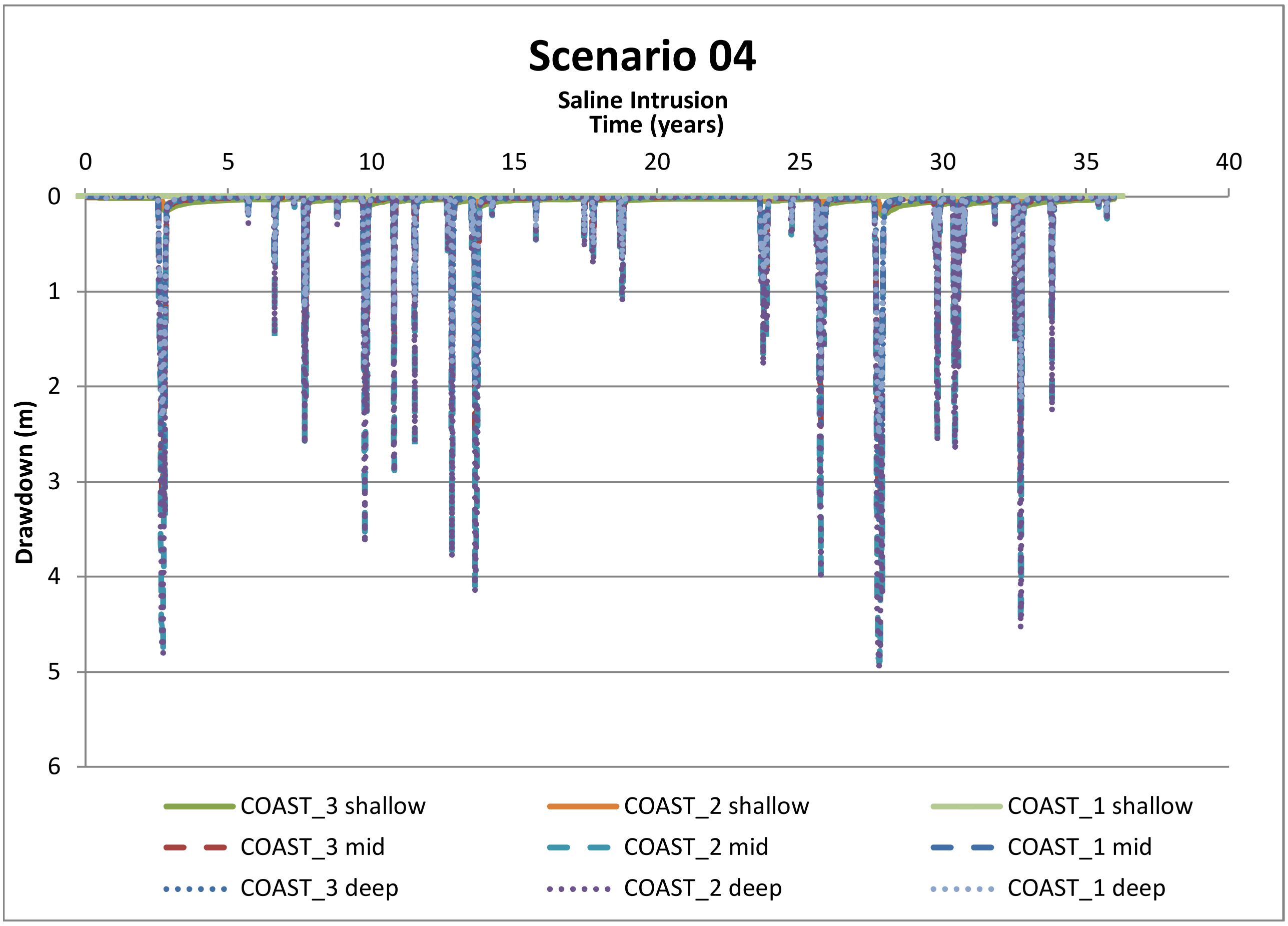


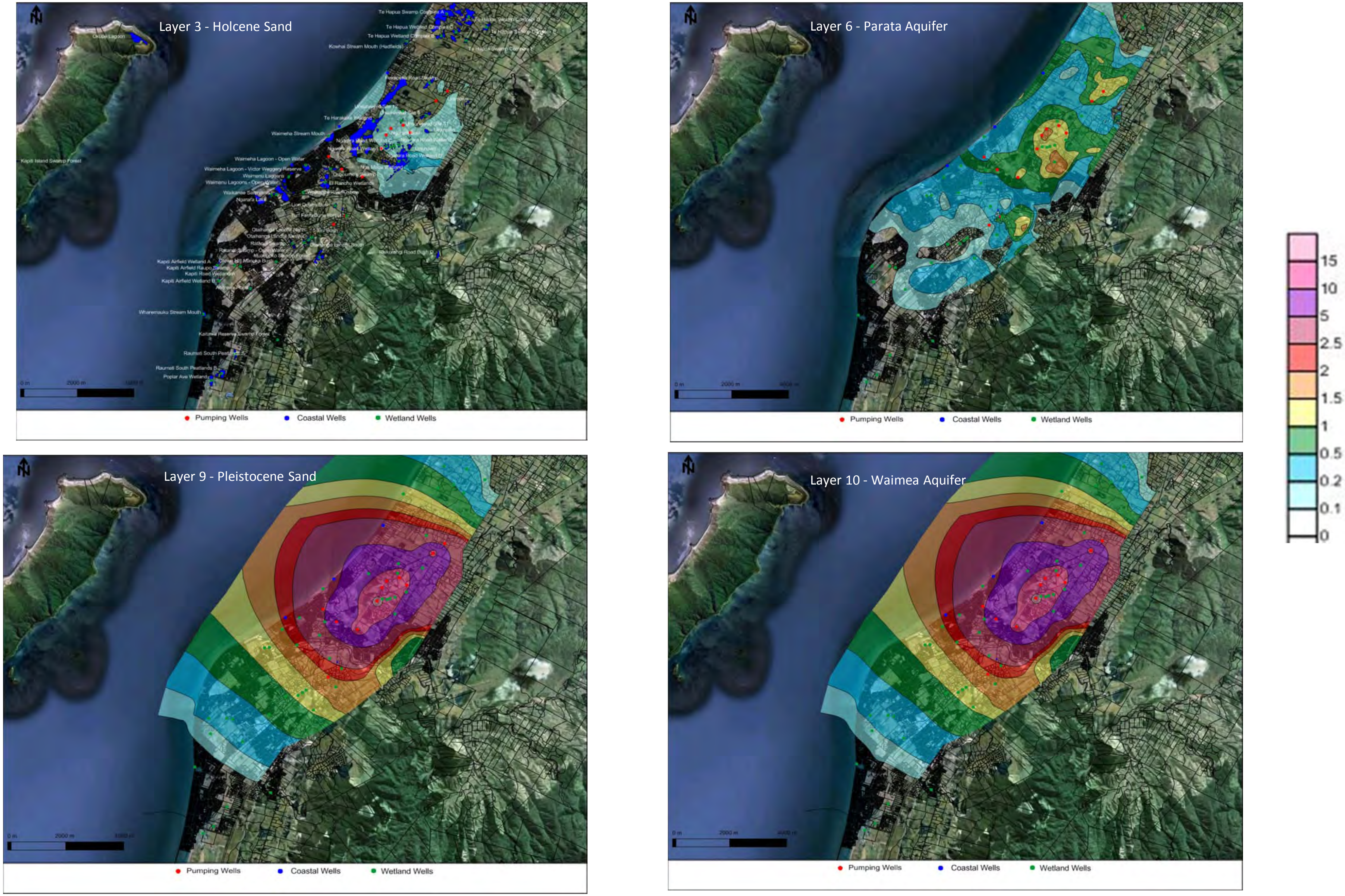
Scenario 04
National Significance Wetlands
Time (years)
Drawdown (m)
WAIKANAE_SALTMARSH
TE_HARAKEKE
TE_HAPUA_D
TE_HAPUA_A
RAUMATI_S_B
NGA_MANU
MUAUPOKO_SWAMP



Scenario 04
District Significance Wetlands
Time (years)
Drawdown (m)
WAIMEHA_LAGOON
TINI_BUSH
TE_HAPUA_C
TE_HAPUA_B
RAUMATI_S_A
PEKAPEKA_SWAMP
OSBOURNES_SWAMP
EL_RANCHO


Scenario 04
Limited Significance Wetlands
Time (years)
Drawdown (m)
WHAREMAUKU_STREAM
WAIMEHA_STREAM
WAIMANU_LAGOONS
UNSURVEYED_SITE_5
TURF_FARM_FOREST
TE_HAPUA_F
TE_HAPUA_E
POPLAR_AVE
OTAIHANGA_S
NGARARA_RD_D
NGARARA_BUSH
KOWHAI_STREAM
KAPITI_AIRFIELD_A
ANDREWS_POND


Scenario 04
Saline Intrusion
Time (years)
Drawdown (m)
COAST_3 shallow
COAST_2 shallow
COAST_1 shallow
COAST_3 mid
COAST_2 mid
COAST_1 mid
COAST_3 deep
COAST_2 deep
COAST_1 deep



Drawdown - Scenario 02 - 27.8 Years

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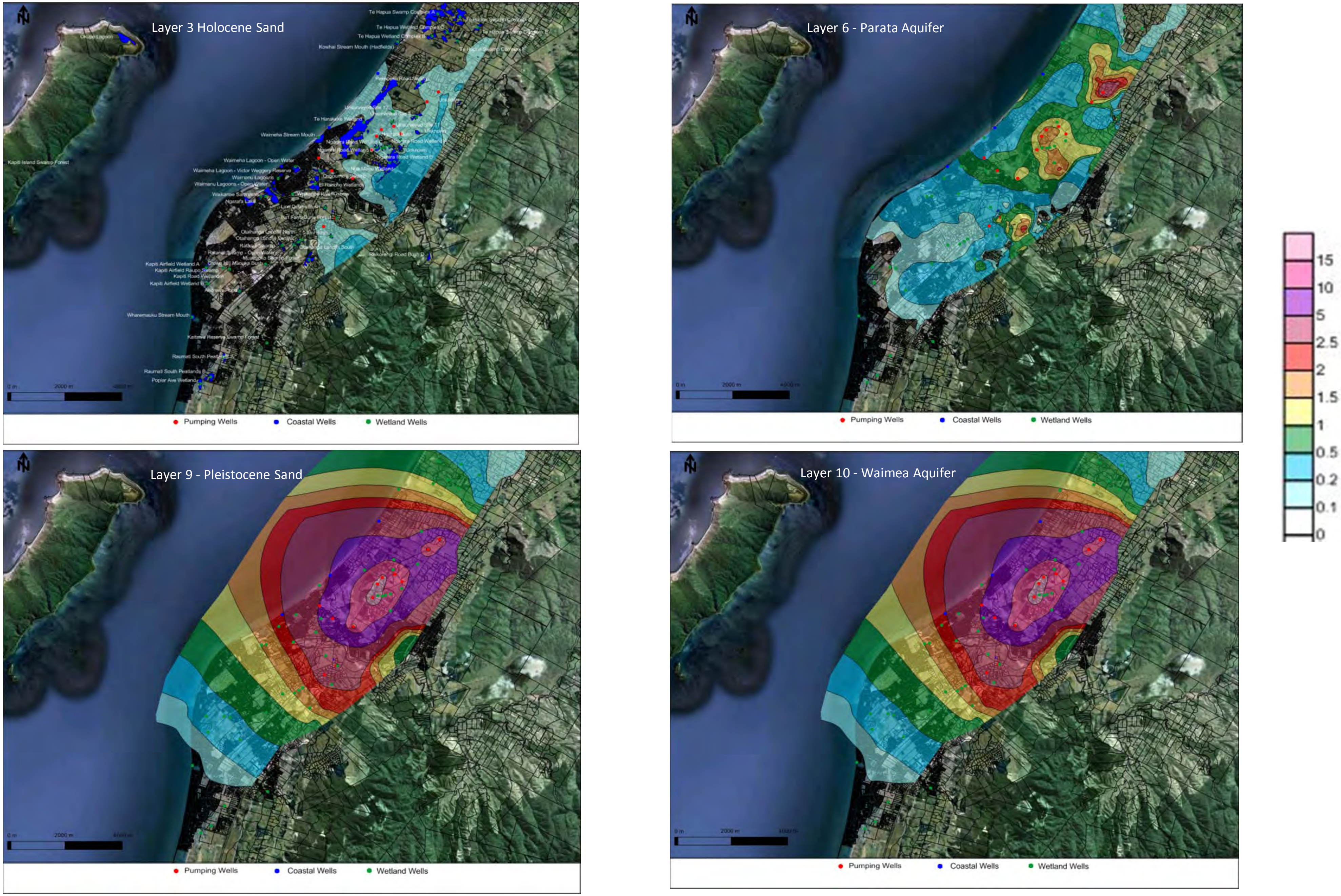
Figure 9



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Drawdown - Scenario 04 - 27.8 Years

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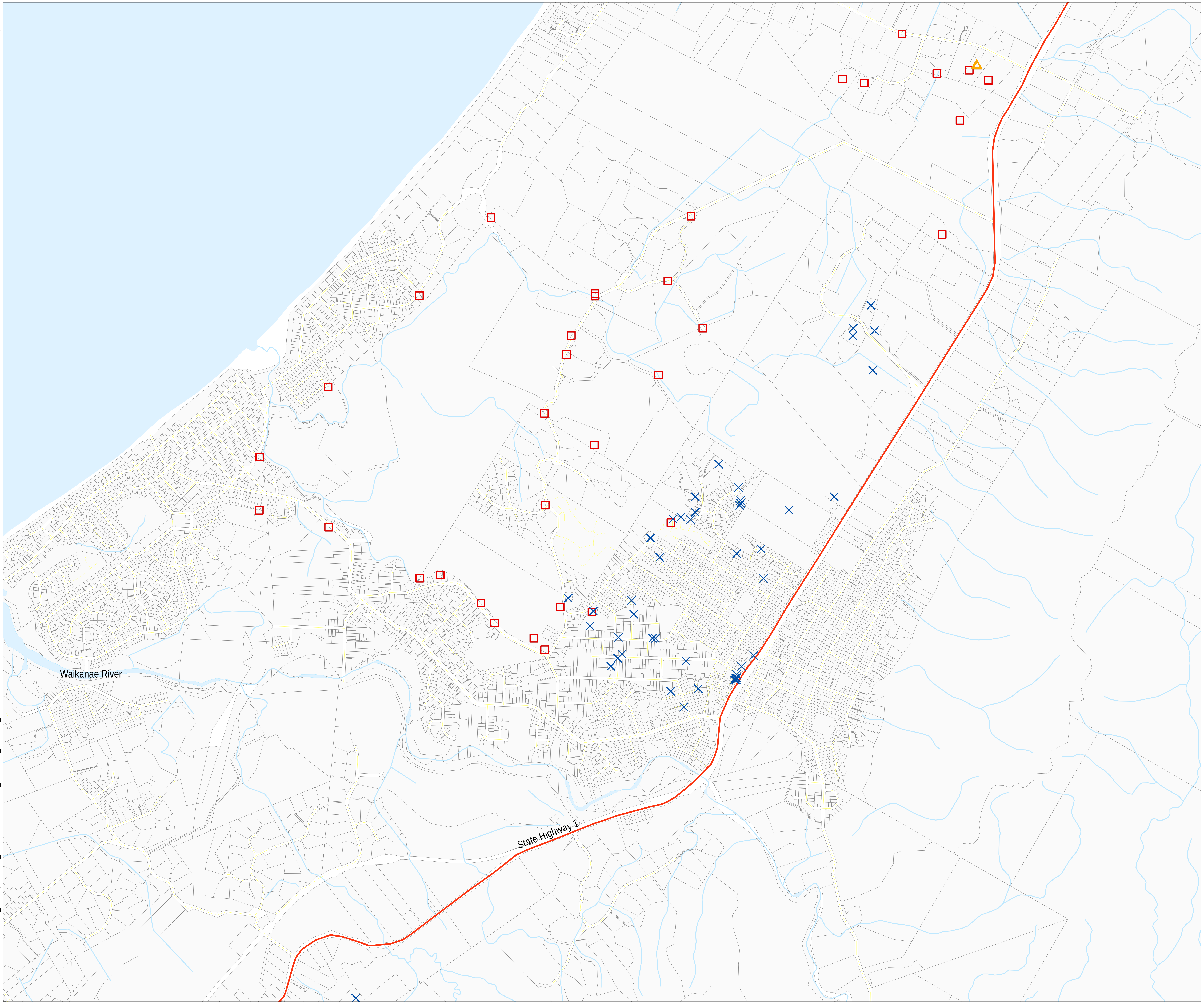
Figure 10



Predicted Drawdown Effects on Identified Existing Kapiti Coast Wells

Figure 11

Legend

- Wells less than 20m deep with drawdowns greater than 200 mm in the Holocene Sand Aquifer
- Wells between 20 and 40 m deep with drawdowns greater than 2m in the Parata Aquifer
- Wells greater than 40 m deep with drawdowns greater than 5 m in the Lower Pleistocene Sand and Waimea Aquifers
- State Highway 1
- Road Network
- Watercourse
- Parcel Boundary

Note : Temporary Drawdown over a 15 week drought period

The bore data contained in this plan supplied by Greater Wellington Regional Council (GWRC) Bore Database. Bore locations are indicative only.

Map intended for distribution as a PDF document.
Scale may be incorrect when printed.

Map Scale @ A2: 1:16,500

0 250 500 1,000
Metres

Revision	Author	Verified	Approved	Date
0.2	BAP	AYF		19/10/2012
0.1	LRK	OK	AH	15/08/2012

N

Client: Kapiti Coast District Council

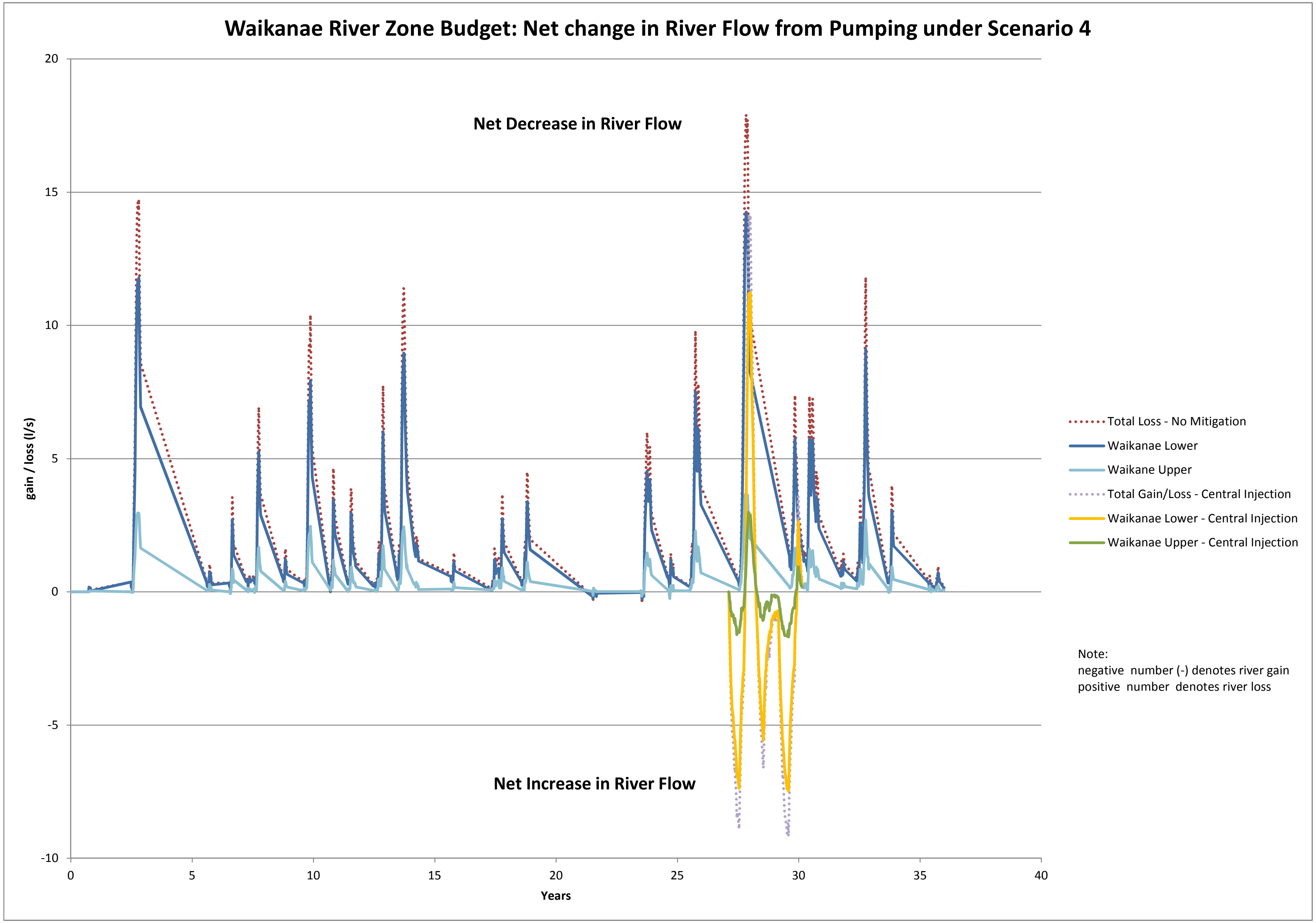
Discipline: GIS

Project: Kapiti Water Supply Review

Drawing No: GIS-6515959-48

CH2M Beca

GIS@beca.com
File: P:\6515\6515959\TGIS\55_Workspaces\01_mxd\GIS-6515959-48_BoreData_Geotech_Rev2.mxd Author: Beca GIS Date: 19/10/2012



Change in River Flow and Drawdowns - Scenario 4 - 27.8 Years

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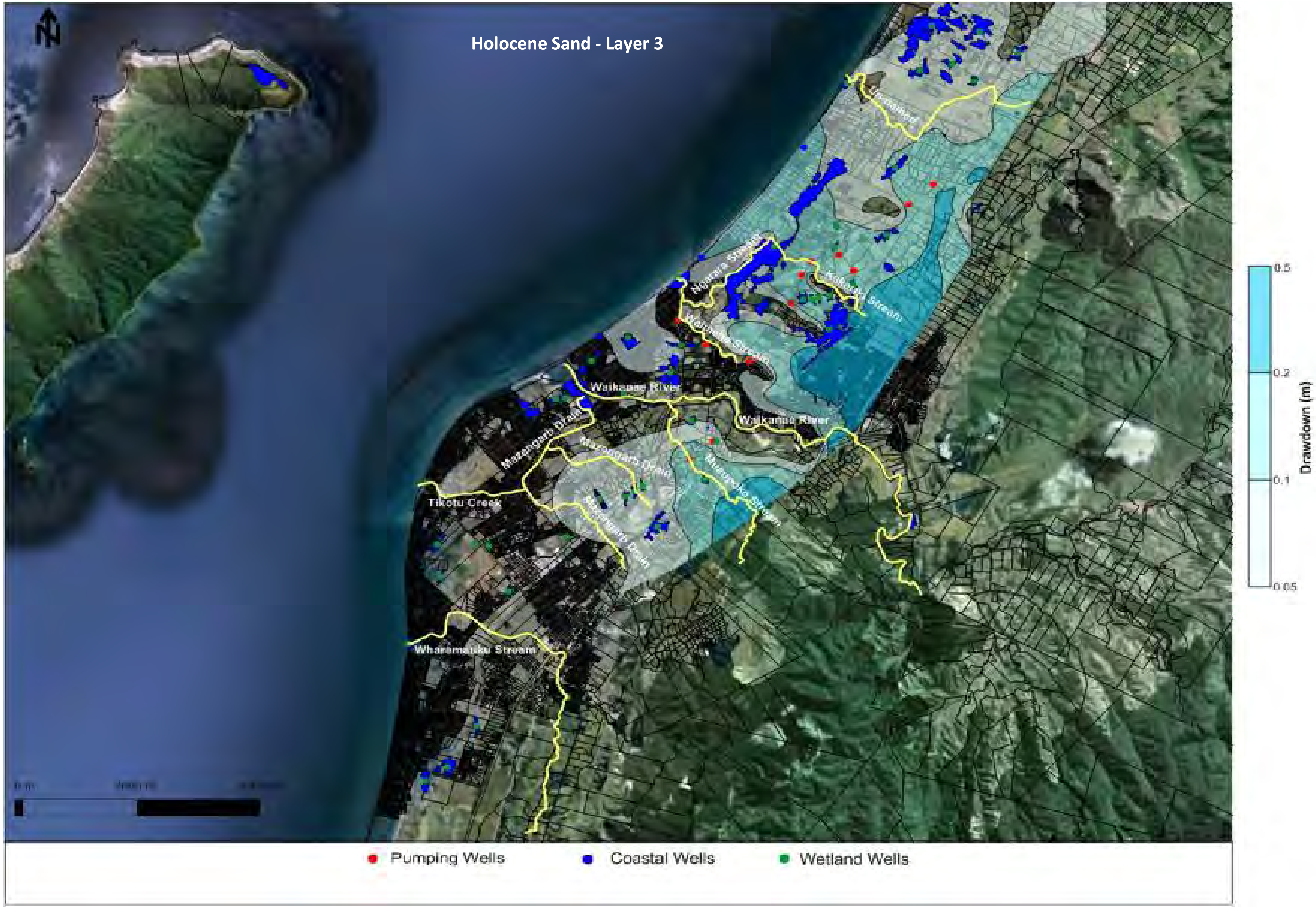
Figure 12a



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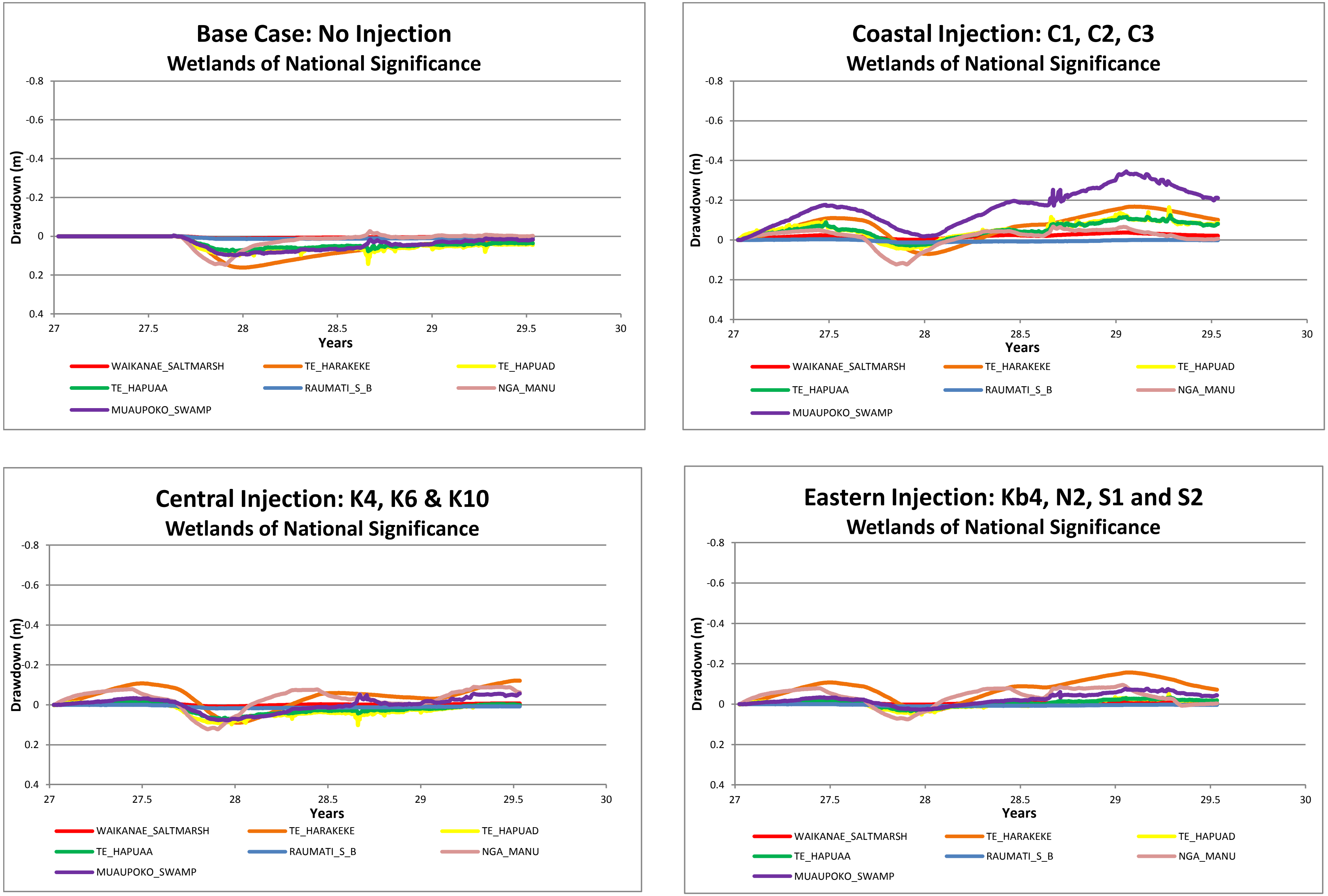
Change in River Flow and Drawdowns - Scenario 4 - 27.8 Years

Figure 12b

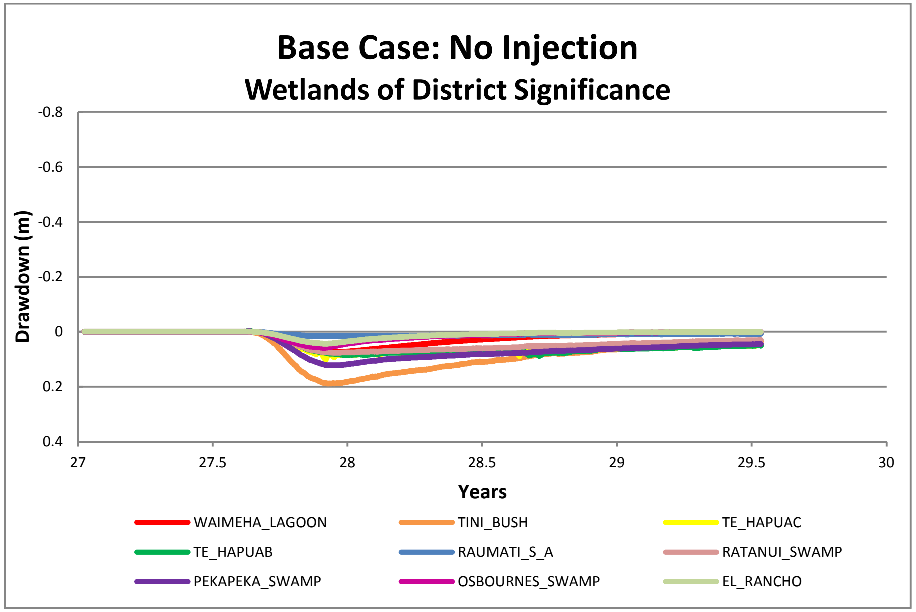


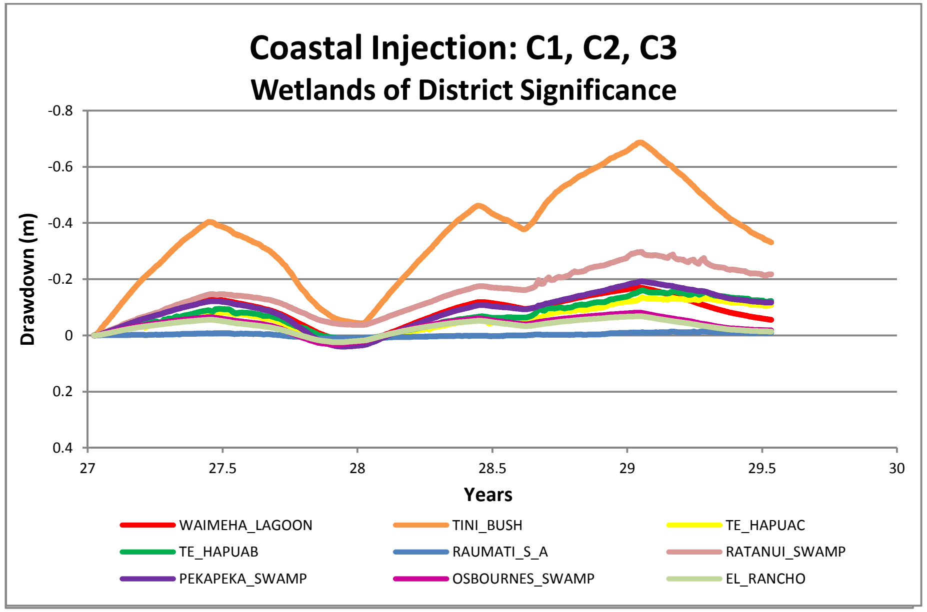
negative (-) drawdown = water rise

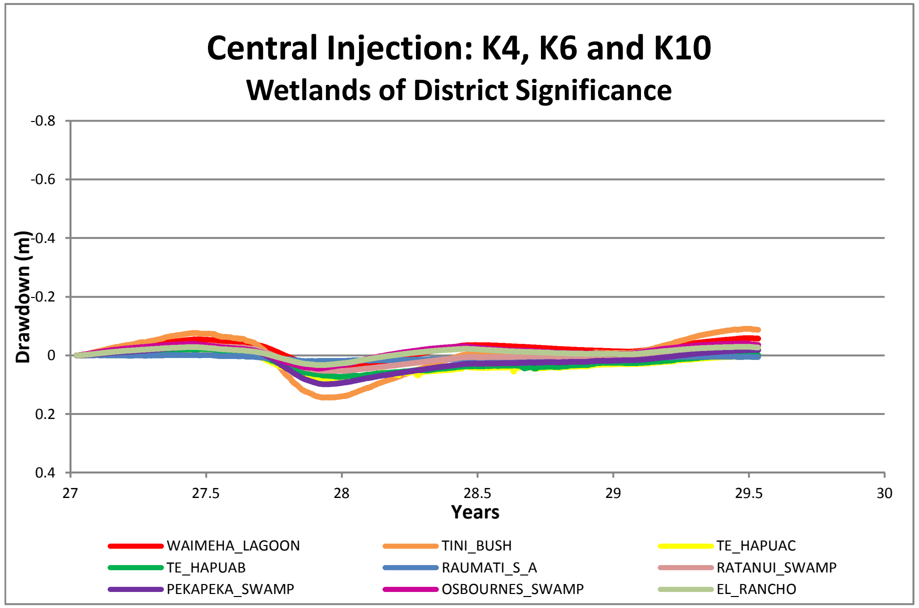
Effects on Wetlands of National Significance

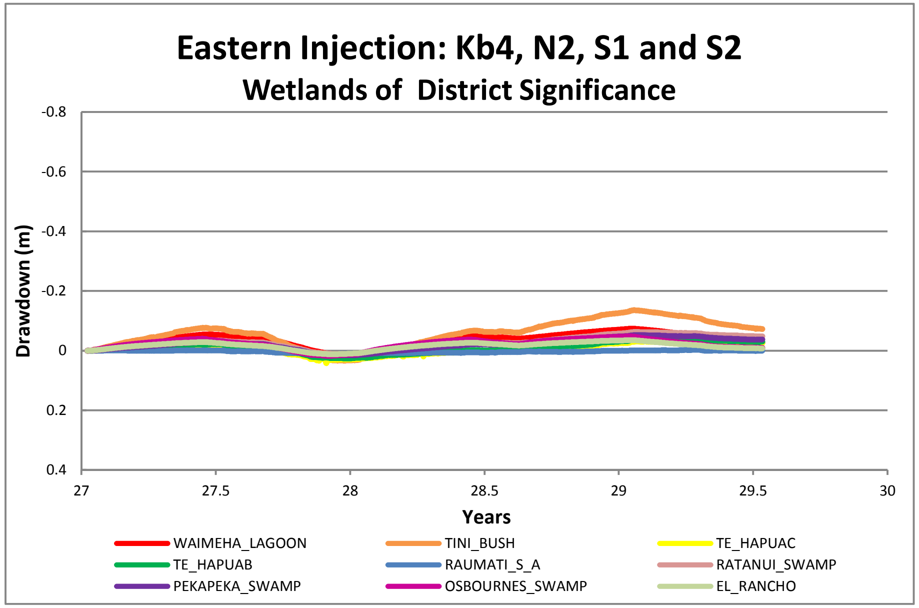
6515959

Figure 13









negative (-) drawdown = water rise

Effects on Wetlands of District Significance

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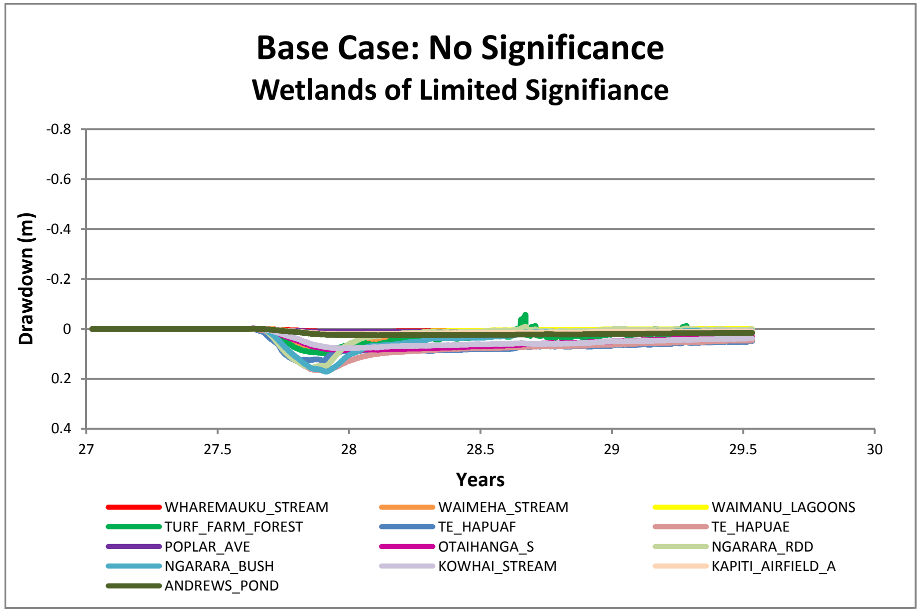
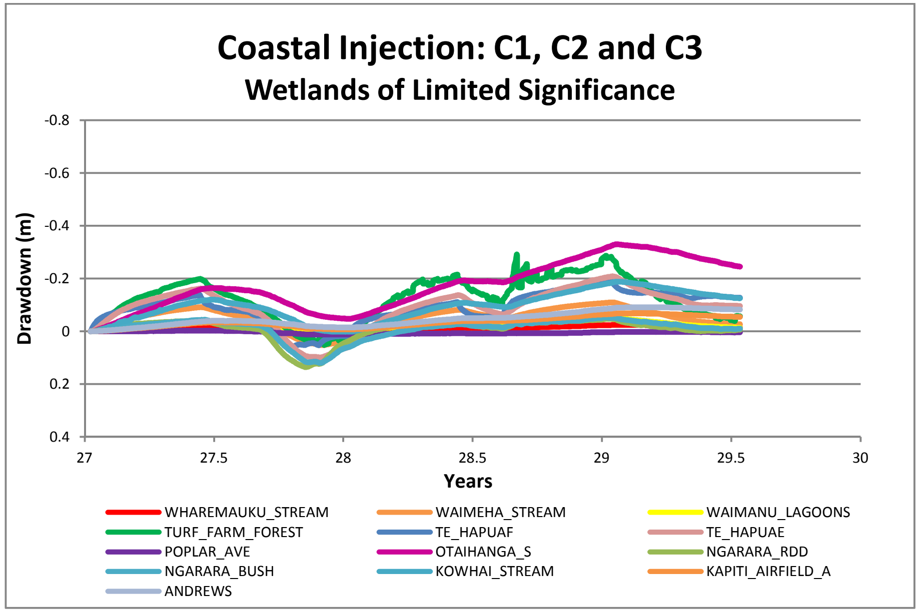
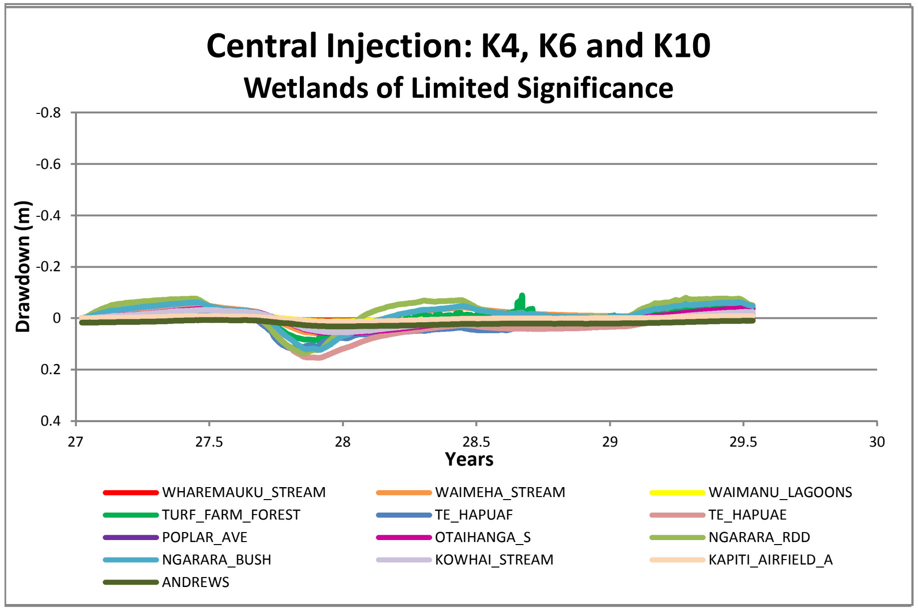
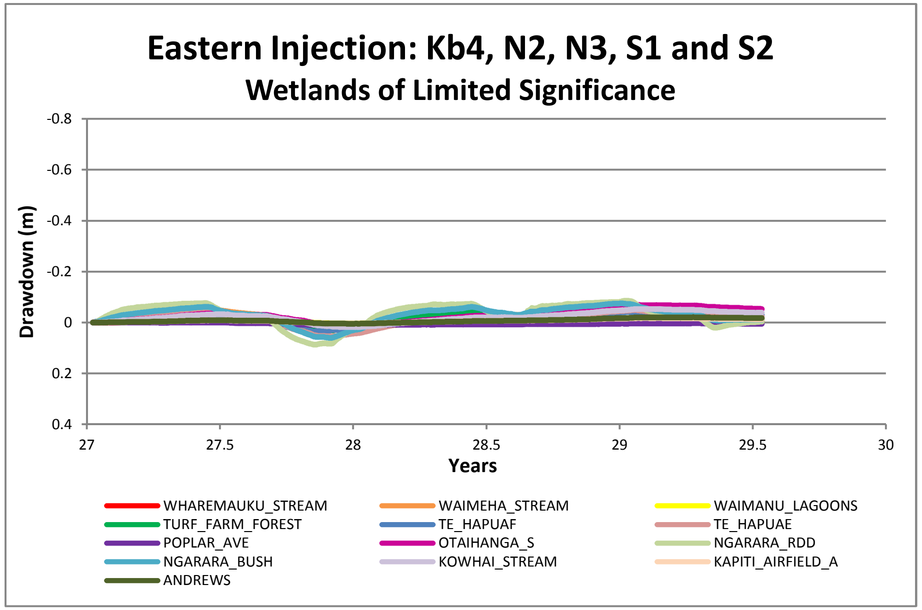
Figure 14









negative (-) drawdown = water rise

Effects on Wetlands of Limited Significance

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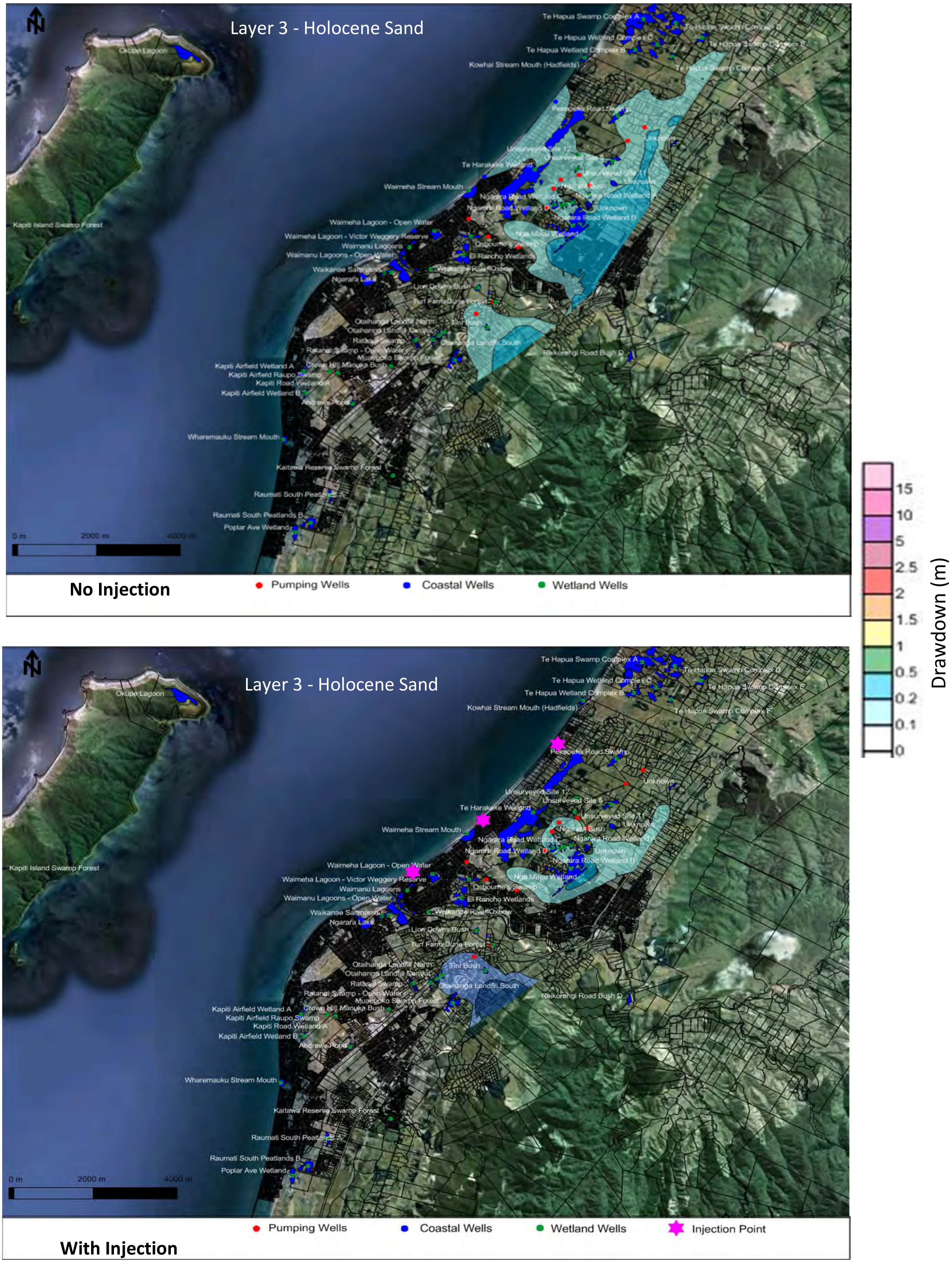
Figure 15



Wetland Aquifer Drawdown Mitigation - Coastal Injection - 27.8 Years

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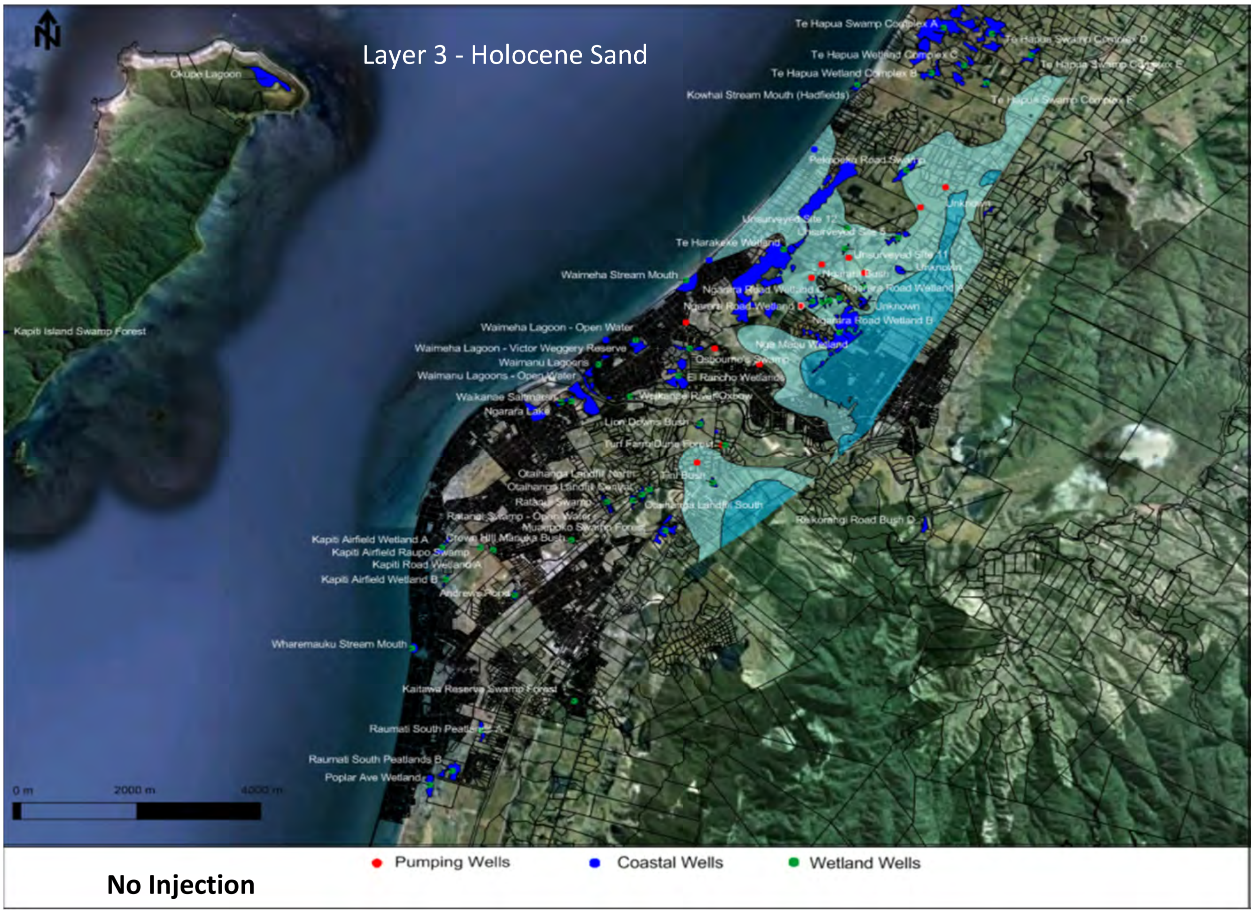
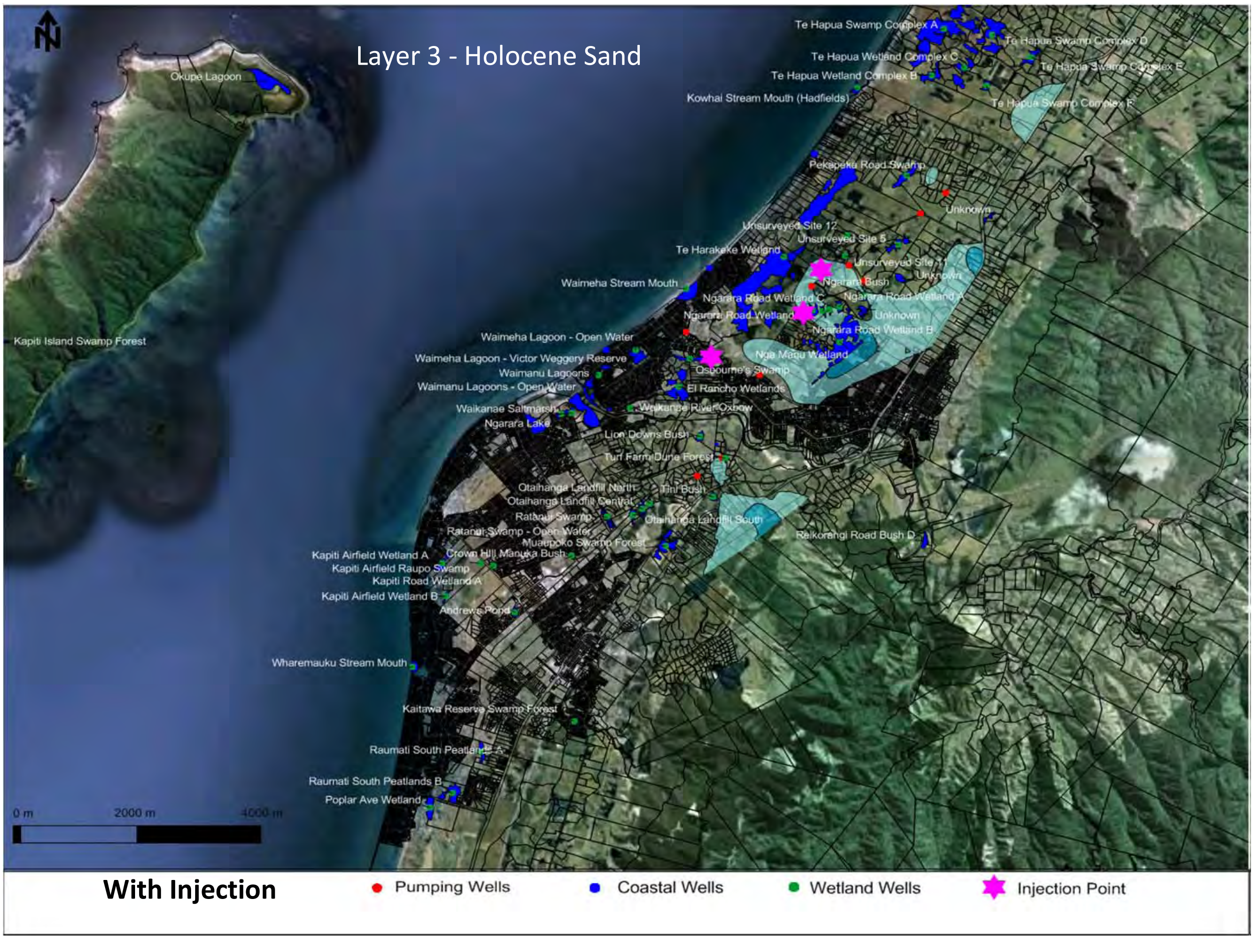
Figure 16





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Wetland Aquifer Drawdown Mitigation - Central Injection - 27.8 Years

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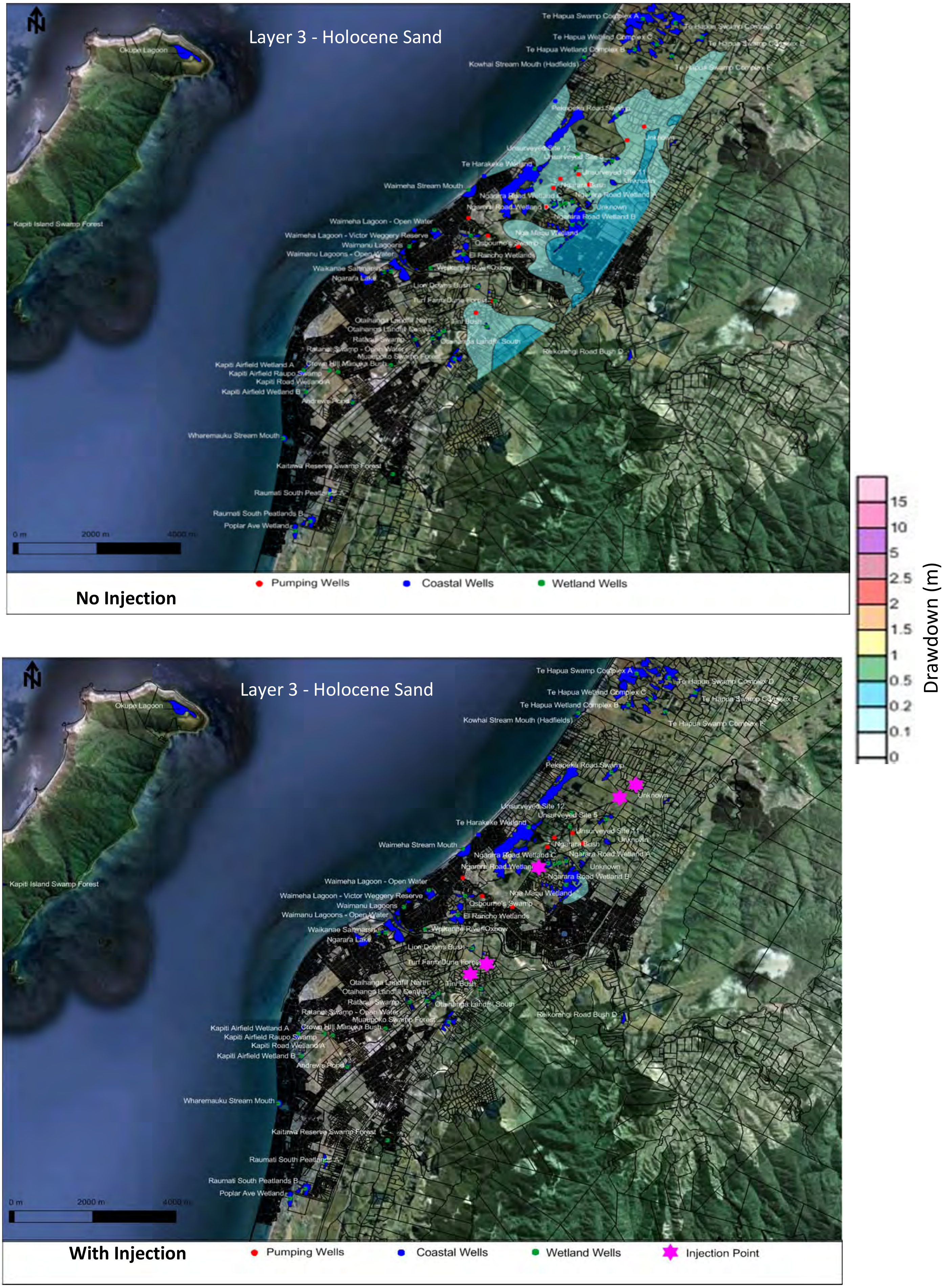
Figure 17



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Wetland Aquifer Drawdown Mitigation - Eastern Injection - 27.8 Years

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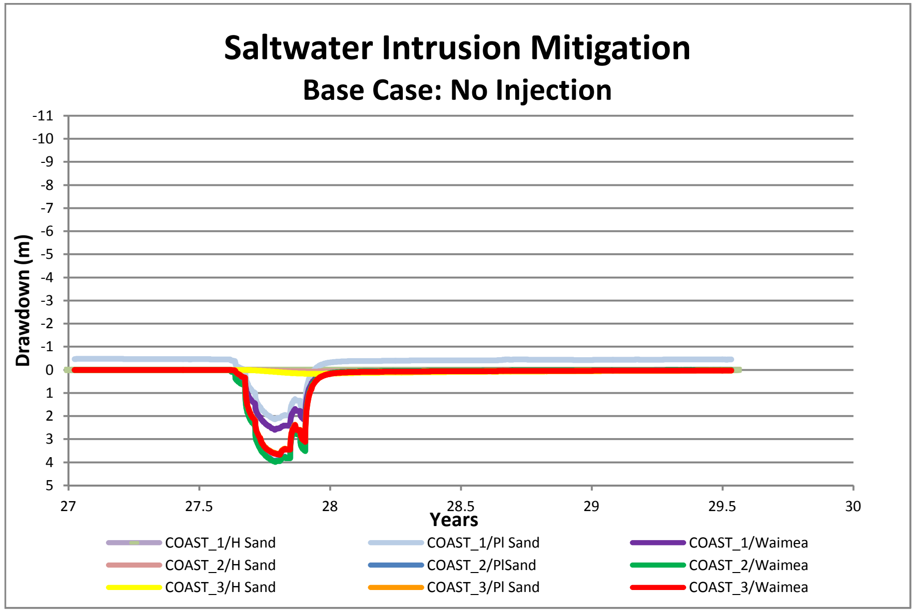
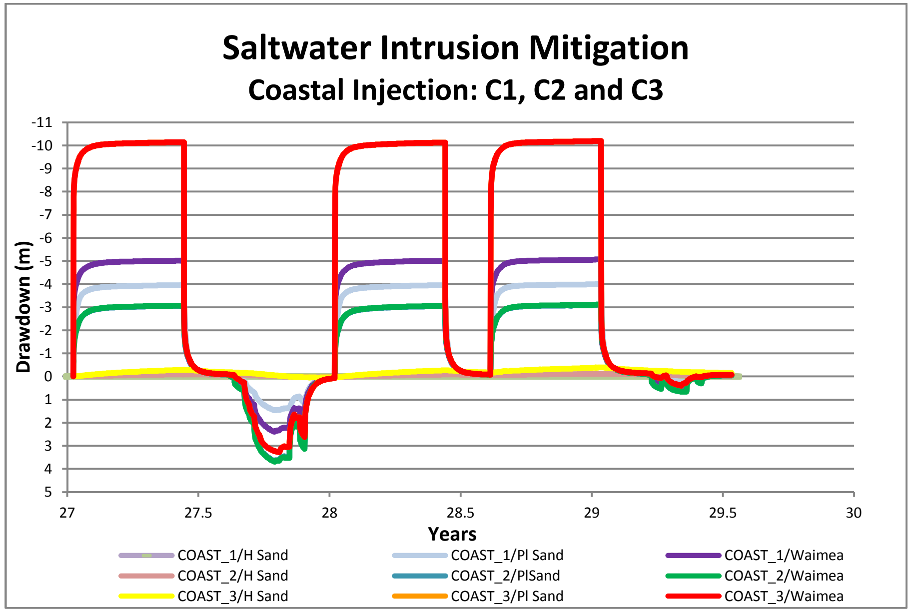
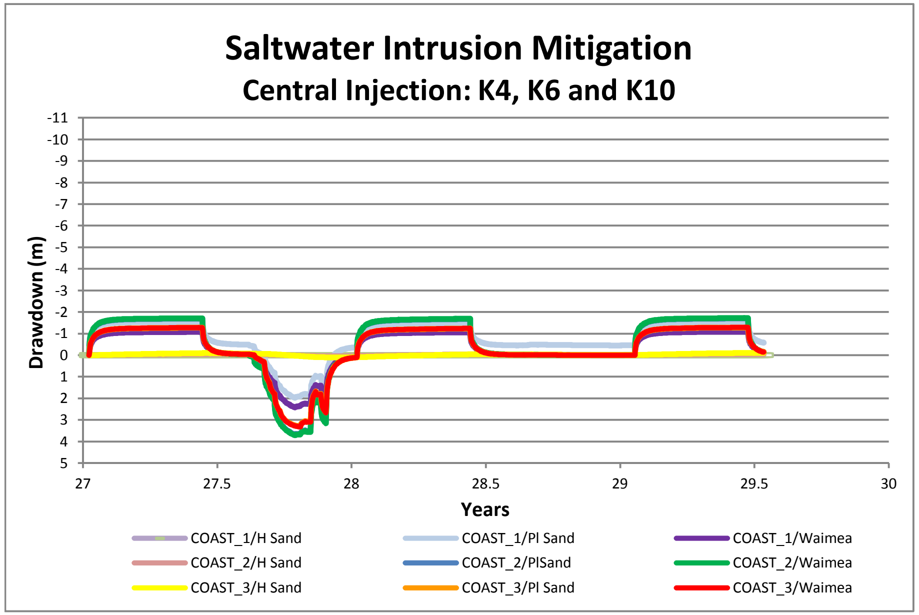
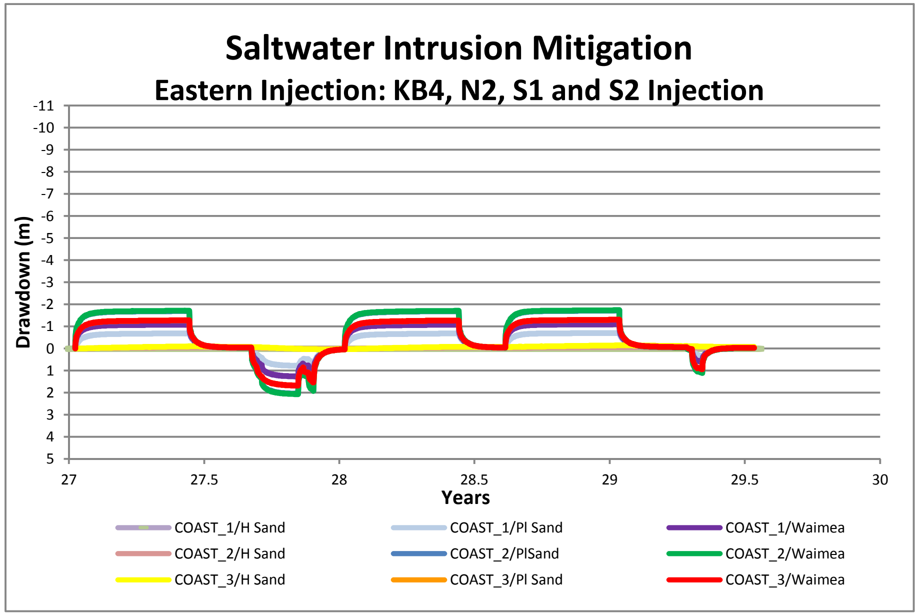
Figure 18









negative (-) drawdown = water rise

Saltwater Intrusion Mitigation

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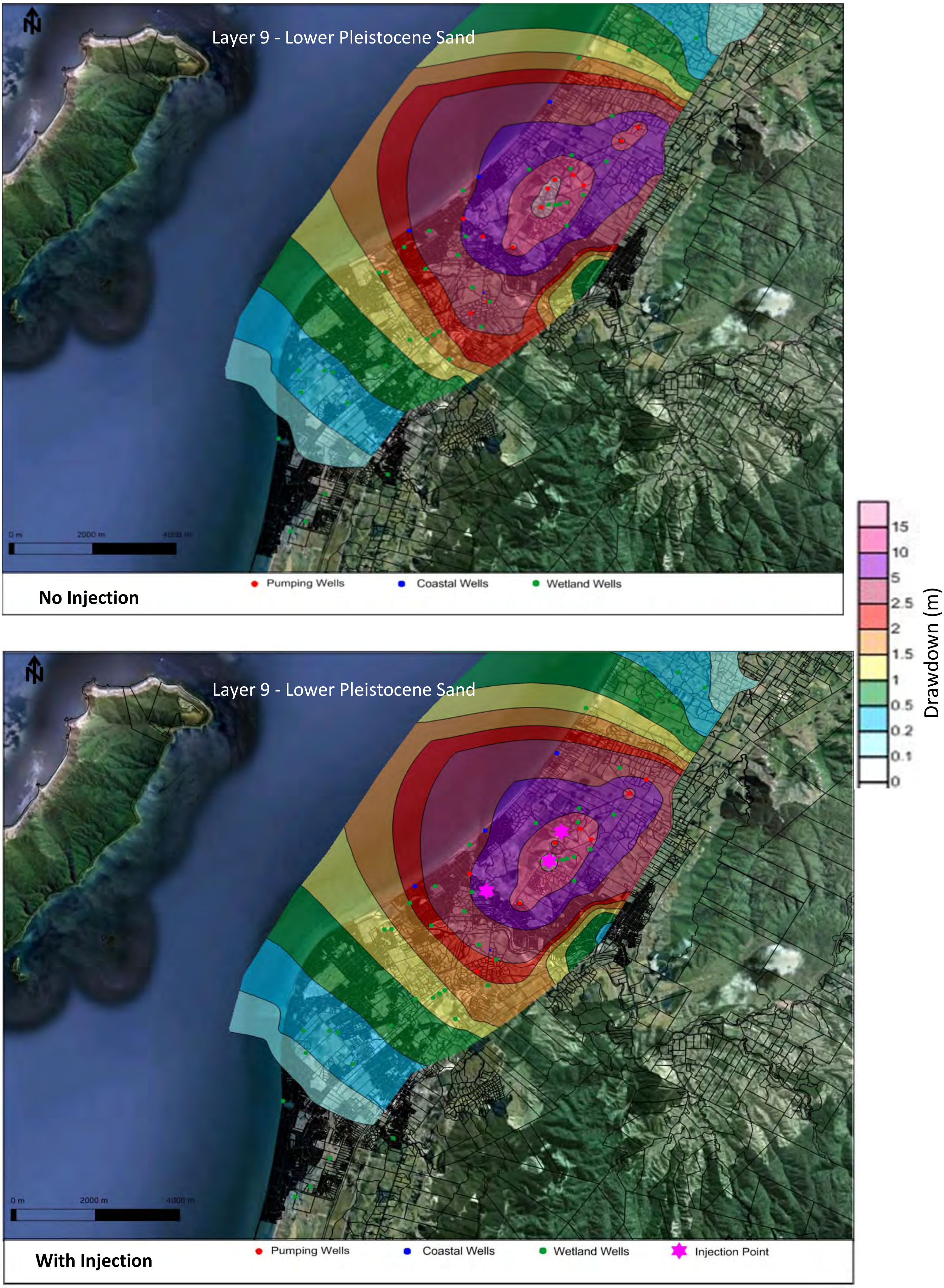
Figure 19



Saline Intrusion Mitigation - Central Injection - 27.8 Years

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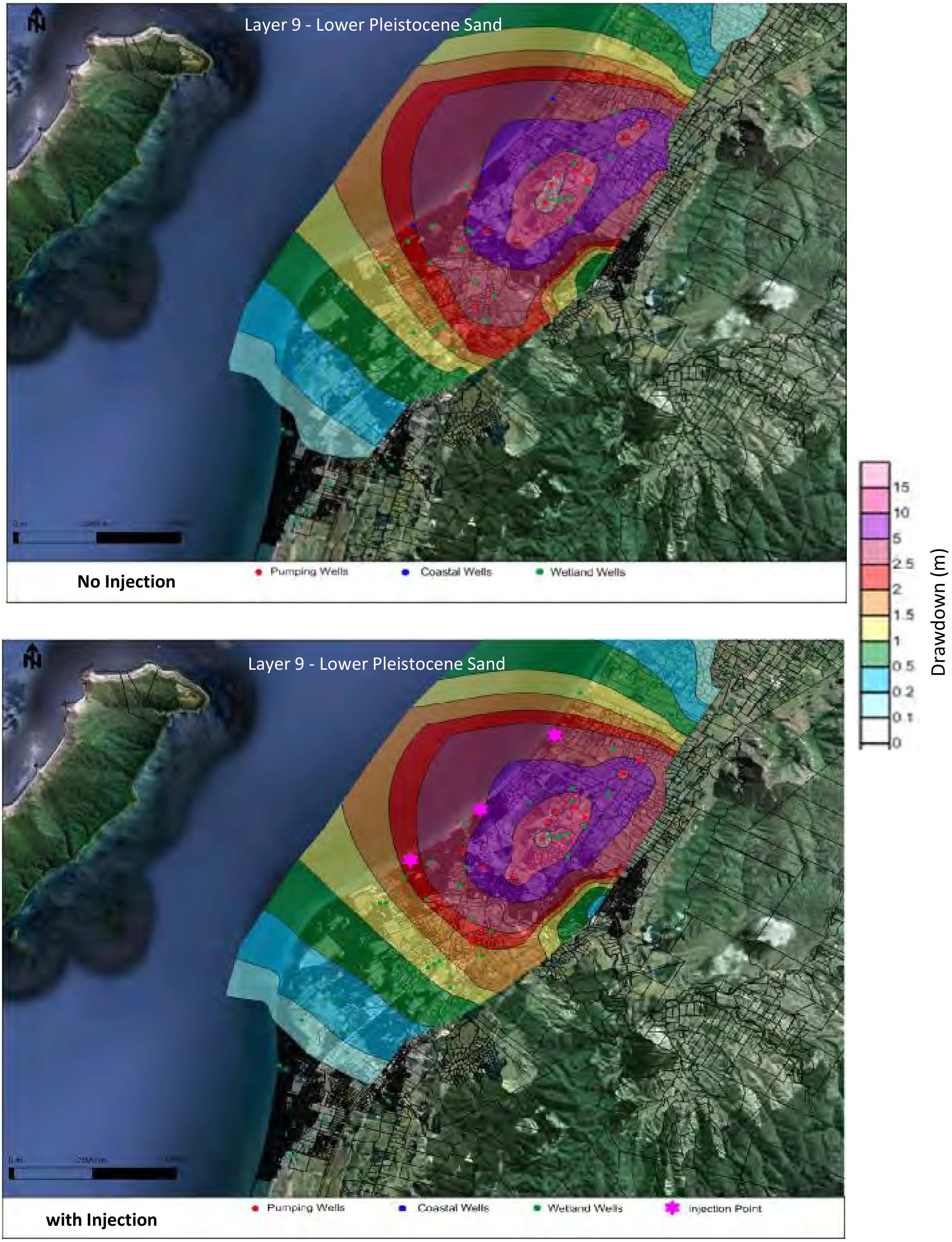
Figure 20



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Saline Intrusion Mitigation - Coastal Injection - 27.8 Years

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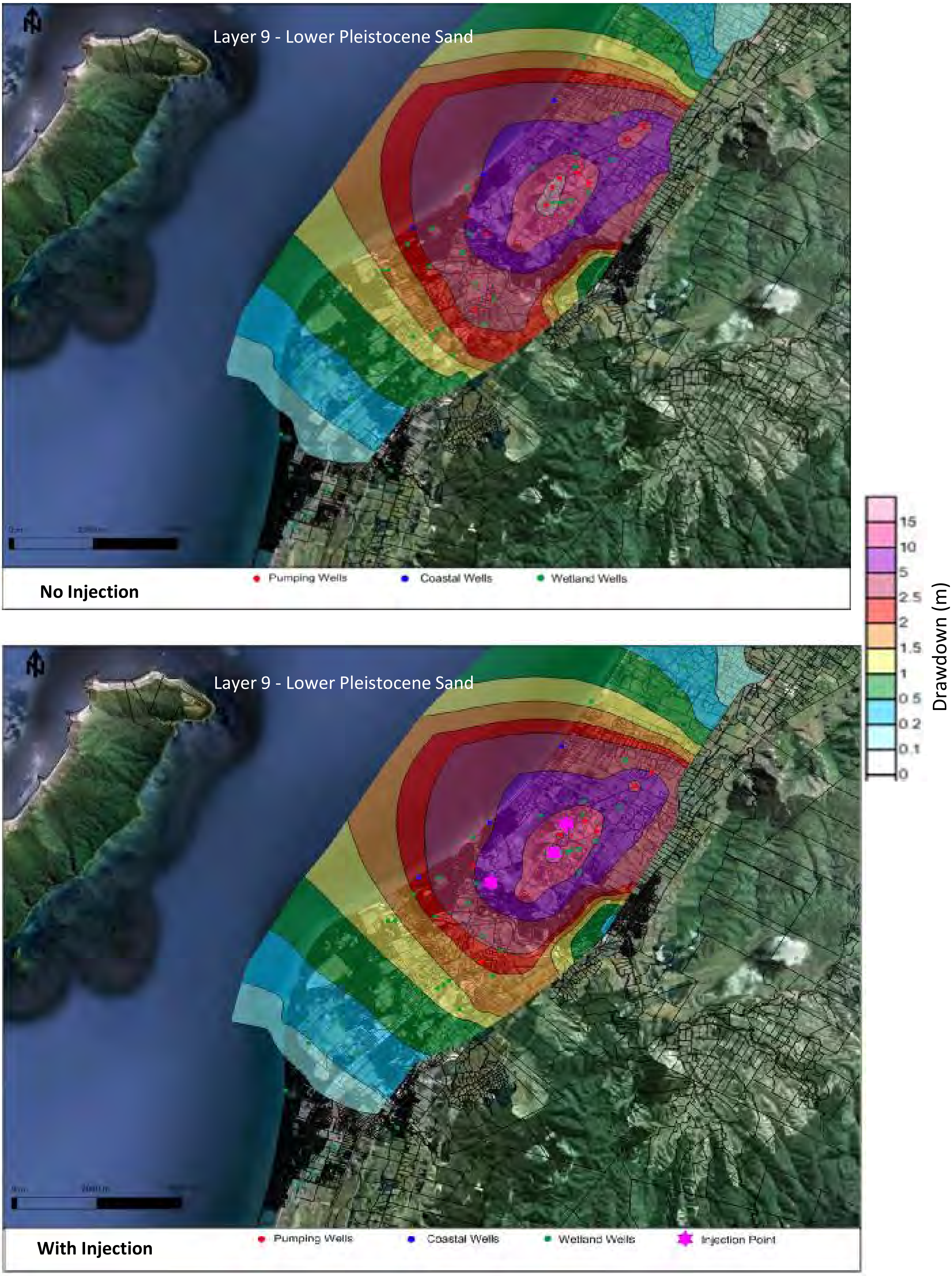
Figure 20



Saline Intrusion Mitigation - Central Injection - 27.8 Years

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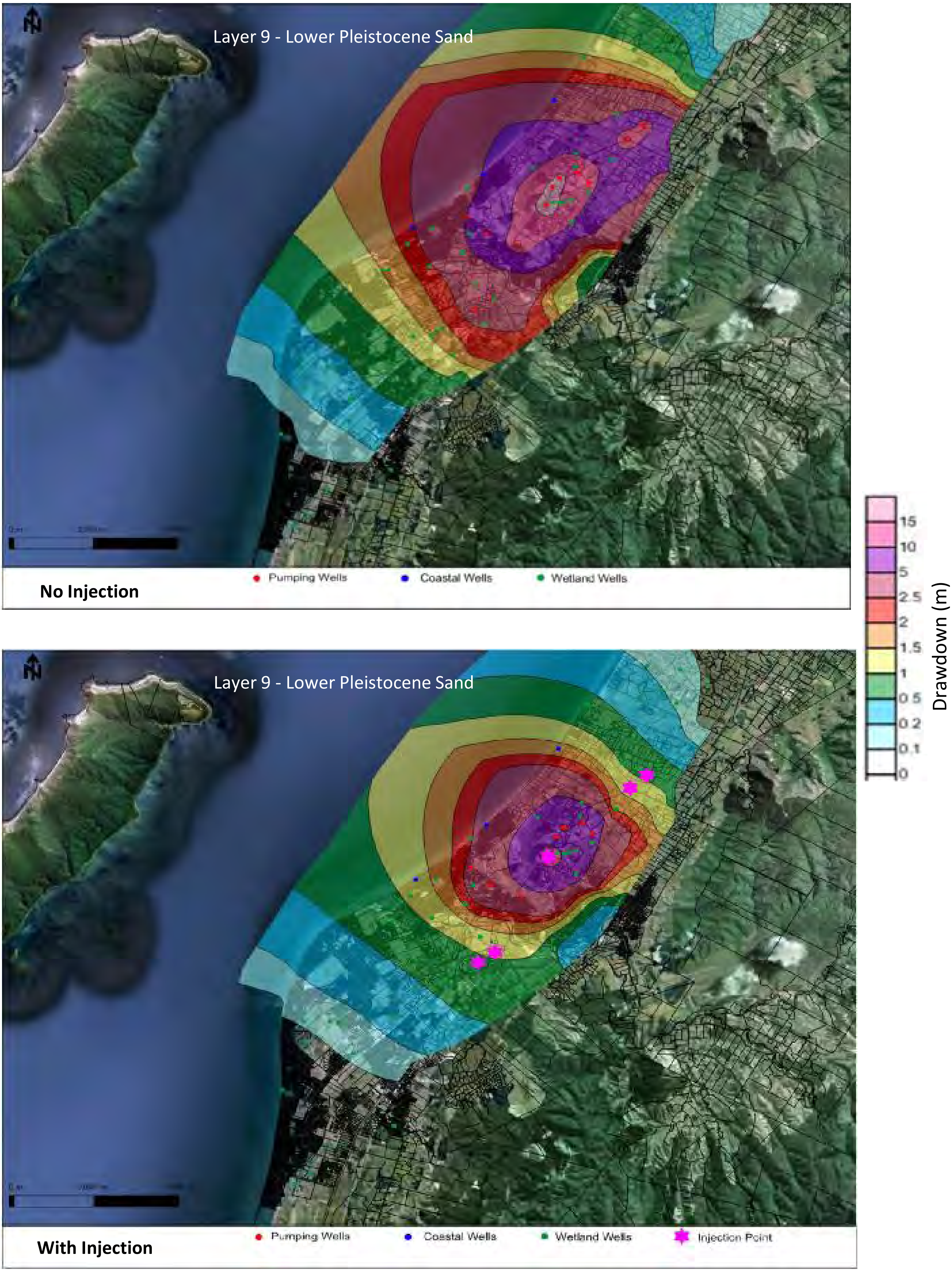
Figure 21



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Saline Intrusion Mitigation - Eastern Injection - 27.8 Years

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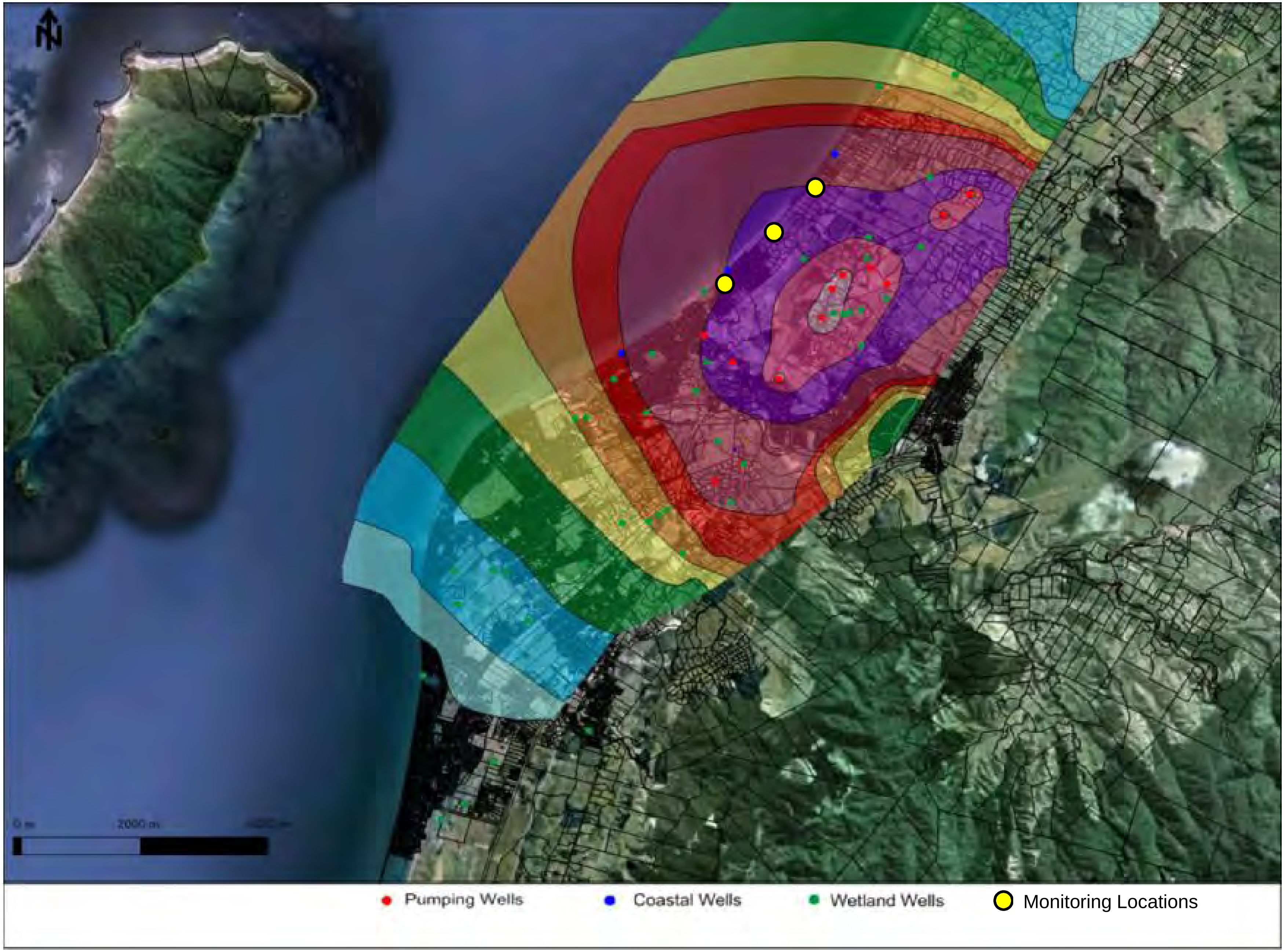
Figure 22



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Saline Intrusion Proposed Monitoring Locations

Figure 23

Appendix A

Geological Cross Sections

Kapiti Coast Water Supply

Cross Section Location Plan

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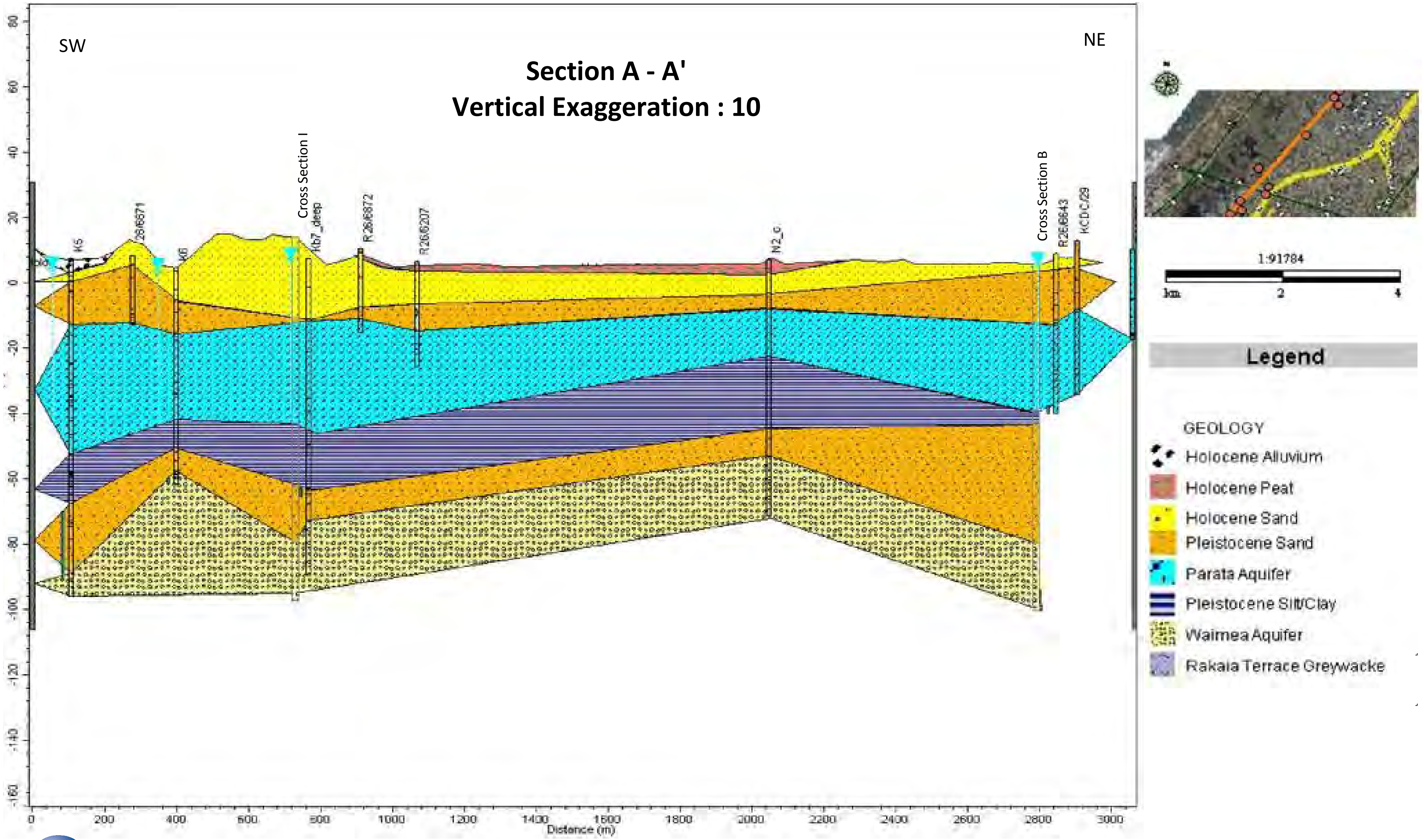
FIGURE A-1

Kapiti Coast Water Supply

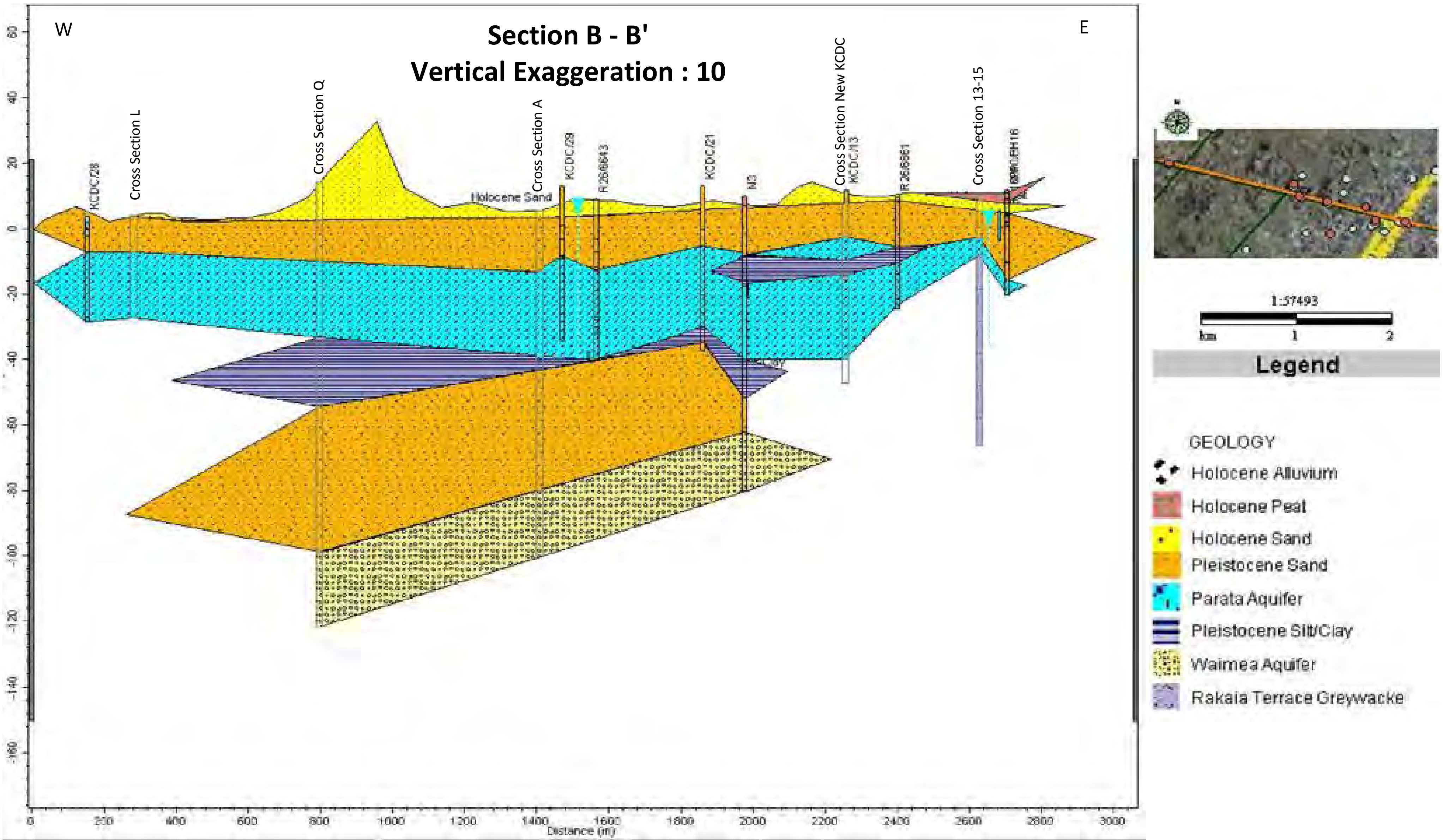


Cross Section A

6515959

Figure A-2

Kapiti Coast Water Supply



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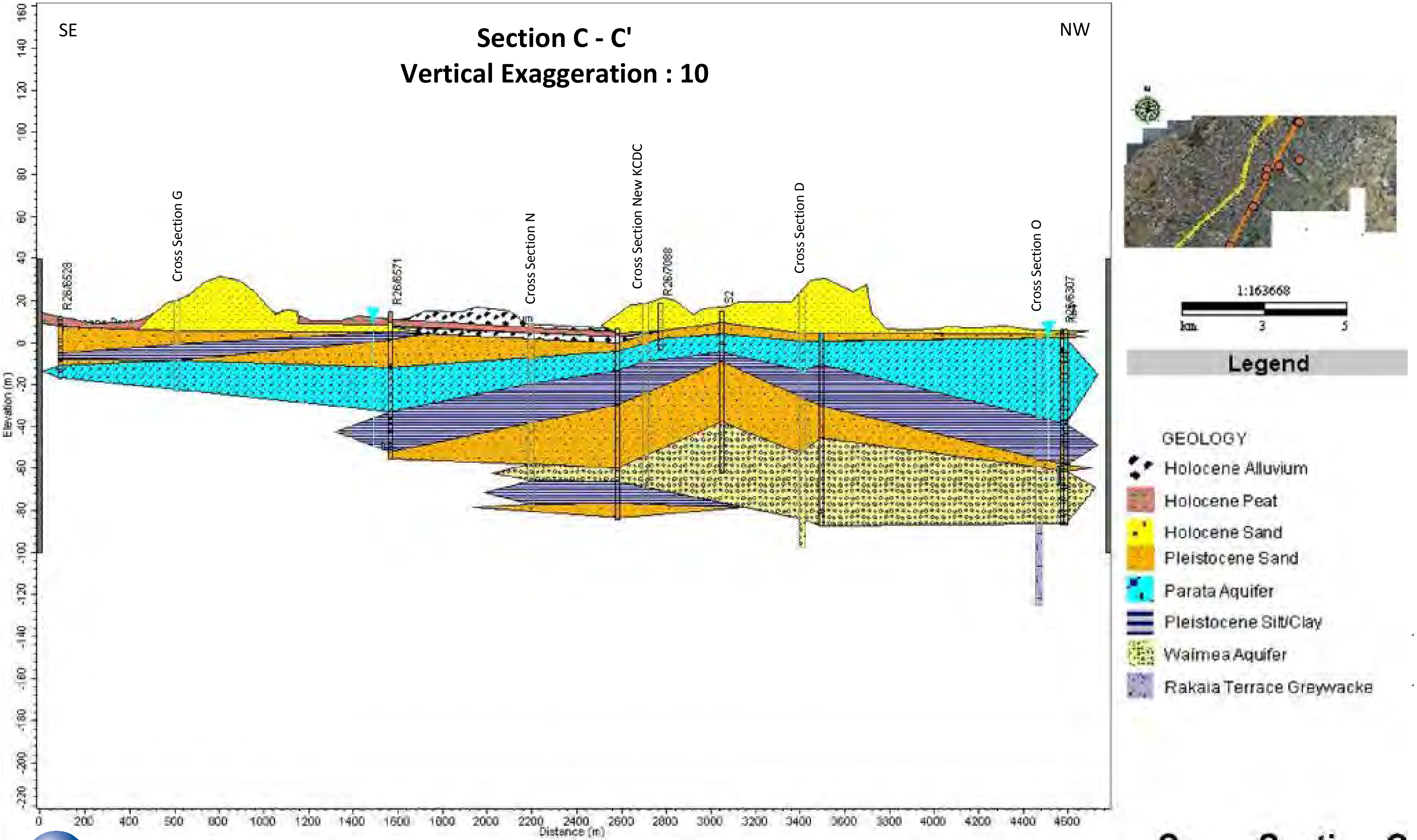
Cross Section B

Figure A-3



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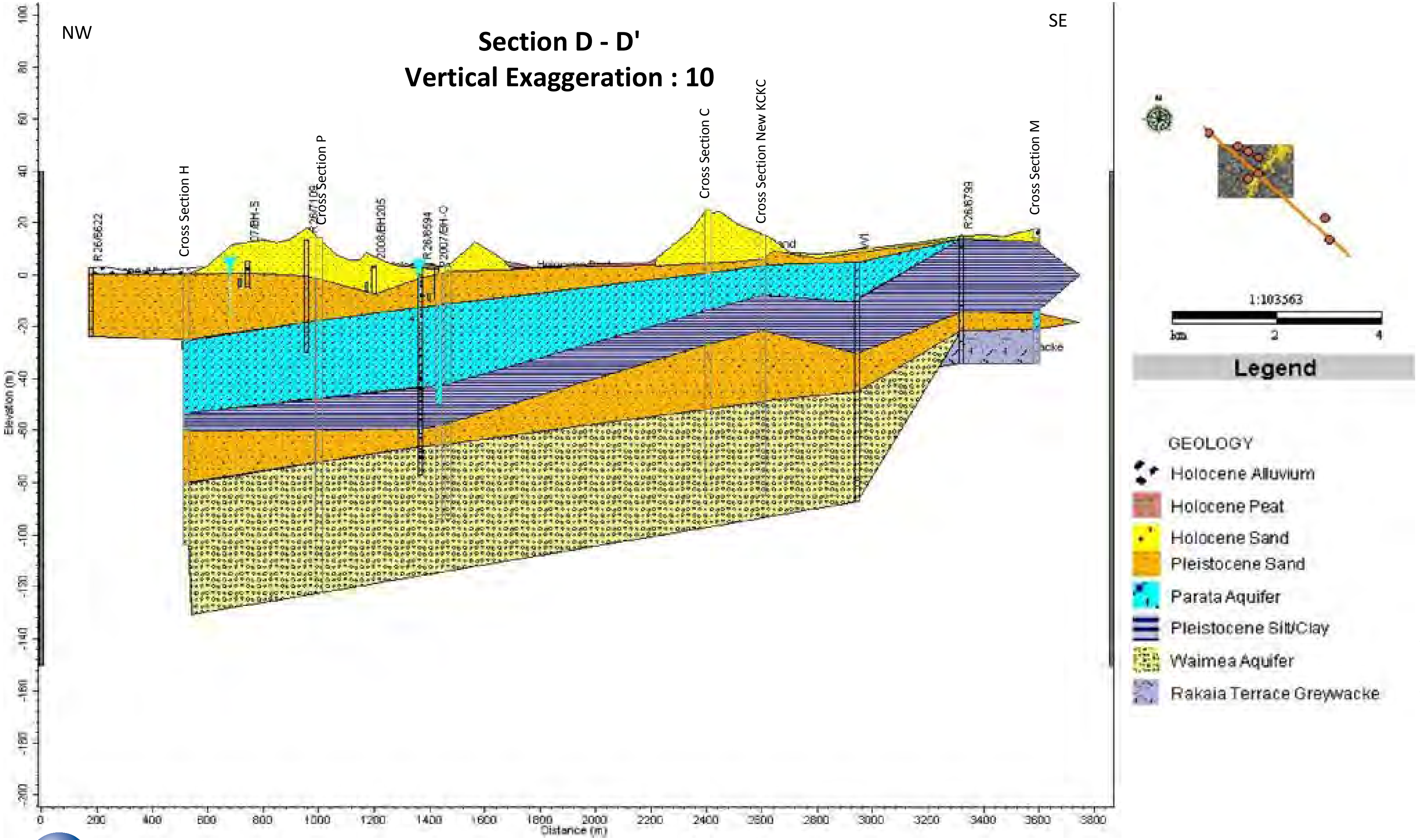
Cross Section C

Figure A-4

Kapiti Coast Water Supply

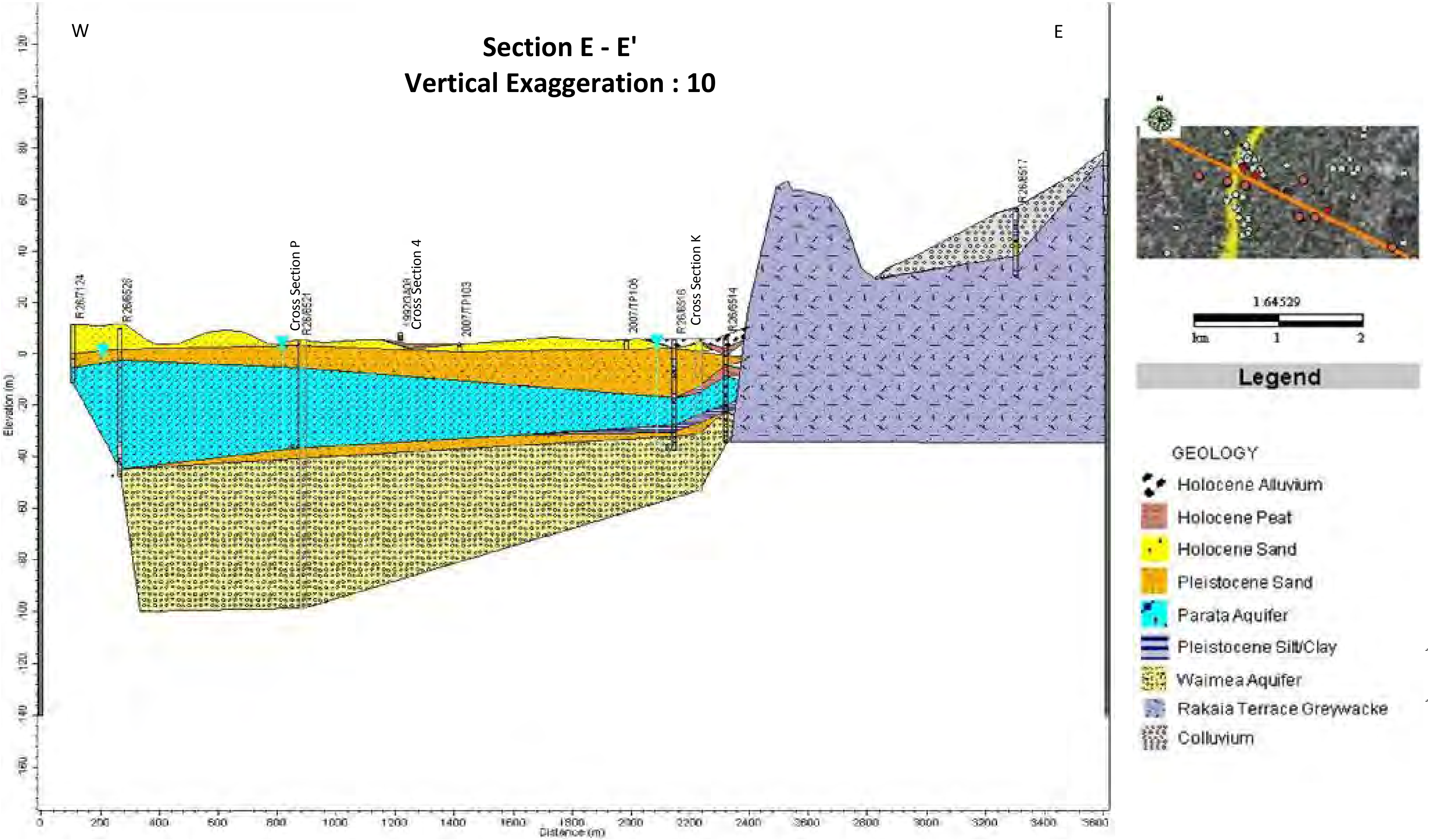


CH2M Beca
6515959

Cross Section D

Figure A-5

Kapiti Coast Water Supply



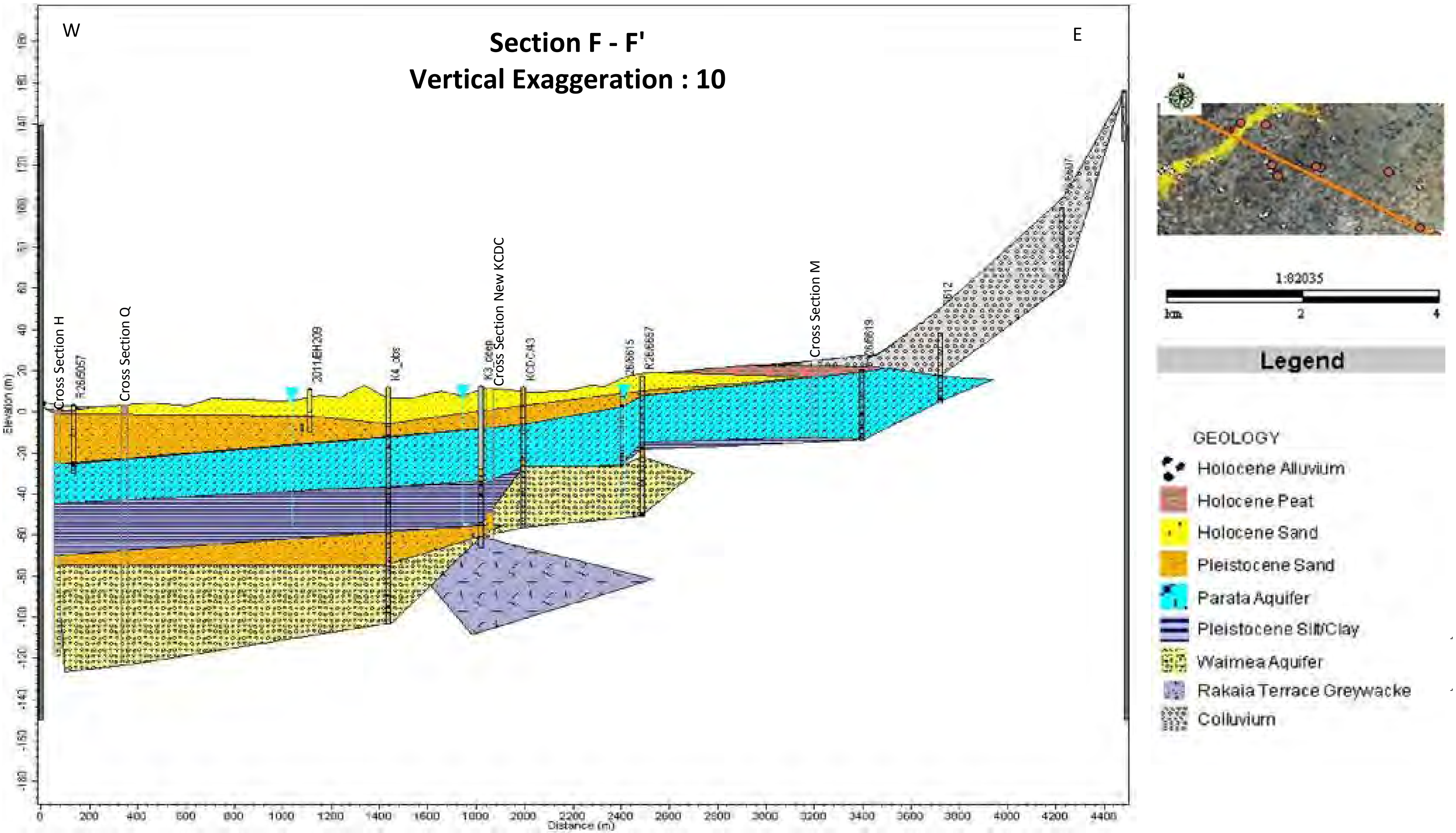
CH2M Beca

6515959

Cross Section E

Figure A-6

Kapiti Coast Water Supply

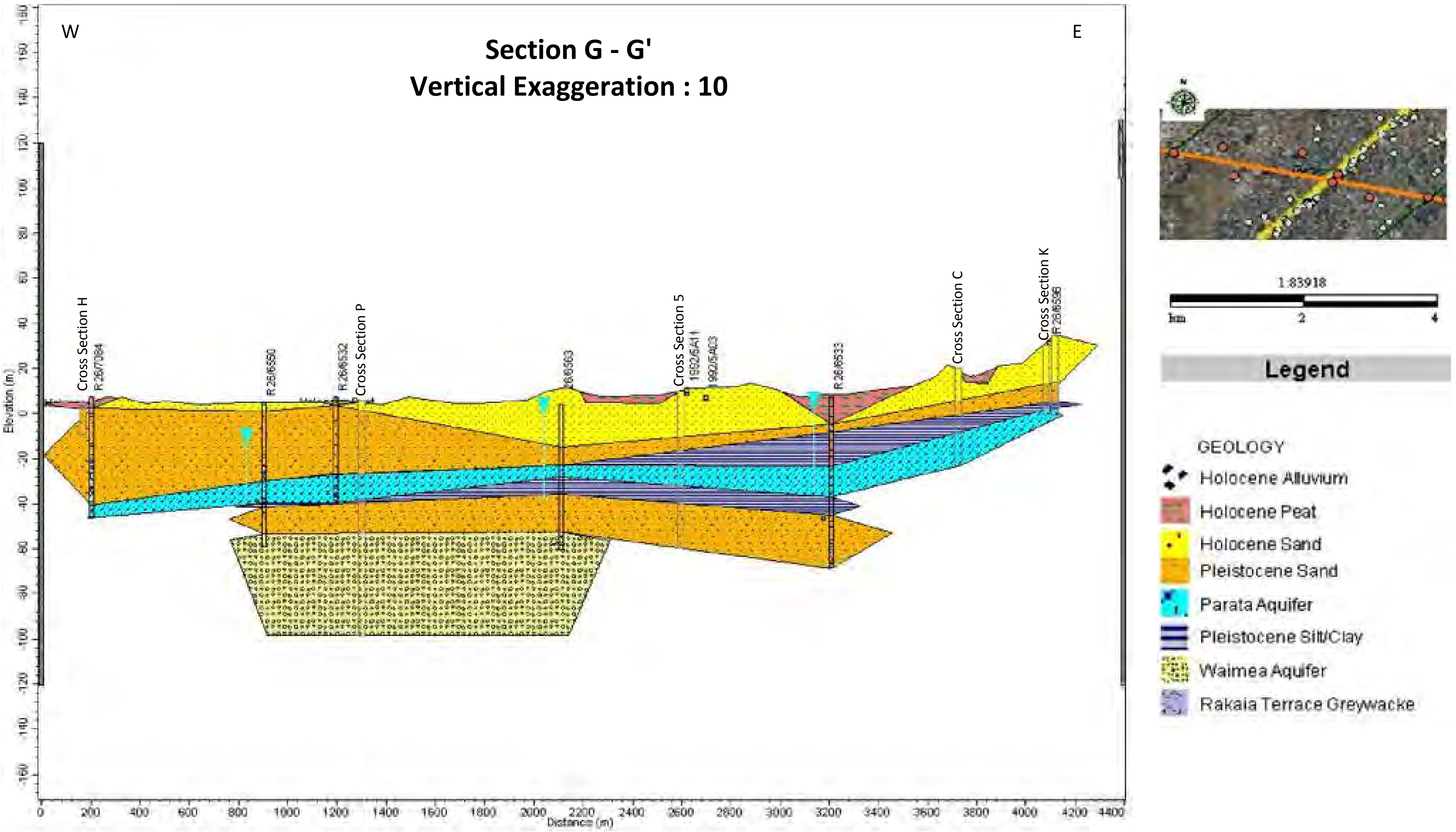


6515959

Cross Section F

Figure A-7

Kapiti Coast Water Supply

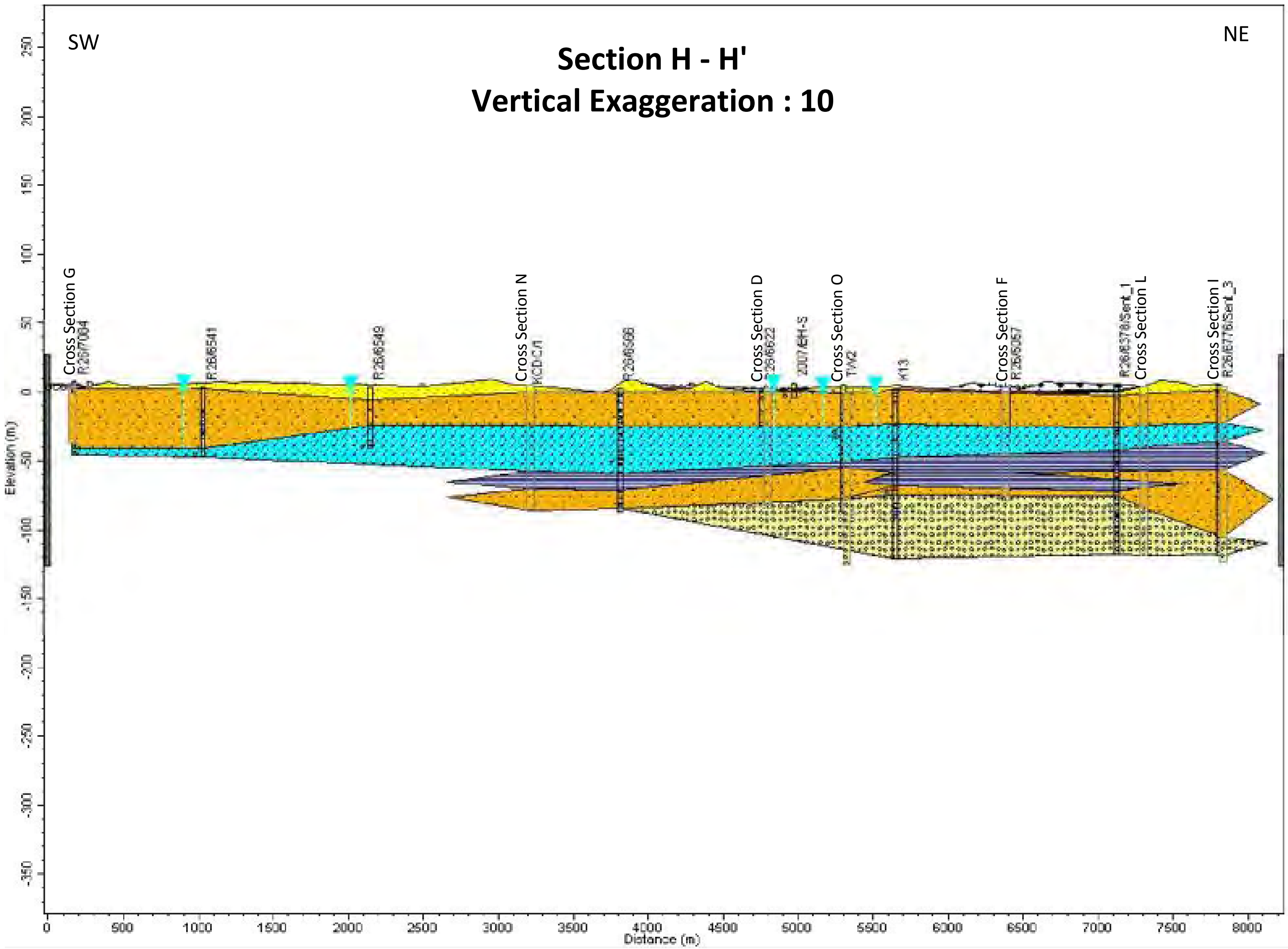


CH2M Beca
6515959

Cross Section G

Figure A-8

Kapiti Coast Water Supply



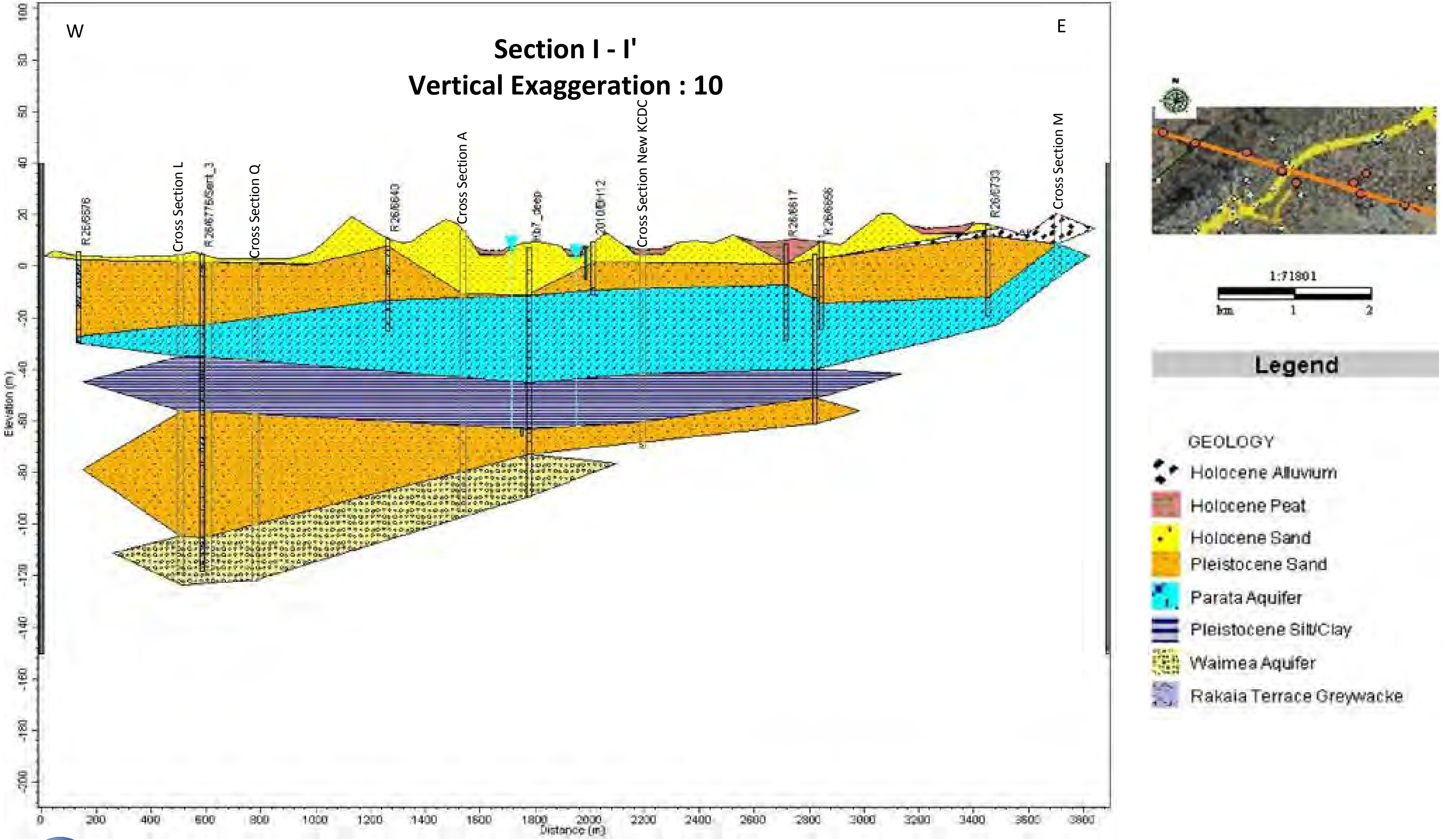
CH2M Beca

6515959

Cross Section H

Figure A-9

Kapiti Coast Water Supply

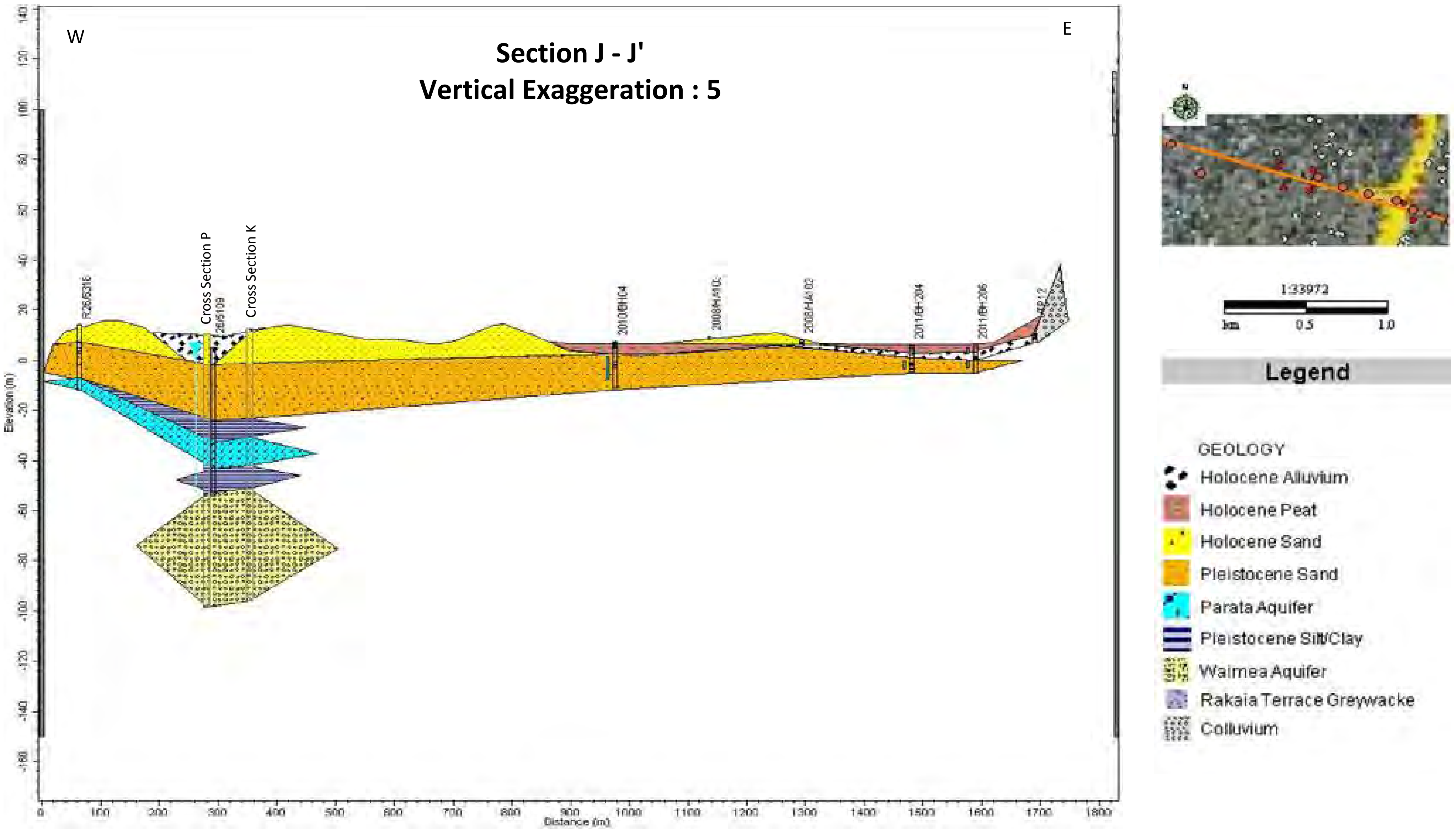


CH2M Beca
6515959

Cross Section I

Figure A-10

Kapiti Coast Water Supply

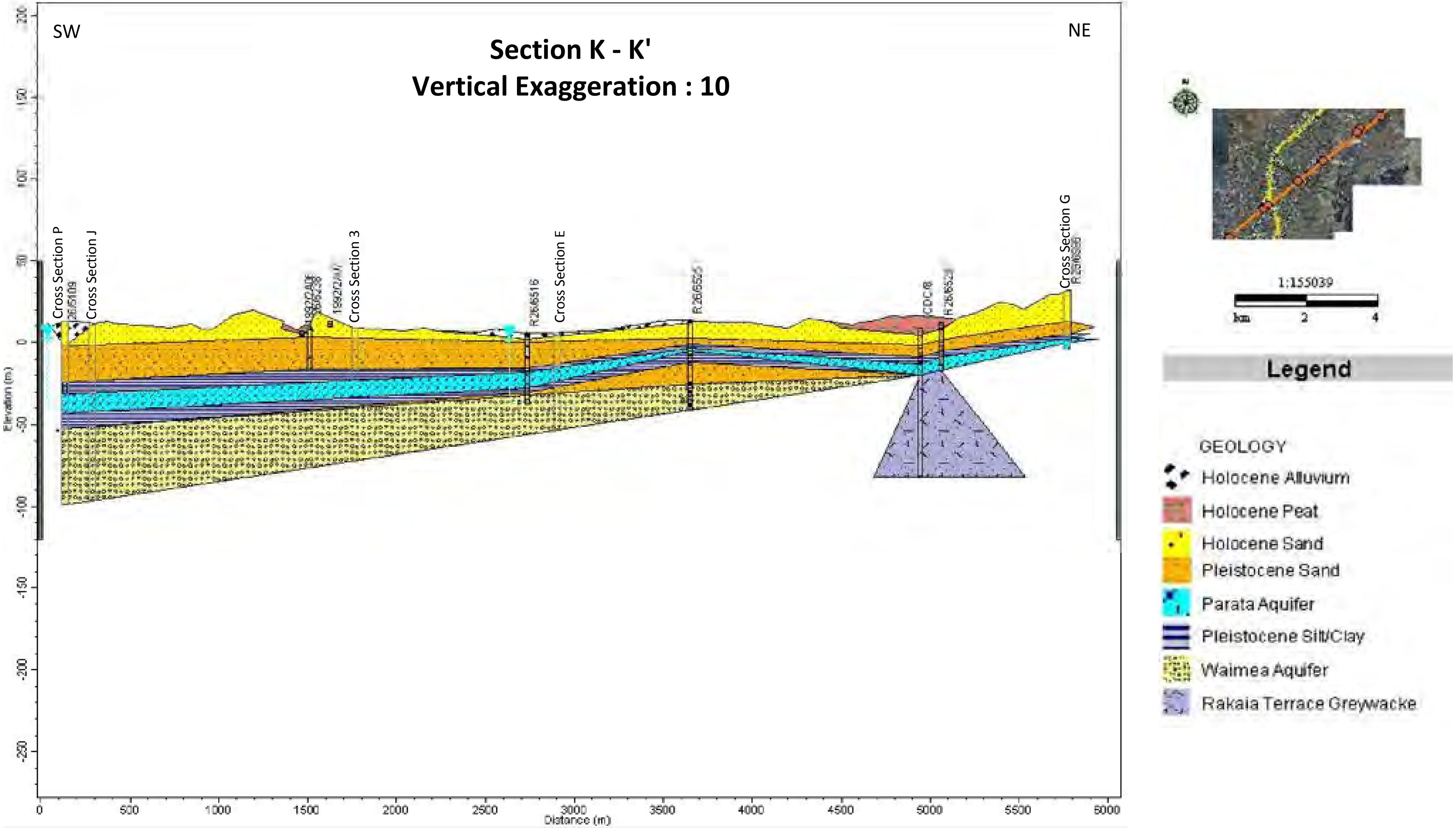


6515959

Cross Section J

Figure A-11

Kapiti Coast Water Supply



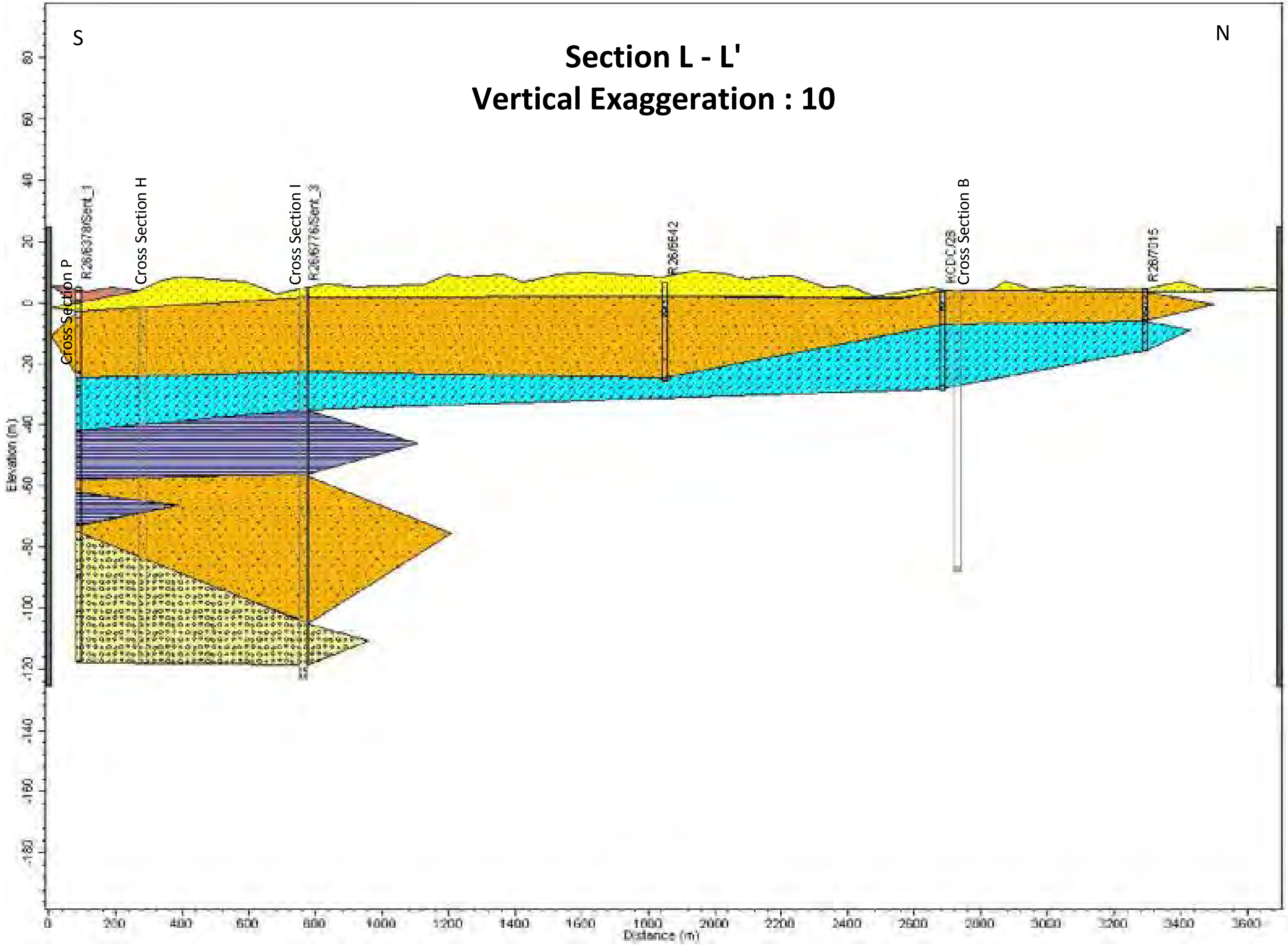
CH2M Beca

6515959

Cross Section K

Figure A-12

Kapiti Coast Water Supply



Legend

GEOLOGY

- Holocene Alluvium
- Holocene Peat
- Holocene Sand
- Pleistocene Sand
- Parata Aquifer
- Pleistocene Silt/Clay
- Waimea Aquifer
- Rakaia Terrace Greywacke

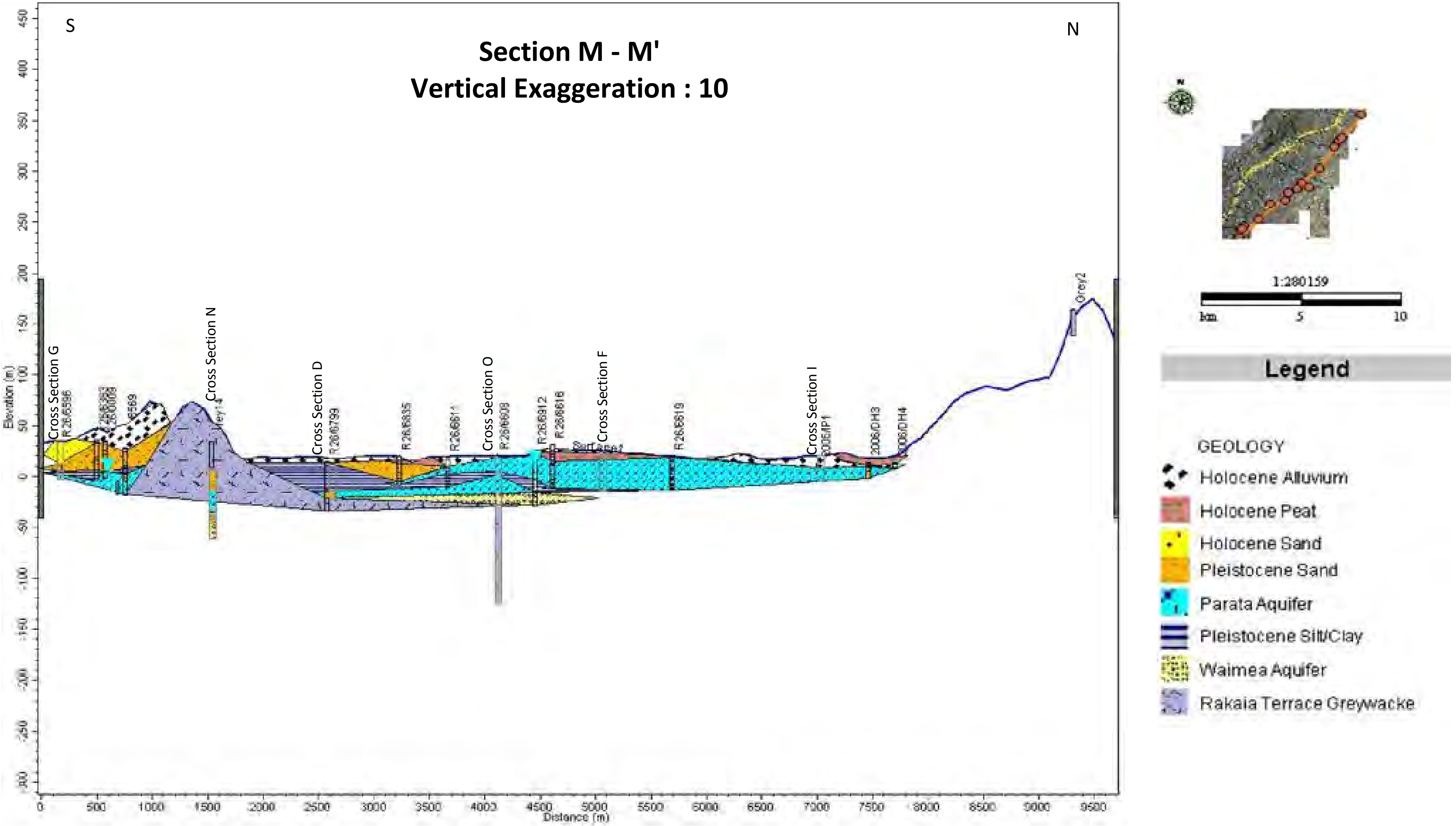
CH2M Beca

6515959

Cross Section L

Figure A-13

Kapiti Coast Water Supply



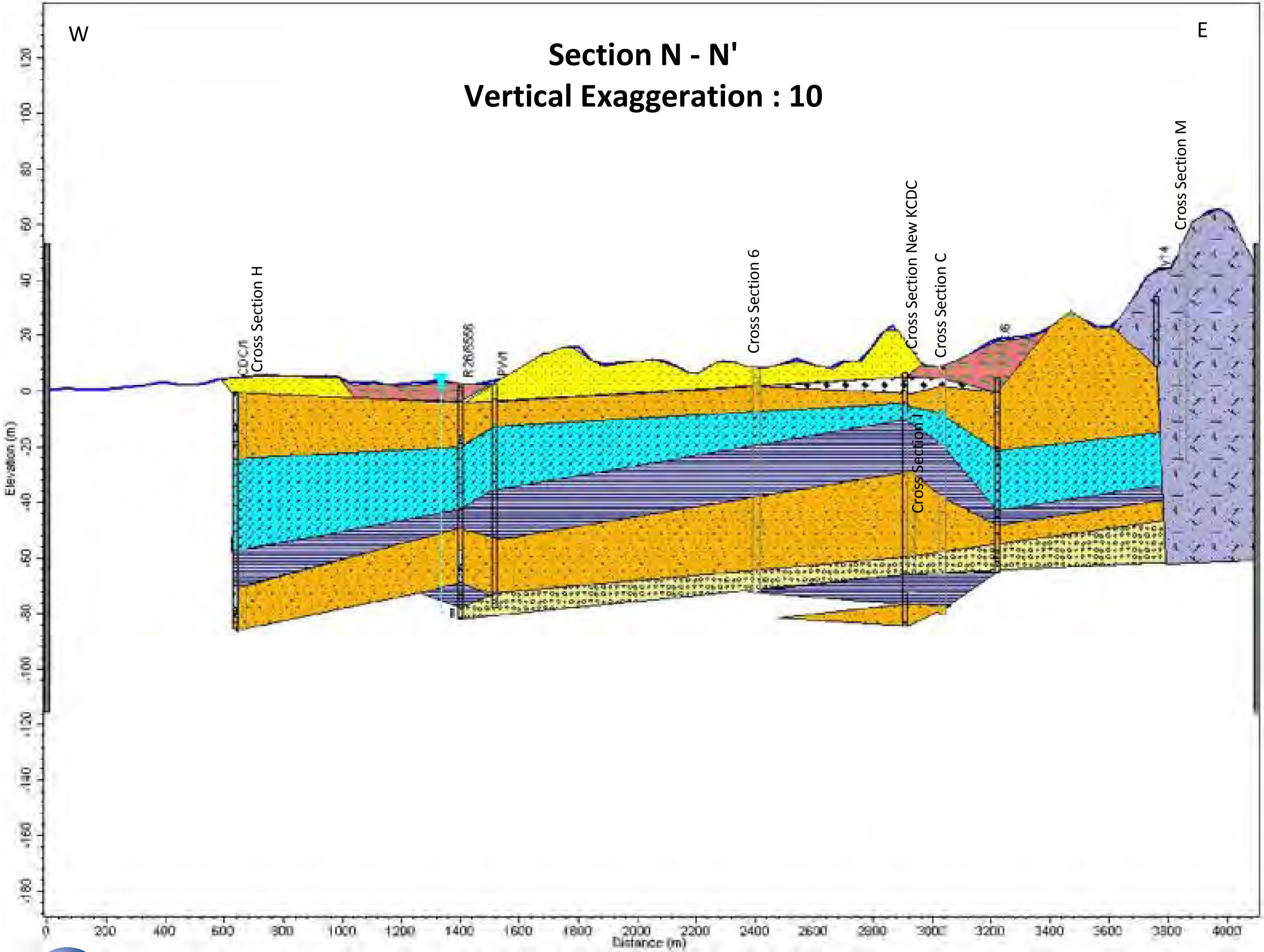
CH2M Beca

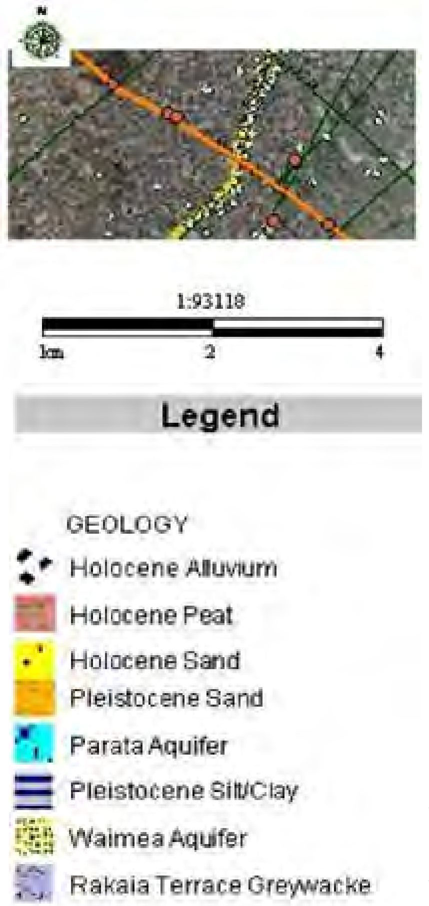
6515959

Cross Section M

Figure A-14

Kapiti Coast Water Supply





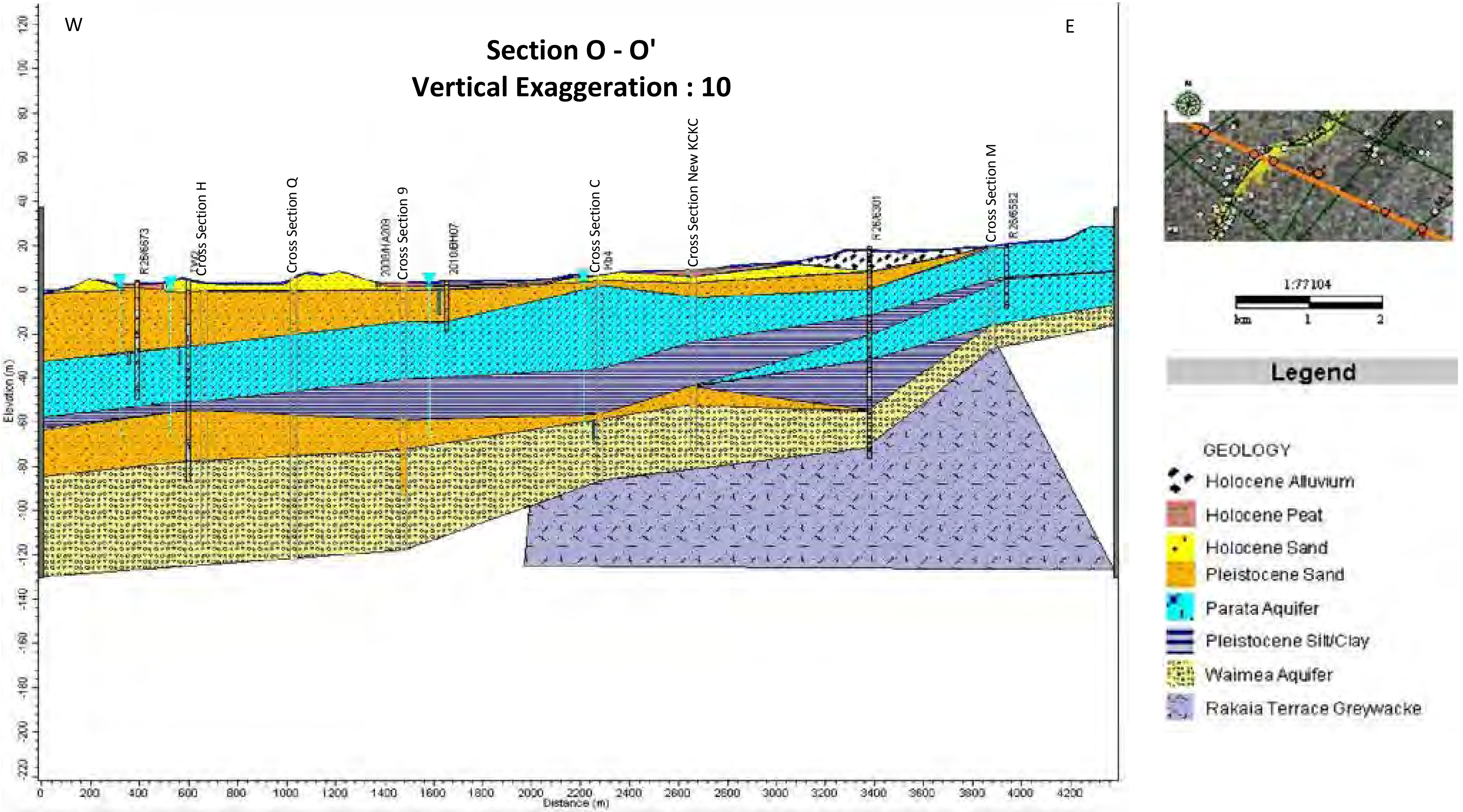
CH2M Beca

6515959

Cross Section N

Figure A-15

Kapiti Coast Water Supply



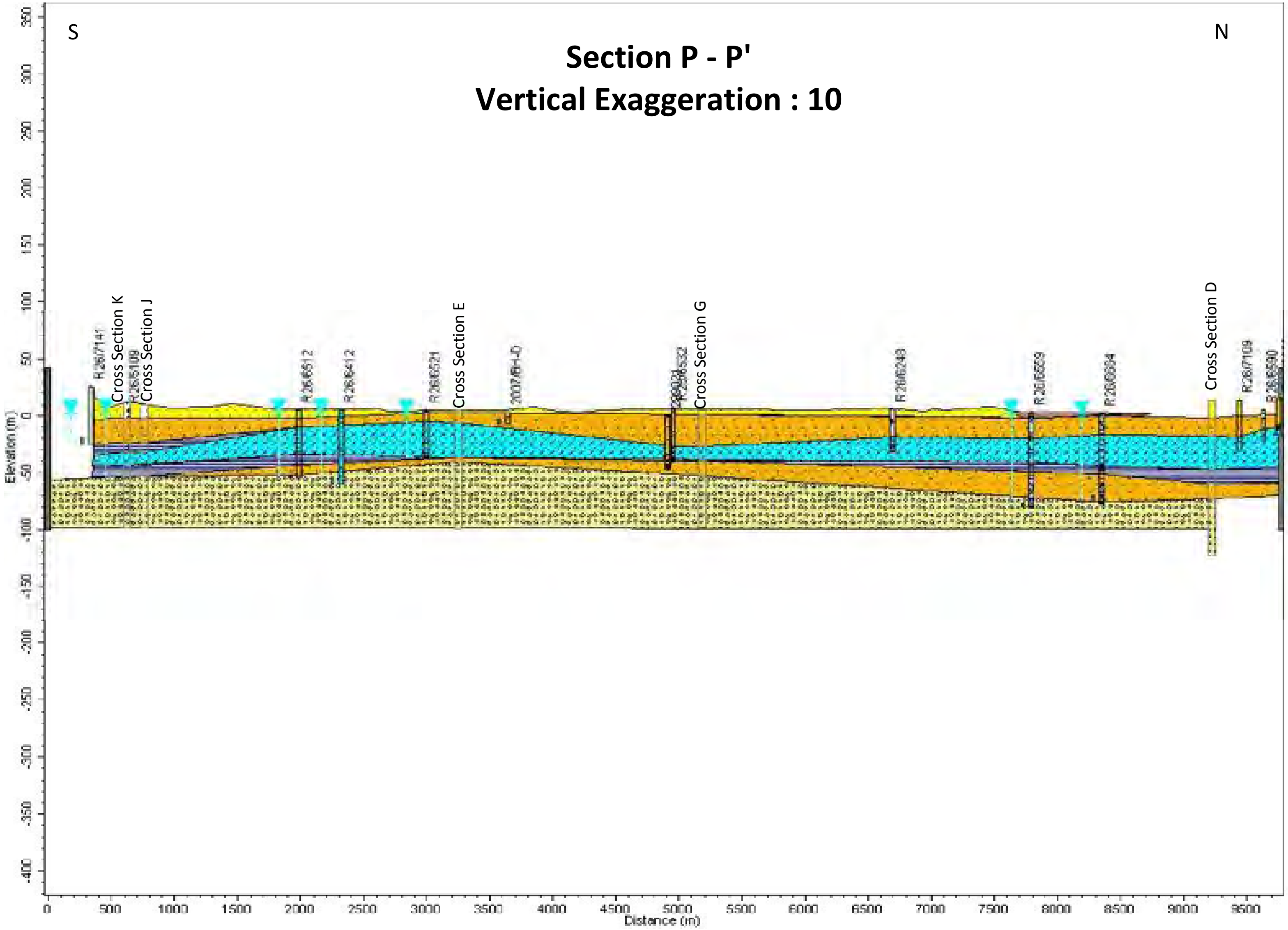
CH2M Beca

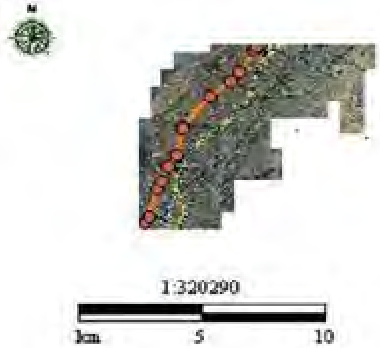
6515959

Cross Section O

Figure A-16

Kapiti Coast Water Supply



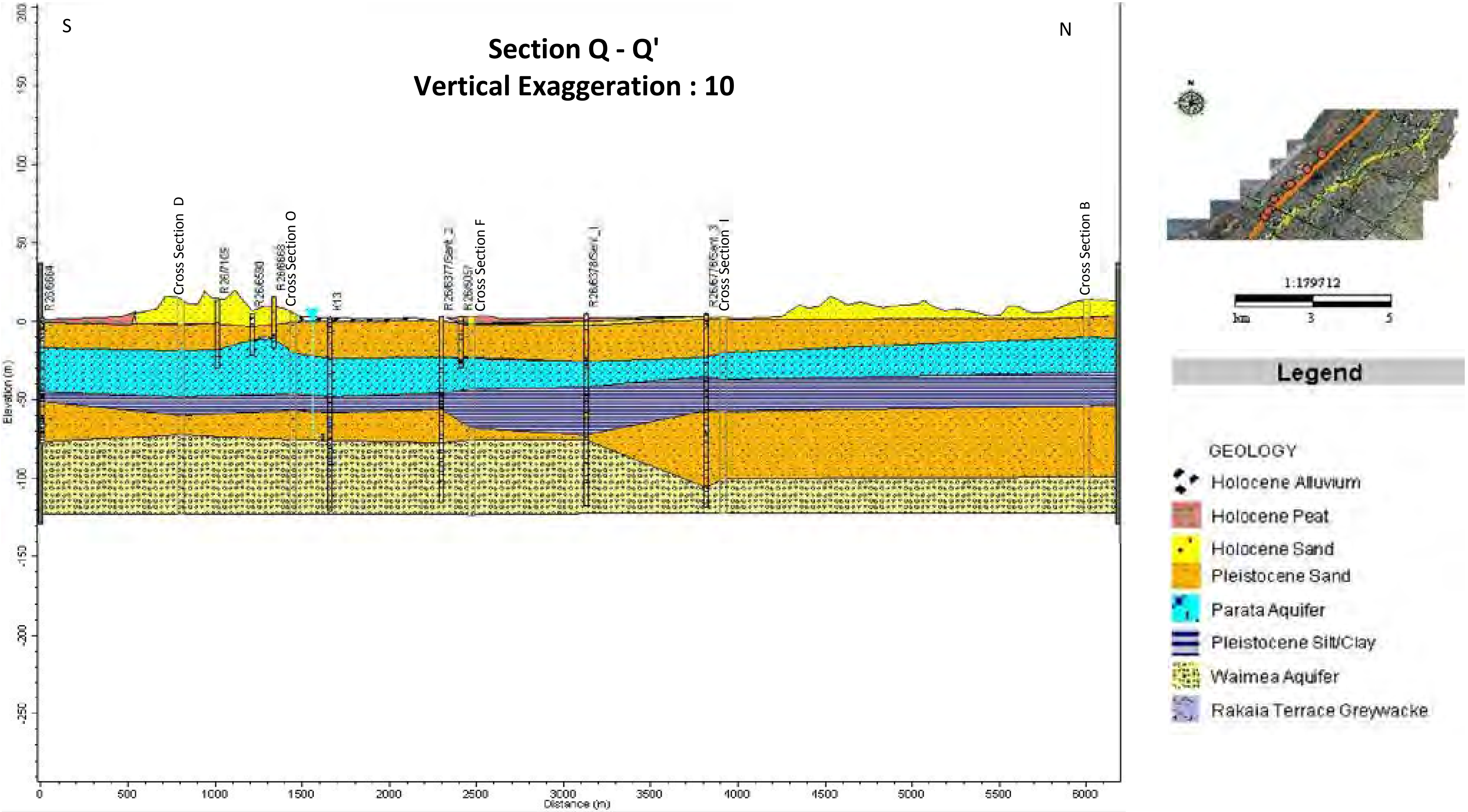


CH2M Beca

6515959

Cross Section P

Figure A-17

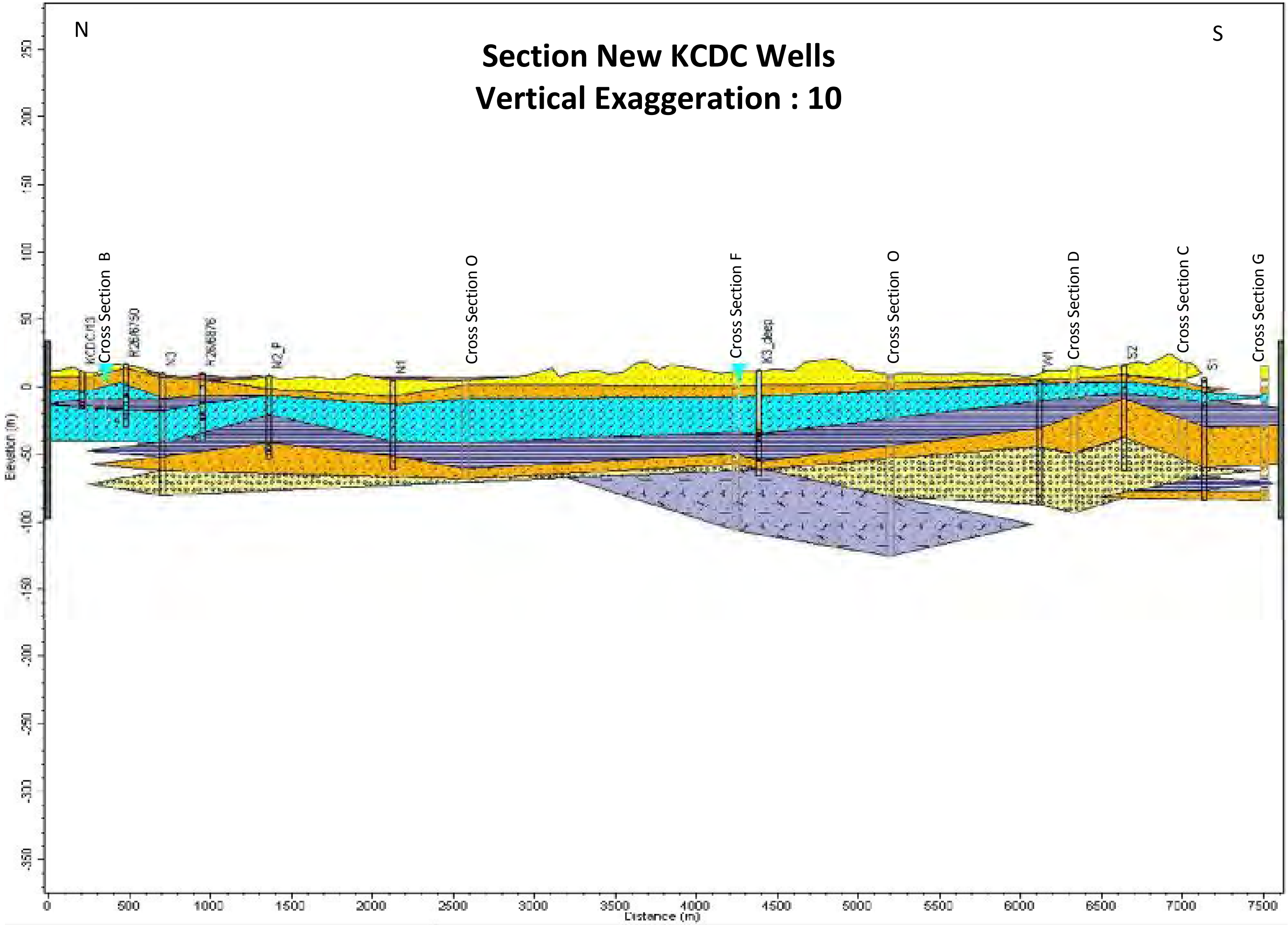


CH2M Beca
6515959

Cross Section Q

Figure A-18

Kapiti Coast Water Supply



CH2M Beca

6515959

Cross Section New KCDC Wells

Figure A-19

Appendix B

Pumping Test Data

Well Hydrogeology and Construction Details

B1

Well	**K4**			**K4 obs**			**Kb4**			**K5**			**K6**		
	Elevation		Depth	Elevation		Depth	Elevation		Depth	Elevation		Depth	Elevation		Depth
Unit	Top (mRL)	Thickness (m)	Top (mBGL)	Top (mRL)	Thickness (m)	Top (mBGL)	Top (mRL)	Thickness (m)	Top (mBGL)	Top (mRL)	Thickness (m)	Top (mBGL)	Top (mRL)	Thickness (m)	Top (mBGL)
Holocene Peat/Alluvium/fill	-	-	-	-	-	-	-	-	-	7.67	4.31	0	-	-	-
Holocene Sand	11.97	6.7	0	12.01	17.59	0	6.48	2.12	0	3.36	2.86	4.31	4.72	10	0
Pleistocene Sand (upper)	5.27	17.6	6.7	-5.58	6.47	17.59	4.36	2.14	2.12	0.5	13.38	7.17	-5.28	10.45	10
Pleistocene Silt	-	0	-	-	0	-	-	0	-	-	0	-	-	0	-
Parata	-12.3	24.8	24.3	-12.1	24.9	24.06	2.22	40.83	4.26	-12.9	39.27	20.55	-15.7	26.05	20.45
Pleistocene Silt	-37.1	15.4	49.1	-37	22.06	48.96	-38.61	19.69	45.09	-52.2	15.28	59.82	-41.8	8.7	46.5
Pleistocene Sand (lower)	-52.5	9.67	64.5	-59	15.77	71.02	-58.3	2.86	64.78	-67.4	21.45	75.1	-50.5	7.1	55.2
Pleistocene Silt	-62.2		74.17	-	0	-	-	0	-	-	0	-	-	0	-
Waimea				-74.8	28.27	86.79	-61.16	24.58	67.64	-88.9	14.79	96.55	-57.6	4	62.3
Bottom (projected) of Waimea				-103		115.06				-104			-61.6		66.3
Deep Silt															
Lower Aquifer															
Greywacke							-85.74		92.22						
Well Screen (Pumping Well)															
Top	-55.7		67.7				-58.77		65.25	-69.6		77.26	-59.5		64.25
Length			5						8.55			21			2.03
Bottom	-60.7		72.7				-67.32		73.8	-90.6		98.26	-61.6		66.28
Well Screen (Shallow Obs)															
Top				2.01		10				-4.64		8			
Length						2						4			
Bottom				0.01		12				-8.64		12			
Well Screen (Deep obs)															
Top				-66		78									
Length						4									
Bottom				-70		82									
Well Coordinates															
Easting	1772811			1772137			1772137			1772982			1773142		
Northing	5474628			5473591			5473591			5475127			5475373		

Well Hydrogeology and Construction Details

B2

Well	Kb7			K10			K13			N1			N2 PW		
	Elevation		Depth	Elevation		Depth	Elevation		Depth	Elevation		Depth	Elevation		Depth
Unit	Top (mRL)	Thickness (m)	Top (mBGL)	Top (mRL)	Thickness (m)	Top (mBGL)	Top (mRL)	Thickness (m)	Top (mBGL)	Top (mRL)	Thickness (m)	Top (mBGL)	Top (mRL)	Thickness (m)	Top (mBGL)
Holocene Peat/Alluvium/fill	-	-	-	3.74	1	0	2.56	0.9	0	13.15	0.2	0	8.84	0.5	0
Holocene Sand	7.78	18.81	0	2.74	2.5	1	2.56	-	-	12.95	11.8	0.2	8.34	9.5	0.5
Pleistocene Sand (upper)	-11	0.56	18.81	0.24	14.6	3.5	7.48	24.9	0.9	1.15	5	12	-1.16	4.9	10
Pleistocene Silt	-	0	-	-	0	-	-	-	-	-	0	-	-	0	-
Parata	-11.6	32.47	19.37	-14.4	24.8	18.1	-2.29	24.2	25.8	-3.85	28.28	17	-6.06	14.55	14.9
Pleistocene Silt	-44.1	19.02	51.84	-39.2	18.4	42.9	-9.26	19.8	50	-32.1	10.72	45.28	-20.6	15.55	29.45
Pleistocene Sand (lower)	-63.1	9.47	70.86	-57.6	36.9	61.3	-15.74	7.2	69.8	-42.9	15	56	-36.2	11	45
Pleistocene Silt	-	0	-	-	0	-		-	-	-	0	-	-47.2	2	56
Waimea	-72.6	22.45	80.33	-94.5	24.8	98.2		46	77	-64	7	71	-64	13	58
Bottom (projected) of Waimea	-95		102.78	-119		123			123	-77		78	-77		
Deep Silt															
Lower Aquifer															
Greywacke															
Well Screen (Pumping Well)															
Top	-65		72.8	-71.4		75.1	-71.04		73.6				-45.3		53.6
Length			9			24			4						5
Bottom	-74		81.8	-95.4		99.1	-75.04		77.6				-50.3		58.6
Well Screen (Shallow Obs)															
Top	-49.2		57	-7.26		10	-7.44		10	-1.85		14.8			
Length			1.5			2			2			9			
Bottom	-50.7		58.5	-9.26		12	-9.44		12	-10.9		23.8			
Well Screen (Deep obs)															
Top	-62.2		70	-77.3		80	-67.44		70	-42.1		55			
Length			3			5			4			9			
Bottom	-65.2		73	-82.3		85	-71.44		74	-51.1		64			
Well Coordinates															
Easting	1773584			1771429			1770966			1774635			1774723		
Northing	5475489			5473876			5474329			5475457			5476384		

Well Hydrogeology and Construction Details

B3

Well	N2 Obs			Brown domestic			N3			S1			S2		
	Elevation		Depth	Elevation		Depth	Elevation		Depth	Elevation		Depth	Elevation		Depth
Unit	Top (mRL)	Thickness (m)	Top (mBGL)	Top (mRL)	Thickness (m)	Top (mBGL)	Top (mRL)	Thickness (m)	Top (mBGL)	Top (mRL)	Thickness (m)	Top (mBGL)	Top (mRL)	Thickness (m)	Top (mBGL)
Holocene Peat/Alluvium/fill	7.07	3.85	0	8	3	0	10.14	3	0	7.64	3	0	-	-	-
Holocene Sand	3.22	6.15	3.85	5	7	3	-	-	-	4.64	3.85	3	15.5	6	0
Pleistocene Sand (upper)	-2.93	4.9	10	-2	5	10	7.14	15.25	3	0.79	3.85	6.85	9.5	5.4	6
Pleistocene Silt	-	0	-	-	0		-8.11	9.15	18.25	-	0	-	-	-	-
Parata	-7.83	14.95	14.9	-7	15	15	-17.26	22.6	27.4	-3.06	9.4	10.7	4.1	8.6	11.4
Pleistocene Silt	-22.8	21.45	29.85	-22	21	30	-39.86	11.8	50	-12.5	15.9	20.1	-4.5	1.4	20
Pleistocene Sand (lower)	-44.2	8.65	51.3	-43	9	51	-51.66	10.1	61.8	-28.4	30.35	36	-5.9	31.45	21.4
Pleistocene Silt	-	0	-	-	0		-	0	-	-	0	-	-		
Waimea	-52.9	24.12	59.95	-52	16	60	-61.76	18.7	71.9	-58.7	6.45	66.35	-37.4	24.35	52.85
Bottom (projected) of Waimea	-77			-77		76	-80.46		90.6	-	-	-	-		-
Deep Silt				(Depths & elevation estimated based on N2 obs, rounded to nearest m)						-65.2	10.65	72.8	-		-
Lower Aquifer										-75.8	6.55	83.45	-		-
Greywacke										-82.4		90	-61.7		77.2
Well Screen (Pumping Well)															
Top															
Length															
Bottom															
Well Screen (Shallow Obs)															
Top	-19.4		26.5	-24		32	-51.46		61.6	-12.4		17	-17		32.5
Length			3			1			8.8			3			6.3
Bottom	-22.4		29.5	-25		33	-60.26		70.4	-15.4		20	-23.3		38.8
Well Screen (Deep obs)															
Top	-44.4		51.5				-63.06		73.2	-52.8		57.4	-46.4		61.9
Length			8						6.3			9			4.2
Bottom	-52.4		59.5				-69.36		79.5	-61.8		66.4	-50.8		66.3
Well coordinates															
Easting	1774741			1775482			1775124			1771150			1771550		
Northing	5476372			5475837			5476737			5471839			5472157		

Well Hydrogeology and Construction Details

B4

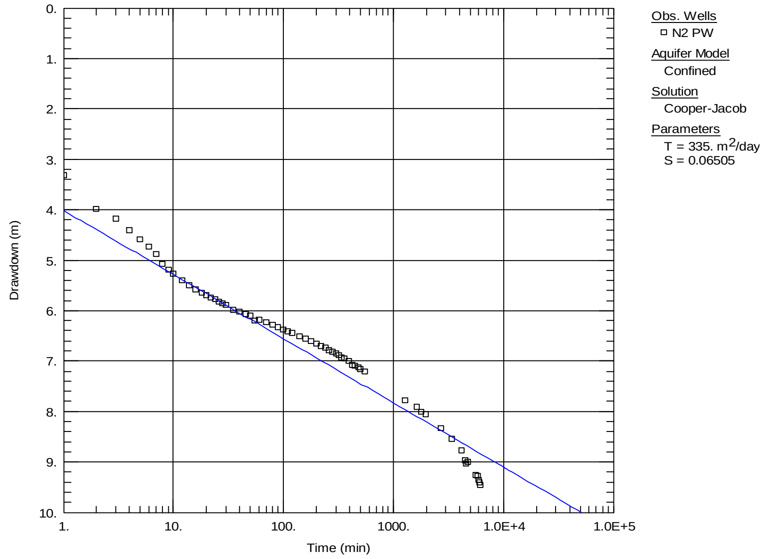
Well	Sentinel 1			Sentinel 2			Sentinel 3			TW1			TW2		
	Elevation		Depth	Elevation		Depth	Elevation		Depth	Elevation		Depth	Elevation		Depth
Unit	Top (mRL)	Thickness (m)	Top (mBGL)	Top (mRL)	Thickness (m)	Top (mBGL)	Top (mRL)	Thickness (m)	Top (mBGL)	Top (mRL)	Thickness (m)	Top (mBGL)	Top (mRL)	Thickness (m)	Top (mBGL)
Holocene Peat/Alluvium/fill	5.13	5.04	0	-	-	-	5.05	0.2	0	-	-	-	-	-	-
Holocene Sand	0.09	2.47		-	-	-	4.85	2.82	0.2	-	-	-	4.68	5.0	0
Pleistocene Sand (upper)	-2.38	22.24	7.51	3.41	26.01	0	2.03	24.72	3.02	4.91	2	0	-0.32	24.5	5
Pleistocene Silt	-	0	-	-	0	-	-	0	-	-	0	-	-	0.0	-
Parata	-24.6	16.78	29.75	-22.6	22.27	26.01	-22.69	12.1	27.74	2.91	13.06	2	-24.8	25.5	29.5
Pleistocene Silt	-41.4	16.06	46.53	-44.9	10.9	48.28	-34.79	21.27	39.84	-10.2	19.82	15.06	-50.3	4.0	55
Pleistocene Sand (lower)	-57.5	4.41	62.59	-55.8	20.93	59.18	-56.06	49.3	61.11	-30	15.16	34.88	-54.3	23.0	59
Pleistocene Silt	-61.9	10	67	-	0	-	-	0	-	-	0	-	-	0.0	-
Waimea	-71.9	45.52	77	-76.7	45.3	80.11	-105.4	17.64	110.41	-45.1	41.85	50.04	-77.3	9.0	82
Bottom (projected) of Waimea	-117		122.52	-122		125.41	-123		128.05	-87		91.89	-86.3		91
Deep Silt															
Lower Aquifer															
Greywacke															
Well Screen (Pumping Well)															
Top													-27.3		32
Length															6
Bottom													-33.3		38
Well Screen (Shallow Obs)															
Top	-105		110.5	-76.6		80	-74.95		80						
Length			12			38			22						
Bottom	-117		122.5	-115		118	-96.95		102						
Well Screen (Deep obs)															
Top															
Length															
Bottom															
Well coordinates															
Easting	1772004			1772082			1772473			1772224			1770573		
Northing	5475388			5475385			5475869			5472454			5474243		

Appendix C

Pumping Test Analyses

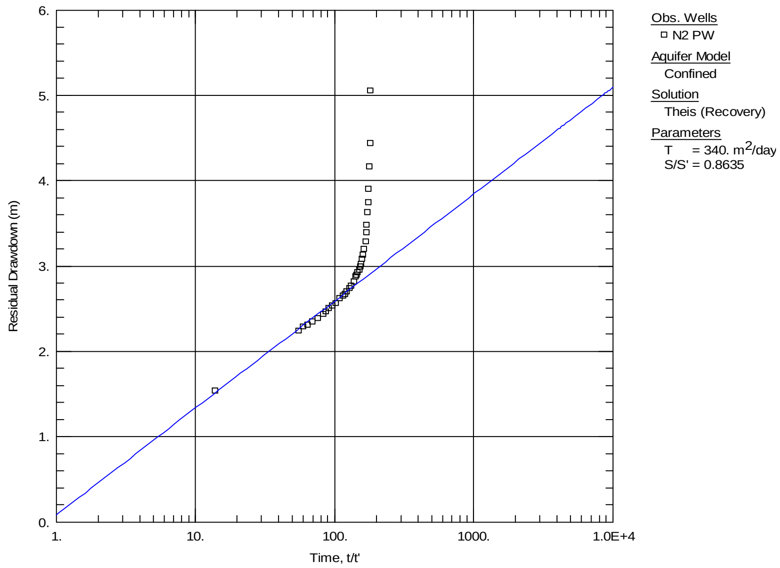
Observation well: N2 shallow

Test period: 23/04/2012 9:00:00 to 30/04/2012 13:15:00
Pumping rate: 32.2 l/s



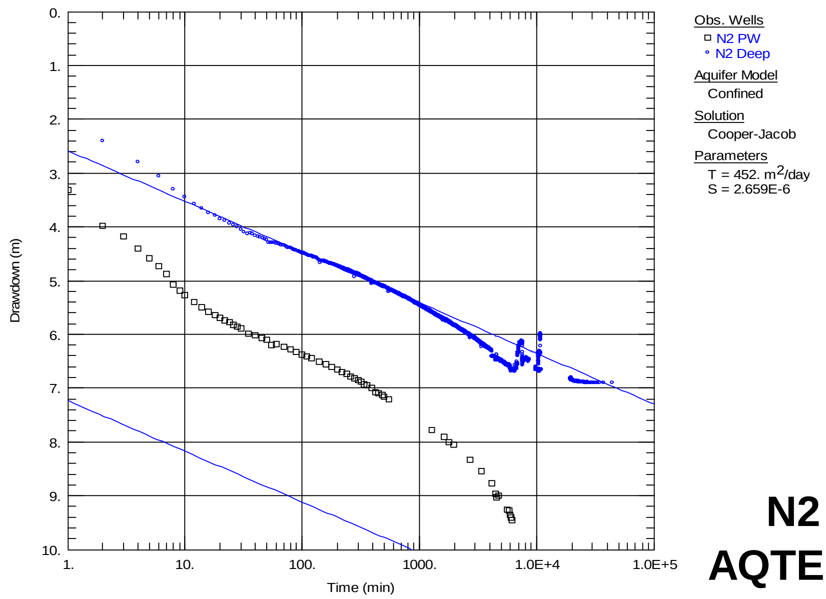
Observation well: N2 Shallow

Test period: 23/04/2012 9:00:00 to 30/04/2012 13:15:00
Pumping rate: 32.2 l/s



Observation well: N2 Deep

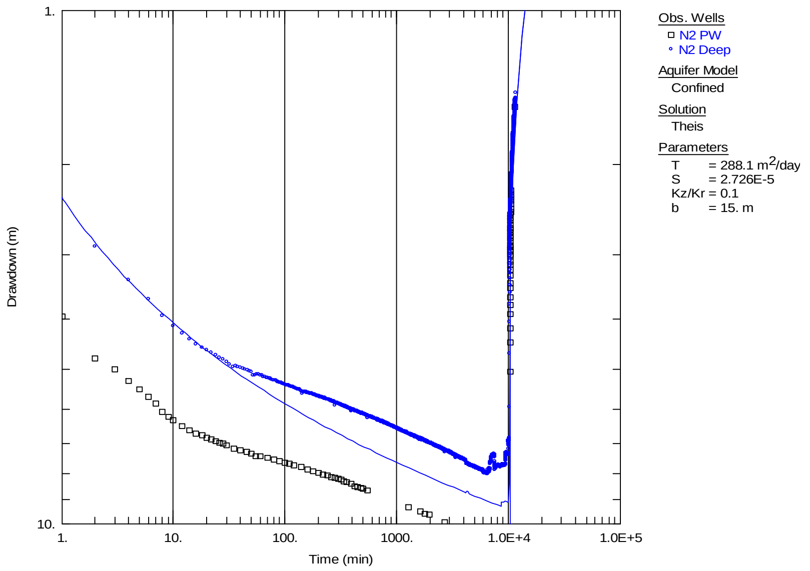
Test period: 23/04/2012 9:00:00 to 30/04/2012 13:15:00
Pumping rate: 32.2 l/s



N2 Pumping Test
AQTESOLV Analysis

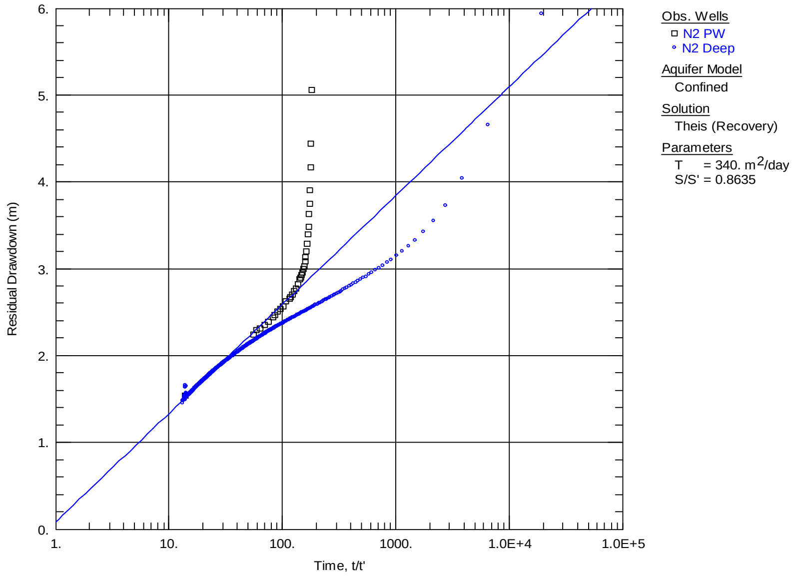
Observation well: N2 Deep

Test period: 23/04/2012 9:00:00 to 30/04/2012 13:15:00
Pumping rate: 32.2 l/s



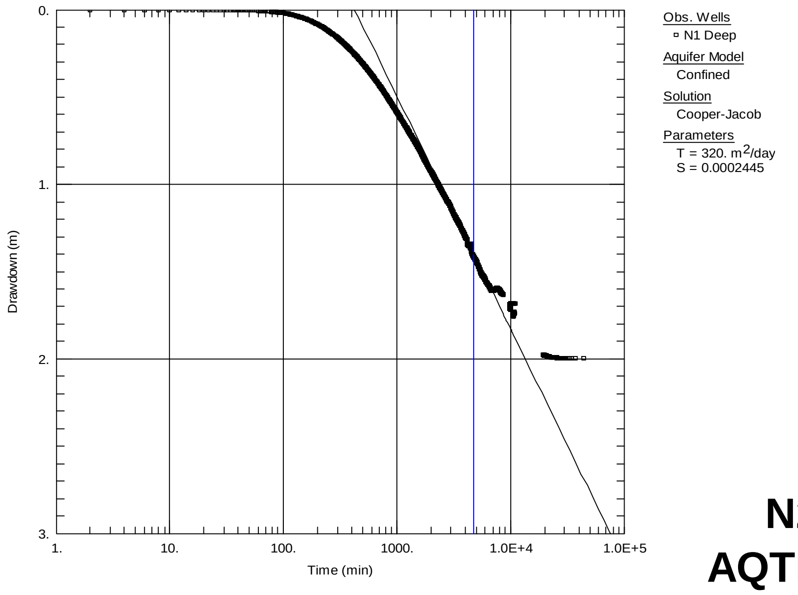
Observation well: N2 Deep

Test period: 23/04/2012 9:00:00 to 30/04/2012 13:15:00
Pumping rate: 32.2 l/s



Observation well: N1 Deep

Test period: 23/04/2012 9:00:00 to 30/04/2012 13:15:00
Pumping rate: 32.2 l/s



N2 Pumping Test
AQTESOLV Analysis

CH2M Beca

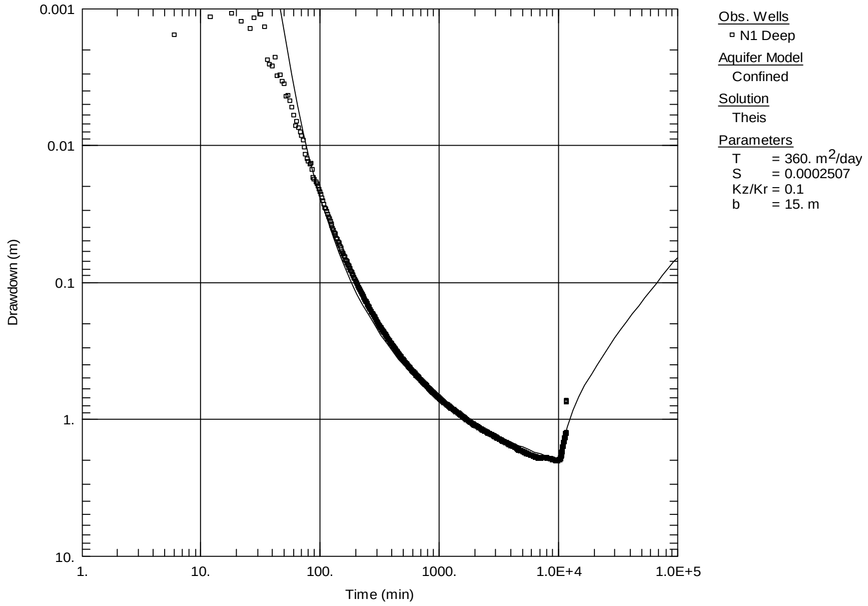
6515959/402

Appendix C

Observation well: N1 Deep

Test period: 23/04/2012 9:00:00 to 30/04/2012 13:15:00

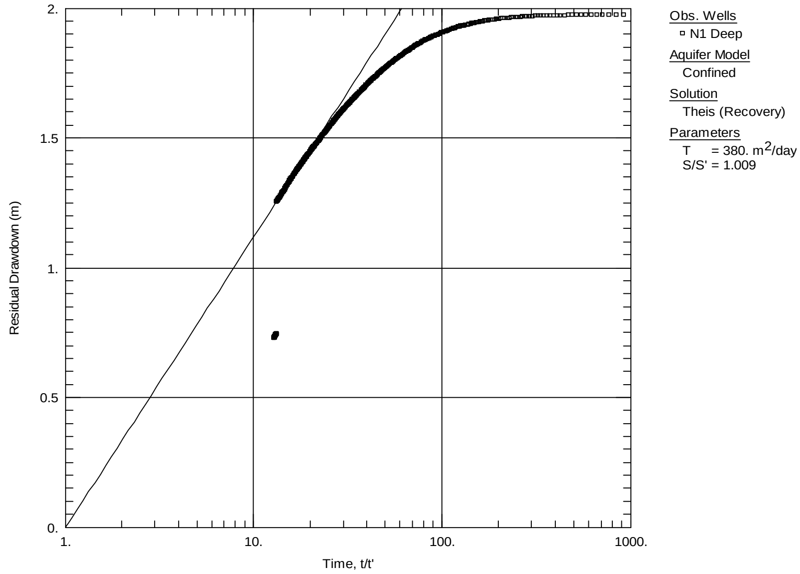
Pumping rate: 32.2 l/s



Observation well: N1 Deep

Test period: 23/04/2012 9:00:00 to 30/04/2012 13:15:00

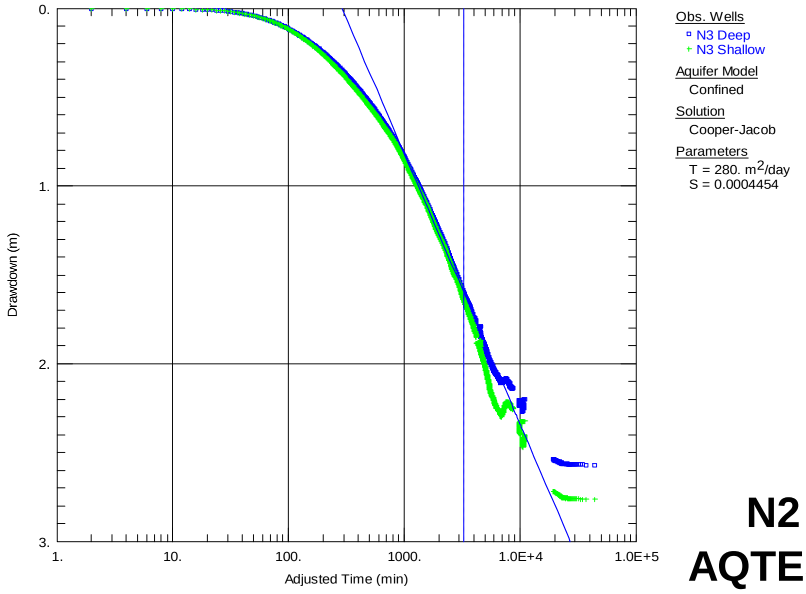
Pumping rate: 32.2 l/s



Observation well: N3 Deep

Test period: 23/04/2012 9:00:00 to 30/04/2012 13:15:00

Pumping rate: 32.2 l/s



N2 Pumping Test AQTESOLV Analysis

CH2M Beca

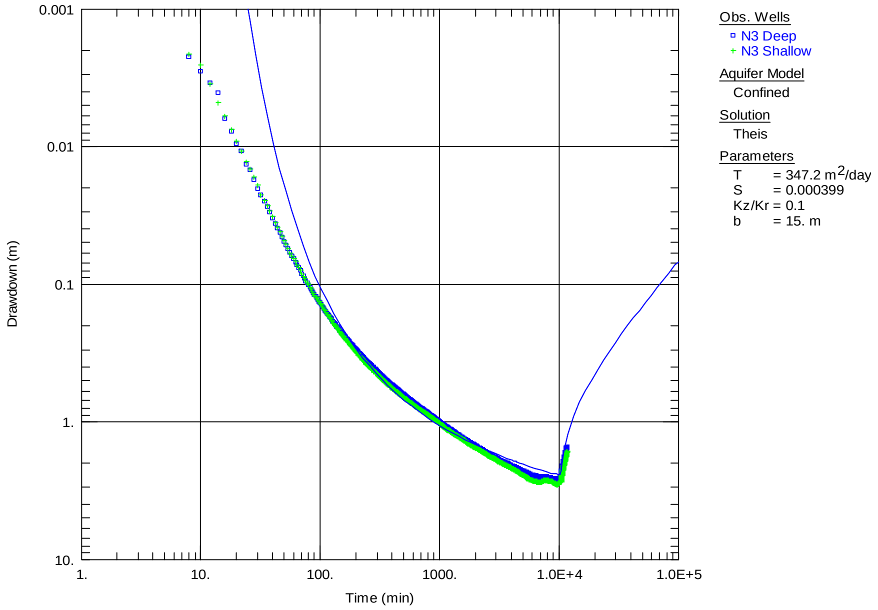
6515959/402

Appendix C

Observation well: N3 Deep

Test period: 23/04/2012 9:00:00 to 30/04/2012 13:15:00

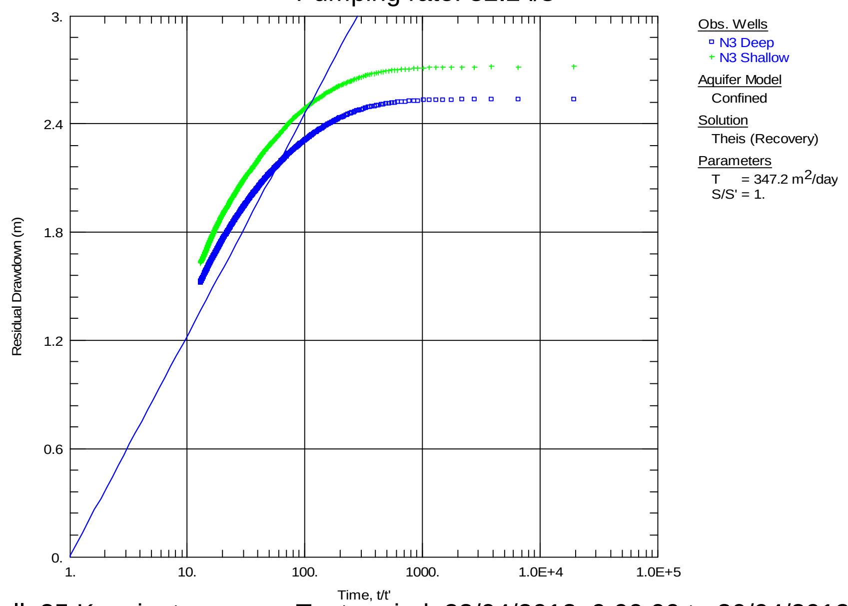
Pumping rate: 32.2 l/s



Observation well: N3 Deep

Test period: 23/04/2012 9:00:00 to 30/04/2012 13:15:00

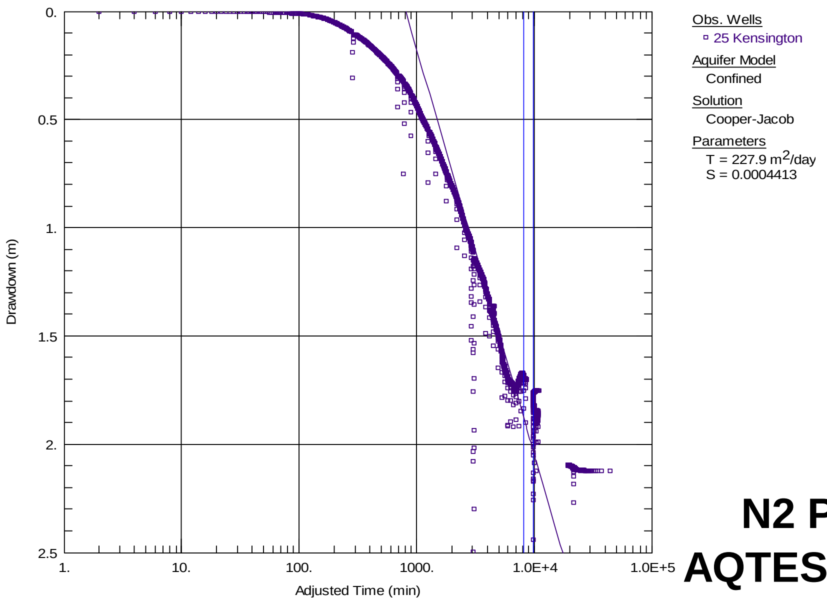
Pumping rate: 32.2 l/s



Observation well: 25 Kensington

Test period: 23/04/2012 9:00:00 to 30/04/2012 13:15:00

Pumping rate: 32.2 l/s



N2 Pumping Test
AQTESOLV Analysis

CH2M Beca

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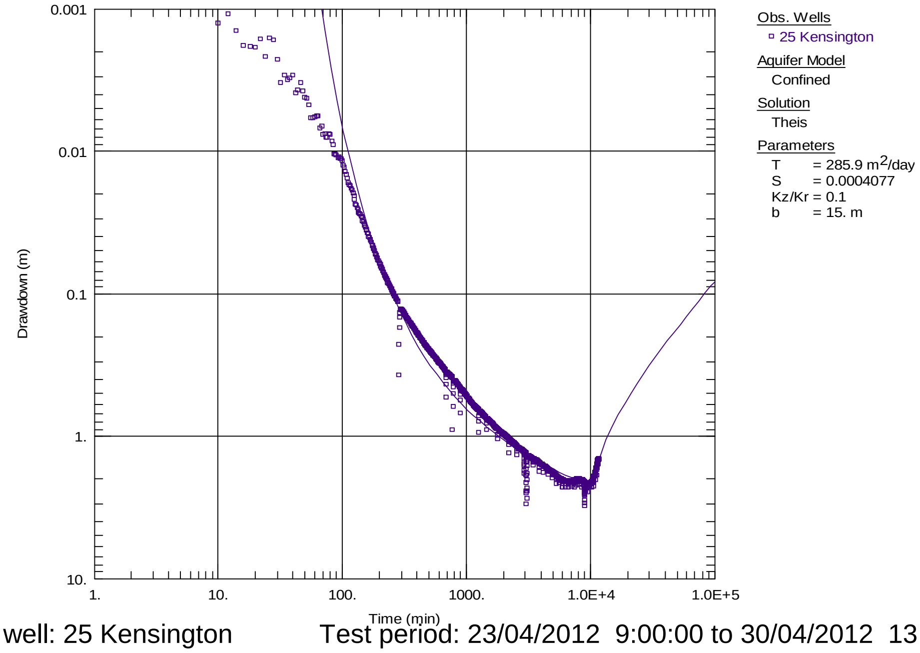
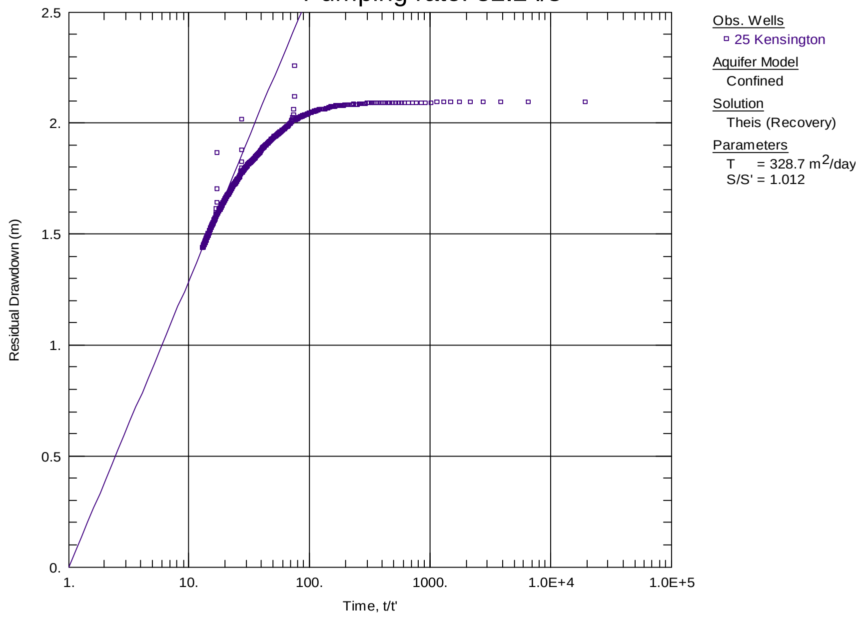
Appendix C

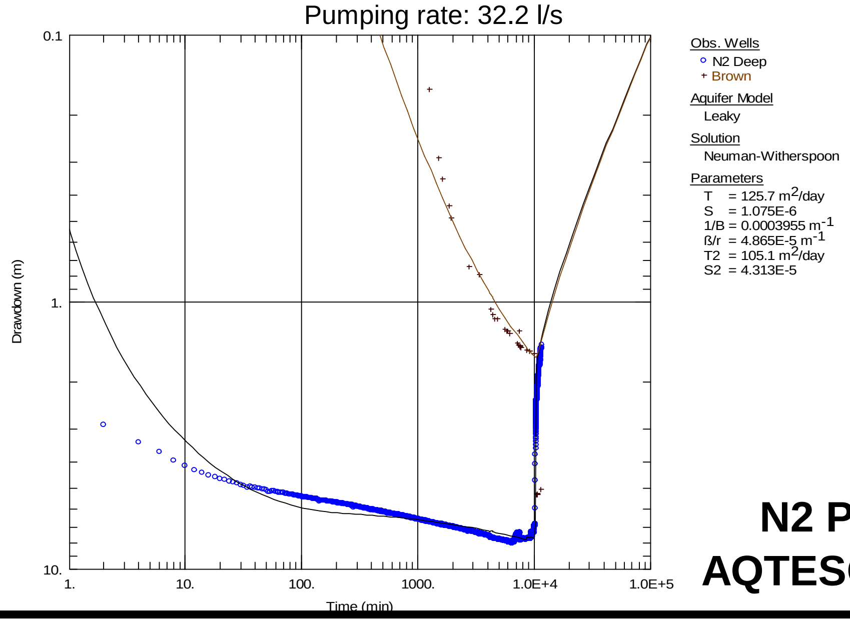
Observation well: 25 Kensington | Test period: 23/04/2012 9:00:00 to 30/04/2012 13:15:00
Pumping rate: 32.2 l/s



Observation well: 25 Kensington | Test period: 23/04/2012 9:00:00 to 30/04/2012 13:15:00
Pumping rate: 32.2 l/s



Observation well: Brown | Test period: 23/04/2012 9:00:00 to 30/04/2012 13:15:00
Pumping rate: 32.2 l/s

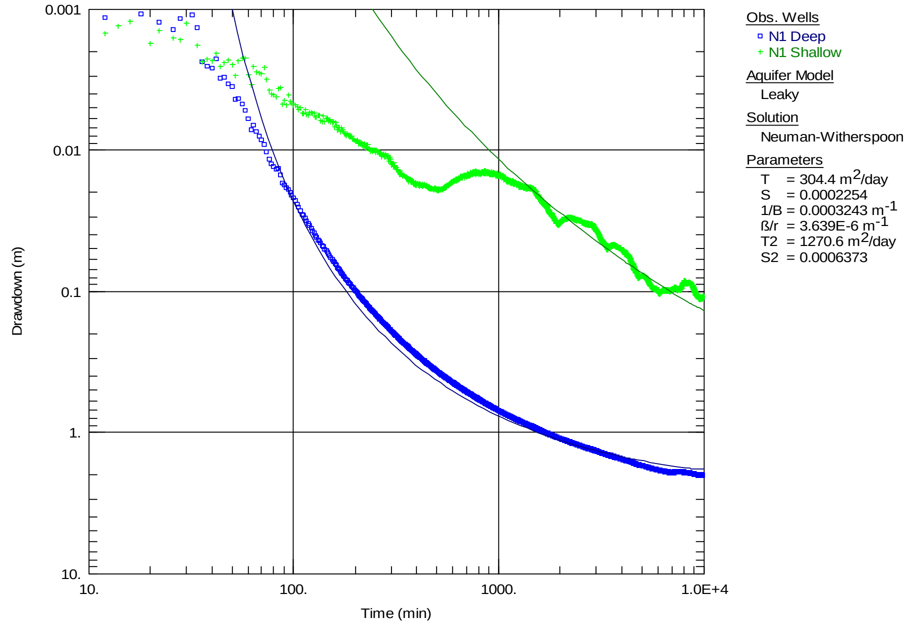


N2 Pumping Test
AQTESOLV Analysis

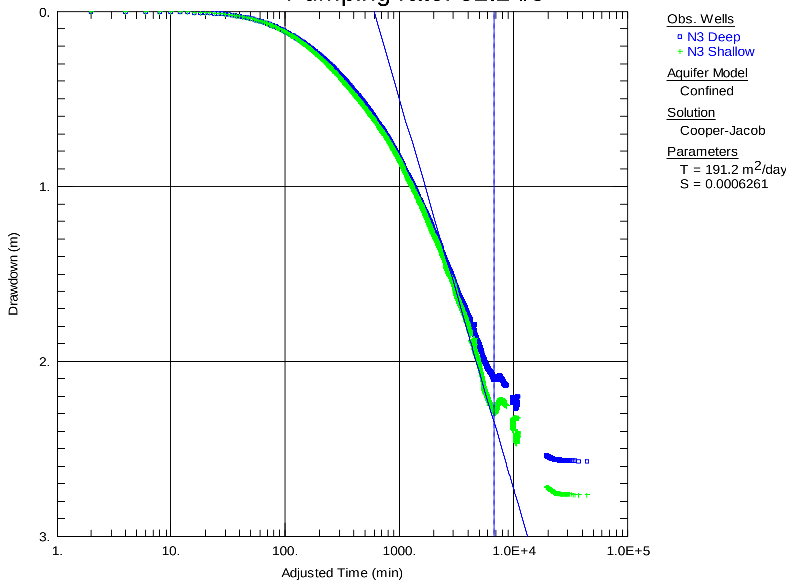
CH2M Beca

Appendix C

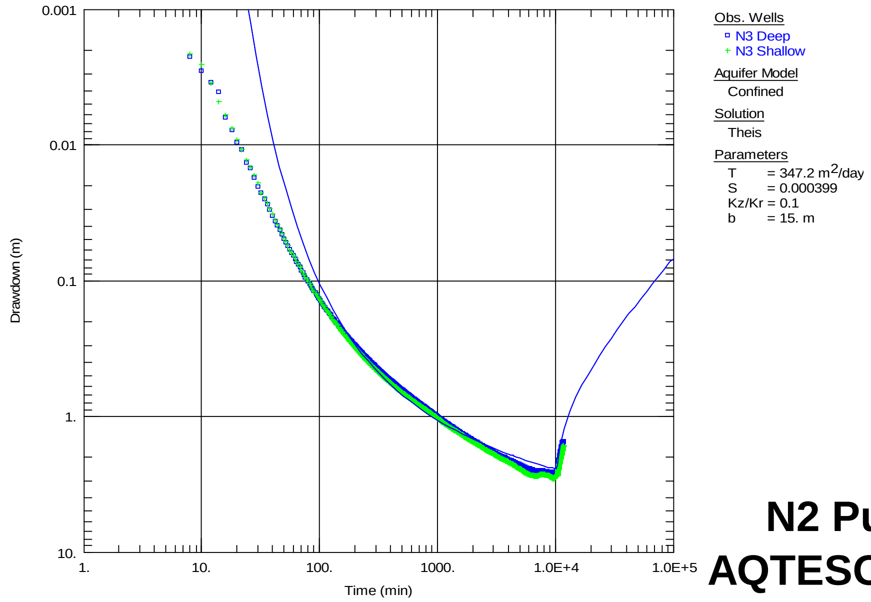
Observation well: N1 Shallow Test period: 23/04/2012 9:00:00 to 30/04/2012 13:15:00
Pumping rate: 32.2 l/s



Observation well: N3 Shallow Test period: 23/04/2012 9:00:00 to 30/04/2012 13:15:00
Pumping rate: 32.2 l/s



Observation well: N3 Shallow Test period: 23/04/2012 9:00:00 to 30/04/2012 13:15:00
Pumping rate: 32.2 l/s



N2 Pumping Test AQTESOLV Analysis

CH2M Beca

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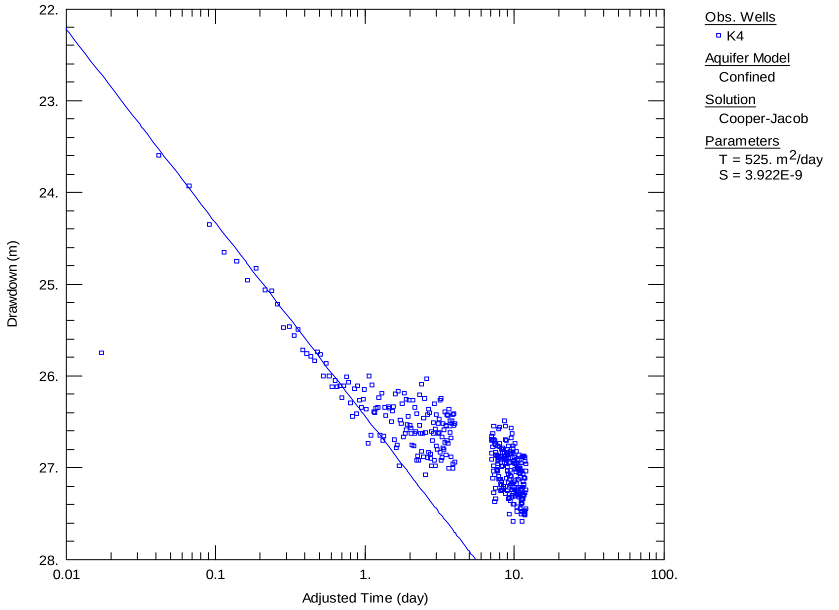
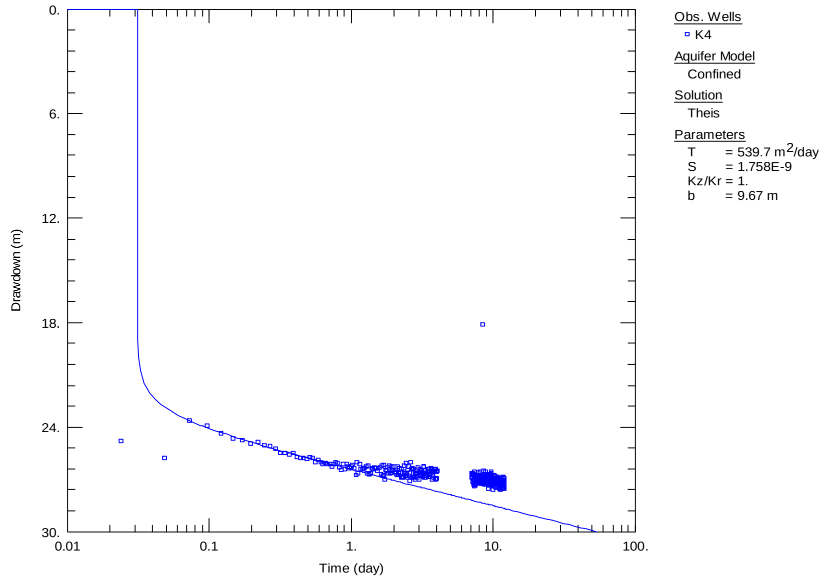
Observation well: K4

Test period: 6/05/2010 10:00:00 to 18/05/2010 9:00:00
Pumping rate: 70 l/s



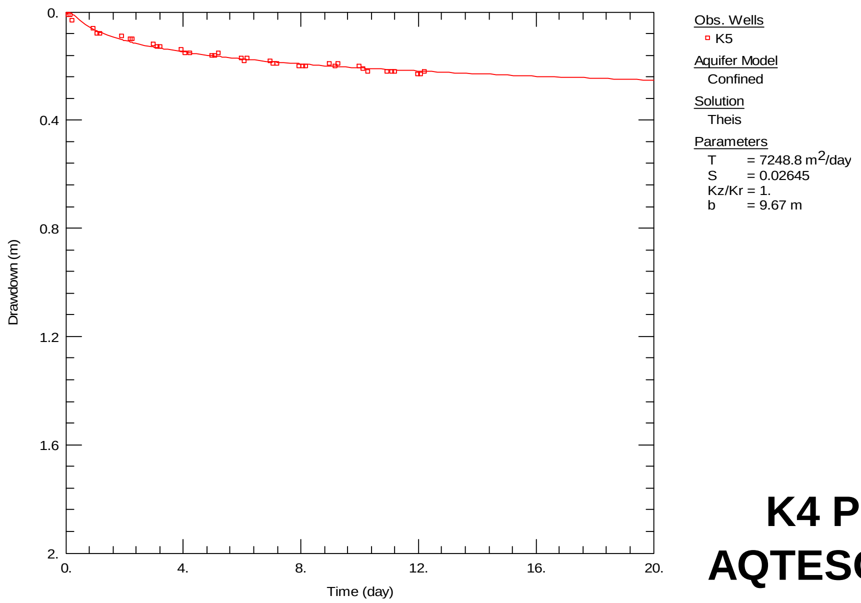
Observation well: K4

Test period: 6/05/2010 10:00:00 to 18/05/2010 9:00:00
Pumping rate: 70 l/s



Observation well: K5

Test period: 6/05/2010 10:00:00 to 18/05/2010 9:00:00
Pumping rate: 70 l/s

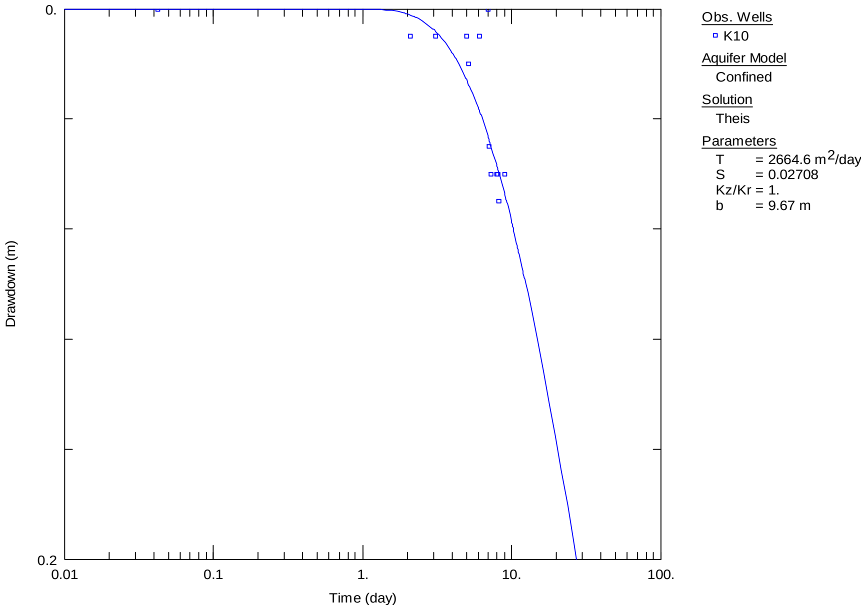


K4 Pumping Test
AQTESOLV Analysis

CH2M Beca

Observation well: K10

Test period: 6/05/2010 10:00:00 to 18/05/2010 9:00:00
Pumping rate: 70 l/s

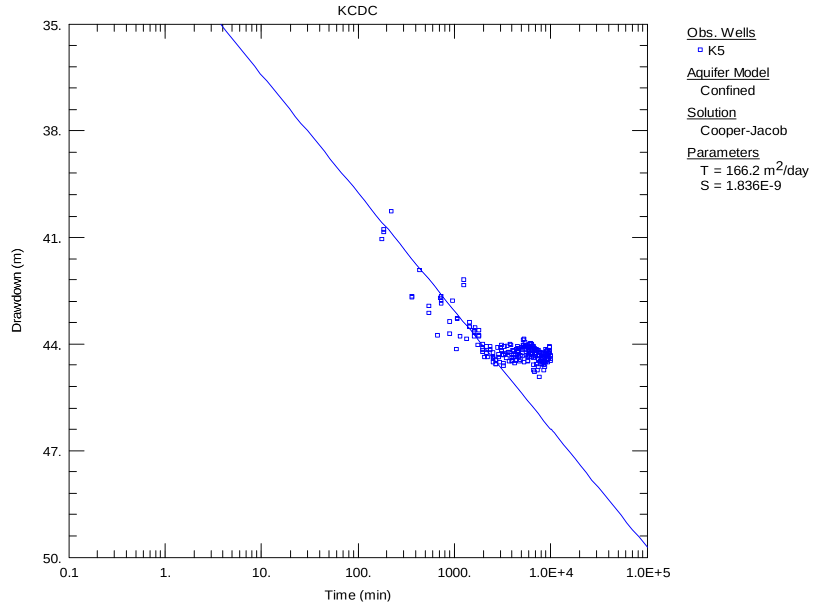


K4 Pumping Test
AQTESOLV Analysis

CH2M Beca

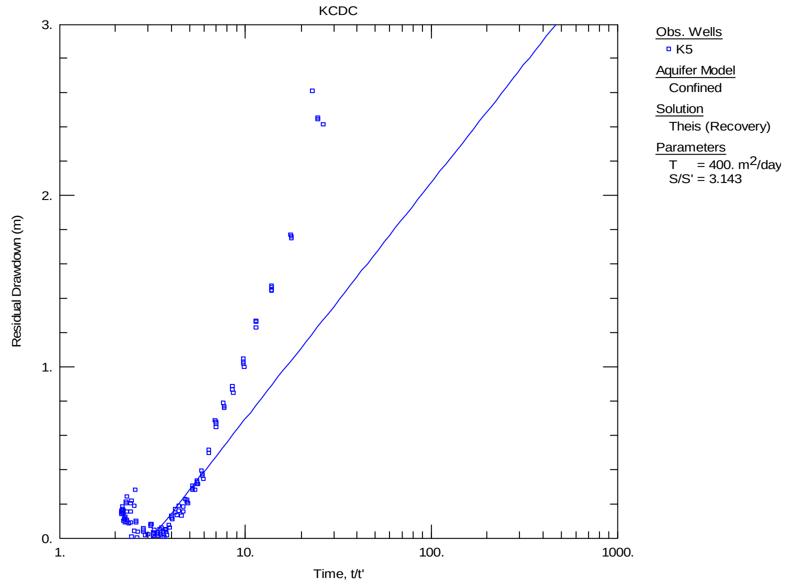
Observation well: K5

Test period: 25/01/2012 11:52:00 to 1/02/2012 10:19:00
Pumping rate: 34.9 l/s



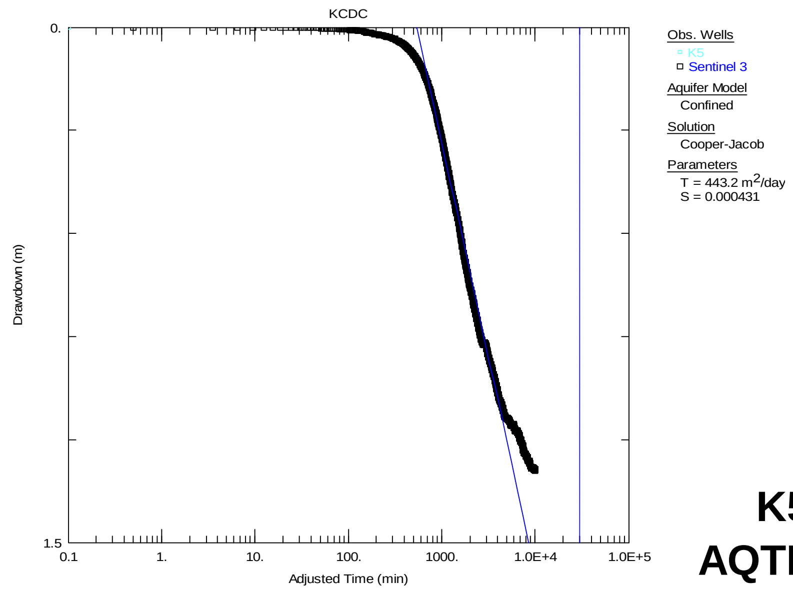
Observation well: K5

Test period: 25/01/2012 11:52:00 to 1/02/2012 10:19:00
Pumping rate: 34.9 l/s



Observation well: Sentinel 3

Test period: 25/01/2012 11:52:00 to 1/02/2012 10:19:00
Pumping rate: 34.9 l/s



K5 Pumping Test AQTESOLV Analysis

CH2M Beca

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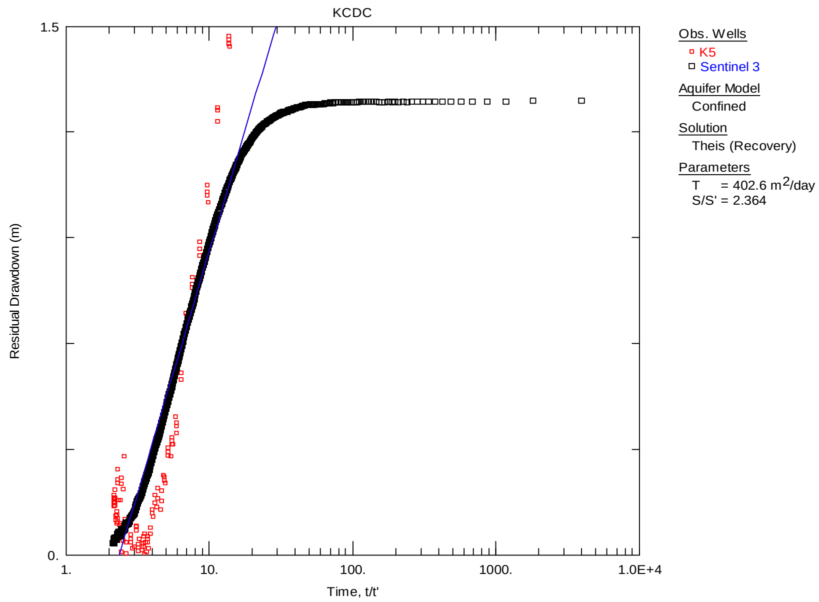
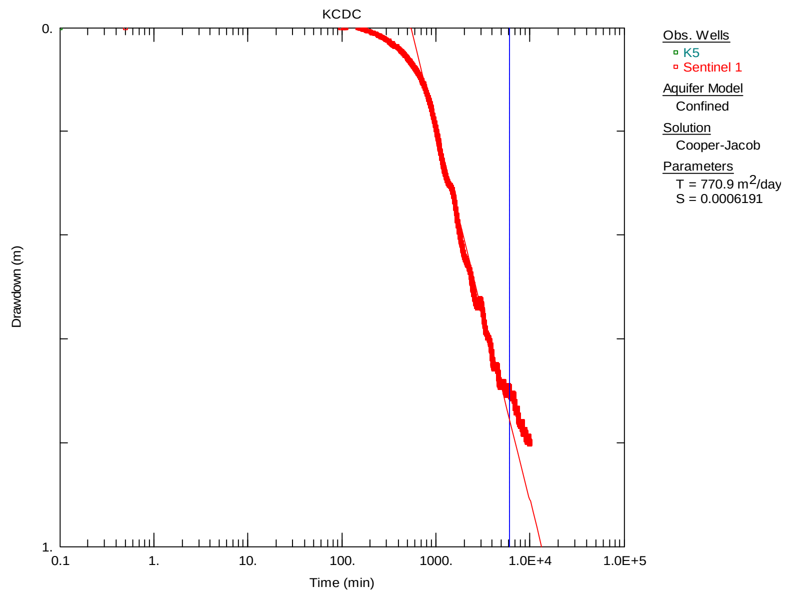
Observation well: Sentinel 3

Test period: 25/01/2012 11:52:00 to 1/02/2012 10:19:00
Pumping rate: 34.9 l/s



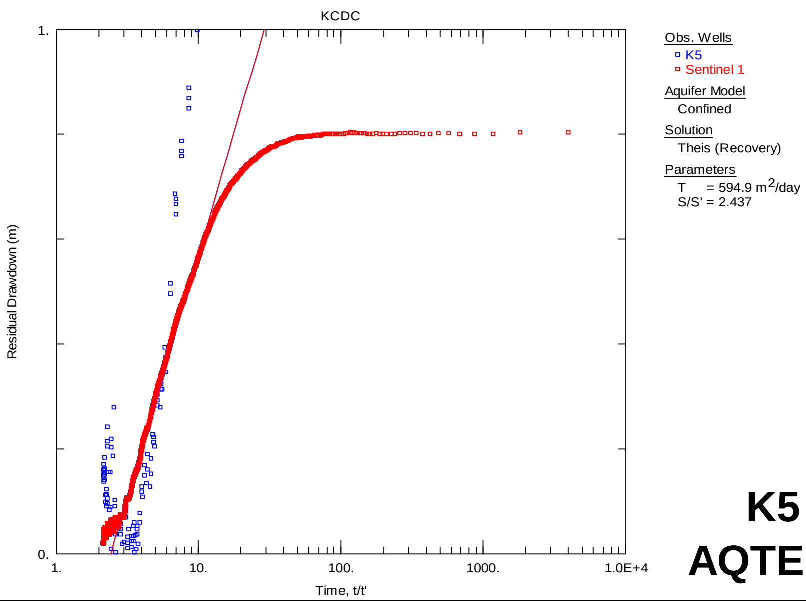
Observation well: Sentinel 1

Test period: 25/01/2012 11:52:00 to 1/02/2012 10:19:00
Pumping rate: 34.9 l/s



Observation well: Sentinel 1

Test period: 25/01/2012 11:52:00 to 1/02/2012 10:19:00
Pumping rate: 34.9 l/s



K5 Pumping Test
AQTESOLV Analysis

CH2M Beca

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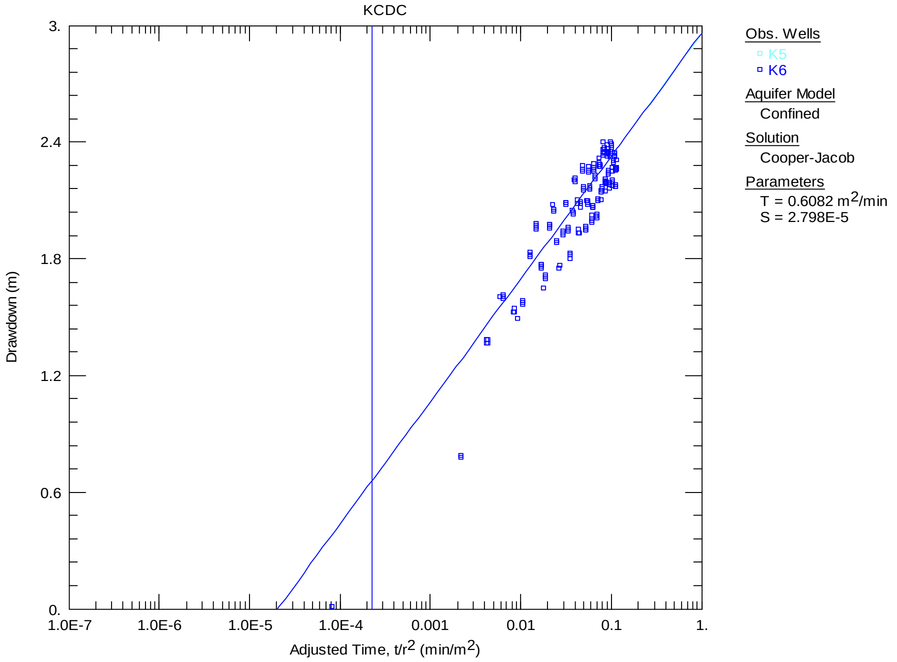
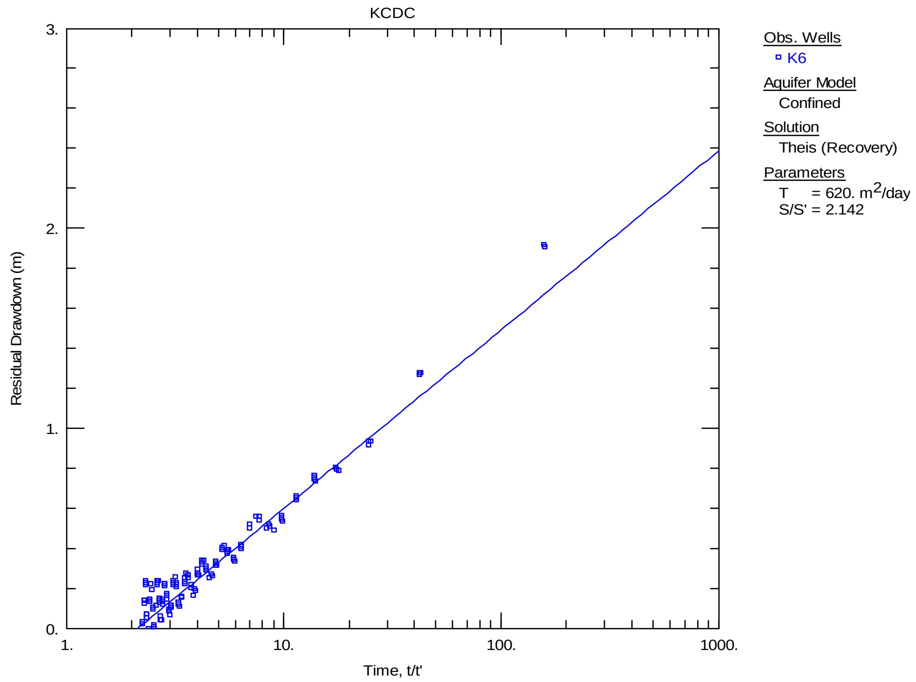
Observation well: Sentinel 3 Test period: 25/01/2012 11:52:00 to 1/02/2012 10:19:00
Pumping rate: 34.9 l/s



Observation well: Sentinel 1 Test period: 25/01/2012 11:52:00 to 1/02/2012 10:19:00
Pumping rate: 34.9 l/s



K5 Pumping Test
AQTESOLV Analysis

CH2M Beca

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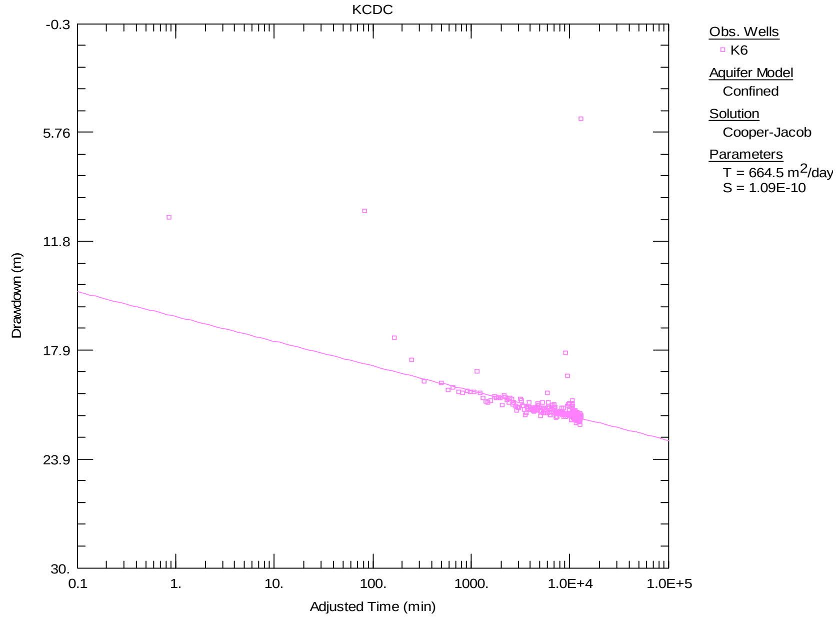
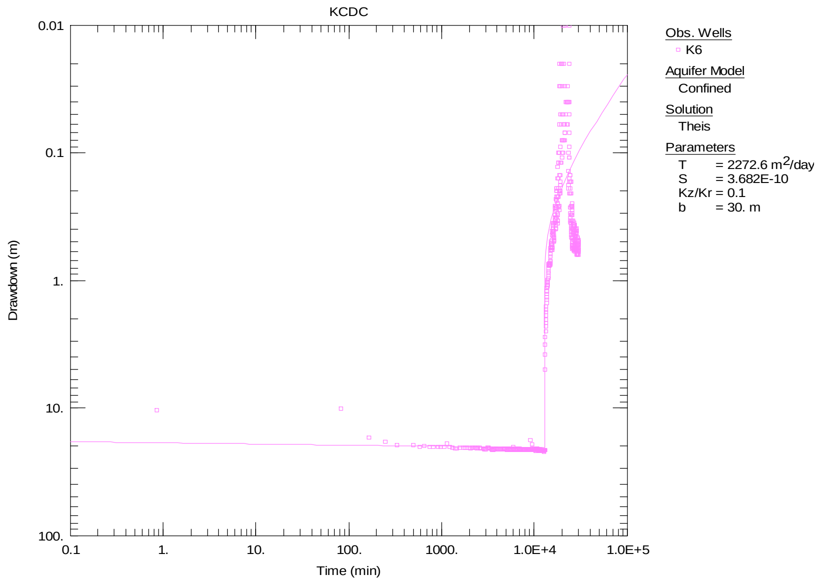
Observation well: K6 Test period: 31/03/2010 8:44:00 to 9/04/2010 9:58:49

Pumping rate: 57.8 l/s



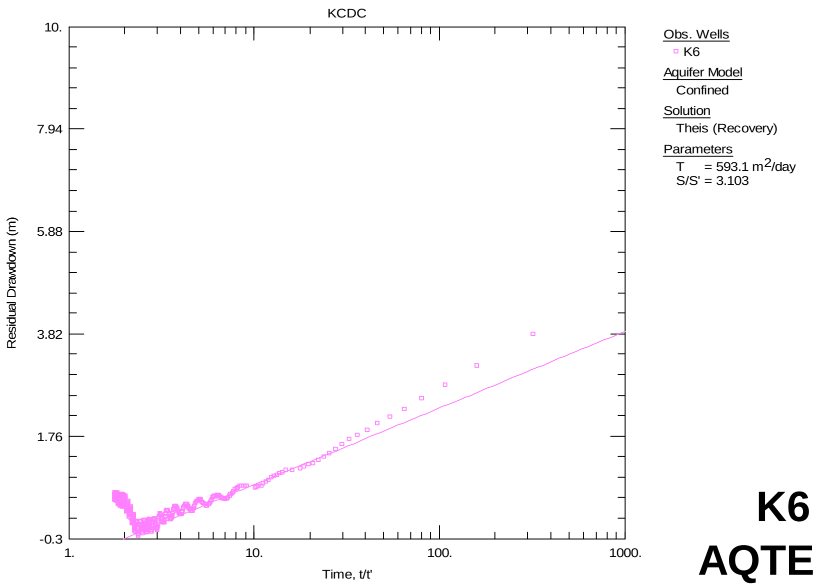
Observation well: K6 Test period: 31/03/2010 8:44:00 to 9/04/2010 9:58:49

Pumping rate: 57.8 l/s



Observation well: K6 Test period: 31/03/2010 8:44:00 to 9/04/2010 9:58:49

Pumping rate: 57.8 l/s

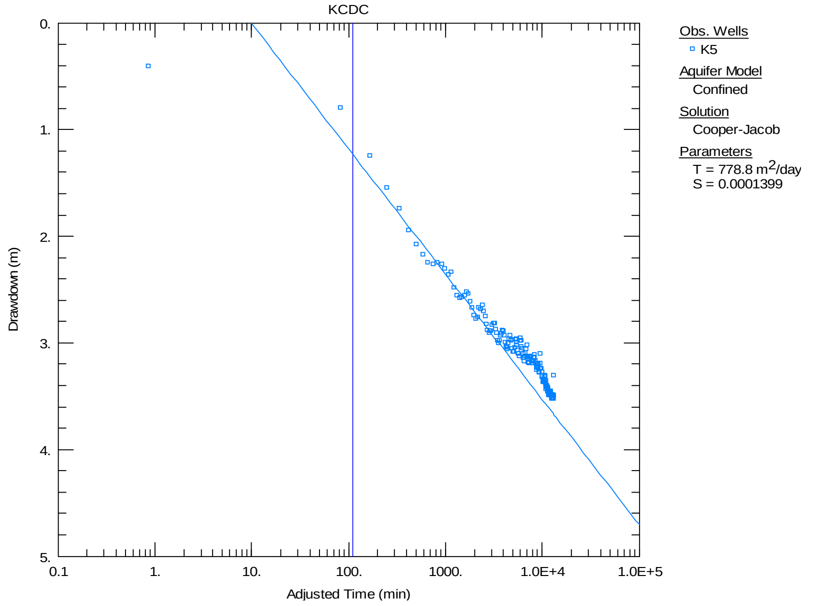


K6 Pumping Test
AQTESOLV Analysis

CH2M Beca

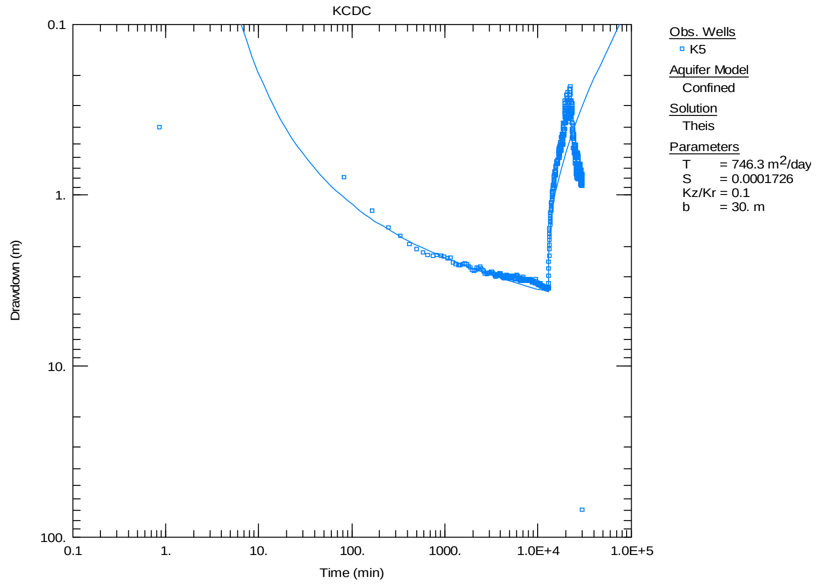
Observation well: K5 Test period: 31/03/2010 8:44:00 to 9/04/2010 9:58:49

Pumping rate: 57.8 l/s



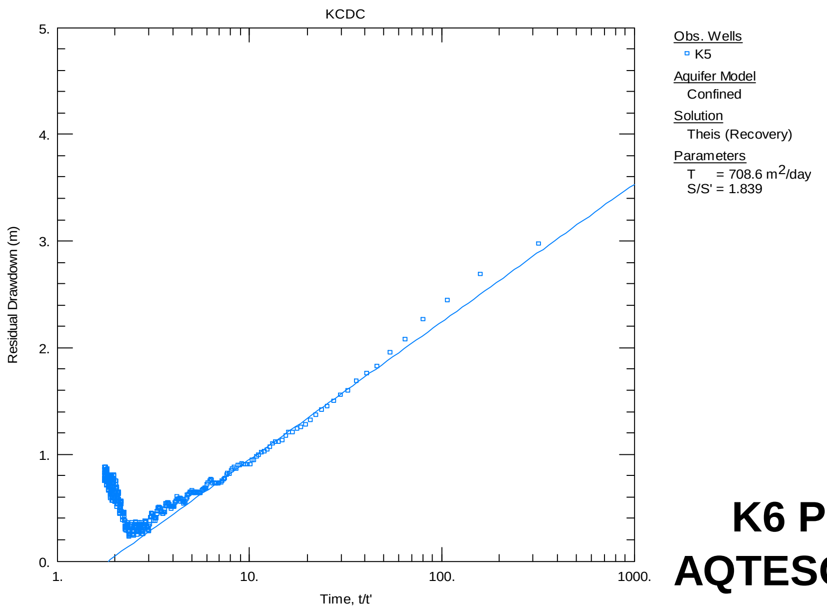
Observation well: K5 Test period: 31/03/2010 8:44:00 to 9/04/2010 9:58:49

Pumping rate: 57.8 l/s



Observation well: K5 Test period: 31/03/2010 8:44:00 to 9/04/2010 9:58:49

Pumping rate: 57.8 l/s

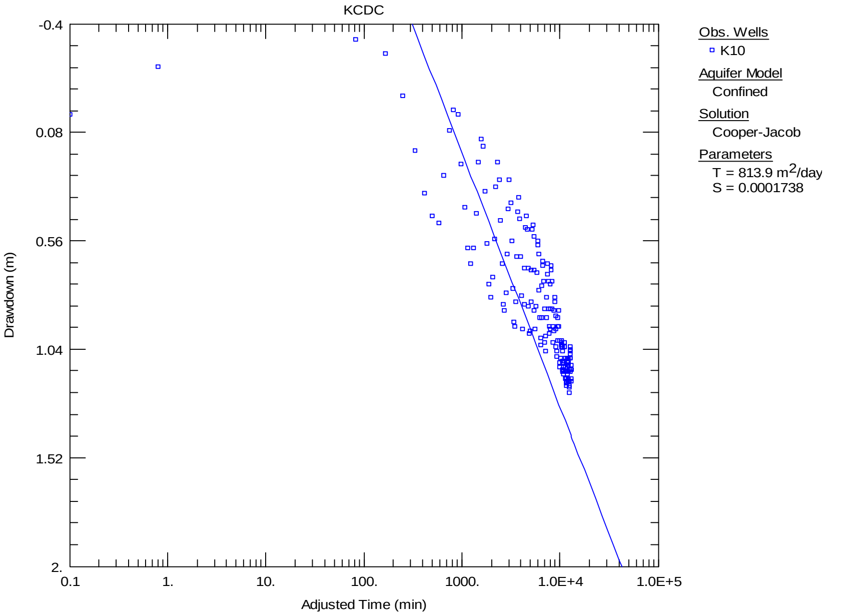


K6 Pumping Test AQTESOLV Analysis

CH2M Beca

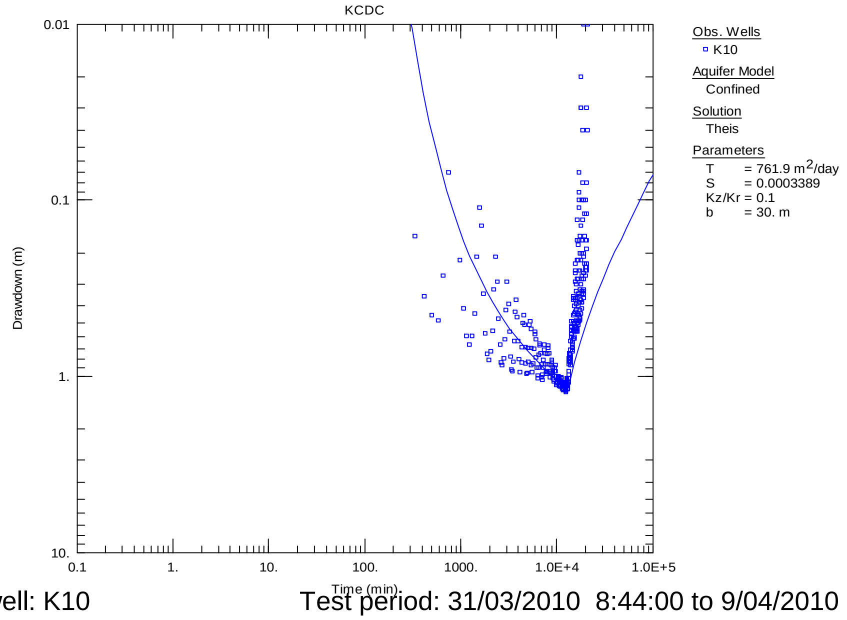
Observation well: K10 Test period: 31/03/2010 8:44:00 to 9/04/2010 9:58:49

Pumping rate: 57.8 l/s



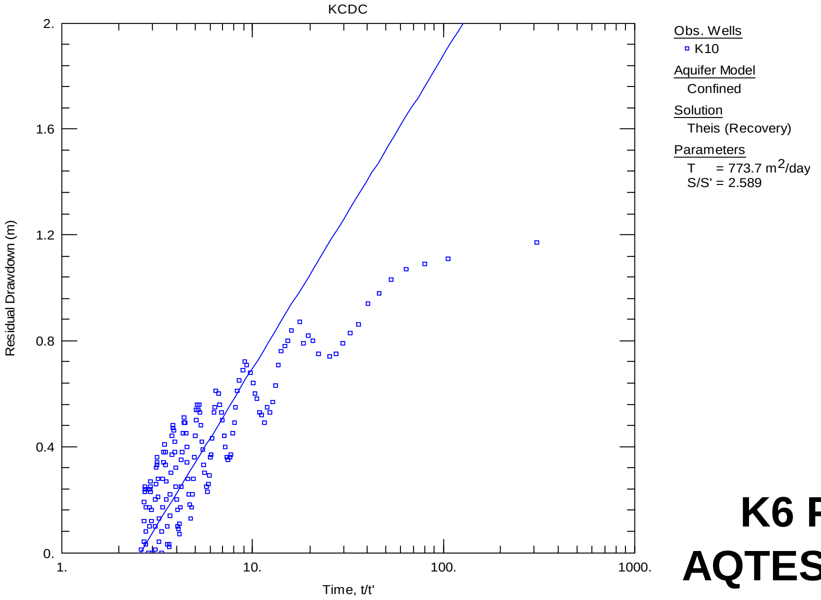
Observation well: K10 Test period: 31/03/2010 8:44:00 to 9/04/2010 9:58:49

Pumping rate: 57.8 l/s



Observation well: K10 Test period: 31/03/2010 8:44:00 to 9/04/2010 9:58:49

Pumping rate: 57.8 l/s



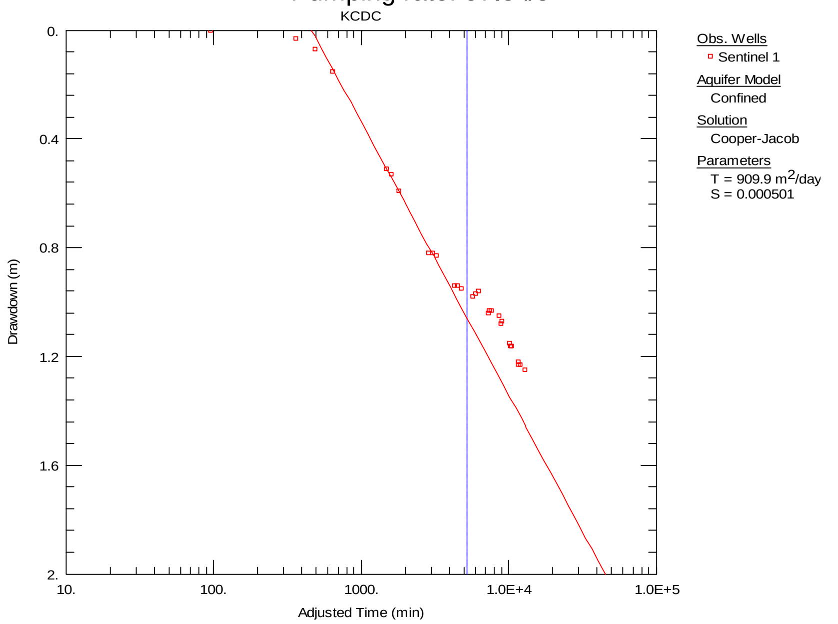
K6 Pumping Test
AQTESOLV Analysis

CH2M Beca

Appendix C

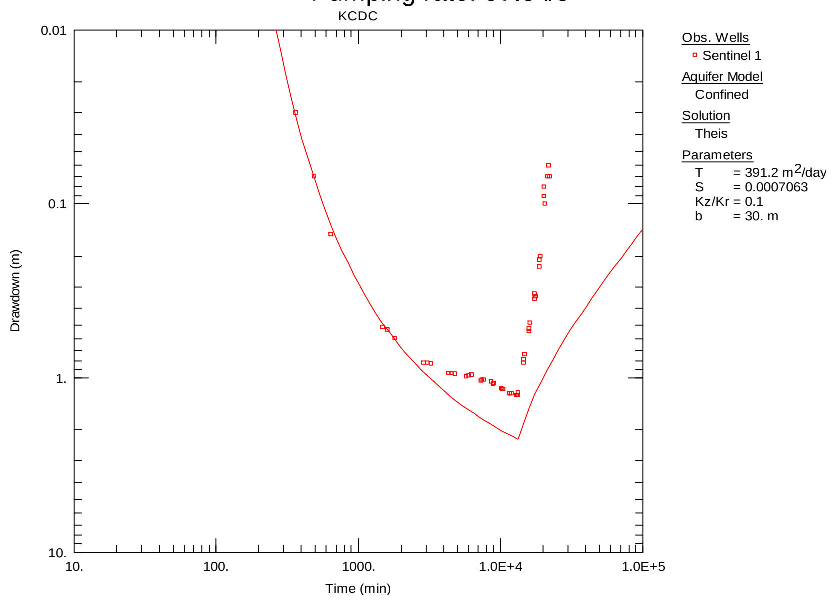
Observation well: Sentinel 1 Test period: 31/03/2010 8:44:00 to 9/04/2010 9:58:49

Pumping rate: 57.8 l/s



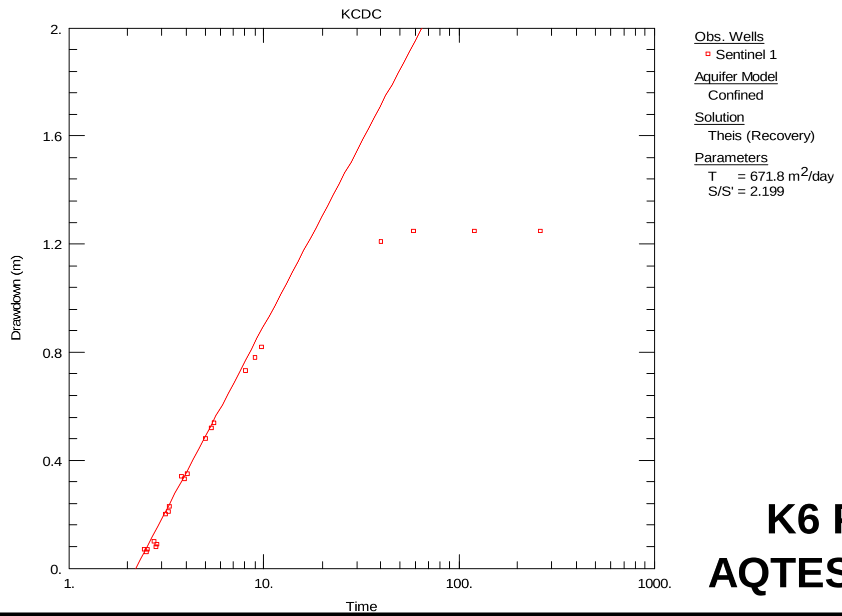
Observation well: Sentinel 1 Test period: 31/03/2010 8:44:00 to 9/04/2010 9:58:49

Pumping rate: 57.8 l/s



Observation well: Sentinel 1 Test period: 31/03/2010 8:44:00 to 9/04/2010 9:58:49

Pumping rate: 57.8 l/s



K6 Pumping Test

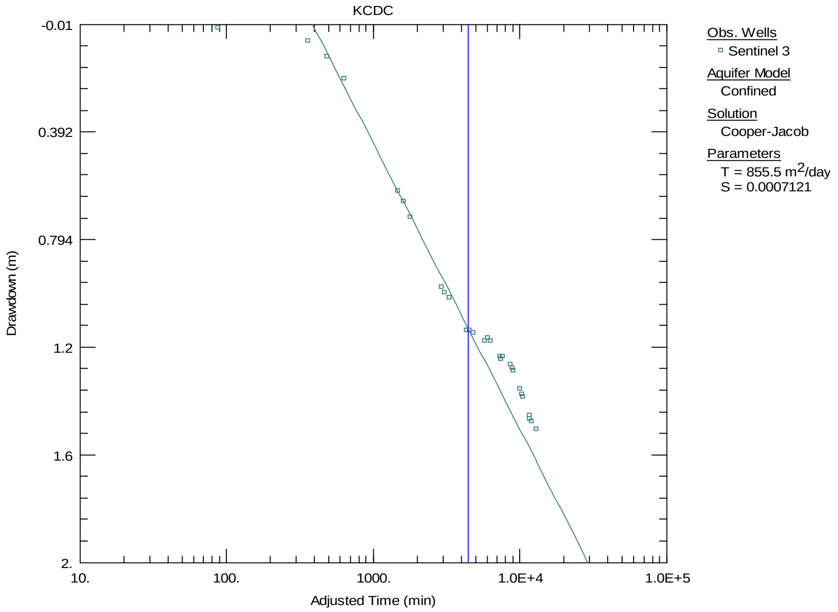
AQTESOLV Analysis

CH2M BECA

Observation well: Sentinel 3

Test period: 31/03/2010 8:44:00 to 9/04/2010 9:58:49

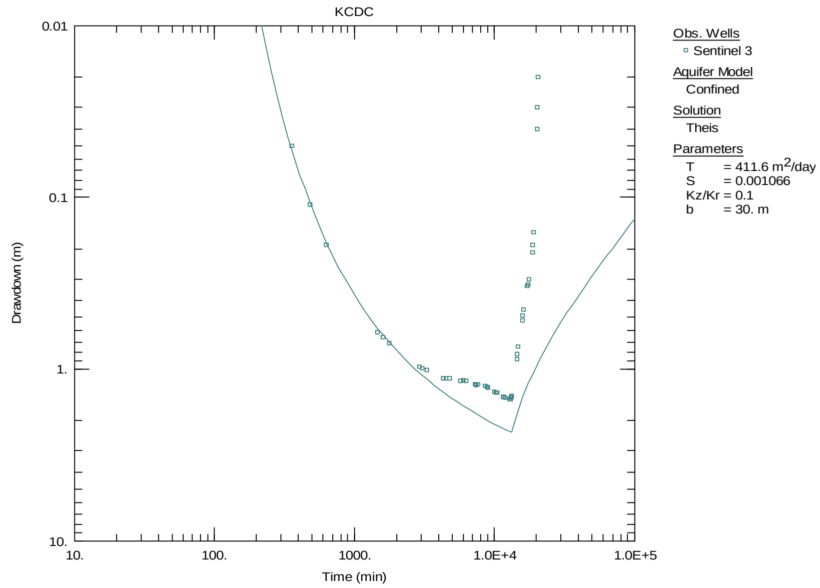
Pumping rate: 57.8 l/s



Observation well: Sentinel 3

Test period: 31/03/2010 8:44:00 to 9/04/2010 9:58:49

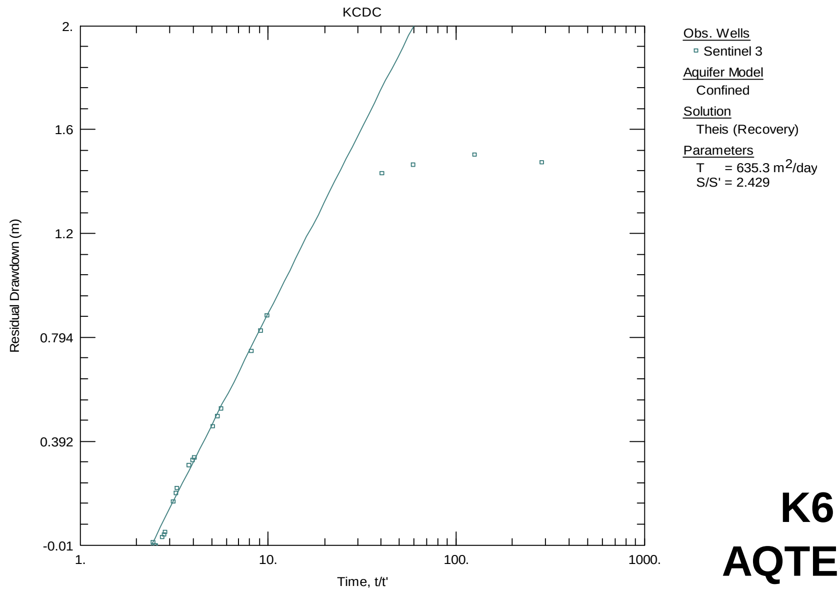
Pumping rate: 57.8 l/s



Observation well: Sentinel 3

Test period: 31/03/2010 8:44:00 to 9/04/2010 9:58:49

Pumping rate: 57.8 l/s



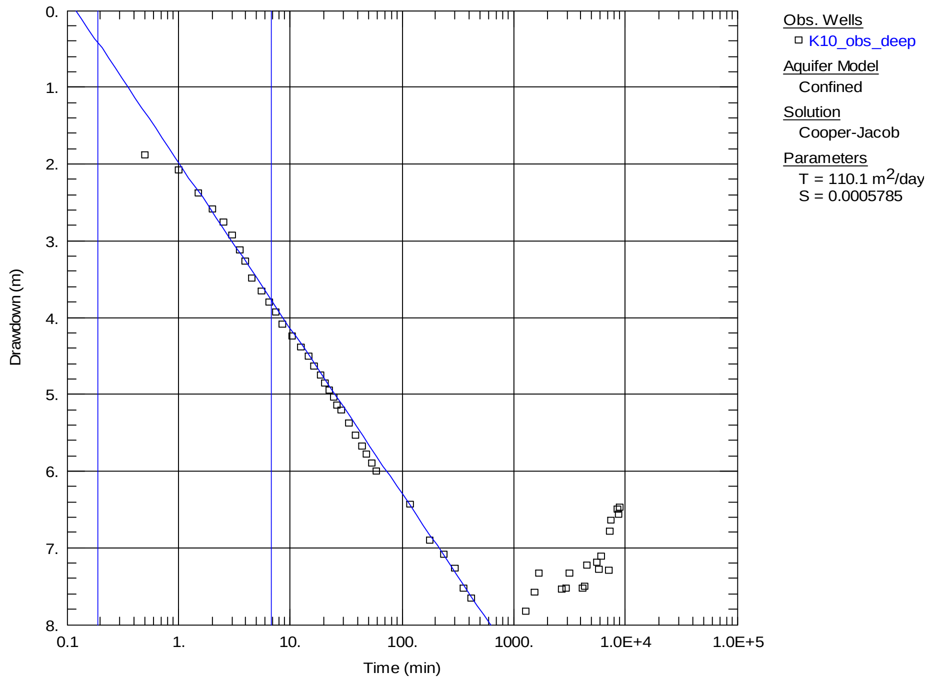
K6 Pumping Test
AQTESOLV Analysis

CH2M Beca

Appendix C

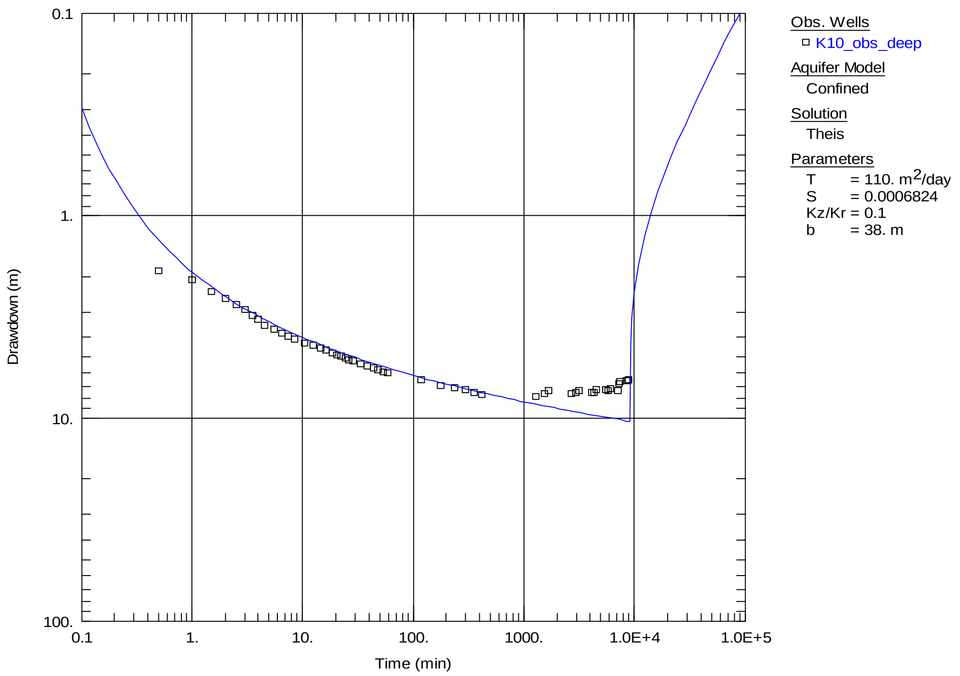
Observation well: K10

Test period: 10/01/2012 10:32:00 to 16/01/2012 16:15:00
Pumping rate: 15 l/s



Observation well: K10

Test period: 10/01/2012 10:32:00 to 16/01/2012 16:15:00
Pumping rate: 15 l/s



K10 Pumping Test
AQTESOLV Analysis

CH2M Beca

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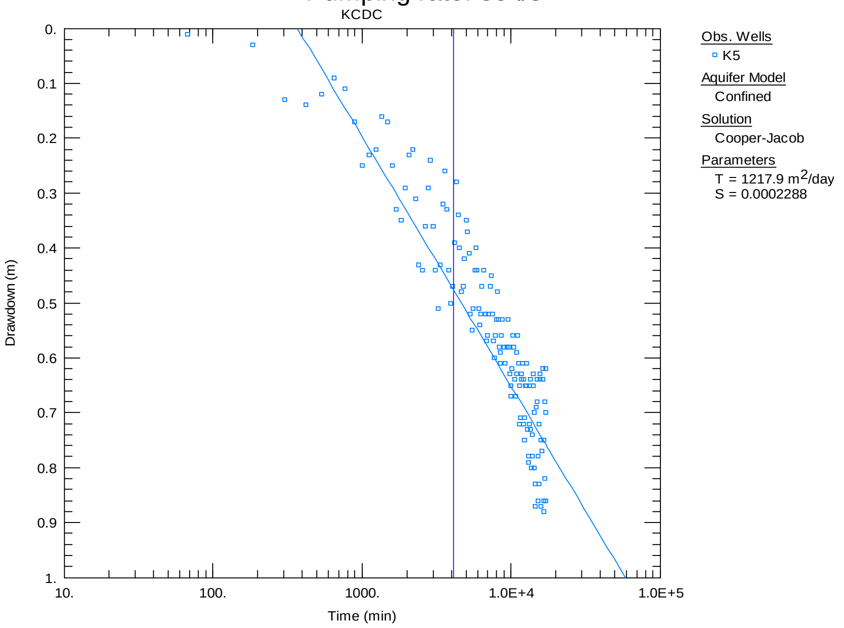
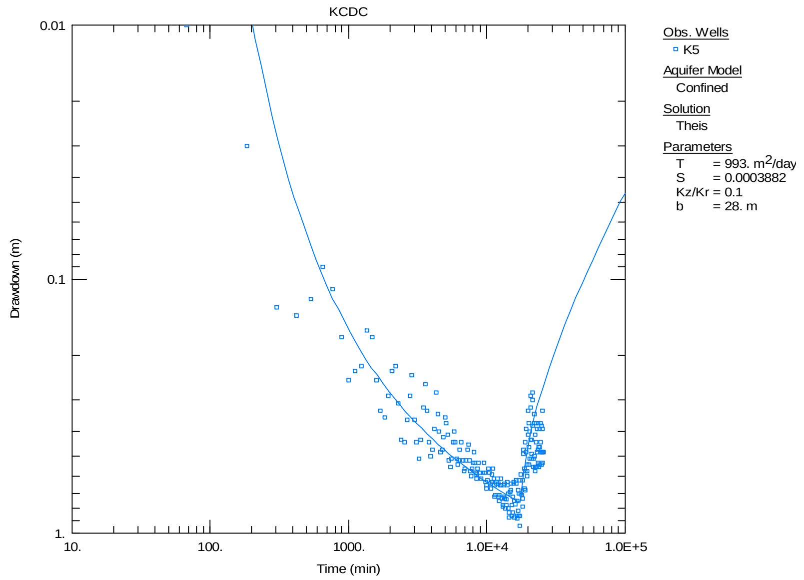
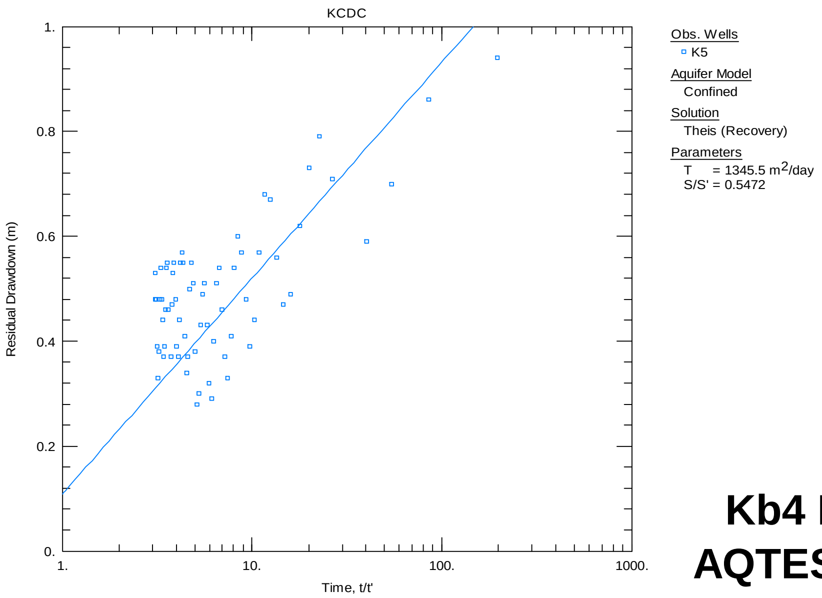
Observation well: K5 Test period: 16/04/2010 13:22:00 to 28/04/2010 14:00:00
Pumping rate: 35 l/s



Observation well: K5 Test period: 16/04/2010 13:22:00 to 28/04/2010 14:00:00
Pumping rate: 35 l/s



Observation well: K5 Test period: 16/04/2010 13:22:00 to 28/04/2010 14:00:00
Pumping rate: 35 l/s



Kb4 Pumping Test
AQTESOLV Analysis

CH2M Beca

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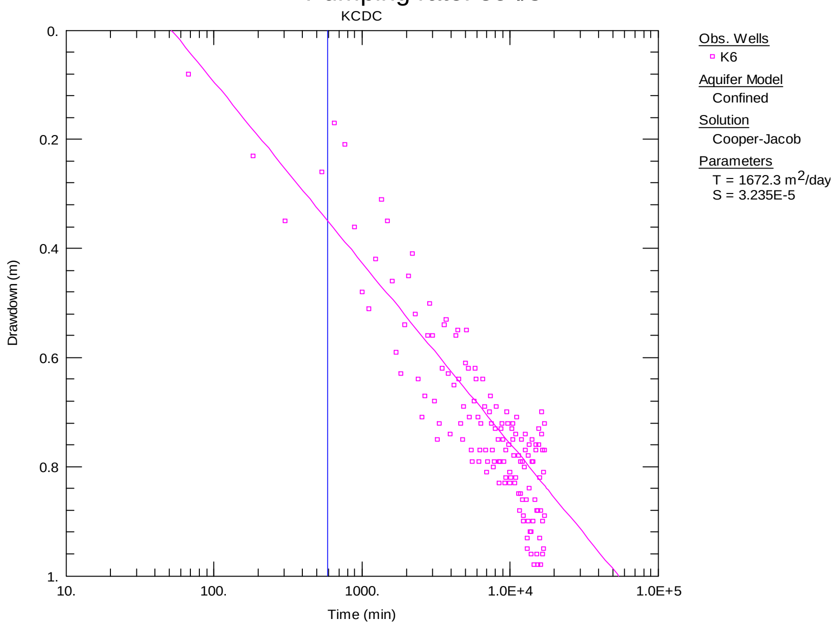
Appendix C

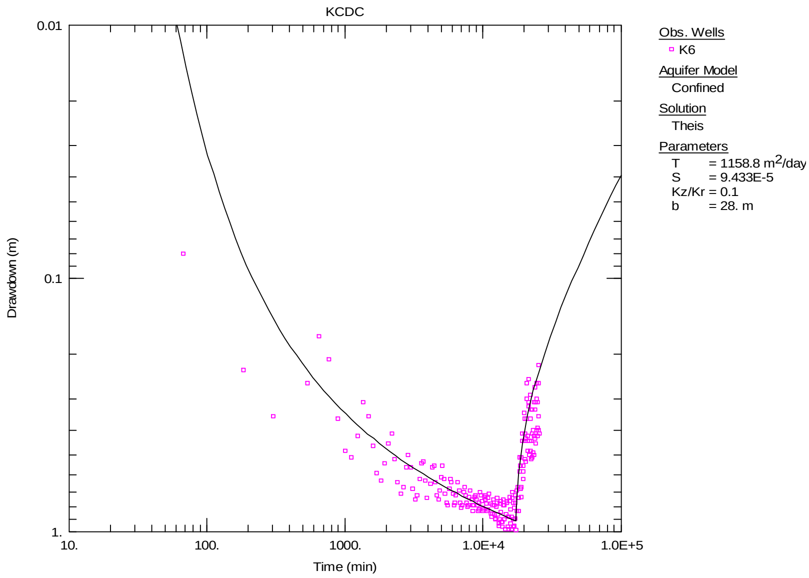
Observation well: K6 Test period: 16/04/2010 13:22:00 to 28/04/2010 14:00:00

Pumping rate: 35 l/s



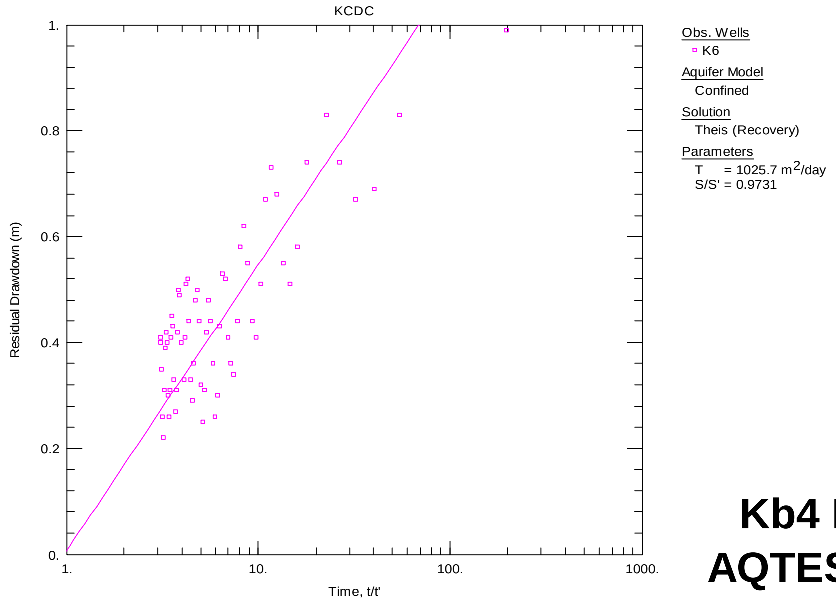
Observation well: K6 Test period: 16/04/2010 13:22:00 to 28/04/2010 14:00:00

Pumping rate: 35 l/s



Observation well: K6 Test period: 16/04/2010 13:22:00 to 28/04/2010 14:00:00

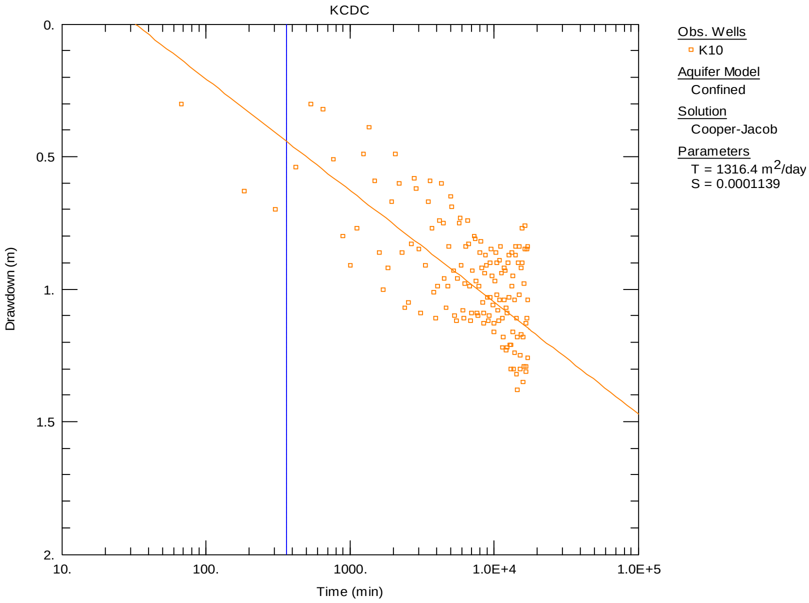
Pumping rate: 35 l/s



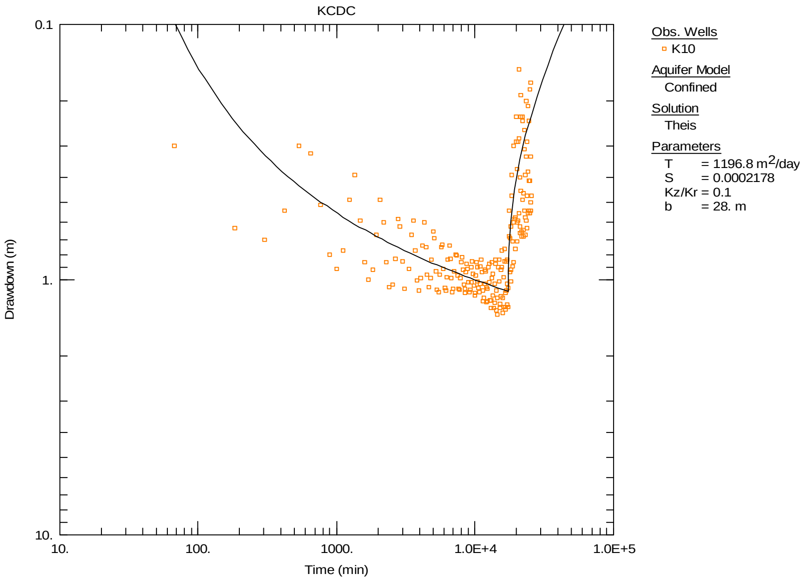
Kb4 Pumping Test
AQTESOLV Analysis

CH2M Beca

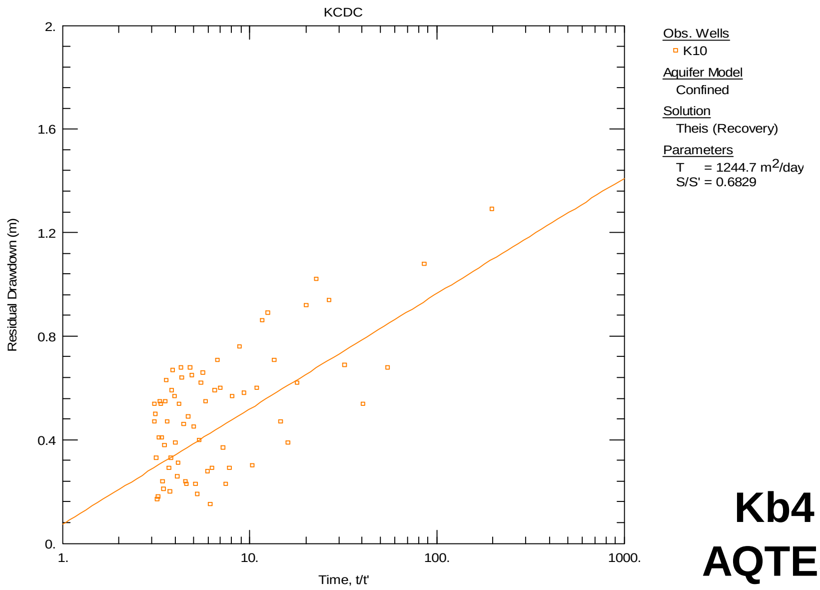
Observation well: K10 Test period: 16/04/2010 13:22:00 to 28/04/2010 14:00:00
Pumping rate: 35 l/s



Observation well: K10 Test period: 16/04/2010 13:22:00 to 28/04/2010 14:00:00
Pumping rate: 35 l/s



Observation well: K10 Test period: 16/04/2010 13:22:00 to 28/04/2010 14:00:00
Pumping rate: 35 l/s



Kb4 Pumping Test
AQTESOLV Analysis

CH2M Beca

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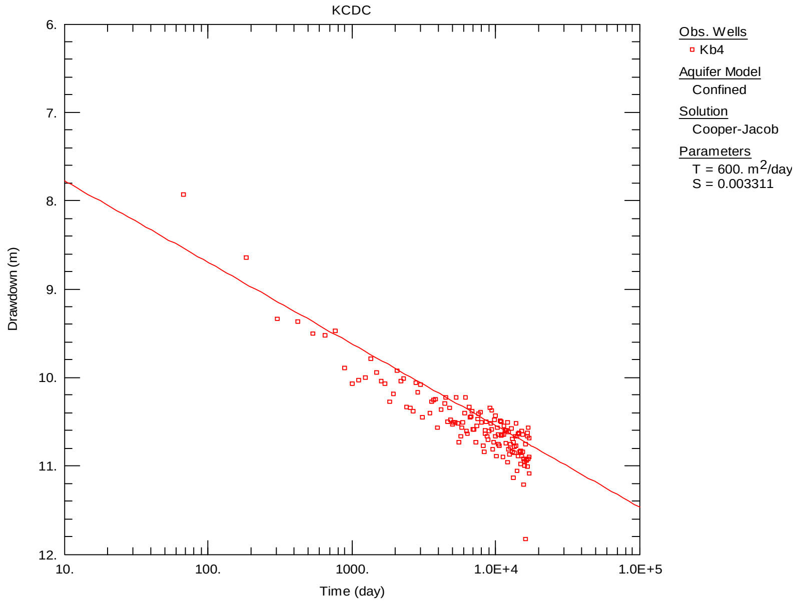
Appendix C

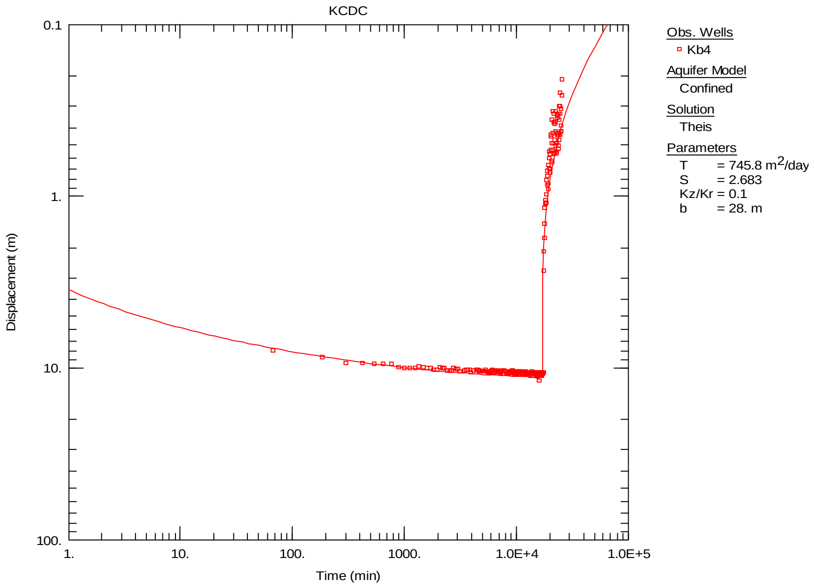
Observation well: Kb4

Test period: 16/04/2010 13:22:00 to 28/04/2010 14:00:00
Pumping rate: 35 l/s



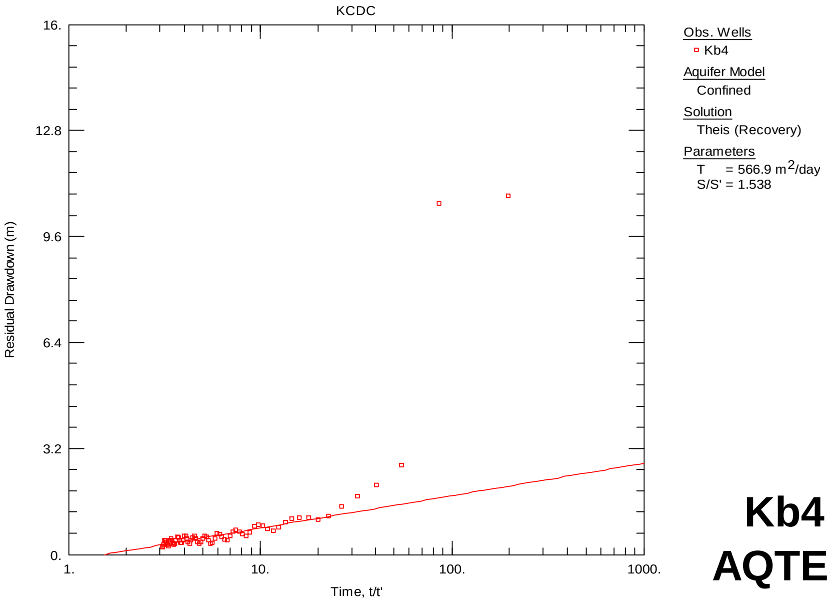
Observation well: Kb4

Test period: 16/04/2010 13:22:00 to 28/04/2010 14:00:00
Pumping rate: 35 l/s



Observation well: Kb4

Test period: 16/04/2010 13:22:00 to 28/04/2010 14:00:00
Pumping rate: 35 l/s



Kb4 Pumping Test
AQTESOLV Analysis

CH2M Beca

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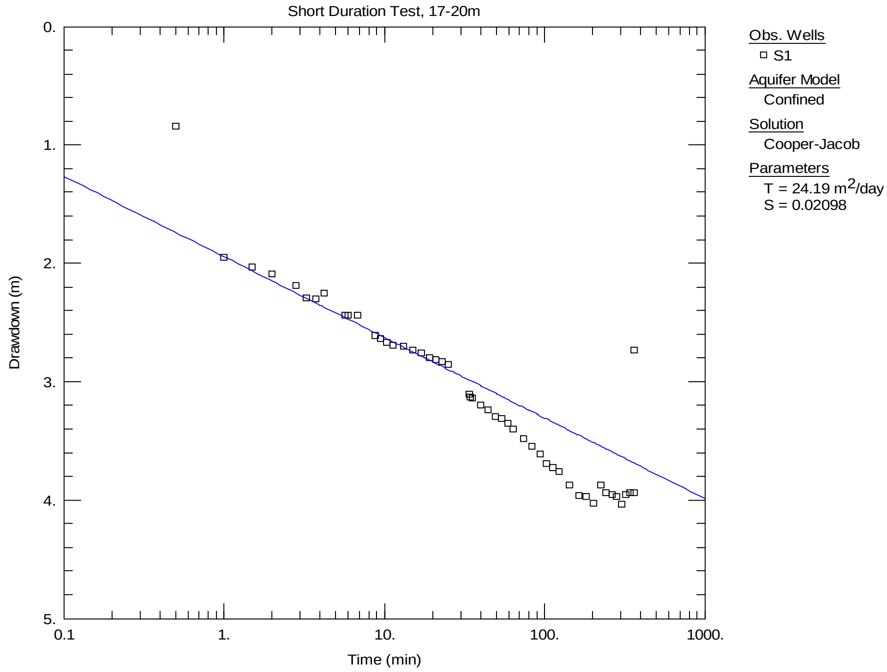
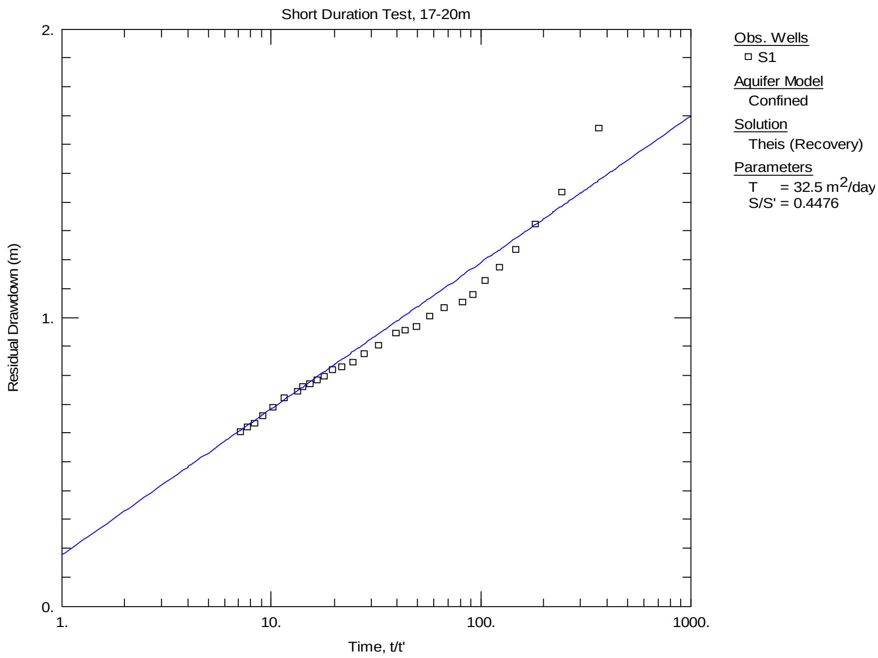
Appendix C

Observation well:S1 Shallow   Test date: 18/05/2011   Pumping duration: 6 hours
Pumping rate: 1.04 to 1.4 l/s



Observation well:S1 Shallow   Test date: 18/05/2011   Pumping duration: 6 hours
Pumping rate: 1.04 to 1.4 l/s



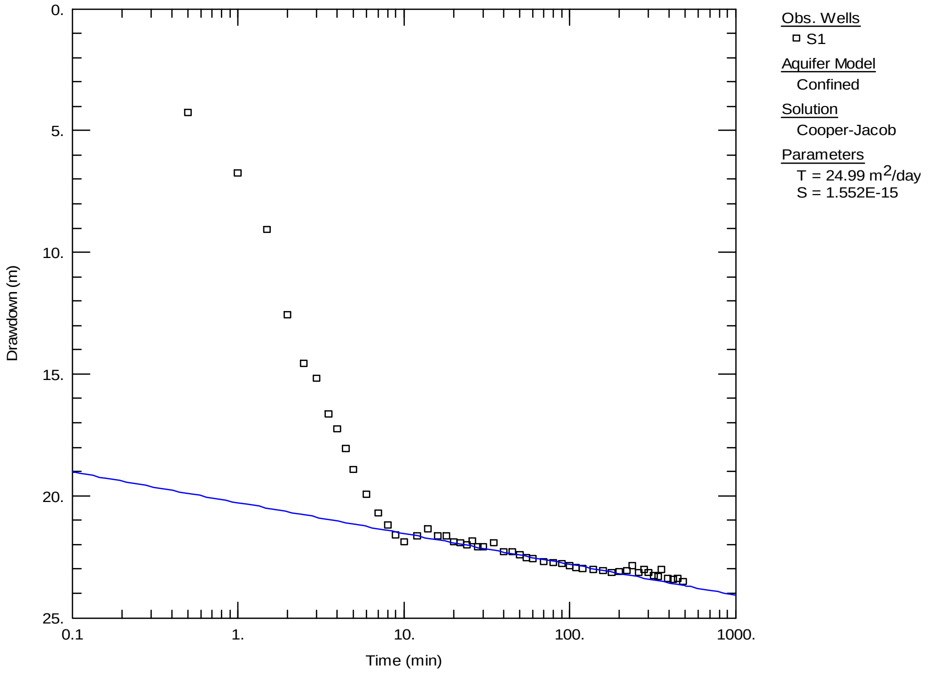
S1 (17-20m) Short Term Pumping Test
AQTESOLV Analysis

CH2M Beca

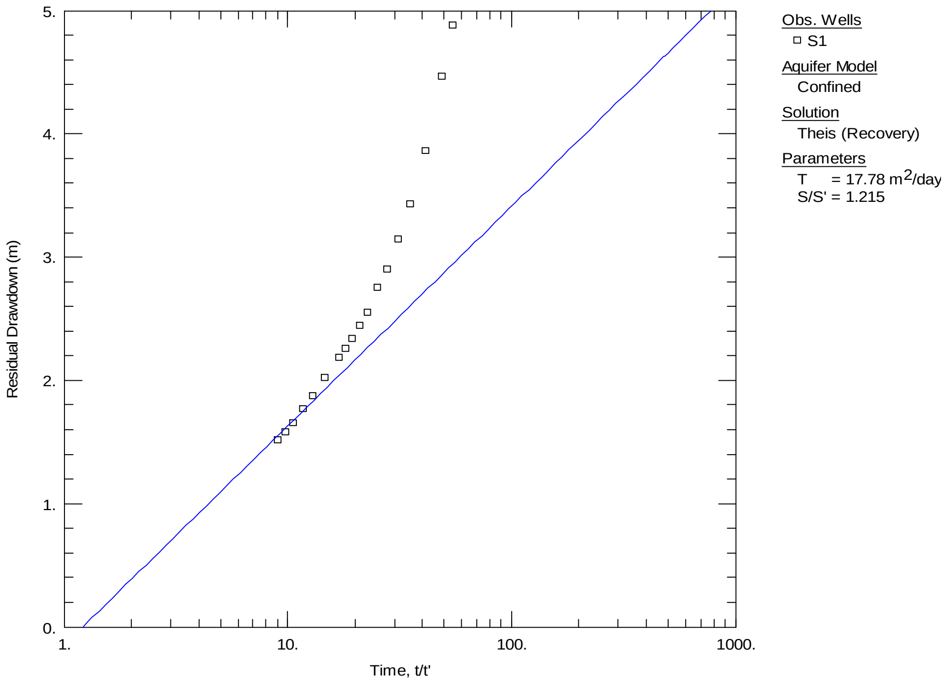
6515959/402

Appendix C

Observation well:S1 Deep Test date: 22/09/2011 Pumping duration: 9 hours
Pumping rate: 1.1 to 1.8 l/s



Observation well:S1 Deep Test date: 22/09/2011 Pumping duration: 9 hours
Pumping rate: 1.1 to 1.8 l/s

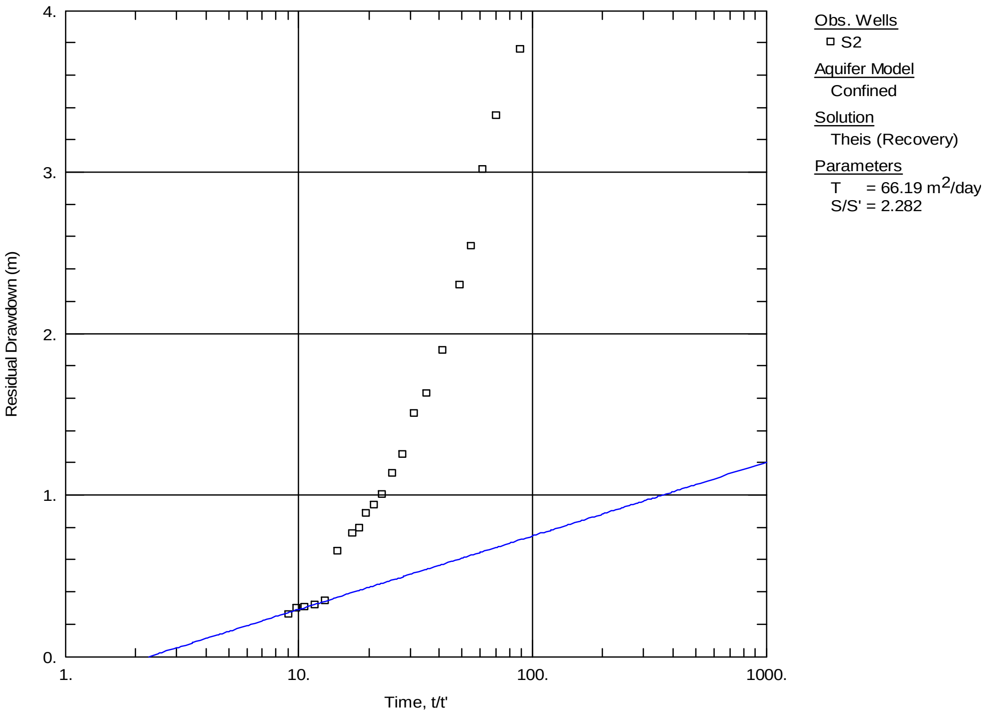


S1 (57.4-66.4m) Short Term Pumping Test
AQTESOLV Analysis

CH2M Beca

Observation well:S2 (27.5-31.5)m Test date:28/01/2012 Pumping duration: 8 hours
Pumping rate: 1.8 to 1.9 l/s

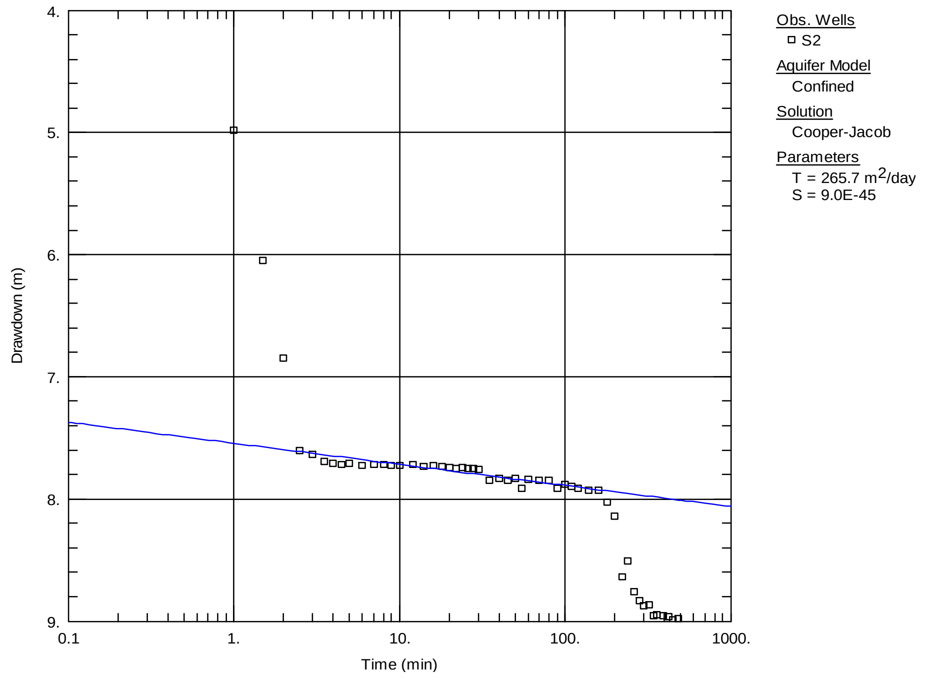
Observation well:S2 (27.5-31.5)m Test date:28/01/2012 Pumping duration: 8 hours
Pumping rate: 1.8 to 1.9 l/s



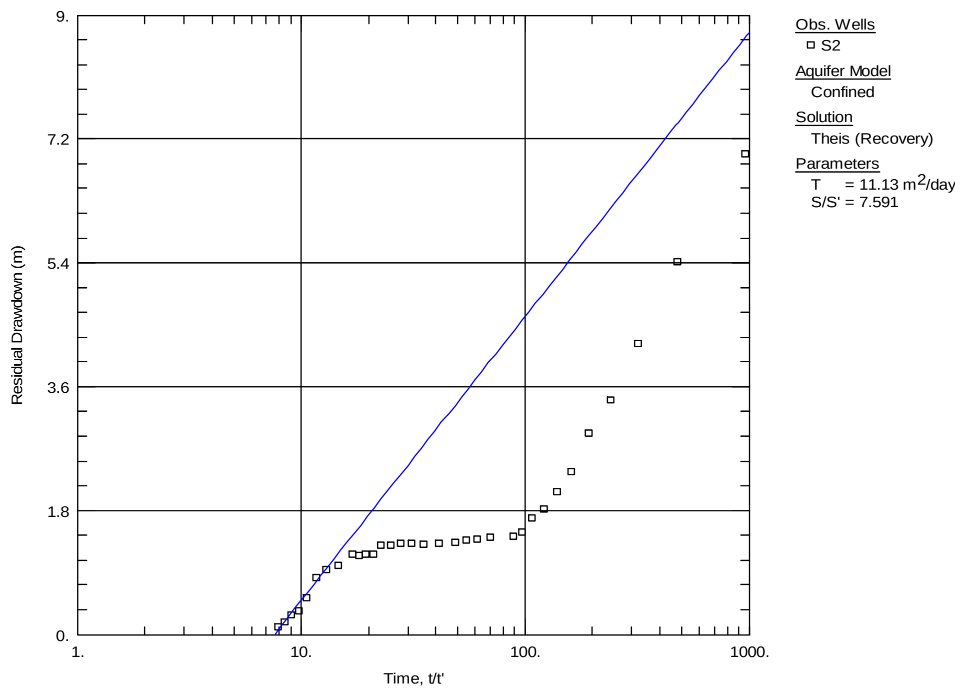
S2 (27.5-31.5m) Short Term Pumping Test
AQTESOLV Analysis

CH2M Beca

Observation well:S2 (33.0 to 39.0)m   Test date:09/02/2012   Pumping duration: 8 hours
Pumping rate: 2.9 l/s



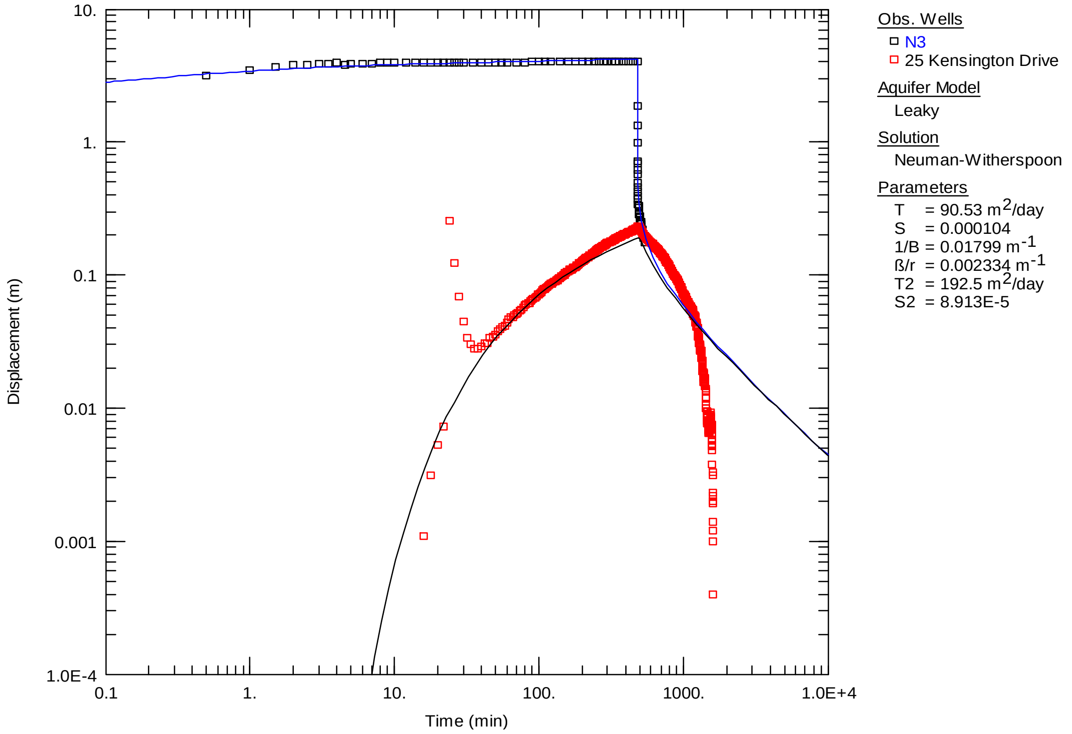
Observation well:S2 (33.0 to 39.0)m   Test date:09/02/2012   Pumping duration: 8 hours
Pumping rate: 2.9 l/s



S2 (33.0-39.0m) Short Term Pumping Test
AQTESOLV Analysis

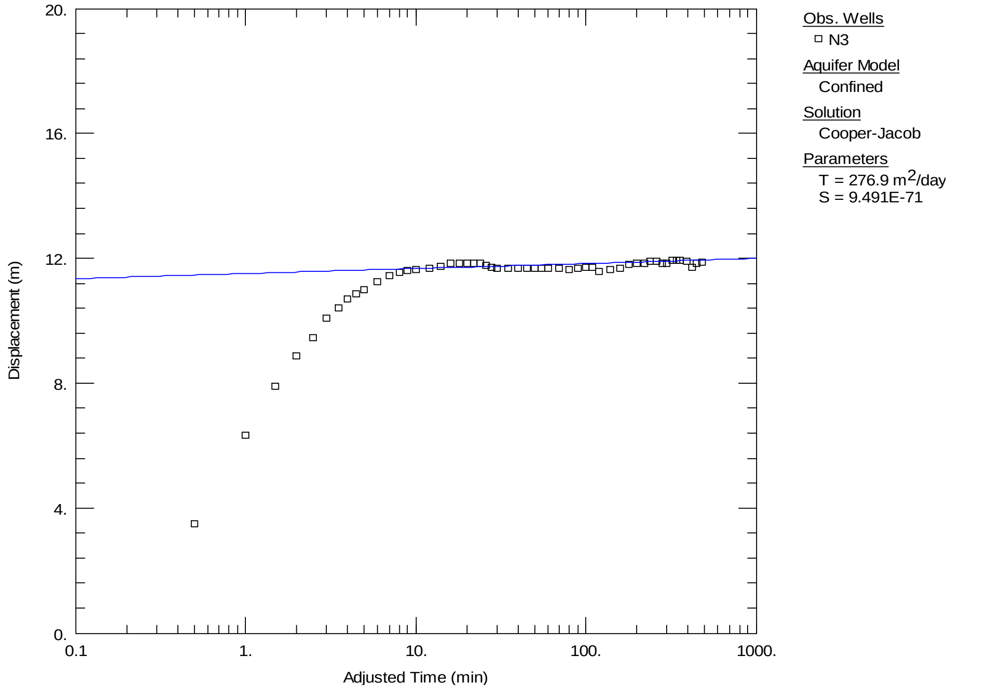
CH2M BECA

Observation well:N3 (60.0 to 69.0)m Test date:18/11/2011 Pumping duration: 7 hours
Pumping rate: 3.7 l/s

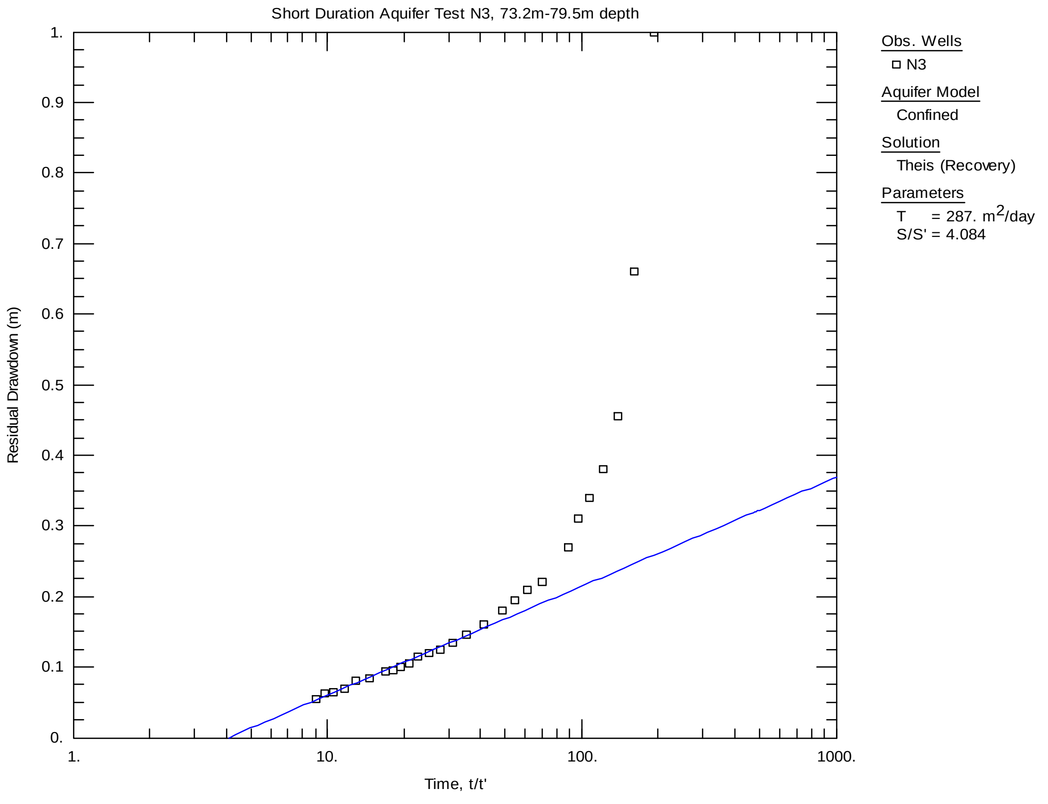


N3 (60.0 to 69.0m) Short Term Pumping Test
AQTESOLV Analysis

Observation well:N3 (73.2 to 79.5)m Test date:13/12/2011 Pumping duration: 6 hours
Pumping rate: 2.8 l/s



Observation well:N3 (73.2 to 79.5)m Test date:13/12/2011 Pumping duration: 6 hours
Pumping rate: 2.8 l/s



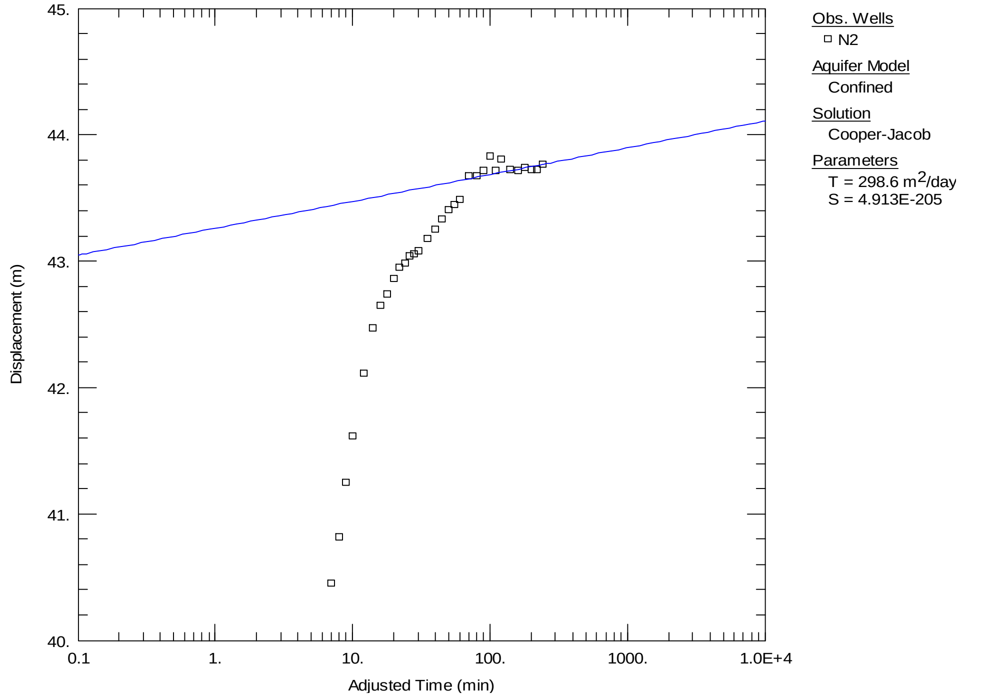
N3 (73.2 to 79.5m) Short Term Pumping Test
AQTESOLV Analysis

CH2M Beca

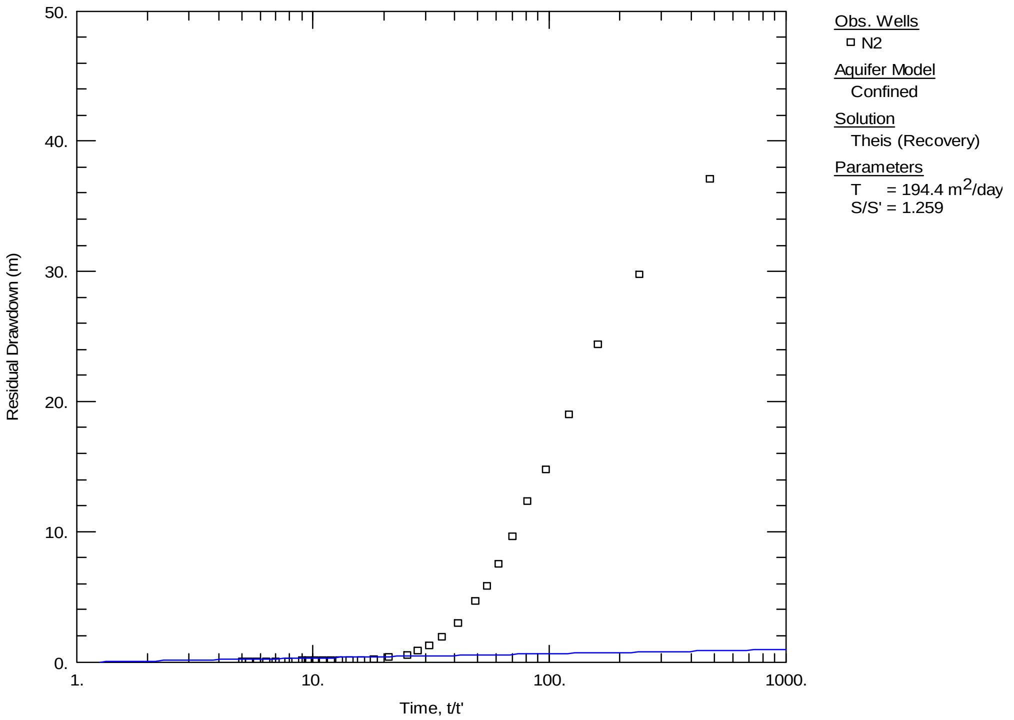
6515959/402

Appendix C

Observation well:N2 (50.8 to 53.8)m Test date:06/07/2011 Pumping duration: 4 hours
Pumping rate: 4 l/s



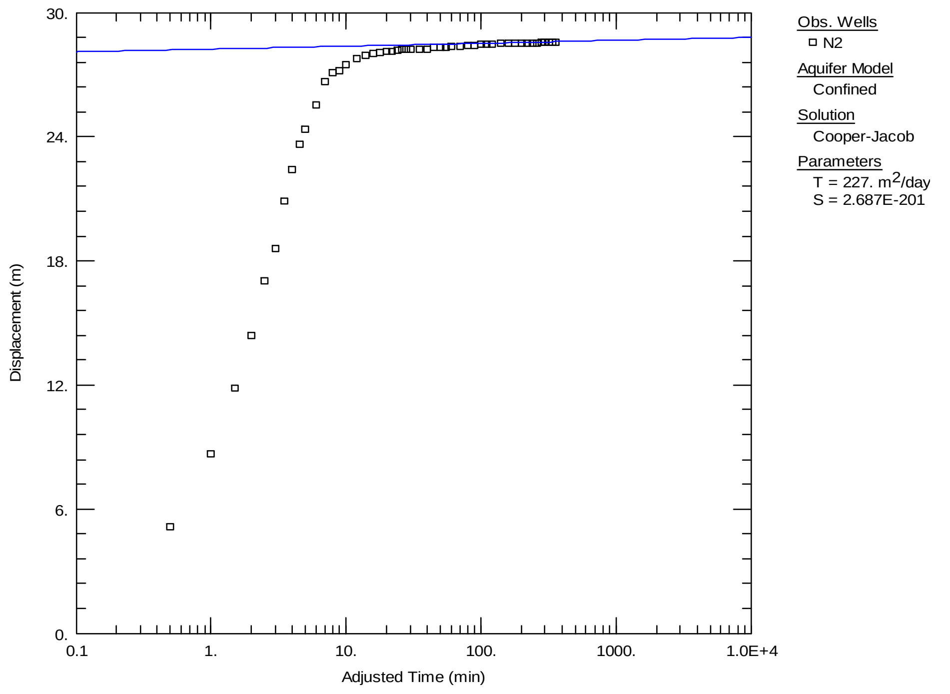
Observation well:N2 (50.8 to 53.8)m Test date:06/07/2011 Pumping duration: 4 hours
Pumping rate: 4 l/s



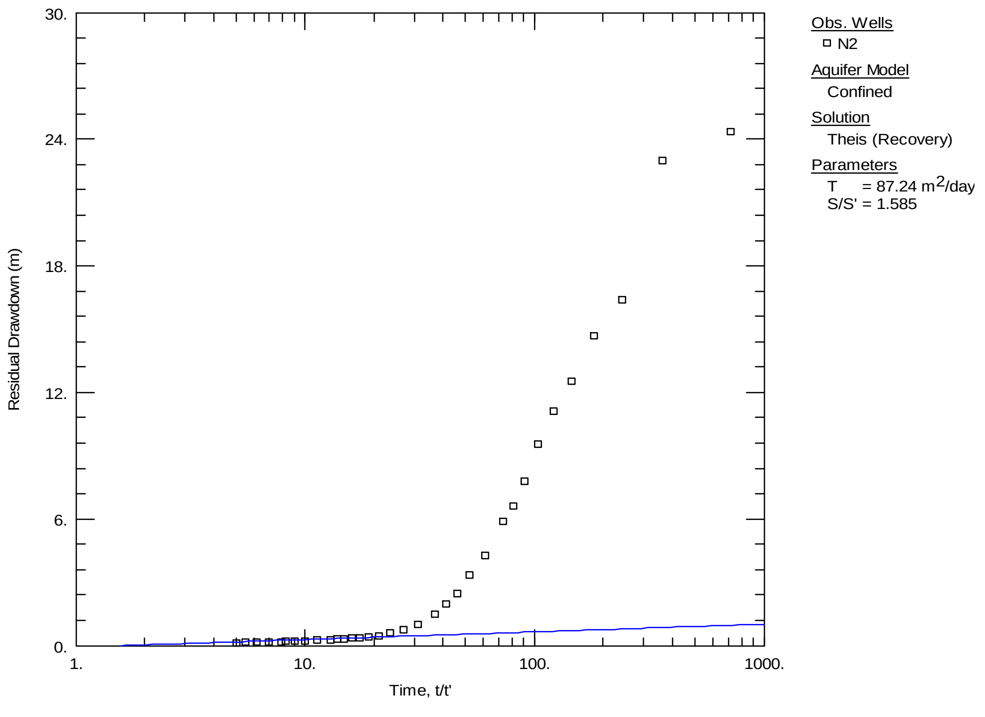
N2 (50.8 to 53.8m) Short Term Pumping Test
AQTESOLV Analysis

CH2M Beca

Observation well:N2 (67.3 to 70.3m)   Test date:26/07/2011   Pumping duration: 5 hours
Pumping rate: 2.0 l/s



Observation well:N2 (67.3 to 70.3m)   Test date:26/07/2011   Pumping duration: 5 hours
Pumping rate: 2.0 l/s



N2 (67.3 to 70.3m) Short Term Pumping Test
AQTESOLV Analysis

CH2M Beca

Appendix C

Appendix D

Numerical Groundwater Model

Set-Up of Groundwater Model

Numerical Code

Three-dimensional groundwater modelling was undertaken using the computer software Visual MODFLOW Pro 2010 (Schlumberger). Visual MODFLOW is a user interface for the 3D finite difference model Modflow 2000 and Modpath developed by the United States Geological Survey (Harbaugh et al, 2000).

MODFLOW is a three-dimensional finite-difference groundwater model originally developed in 1984; and is currently the world wide “standard” for numerical groundwater modelling. It is the most widely used model in the world for this type of 3-dimensional problem (also used by GWRC) and is able to address the scale and complexity of the aquifer system at the Kapiti Coast.

The groundwater flow equation is solved using the finite-difference approximation. The flow region is subdivided into blocks in which the material properties are assumed to be uniform. In plan-view the blocks are made from a grid of mutually perpendicular lines that may be variably spaced, and the water level in each block is calculated.

For the purposes of this project, the Preconditioned Conjugate-Gradient Package (PCG2) was used, whereby convergence of the solver is determined using both head change and residual criteria. The PCG2 package is described in detail in Hill (1990).

Numerical Model Set-Up

Surface

The surface layer of the model has been imported from recent LIDAR data at 10 m resolution commissioned by KCDC. In areas where no LIDAR data is available the surface has been contoured from existing topographical data.

Model Grid

The model domain covers an area of 15.5 km x 11.5 km (178 km^2), and the grid is aligned to the coastline in order to allow the general groundwater flow direction to be from right to left in the model. The model extends into the Tararua foothills to the East. The northern boundary is located just north of Peka Peka Road and the southern boundary is located at Raumati South.

The model extends from approximately 300 m above sea level to 130 m below sea level, and comprises 12 layers, each 147 rows by 373 columns. A cell size of 40 m by 40 m was used in the areas around immediately surrounding the production wells coarsening outwards (200 m x 200 m at the edge of the model) resulting in cell sizes ranging between 1,600 m^2 and 40,000 m^2.

Model Boundaries

There are a number of surface water bodies (streams, wetlands and the sea) which dissect the model area. Because of the regional nature of the model and coarse cell size, only the main surface water bodies have been considered.

The Waikanae River and Waimeha Stream have been modelled using the River Package function that simulates surface water / groundwater interaction via a seepage layer which separates the surface water body from the groundwater body. Depending on the hydraulic gradient between the two systems, the rivers can act as recharge or discharge zones.

The Mazengarb Drain is modelled using the Drain Package Function.

The coastal boundary has been modelled using the Constant Head function on the surficial layers cropping out into marine waters within 1.5 km of the coast. This boundary simulates sea level at 0 m head. This boundary condition is discussed further below in Saline Intrusion.

No flow boundaries have been assigned north of Peka Peka Road and south of Raumati South. The eastern boundary has been assigned as a no flow boundary where the greywacke is outcropping at the foothills of the Tararua Ranges.

Surface water – groundwater interactions

A number of surface water bodies located in the model area interact with the groundwater system. The Waikanae River is the largest contributor but also the spring fed Waimeha Stream and Mazengarb drain interacts with the underlying sand and gravel layers.

The Waikanae River loses a considerable portion of the flow to groundwater in the reach from State Highway 1 road bridge to Jim Cooke Memorial Park (JCMP), whereas the river gains from groundwater from JCMP to the mouth of the river[19].

Table D1 – River and Drain Conductances

Surface Water Unit	Initial Conductance (m/day)	Final Conductance (m/day)
Waikanae River	5,000	40,000
Waimeha Stream	50,000	50,000
Ngarara Stream	50,000	50,000
Mazengarb Drain	1,000	1,500
Local Agricultural Drains	50,000	50,000

The river bed conductance values for the streams and rivers in the modelled area derived by Jones and Gyopari (2005) were initially applied to this model. They were then adjusted to replicate the river losses to the groundwater system above Jim Cooke Memorial Park and gains below.

Hydrogeological Units

The 3-dimensional distribution of hydrogeological units was set up using existing well data records (GWRC), investigations carried out as part of this project, site-specific investigations undertaken as part of the M2PP project, the computer programme Hydro GeoAnalyst (HGA) and the URS (2005) ground model. Model layers created in HGA were exported into text files, gridded in Surfer 9.0 and then imported into Visual Modflow as layer elevations.

Initially, the hydrogeological parameters were assigned based on the results of pumping testing and previous groundwater models for this area. The hydraulic boundaries from Jones and Gyopari (2005)[20] have been applied to the surface water bodies and the shallow unconfined aquifer in this project. The parameters were then altered as calibration (see following section) was undertaken.

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[20]The objectives of the report by Jones and Gyopari, 2005: Investigating the Sustainable Use of Shallow Groundwater on the Kapiti Coast included a characterisation and conceptualisation of the shallow hydrogeological environment, an assessment of the hydraulic properties of shallow geological units and an evaluation of the water balance for the shallow groundwater system including flows between surface water and groundwater.

Table D2 - Adopted Hydrogeological Properties

Hydrogeological Unit	Horizon		Hydrogeological Parameters			
	Layer	Hydraulic Role	K_h (m/day)	K_v/K_h	S_s	S_y
Holocene Peat	1-2	Aquitard	3.63	0.02	0.05	0.50
Waikanae River Gravel/Alluvium	1-5	Unconfined Aquifer	260 – 1296	0 - 0.01	0.03	0.30
Holocene Sand	1-3	Unconfined Aquifer	65	0	0.005	0.15
Pleistocene Sands	4	Unconfined Aquifer	22.5	0.36	0.0025	0.10
Pleistocene Silts	5,7,11	Leaky Aquitard	0.017	0.1	3.66e-5	0.05
Parata Terrestrial Gravel	6,8	Aquifer	0.17	0.1	2.46e-5	0.25
Pleistocene Sands deep	9,12	Aquifer	26	0.06	3.15e-6	NA
Waimea Terrestrial Gravel	10	Aquifer	0.60	0.12	5e-6	NA
Greywacke Bedrock	-	No-flow boundary	0	0	0	0

Groundwater Recharge

Rainfall as measured at the Paraparaumu airport over the period 2003-2011 averages 1311 mm/year. The proportion of that rainfall that recharges to the groundwater varies with land use (urban vs non-urban) and soil type (peat vs sand vs gravel) and this has been considered through the establishment of different recharge zones as outlined in Table D3.

Table D3 - Recharge Factors

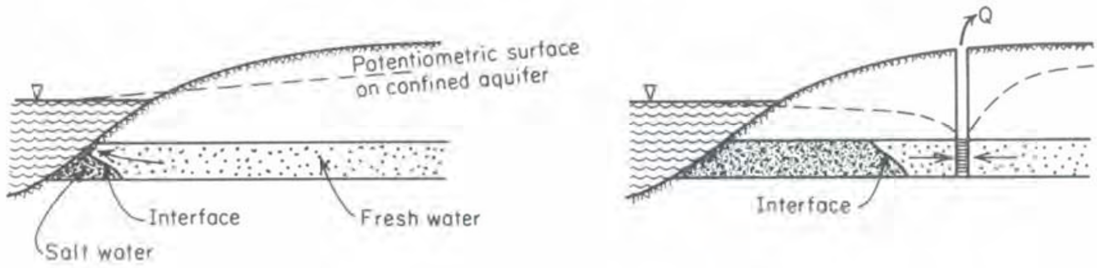
Soil and Land Use type	Soil Recharge Factor	Land Use Recharge Factor	Total Recharge Factor
Urban sand	0.4	0.15	0.06
Non-urban sand	0.4	1.0	0.40
Urban peat	0.35	0.15	0.05
Non-urban peat	0.35	1.0	0.35
Urban Parata	0.5	0.15	0.08
Non-urban Parata	0.5	1.0	0.50

Where a factor of 1.0 indicates that 100 % of rainfall is available for recharge e.g. 40 % of all rainfall that falls on sand is available for recharge however in the urban area, up to 85 % of that rainfall will be captured by drainage and stormwater so only 6 % of total rainfall is actually available for recharge

The calculated recharge factors have been applied to the rainfall series on a fortnightly basis.

Saline intrusion

Modelling the potential for the intrusion of saline water was approached by using Modflow to calculate heads and using these heads to indicate the potential for intrusion to occur. Because of the density difference between fresh water (density of ~1.00 kg/L) and sea water (density ~1.025 kg/L), fresh water within an aquifer tends to “float” on top of any sea water intruding the aquifer. Based on the conservative Ghyben-Herzberg assumption, the head above mean sea level (amsl) indicates the depth (~40 x the head above 0 amsl) where fresh water within an aquifer “seals” out sea water from intruding the aquifer at that point. Where the bottom of the aquifer is shallower than this depth saline intrusion is unlikely. Using this approach, pumping a well at an inland location can lower the head in the aquifer (near the well) without causing lateral saline intrusion *as long as the head in the aquifer remains high enough between the well and the coast to seal out the marine water*. If pumping causes the head in the aquifer to decline to a level where the bottom of the fresh water within the aquifer rises above the bottom of the aquifer between the well and the coast (the depth to the bottom of the aquifer is greater than 40 times the head above mean sea level), the marine water can move inland beneath the fresh water and lateral saline intrusion occurs, as shown in the figure below (Freeze and Cherry, 1979).



In our model we have modelled the offshore aquifers by projecting them a distance of 1.5 km offshore at the dip observed on-shore. We then compared these projections to bathymetric data to assess which layers might outcrop in seawater within this distance. We applied a constant head of 0 m along the tops of the layers cropping out and "no-flow" boundaries to deeper layers. This approach is conservative in that bathymetric data suggest that the deeper aquifer may not outcrop in sea waters for distances of more than 10 km from the coast.

The overall approach is an approximation. Our approach based on the Ghyben-Herzberg relationship does not take the dynamic nature of the flow system into account. Seaward flow within the aquifer pushes out the saltwater/freshwater interface as noted in Freeze and Cherry (1979). Tidal action and seasonal variations in flow cause the boundary between marine and fresh water to become a zone and not a sharp interface through dispersive mixing. Therefore, the use of head data to indicate saline intrusion serves as a guideline but is not definitive of the actual locations were marine water is likely to occur within an aquifer.

Model Calibration

Steady State Calibration

Initially a steady state model was developed, and this model was calibrated using the average static water levels and the average rainfall recharge as supplied by GWRC along with representative water levels recorded in KCDC production wells.

The majority of the GWRC monitoring wells are screened in the shallow aquifers and therefore water levels from the pumping tests were included in the calibration. Non-pumping (so called "static") water levels taken as part of the constant rate pumping tests were used for calibration of deeper aquifers. Although these are not true steady state water levels their use does help to include key aquifer model layers are included in the calibration. For the steady state model a calibration to the data was achieved with a normalised RMS of 11.6%, a residual mean error of +/- 0.3 m for average groundwater levels in all calibrated wells and a mass balance discrepancy of 2% (i.e. approximately the same amount of water enters the aquifer system as leaves the aquifer system). Figure D1 shows the steady state model calibration statistics.

Transient Model

The objective of the transient calibration was to develop a model that can simulate the groundwater system under seasonal changes in the boundaries and replicates constant-rate pumping tests. This was achieved by applying a recharge time series (8 years of data from March 2004 to March 2012) and matching the associated water level records to modelled water level heads. The next step was to calibrate to results of the N2 and Kb4 the pumping test. These tests were selected to allow calibration in the northern (N2 test) and central (Kb4 test) of the modelled area. (No long-term, constant-rate tests have been conducted using production wells in the southern portion of the modelled area.) The calibration plots from the time series are provided in Figure D2-a through D2-E with the pumping tests shown in Figure D3.

The transient calibration has involved assigning hydraulic conductivities and storage properties to the 12 model layers and adjusting these parameters in an iterative process to obtain a match to groundwater water levels.

Simulated Water Balance

Under steady state conditions calculated inflows to the model are 310,000 m^3/day[21], with inflows resulting from rainfall recharge and river leakage. This water budget assumes no inflow from the eastern greywacke boundary or the bottom greywacke boundary as these boundaries were modelled as "no-flow." This assumption is therefore conservative as in reality there are fractures that will be contributing some unknown amount of water to the groundwater flow system (but not the model).

Modelling Scenarios

Once a suitable calibrated groundwater model had been achieved, four 36-year model scenarios were tested:

- Scenario 1: A constant population equal to that at 2049, under an assumption of moderate growth. Under this scenario the maximum combined pumping rate[22], averaged over the peak week was 23,500 m^3/day from a total of up to eight wells, all of which are existing or under construction
- Scenario 2: A constant population equal to that at 2049, under an assumption of high population growth. Under this scenario the maximum combined pumping rate, averaged over the peak week was 28,000 m^3/day from a total of up to ten wells, eight of which are existing or under construction with two additional wells planned for future construction
- Scenario 3: A constant population equal to that at 2060, under an assumption of moderate population growth. Under this scenario the maximum combined pumping rate, averaged over the peak week was 24,000 m^3/day from a total of up to eight wells, all of which are existing or under construction; and
- Scenario 4: A constant population equal to that at 2060, under an assumption of high population growth. Under this scenario the maximum combined pumping rate, averaged over the peak week was 29,700 m^3/day from a total of up to eleven wells, eight of which are existing or under construction with three additional wells planned for future construction.

Wells used in each simulation were selected following a hierarchy based on three main factors:

- Water quality and compatibility with river water (primarily an issue of phosphorous concentration)

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[21] The model calculates to 8 significant figures. We present the results to two to better indicate model accuracy.

[22] Total daily pumping rates are rounded to the nearest hundred m^3/day.

- Proximity to other wells (to limit interference and spread drawdown and avoid concentration of drawdown where sea water intrusion might occur); and
- Overall pumping and delivery costs (to avoid wasteful energy use and unnecessary costs to KCDC).

In each scenario the well at hierarchy level 1 was pumped (simulated in the model) first at its anticipated long-term sustainable pumping rate. When more water was needed than could be supplied by this one well, the well with hierarchy level 2 was then pumped alongside with the first well as long as needed. In total up to 11 wells are anticipated to fulfil the minimum river flow with hierarchy level 1 (KCDC Kb4) used regularly and hierarchy level 1 (K13) used only occasionally. The planned well-use hierarchy, peak weekly pumping rates for each well during for scenario are included in Table D4.

Table D4 – Well Hierarchy and Pumping Rates in Four Modelled Scenarios

Scenario	Max Weekly Q (l/s)/ (m^3/day)	Kb4 1	N2 2	K4 3	K6 4	Kb7 5	K10 6	K12 7	K5 8	N3 9	S1 10	S2 11
					Peak Pumping Rate (l/s)							
1: 2049 Population - Mod Growth	272/ 23,500	45	25	80	58	10	17	8	29	0	0	0
2: 2049 Population - High Growth	324/ 28,000	45	25	80	58	10	17	8	46	25	10	0
3: 2060 Population - Mod Growth	278/ 24,000	45	25	80	58	10	17	8	35	0	0	0
4: 2060 Population - High Growth	344/ 29,700	45	25	80	58	10	17	8	46	25	25	5

The amounts and timing for the simulated pumping of each well was derived from an analysis of river flows. This analysis used 36 years of historical river flow data 1975 - 2011 to define possible river flow during a simulation from Year 0 through Year 35 scenarios. This 36-year period of river flow includes periods of both high water and drought. All four scenarios used this 36-year period data as if it were to be repeated starting at Year 0 (planned for 2014). These historical flows allow for a representative simulation indicating when and by how much, river flows would needed to be augmented with pumped water from the KCDC wells.

Mitigation Scenarios

Three scenarios were modelled to explore the potential for injection of groundwater to mitigate reduced water levels (drawdowns) caused by pumping of the KCDC wells. The scenarios were not modelled to develop a mitigation procedure that optimises injection rates, timing and locations. Rather, the scenarios were modelled to indicate whether injection has the potential to mitigate deleterious environmental effects. If modelled drawdown is reduced through one or more of the injection scenarios, then it indicates that injection should be considered as an option if monitoring indicates that adaptive management is needed. At that point (or before) a number of injection scenarios could be modelled to develop an optimised mitigation strategy.

The potential mitigation scenarios were modelled based on the planning assumption that river water would be available during the wetter months of winter and early spring for injection at the rate of 10,000 m^3/day (about 115 L/s). All three mitigation scenarios modelled a four year period beginning with year 27 that included the 50-year drought with its associated highest demand (pumping withdrawal rates) of Scenario 4. In these mitigation scenarios, water was injected during the winter/early spring for 150 days starting with the first week of July of each year. A total injection rate of 10,000 m^3/day was distributed to a different set of injection wells in each of the mitigation scenarios to assess the feasibility of injection to reduce drawdowns in the Holocene Sand Aquifer and the Lower Pleistocene Sand and Waimea aquifers. Any reduction of drawdown resulting from the mitigation scenarios in these aquifers would result in a reduction of:

- Potential for saline water intrusion,
- Drawdown effects in the aquifers underlying the wetlands,
- Drawdown effects on existing wells, and
- Reductions in flow in the Waikanae River and various streams in the area.

The three sets of injection wells and the injection rates used are shown in Table D5.

Table D5 – Mitigation Scenario Wells and Injection Rates

Mitigation Injection Scenario	Injection Well /rate [m^3/day- L/s]	Injection Well /rate [m^3/day- L/s]	Injection Well /rate [m^3/day- L/s]	I Injection Well /rate [m^3/day- L/s]	Injection Well /rate [m^3/day- L/s]
Coastal	**C1**	**C2**	**C3**		
	3,335 - 38.6	3,335 - 38.6	3,335 - 38.6		
Central	**K4**	**K6**	**K10**		
	4,000 - 46.3	4,000 - 46.3	2,000 - 23.1		
Eastern	**N3**	**N2**	**Kb4**	**S1**	**S2**
	1,771 - 20.5	2,160 - 25.0	3,193 - 37.0	2,160 - 25.0	1,418 - 16.4

Results of Numerical Modelling

Drawdown Interference

Contour maps of simulated drawdowns in the shallow aquifer (Holocene sand), Parata, lower Pleistocene sand and Waimea aquifers for Scenarios 2 and 4 (as described above) for the worst-case simulated drawdowns are given in Figures D4 to D11.

The predicted drawdown indicates that the interference effects between the KCDC production wells will be about 15+ m in the Upper Pleistocene and Waimea aquifers under Scenario 4 and 10 to 15 m under Scenario 2. Drawdowns under the lower pumping rates of Scenarios 1 and 3 are less. Drawdowns in the Parata Aquifer under Scenario 4 are predicted to be about 5+ m. Modelling suggests that during the 50-year drought at Year 27.8 of Scenario 4 abstraction would have a drawdown effect on privately owned wells screened in the shallow unconfined aquifer of less than 0.5 m.

Effects on Wetlands and Surface Water Bodies

The drawdown contour maps also indicate the potential effects on wetlands and surface water bodies. Figure D8, the drawdown contour map for Scenario 4 (the highest and longest pumping period) after the longest and most severe drought illustrate the worst-case conditions of water level changes caused by the pumping of KCDC wells on the shallowest aquifers and therefor wetlands and surface water bodies. The figure shows the effects to shallow groundwater as indicated by the drawdowns in the Holocene Sand Aquifer beneath key identified wetlands could be as much as 170 mm. The changes are less than the normal variations in water levels of 1 to 2 m observed in wells completed in the shallow aquifers as shown in Figure 2 of the main body of the report.

Marine Water (Saline) Intrusion

Contour maps of simulated drawdowns in the shallow aquifer (Holocene sand), Parata, lower Pleistocene sand and Waimea aquifers for Scenarios 1 through 4 (as described above) are given in Figures D4 to D11. The predicted water level drawdown contours indicate that saline water intrusion caused by pumping the KCDC production wells may move inland as indicated by drawdowns of 4+ m under Scenario 2 and 5+ m under Scenario 4. Modelling suggests that during the 50-year drought period of Scenario 4, abstraction would have had a drawdown effect on privately owned wells screened in the shallow unconfined aquifer of less than 0.5 m.

Water Budget

The total volume of groundwater entering and leaving the modelled aquifer system under natural steady state conditions (i.e. no pumping) based on 2003 to 2012 rainfall is predicted to be in the order of 310,000 m^3/day, as shown in Table D6. Supporting figures D12 and D13 present the assigned zone budgets and output tables.

Table D6 - Modelled Steady State Water Budget

	Steady-State
INFLOWS [m^3/day]	
Recharge	70,300
River Leakage	152,000
Storage	0
TOTAL	222,300
OUTFLOWS [m^3/day]	
Domestic Abstraction/ET	6,400
River leakage	169,300
Flow Offshore	41,900
Drains	8,000
Storage	0
TOTAL	225,600
INFLOWS – OUTFLOWS (% discrepancy)	-3300 (-0.01%)

Waikanae River gauging indicates a flow loss of approximately 300 L/s to the underlying aquifer between State Highway 1 and Jim Cooke Memorial Park and a 300 L/s gain to the river down gradient (Jones and Gyopari, 2005). River discharge rates are presented below in Table D7.

Table D7 - Modelled flow in Rivers

	Steady-State	Scenario 2	Scenario 4
Waikanae River (SH1 – James Cook)	-240	-178	-176
Waikanae River (below James Cook)	360	205	224

Potential Mitigation Options

Drawdown maps of the Holocene Sand Aquifer for year 27.8 with mitigation injection are shown for the coastal injection mitigation option (Figures D-14), the central injection mitigation option (Figures D-15) and the eastern injection option (D-16). The drawdown maps show that injection has the potential to mitigate drawdown effects in the Holocene Sand Aquifer underlying the wetlands in the project area. Figure D-8 shows that without injection, drawdowns in the Holocene Sand Aquifer beneath the nationally ranked wetlands within the modelled area are about 140-170 mm in the worst cases (the Harakeke and Nga Manu wetlands) to just a few millimetres in the best cases (Waikanae saltmarsh and the Raumati South wetland).

Under the coastal injection scenario (D-14), drawdown in the Holocene Sand Aquifer reduces to about 70 mm beneath Te Harakeke wetland, about 110 mm beneath the Nga Manu wetland, and a few tens of millimetres in the shallow aquifer beneath the other wetlands of National significance. Under the eastern injection scenario (D-16), the drawdown reductions are even greater. With injection, the largest drawdown is reduced to about 70 mm beneath the Nga Manu wetland. Figure D-15 (central injection) shows that drawdowns beneath wetlands are also reduced through injection. Injection to reduce drawdowns beneath wetlands of limited significance is most effective when injection occurs in the eastern locations, most likely because the low-value wetlands are mostly located in the eastern portion of the project area. Comparison of the potential reductions of drawdowns under the three scenarios, indicates that the eastern injection scenario appears to be the most promising for future mitigation of drawdown effects on wetlands.

Additional modelling could be used to refine and optimize such mitigations by finding the optimal locations, rates and timing to reduce water level changes to acceptable levels.

Potential to Mitigate Saline Intrusion

Figures D-17, D-18 and D-19 show the modelled changes in water levels in the Holocene Sand, and Lower Pleistocene Sand /Waimea aquifers resulting from the injection at three imaginary wells followed by withdrawal from the KCDC production wells over their highest demand period (year 27 that includes the 50-year drought). Comparison of these drawdowns with those of the same time period (year 27.8) indicate that the differences with and without injection are small. There is, however, a relatively small improvement in reduction of water levels in the Lower Pleistocene Sand Aquifer following the eastern over the coastal injection and central injection scenarios.

The modelling indicates that the injection appears to have begun and ended too early in the season to be efficient and effective as mitigation for salt water intrusion. Injection is a method used at many international locations to manage saline intrusion. We believe that further exploration through modelling to better optimise injection scenarios would better assess the potential for injection to mitigate saline intrusion.

Model Boundary Edge Effects

A number of the drawdown figures generated using the model show drawdowns extending to the northern boundaries of the figures. The northern edge of the figures lies about 800 m from the model’s northern boundary. Ideally, a model is constructed such that pumping effects do not extend to the model’s boundaries because the boundary can affect heads (water levels) near the boundary. The type and magnitude of the effect is controlled in part by the type of boundary. In the case of the KCDC model, the northern boundary consists of “inactive model cells.” These operate as “no-flow” boundaries, neither contributing flow into or out of the model (as would constant head or general head boundaries), nor holding the head at a constant value and drawdown at “0” (as would a constant head boundary). Because the no-flow boundary does not allow the effect of the drawdown to spread out further than the model boundary, drawdowns are over-calculated by the model. Therefore, the model-predicted drawdowns in the vicinity of the model boundaries are greater than those that would actually occur were the boundary moved several kilometres to the north of that used. Unfortunately there is limited data from the area north of the boundary. KCDC has drilled no investigation or production wells and conducted no pumping tests in this area. For this reason the model boundary used in the original KCDC model has been retained.

Sensitivity Analysis

Sensitivity analyses have been carried out by systematically multiplying the calibrated hydraulic conductivity in turn by factors of 0.1, 0.5, 5, and 10 in the steady state model using the calibration target wells (GWRC and KCDC). The sensitivity of the model to these changes is presented in Figure D-20 which shows the changes in RMS (Root Mean Squared) error in metres caused by multiplying the indicated hydraulic conductivity by the four values (0.1, 0.5, 5, and 10). The "Change in RMS" on each graph is the difference between the RMS error in the final model and the same model when the hydraulic conductivity multiplied by the indicated value. A large change in the modelled heads (as expressed by a larger "change in RMS") caused by minor changes in the parameter value indicates that the model is sensitive to that parameter. Figure D-20 shows that the model in general, is relatively insensitive to changes in hydraulic conductivity in the aquifers. The indicated highest sensitivities are to: *increased* hydraulic conductivity in the Holocene sands and river gravels/ river conductances, and *decreased* hydraulic conductivities in the Lower Pleistocene sands and Waimea gravels.

The sensitivity to changes in storativity and specific yield shown in Figure D-21, has been assessed using the Scenario 4 transient model. In these sensitivity analyses we have changed the storage parameter values using similar multipliers (0.1, 0.5, 5, and 10) with the exception that a specific yield multiplied by 10 would generate values that are not physically possible. Instead, we used an upper-end multiplier of 5. (These specific yield multipliers only apply when the aquifer is unconfined, in this case, the Holocene sand and where shallow enough to be unconfined, the upper Pleistocene sands and Parata gravels.) Because they are often in direct hydraulic continuity, we adjusted the storativity of the Waimea and lower Pleistocene sand aquifers together in the same storativity sensitivity analyses. In a similar manner, we combined the Holocene and upper Pleistocene sands in our sensitivity to storativity and specific yield changes. These analyses indicate that the model is generally insensitive to small changes in storativity. However, the model is moderately sensitive to changes in the storativity of the Pleistocene silts that separate the major aquifers at some locations.

These results support the conclusion that a robust calibration has been achieved.

Model Limitations

Model Calibration

A reasonable-to-good "steady-state" calibration to average recharge and average water levels was achieved. The model was calibrated to the water level data from the GWRC monitoring wells and selected non-pumping water levels observed at the beginning of the constant rate pumping tests carried out at K4, K6, Kb4, in March and April 2010, and K5, K10 and N2 carried out in Jan – May 2012. Although the combination of data from these various time periods does not represent true steady state conditions, they provided a good starting point for the calibration to transient conditions.

A reasonable-to-good long-term transient calibration to recharge and water level time series from March 2004 to March 2012 (8 years) was achieved. The calibration enables the model to generally simulate the seasonal peaks and troughs while generally maintaining the overall observed trend in water levels. We note that the individual model layers have been assumed to be homogeneous which in some cases results in deviations between calculated and observed water levels of up to 2 m. Investigation wells and pumping tests did not provide sufficient detail to justify sub-division of the aquifer into separate zones with different properties. An exception was the lowering of hydraulic conductivity where the software package HydroGeoAnalyst artificially increased the thickness of the aquifers beyond the areas where well data were input into the programme. In these areas zonation was used to allow the best-estimates of transmissivity to be consistent with those of tested areas. The increased detailed analyses of geology coupled with pumping tests results did allow for an increase in the number of layers to 11 from 5 in the original CH2M Beca model. The additional layering was based on better recognition of the various aquifer and aquitard units in the project area.

A reasonable-to-good calibration to drawdowns monitored in observation wells during aquifer tests was achieved. This calibration allows the model to replicate the pumping scenarios proposed for the KCDC wells to supplement river flow during periods of high surface water demands and low river flows.

Therefore we consider the calibration to be appropriate for assessing the long term effects from the well field.

Limitations and Appropriate Use of Modelling Results

All models have limitations and this model, although robust and well supported by field data, is no exception. This model and its simulation gives a prediction of water level changes that are likely under the assumptions of future hydrologic conditions and the assumptions made to reduce the variability of the natural world into defined units with defined properties. None of these assumptions are (or can be) exact and therefore the actual response to future hydrologic activities (such as pumping the KCDC wells) will differ to some extent from those predicted by the model. The model does, however, give our best prediction of what is likely to occur based on these assumptions.

Because some deviation from predicted and future hydraulic responses will occur, we recommend monitoring to both verify model predictions and to provide information for future updates to the model. Any conditions required as part of a consent should be based on such monitoring. If the response of the system differs from that predicted, the model can and should be used to investigate why the system is behaving as it is. A model is an appropriate tool to better understand a hydraulic system by allowing investigation into the sensitivity to variations in values of various parameters. By identifying the parameters values to which the model is sensitive, the appropriate data can be collected in the future with less attention paid to less significant parameter values to which the model is not sensitive.

Another limitation of the model is its focus on certain areas (primarily the areas of concern such as near KCDC wells and near the Waikanae River) and less on areas further afield or with sparse data. In such areas where geological information and water level observations are limited, the model will likely be less accurate and its predictions should be considered with this understanding in mind.

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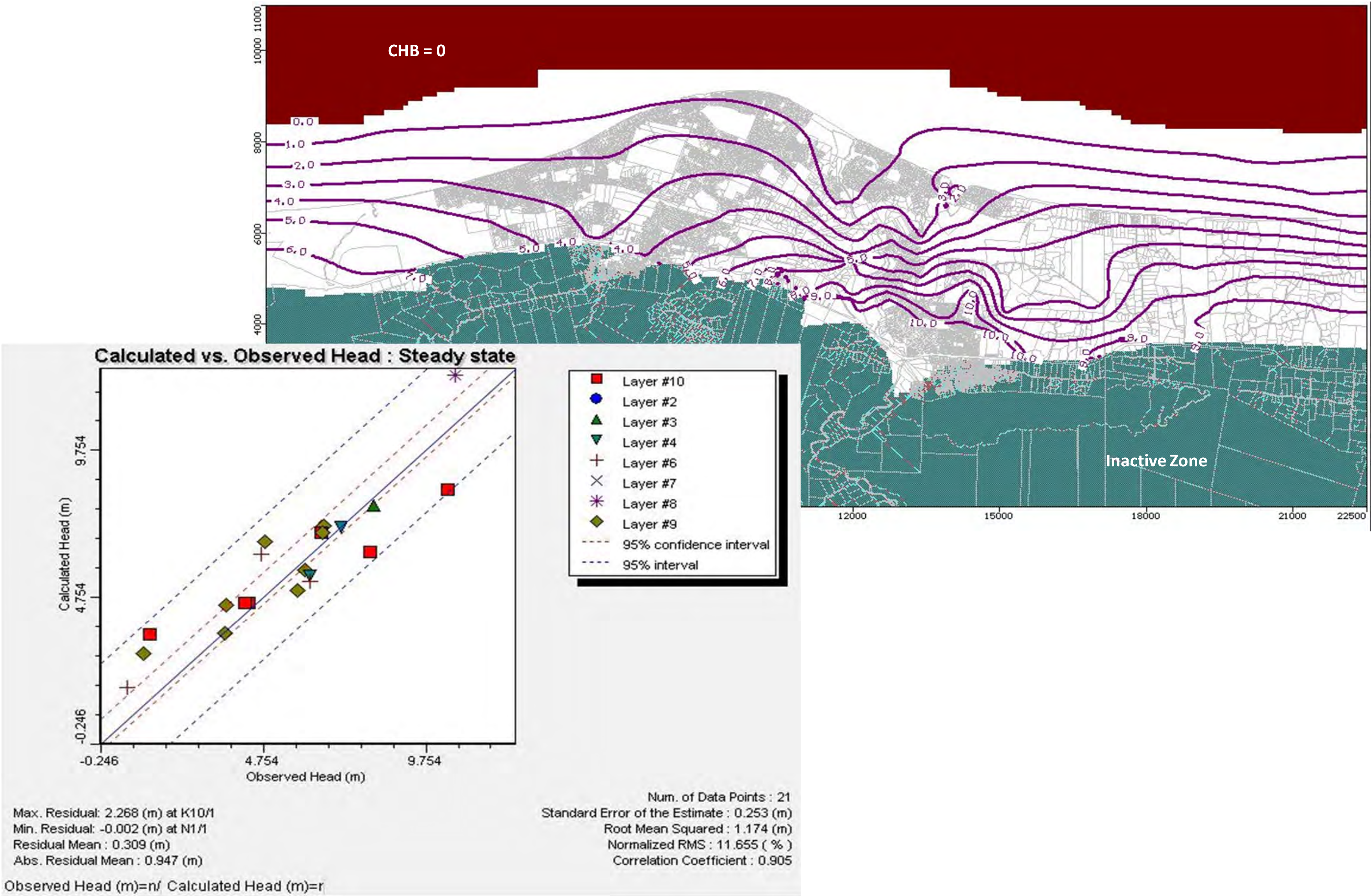
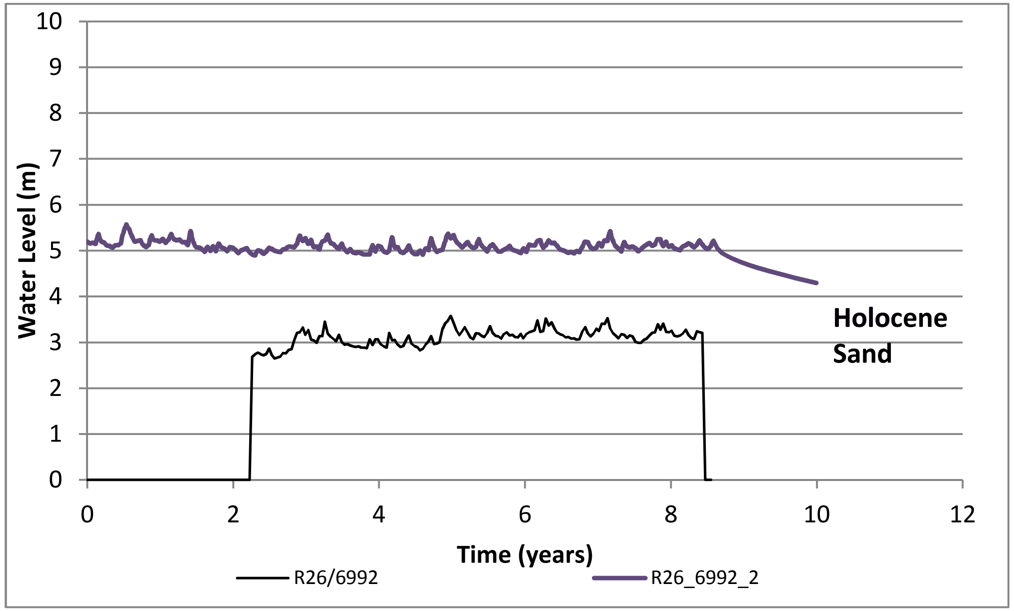
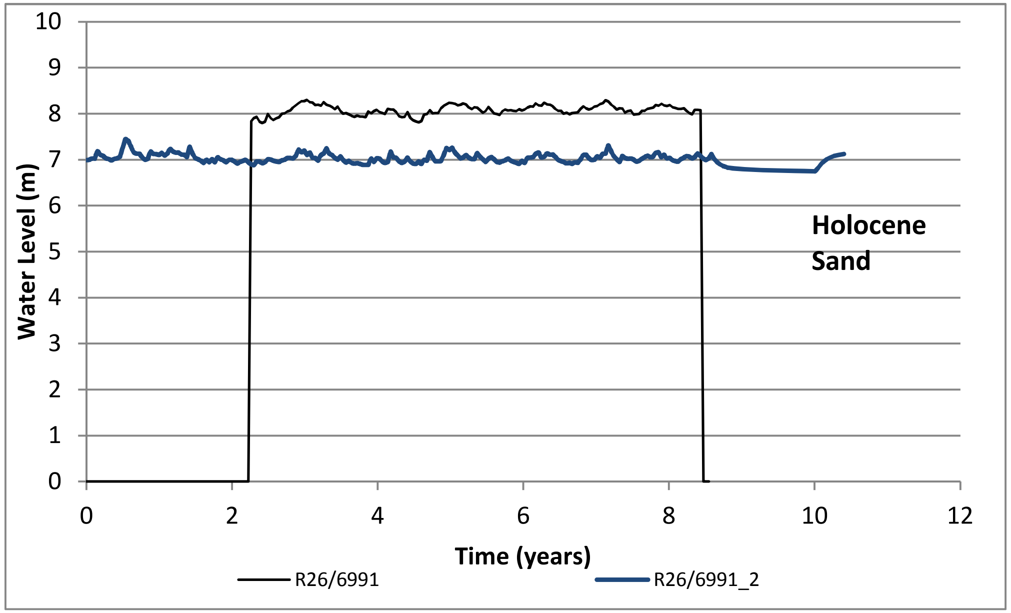


CH2M Beca

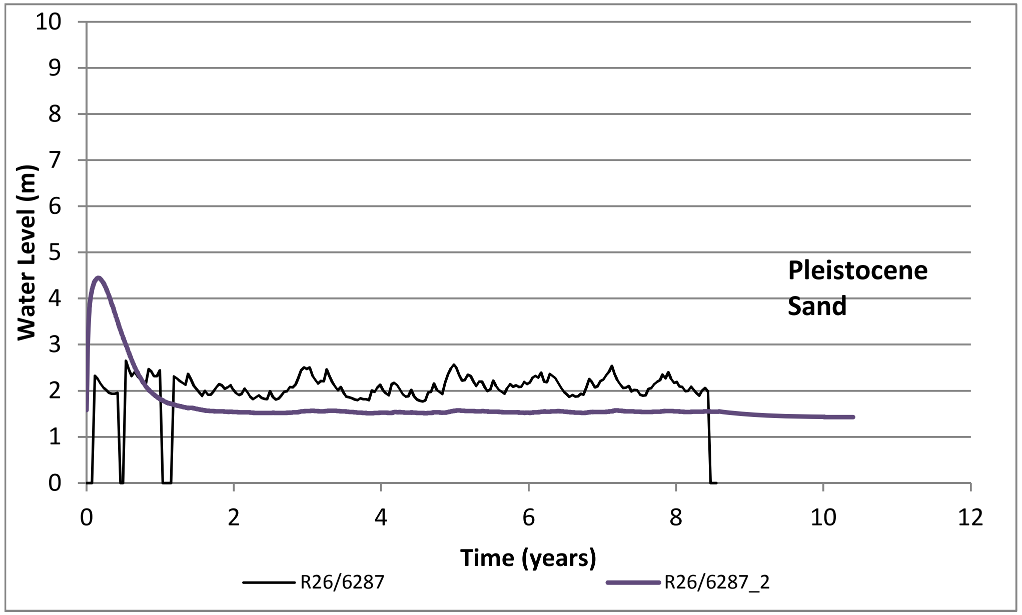
Steady state model calibration and predicted steady state g/w contours

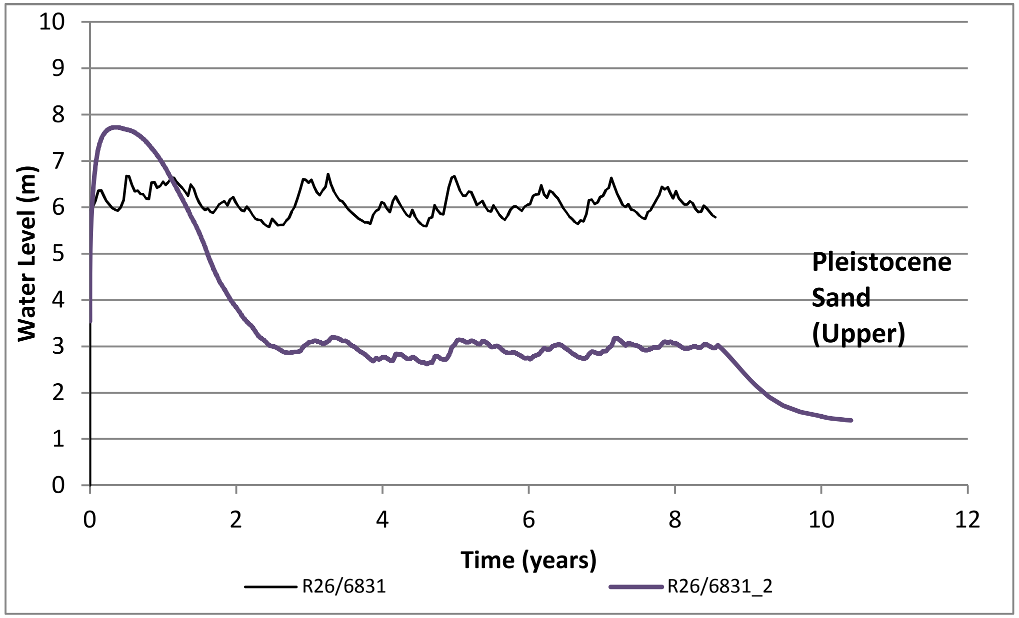


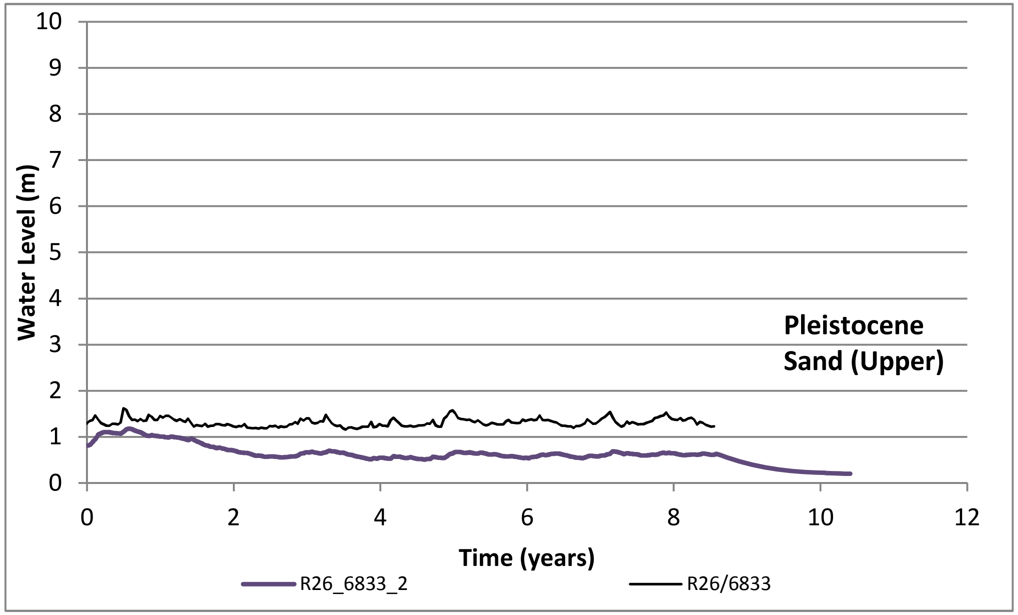


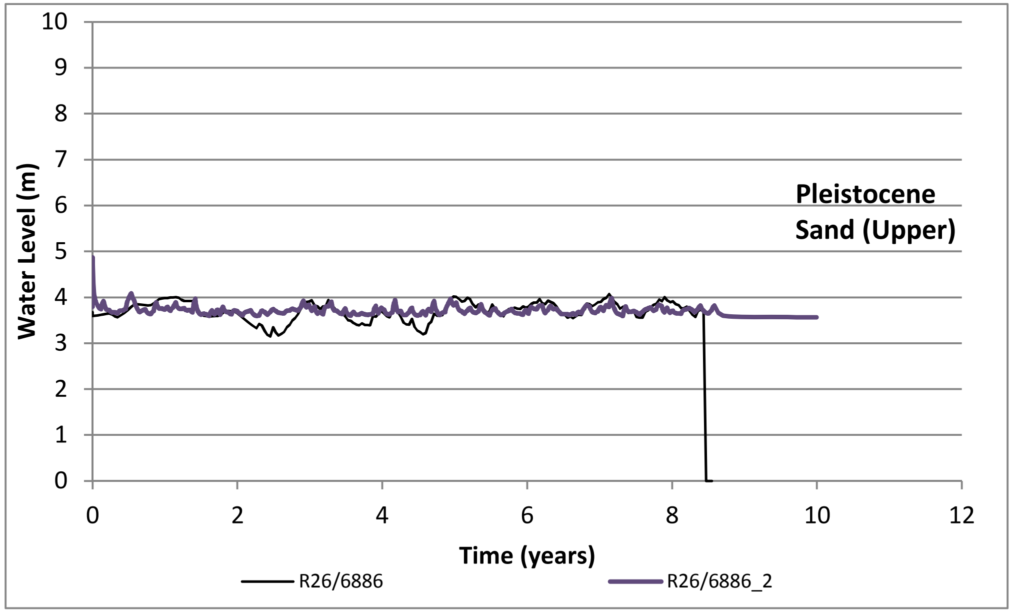
Well Number _2 = Modelled Water Level No suffix = Monitored Water Level

Transient 'long term' Calibration









CH2M Beca

Well Number _2 = Modelled Water Level No suffix = Monitored Water Level

Transient 'long term' Calibration

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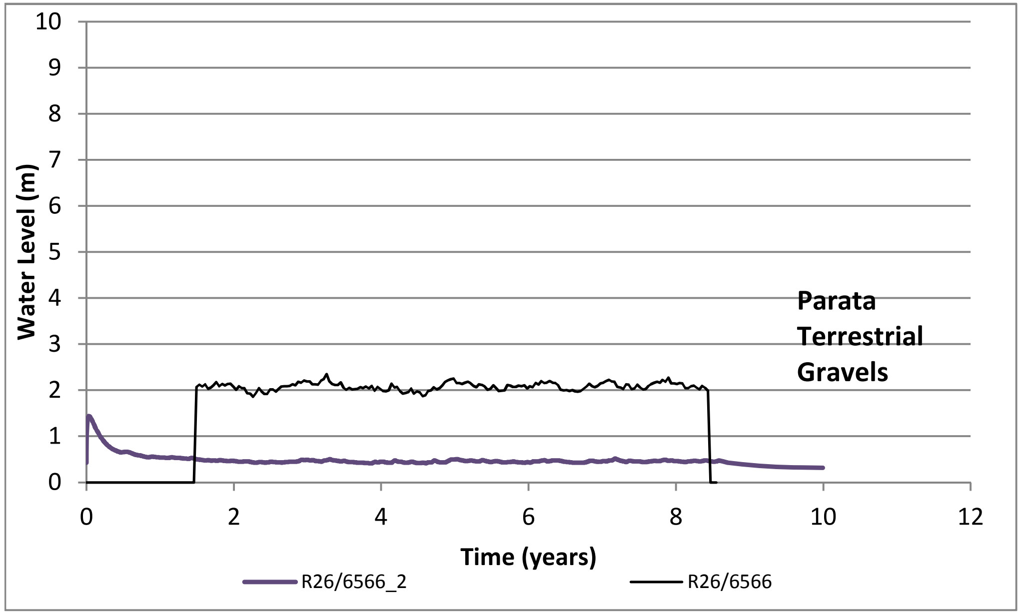
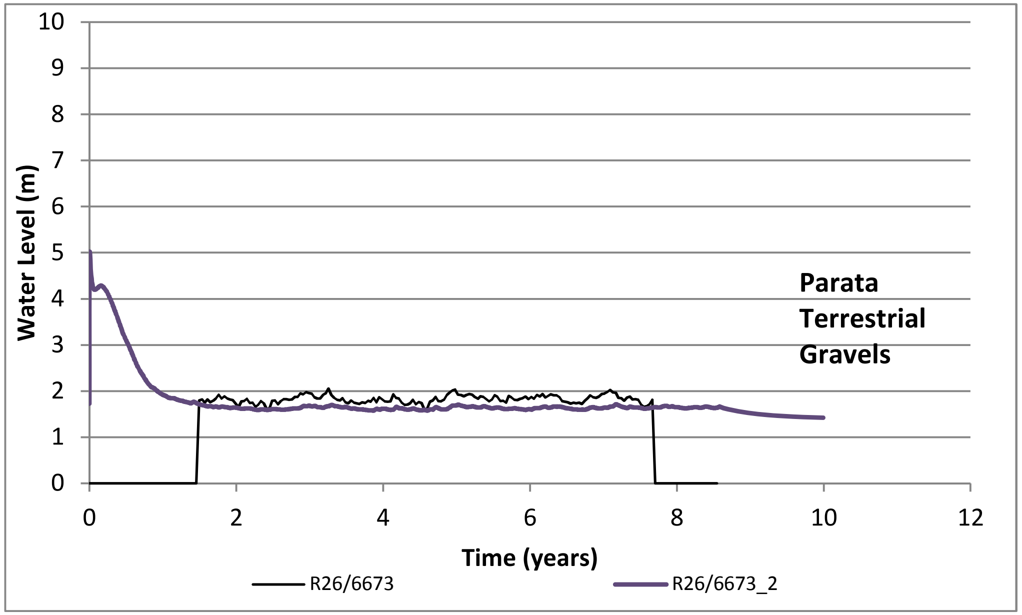
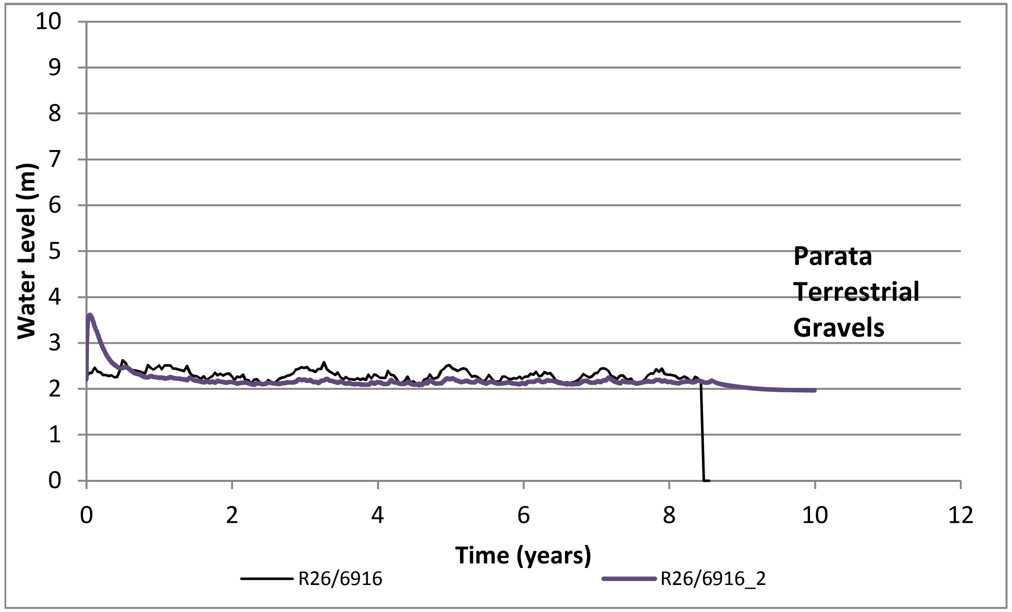
D2-B







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Transient 'long term' Calibration

CH2M Beca

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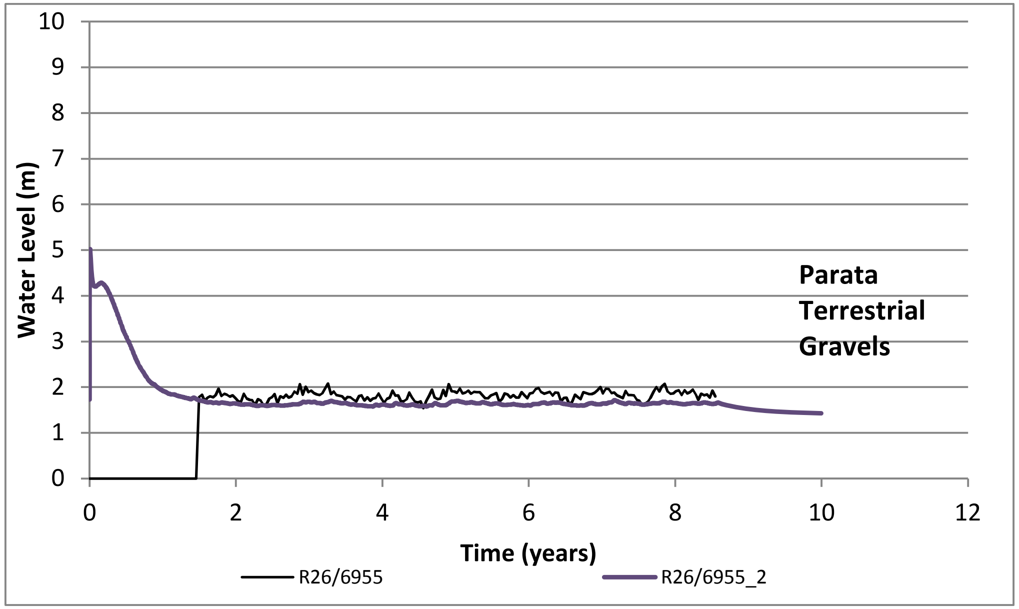
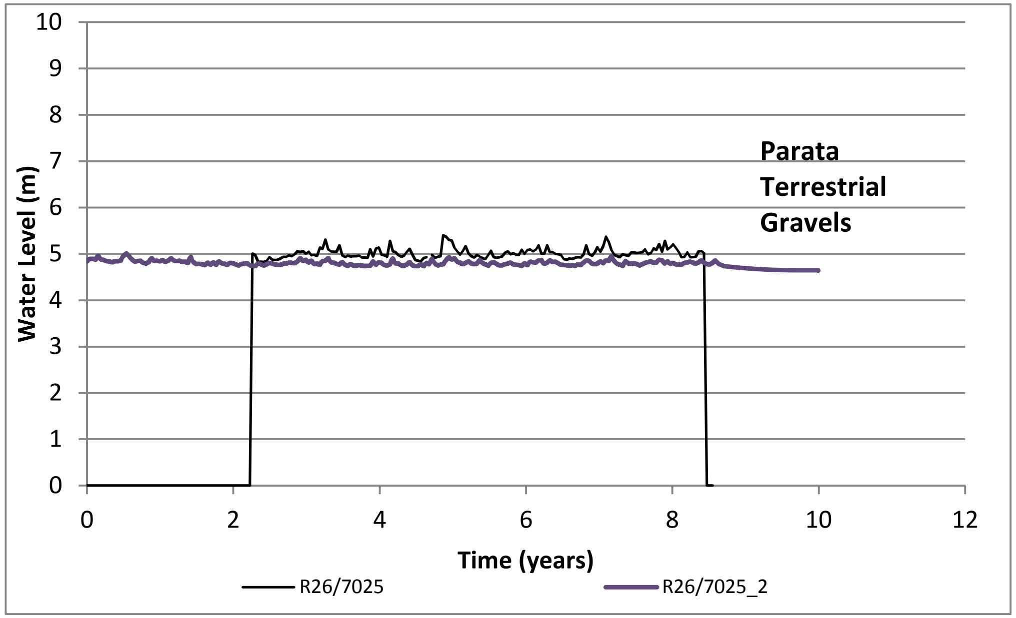
D2-C





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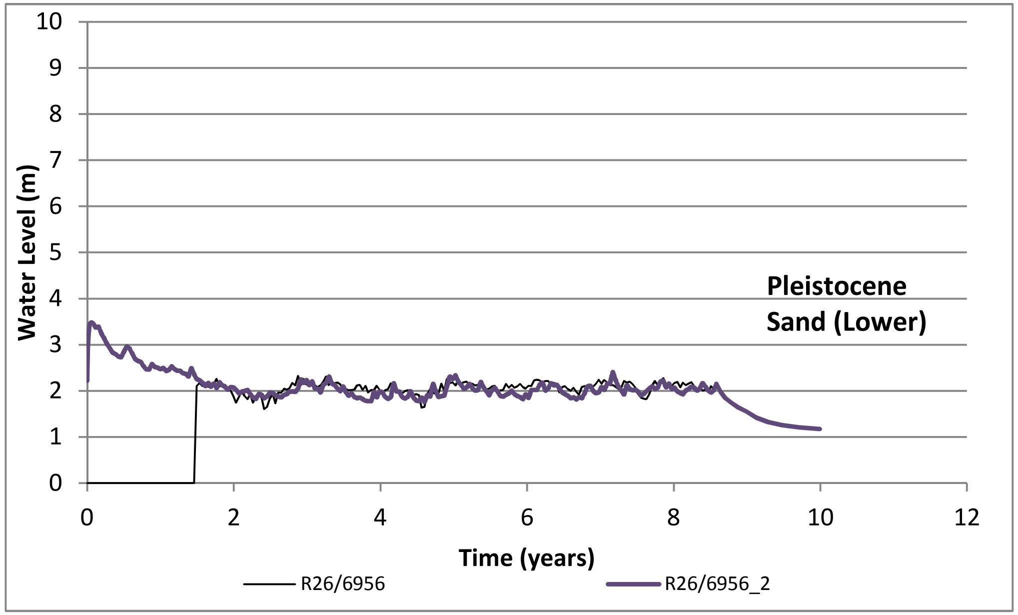

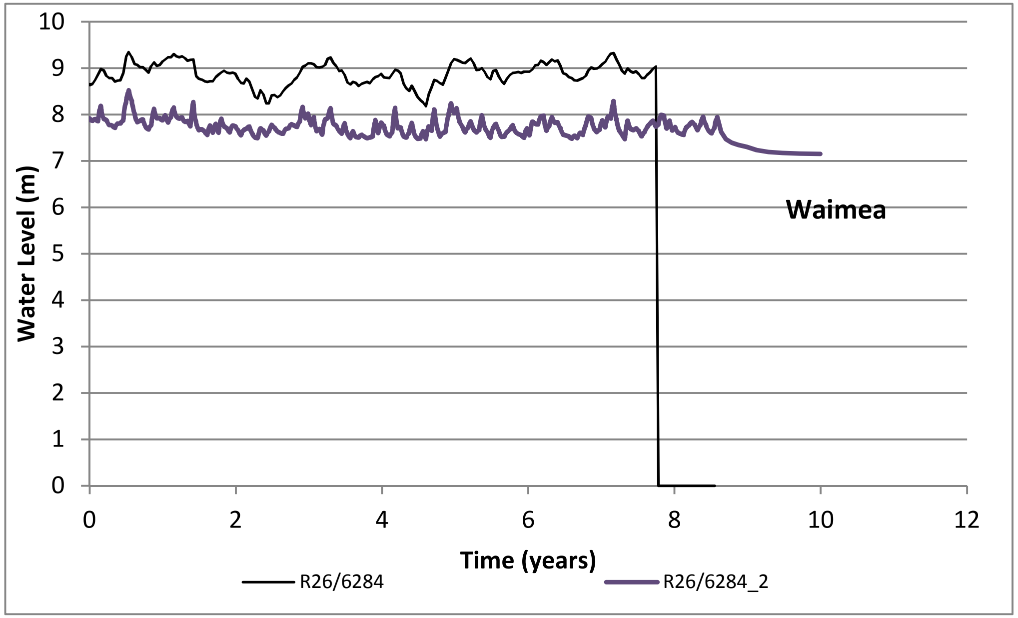

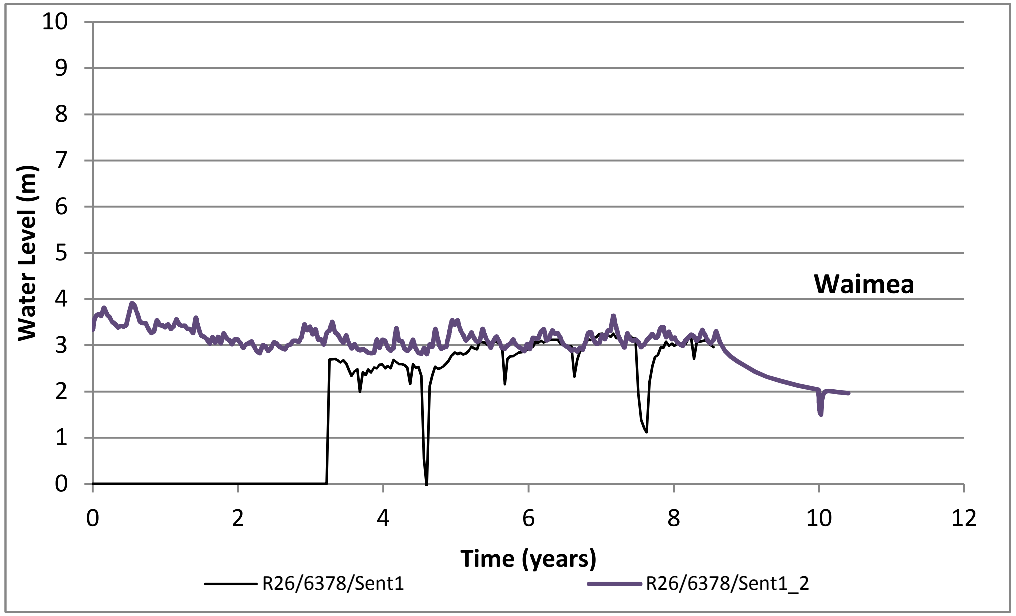

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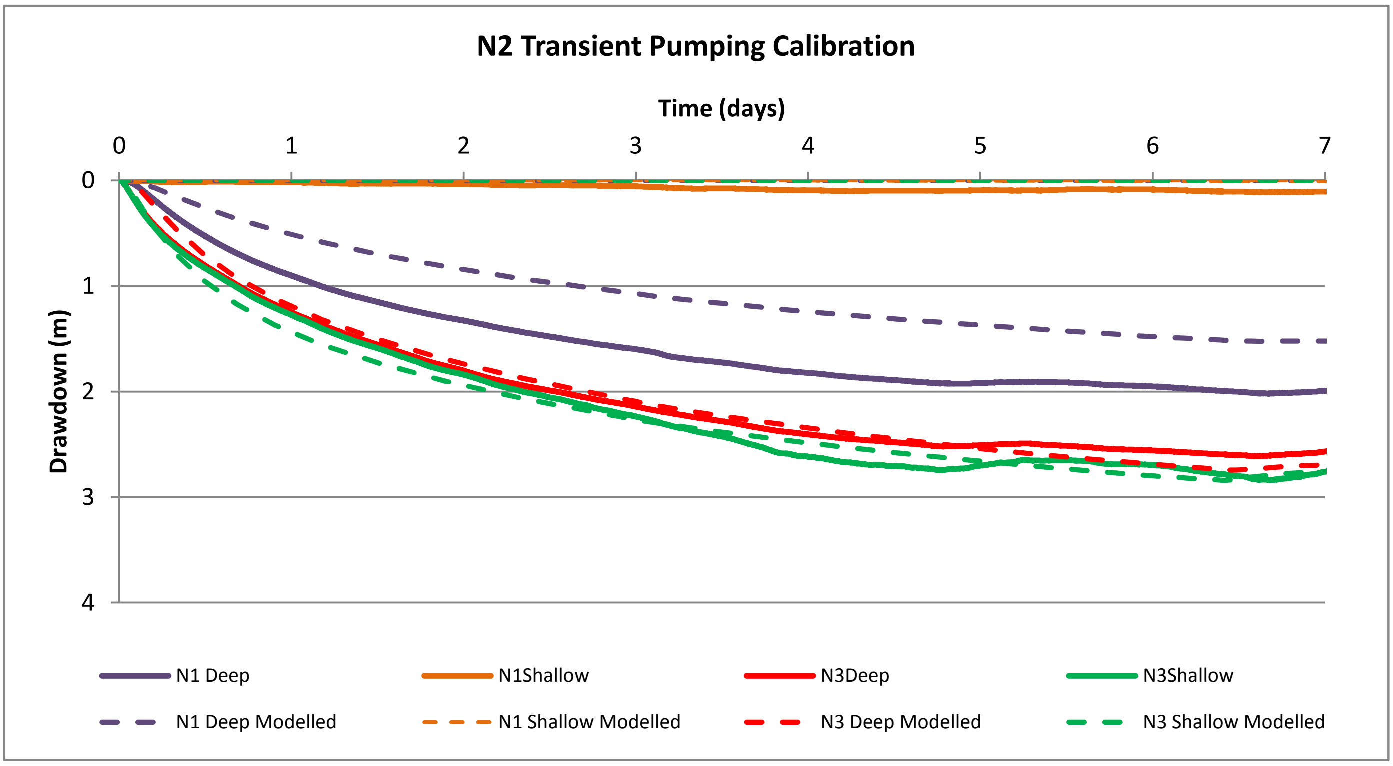
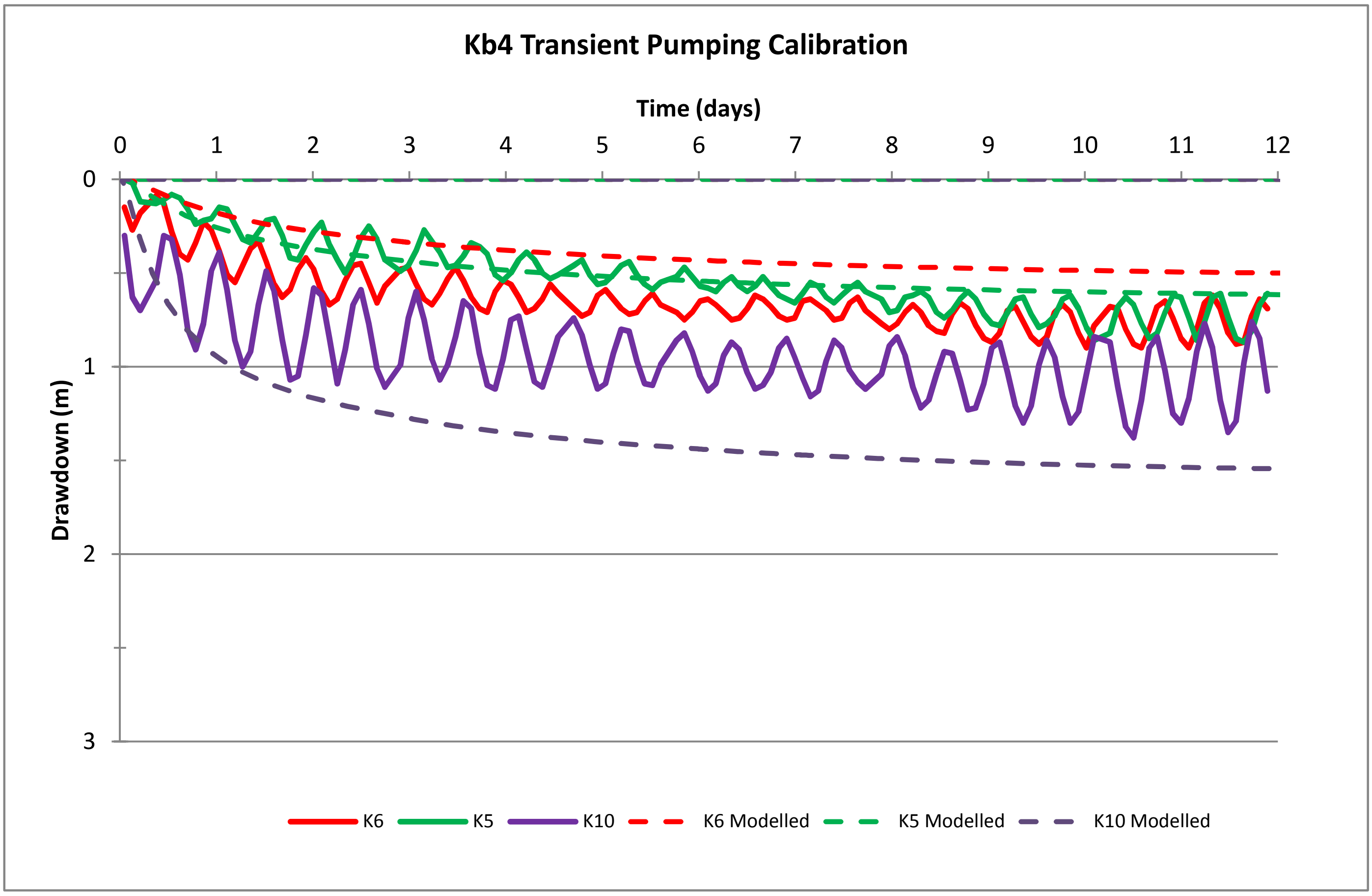
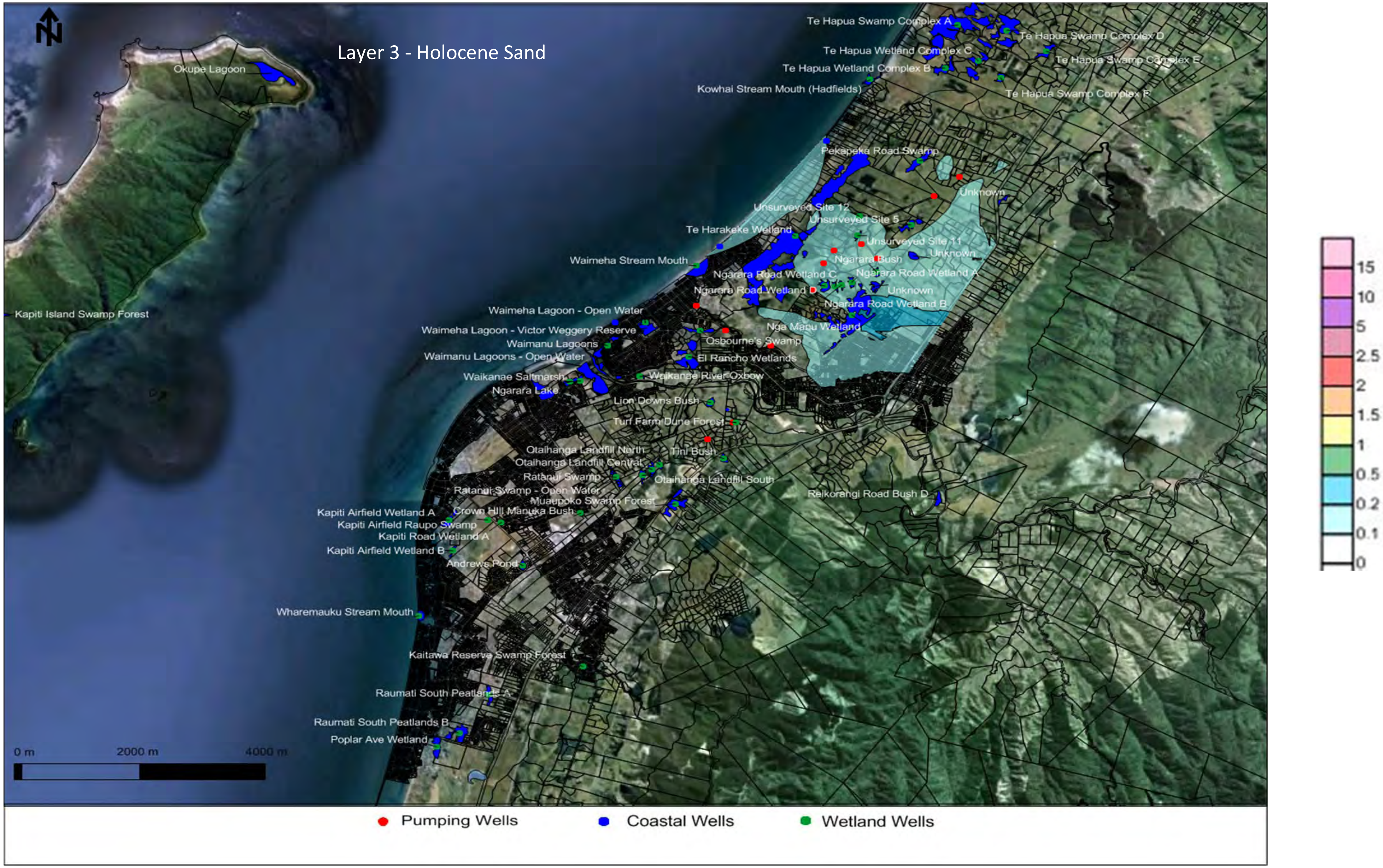
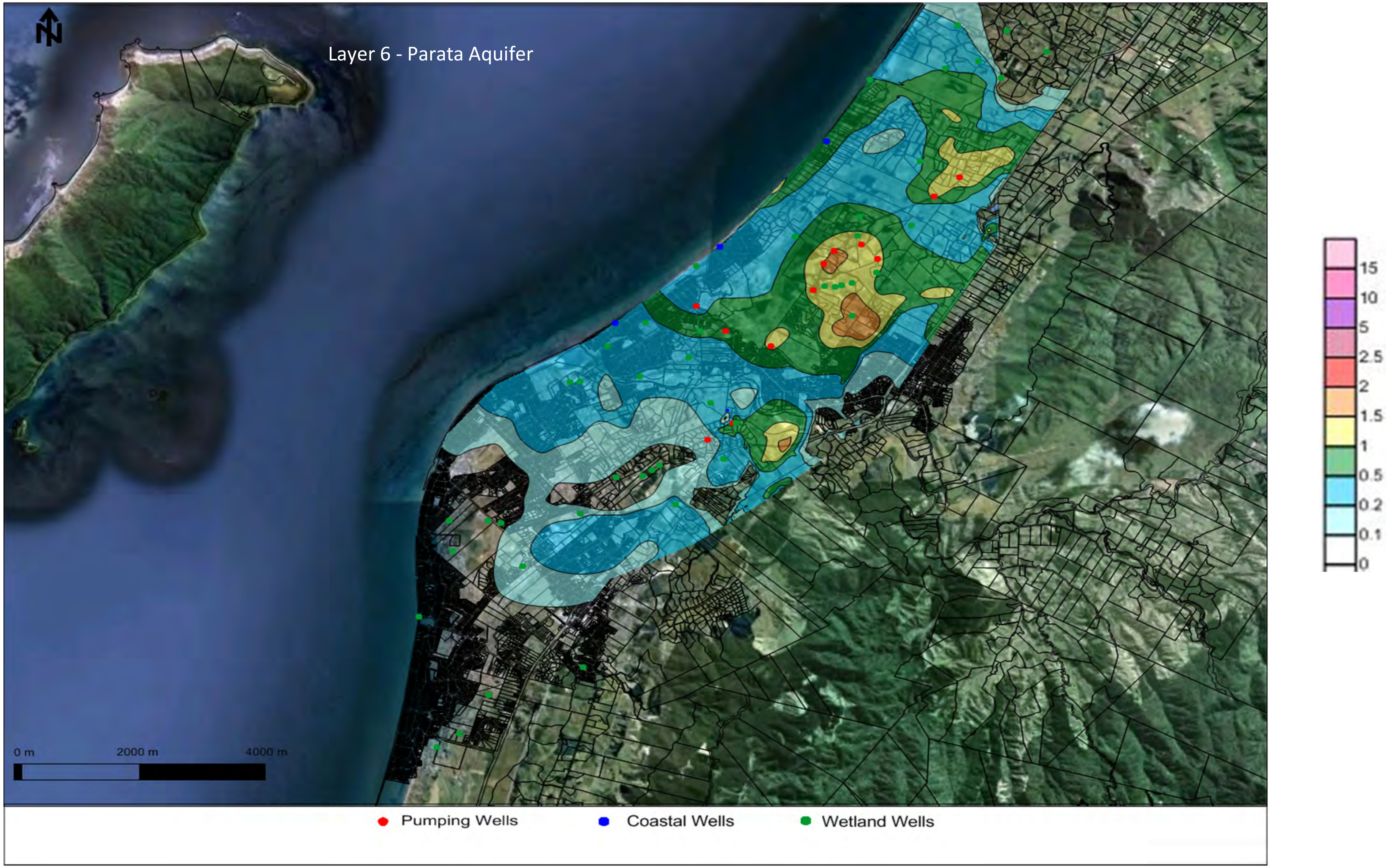

N2 Transient Pumping Calibration
Time (days)
0
1
2
3
4
5
6
7
Drawdown (m)
0
1
2
3
4
N1 Deep
N1Shallow
N3Deep
N3Shallow
N1 Deep Modelled
N1 Shallow Modelled
N3 Deep Modelled
N3 Shallow Modelled


Kb4 Transient Pumping Calibration
Time (days)
0
1
2
3
4
5
6
7
8
9
10
11
12
Drawdown (m)
0
1
2
3
K6
K5
K10
K6 Modelled
K5 Modelled
K10 Modelled



Scenario 02 - Drawdown - Holocene Sand - 27.8 Years

CH2M Beca



Scenario 02 - Drawdown - Parata Aquifer - 27.8 Years

CH2M Beca

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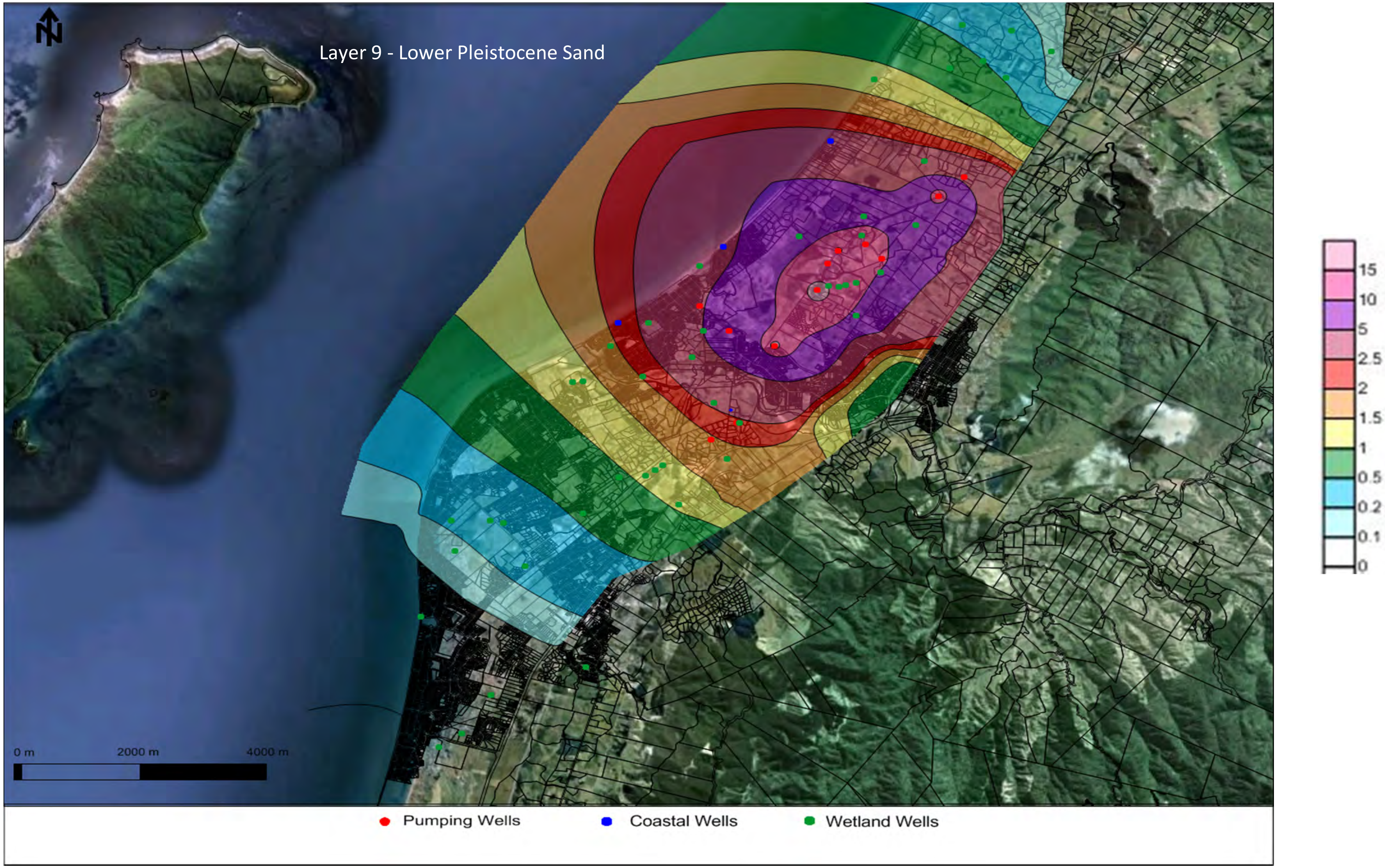

Scenario 02 - Drawdown - Lower Pleistocene Sand - 27.8 Years

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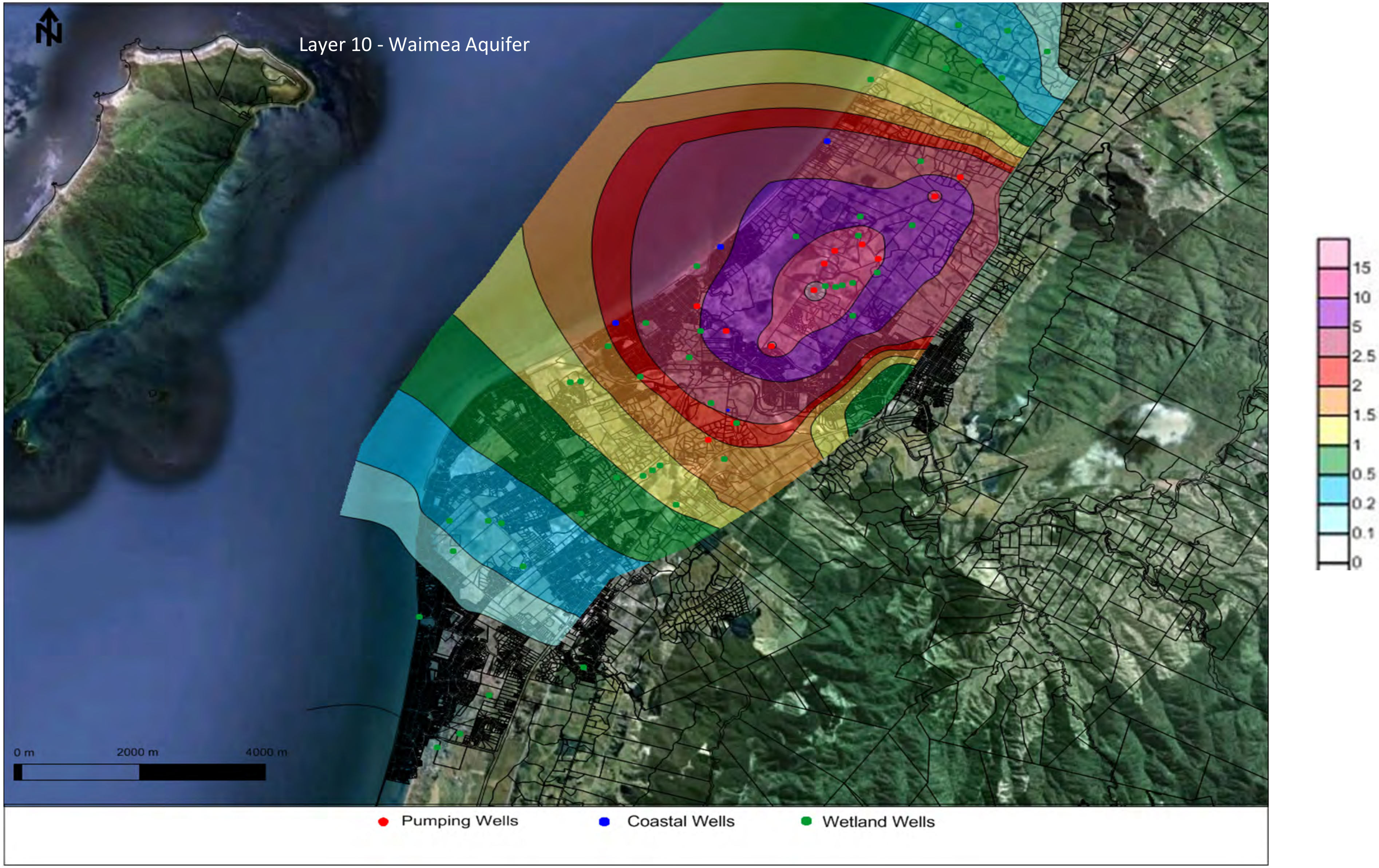

CH2M Beca

Scenario 02 - Drawdown - Waimea Aquifer - 27.8 Years

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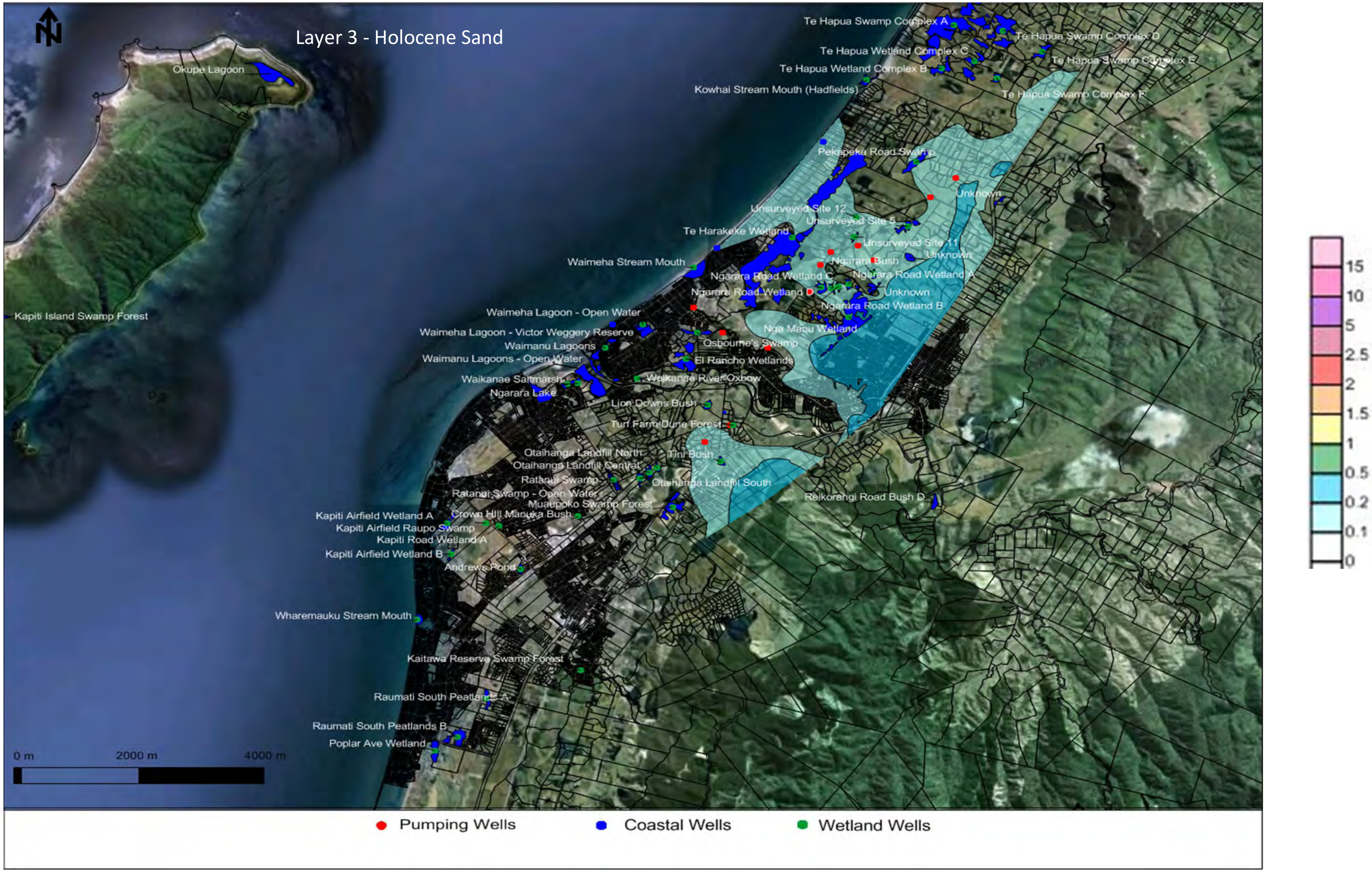
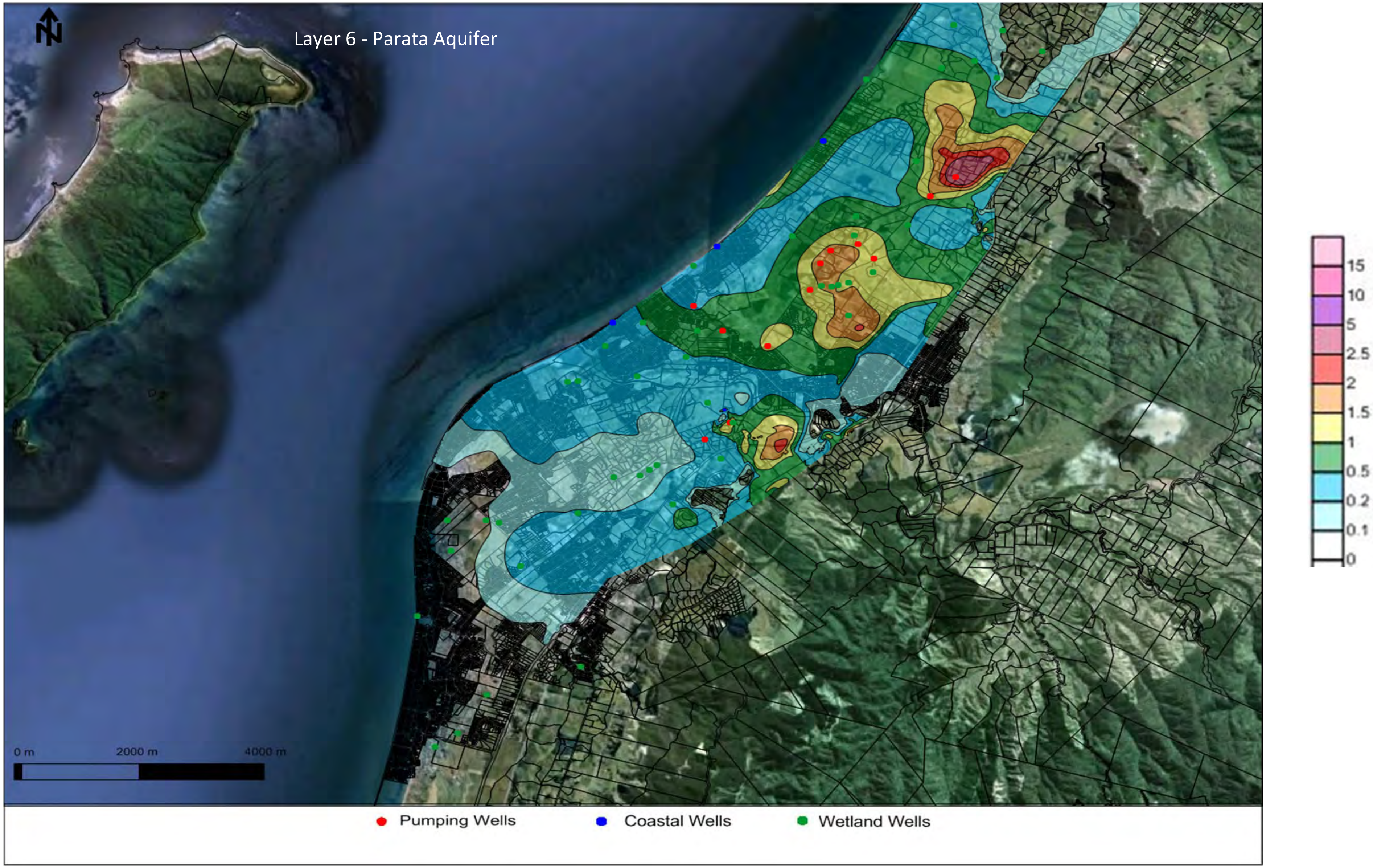
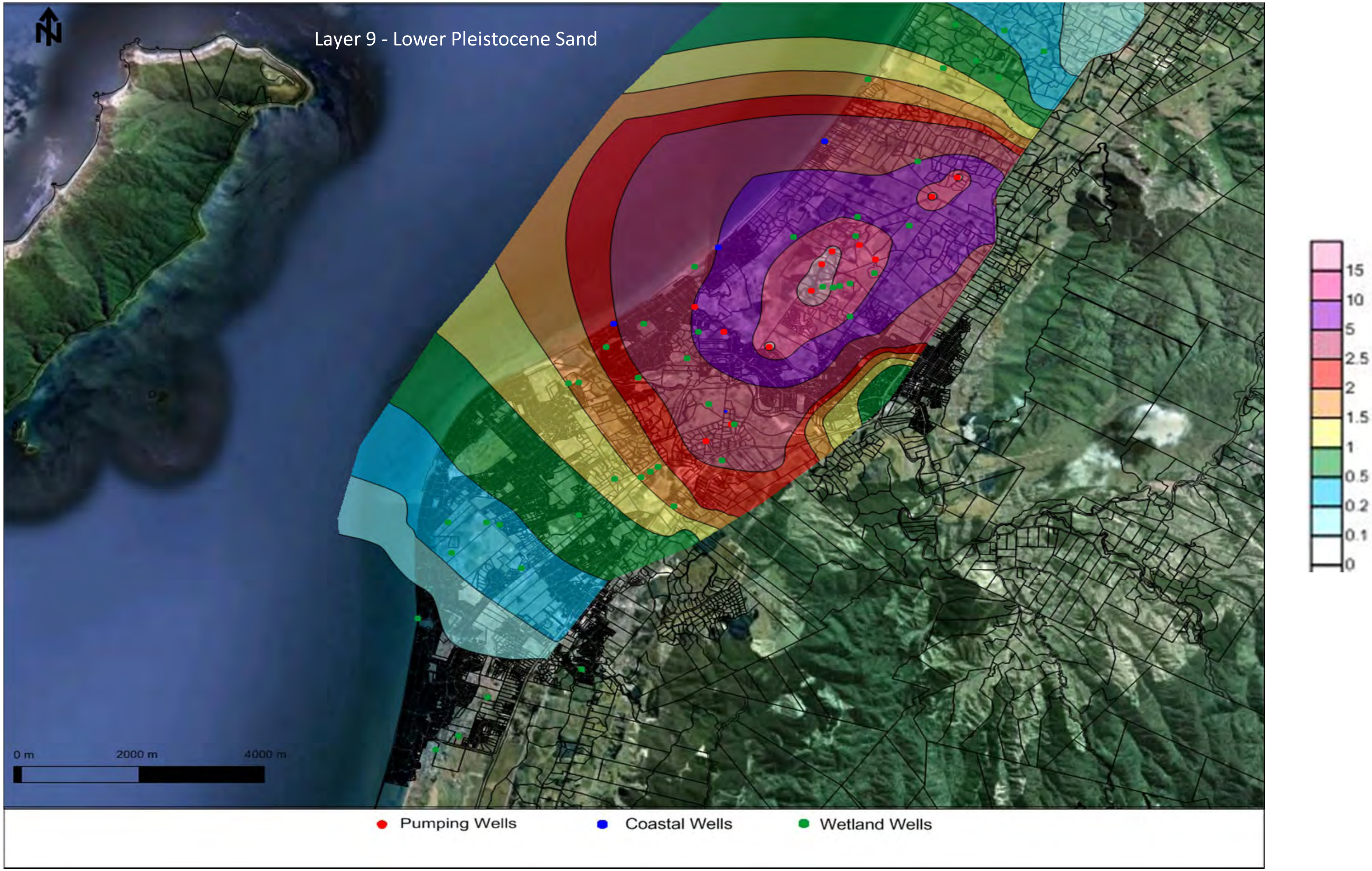


CH2M Beca

Scenario 04 - Drawdown - Holocene Sand - 27.8 yrs



Scenario 04 - Drawdown - Parata Aquifer - 27.8 yrs



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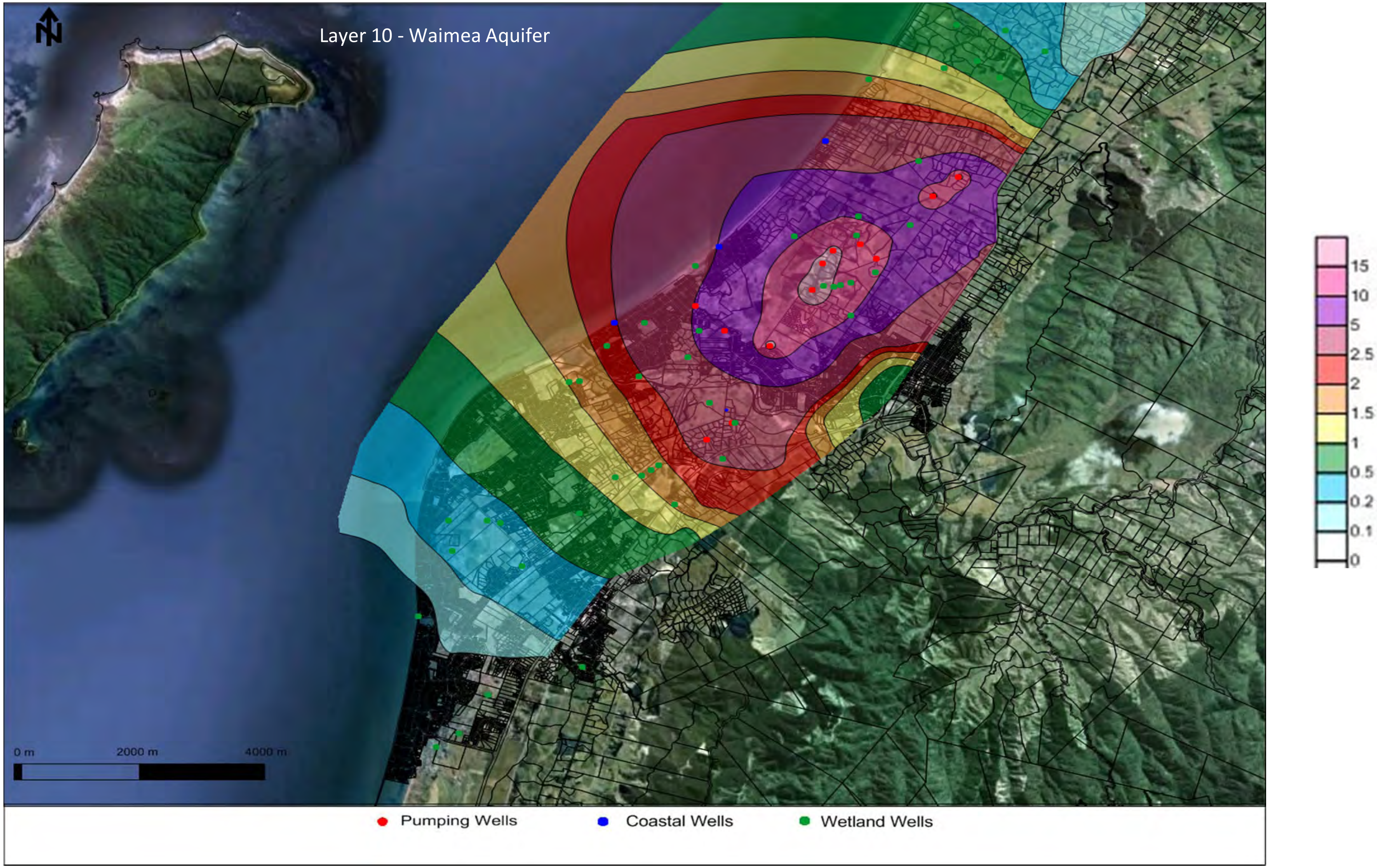
Scenario 04 - Drawdown - Pleistocene Sand - 27.8 yrs



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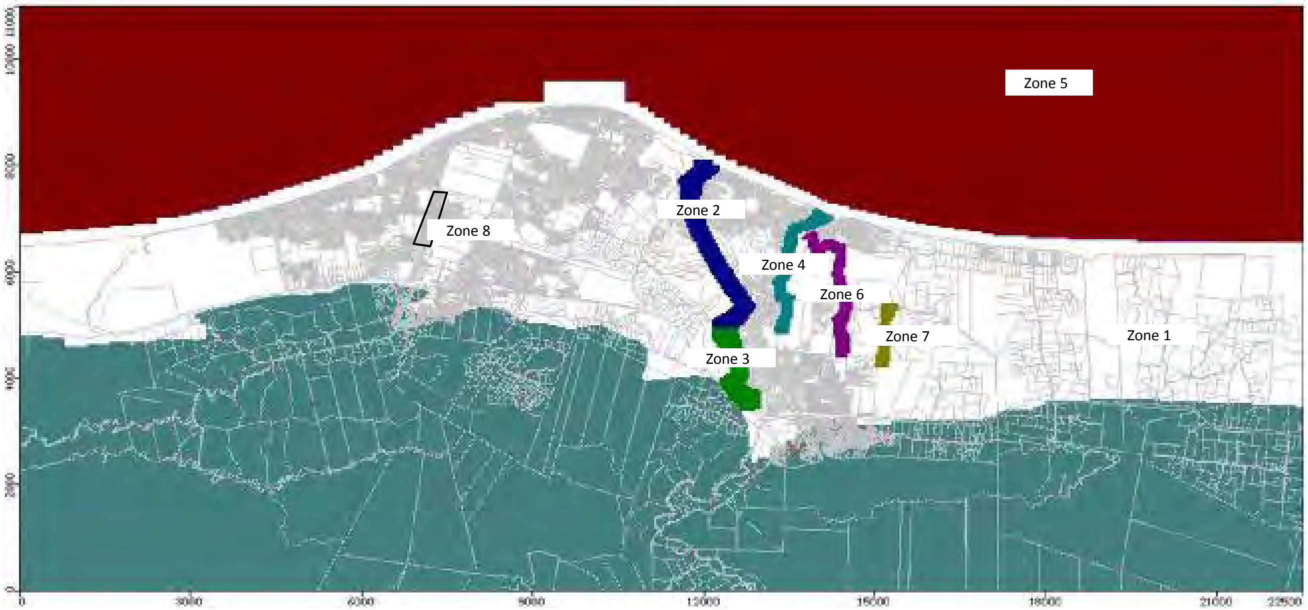
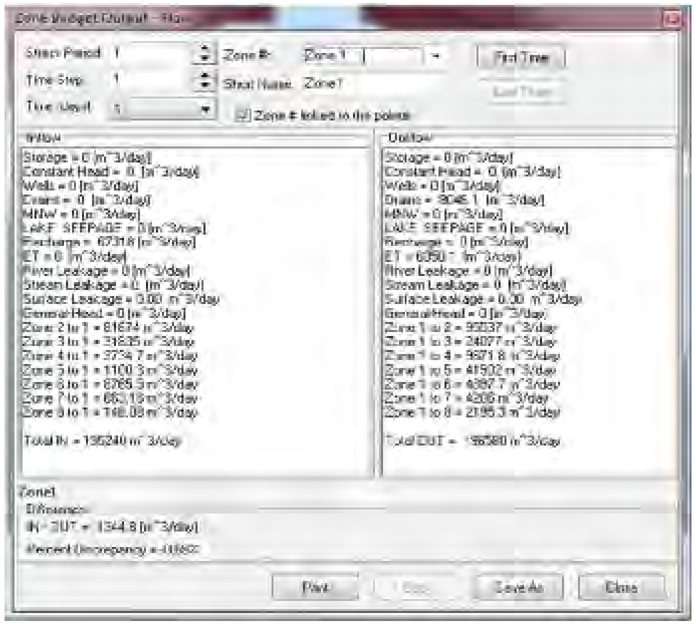
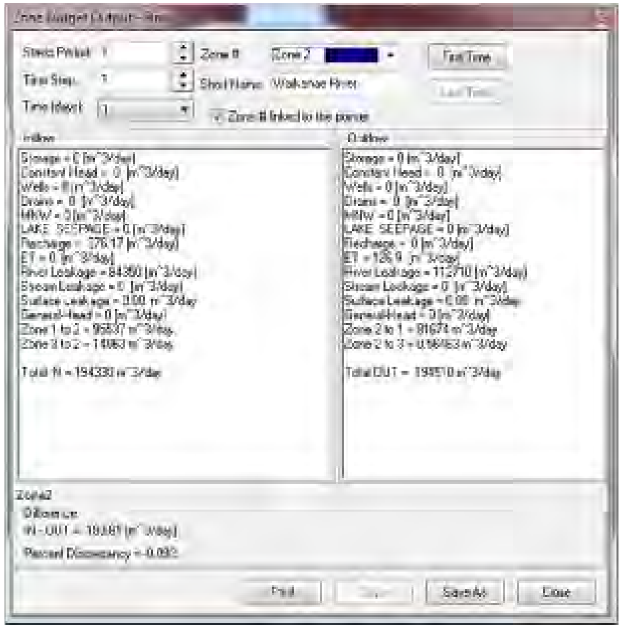
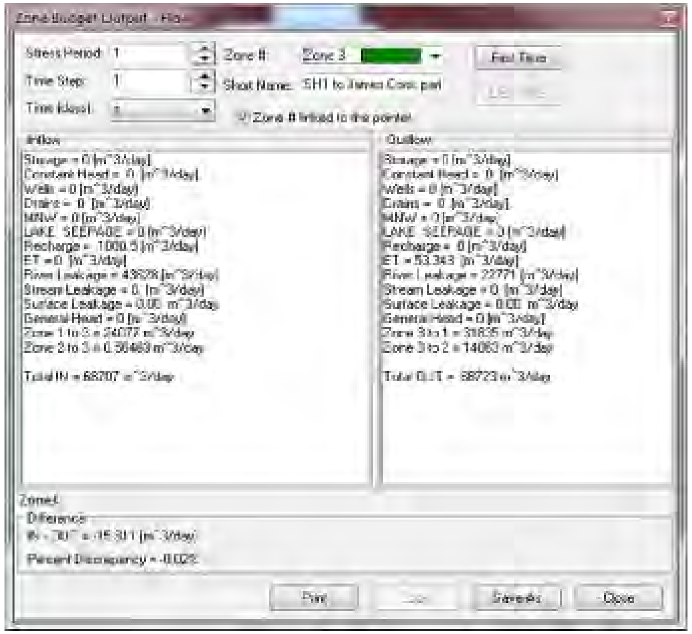
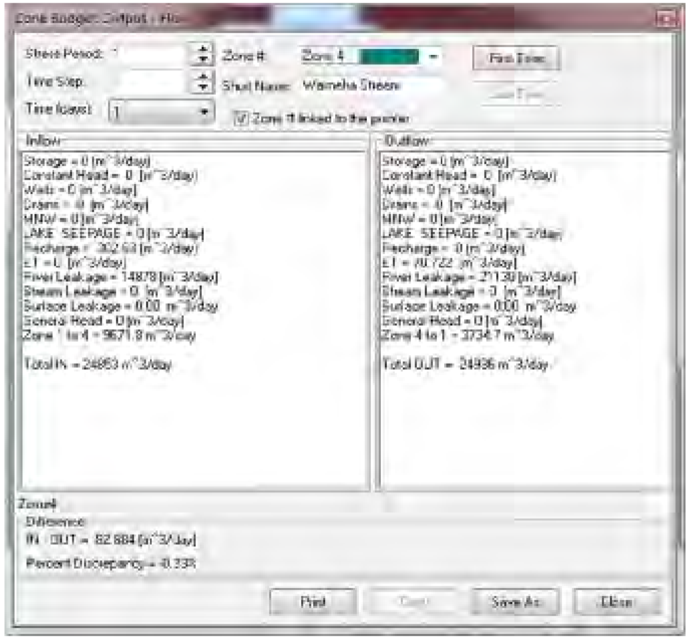
Scenario 04 - Drawdown - Waimea Aquifer - 27.8 yrs





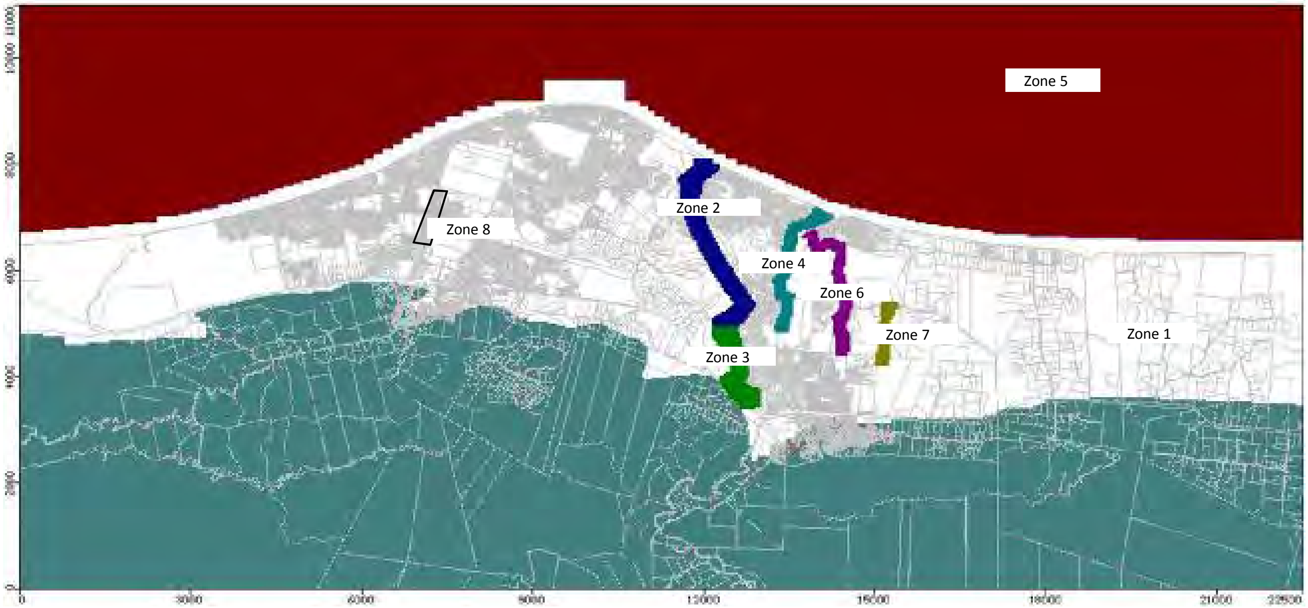


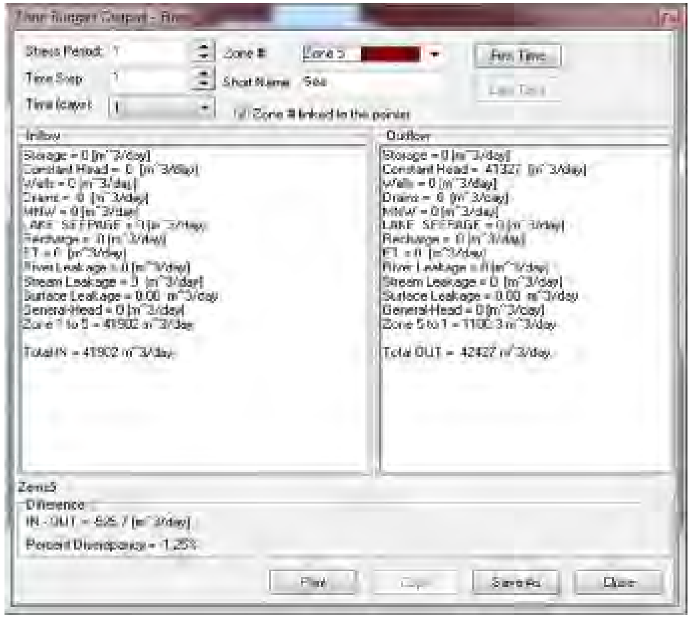


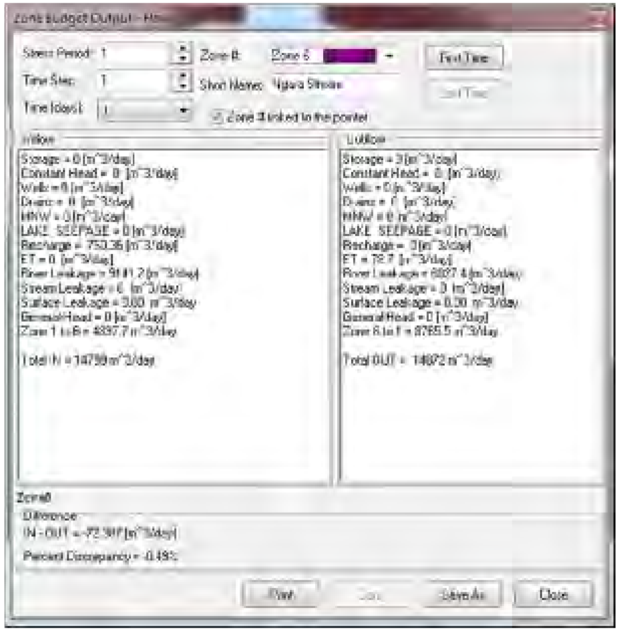


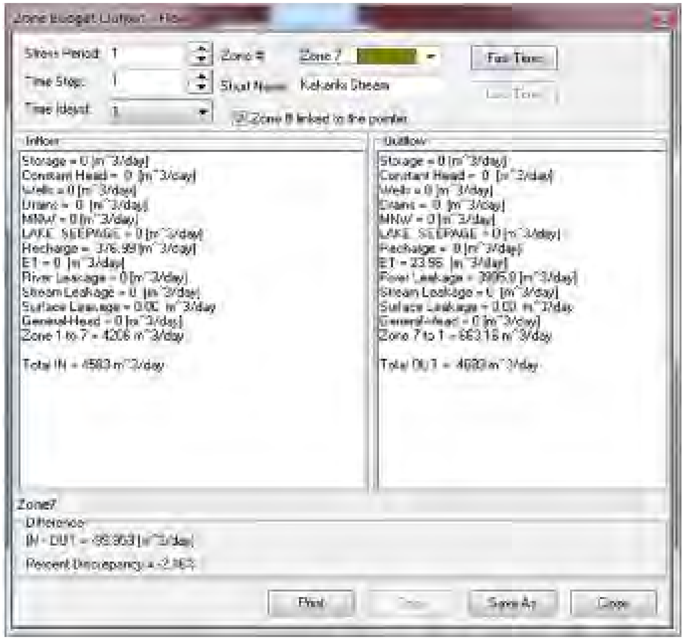
CH2M Beca

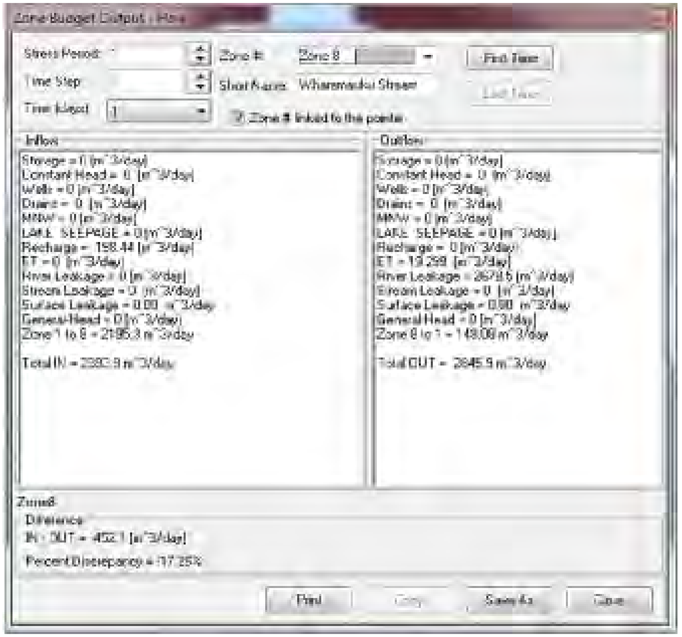
Water Budget











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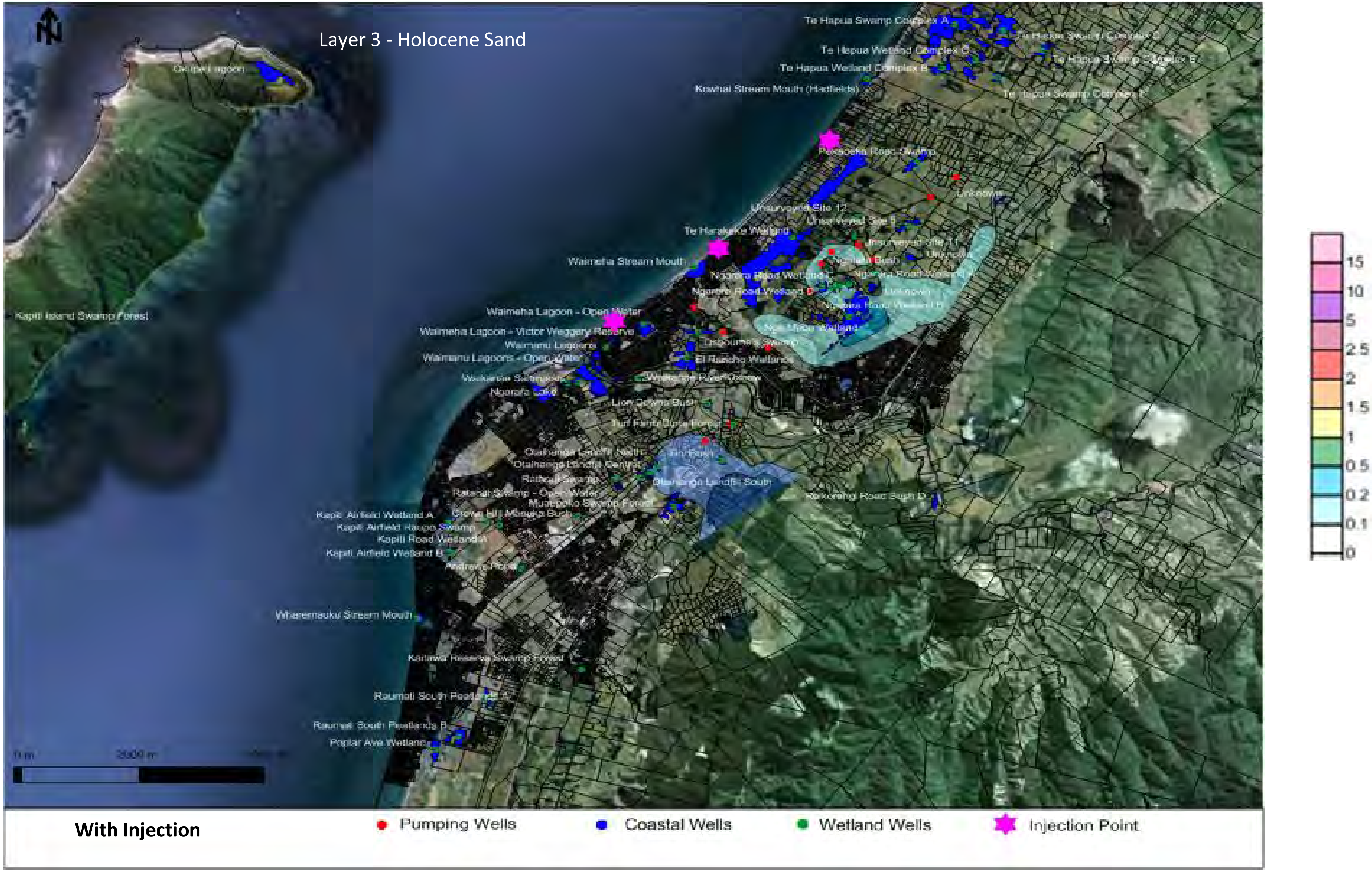
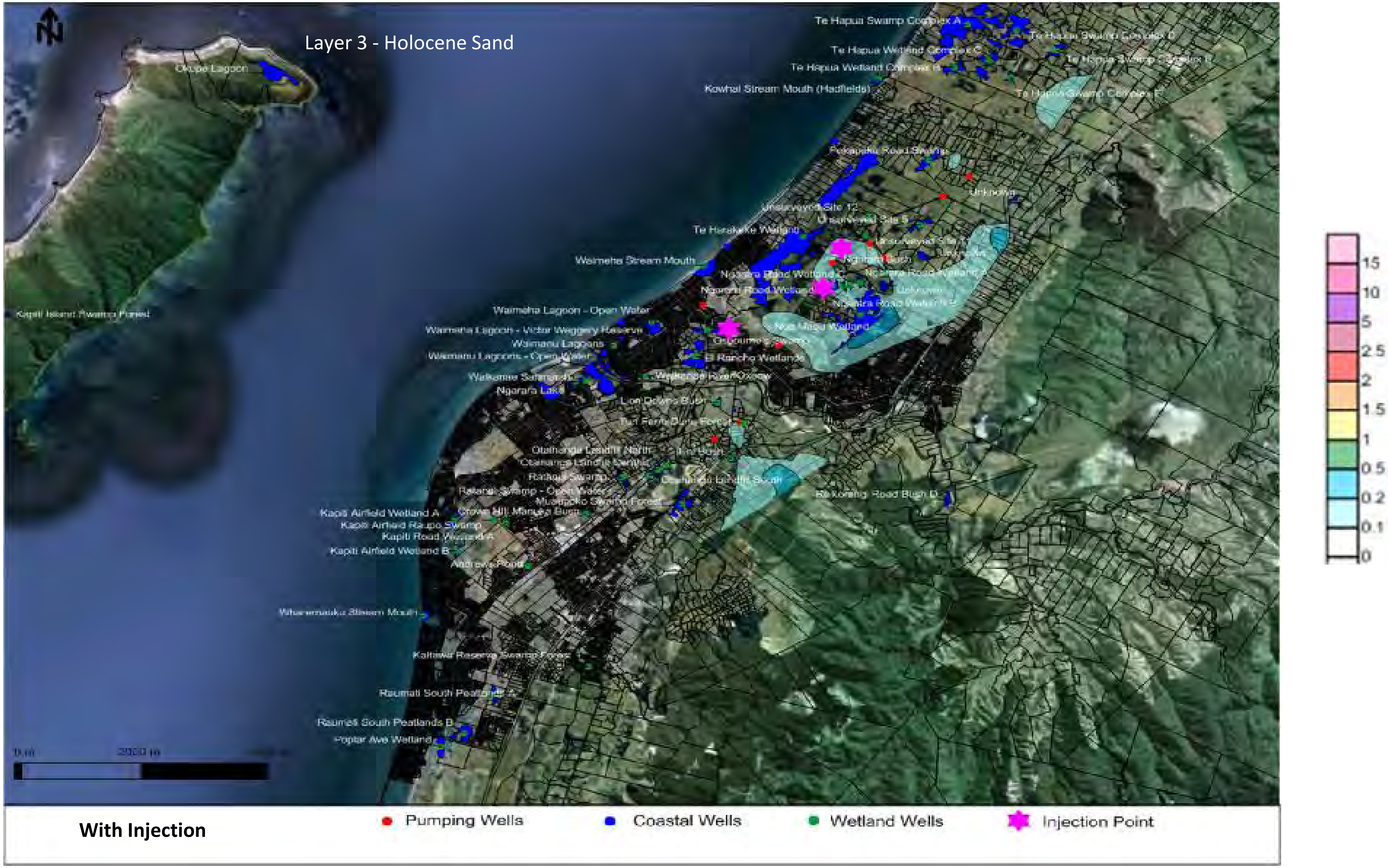
Water Budget

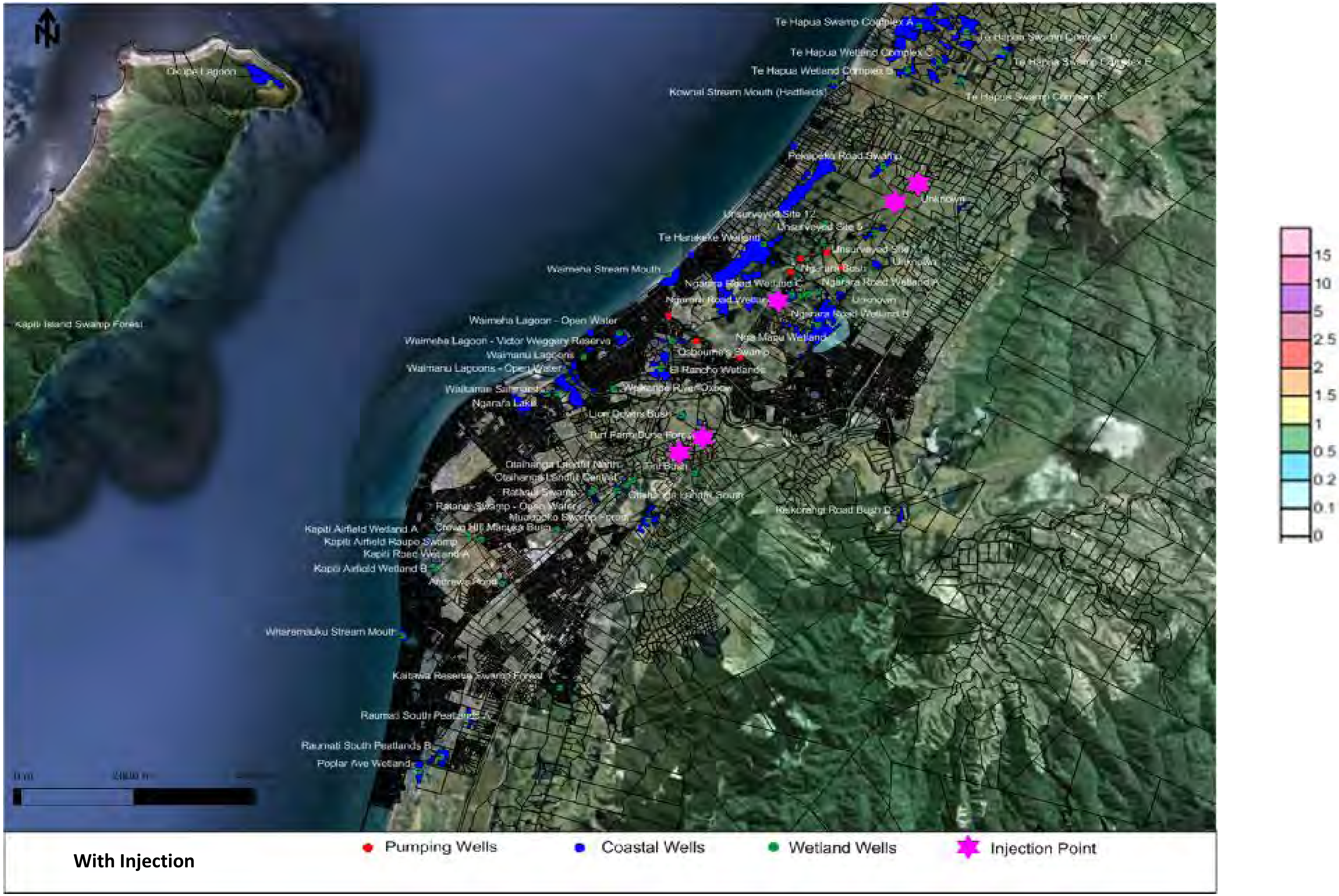


Wetland Aquifer Drawdown Mitigation - Coastal Injection - 27.8 Years



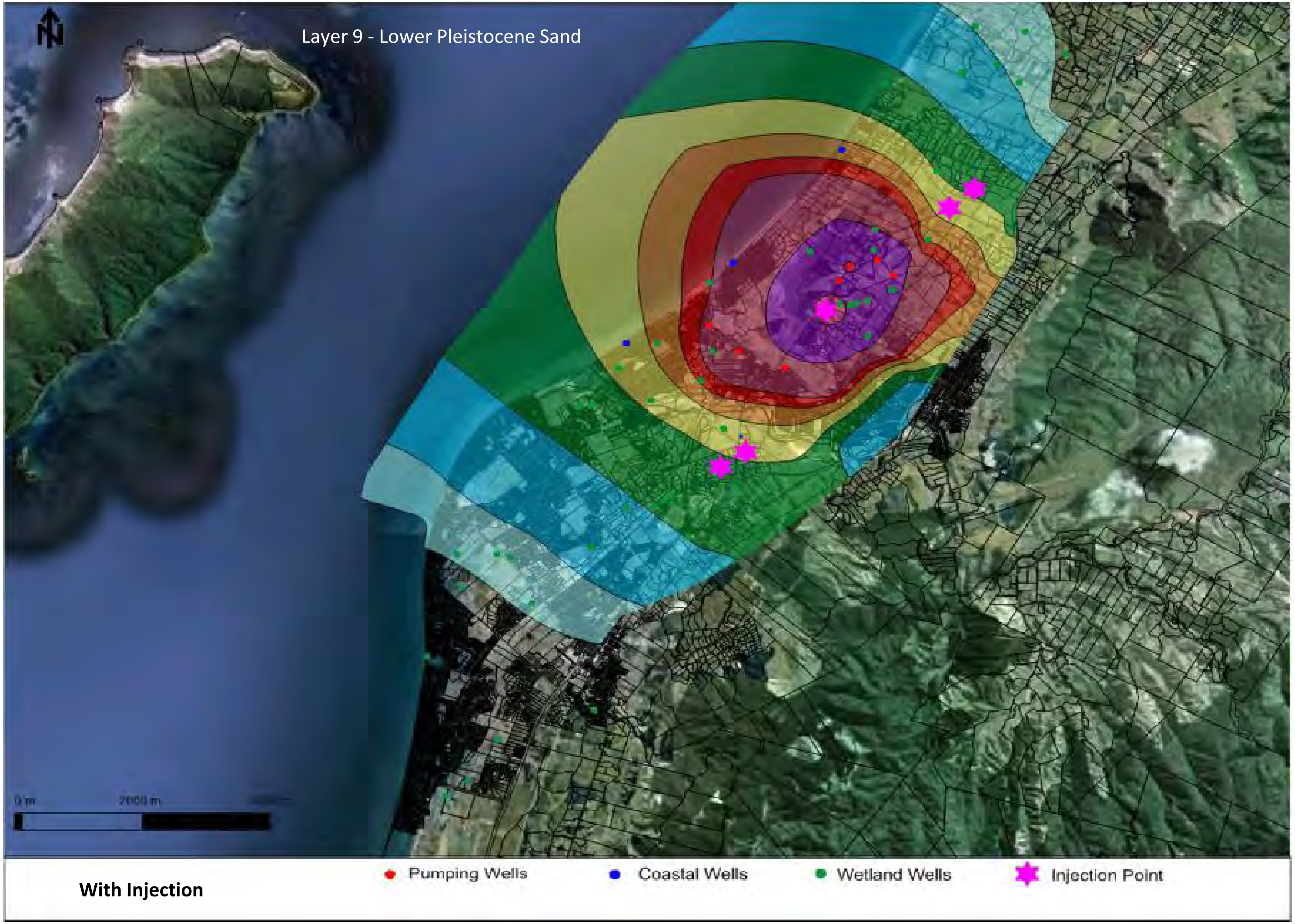
Wetland Aquifer Drawdown Mitigation - Central Injection - 27.8 Years

CH2M Beca



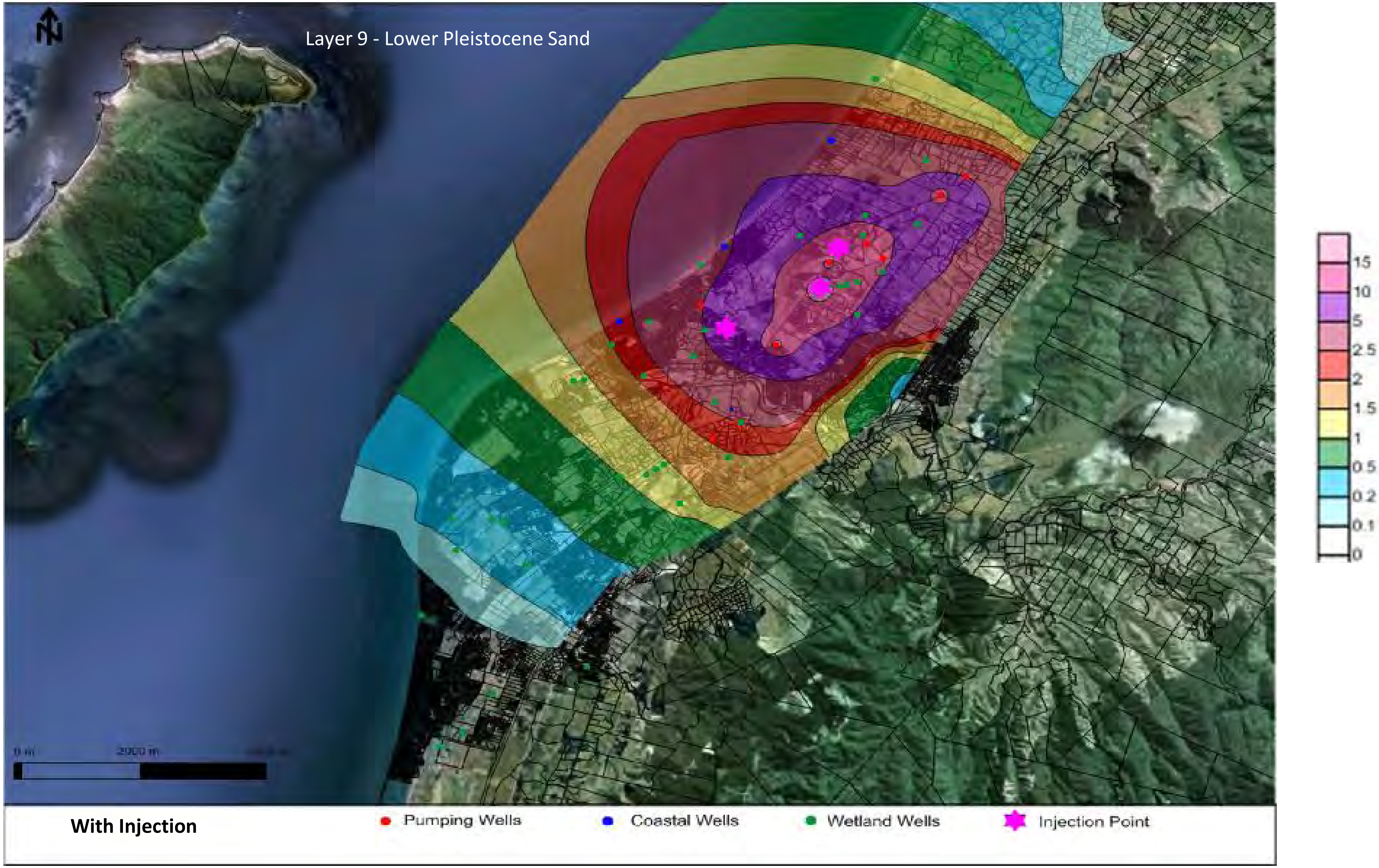
CH2M Beca

Wetland Aquifer Drawdown Mitigation - Eastern Injection - 27.8 Years



Saline Intrusion Mitigation - Coastal Injection - 27.8 Years

CH2M Beca



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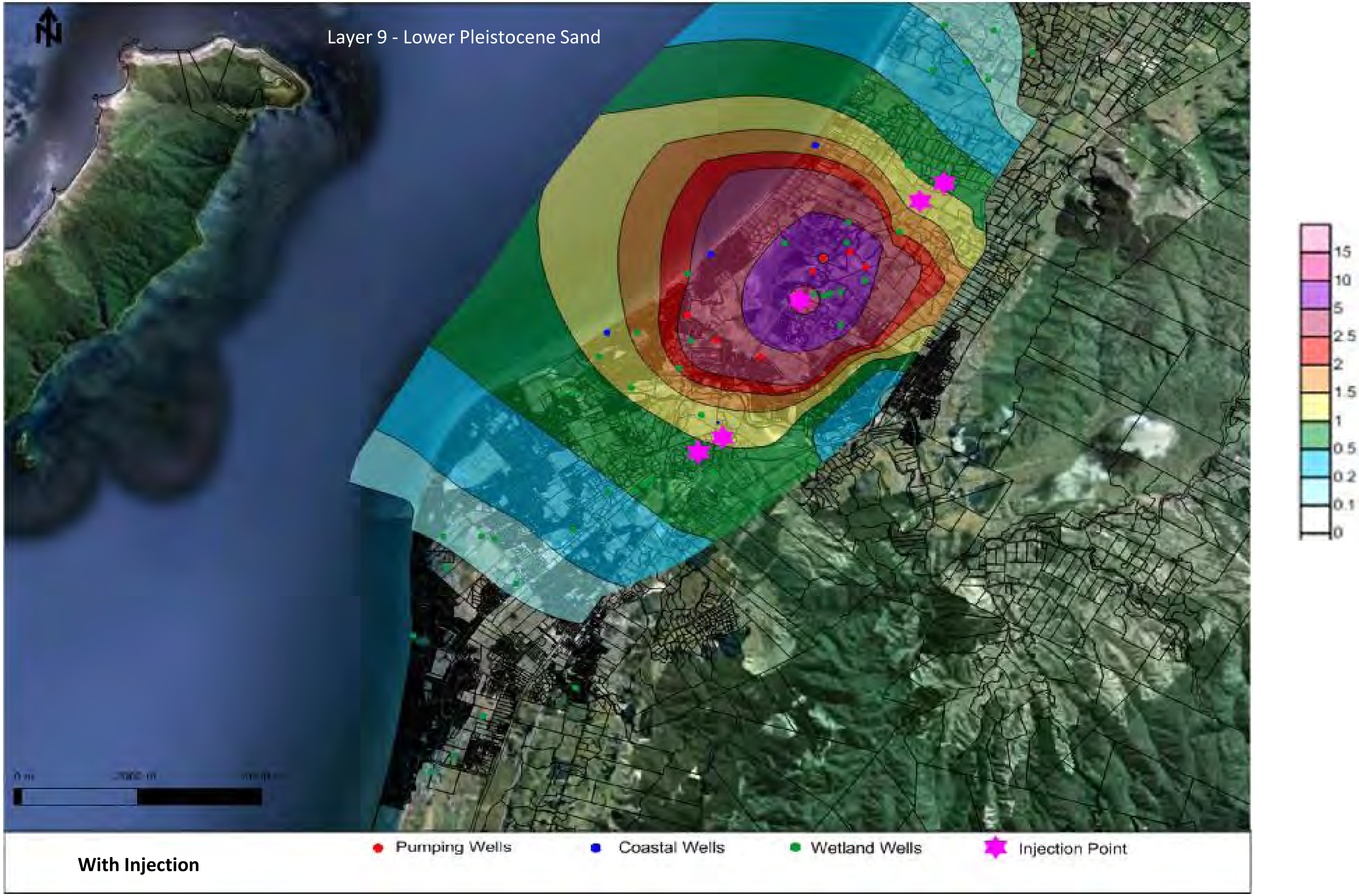
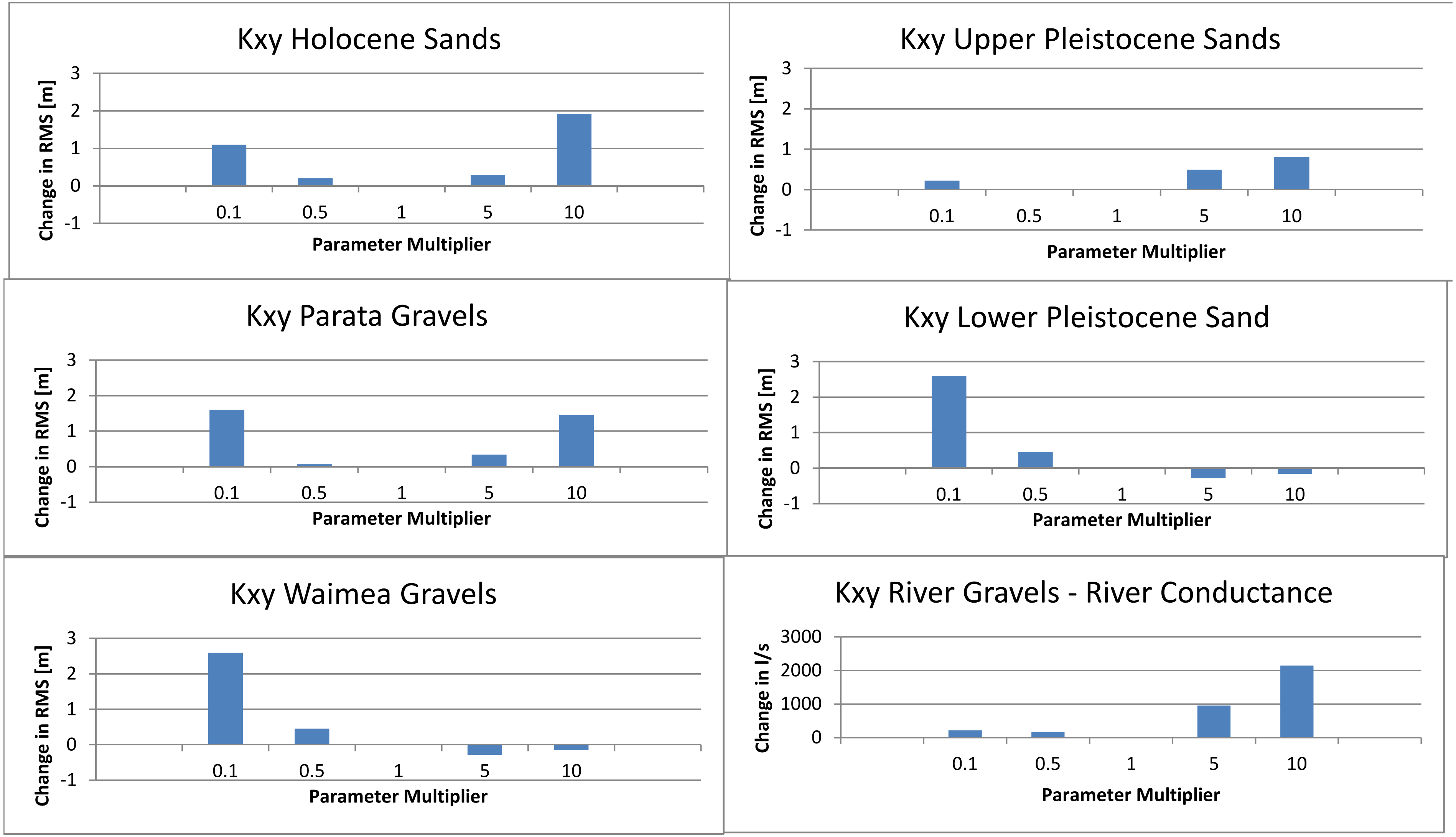
Saline Intrusion Mitigation - Central Injection - 27.8 Years



CH2M Beca

Saline Intrusion Mitigation - Eastern Injection - 27.8 Years



CH2M Beca

Sensitivity Analysis

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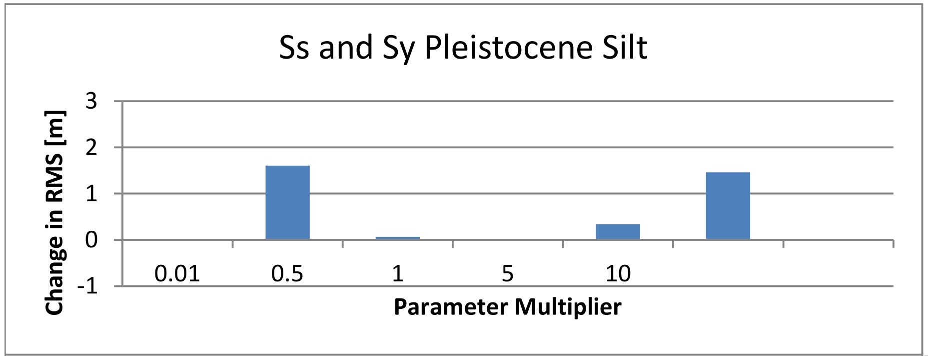
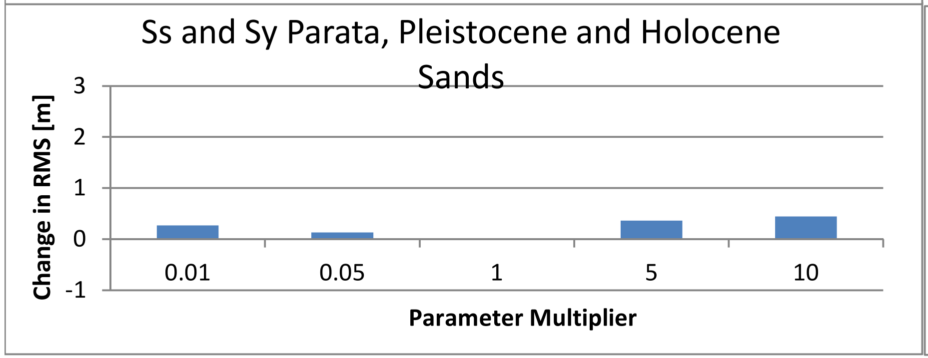
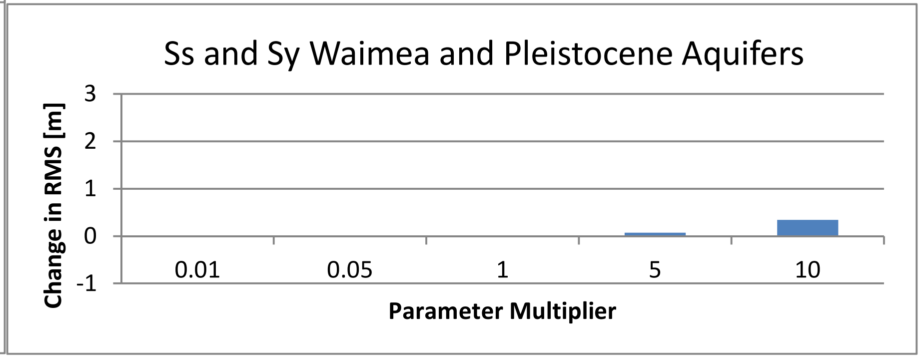
Figure D20







Sensitivity Analysis

CH2M Beca

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Figure D21

Appendix E

Peer Review Comments and Resolution

The following peer review recommendations were made after GNS Science reviewed the original conceptual 3D model in November 2010. The original conceptual model was then refined in accordance with these recommendations for development of the first-iteration model. The updated model presented in this report addresses all of the points raised by GNS, listed below, along with Beca's resolution to these comments.

Recommendation	Description	Resolution
1 Representation of Geology	The model should be constructed in a manner that reflects what is known about site geology; a model of uniform thickness in four layers does not accomplish this	Available borehole logs from GWRC records, KCDC well details, the M2PP project and investigation bores drilled as part of this project were used to develop 3D geological profile (using program HGA), taken into MODFLOW model
2 Grid Orientation and Resolution	The grid should be oriented roughly parallel to the coast and line up with the direction of groundwater flow cell. Resolution of the grid in the vicinity of the Waikanae River and operating production wells should be in the order of 10 m or less on each side. The vertical resolution of layers may vary from 5 m to 10 m.	Grid oriented parallel to the coast with flow from the hills to the sea. Resolution of grid varies 20 m x 20 m in area of interest to 200 m x 200 m at model edge. Modflow allows a maximum of 500 x 500 cells per layer; this means the 20 m x 20 m cells are the minimum cell size for this problem.
3 Coastal Margin	The constant head boundary cells at the coast should be implemented in each layer with adjustments to the depth of saltwater	Other methods of coastal margin modelling were researched. The sub-surface materials beneath the coast were extended off shore for several kilometres and constant head boundaries were applied to the surface as modelled based on bathymetry data.
4 Eastern Boundary	No flow boundaries should be assigned in all four layers	Greywacke hills were input as no-flow boundaries along the eastern margins and base of the model.
5 Weekly Rainfall Recharge	Rainfall recharge of groundwater in transient simulation should reflect temporal variations based on available data from the nearby Paraparaumu airport weather station	Rainfall recharge data from Paraparaumu Airport for the period July 1975 to June 2011 has been used. This data includes the 2003 drought. Recharge is modelled using weekly data from this period
6 River Gauging	The Waikanae River should be better defined in the model and calibrated against gauging data. The four smaller streams and drains should be included in the model. Routine gauging of the Waikanae River at several points (upstream, middle, and downstream) would be useful in providing data for incorporation into the model, and for checking model calibration	Limited gauging data is available. The river has been modelled as per the Jones and Gyopari 2005 model which reported the loss and gain effect of volume in the river downstream.

Recommendation	Description	Resolution
7 Zones of K and S	The model should adequately reflect the hydrogeology of the area of interest and variation in aquifer hydraulic properties. The use of uniform K and S values, particularly with respect to the Waimea aquifer where data on variation are available, does not do so.	K and S values used have been evaluated from long duration pumping tests in the existing wells. This variation is better addressed by sensitivity analysis using the expected and an upper and lower bound value. K and S values obtained from various tests in aquifers will always vary and this is particularly so in a coastal alluvial aquifer system.
8 Lidar Data	The placement of wells in the model should be consistent with their actual construction	Updated Lidar data has been used to form the surface of the model.
9 Sensitivity Analyses	A sensitivity analysis should be conducted and presented in the groundwater report. Groundwater recharge, aquifer and aquiclude K and S values, and the flow and riverbed conductance of the Waikanae River are important variables	Sensitivity analyses have been carried out assuming upper and lower bound values of K, storage values (Ss and Sy) and varying river conductance. Refer Appendix D – Sensitivity Analysis section.
10 Particle Tracking	There is potential for seawater intrusion. This should be carefully considered by review of groundwater flow vectors and Modpath particle tracking	Modpath tracking has been applied to compare with indications from flow vectors. The results were reported in sections 5.1.1 and 5.2.1 in the 2011 report.
11 Monitoring Well Network	An appropriate network of wells for monitoring water levels in each aquifer (shallow sand, Parata and Waimea) should be established. This would be useful in model calibration, monitoring for seawater intrusion and tracking aquifer status over time	Additional well construction and monitoring is proposed for early 2013.
12 Reporting	A detailed model report consistent with guidelines recommended by PDP (2002) should be prepared to document the model	Reporting has been undertaken accordance with the Beca groundwater reporting standard, which is based on the guidelines outlined Anderson & Woessner (2002) *Applied Groundwater Modelling: Simulation of Flow and Advective Transport* and recommended by USGS. The MfE *Groundwater Model Audit Guidelines* referred to by GNS cover flow modelling in general, including contaminated sites. The Beca report covers off the sections that the Guidelines suggest could be included in a groundwater modelling report. The Guidelines also reference Anderson & Woessner (2002).

Appendix F

Results of the Well Owner Survey

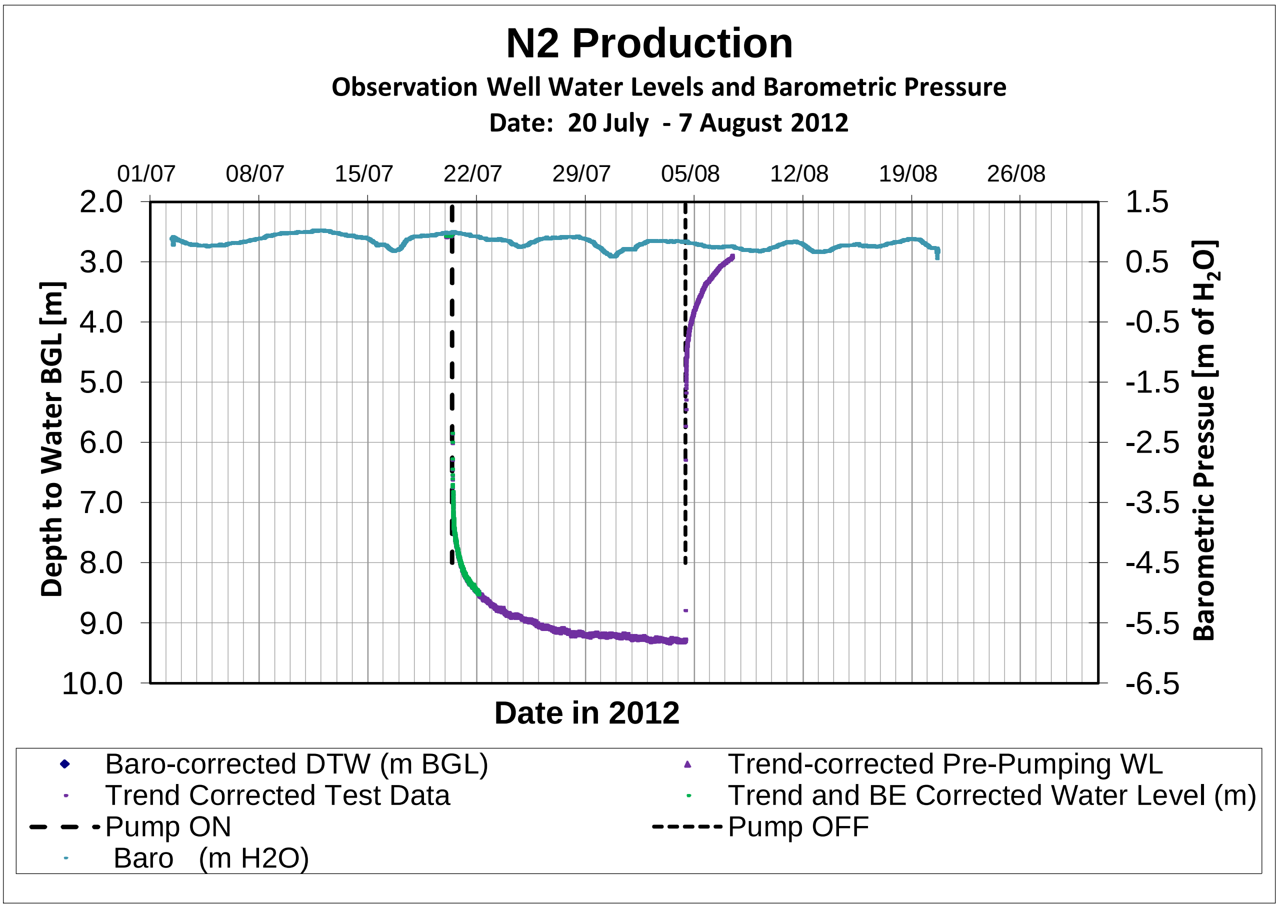
Well number	Depth m (According to Boreholes-Rates sheet)	Q1 - Do you have a bore? If no - no bore, disconnected?	Q3 - Is it in use? What for? (E.g. domestic, irrigation, stock water, etc.)	Q4 - What kind of pump do you have? (E.g. surface pump, line shaft turbine, no pump, etc.)	Q5 - How much does your well pump? (l/s, m3/day, etc.)	Q6 - Does your well reliable produce all the water you need? When do you have problems? (E.g. dry periods)	Q7 - Does your well ever go dry, suck air or shut down due to insufficient water?	Q8 - Do you have any details on how deep your bore is? (Screened and at what depth? Depth of pump? Inlet to riser pipe? Etc.)
R26/6258	12.31	No, the bore is on the neighbours property (11a)						
R26/6258	12.31	Yes	Very rarely. Used to water fruit trees about once a season.	Surface pump.	Don't know	Yes	No	12 m. Think its 12m
R26/6740	54.26	Yes. Have two bores	Irrigation for nursery plants. Not potable.	Submersible. At bottom of bore.	Don't know. Don't use a lot. Not big facility. Only source of water on property other than natural rainfall. Second bore is simply a backup.	Yes	No	Not deep. Unsure. Very high water table (less than 1m below surface).
R26/6624	10.2	Yes	Garden irrigation in summer	Surface pump	No	Yes	No	12 or 16m
R26/6129	0	No. They do, however, have a pump from the stream which stopped working years ago.						
R26/5106	0	No answer 28.08 am						
R26/5106	0	See other entry for this address						
R26/6706	15	Yes	No, not in use. Have only been at property since April. Bore is only hooked up to external fittings for the garden	Don't know	No	N/A	Don't know	No
R26/6158	0	No bore on property						
R26/5126	1.5	Yes	Watering the garden.	Electric pump. On the surface.	Not in use at the moment. Typically over dryer periods.	Yes	No	1.5 m. Approximately 1.5m. Large section concrete pipe which has been excavated in the centre. Stream water runs into bottom.
R26/6701	0	Yes	Domestic. Water troughs. Potable	Submersible	No	Yes	No	30 m
R26/6607	38.1	No bore present on property.						
R26/7137	50	Yes	Domestic. Garden watering.	Yes, surface pump. Franklin electric. Pump Iowara 1gs06,75KW single phase pump.	Only use it in summer. Not measured. Just 10 pop-up irrigators. Typically used for half an hour each.	Yes	No	Very deep.
R26/6180	0	No, never had bore.						
R26/5215	0	Yes	Watering garden in summer.	Surface pump	No. Very little. Only leave it on enough to wet the ground then turn it off.	Yes	No	6 m About
R26/6168	0	No. Have a tank off roof.						
R26/6702	9	Yes	Toilet in sleep out uses bore water. Stock water. Historically used for irrigation.	Surface pump	Don't know	Yes	No	Shallow. Don't know
R26/7207	18	Overseas. Call back after 26th of September. Left message on 23.8						
R26/6181	0	No, has a spring but no bore (or pump).	Just runs down the road in winter but is used on the garden in summer. Not potable.	No pump	Don't know	Yes	No	0m
R26/6073	0	Yes	Intermittent. Only used for watering the garden	2.5 horsepower pump. Surface pump	Only used in summer. Less than daily.	No. Not taped into a heavy supply of water. Takes a while for the area around the base of the bore to replenish itself. Capable of pumping less tan 12L/minute. Barely enough to power a sprinkler.	Yes, due to insufficient water. Occurs regularly.	11 -12m
R26/6171	0	No bore						
R26/6793	17.5	Yes	Water gardens and irrigate field.	Don't know. Pumps at the bottom of the bore (underground)	Only used in summer for the field. Limited al year roud use for gardens	Yes	No	18 m deep
R26/6960	33	Yes	Water troughs around farm and for farm buildings. Potable (but has a bit of iron in it)	Submersible. 27m down hole. Big pump just put in recently.	No. Permit allows 40,000L/day perhaps. Check council permit to confirm. Doesn't use anywhere near that. Probably less than 1000L/day.	Yes	No	63 m
R26/6612	34.4	No bore						
R26/6612	34.4	Yes for Nursery at 12 Uta Street	Irrigation for plants in nursery	Submerged down in well	Don't know. Varies widely. Summer every night for 2 months. In winter it's hardly used at all.	Yes	No.	33 m

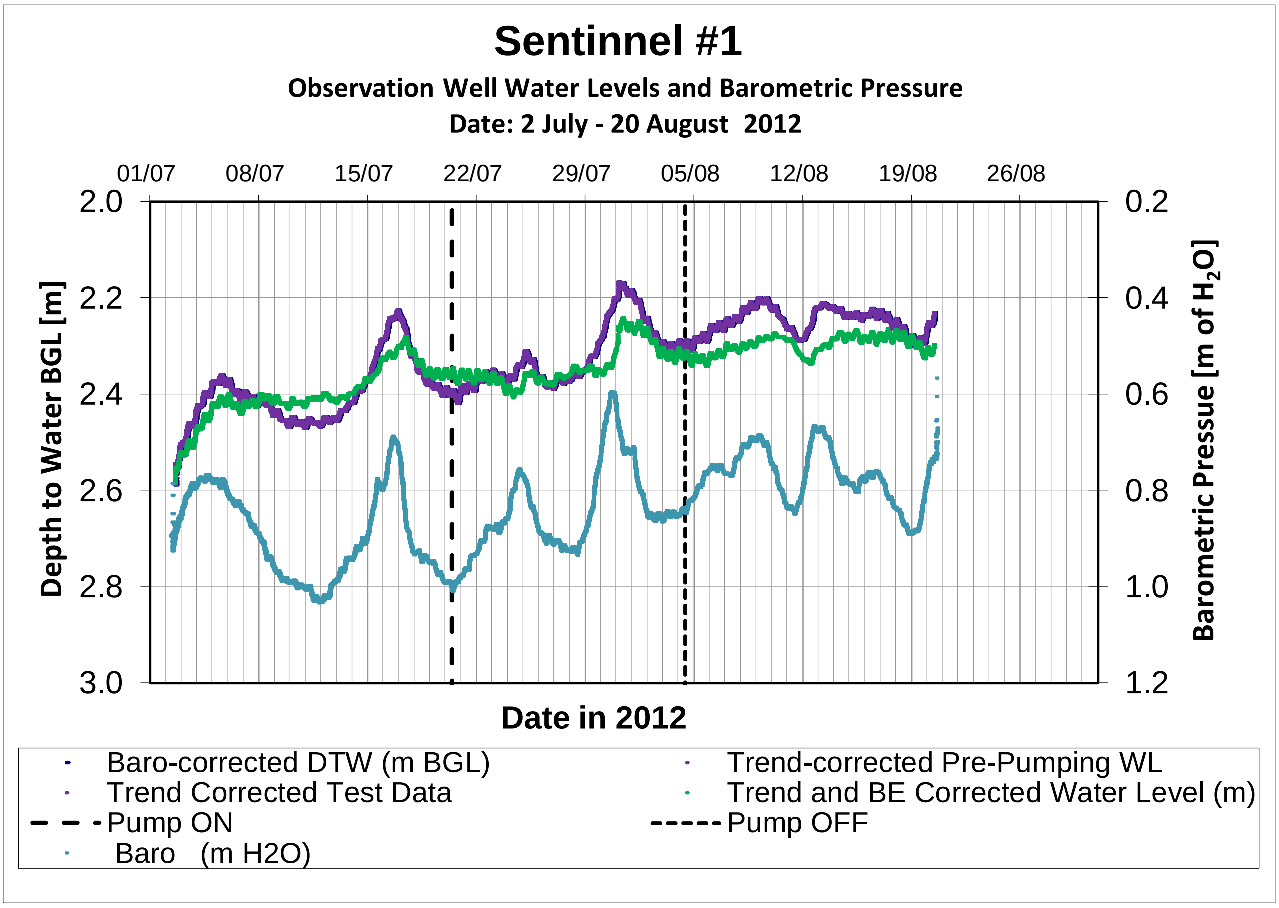
Well number	Depth m (According to Boreholes-Rates sheet)	Q1 - Do you have a bore? If no - no bore, disconnected?	Q3 - Is it in use? What for? (E.g. domestic, irrigation, stock water, etc.)	Q4 - What kind of pump do you have? (E.g. surface pump, line shaft turbine, no pump, etc.)	Q5 - How much does your well pump? (l/s, m3/day, etc.)	Q6 - Does your well reliable produce all the water you need? When do you have problems? (E.g. dry periods)	Q7 - Does your well ever go dry, suck air or shut down due to insufficient water?	Q8 - Do you have any details on how deep your bore is? (Screened and at what depth? Depth of pump? Inlet to riser pipe? Etc.)
R26/6727	0	Yes	Stock water, house water.	Buried in ground. Been there for 30 years	Don't know	Yes	No	No.
R26/6704	10	Yes	Watering the garden.	Small. Electric. On the surface	Don't know	Yes	No	11 m. Had it for 14 years. Approximately 11m. Sand trap.
R26/5127	11.6	Yes	Domestic use.	Don't know. Campbell's installed it.	Don't know. Have had it for 8 years.	Yes	No	No
R26/6289	78.2	No bore on property						
R26/6200	0	Yes	Domestic and garden.	Down the shaft. Submersible. Campbell's water service it.	Don't know. Depends on water use.	Yes	No	34 m deep approximately.
R26/6201	0	No bore at this property						
R26/6185	0	Yes, but it hasn't worked for 15 years.		Don't know				Don't know
R26/6165	0	No, never had bore.						
R26/6203	0	No bore that they know of. They rent the house and have done for 4 years.						
R26/6202	0	Wrong number						
R26/7060	0	Yes	Under repair at the moment. Watering the garden.	Surface pump	No. very little.	Yes	No	34 m, but not sure.
R26/7212	19	Yes	Used to irrigate garden.	Plastic dog-box size up over bore. Think is submerged. Fitted 4-5 years ago	Used to irrigate garden in summer by sprinkler systems which is controlled by timer. Comes on at 3am and runs for half an hour. Approximately 15 heads.	Yes	No	No
R26/6703	4	Yes	Stock water. Not potable. Used to water garden and wash car etc.	Surface pump.	No. No stock currently on property. Infrequently used.	Yes	No	4 m
R26/6202	0	No bore on property.						
R26/6199	0	Yes	Domestic, livestock and garden	Don't know.	Don't know.	Yes	No	36 m
R26/6626	15.8	Talk to Phil Stroud						
R26/7201	45	Yes	Stock water supply	Submersible pump	1200 gallons/hour	Yes	No	36 m
R26/6135	0	Yes	Irrigation, domestic (not potable)	Don't know.	Just in summer. One hour three times a week. Residential sized garden.	Yes	No	No
R26/6643	49	Yes	Domestic purposed. Potable water	Surface pump. Small. Self priming pump	No	Yes	No	50 -something metres. On record on GWRC database.
R26/6158	0	No bore						
R26/6778	80	No. On city supply.						
R26/6747	69.51	Yes	Domestic water. Potable	Submersible. Three phase electric pump.	Approximately 1500L/week	Yes, but at times in can become quite salty when in high use.	No	4.2 m
R26/6150	0	No bore on property						
R26/6121	0	No bore at this address.						
R26/6150	0	No. On city supply.						
R26/6750	43.2	We monitored this bore N3						
R26/6780	80	Yes	Stock water	Submersible pump	Not a lot. Lightly stocked land. Low usage	Yes	No	Held at Wellington Regional Council as part of consent application.
R26/6708	0	Yes	Household water. Some irrigation. Potable water.	Surface pump	Not really. Only two people most of the time. Not high use.	Yes	No	30 m About
R26/7113	12	Yes	Irrigation for garden	Put in by previous owner. Surface pump beside garage.	Don't know. On automatic timer. Used mainly in summer.	Yes	No	6 m. Approximately
R26/6734	42.15	Left message on 23.08 pm No answer 27.08. Straight to answerphone every time.						
R26/6114	0	Yes	Usually, but pump is currently broken. Going to fix soon. Usually used for irrigation. Household garden.	Submersible	No. Comes on every second day for 20 minutes. On in summer. No on during wet summers.	Yes	No	17-18 m at a guess.
R26/6174	0	We don't have number						
R26/6164	0	Yes	Watering gardens in summer months	Underground pump. In the bore itself	No. Give annual beds a deep watering once a week in summer.	Yes	No	40 m. 150 diameter.

Well number	Depth m (According to Boreholes-Rates sheet)	Q1 - Do you have a bore? If no - no bore, disconnected?	Q3 - Is it in use? What for? (E.g. domestic, irrigation, stock water, etc.)	Q4 - What kind of pump do you have? (E.g. surface pump, line shaft turbine, no pump, etc.)	Q5 - How much does your well pump? (l/s, m3/day, etc.)	Q6 - Does your well reliable produce all the water you need? When do you have problems? (E.g. dry periods)	Q7 - Does your well ever go dry, suck air or shut down due to insufficient water?	Q8 - Do you have any details on how deep your bore is? (Screened and at what depth? Depth of pump? Inlet to riser pipe? Etc.)
R26/6067	0	Yes	Domestic. To water lawns and plants.	Don't know	Only in summer. Very little. Only on orchard area. Not used daily.	Yes	No	No
R26/6395	4	No. Got a permit 3-4 years ago for a shallow bore. Withdrew formally from application process after finding no water. Historically there may have been another bore at one stage, however it is not in use now and they don't know where it is.						
R26/6321	8	Yes	Stock and irrigation. Sometimes house water.	Deep well injector pipe. On the surface.	Don't know	Yes	Can take time to start up during drought.	No.
R26/7196	5.5	Wrong number						
R26/6134	0	No bore. Serviced by town water supply.						
R26/6163	0	No bore on the property.						
R26/6759	43	Yes	Irrigation, washing cars and outside use	Surface pump in garage.	All year round. More so in dry periods	Yes	No	45 m
R26/6109	0	No bore.						
R26/6099	0	No bore.						
R26/6659	15.2	No bore on property.						
R26/6980	50	Yes	Limited use. Goes to a storage tank and then used for outdoor taps. Includes troughs for livestock	Submersible	30L / day at a guess	Yes	No	58 m
R26/6572	0	Yes	Irrigation	Deep bore pump. Berried in ground.	Mainly in summer.	Yes	No	27 m approximately
R26/6619	33.9	Yes	Used for cleaning	Surface pump. Grundfos?	Don't know	Yes	No	20 m. Approximately
R26/6352	6	See other record for this address						
R26/6352	6	Yes	Summer for garden	Surface pump	No. Never running for long periods. Half an hour on soaker hoses.	Yes	No	6 m approximately
R26/6177	0	No, Uses bore water, but bore is not on this property						
R26/6761	12	Yes	Domestic. Stock drinking water. Garden irrigation. Potable. Goes into holding tank, through filter and then into house.	New one just put in. Surface pump.	Don't know. Perhaps 200L/day for cows. Definitely under 500l/day total. Varies.	Yes. Original pump was pumping too fast. Slower pump now allows replenishment of water.	Did before smaller pump was installed.	40 m approximately
R26/6377	118.12	No bore. Have permit for water take from stream.						
R26/6621	18.59	See other record for this address						
R26/6621	18.59	Yes	Unsure. Think for farm purposes. May have had three bores.	Don't know	Don't know	Yes	No	No
R26/6627	0	No bore in their property. It is on 3 Greenhill Road. Call Bill Collins						
R26/6762	0	Wrong number						
R26/6735	0	Yes	Domestic water and animal troughs	Surface pump	10,000L/week approximately.	Yes	Has occurred once in last two years. Self rectified.	6 -8 m. Approximately
R26/6101	0	Yes	Gardening. Not sure if its potable.	Submersible grunfos.	Not used in winter much. Mainly in summer. Hobby growing roses.	Yes	Pressure is not great. Otherwise no. It has not ever gone dry.	18 m approximately.
R26/6876	49.01	Yes	Domestic. It's the sole water supply for the property.	Pump at the foot of the bore pipe	Don't know	Yes	No	No
R26/6151	0	Yes	Domestic. Garden watering	Pump is underground	Don't know	Yes	No	12 m Perhaps 12m.

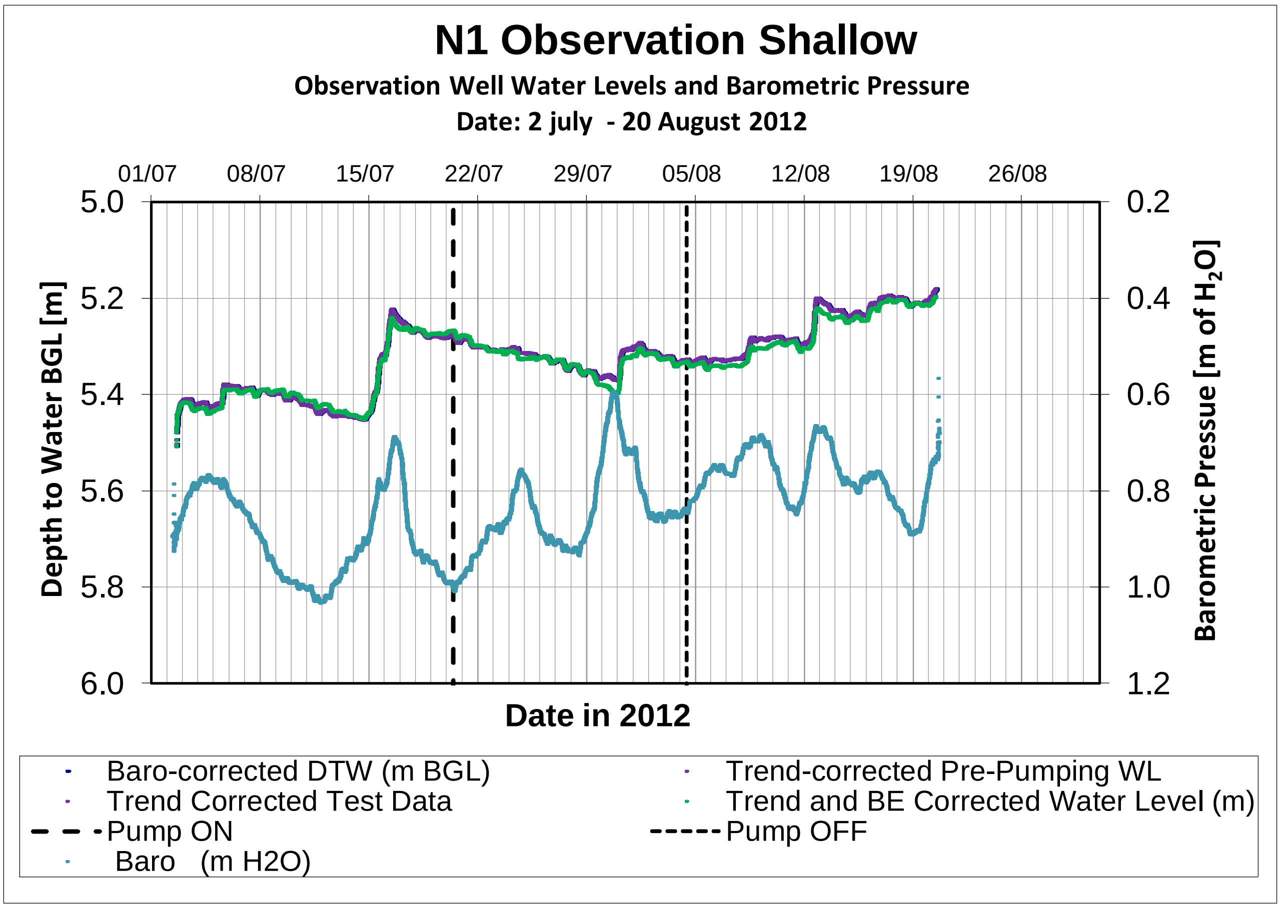
Appendix G

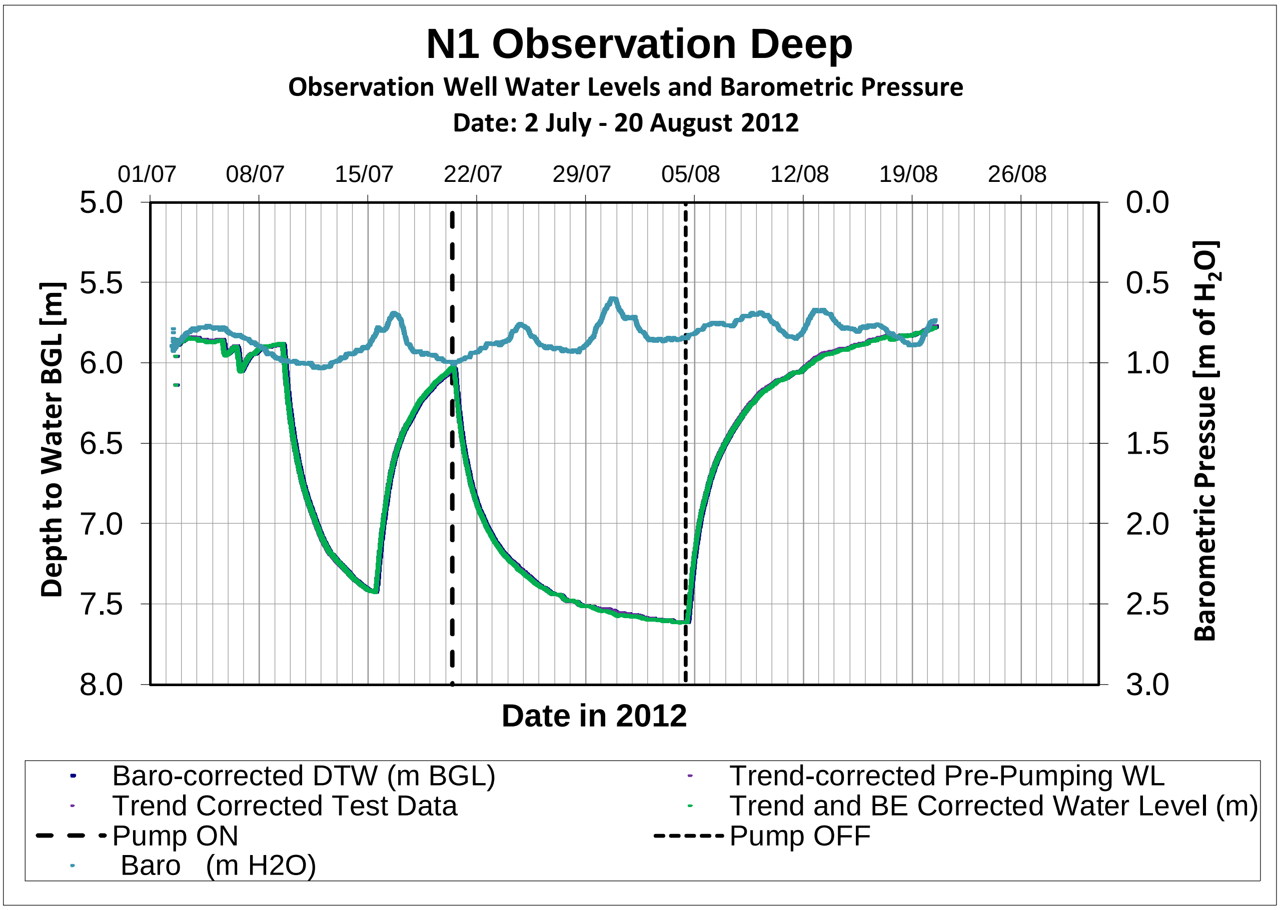
Analysis of July 2012 Pumping Test of N2 PW

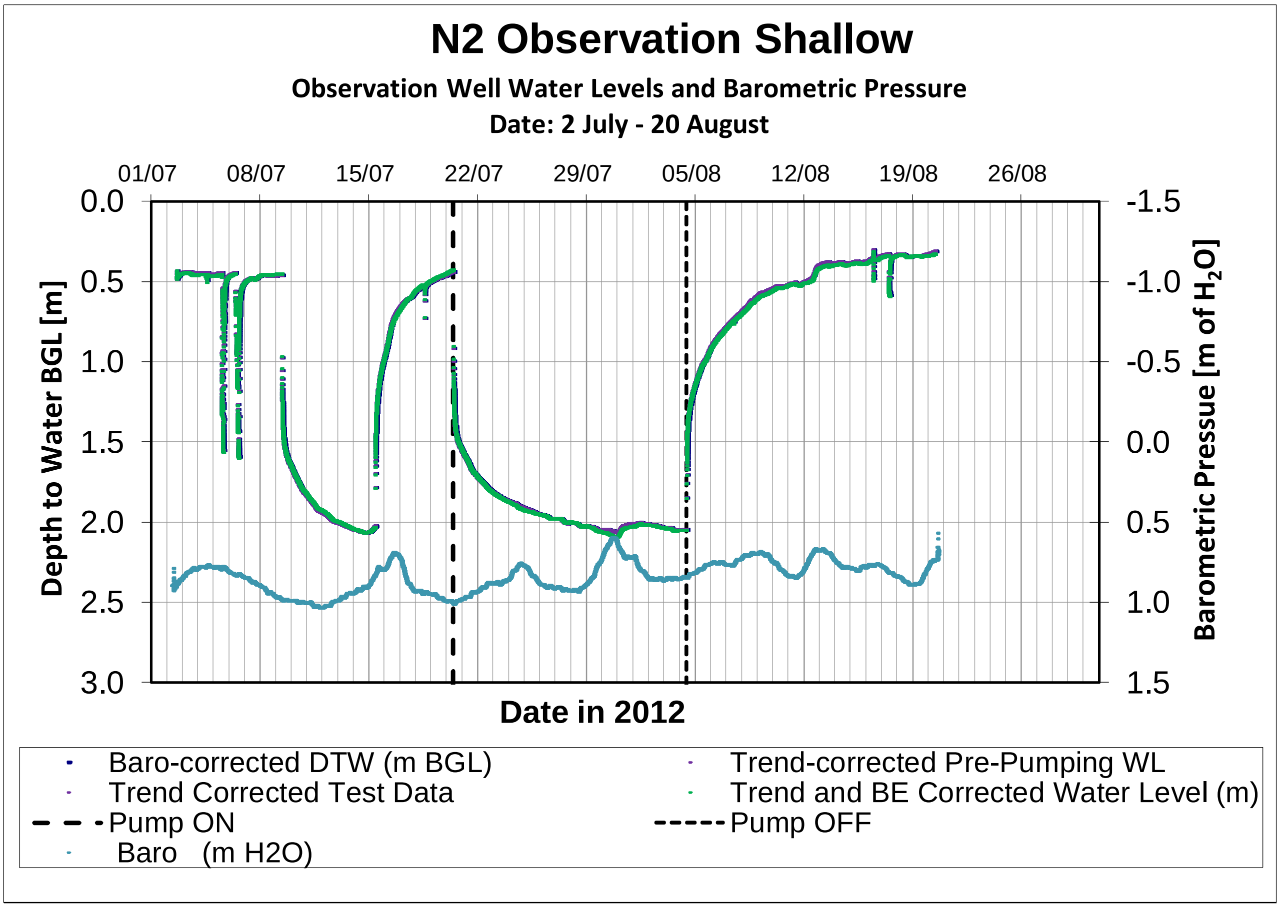

N2 Production
Observation Well Water Levels and Barometric Pressure
Date: 20 July - 7 August 2012
01/07
08/07
15/07
22/07
29/07
05/08
12/08
19/08
26/08
Depth to Water BGL [m]
Barometric Pressue [m of H_2O]
Date in 2012
Baro-corrected DTW (m BGL)
Trend Corrected Test Data
Pump ON
Baro (m H2O)
Trend-corrected Pre-Pumping WL
Trend and BE Corrected Water Level (m)
Pump OFF

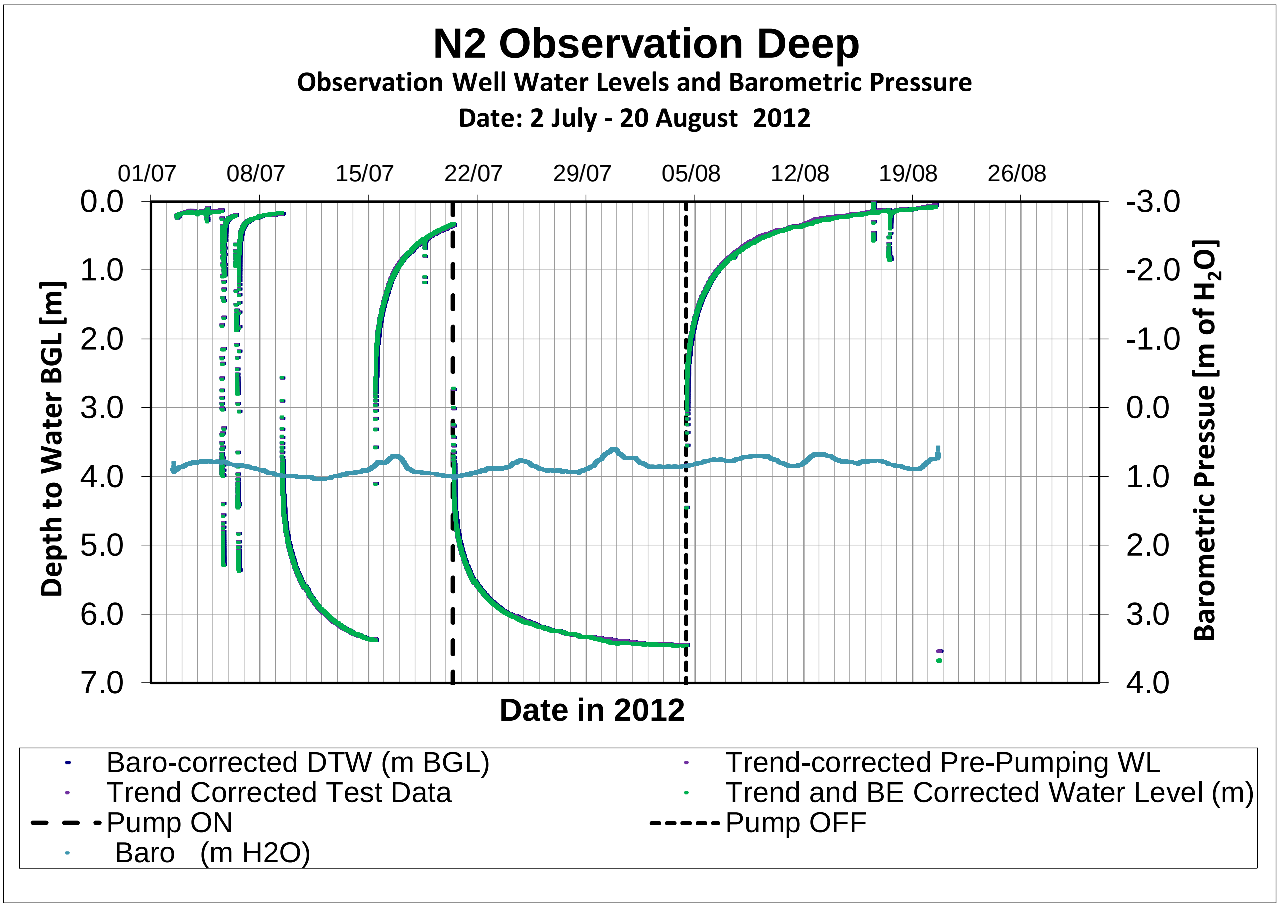

Sentinnel #1
Observation Well Water Levels and Barometric Pressure
Date: 2 July - 20 August 2012
01/07
08/07
15/07
22/07
29/07
05/08
12/08
19/08
26/08
Depth to Water BGL [m]
Barometric Pressue [m of H_2O]
Date in 2012
Baro-corrected DTW (m BGL)
Trend Corrected Test Data
Pump ON
Baro (m H2O)
Trend-corrected Pre-Pumping WL
Trend and BE Corrected Water Level (m)
Pump OFF

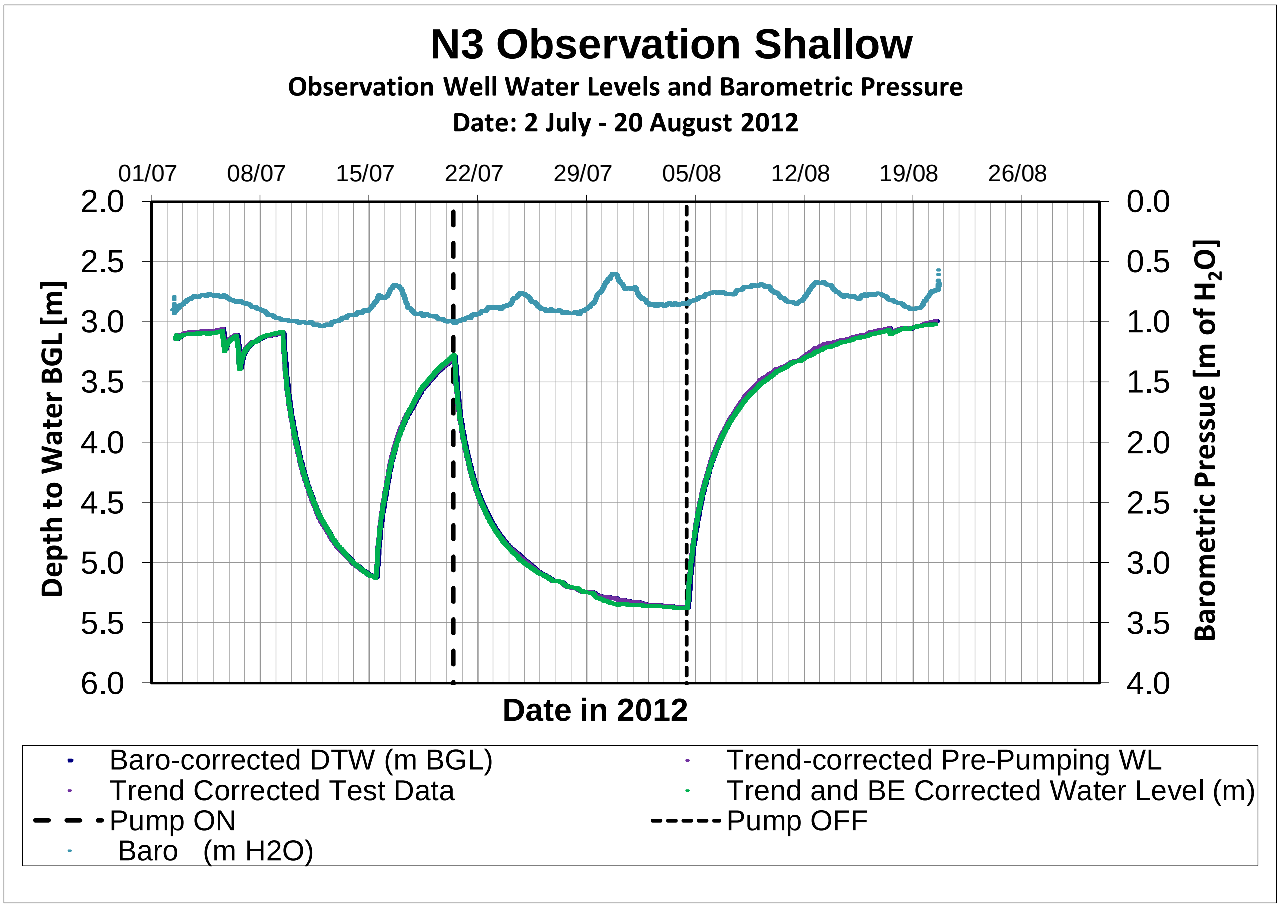
CH2M Beca


N1 Observation Shallow
Observation Well Water Levels and Barometric Pressure
Date: 2 july - 20 August 2012
01/07
08/07
15/07
22/07
29/07
05/08
12/08
19/08
26/08
5.0
5.2
5.4
5.6
5.8
6.0
0.2
0.4
0.6
0.8
1.0
1.2
Depth to Water BGL [m]
Barometric Pressue [m of H2O]
Date in 2012
Baro-corrected DTW (m BGL)
Trend Corrected Test Data
Pump ON
Baro (m H2O)
Trend-corrected Pre-Pumping WL
Trend and BE Corrected Water Level (m)
Pump OFF

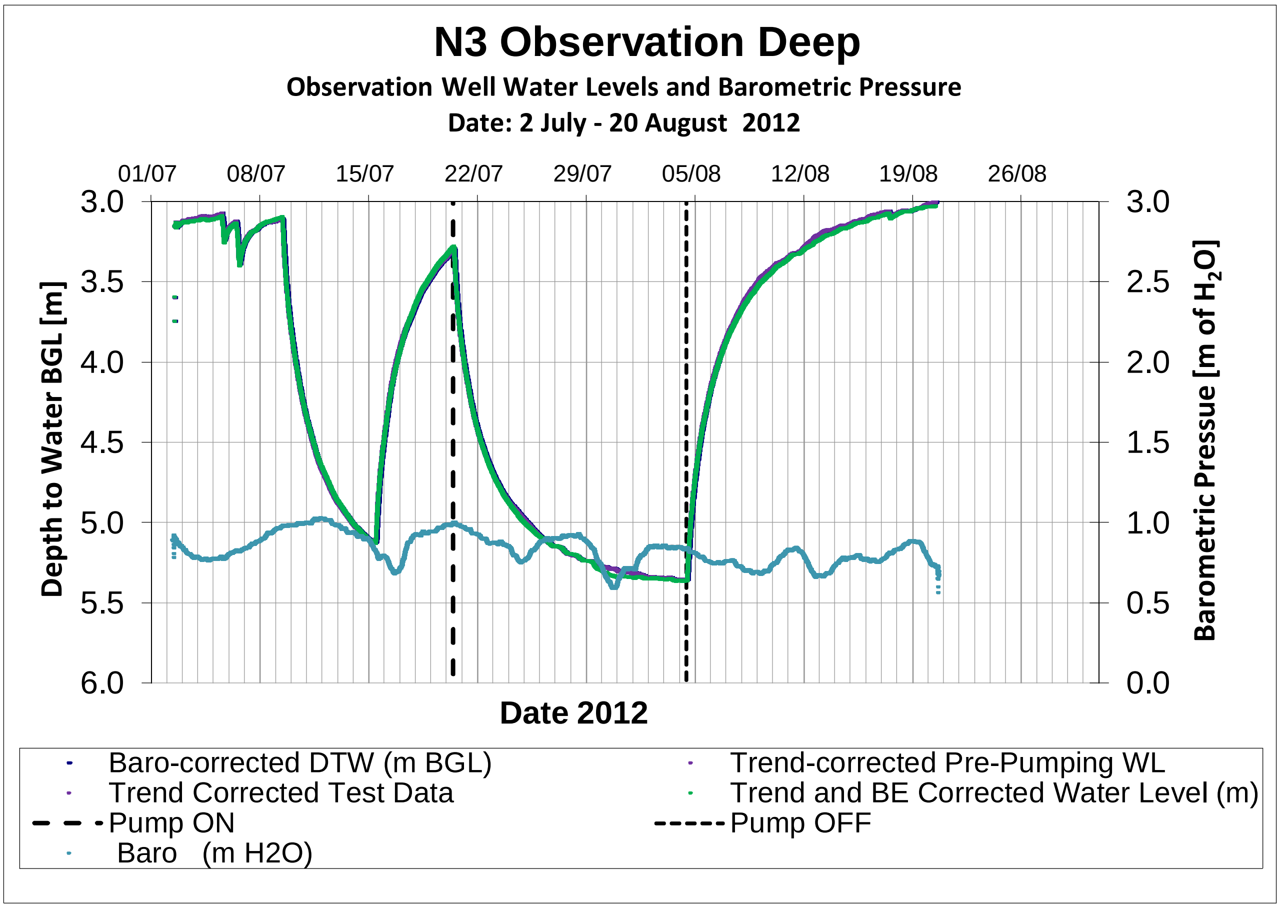

N1 Observation Deep
Observation Well Water Levels and Barometric Pressure
Date: 2 July - 20 August 2012
01/07
08/07
15/07
22/07
29/07
05/08
12/08
19/08
26/08
5.0
5.5
6.0
6.5
7.0
7.5
8.0
0.0
0.5
1.0
1.5
2.0
2.5
3.0
Depth to Water BGL [m]
Barometric Pressue [m of H2O]
Date in 2012
Baro-corrected DTW (m BGL)
Trend Corrected Test Data
Pump ON
Baro (m H2O)
Trend-corrected Pre-Pumping WL
Trend and BE Corrected Water Level (m)
Pump OFF


N2 Observation Shallow
Observation Well Water Levels and Barometric Pressure
Date: 2 July - 20 August
01/07
08/07
15/07
22/07
29/07
05/08
12/08
19/08
26/08
Depth to Water BGL [m]
0.0
0.5
1.0
1.5
2.0
2.5
3.0
Barometric Pressue [m of H2O]
-1.5
-1.0
-0.5
0.0
0.5
1.0
1.5
Date in 2012
Baro-corrected DTW (m BGL)
Trend-corrected Pre-Pumping WL
Trend Corrected Test Data
Trend and BE Corrected Water Level (m)
Pump ON
Pump OFF
Baro (m H2O)

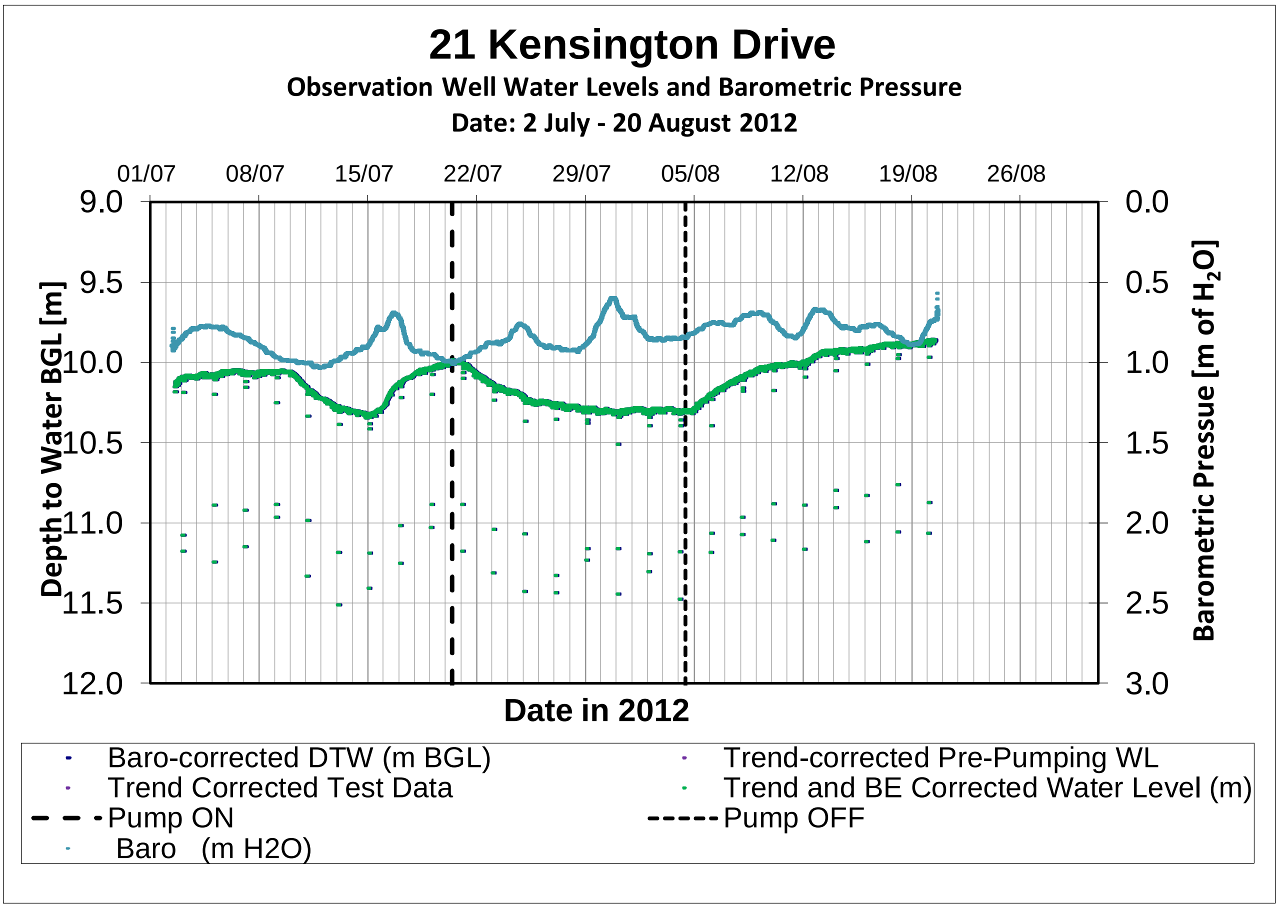

N2 Observation Deep
Observation Well Water Levels and Barometric Pressure
Date: 2 July - 20 August 2012
01/07
08/07
15/07
22/07
29/07
05/08
12/08
19/08
26/08
Depth to Water BGL [m]
0.0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
Barometric Pressue [m of H2O]
-3.0
-2.0
-1.0
0.0
1.0
2.0
3.0
4.0
Date in 2012
Baro-corrected DTW (m BGL)
Trend-corrected Pre-Pumping WL
Trend Corrected Test Data
Trend and BE Corrected Water Level (m)
Pump ON
Pump OFF
Baro (m H2O)



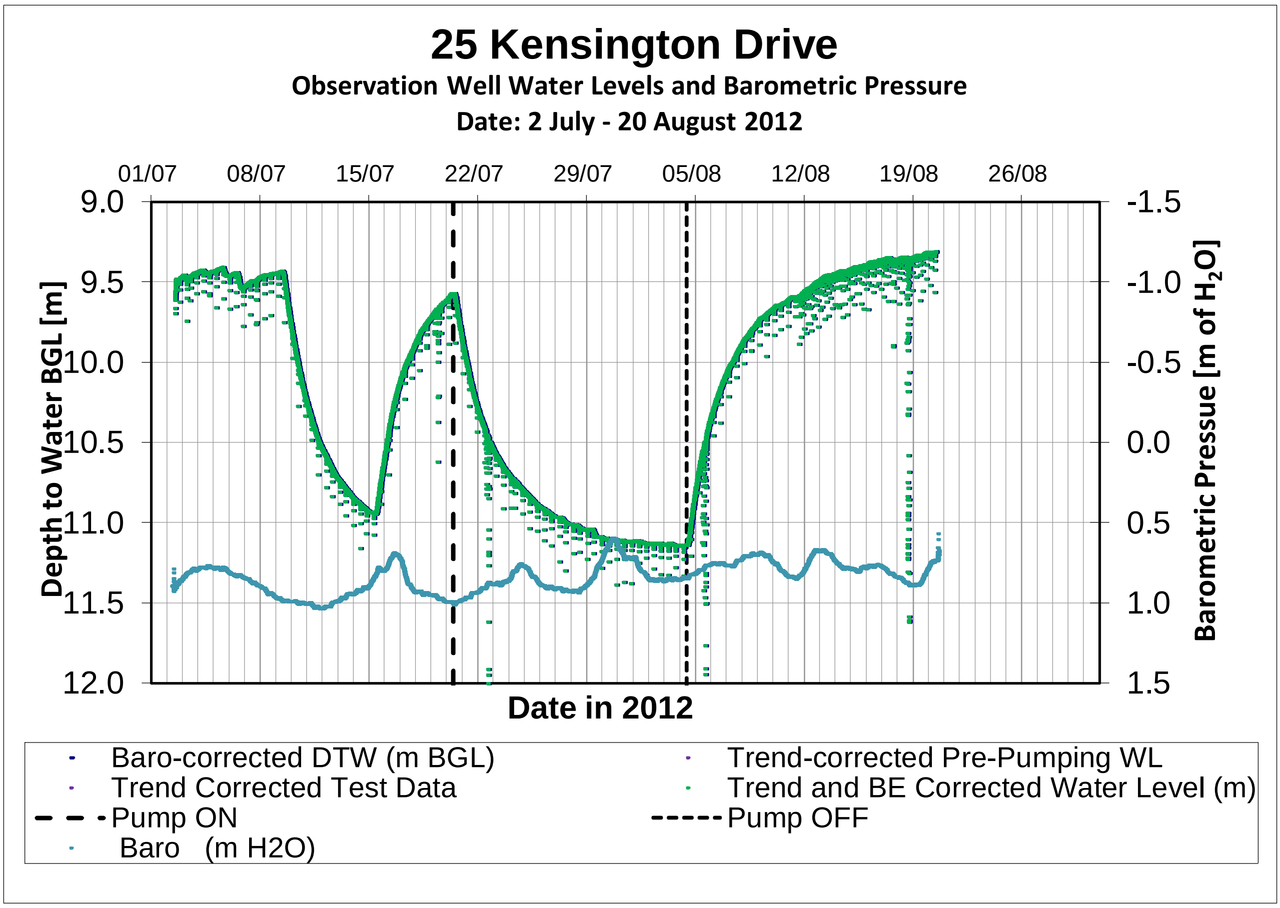
N3 Observation Shallow
Observation Well Water Levels and Barometric Pressure
Date: 2 July - 20 August 2012
01/07
08/07
15/07
22/07
29/07
05/08
12/08
19/08
26/08
Depth to Water BGL [m]
Barometric Pressue [m of H_2O]
Date in 2012
Baro-corrected DTW (m BGL)
Trend-corrected Pre-Pumping WL
Trend Corrected Test Data
Trend and BE Corrected Water Level (m)
Pump ON
Pump OFF
Baro (m H2O)



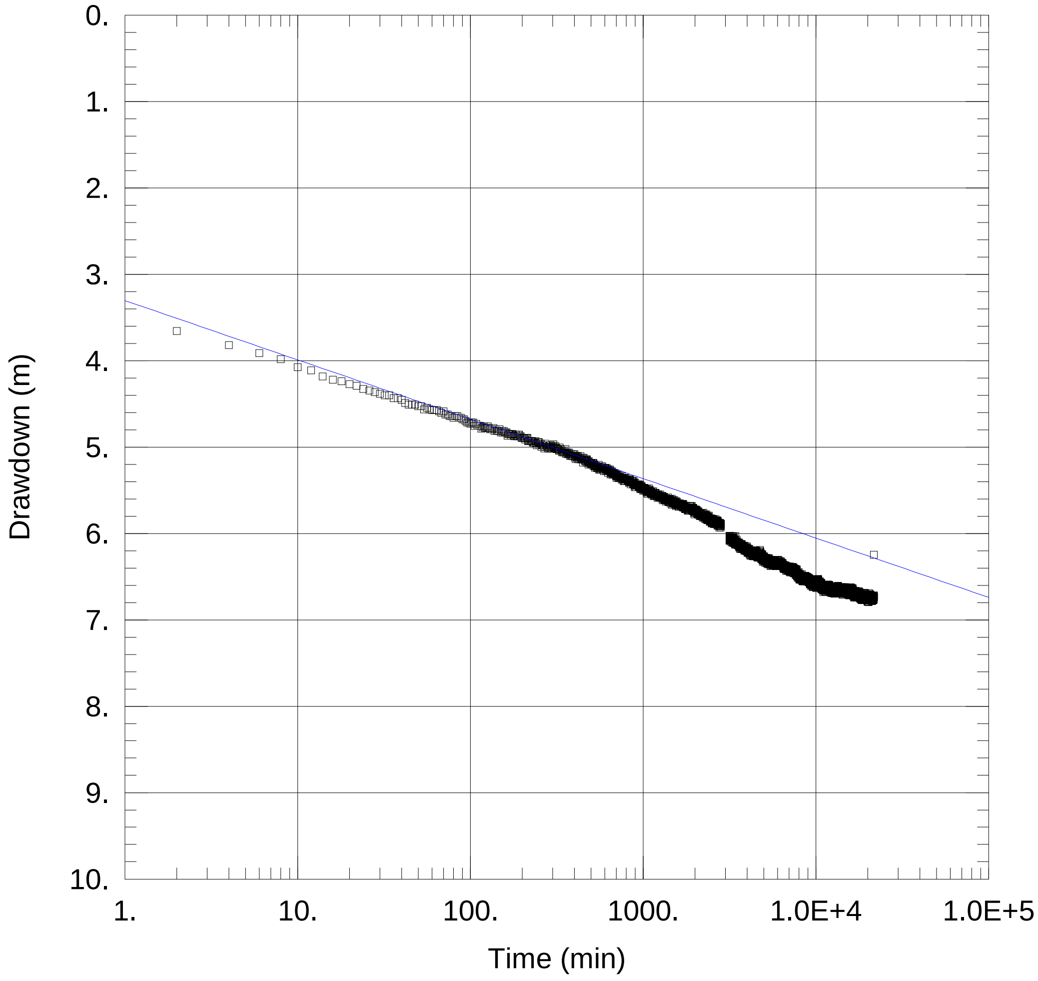
N3 Observation Deep
Observation Well Water Levels and Barometric Pressure
Date: 2 July - 20 August 2012
01/07
08/07
15/07
22/07
29/07
05/08
12/08
19/08
26/08
Depth to Water BGL [m]
Barometric Pressue [m of H_2O]
Date 2012
Baro-corrected DTW (m BGL)
Trend-corrected Pre-Pumping WL
Trend Corrected Test Data
Trend and BE Corrected Water Level (m)
Pump ON
Pump OFF
Baro (m H2O)



21 Kensington Drive
Observation Well Water Levels and Barometric Pressure
Date: 2 July - 20 August 2012
01/07
08/07
15/07
22/07
29/07
05/08
12/08
19/08
26/08
9.0
9.5
10.0
10.5
11.0
11.5
12.0
0.0
0.5
1.0
1.5
2.0
2.5
3.0
Depth to Water BGL [m]
Barometric Pressue [m of H2O]
Date in 2012
Baro-corrected DTW (m BGL)
Trend Corrected Test Data
Pump ON
Baro (m H2O)
Trend-corrected Pre-Pumping WL
Trend and BE Corrected Water Level (m)
Pump OFF



25 Kensington Drive
Observation Well Water Levels and Barometric Pressure
Date: 2 July - 20 August 2012
01/07
08/07
15/07
22/07
29/07
05/08
12/08
19/08
26/08
9.0
9.5
10.0
10.5
11.0
11.5
12.0
-1.5
-1.0
-0.5
0.0
0.5
1.0
1.5
Depth to Water BGL [m]
Barometric Pressue [m of H2O]
Date in 2012
Baro-corrected DTW (m BGL)
Trend Corrected Test Data
Pump ON
Baro (m H2O)
Trend-corrected Pre-Pumping WL
Trend and BE Corrected Water Level (m)
Pump OFF



WELL TEST ANALYSIS

Data Set: P:\...\N2_PW_CJ_CRJuly2012.aqt
Date: 09/07/12 Time: 14:37:50

PROJECT INFORMATION

Company: Beca
Client: KCDC
Project: 6515959
Location: Waikanae
Test Well: KCDC 2012 N2
Test Date: 20 July-4 August 2012

AQUIFER DATA

Saturated Thickness: 15. m Anisotropy Ratio (Kz/Kr): 0.1

WELL DATA

Pumping Wells

Well Name	X (m)	Y (m)
N2	1774723	5476384

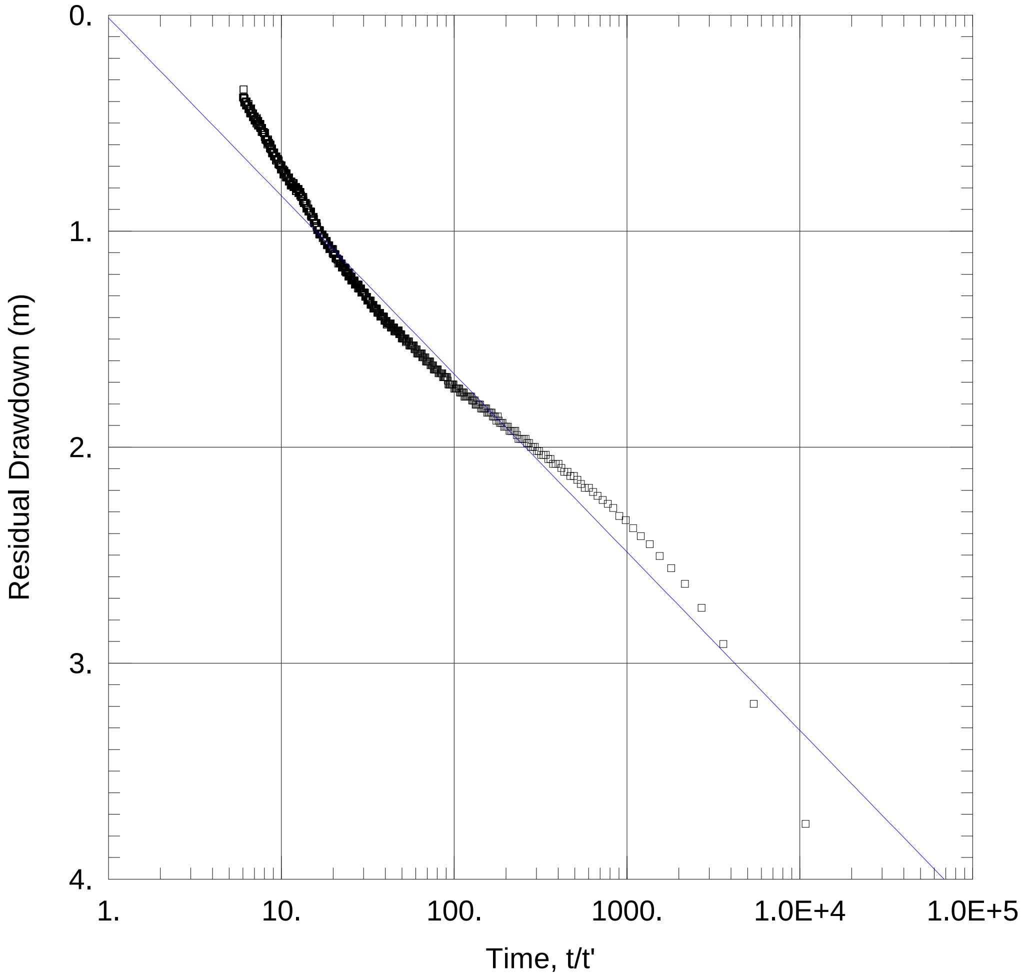
Observation Wells

Well Name	X (m)	Y (m)
N2	1774723	5476384

SOLUTION

Aquifer Model: Confined Solution Method: Cooper-Jacob

T = 600. m^2/day S = 0.00258



WELL TEST ANALYSIS

Data Set: P:\...\N2_PW_Rec_CRJuly2012.aqt
Date: 09/07/12 Time: 14:39:23

PROJECT INFORMATION

Company: Beca
Client: KCDC
Project: 6515959
Location: Waikanae
Test Well: KCDC 2012 N2
Test Date: 20 July-4 August 2012

AQUIFER DATA

Saturated Thickness: 15. m Anisotropy Ratio (Kz/Kr): 0.1

WELL DATA

Pumping Wells

Well Name	X (m)	Y (m)
N2	1774723	5476384

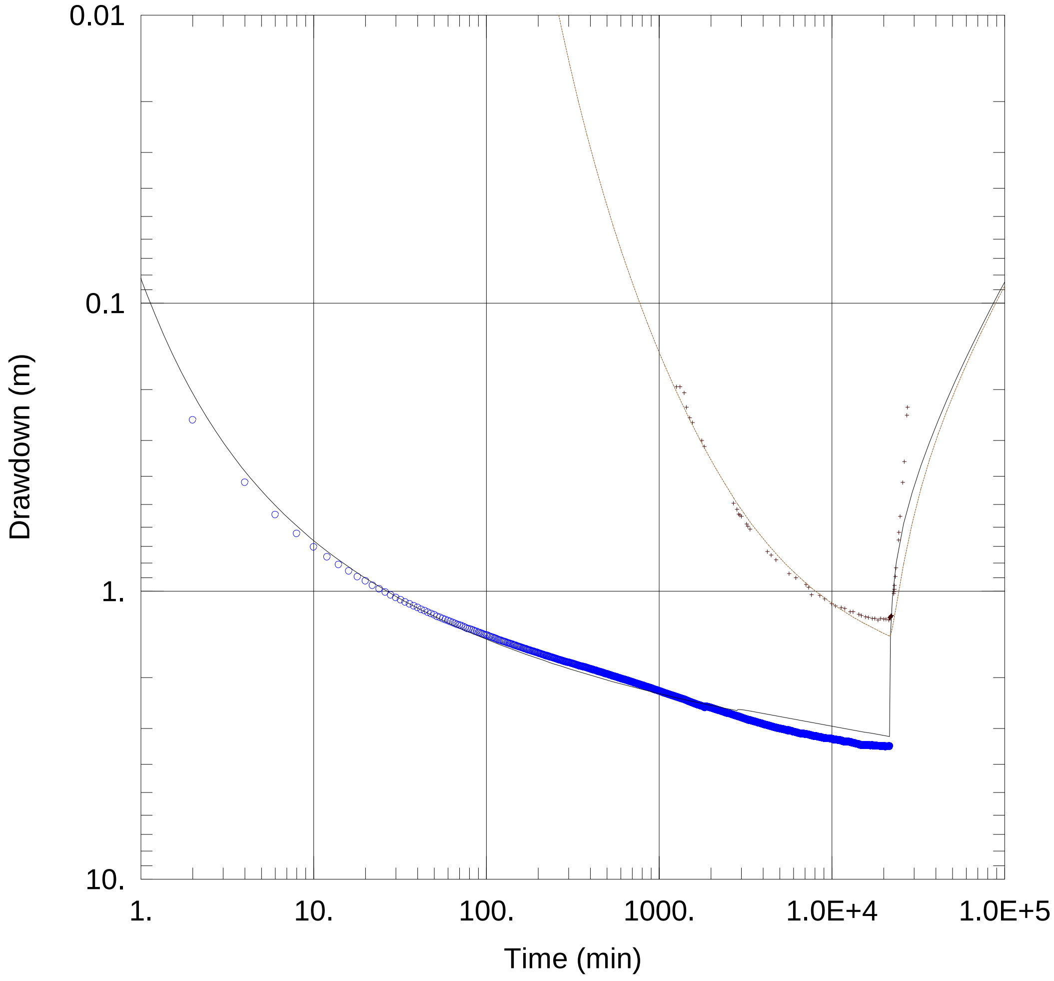
Observation Wells

Well Name	X (m)	Y (m)
N2	1774723	5476384

SOLUTION

Aquifer Model: Confined Solution Method: Theis (Recovery)

T = 500. m^2/day S/S' = 0.9661



WELL TEST ANALYSIS

Data Set: P:\...\Brown N2_NW_CRJuly2012.aqt
Date: 09/07/12 Time: 14:24:01

PROJECT INFORMATION

Company: Beca
Client: KCDC
Project: 6515959
Location: Waikanae
Test Well: KCDC 2012 N2
Test Date: 20 July-4 August 2012

AQUIFER DATA

Saturated Thickness: 15. m
Aquitard Thickness (b'): 20. m
Anisotropy Ratio (Kz/Kr): 0.1
Aquitard Thickness (b"): 20. m

WELL DATA

Pumping Wells

Well Name	X (m)	Y (m)
N2	1774723	5476384

Observation Wells

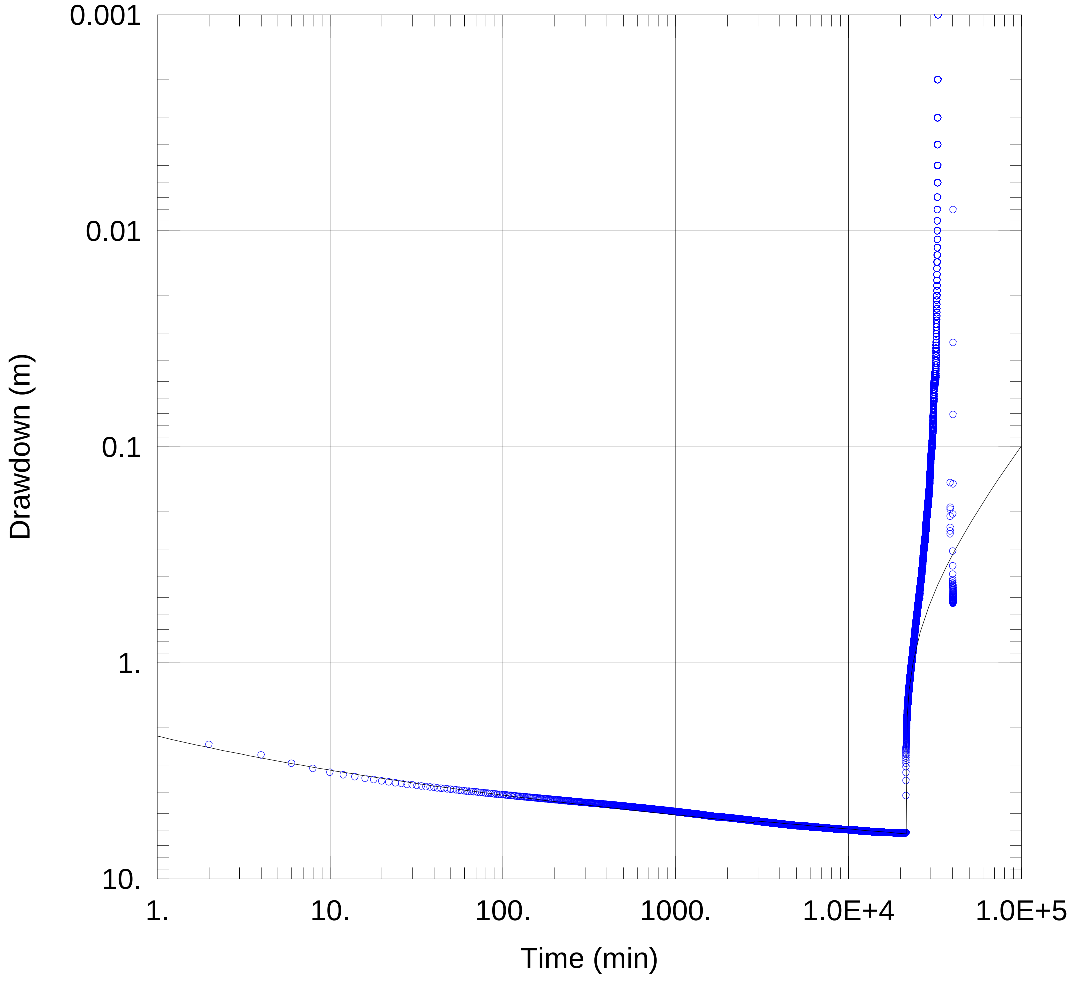
Well Name	X (m)	Y (m)
◦ N2 Deep	1774262	5476589
· Brown	1774196.41	5472692.4

SOLUTION

Aquifer Model: Leaky
Solution Method: Neuman-Witherspoon

T = 500. m^2/day
1/B = 4.646E-5 m^{-1}
T2 = 15.06 m^2/day
S = 5.4E-6
ß/r = 3.289E-6 m^{-1}
S2 = 2.0E-6

G8



WELL TEST ANALYSIS

Data Set: P:\...\N2_deep_Theis_CRJuly2012.aqt
Date: 09/07/12 Time: 14:36:21

PROJECT INFORMATION

Company: Beca
Client: KCDC
Project: 6515959
Location: Waikanae
Test Well: KCDC 2012 N2
Test Date: 20 July-4 August 2012

WELL DATA

Pumping Wells

Well Name	X (m)	Y (m)
N2	1774723	5476384

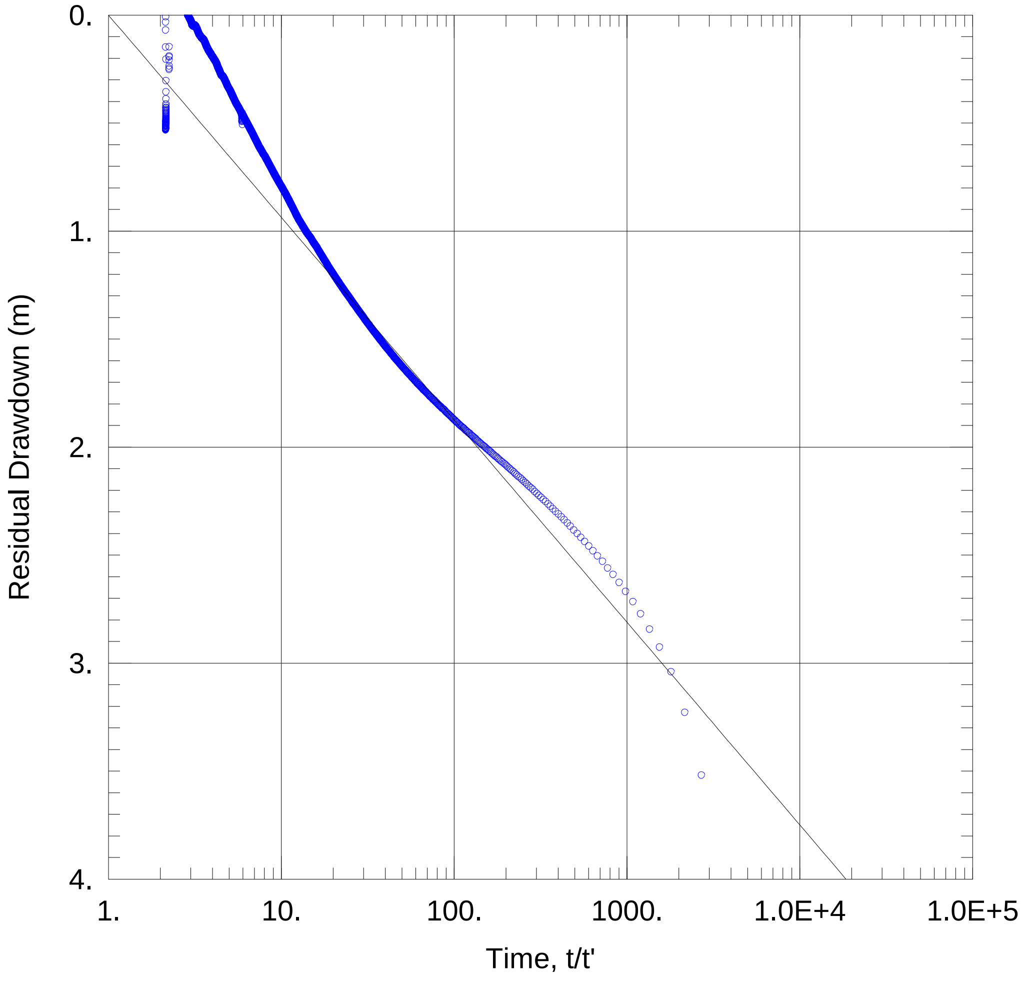
Observation Wells

Well Name	X (m)	Y (m)
○ N2 Deep	1774262	5476589
· Brown	1774196.41	5472692.4

SOLUTION

Aquifer Model: Confined
Solution Method: Theis

T = 440. m^2/day
S = 1.437E-8
Kz/Kr = 0.1
b = 15. m



WELL TEST ANALYSIS

Data Set: P:\...\N2_deep_Recs_CRJuly2012.aqt
Date: 09/07/12 Time: 14:34:59

PROJECT INFORMATION

Company: Beca
Client: KCDC
Project: 6515959
Location: Waikanae
Test Well: KCDC 2012 N2
Test Date: 20 July-4 August 2012

AQUIFER DATA

Saturated Thickness: 15. m Anisotropy Ratio (Kz/Kr): 0.1

WELL DATA

Pumping Wells

Well Name	X (m)	Y (m)
N2	1774723	5476384

Observation Wells

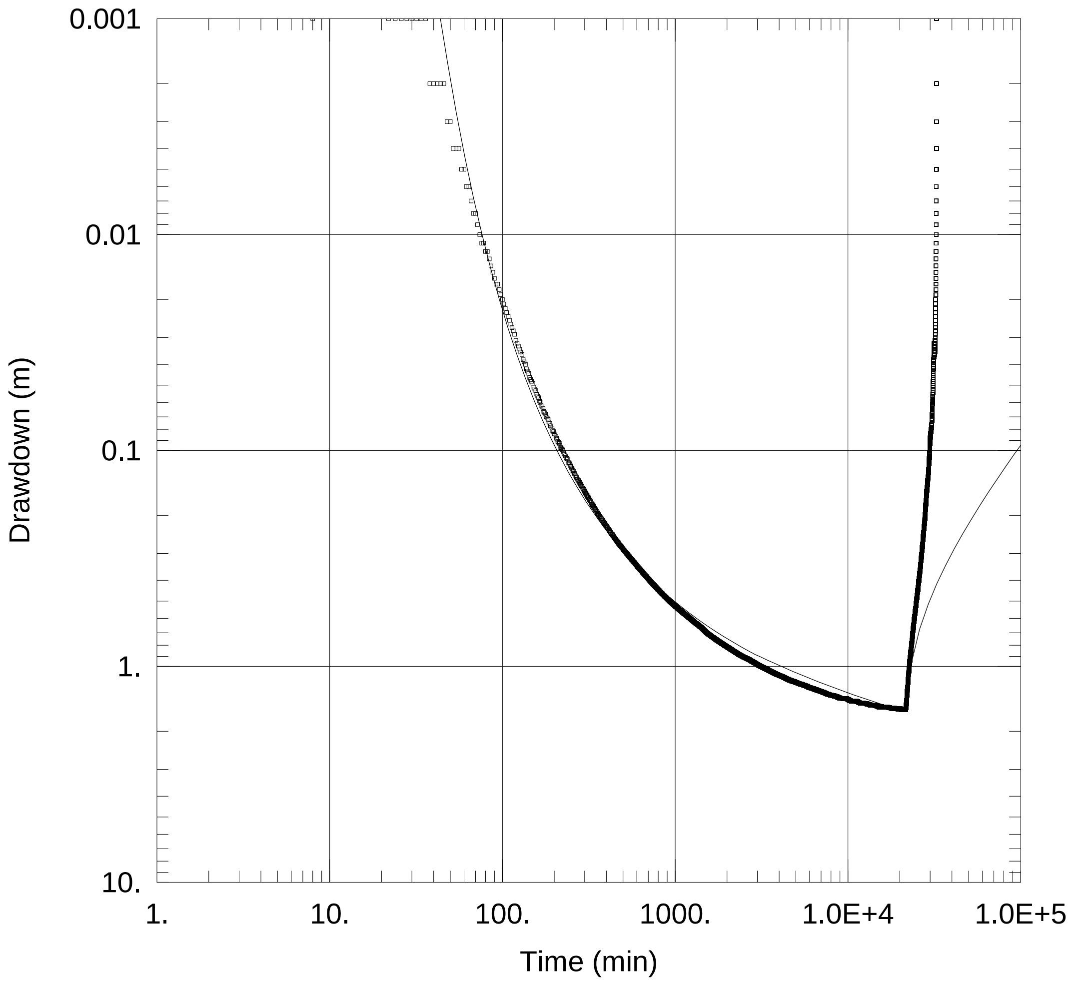
Well Name	X (m)	Y (m)
N2 Deep	1774262	5476589
Brown	1774196.41	5472692.4

SOLUTION

Aquifer Model: Confined Solution Method: Theis (Recovery)

T = 440. m^2/day S/S' = 1.

G10



WELL TEST ANALYSIS

Data Set: P:\...\N1Deep Theis_N2 CRJuly2012.aqt
Date: 09/07/12 Time: 14:33:14

PROJECT INFORMATION

Company: Beca
Client: KCDC
Project: 6515959
Location: Waikanae
Test Well: KCDC 2012 N2
Test Date: 20 July-4 August 2012

WELL DATA

Pumping Wells

Well Name	X (m)	Y (m)
N2	1774723	5476384

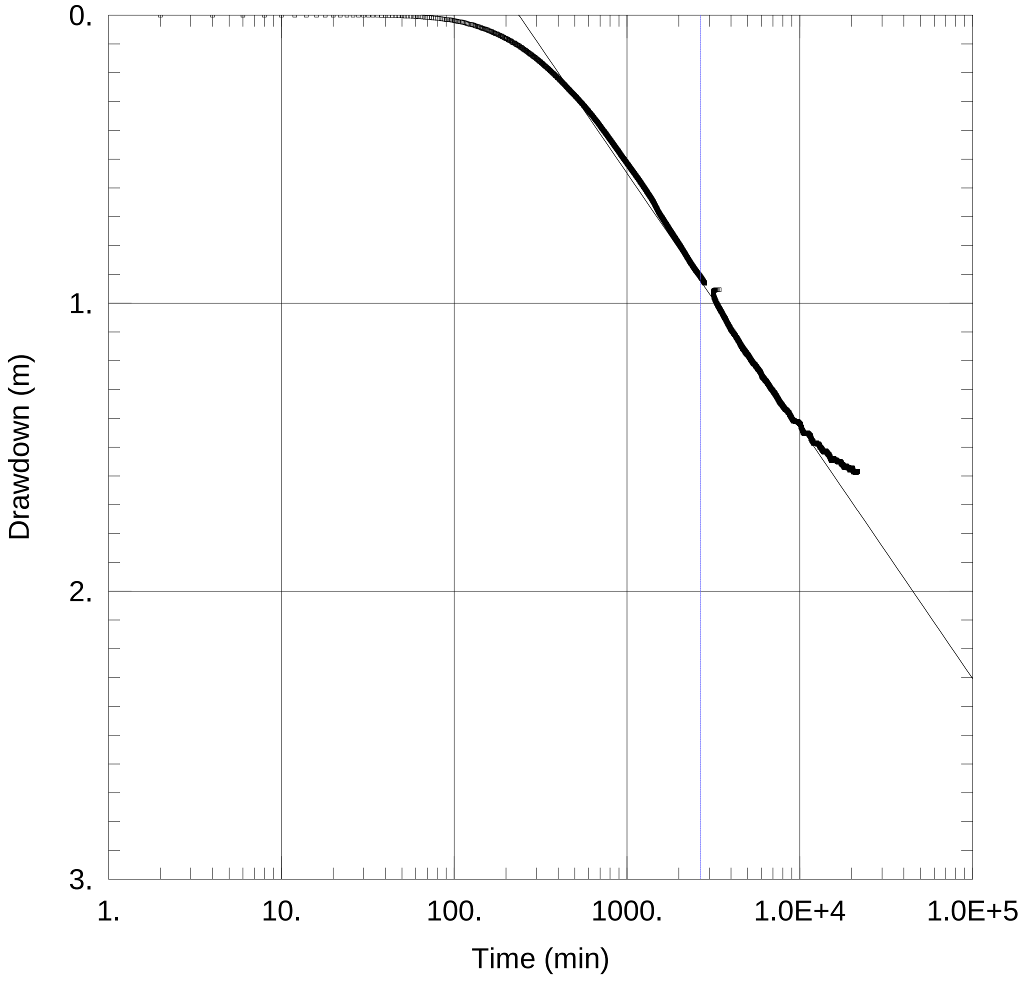
Observation Wells

Well Name	X (m)	Y (m)
N1 Deep	1774634.78	5475457.04
N1 Shallow	1774634.78	5475457.04

SOLUTION

Aquifer Model: Confined
Solution Method: Theis

T = 460. m^2/day
S = 0.00028
Kz/Kr = 0.1
b = 15. m



WELL TEST ANALYSIS

Data Set: P:\...\N1Deep CJ_N2 CRJuly2012.aqt
Date: 09/07/12 Time: 14:27:32

PROJECT INFORMATION

Company: Beca
Client: KCDC
Project: 6515959
Location: Waikanae
Test Well: KCDC 2012 N2
Test Date: 20 July-4 August 2012

AQUIFER DATA

Saturated Thickness: 15. m Anisotropy Ratio (Kz/Kr): 0.1

WELL DATA

Pumping Wells

Well Name	X (m)	Y (m)
N2	1774723	5476384

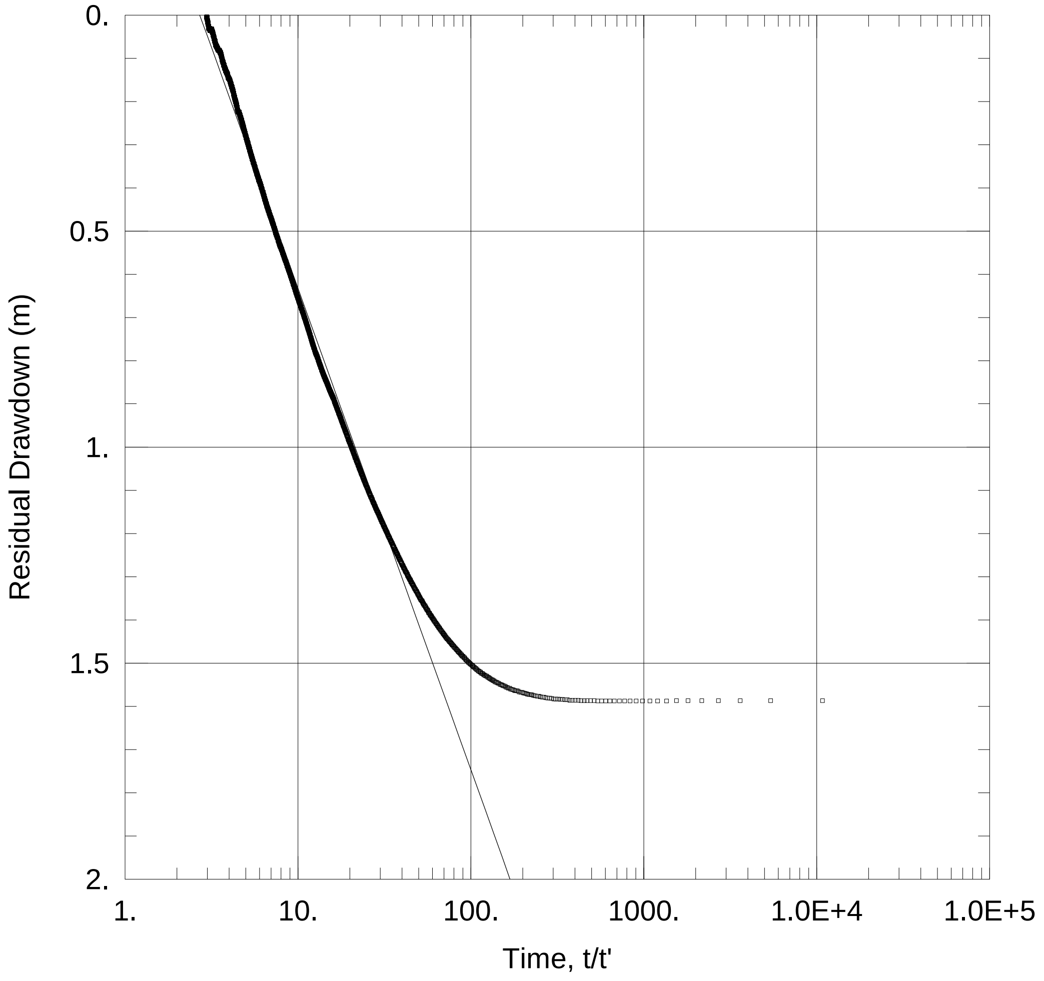
Observation Wells

Well Name	X (m)	Y (m)
N1 Deep	1774634.78	5475457.04
N1 Shallow	1774634.78	5475457.04

SOLUTION

Aquifer Model: Confined Solution Method: Cooper-Jacob

T = 470. m^2/day S = 0.0002



WELL TEST ANALYSIS

Data Set: P:\...\N1Deep Rec_N2 CRJuly2012.aqt
Date: 09/07/12 Time: 14:29:18

PROJECT INFORMATION

Company: Beca
Client: KCDC
Project: 6515959
Location: Waikanae
Test Well: KCDC 2012 N2
Test Date: 20 July-4 August 2012

AQUIFER DATA

Saturated Thickness: 15. m Anisotropy Ratio (Kz/Kr): 0.1

WELL DATA

Pumping Wells

Well Name	X (m)	Y (m)
N2	1774723	5476384

Observation Wells

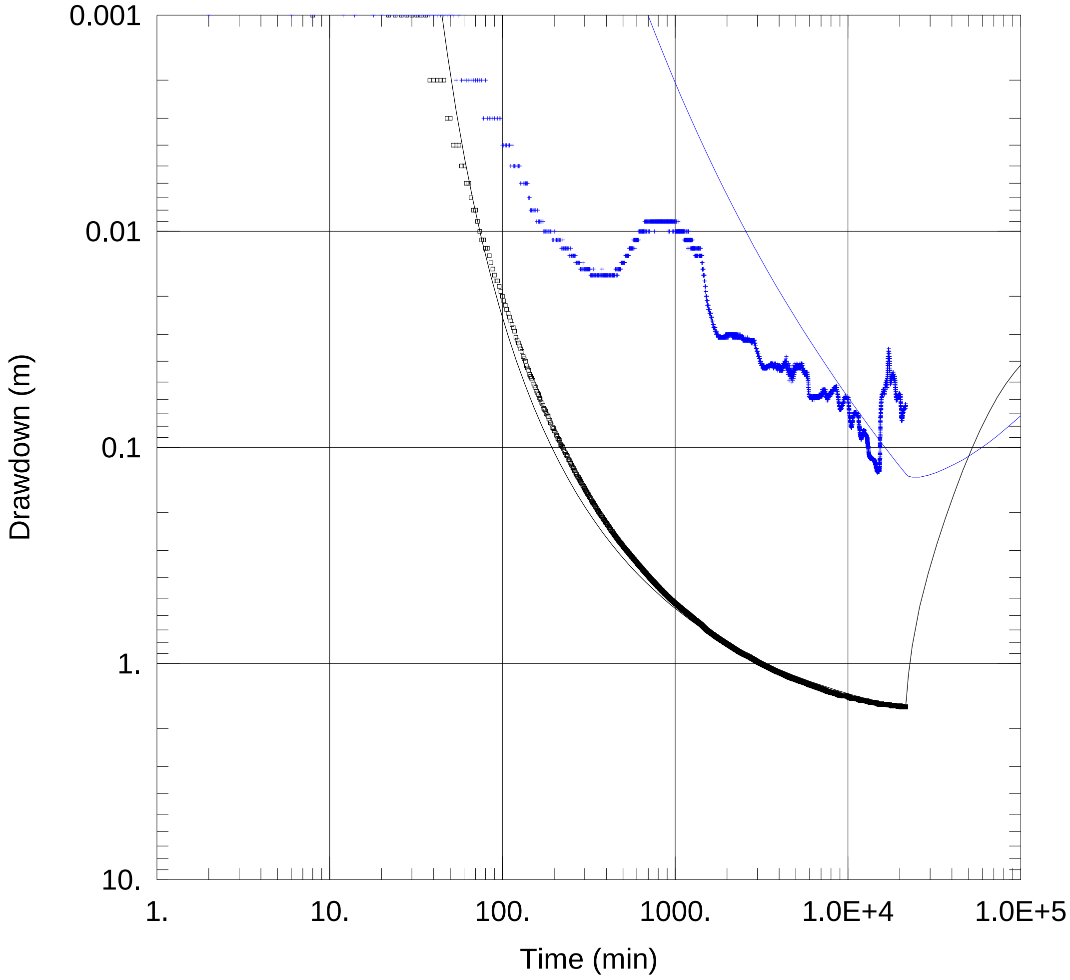
Well Name	X (m)	Y (m)
N1 Deep	1774634.78	5475457.04
N1 Shallow	1774634.78	5475457.04

SOLUTION

Aquifer Model: Confined Solution Method: Theis (Recovery)

T = 370. m^2/day S/S' = 2.707

G13



WELL TEST ANALYSIS

Data Set: P:\...\N1Deep Shallow NW_N2 CRJuly2012.aqt
Date: 09/07/12 Time: 14:31:33

PROJECT INFORMATION

Company: Beca
Client: KCDC
Project: 6515959
Location: Waikanae
Test Well: KCDC 2012 N2
Test Date: 20 July-4 August 2012

AQUIFER DATA

Saturated Thickness: 15. m
Anisotropy Ratio (Kz/Kr): 0.1
Aquitard Thickness (b'): 6.5 m
Aquitard Thickness (b"): 10. m

WELL DATA

Pumping Wells

Well Name	X (m)	Y (m)
N2	1774723	5476384

Observation Wells

Well Name	X (m)	Y (m)
▫ N1 Deep	1774634.78	5475457.04
· N1 Shallow	1774634.78	5475457.04

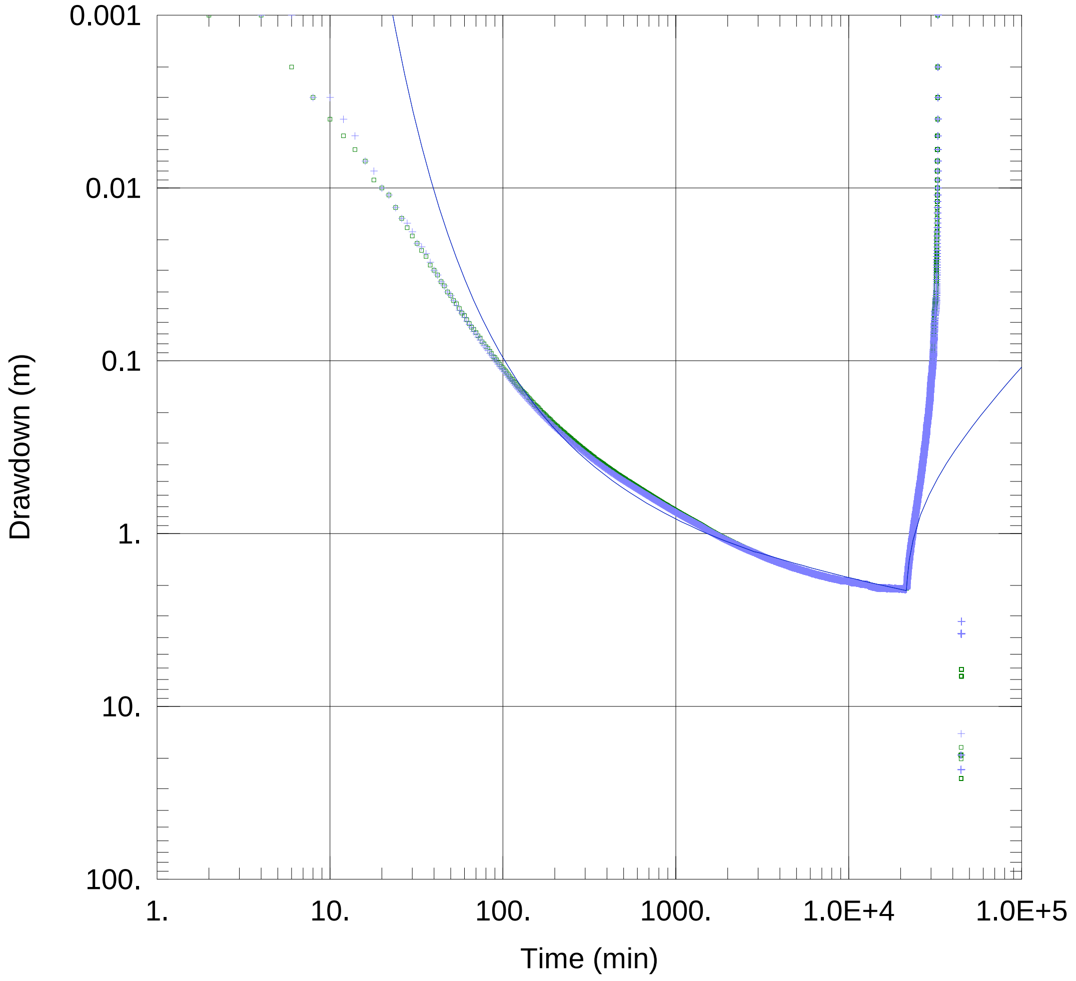
SOLUTION

Aquifer Model: Leaky
Solution Method: Neuman-Witherspoon

T = 410. m^2/day
1/B = 0.0001625 m^{-1}
T2 = 130. m^2/day

S = 0.00025
ß/r = 2.576E-6 m^{-1}
S2 = 0.001122

G14



WELL TEST ANALYSIS

Data Set: P:\...\N3 S and D Theis_N2 CRJuly2012.aqt
Date: 09/07/12 Time: 14:44:50

PROJECT INFORMATION

Company: Beca
Client: KCDC
Project: 6515959
Location: Waikanae
Test Well: KCDC 2012 N2
Test Date: 20 July-4 August 2012

WELL DATA

Pumping Wells

Well Name	X (m)	Y (m)
N2	1774723	5476384

Observation Wells

Well Name	X (m)	Y (m)
N3 Deep	1775124	5476737
N3 Shallow	1775124	5476737

SOLUTION

Aquifer Model: Confined

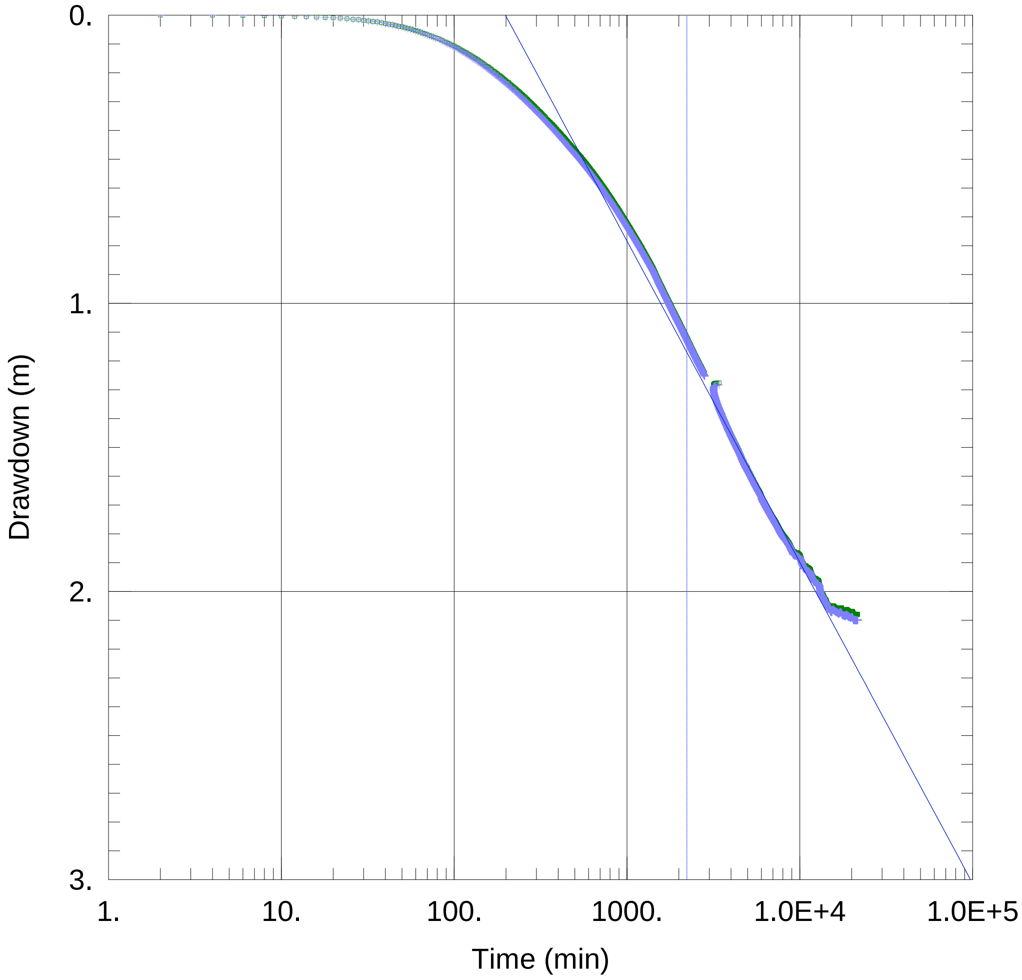
Solution Method: Theis

T = 400. m^2/day

Kz/Kr = 0.1

S = 0.0004

b = 30. m



WELL TEST ANALYSIS

Data Set: P:\...\N3 S and D CJ_N2 CRJuly2012.aqt
Date: 09/07/12 Time: 14:41:06

PROJECT INFORMATION

Company: Beca
Client: KCDC
Project: 6515959
Location: Waikanae
Test Well: KCDC 2012 N2
Test Date: 20 July-4 August 2012

AQUIFER DATA

Saturated Thickness: 30. m Anisotropy Ratio (Kz/Kr): 0.1

WELL DATA

Pumping Wells

Well Name	X (m)	Y (m)
N2	1774723	5476384

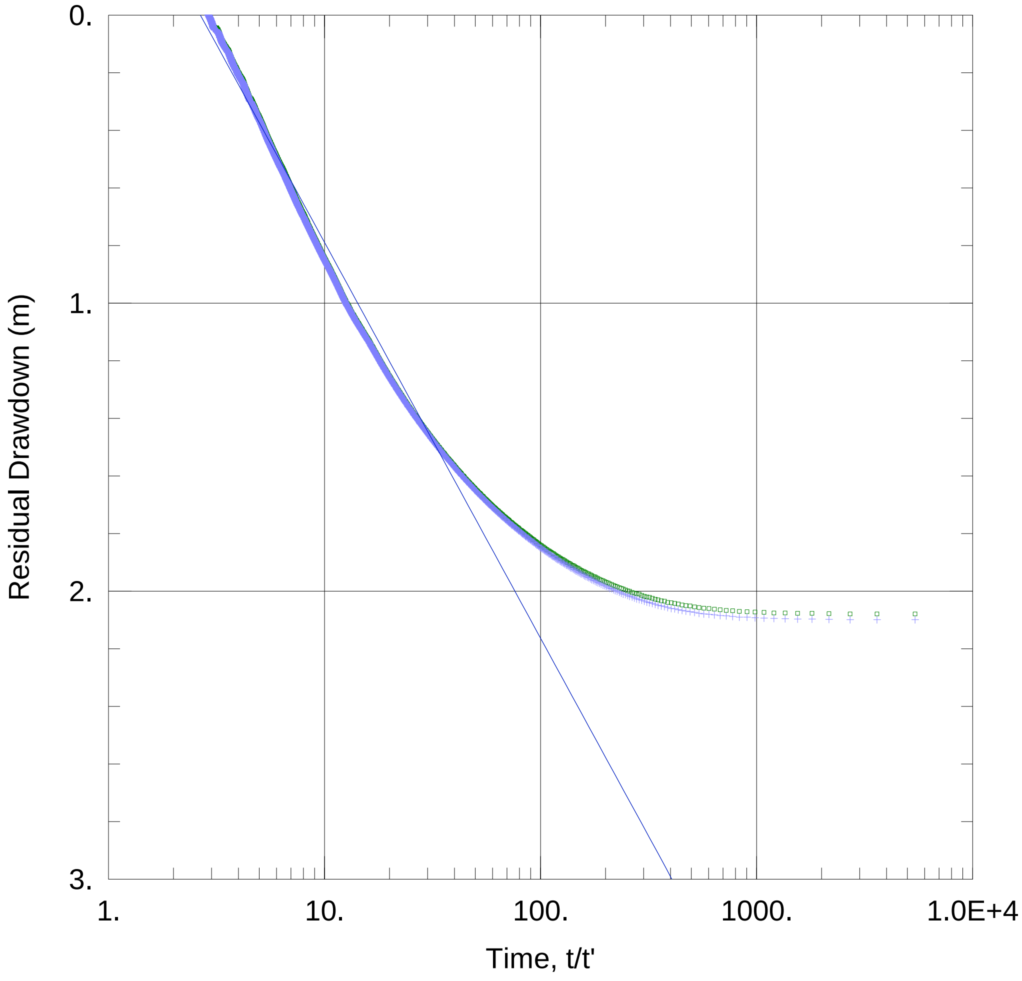
Observation Wells

Well Name	X (m)	Y (m)
N3 Deep	1775124	5476737
N3 Shallow	1775124	5476737

SOLUTION

Aquifer Model: Confined Solution Method: Cooper-Jacob

T = 370. m^2/day S = 0.0004



WELL TEST ANALYSIS

Data Set: P:\...\N3 S and D Rec_N2 CRJuly2012.aqt
Date: 09/07/12 Time: 14:42:48

PROJECT INFORMATION

Company: Beca
Client: KCDC
Project: 6515959
Location: Waikanae
Test Well: KCDC 2012 N2
Test Date: 20 July-4 August 2012

AQUIFER DATA

Saturated Thickness: 30. m Anisotropy Ratio (Kz/Kr): 0.1

WELL DATA

Pumping Wells

Well Name	X (m)	Y (m)
N2	1774723	5476384

Observation Wells

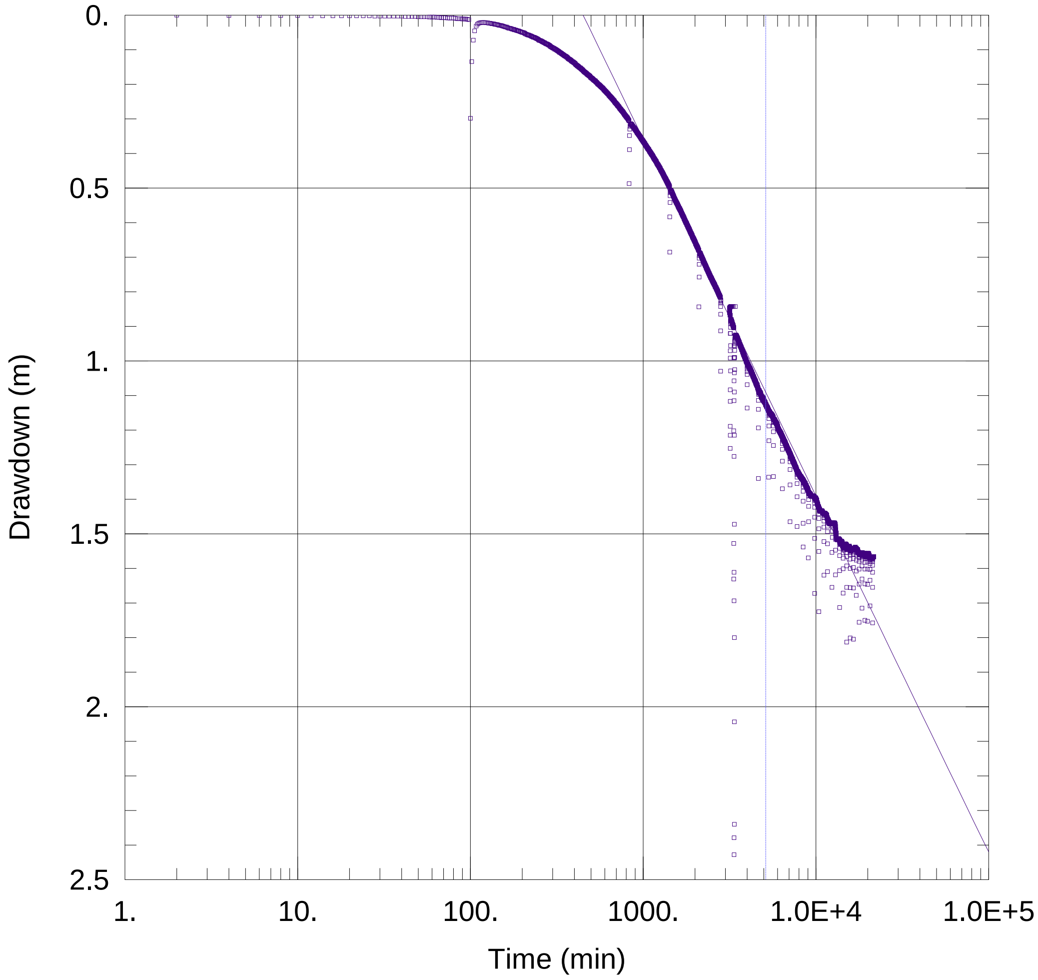
Well Name	X (m)	Y (m)
N3 Deep	1775124	5476737
N3 Shallow	1775124	5476737

SOLUTION

Aquifer Model: Confined Solution Method: Theis (Recovery)

T = 300. m^2/day S/S' = 2.664

G17



WELL TEST ANALYSIS

Data Set: P:\...\25 Kensington CJ N2 CRJulyr2012.aqt
Date: 09/07/12 Time: 14:12:12

PROJECT INFORMATION

Company: Beca
Client: KCDC
Project: 6515959
Location: Waikanae
Test Well: KCDC 2012-N2
Test Date: 20July-4 August 2012

AQUIFER DATA

Saturated Thickness: 15. m Anisotropy Ratio (Kz/Kr): 0.1

WELL DATA

Pumping Wells

Well Name	X (m)	Y (m)
N2	1774723	5476384

Observation Wells

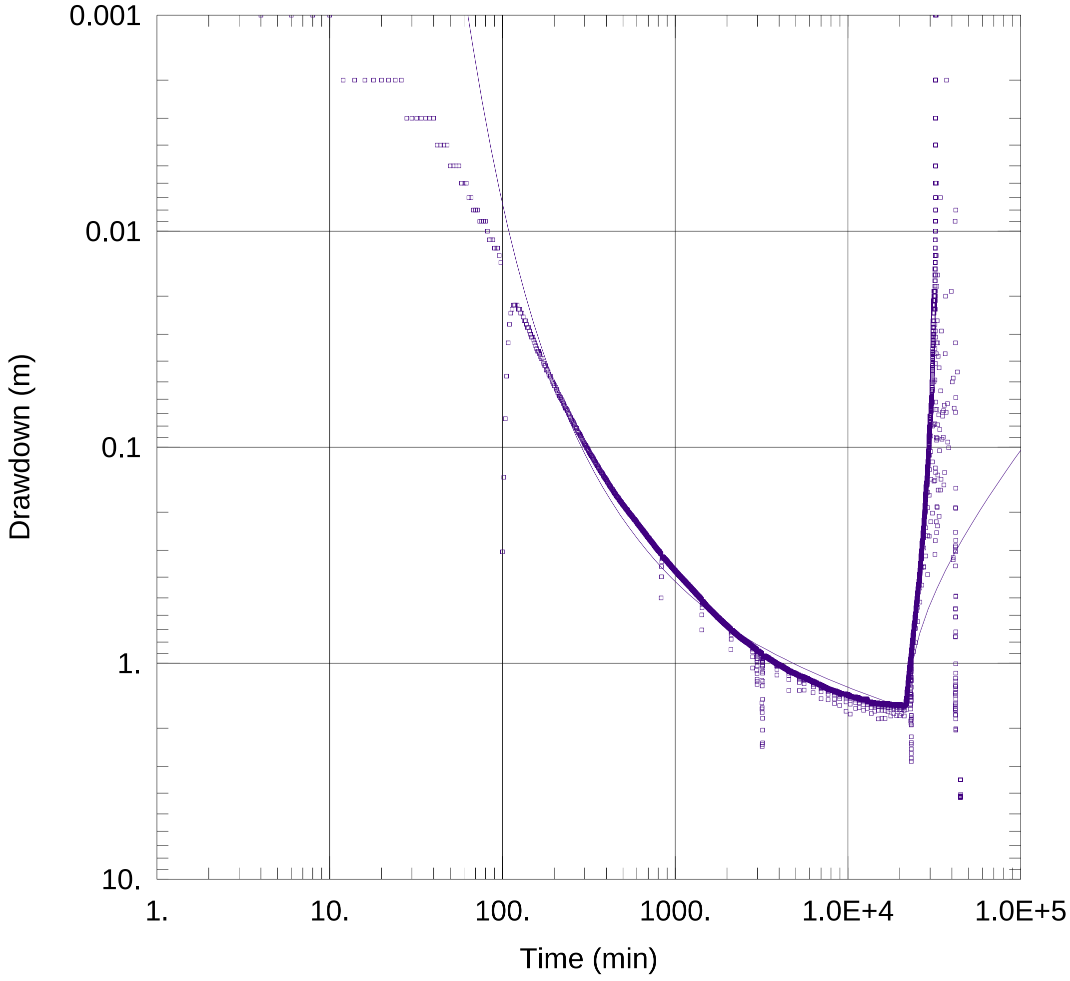
Well Name	X (m)	Y (m)
25 Kensington	1775122.1	5477085.2

SOLUTION

Aquifer Model: Confined Solution Method: Cooper-Jacob

T = 400. m^2/day S = 0.00043

G18



WELL TEST ANALYSIS

Data Set: P:\...\25 Kensington Theis N2 CRJulyr2012.aqt
Date: 09/07/12 Time: 14:17:40

PROJECT INFORMATION

Company: Beca
Client: KCDC
Project: 6515959
Location: Waikanae
Test Well: KCDC 2012 N2
Test Date: 20 July-4 August 2012

WELL DATA

Pumping Wells

Well Name	X (m)	Y (m)
N2	1774723	5476384

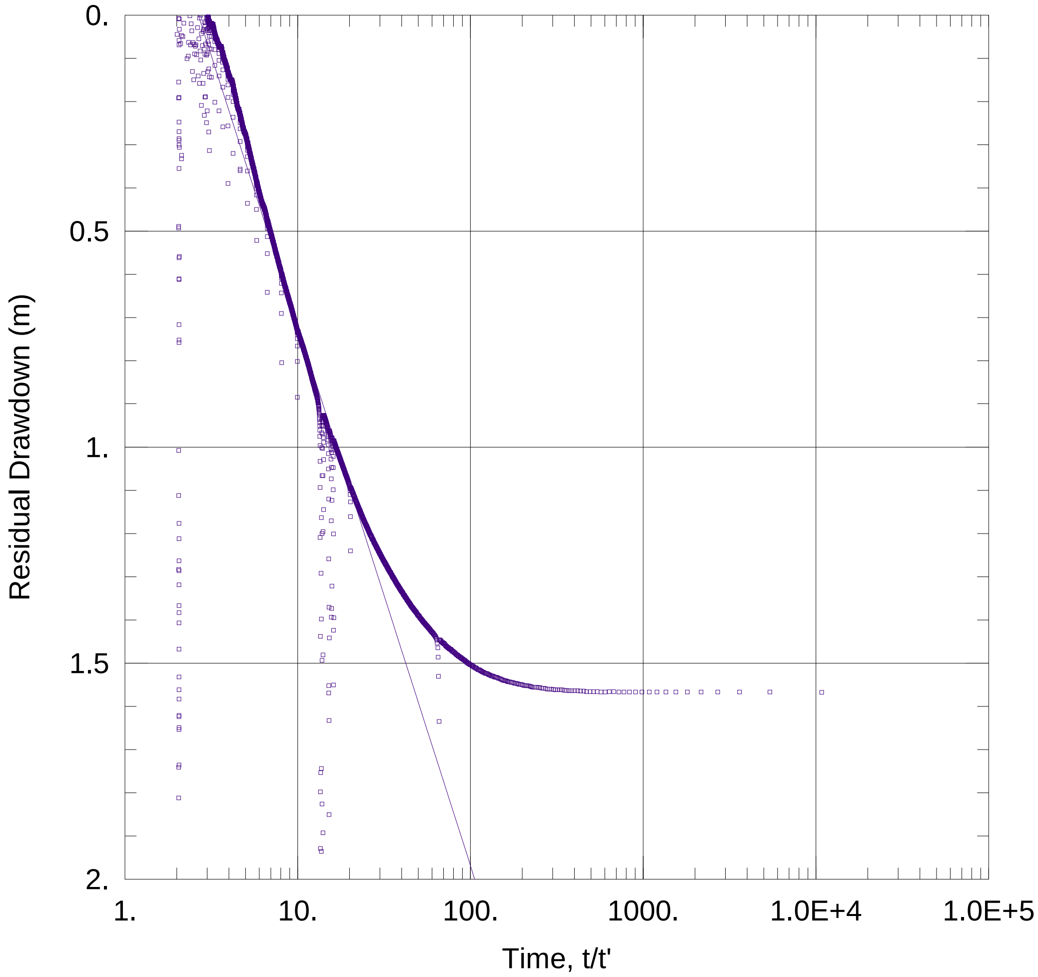
Observation Wells

Well Name	X (m)	Y (m)
25 Kensington	1775122.1	5477085.2

SOLUTION

Aquifer Model: Confined
Solution Method: Theis

T = 420. m^2/day
Kz/Kr = 0.1
S = 0.0005
b = 15. m



WELL TEST ANALYSIS

Data Set: P:\...\25 Kensington Rec N2 CRJulyr2012.aqt
Date: 09/07/12 Time: 14:15:21

PROJECT INFORMATION

Company: Beca
Client: KCDC
Project: 6515959
Location: Waikanae
Test Well: KCDC 2012 N2
Test Date: 20 July-4 August 2012

AQUIFER DATA

Saturated Thickness: 15. m Anisotropy Ratio (Kz/Kr): 0.1

WELL DATA

Pumping Wells

Well Name	X (m)	Y (m)
N2	1774723	5476384

Observation Wells

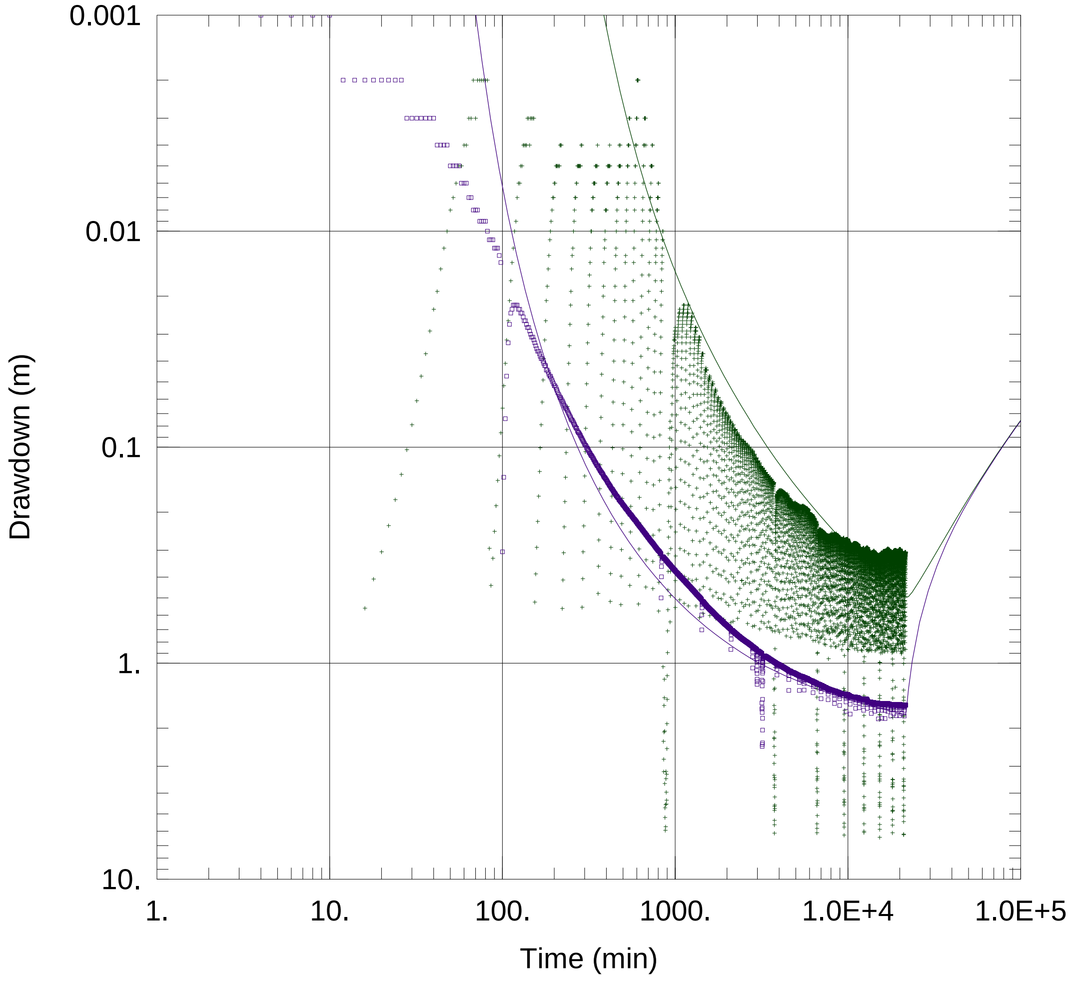
Well Name	X (m)	Y (m)
25 Kensington	1775122.1	5477085.2

SOLUTION

Aquifer Model: Confined Solution Method: Theis (Recovery)

T = 330. m^2/day S/S' = 2.659

G20



WELL TEST ANALYSIS

Data Set: P:\...\Kensingtons_NW_N2 CRJulyr2012.aqt
Date: 09/07/12 Time: 14:25:55

PROJECT INFORMATION

Company: Beca
Client: KCDC
Project: 6515959
Location: Waikanae
Test Well: KCDC 2012 N2
Test Date: 20 July-4 August 2012

AQUIFER DATA

Saturated Thickness: 15. m
Anisotropy Ratio (Kz/Kr): 0.1
Aquitard Thickness (b'): 6.5 m
Aquitard Thickness (b"): 10. m

WELL DATA

Pumping Wells

Well Name	X (m)	Y (m)
N2	1774723	5476384

Observation Wells

Well Name	X (m)	Y (m)
21 Kensington	1775345.1	5476827.2
25 Kensington	1775122.1	5477085.2

SOLUTION

Aquifer Model: Leaky
Solution Method: Neuman-Witherspoon

T = 300. m^2/day
S = 0.0004
1/B = 0.000369 m^{-1}
ß/r = 2.864E-5 m^{-1}
T2 = 280. m^2/day
S2 = 0.00033

G21