Masterton Wastewater Upgrade: Groundwater Report

Prepared for

Beca Carter Hollings & Ferner Limited

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Executive Summary

The Masterton District Council is proposing to upgrade its Wastewater Treatment Plant (WWTP) at Homebush, adjacent to the Ruamahanga River. The chosen scheme involves irrigation of treated wastewater from the existing ponds over an area of approximately 89 ha of land to the north of the ponds. This report details the groundwater modelling that has been carried out for the proposed Masterton Wastewater Treatment System (WWTP) upgrade at the Homebush site. The modelling was carried out to assess the potential effects of the irrigation scheme on groundwater flow and quality at the site.

The modelling was carried out using the MODFLOW finite difference code via Waterloo Hydrogeologic pre-and post-processor Visual MODFLOW 4.1. Three stages of modelling were carried out:

- an initial transient model to reproduce existing groundwater conditions, to demonstrate the model calibration was satisfactory;
- a steady state model to estimate mounding of the groundwater level within the aquifer under two irrigation scenarios, and calculation of discharge to the Makoura Stream and Ruamahanga River, summed over a number of reaches in each waterway; and
- modelling of the migration of contaminants (E.coli, adenovirus, nitrate and phosphorus) using the steady state MODFLOW model and the contaminant modelling software, MT3DMSMT, calculated as average concentrations discharging to the Makoura Stream or Ruamahanga River.

The discharge flow estimates and discharge concentrations were, in turn, used by others in predicting effects on the receiving water quality (Ruamahanga River) and for an assessment of the impacts on human health for users of the river.

The models were based on extensive hydrogeological site investigations, involving numerous test pits, hand auger holes and deeper boreholes completed as monitoring wells. Several years of groundwater level monitoring and a short period of detailed monitoring with transducers provide a good understanding of groundwater-surface water interactions.

The site is within the flood plain of the Ruamahanga River. The conceptual geological model for the site is a four layered system of alluvium, consisting of surficial silt and silty clay overbank deposits averaging two metres thick, an underlying gravel aquifer averaging ten metres thick, a variable thickness aquiclude and a further gravel aquifer underlying this. Groundwater within the shallow gravel aquifer flows southward towards the Ruamahanga River, which acts as a discharge boundary, and lies variously just within the surficial silts or within the gravel aquifer immediately below. Older, less permeable tertiary rocks exist across the river, and act as a no-flow boundary. The groundwater is in hydraulic connection with the river, responding rapidly, but in considerably damped manner, to flood events in the river.

The groundwater modelling was limited to predicting the effects on the aquifer, using the results of modelling, carried out by HortResearch, of the process of infiltration and natural treatment of the applied wastewater through the surficial soils. This modelling provided aquifer recharge estimates and contaminant concentrations at an assumed aquifer level of 1 m below the surface. The data were provided as time-series averaged over each of 11 sub-areas that the site was divided into for the purposes of the modelling.

HortResearch initially provided recharge data for the existing un-irrigated situation, with which the model could be calibrated by comparing with groundwater levels measured in the 21 monitoring wells on the site. Aquifer recharge estimates were then provided for “Average Rate” (the ultimately preferred Option 6) and “High Rate” (Option 3) irrigation scenarios. These scenarios equate to an average aquifer recharge over the complete site of 4.6 mm/day and 6.6 mm/day, respectively, compared with the un-irrigated average recharge of 0.62 mm/day.

The calculations of mounding of the groundwater level showed that the maximum effect would be of the order of 0.2 m. This amount of mounding has a negligible effect on the natural flow direction, being well within natural variation of groundwater level. The modelling also showed that the majority of the additional recharge finds its way to the Ruamahanga River, with some discharge occurring in the reaches of the river immediately to the east of the irrigation area, but the majority of the discharge occurring in the reach immediately south of the wastewater treatment ponds.

Without the irrigation the model predicts a natural increase in the Ruamahanga River flow between the top of the site and downstream of the ponds of about 0.25 m^3/s (21,900 m^3/day) from groundwater inflow. This equates to about 9% of the flow at Wardell’s Bridge at the summer low flow (5th percentile) of 2.7 m^3/s. With irrigation there is a slightly larger groundwater discharge to the river adjacent to the site of 0.29 m^3/s (25,000 m^3/day) for High Rate irrigation and 0.01 m^3/s (450 m^3/day) smaller than that for Average Rate irrigation. Put into context with a summer low flow of 2.7 m^3/s (233,000 m^3/day), the irrigation increase for the High Rate irrigation amounts to 1.3% of that flow, and less than half of that for the half median flow (6.15 m^3/s), the flow above which direct discharge of wastewater to the river may occur.

A smaller component of the irrigation recharge discharges to the Makoura Stream. The estimated increase in average stream flow is predicted to be about 4% of the natural downstream flow for Average Rate irrigation and a 6% increase for High Rate irrigation. In absolute terms, the increases amount to about 11 l/s (or 910 m^3/d) for High Rate irrigation and 7 l/s (600 m^3/day) for Average Rate irrigation.

The contaminant modelling has predicted that there will be increases in bacteria, nitrate-N and phosphorus in the groundwater at the site boundaries adjacent to the Makoura Stream and the Ruamahanga River. There is a rapid drop-off in concentrations beyond the actively irrigated areas. Concentrations of bacteria and nitrate will remain relatively constant throughout the project’s life, but phosphorous concentrations will increase, reflecting an increase in phosphorus concentrations in the drainage water from the surface soil. In general, the concentrations at the site boundaries are predicted to be less than or similar to background concentrations in the groundwater, but phosphorus concentrations late in the project's life (modelled at 28 years) may be greater than background concentrations. The modelled phosphorus concentrations are conservative, however, as adsorption in the aquifer has not been allowed for.

Groundwater concentrations at the site boundaries of E.coli, nitrate and phosphorus concentrations early in the project's life are expected to range from being considerably less than, to being similar to, background concentrations in the Ruamahanga River and Makoura Stream. Phosphorus concentrations at late stages may be up to eight times higher than the background concentrations, noting that the phosphorous concentrations are likely to be over-predictions.

The increases in E.Coli and nitrate concentrations in both the river and stream after mixing are predicted to be small (<10%) relative to background concentrations, as are phosphorus concentrations in the early stages of the project's life, given the at least ten times dilution available in the river at the summer low flow of 2.7 m^3/s and 15 times dilution available in the stream. Phosphorus concentration increases in the river at 28 years are conservatively predicted to be similar to the background concentrations in the river (median of 0.01 mg/L), but only 10% of the background concentration in the stream (0.01 mg/L). Predictions for 20 years are about half the 28 year predictions.

The minimal concentrations of contaminants within the groundwater at the site boundaries, and the predicted groundwater flow paths post-irrigation show that the irrigation will not affect the water quality in neighbouring wells. The groundwater does not flow towards these wells and, even if it did, the modelling shows the wells are too far away (the nearest being about 540 m away) for there to be any effects from contaminants.

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1.0 Introduction

The Masterton District Council is proposing to upgrade its Wastewater Treatment Plant (WWTP) at Homebush, adjacent to the Ruamahanga River. The chosen scheme takes treated wastewater from the existing ponds for irrigation over an area of approximately 89 ha of land to the north of the ponds. Pattle Delamore Partners (PDP) has been engaged by Beca Carter Hollings & Ferner Ltd (Beca) to examine the underlying aquifer and assess groundwater flow, and transport and fate of contaminants in the groundwater, arising from the irrigation. Based on this scope, the major issues dealt with in this report are:

- Changes in natural groundwater flow levels and patterns from the additional recharge, and in particular mounding within the aquifer;
- Changes in groundwater quality in the underlying aquifer;
- Changes in the quality of base-flow to the Ruamahanga River and Makoura Stream

The information from this study provides input into other studies carried out by the National Institute of Water and Atmospheric Research Ltd (NIWA) and the Institute for Environmental Science and Research (ESR) in estimating risks to human health and the environment at the ultimate discharge points of the groundwater.

The study is limited to assessing the gravel aquifer that underlies the site. Modelling of the infiltration of the wastewater through the surface soils has been carried out by HortResearch. The results of that modelling have been used as input into this study.

The issues outlined above have been addressed using field data collected from the site by PDP and others over the past seven years in combination with quantitative assessment techniques including predictive numerical and analytical groundwater flow and contaminant transport modelling. Details of these techniques and the predicted changes are provided in this report, alongside an interpretation of the results.

This report also includes an outline of the geology and hydrogeology of the area, the groundwater flow system and groundwater-surface water interaction at the site.

2.0 Geology and Hydrogeology

2.1 Summary of Investigations

The WWTP and proposed irrigation area is located adjacent to the Ruamahanga River at Homebush (Figure 1). The area designated for the proposed irrigation is shown in Figure 2. Numerous boreholes, test pits and hand-augured holes have been excavated and drilled across the site in the last seven years as part of investigations for the earlier Rapid Infiltration Basin scheme and the current proposal (Opus, 1998; Beca, 2005a; PDP, 2005). This has enabled a good understanding of the geological structure of the deposits in the area and the hydraulic properties of the various strata.

PDP has primarily been responsible for drilling and installation of monitoring wells, of which there are 21 around the site (HB1 to HB22, excluding HB8). Most of the wells are shallow, around 5 m, but some have been drilled to about 20 m. All available bore logs are included in Appendix B and locations can be seen in Figure 5.

Some of these wells have been pump or slug tested to provide estimates of hydraulic conductivity of the gravel aquifer. Regular monitoring by Masterton District Council staff (Figure 7) has provided information on groundwater levels, with length of records for individual wells varying between one and six years, with the majority of the wells having a two year record. In addition, installation of transducers in several monitoring wells in March 2005 enabled the short-term interaction between the Ruamahanga River and local ground water levels to be assessed.

2.2 Regional Hydrogeology

The WWTP is located on the floodplain of the Ruamahanga River. The Ruamahanga River is largely responsible for the geology in the vicinity of this site (Figure 3) by depositing unconsolidated sediments ranging from very coarse grained gravel strata to very fine grained silt and clay strata. In the study area, gravel deposits are overlain by silt-dominated strata, which represent overbank floodplain deposits associated with past high water levels occupying large sections of the floodplain. As the gravel-dominated channel has meandered across the floodplain, overbank deposits have been stripped off and replaced by new deposits of gravel. The Ruamahanga River is a major source of recharge to the aquifers formed in these gravel deposits. A geological cross-section as interpolated from the available data is shown in Figure 4.

The resulting aquifer system forms part of the Te Ore Ore groundwater zone identified by Butcher (1996). The site is located at the extreme south-west extent of the zone, with the Masterton – Martinborough Road marking the approximate boundary with the Masterton groundwater zone, and the older, tertiary-age rocks of the high ground over the river to the east and south-east forming another boundary.

Four aquifers have been identified within the alluvial deposits of the Te Ore Ore basin. The uppermost is an extensive unconfined, or semi-unconfined, aquifer (Aquifer T1). This aquifer is predominantly comprised of compact brown gravel with a variable sand, silt and clay content. Hydraulic properties of this aquifer are spatially highly variable with an average transmissivity of 880 m^2/day (Opus, 1998).

The regional groundwater flow direction is expected to be largely controlled by the Waingawa and Ruamahanga rivers. Regional groundwater flow has been assessed through piezometric surveys carried out by Wellington Regional Council. The interpreted regional piezometric contours are shown in Figure 6. This shows the flow direction is in a south-easterly direction, near the Waingawa River in the west, and a more southerly direction near the Ruamahanga River in the east.

Four surveys have been carried out in the shallow aquifer over a range of areas between April 1977 and October 1993 (pers.comm. Lindsay Annear, November, 2005). Based on these plots, it appears that the rivers exert a major control on head distribution across the wider plains area, although the apparent flow patterns do vary somewhat between the different piezometric surveys.

2.3 Homebush Geology

The on-going fluvial transport, sedimentation and erosion processes associated with the Ruamahanga River are responsible for the composition of the geological strata at the Homebush site.

The geological investigations have revealed extensive surficial sediments consisting of silts, clay, and silty fine sand deposits. These silty deposits, formed by overbank deposition from the Ruamahanga River, cap more permeable gravel dominated deposits, with interstitial clay, silt and sand. A cross-section showing the surface geology across the Homebush site is included in Figure 4.

A large number of test pits and boreholes have penetrated this layer to intercept the underlying gravels, providing excellent spatial coverage of the thickness of this layer. The locations of these are indicated in Figure 5. The geological investigations have revealed that these capping sediments form deposits of variable thickness (~0.4 – 4.5 m), with an average thickness of approximately 2 m. The deposits are heterogeneous and anisotropic.

In the Ruamahanga River valley, the thicknesses of the shallow alluvial gravel deposits are up to 15 m. The thickness of these gravel deposits is generally assumed to be in the order of less than 10 m thickness in the study area, based on information from the deeper investigation boreholes.

HB18, which was installed at the north-western end of the site, showed 4.5 m of clayey silt and clayey silt sand deposits overlying a 3 m thick sandy gravel deposit. This is underlain by a series of alternating horizons of clayey silt, clayey silt-bound gravel and sandy gravel deposits between 7.5 and 14.5 metres below ground level (mbgl).

At the south-western corner of the site, HB19 revealed gravely clay to a depth of 0.5 m underlain by a 9 m thickness of gravel and gravelly sand deposits. A clay-bound gravel deposit was encountered between 9.5 mbgl and 9.8 mbgl. This material is commonly found across the site at similar depths, but varies in thickness and is discontinuous. The remainder of the bore hole continued to a depth of 17.5 m with the strata predominantly consisting of sandy gravel.

Wells HB6 and HB7 are located a few metres apart near the centre of the site. Both bore holes revealed a 3 m thick surficial silt deposit overlying a 5 m thick gravel deposit. Silt-bound gravel was encountered in both wells at 8 mbgl. Beyond this, silt-bound gravels were encountered to 25 mbgl in HB7 which is inconsistent with surrounding observations and has been used cautiously in geological interpretations of the site.

The bore log for HB5 showed 2.5 m of silty strata overlying 5 m of gravel strata, with a silt-bound deposit encountered at 8 m. This well is located close to the Ruamahanga River at the east of the site. As the well was not drilled beyond 8.5 m, the extent of this confining layer (silt-bound gravel) is unknown. This is also the case for the bore-log for HB9, where a silt-bound gravel layer was intercepted at 11 m below an 8 m thickness of gravel. HB9 is situated just to the north of the existing wastewater ponds.

The bore logs for these and other wells across the site support the conceptual model of a surficial low permeability silt deposits of variable thickness that overlie more permeable gravel deposits. In summary, the detailed geological investigations carried out at the site have enabled the following interpretations to be made of the general geological structure across the site:

- Surficial fine-grained sediments of variable thickness ranging between 0.4 and 4.5 m but typically 1.5 to 2.5 m across the site. These sediments are the result of overbank deposition from the Ruamahanga River.
- Gravel and sandy gravel deposits are found beneath these surficial sediments. The thickness of these gravel deposits range from 2 to 9 m. These deposits are a result of fluvial deposition and erosion processes associated with the Ruamahanga River.
- Silty deposits have been encountered below the sandy gravel layer at depths ranging from 3.8 to 11 m below ground level. The thickness of these deposits varies greatly between the well locations. For example, the log for HB7 revealed silt-bound gravels between 8 and 17 m below ground level, but the log for HB19 revealed only 0.3 m thickness of clay-bound gravel at a depth between 9.5 and 9.8 m below ground level. In some holes, the thin horizons of silt, clay and clayey gravels may represent localised lenses. The variable nature of these deposits leads to some uncertainty in tracing such deposits between boreholes.
- The log for HB19 shows that further gravel deposits lie beneath this silty layer to a depth of 17.5 m. This contrasts to the log for HB7 which shows silt-bound gravels between 8 and 17 m below ground. It appears that the geology beneath the upper sandy gravel aquifer is variable across the site. It is possible that there may be extensive gravel deposits below depths of 10 m, but there are insufficient deep borehole logs to confirm this.

- It appears that the upper aquifer is bounded above by surficial low permeability deposits consisting of silts, clayey silts, and sandy silts while at depth it is bounded by silt-bound gravels and silt horizons. Some of the investigation wells have partially penetrated what is thought to be the lower aquifer or deeper water bearing gravel deposits. The extent of the alluvial deposits below this is poorly understood due to a lack of deep investigation bores that penetrate the full thickness of unconsolidated material through to basement rocks, although the delineation of deeper aquifer systems is outside the scope of this investigation.

2.4 Shallow Groundwater System

The shallow groundwater level is typically less than 2 m from the ground surface, lying within the surficial silt deposits where sufficient thickness exists, but otherwise within the underlying gravel. Test pits dug in January 2005 (Beca, 2005a) showed that the water levels increased during excavation when the pits penetrated into the underlying gravels, indicating that the surface sediments act as a confining (or semi-confining) layer to the aquifer in the underlying gravels, when piezometric levels are sufficiently high.

Monitoring over several years within monitoring wells has shown that the variation in groundwater level is small, less than 2 m, and usually less than 1 m. Groundwater level monitoring records are shown in Figure 7.

Detailed groundwater level monitoring data collected using electronic transducers showed that groundwater response to flood events in the Ruamahanga River to be rapid, but muted. Data collected from several monitoring wells in March 2005 is plotted alongside river level data in Figure 8. A 265 m^3/s flood in late March 2005, equivalent to a 1.6 m rise in river level at Wardell’s gauging station, resulted in a 70 – 90 mm rise in water level in most monitoring wells, with a greater rise in wells closer to the river, for example 170 mm in HB3 between Pond 2 and the river, and 120 mm in HB14 at the northern end of the site. The rise in the monitoring wells closely followed the river, with the subsequent fall being somewhat slower; the river typically falling over a one to three day period, whereas the wells took several days to return to the pre-flood level.

2.5 Surface water system

The surface water in the study area consists of the Ruamahanga River, the Makoura Stream, and various drainage ditches.

The Ruamahanga River rises in the Tararua Ranges and is joined by other rivers before ultimately flowing into Palliser Bay on the Wairarapa south coast. The Makoura Stream rises in Masterton and joins the Ruamahanga River just upstream of Wardell’s Bridge (Figure 1). Concurrent gauging surveys carried out in March 2005 and water level surveys indicate that the Makoura Stream starts to gain water from groundwater near well HB18. It appears that it continues to gain water between this location and its confluence with the Ruamahanga River, but this may vary depending on surrounding groundwater elevations. The difference in flow attributed to groundwater between the top and bottom (near HB19) of the site was found to be about 100 l/s in March 2005.

Treated wastewater from the treatment ponds is currently discharged to the Makoura Stream at the southern end of Pond 4 (the new maturation cell constructed within Pond 3 as part of the interim upgrade), several hundred metres north of its confluence with the Ruamahanga River.

A cut-off drain has been constructed around the northern perimeter of the wastewater ponds to intercept any seepage occurring from the ponds. This drain also allows surface water and groundwater levels to drain more quickly as floods receded.

2.6 Groundwater-surface water interaction

The shallow aquifer in the area is considered to have a significant hydraulic connection to the Ruamahanga River and the Makoura Stream. The groundwater flow direction is generally towards the south with some deviation to both the south-west and south-east depending on location within the site. Groundwater level and river stage height information indicates that the Ruamahanga River gains from groundwater along the majority of its length adjacent to the Homebush site during average river flows. At other times, depending on the relative heights of river stage and groundwater level, groundwater may either discharge to the river or receive recharge through river bed losses. For example, the rapid increase in groundwater levels that has been observed during floods in the river suggests that the hydraulic gradient is reversed during flood conditions and that the river contributes significant flow to groundwater.

Groundwater contour maps from surveyed data indicate that on the eastern side of the site groundwater flow is towards the Ruamahanga River. Groundwater in the centre and to the west of the site runs due south, with some variation to the south-west where groundwater seepage enters the Makoura Stream and to the south-east where groundwater enters the Ruamahanga River. The groundwater contours at the southern end of this site indicate that flow is directly south, towards the Ruamahanga River. A plot of interpolated groundwater contours based on water level measurements from 28 October 2005 is given in Figure 9**.** The flow directions indicated by the contours are expected to remain consistent regardless of seasonal changes in groundwater level, as the long-term monitoring of water levels (Figure 7) shows that all the monitoring points rise and fall in concert.

Water level surveys have shown that the surface water level in the Makoura Stream is generally lower than groundwater levels (although not adjacent to the northern end of the site), indicating that it will gain water from groundwater. As outlined in section 2.5, concurrent gaugings of the Makoura Stream have shown that it gains water along its course through the site. The vegetation that is present along much of the stream’s course through the site prevented the identification of potential sources of flow in the Makoura Stream such as drains and field tile drainage discharge points. However, the contribution of flow from a side drain that joins the stream from the west was quantified through a gauging.

The base of the stream is predominantly within the surficial fine-grained sediments along its length with some reaches that have cut through to the underlying gravel deposits. Analysis of the gauging data showed that the streambed conductance ranges between 2 and 160 m/day.

Groundwater level monitoring suggests that the groundwater in the silts and gravels is driven by regional groundwater gradients and rainfall recharge, except under flood stage river conditions, when seepage of surface water from the river contributes additional flow. This additional river flow results in higher driving heads into the adjacent shallow aquifer, lifting groundwater levels predominantly across the eastern areas of the site, depending on the magnitude of the flow event. The Ruamahanga River is likely to act as a major flow divide at least in the shallow gravel aquifer.

3.0 Groundwater quality and contaminant pathways

3.1 Potential contaminant pathways

The proposed wastewater irrigation scheme will result in the aquifer receiving drainage water that has higher levels of some contaminants than those found in usual rainfall-derived recharge. The purpose of the land-based disposal system is to utilise the natural treatment provided by the surficial soils at the site. In addition, the residual concentrations in the drainage water reaching the underlying aquifer will be further reduced through dilution with groundwater, and through the subsequent dispersion, advection, adsorption and filtration in the aquifer. Identifying all the possible routes the solutes and particulates may take through the environment is important in assessing potential environmental impacts and risks.

Prior to carrying out any form of assessment, the possible flow pathways from the wastewater disposal areas were considered. The following pathways were identified:

- Historic drainage via tile drains;
- Seepage into the surficial soils and underlying gravel aquifer;
- Migration through the gravel aquifer;
- Base flow or groundwater seepage into surface water features.

There is anecdotal evidence of tile drains having been installed historically in the south-west of the site (part of the paddock immediately to the north of Pond3), due to the generally poor drainage of the soil in this area. The locations, number of tile drains and discharge point(s) are unknown, although an earthenware pipe was found protruding from the bank of the Makoura Stream near the ponds. If the drains exist they potentially provide a preferential drainage path for the irrigated wastewater. However, it is thought the drains, if they exist, were installed many years ago, and their effectiveness will now be significantly reduced by clogging and closure of spaces around the drains that would have existed at installation. Also, the area involved is small relative to the total irrigated area. In the absence of firm evidence, and given the absence of any effective drainage occurring in the area (the south-east part of the paddock is wet in winter), the possible presence of these drains has been ignored. This is not considered to create a significant error in the groundwater analysis.

Seepage through the surficial soils to the underlying gravel aquifer or water table will be the primary pathway for wastewater, following irrigation application. The proposed irrigation application rates vary over the site depending on the capacity of the surficial soils to transmit the wastewater through to the gravel aquifer. This is a relatively short but significant pathway, because as the wastewater passes through the soil it undergoes a large part of the natural treatment on which the scheme relies. Most of the filtration and attenuation of microbial contaminants will occur within these near surface sediments as well as a significant uptake of phosphorus and nitrate in the pasture root zone.

Once the irrigated wastewater enters the gravel aquifer, further treatment occurs, as microbiological and chemical constituents will be naturally diluted, dispersed and attenuated and then transported along groundwater flow paths.

As discussed previously, groundwater flow direction in the gravel aquifer is generally towards the south with some deviation to both the south-west and south-east depending on location within the site (as shown in Figure 9), with the Ruamahanga River and the Makoura Stream being in hydraulic connection with the aquifer system.

Groundwater seeping into the bottom of a stream or river provides the base-flow to the stream, and the rate at which base-flow occurs is controlled by the hydraulic connection. Given the direction of the groundwater flow at the site, essentially directly towards the Ruamahanga River, and given that below the shallow gravel aquifer is a lower permeability layer acting as a more or less efficient aquitard, and that across the river (on the true left bank) is a low permeability boundary consisting of older rocks (PDP, 2006a), most of the shallow groundwater passing through the site is expected to discharge into the Ruamahanga River and Makoura Stream as base-flow. This is also expected to be the ultimate removal pathway for most of the additional flow to the aquifer from treated wastewater applied to the land-based disposal system, once it has reached the aquifer. Prior to that point there will have been losses to evapotranspiration and storage in the upper layers of the soil.

The rates of flow and the contaminants remaining in the groundwater at the point of discharge in the river and stream are discussed in subsequent sections of this report.

3.2 Existing groundwater quality

Groundwater quality has been measured in a number of monitoring wells since 2003 as part of the pond discharge consent requirements. Monitoring has included all four wells between the ponds and the Ruamahanga River (HB1 to HB4), three wells up-gradient of the ponds (HB9, HB6 and HB5, in increasing distance up-gradient); Forbes irrigation bore (HB10) and one well west of the ponds (HB11). These wells have been monitored for a range of general groundwater quality parameters specified in the consent – details are contained in Beca (2004a and 2005b).

The consent monitoring shows groundwater quality up-gradient of the ponds is generally good, with all but E. coli of the parameters tested complying with the New Zealand Drinking-water Standards 2005 (MoH, 2005). Despite the land being used for dairy farming, even E. coli complies (i.e. is < 1/100 ml) for about 50% of the samples, with the balance being at or close to 1/100 ml.

The one-off testing in HB6 for a suite of metals listed in the drinking-water standards showed a general absence of these metals (at the laboratory detection limits) and in all cases compliance with the standards. There was also an absence of PAHs (at detection limits ranging from 0.0001 to 0.0005 mg/L) in HB6, an expected result for groundwater in a rural area.

Well HB 11, to the west of the ponds appears to have water of slightly different origin to that of the wells north of the ponds, being distinctly harder, and having higher iron, manganese, bicarbonate, sodium and chloride concentrations than the wells to the north of the ponds.

4.0 Groundwater Flow Model

To enable potential effects of the proposed irrigation scheme on groundwater to be assessed, a groundwater model representative of the hydrogeological setting was required. A numerical groundwater flow model has been developed using the USGS finite-difference code MODFLOW and the Waterloo Hydrogeologic pre-and post-processor Visual MODFLOW 4.1. The numerical model allows a three-dimensional representation of hydrogeological parameters, groundwater flow paths, and contaminant migration.

The first step in the model was to produce a transient simulation that reproduced the natural, pre-irrigation, situation in order to gain confidence that the conceptual geological model, the hydraulic conductivity estimates assigned to the aquifer and the recharge estimates, were a good approximation to the true situation. This involved calibrating the model to groundwater level, river stage and Makoura Stream flow data collected from the site over the past three years.

The next stage in the modelling was to assess the changes in groundwater levels and flow patterns resulting from the irrigation using the calibrated model. Both transient and steady-state calibrated models were used to assess these changes. In addition to changes in groundwater levels, changes in groundwater seepage rates to the Ruamahanga River and Makoura Stream were assessed.

The steady-state model was then used to assess potential contaminant transport at the site. As the particle travel times in the aquifer are large relative to the irrigation application periods, transient modelling was not required for this stage. The purpose of this modelling was to predict contaminant concentrations in the groundwater seepage entering the Makoura Stream and the Ruamahanga River.

4.1 Preparation of Data for Model Input

Model characterisation involves taking field data describing the aquifer system and translating that information to input variables that the model can then use to solve governing equations of flow and transport. The input variables used for the model are summarised below and described in the following sections:

- Model Domain
- Topographic Data
- Climate Data
- Surface Water Data
- Hydrogeological Data
- Boundary Conditions

4.1.1 Model Domain

The area of interest, or model domain, comprises what is considered a near complete representation of the aquifer system at the Homebush Wastewater Treatment Site, and is based on hydrogeological investigations at the site and encompasses the wider area of the Wairarapa plains to provide suitable surrounding aquifer or boundary conditions. The model domain (Figure 10) and setup primarily focuses on the Homebush site, but the model also incorporates a larger area of the aquifer system that includes the Waingawa River in the west and the hills composed of basements rocks near Whangaehu in the north and east. This was done to ensure the location of the model boundaries were set wide enough to avoid boundary effects or artefacts of locating the model margins too close to the site. It is also apparent that there is some influence on the groundwater flow direction from the Waingawa River across the wider Wairarapa Plains.

It can be seen in Figure 6 that the groundwater flow is in a south-easterly direction parallel to the Waingawa River across most of the plains and then changes to a southerly direction near the hills where it meets a no-flow boundary formed by the outcropping of the basement rock. The position of the model domain was chosen so that the lateral boundaries of the model were approximately parallel to the groundwater flow direction.

It is not the intention of the model to accurately define the wider system. Thus, outside of the Homebush site, the model setup is coarser, employing a 100 m x 100 m grid, and only provides approximate head conditions in the wider aquifer system. In the irrigation study area the grid has been refined to 10 m x 10 m cells. It is considered that, for the purposes of modelling small-scale effects resulting from activities on the Homebush site, this arrangement is a sufficient numerical representation of the local aquifer conditions.

Due to the orthogonal nature of the grid discretisation, the major axis of flow is oriented north-south. Model cells considered outside the aquifer system, or that naturally act as no-flow boundaries, were designated as inactive. These are shown in Figure 10.

It should be noted that the modelling does not include the effects of direct leakage from the Homebush ponds to the Ruamahanga River. This leakage, estimated to be in the range of 800 ± 900 m^3/day (PDP, 2006b), and assumed to travel relatively directly from the ponds to the Ruamahanga River, possibly facilitated by higher permeability zones within an old meander system under the ponds, is considered to have no major effect on the wider groundwater flow regime.

4.1.2 Topographic Data

The topographical profile used in the model was developed from the numerous spot elevations surveyed at well heads, test pits and auger holes across the site. A digital elevation model (DEM) was also derived from 1:50,000 scale topographic data sets (NZMS 260 series).

4.1.3 Recharge Estimates

Water budget modelling has been carried out by HortResearch (2006), taking into account rainfall, irrigation, soil storage, evapotranspiration, runoff, and soil drainage. It is this latter component that forms the aquifer recharge used as input in the aquifer modelling. The HortResearch modelling was completed for the base-case scenario, pre-irrigation development, in which rainfall is the only local recharge, and post-irrigation development, in which various wastewater application rate scenarios add to the recharge. The outputs of the HortResearch modelling defined the amount of recharge applied to the gravel aquifer unit in the MODFLOW model, after migration through the unsaturated zone. The results of this modelling can be reviewed in HortResearch (2006).

4.1.4 Surface Water Data

The Makoura Stream and Ruamahanga River form hydraulic boundaries within the model that either remove water from the model via groundwater seepage or recharge the aquifers via seepage from these waterways to the aquifers. To incorporate the effects of the Makoura Stream and Ruamahanga River into the model, stage and bed elevations were interpolated between several surveyed locations adjacent to the site.

The hydraulic gradient of the Ruamahanga River was assumed to be constant for all river flows so, for each time step, the stage in each model cell was extrapolated based on the measured stage at the Wardell's Bridge gauging site. This information was entered into the River Boundary which was used to replicate the Ruamahanga River in the MODFLOW model. Estimates of river depths were used to extrapolate the river bed elevation in its normal channel course.

Only one set of stage and flow measurements were used for the Makoura Stream, as there are no transient records of stage or flow in this stream. Therefore, the stage height in the Makoura Stream was fixed in the MODFLOW model. Given the small flows in the stream the error created by this approximation is considered to be insignificant. Streambed conductance values in the model were set to the values calculated from the results of the concurrent flow gaugings carried out in March 2005.

The river stage elevations across the wider areas of the Wairarapa Plains were based on heights shown in the 1:50,000 topographic maps, with an arbitrary width of 30 m used for all river cells outside of the site extents. The streambed conductance values of the rivers were set to match the hydraulic conductivity of the surrounding aquifer cells as it is assumed that the gravel riverbeds provide no more resistance to groundwater-surface water interaction than the underlying gravels.

4.1.5 Hydrogeological Data

The hydrogeological arrangement of the model, at the site, is based on field observations from the many boreholes, hand auger holes, and test pits excavated at the site over the past several years. In general terms, the hydrogeological units comprise:

- Surficial confining strata – This has an average thickness of 2 m with a range of 0.4 m to 4.5 m. Lower hydraulic conductivities ranging between 1.1 x 10^{-3} and 0.14 m/day have been set across the northern and western parts of the site based on field test results in these areas. Higher hydraulic conductivities ranging upwards of 0.1 m/day have been set in the eastern parts of the site based on hydraulic conductivity testing in these areas. Hydraulic conductivity zonation for layer 1 is displayed in Figure 11.

- Upper gravel strata – This varies in thickness from 2 m to 9 m with a general decrease in hydraulic conductivity away from the Ruamahanga River. Hydraulic conductivities of 150 m/day and 350 m/day have been used in the model for this layer. These values are consistent with field test results and have enabled a good calibration of the model to be achieved.
- Lower confining strata – This layer has been modelled as discontinuous and variable in thickness.
- Lower gravel strata –This has been modelled as one continuous layer with a lower hydraulic conductivity than the upper gravel strata as these gravel deposits are expected to be less permeable as they are older.

Two model layers per stratigraphic component have been applied in the model (a total of eight). This allows better calculation of head changes across layers of contrasting hydraulic conductivity.

The resulting aquifer parameters used in the flow simulations are summarised in the following table.

Table 1: Aquifer Parameters used in MODFLOW modelling.

Hydrogeological Unit	**Hydraulic Conductivity (m/day)**	**Specific Yield**	**Specific Storage**	**Effective Porosity**
Surficial Confining Unit (Layers 1 & 2)	0.0155 – 1.59	0.1	0.0001	0.1
Upper Gravel Unit (Layers 3 & 4)	350	0.2	0.0001	0.3
Lower Confining Unit (Layer 5)	10	0.1	0.0001	0.2
Lower gravel unit (Layers 6 & 7)	250	0.2	0.0001	0.3

4.1.6 Boundary Conditions

No-flow boundaries have been assigned at the interface between the unconsolidated sediments and the consolidated basement rocks that form the hills surrounding the Wairarapa Plains.

River boundaries have been applied across the northern and western margins of the model. This provides coarse replication of the head control that the Waingawa River and upper reaches of the Ruamahanga River have on groundwater flow across the wider plains area. The river boundaries in the western and northern parts of the model have been derived from the Land Information New Zealand’s topographical database (NZTopo). These river boundaries enable replication of the piezometric head distribution revealed in the piezometric survey in 1984 that shows a slight south-easterly flow direction west of the site. The river boundary stage heights south of Wardell's Bridge have also been derived using heights from the topographical database.

4.2 Calibration of Model

A MODFLOW model produces a solution of the groundwater head and flow in each active cell. Any complete model solution may be viewed in terms of calculated groundwater flow paths and velocities. In each case, calibration data is required to substantiate or test the solutions the model produces. Successive runs of the model are usually separated by an analysis of the results and a refinement of the aquifer parameters used until a stable and reasonable solution is attained for the monitoring data.

Calibration of a groundwater model generally involves adjusting parameters (such as hydraulic conductivity and storage values) so that the modelled values resemble as closely as possible the field monitoring data. Most of the calibration was completed manually, however an automated parameter estimation program (WINPEST) was used as a check on the range of parameters utilised, which showed similar parameters to those derived by manual calibration. Data collected between September 2003 and October 2005, the most complete data set available, was utilised throughout the calibration process. Groundwater level measurements were made from only a small number of wells prior to September 2003.

The values of hydraulic head collected from the field to be used as targets in the model consist of monitoring data collected by the Masterton District Council and PDP from 21 wells across the site. This provided data coverage for the shallow aquifer beneath the site. Additionally, piezometric maps produced by the Wellington Regional Council (shown in Figure 5) provided guides for model outputs of piezometric head. Simulated piezometric contours are shown in map format in Figure 12.

A plot of simulated versus measured heads is shown in Figure 13 for the 21 wells used for steady state calibration. This plot provides a guide as to the degree of calibration of the simulations; the closer the simulated heads are to the observed heads the better the calibration. The relative difference between the simulated groundwater levels and the measured groundwater levels (the residual errors) are shown in Figure 14 in the form of a histogram. Figure 14 shows the residuals tend to be positive, meaning that the modelled heads are slightly higher than observed heads. The source of the disparity is likely explained by the uncertainties in our knowledge of groundwater discharge to the surface waterways, recharge from the rivers, effective rainfall recharge and regional and depth variation in aquifer hydraulic conductivity. Any mathematical modelling exercise such as the one in this report has to be viewed in light of these uncertainties.

A measure of the residual errors is the root mean squared error (RMS) and the mean error. For the steady-state simulation, calibrated to groundwater levels between September 2003 and October 2005, the RMS is 0.136 m and the normalised root mean squared error is 5.3%. The software developer, Waterloo Hydrogeologic, considers a model with a normalised root mean squared error less than 10% to be a calibrated model. This means that the discrepancies between the simulated and observed heads are small, and the model is therefore well calibrated and provides a good representation of the groundwater flow system.

A qualitative sensitivity analysis has been carried out, whereby the sensitivity of the numerical output to changing those parameters that affect the model the most is assessed. This sensitivity analysis suggests the following:

1. The simulated heads across the site area in the model are particularly sensitive to changes in the stage of the Ruamahanga River. This is consistent with field monitoring carried out at the site which showed rapid changes of groundwater levels during changes in flow and stage in the Ruamahanga River.
2. The simulated heads across the site were reasonably sensitive to the hydraulic conductivity of the lower permeability layer (represented by layer 5 in the model). The relative change in simulated heads resulting from altering the confining layer hydraulic conductivity was greater than that which resulted from changes made to hydraulic conductivity in the surrounding aquifer layers.

4.3 Modelled Scenarios

Once model calibration was achieved, the model was then used to assess the potential changes in groundwater levels and flow patterns resulting from the proposed irrigation at the site.

Both transient and steady-state MODFLOW simulations were used to assess the groundwater flow and level changes resulting from the irrigation. A dry-land scenario (pre-irrigation) and two irrigated scenarios (Option 3 and Option 6 as described in HortResearch (2006)) were run over a two-year period. The dry-land scenario was calibrated to head observations collected from over twenty wells, from September 2003 through to October 2005. This ensured that the model could adequately replicate short to medium term changes in hydraulic head, and therefore similarly timed responses once irrigation was applied.

Options 3 and 6 represent a high and average irrigation schedule, respectively, of several scenarios considered by HortResearch (2006), with Option 6 being the eventual preferred option. These two scenarios represent area-weighted average increases in drainage to the aquifer over the irrigated area of 6.6 mm/day and 4.6 mm/day respectively. The average drainage to the aquifer under dry-land (natural) conditions is calculated to be 0.62 mm/day. These values have been calculated from the HortResearch predicted drainage rates.

For their work, HortResearch (2006) divided the site into 11 areas that were representative of the average hydraulic properties of the near-surface soils over the site. These same areas were used in the PDP model, with corresponding aquifer recharge rates applied to the upper-most wet cell in any vertical column (which was normally within layers 2 and 3 in the model) for the dry land and irrigated scenarios. The recharge rates for each of the 11 areas for the two irrigations scenarios are shown in Table 2.

Table 2: Drainage inputs to aquifer used in MODFLOW modelling.

Area	**Irrigated Area (ha)**	**Option 6**		**Option 3**	
		Average Drainage (mm)	**Average Daily Drainage (m^3/day)**	**Average Drainage (mm)**	**Average Daily Drainage (m^3/day)**
Plot 1	6.1	3.8	231	5.2	317
Plot 2	4.2	4.2	174	7.2	298
Plot 3	4.9	2.9	143	4.4	216
Plot 4	5.4	6.2	335	9.4	508
Plot 8	7.6	7.1	536	10.6	806
Plot 5	5.1	5.1	260	7.8	400
Plot 6	5.1	5.4	279	8.1	416
Plot 7	5.4	7.1	381	10.6	574
Plot 9	5.1	6.9	352	10.5	534
Plot 10	4.4	6.9	307	10.5	465
Plot 11	21.4	1.9	410	1.9	408
Total	74.7		3408		4944

5.0 Contaminant Model

Predictive modelling was undertaken to assess the potential transport of key contaminants in the gravel aquifer from the proposed irrigation of the treated wastewater across the site using the steady state flow simulation produced by MODFLOW. This was carried out using the contaminant modelling software, MT3DMS, which is available in Visual MODFLOW 4.1. MT3DMS simulates advection, dispersion and reactions of contaminants in groundwater flow systems.

The constituents that were modelled are:

- E.Coli;
- Adenovirus;
- Nitrate (expressed as nitrogen);
- Phosphorus.

E.Coli was used in the modelling as this is the most commonly used indicator for bacterial transport. Initially, it was proposed that E.Coli would be used as an indicator of viral transport as well as bacterial transport. However, ESR was incorporating viruses into their modelling of potential health effects arising from the direct river discharge, and for completeness, they required estimates of viral concentrations in the groundwater seepage to the waterways. Adenovirus has been chosen as the viral indicator on advice from ESR (pers. comm. Andrew Ball). ESR modelling of viruses in the Ruamahanga River indicated that adenovirus poses the greatest health risk of all viruses likely to be present in the pond wastewater.

HortResearch provided predicted concentrations of E.Coli, nitrate-N and phosphorus in the drainage water at 1 m depth, with the drainage rates as for options 3 and 6 (i.e. average drainage rate of 6.6 mm/day for Option 3 and 4.6 mm/day for Option 6). This represents an assumption that the water table is at a depth of 1 m. The average depth to water across the site is actually 1.8 m, so a value of 1 m is conservative (the microbial concentrations would be lower at 1.8 m as there would be more attenuation of micro-organisms), but allows for the situation of an extreme high groundwater level. The averaged concentrations of the contaminants in the drainage water for each of the 11 sub-areas and the two irrigation scenarios are given in Table 3 and Table 4. These were added to a steady-state flow solution. For comparison, the input concentrations that HortResearch used in their modelling are shown in Table 5.

An initial concentration of viruses in the drainage water was not available from the HortResearch modelling as it was not part of their work scope. In the then absence of adenovirus determinations in the Masterton wastewater (a single determination was subsequently carried out on a sample collected in October 2005 as part other investigations), and as a conservative approximation, the adenovirus concentration was set to 10 virus/L, based on the maximum concentration recorded in 22 samples taken from the outlet of the Bromley oxidation ponds in Christchurch (pers. comm. Andrew Ball).

As the virus concentration was set to a value representing typical concentrations in pond wastewater, the modelled concentrations will be greatly overestimated as substantial attenuation of viruses is expected to occur in the unsaturated zone, prior to the drainage water reaching the groundwater table.

Time-averaged values were used for drainage rates and the concentrations of nitrate-N, E.Coli and viruses in the model. The reason for this was that the model was run as a steady-state model. While the values of these input parameters do fluctuate seasonally with time, there are no long-term trends in the data for these input parameters. As the contaminants will move slowly through the shallow aquifer, it is appropriate to use long-term averages for the input concentrations and recharge rates. If the maximum recharge rates and concentrations were used the steady-state concentrations would be overestimated. The exception to this use of time-averaged values for the input parameters is the concentration of phosphorus.

As detailed in the HortResearch (2006) report, the concentration of phosphorus in the drainage water is expected to increase with time. For this reason, two time periods have been considered, representing short-term and long term application of the wastewater.

The first time period is approximately 4.5 years into the wastewater application, and used phosphorus input concentrations equivalent to the average concentration over the first eight years of the HortResearch predictions (being the length of record available for wastewater inflows and outflows). The second time period considered, 28 years, used the final values from the HortResearch predictions at the beginning of the 29th year of wastewater application. This time was chosen by HortResearch as being the length of climate record available, but required the generation of a synthetic flow record for years nine to 28 based on a correlation between the climate data and the eight years of available flow data (HortResearch, 2006). The longer period is roughly equivalent to the desired resource consent duration for the upgrade.

The average input concentrations over these time periods are presented in Table 3 and Table 4 for each of the sub-areas (identified as plots 1 to 11 in the tables). Note that the 28 year simulation has only been carried out by HortResearch for Option 6 (the preferred scenario), therefore only the short-term (approximately 4.5 years) effects have been assessed for the high rate irrigation scenario of Option 3, based on the eight-year predictions.

Table 3: Input concentrations used for steady-state MT3DMS transport modelling for Irrigation Option 6.

Species	**Plot 1**	**Plot 2**	**Plot 3**	**Plot 4**	**Plot 5**	**Plot 6**	**Plot 7**	**Plot 8**	**Plot 9**	**Plot 10**	**Plot 11**
E.Coli (cfu/100 ml)	1.37	6.83	1.34	12.30	6.59	5.21	16.32	19.98	19.42	19.94	0.07
Nitrate-N (mg/L)	1.48	1.97	1.84	2.29	2.09	1.66	2.13	3.02	2.89	2.88	0.05
Phosphorus (mg/L) (Average over first eight years)	0.005	0.013	0.004	0.009	0.005	0.004	0.016	0.009	0.038	0.038	0.003
Phosphorus (mg/L) (28 year values)	0.010	0.075	0.008	0.104	0.031	0.035	0.207	0.091	0.959	0.986	0.003
Virus1 (virus/L)	10	10	10	10	10	10	10	10	10	10	10

Notes: *1.* No attenuation of viruses through the unsaturated zone has been accounted for.

Table 4: Input concentrations used for steady-state MT3DMS transport modelling for Irrigation Option 3.

Species	**Plot 1**	**Plot 2**	**Plot 3**	**Plot 4**	**Plot 5**	**Plot 6**	**Plot 7**	**Plot 8**	**Plot 9**	**Plot 10**	**Plot 11**
E.Coli (cfu/100 ml)	4.26	20.18	4.41	24.88	17.82	14.36	30.79	35.06	35.34	34.87	0.07
Nitrate-N (mg/L)	1.36	2.12	1.67	2.44	2.16	1.82	2.35	3.10	2.98	2.99	0.05
Phosphorus (mg/L) (average over first eight years)	0.005	0.020	0.005	0.014	0.006	0.005	0.025	0.014	0.066	0.065	0.003
Virus[1] (virus/L)	10	10	10	10	10	10	10	10	10	10	10

Notes: *1.* No attenuation of viruses through the unsaturated zone has been accounted for.

Table 5: Input concentrations used in HortResearch Modelling

Species	**Concentration applied to soil surface**
E.Coli (cfu/100 ml)	1000 (winter) 200 (summer)
Nitrate-N (mg/L)	11.5 Total N (50% nitrate and 50% ammonium)
Phosphorus (mg/L)	2.5
Virus (virus/L)	Not modelled

5.1 Model set-up and parameters used

For the contaminant modelling, it was considered that the main controls on the transport of nitrate and phosphorus in groundwater are advection and dispersion. It should be noted, however, that adsorption is also likely to influence the transport of phosphorus in ground water. The modelling of phosphorus will therefore be conservative as adsorption has not been allowed for.

An additional transport control was incorporated into the modelling of E.Coli and adenovirus. This term is the natural micro-organism die-off rate, which was based on:

- For E.Coli a T90 value (time for 90% of the coliforms to die-off) of 135 hours, based on information supplied by ESR (pers. comm. Andrew Ball). This value was based on testing carried out by Sinton (2002). Through discussion with ESR staff members, it was decided that the value determined from this testing would be most appropriate to base the modelling on as the testing was carried out in the dark at 14 degrees (similar conditions to aquifer at the Homebush site) in a sample containing 10% pond stabilised wastewater. The transport modelling did not account for bacterial filtration or adsorption, given the uncertainty of appropriate factors for the Homebush aquifer, so the results will be conservative.
- For adenovirus a T90 value of 62 days was used. This was based on testing carried out in a sample of tap water containing Adenovirus 41 by Enriquez *et al.* (1995). The test was carried out at 15 degrees in the dark. As with the bacterial modelling, filtration and adsorption effects were not included. Input parameters governing the transport equations used in the MT3DMS modelling are summarised in the following table.

Table 6: Input Parameters used for MT3DMS transport modelling.

Parameter	**First Order Decay [day^{-1}]**	**Dispersivity (m)**
Bacteria	0.41	10
Virus	0.037	10
Nitrate-N	-	10
Phosphorus	-	10

6.0 Modelling Results

6.1 Groundwater Modelling Results

6.1.1 Mounding Estimates

The transient simulations were used primarily to achieve calibration of the model with the measured data to ensure that the model was representative of the groundwater system at the Homebush site. The results of the transient modelling were also used to identify the change in hydraulic head between the irrigated scenarios and the existing un-irrigated situation to assess the degree of mounding that could result from the irrigation.

The changes in piezometric head at the observation wells for Option 6 are plotted in Figure 15. This illustrates the changes that could have been expected to occur in groundwater levels if irrigation was occurring over the period from September 2003 to October 2005, the period of available groundwater data. This is expected to be generally representative of the long-term situation. Figure 15 shows the maximum simulated change to be less than 0.2 m, and commonly less than 0.05 m.

The estimates were checked using an analytical solution described in Hunt (2003) which showed compatible results, although the changes were predicted to be slightly higher, an expected result as the analytical model is based on simplifying assumptions that generally result in larger predicted mounding estimates than numerical models.

For Option 3, the maximum mounding is predicted to be less than 0.2 m, on average, and commonly less than 0.1 m. The mounding result for Option 3 is shown in Figure 16.

Assessment of potential mounding was limited to estimating changes in the gravel aquifer as part of the assessment of the change in groundwater flow patterns at the site. The groundwater model was not used to assess the potential mounding in the surficial confining sediments at the site. The potential for mounding in the surficial soils at the site was incorporated into HortResearch's modelling of the unsaturated zone (HortResearch, 2006).

6.1.2 Discharge Estimates

The steady-state groundwater modelling has been used to assess the expected changes in base flow to the Makoura Stream and to the Ruamahanga River. The total predicted seepage rates are summarised and compared with the un-irrigated situation in Table 7.

The Makoura Stream naturally increases in flow in its lower section by about 100 l/s. Four gaugings carried out at the northern end of the Homebush site in March 2005 gave flow rates ranging between 60 and 84 l/s (5,000 – 7,300 m^3/day), while gaugings further downstream at the pond access bridge measured a flow of 170 l/s (15,000 m^3/day). The increase of 100 l/s over this reach is 59% of the downstream flow (Table 7).

Analysis of the flow and water level information indicates that the stream does not gain groundwater seepage in the upstream part of the site as the stream levels are above groundwater levels. Through the lower section of the site the stream level is consistently lower than groundwater levels, which results in groundwater seepage entering the stream.

The model indicated that the upstream sections of the Makoura Stream will continue to have stream stages above groundwater level under irrigation for both options 3 and 6, thus discharge from the groundwater to the stream cannot occur. However, the modelling showed that, with irrigation, there is predicted to be a small increase in groundwater discharge from the true left bank in the downstream sections of the Makoura Stream, but the increase is small relative to the natural increase over that reach – an increase of about 11 l/s (or 910 m^3/day) for Option 3 and 7 l/s (600 m^3/day) for Option 6. In percentage terms (Table 7), the increase from upstream to downstream is 63 to 65 % of the natural downstream flow, but 59% of this is natural, therefore the increase from irrigation for the two irrigation options is predicted to be only 4 to 6% of the natural downstream flow, for the two modelled scenarios.

Similar calculations have been carried out for the Ruamahanga River. Without the irrigation the model predicts a natural increase in the river between the top of the site and downstream of the ponds (but upstream of the Makoura confluence) of about 0.25 m^3/s (21,900 m^3/day) from groundwater inflow. This equates to about 9% of the summer low flow of 2.7 m^3/s [1] (5th percentile of summer flows - NIWA, 2006) measured at Wardell's Bridge. With irrigation there is a slightly larger increase of 0.29 m^3/s (25,000 m^3/day) for Option 3 (High Rate irrigation) and 0.01 m^3/s (450 m^3/day) smaller than that for Option 6 (Average Rate irrigation). Put into context with the summer low flow of 2.7 m^3/s, the irrigation increase for the High Rate irrigation amounts to only 1.3% of that flow, and less than half of that for the half median flow (6.15 m^3/s), the latter being the flow above which direct discharges of wastewater to the river may occur.

Table 7: Flow increase in Makoura Stream and Ruamahanga River from groundwater discharge

	Increase in flow upstream to downstream past site (m^3/s)			**Increase as a percentage of natural downstream flow**		
Scenario	Natural	High Rate	Ave Rate	Natural	High Rate	Ave Rate
Makoura Stream	0.1	0.11	0.11	59%	65%	63%
Ruamahanga River	0.25	0.29	0.28	9.4%	10.7%	10.2%

6.2 Contaminant Modelling Results

The predicted concentrations of the four contaminants at the site boundaries are summarised in Table 8 and shown as concentration contours in figures 17 and 18 for Option 6, and figures 19 and 20 for Option 3. Note that, for phosphorus, the contour

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[1] 2.7 m^3/s is the equivalent of 233,000 m^3/day

plots are for the early stages of the project's life, but the later stage plots will have a generally similar pattern but with greater values. Table 8 shows both the early and late stage results for phosphorus.

In Table 8 the predictions have been subdivided into a number of reaches, corresponding to the edge of each irrigation area (the 11 irrigation areas as shown in Figure 2). Average concentrations for each reach have been estimated from the concentration contours.

Table 8: Modelled concentrations along river and stream boundaries for Option 3 and 6

Waterway	**Adjacent Irrigated Plot No**	**E.Coli (CFU/100 mL)**		**Adenovirus (virus/L)**		**Nitrate-N (mg/L)**		**Phosphorus (mg/L)**		
		Opt 3	**Opt 6**	**Opt 3**	**Opt 6**	**Opt 3**	**Opt 6**	**Opt 3 (4.5 yr)**	**Opt 6 (4.5 yr)**	**Opt 6 (28 yr)**
Makoura	1	1	1	2	2	0.5	0.5	0.001	0.001	0.002
Makoura	2	1	1	0.8	0.8	0.5	0.5	0.005	0.005	0.028
Makoura	3	0.5	0.5	0.8	0.8	0.5	0.5	0.0025	0.001	0.002
Makoura	4	3	1	2	1.5	1	0.8	0.0075	0.005	0.058
Makoura	5	2	0.5	1	0.5	0.5	0.3	0.0025	0.001	0.007
Makoura	11	0.05	0.01	0.5	0.5	0.01	0.01	0.001	0.001	0.001
Ruamahanga	8	10	5	2.5	0.5	2	1	0.01	0.005	0.049
Ruamahanga	9 & 10	10	5	0.8	0.3	0.5	0.3	0.01	0.005	0.129
Ruamahanga	Ponds	0.0001	0.0001	0.2	0.1	1	1	0.02	0.01	0.162

The predictions assume a 20 m buffer zone between the irrigated areas and the stream and river, as set out in the conceptual design of the proposed irrigation scheme, except the discharge designated "Ponds" is for groundwater flowing under the ponds and has been estimated for a location between the ponds and the river. In places where there will actually be more than the 20 m design minimum separation distance between the irrigated areas and the river or stream, the concentrations at the point of discharge to the relevant waterway can be expected to be less than predicted in Table 8, as the modelling shows there is a rapid drop-off in concentrations outside the irrigated area.

The degree of attenuation that the aquifer provides can be determined by calculating percentage removal rates. Removal rates are a function of travel path length (and hence travel times) with the obvious result that removal rates are lowest for the short travel distances to the Makoura Stream and the northernmost reach of the Ruamahanga river and greatest for the longest travel path directly south to the river beyond the ponds. The removal rates are shown in Table 9.

The percentage removal rates can be used to recalculate discharge concentrations for different initial concentrations (in the modelling the relationship between concentration at the source and anywhere in the aquifer is directly linear), for example phosphorus concentration can be calculated for Year 20 by using the removal rates and the input concentration (the soil drainage water concentration) for this time, being about half those applicable for Year 28. Similarly, if at some stage virus attenuation through the unsaturated zone is modelled, then the modified initial concentration can be factored by the appropriate percentage removal rate to obtain the discharge concentration.

Table 9: Percent-removal rates for Options 3 and 6

Waterway	Adjacent Irrigated Plot No	E.coli		Adenovirus		Nitrate-N		Phosphorus	
		Opt 6	Opt 3	Opt 6	Opt 3	Opt 6	Opt 3	Opt 6	Opt 3
Makoura	1	27%	77%	80%	80%	66%	63%	78%	79%
Makoura	2	85%	95%	92%	92%	75%	76%	62%	75%
Makoura	3	63%	89%	92%	92%	73%	70%	76%	45%
Makoura	4	92%	88%	85%	80%	65%	59%	44%	47%
Makoura	5	92%	89%	95%	90%	86%	77%	78%	60%
Makoura	11	86%	29%	95%	95%	80%	80%	63%	63%
Ruamahanga	8	75%	71%	95%	75%	67%	35%	46%	28%
Ruamahanga	9 & 10	75%	72%	97%	92%	90%	83%	87%	85%
Ruamahanga	Ponds	100%	100%	99%	98%	38%	40%	3%	0%

6.2.1 Model Predictions Compared with Groundwater Concentrations

The effects on the groundwater at the scheme boundaries may be assessed by comparing the modelled increase in concentrations of nitrate-N, phosphorus and E. coli at these points (as shown in Table 8) with background concentrations in the groundwater (Table 10).

The average background nitrate-N concentration determined from the consent monitoring samples taken from the wells upgradient of the ponds between March 2003 and March 2005 (Beca 2004a, 2005b) is 1.3 mg/L. Average background phosphorus concentration (the majority of which is in the form of dissolved reactive phosphorus – DRP) over the same time period is 0.02 mg/L.

The modelling shows that the increase in nitrate in the underlying aquifer will range from being similar to the background concentration to being a small fraction of the background concentration, with the highest concentrations being found on the river boundary of Plot 8 and for groundwater flowing under the ponds. Option 6 (the preferred option) performs better than Option 3, an expected results given the lower input concentrations. The total background and modelled increase for nitrate-N is well below the New Zealand Dinking-Water Standard 2005 (MoH, 2005) criterion of 11.3 mg/L.

Table 10: Background concentrations in ground and surface water 2003/05

	E. Coli (cfu/100 ml)		**Nitrate-N (mg/L)**		**DRP (mg/L)**	
Location [1]	Mean	Median	Mean	Median	Mean	Median
Groundwater HB5, 6 and 9	1.2	1	1.3	1.3	0.02	0.014
Makoura Stream at Mak1	1040	420	3.5	3.7	0.02	0.02
Ruamahanga River at Rua1	450	60	0.6	0.7	0.01	0.01

Notes: 1. From consent monitoring, Beca (2004a, 2005b)

Changes in phosphorus concentration in the underlying aquifer at the site boundaries will be small relative to the background concentration in the initial years, but increase during the project's life as the phosphorus concentration increase in the drainage water from the surface soil. After 28 years the predicted phosphorus concentrations at the site boundaries for Average Rate irrigation of Option 6 (the preferred option) will range from being about a tenth of the background concentration to up to 10 times the background concentration, depending on location. The highest concentrations are for the more freely draining areas 9 and 10, adjacent to the Ruamahanga River, and for groundwater passing under the ponds, but otherwise the increase in phosphorus concentration is predicted to be of a similar order of magnitude to, or lower than, the background concentration (Table 8). As noted earlier, however, these predictions will be conservative (over-predict) as the modelling has not included adsorption of phosphorus within the aquifer.

The modelled E.coli concentrations at the site boundary also range from being lower than to being slightly higher than the background concentrations, depending on location. The average E.coli level in the samples taken from the wells upgradient of the ponds is 1.2 cfu/100 ml (Table 10). Again, the most significant change is expected to occur along the Ruamahanga River boundary adjacent to areas 9 and 10, where the river forms the eastern site boundary, with a predicted increase of 5 cfu/100 ml for Option 6 and 10 cfu/100 ml for Option 3. The irrigation scheme under Option 3 involves high application rates in the plots adjacent to the Ruamahanga, which is the reason why the predicted E.coli levels are the highest at that location.

There were no adenovirus measurements at the site when the groundwater modelling exercise commenced. However, single samples of the groundwater from bore HB6 and the wastewater subsequently became available. Adenovirus was not found in either the groundwater or wastewater, at detection limits of 1 TCID50/L and 5 TCID50/L , respectively. The latter suggests that the input concentrations to the model were more conservative than necessary. It is beyond the scope of this report to consider the effects of viruses on the groundwater (or the receiving waters) in any detail, however, given the conservatism of the modelling (no filtration allowed for in the soil or aquifer), the results suggest negligible effects from viruses on the groundwater at the site boundaries.

6.2.2 Model Predictions Compared with Receiving Water Concentrations

Consent monitoring carried out since 2003 (Table 10) found median values of nitrate-N and E. coli in the Makoura Stream upstream of the pond discharge (site Mak1) to be 3.7 mg/L and 420 cfu/100 ml, respectively. Equivalent values for the Ruamahanga River upstream of the Makoura Stream discharge (site Rua1) were 0.7 mg/L and 60 cfu/100ml, respectively. In all cases the modelled concentrations are of a similar order of magnitude or small compared with receiving water concentrations. After dilution, when the groundwater seepage from the irrigation mixes with the flow in the Makoura Stream (at least 15 times dilution) or the Ruamahanga River (at least 10 times dilution) the concentration increase in the two water bodies will be small compared with the background concentrations.

For phosphorus, median background concentration of DRP from 2003 to 2005 were 0.02 mg/L in the Makoura at site Mak1 and 0.01 mg/L in the Ruamahanga at site Rua1. These concentrations are similar to the background concentrations in the groundwater. As noted above, the predicted groundwater concentrations are low in the early stages of the project’s life, with the highest concentrations being similar to the receiving waters. After mixing, phosphorus concentration increases will be small compared with the background concentrations (less than 10%) in the early stages of the project’s life.

For Option 6 after 28 years, phosphorus concentrations in the groundwater at the site boundaries are predicted to be roughly ten times the concentrations predicted in the early stages. This means that, for some locations, the groundwater concentrations are higher than the median receiving water concentrations. After dilution, however, the flow-weighted average increase in concentration the Ruamahanga River at the summer low flow of 2.7 m^3/s is 0.013 mg/L, similar to the median concentration at Rua1, but noting that this is a conservative prediction, as the aquifer will actually adsorb phosphorus before it reaches the river. A similar calculation for the Makoura Stream shows the phosphorus concentration increase at 28 years will be about 10% of the background concentration.

6.3 Effects on Private Bores

A number of private water supply bores exist to the south-west of the ponds, the closest of which is approximately 540 m from Pond 3. The private bores are shown in Figure 5. The groundwater flow patterns determined through water levels surveys have shown that the groundwater currently flows in a predominately southerly direction and that groundwater derived from rainfall recharge across the site proposed for irrigation does not flow towards any neighbouring wells. The groundwater model indicates that the proposed irrigation will not create any major changes to the existing groundwater flow patterns and that the irrigated wastewater will not flow towards any neighbouring wells. Regardless of the considerable attenuation of contaminant concentrations shown by the contaminant modelling, the groundwater flow direction means that the proposed irrigation will not have any effect on the water quality in neighbouring wells. The low predicted contaminant concentrations at the site boundary provide additional assurance against any effects.

7.0 Conclusions

A groundwater model has been set-up to predict the effects of the proposed irrigation at the site on groundwater flow and to calculate potential contaminant transport. The model was based on field data obtained through numerous geological and hydrogeological investigations carried out at the Homebush site. Prior to using the model for predictive work, the model was calibrated to observation data. The recharge data supplied by HortResearch for the existing un-irrigated situation was incorporated into the model calibration. This calibration process resulted in a model that is representative of the hydrogeological system at the Homebush site, and is therefore appropriate to use for predictive work.

Predictive modelling of the potential effects of the proposed irrigation scheme on groundwater flow has been based on the aquifer recharge rates and contaminant concentrations in the drainage water provided by HortResearch. The predicted aquifer recharge rates for two irrigation scenarios – high rate irrigation (Options 3) and the preferred average rate irrigation (Option 6) – have been used in the model to assess the effects the recharge will have on groundwater levels, flow direction, groundwater-surface water interaction and contaminant concentrations in the aquifer at the site boundaries.

The predictive modelling allows the following conclusion to be drawn:

1. The hydraulic modelling suggests that groundwater mounding in the underlying aquifer is likely to be less than 0.2 m. This water level rise will not significantly alter groundwater flow directions, which are generally southward to the Ruamahanga River, but will result in an increase in groundwater seepage into both the Makoura Stream and the Ruamahanga River.

2. The modelling suggests that the irrigated water will ultimately emerge in either of the Makoura Stream and the Ruamahanga River. The increase in flow in both waterways from the irrigation is small relative to the natural increase from groundwater discharge adjacent to the site – less than 12% of the natural inflows – and even smaller when compared with the flows in the stream and river. The irrigation increase in the Makoura Stream is predicted to be less than 6% of the flow at the downstream end of the site and for the Ruamahanga River, less than 1.3% of the summer low flow of 2.7 m^3/s measured at Wardell's Bridge.

3. The contaminant modelling has predicted that there will be increases in bacteria, nitrate-N and phosphorus in the groundwater at the site boundaries adjacent to the Makoura Stream and the Ruamahanga River. Concentrations of bacteria and nitrate will remain relatively constant throughout the project's life, but phosphorous concentrations will increase, reflecting an increase in phosphorus concentrations in the drainage water from the surface soil.

4. In general, the concentrations of these contaminants in the groundwater at the site boundaries are expected to be less than or similar to background concentrations in the groundwater, but phosphorus concentrations late in the project's life (modelled at 28 years) may be greater than background concentrations. The modelled

phosphorus concentrations are conservative, however, as adsorption in the aquifer has not been allowed for.

5. Groundwater concentrations at the site boundaries of E.coli, nitrate and phosphorus concentrations early in the project's life are expected to range from being considerably less than, to being similar to, background concentrations in the river and stream. Phosphorus concentrations at late stages may be higher than the background concentrations, noting that the phosphorous concentrations are likely to be over-predictions.

6. The increase in E.Coli and nitrate concentrations in both the river and stream after mixing are predicted to be small (<10%) relative to background concentrations, as are phosphorus concentrations in the early stages of the project's life. Phosphorus concentration increases in the river at 28 years are conservatively predicted to be similar to the background concentrations in the river.

7. The predicted groundwater flow paths post-irrigation indicate that the irrigation will not affect the water quality in neighbouring wells several hundred metres to the south-west

8.0 References

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Appendix A: Figures

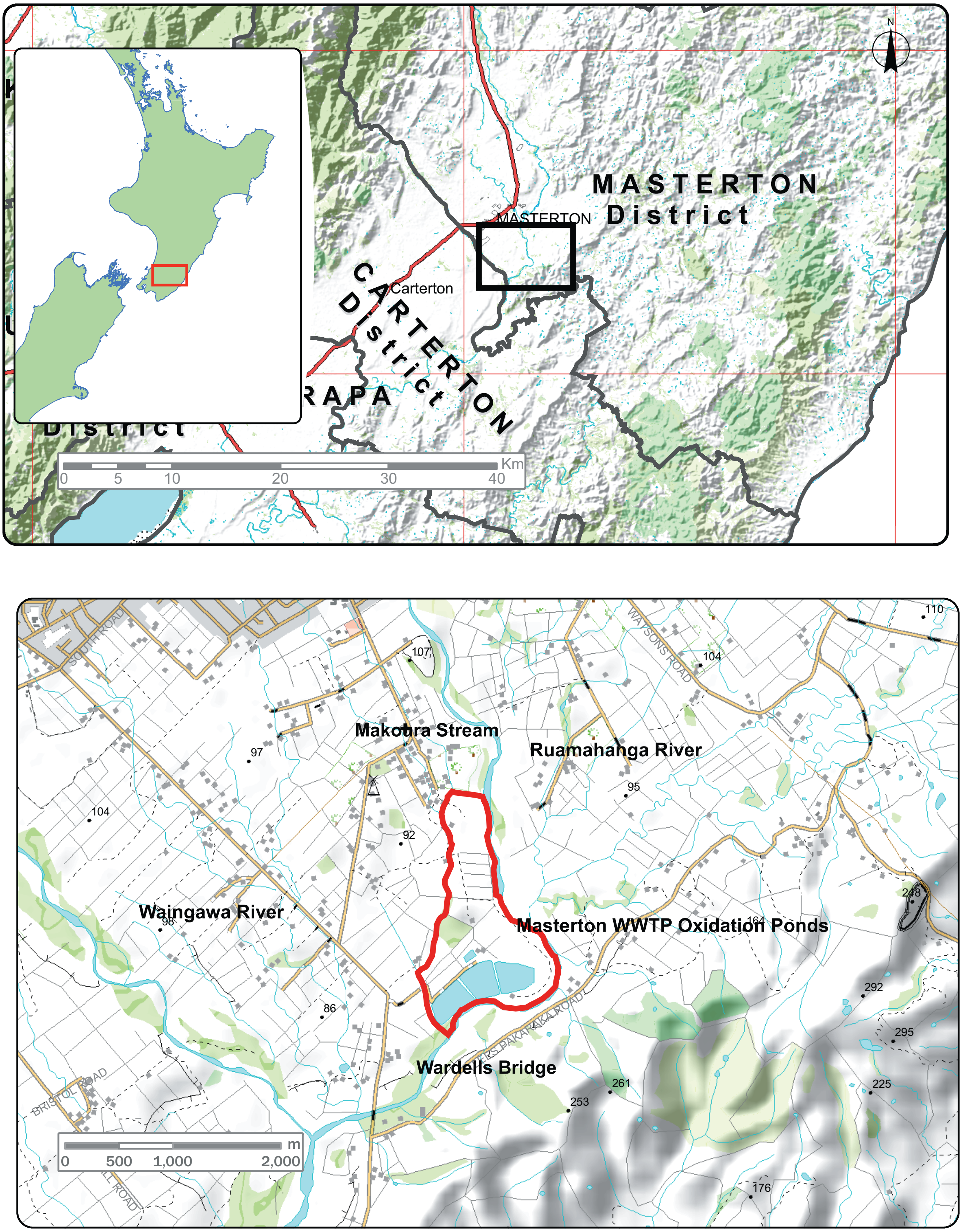


Figure 1: Maps showing site location

Legend

🟥 Masterton WWTP Upgrade Site Extents

Notes:
Topographical Information supplied by
Corax Topo 2005 (Olivier and Co)

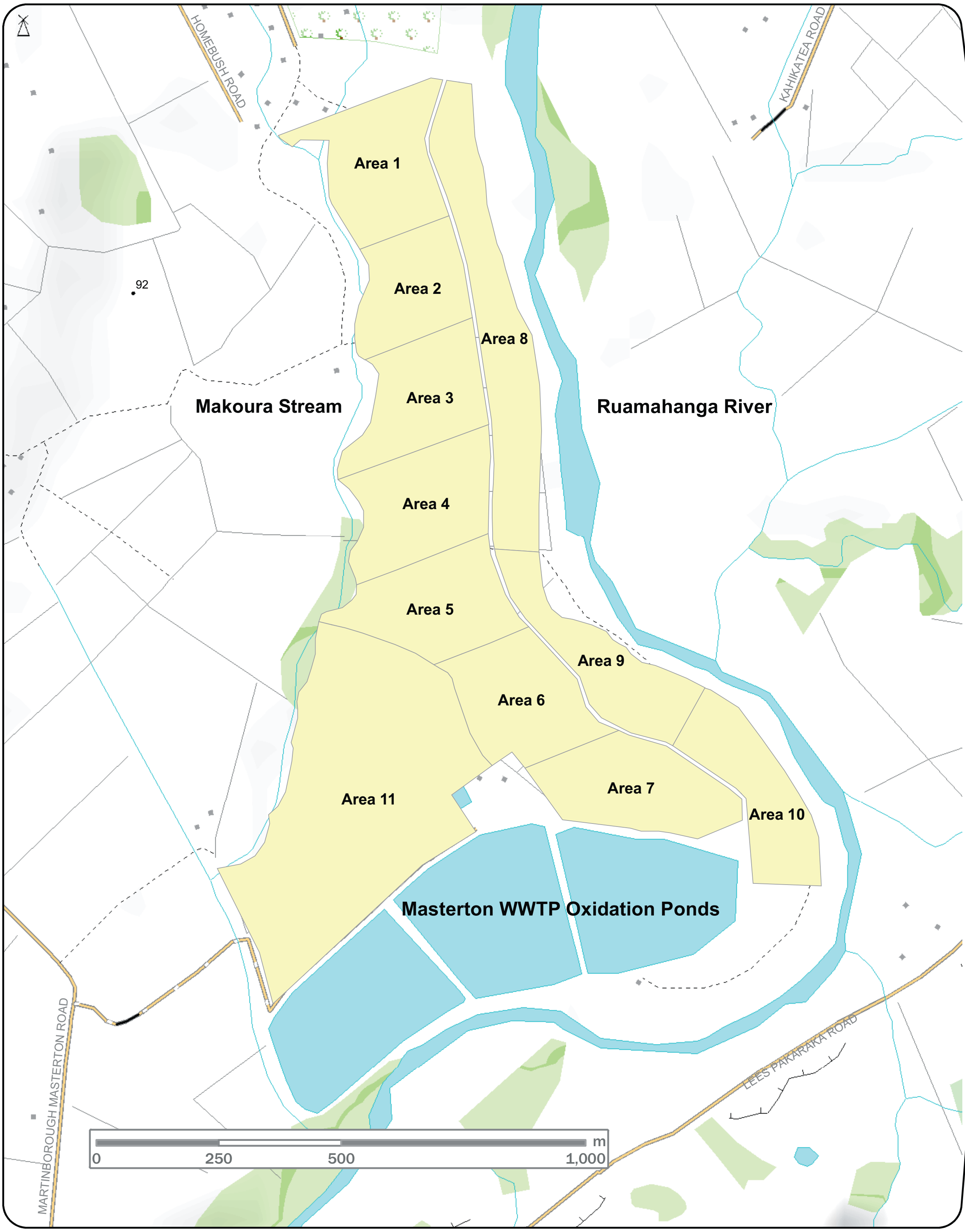
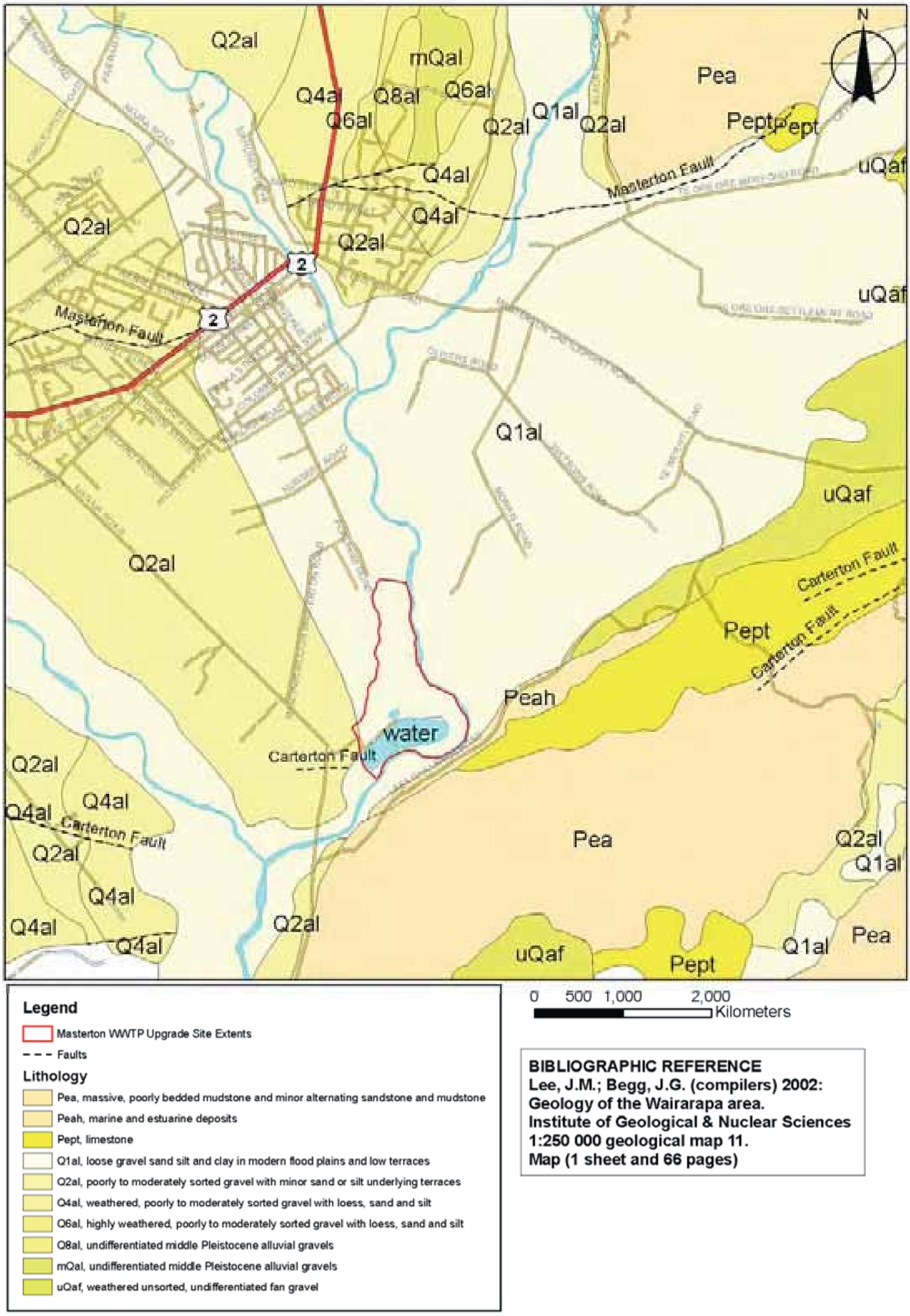


Figure 2: Map showing proposed area of irrigation

Legend

🟨	Proposed Irrigation Areas

Notes:
Topographical Information supplied by
Corax Topo 2005 (Olivier and Co)



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Institute of Geological & Nuclear Sciences
1:250 000 geological map 11.
Map (1 sheet and 66 pages)

Figure 3: Map showing surface geology across the wider Homebush area.

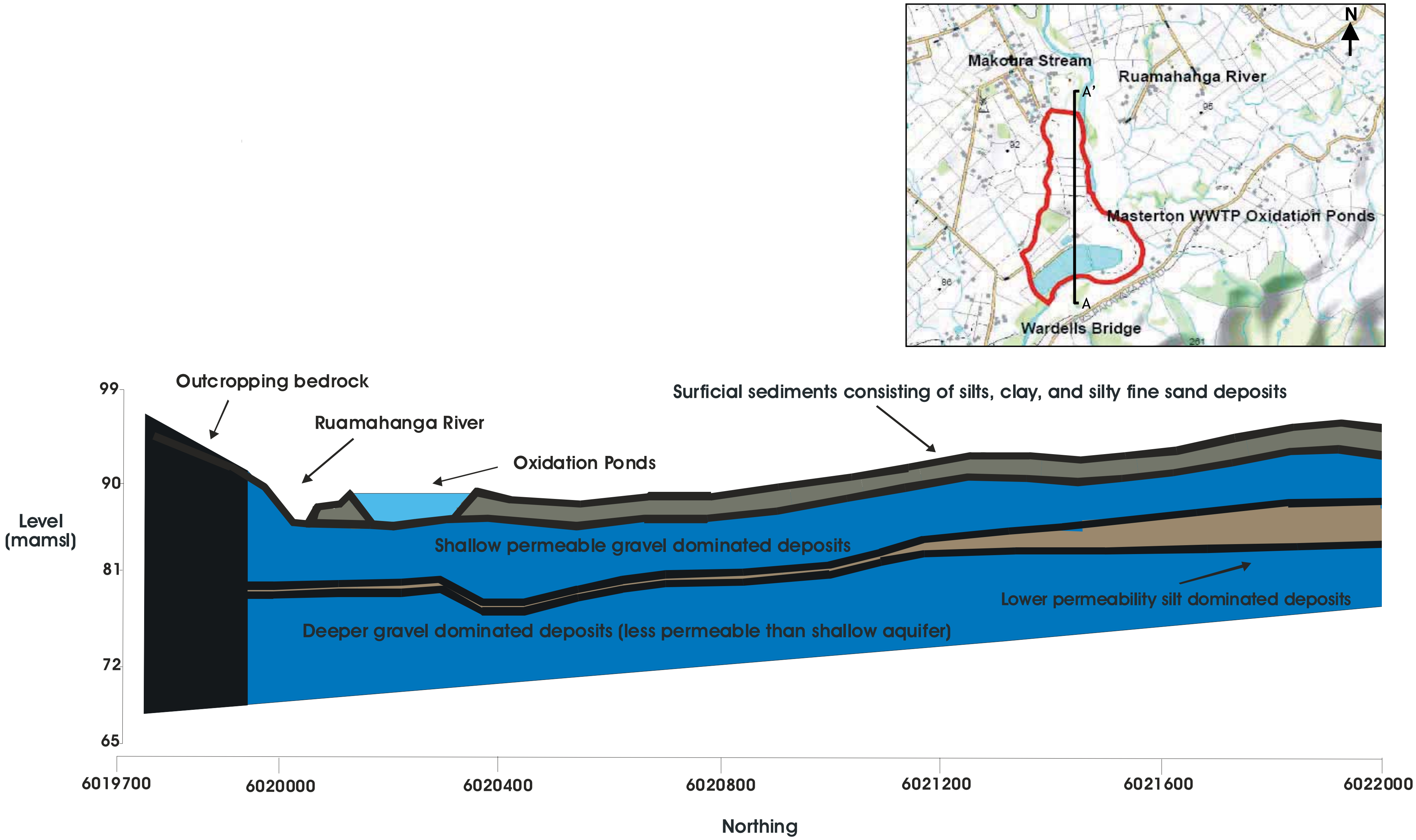


Figure 4: Geological Cross-section - A-A'

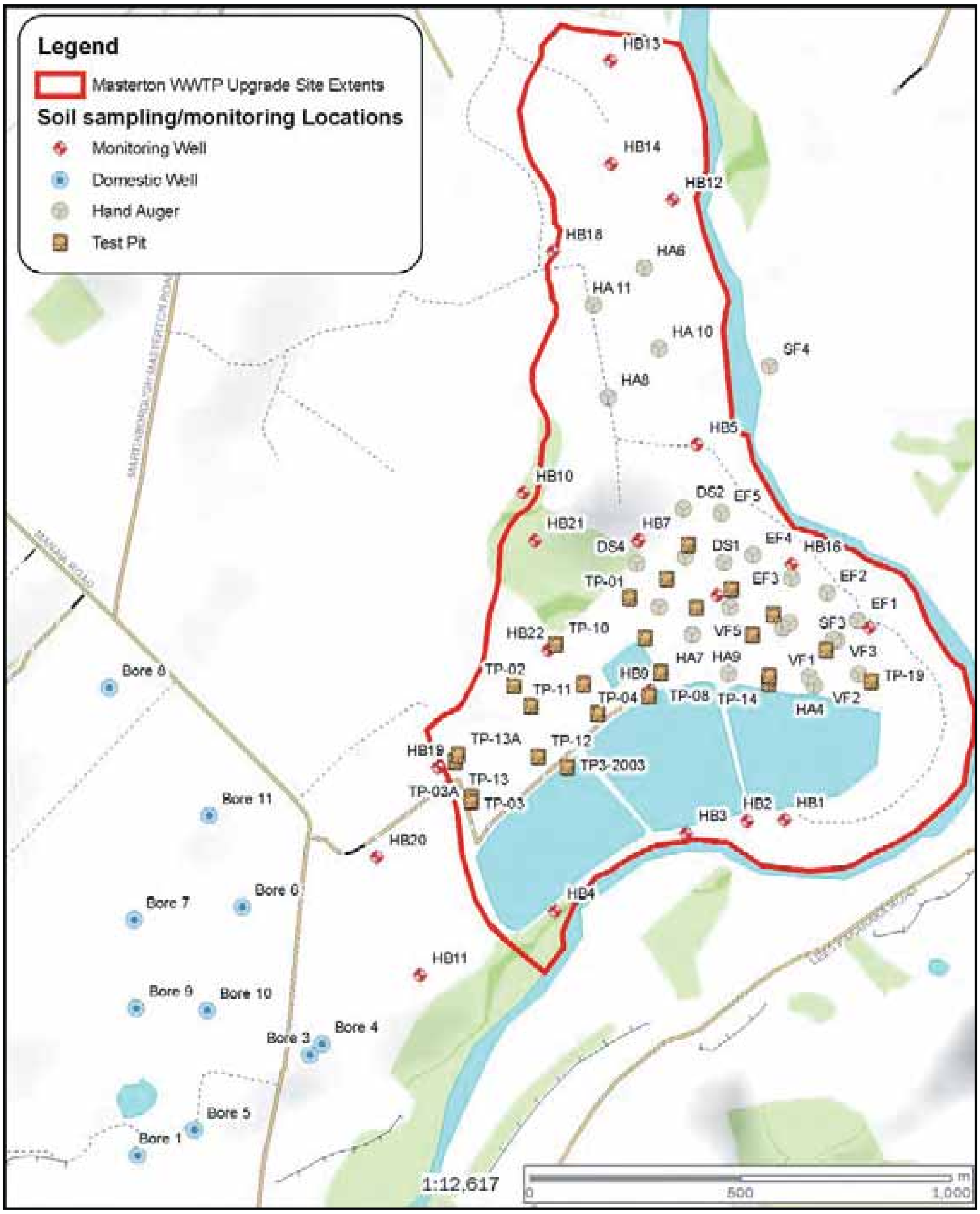


Figure 5: Map showing locations of wells, test pits and bore holes at and in the vicinity of the Masterton WWTP site

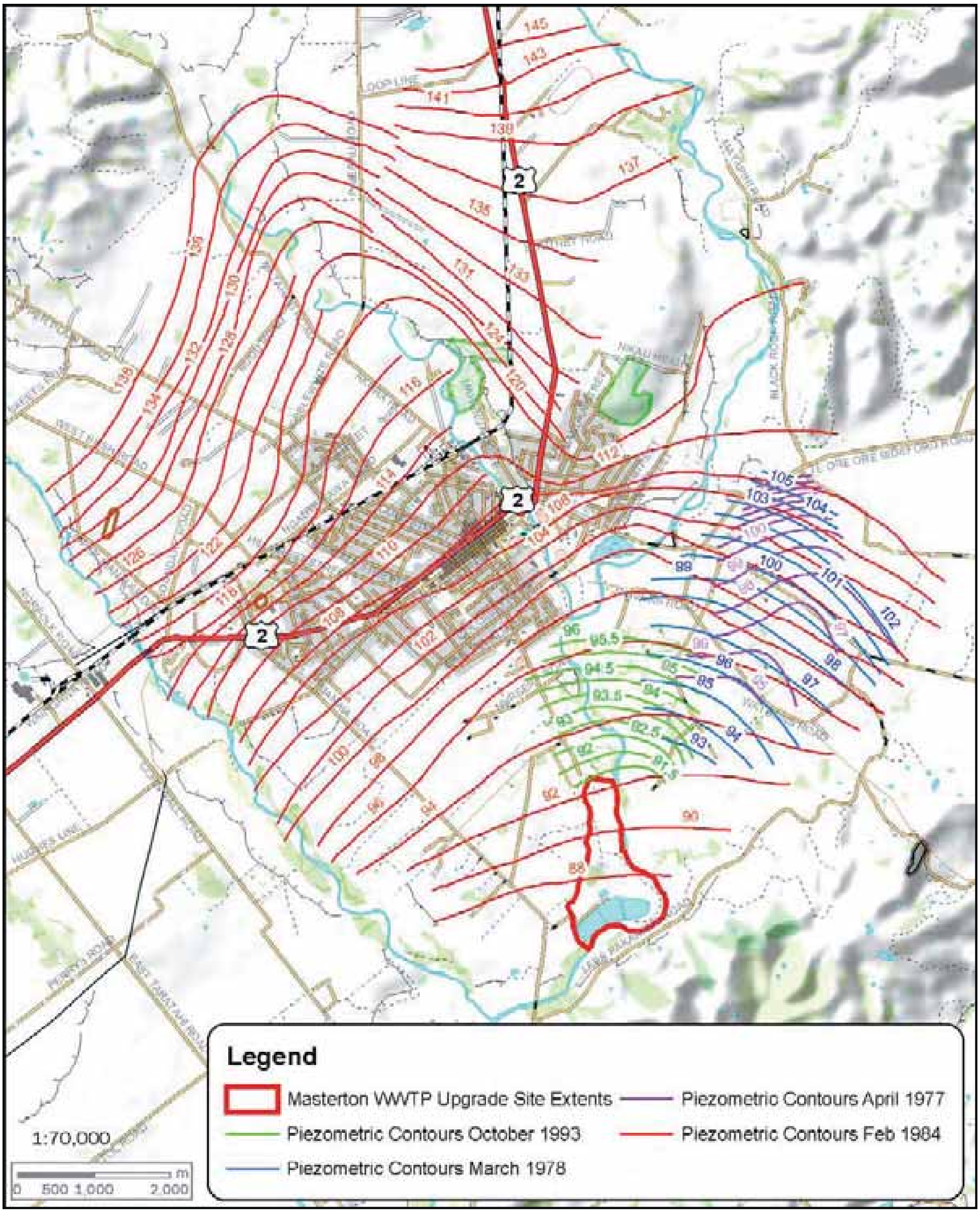


Figure 6: Map showing piezometric contours surveyed by Wellington Regional Council. Groundwater flow direction is perpendicular to the contours.

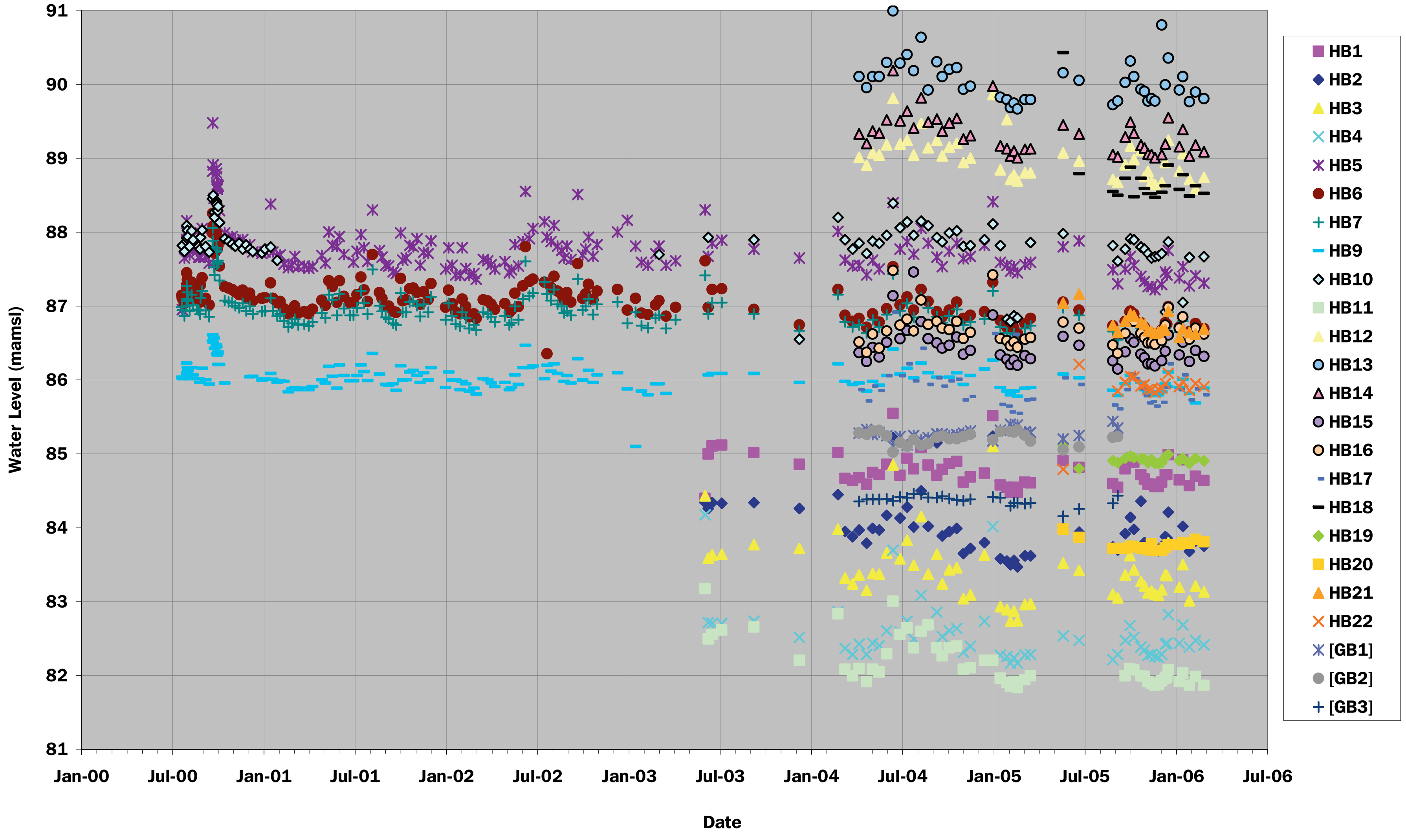


Figure 7: Long-term groundwater monitoring records (3 surface water gauging sites on the Makoura Stream are also included)

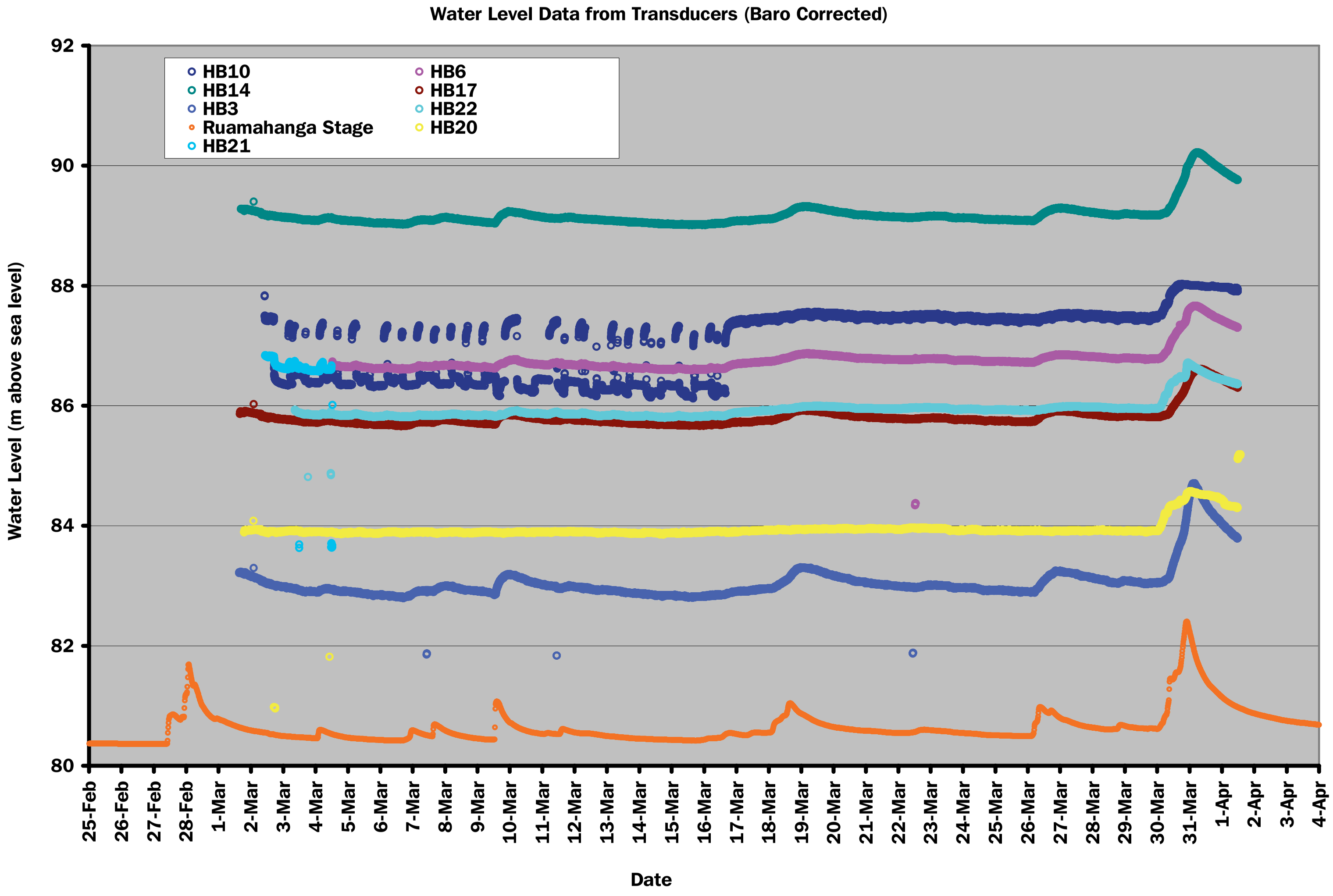


Figure 8: Groundwater levels in 8 wells across the site and Ruamahanga River Stage at Wardells Bridge recorded over February-April 2005

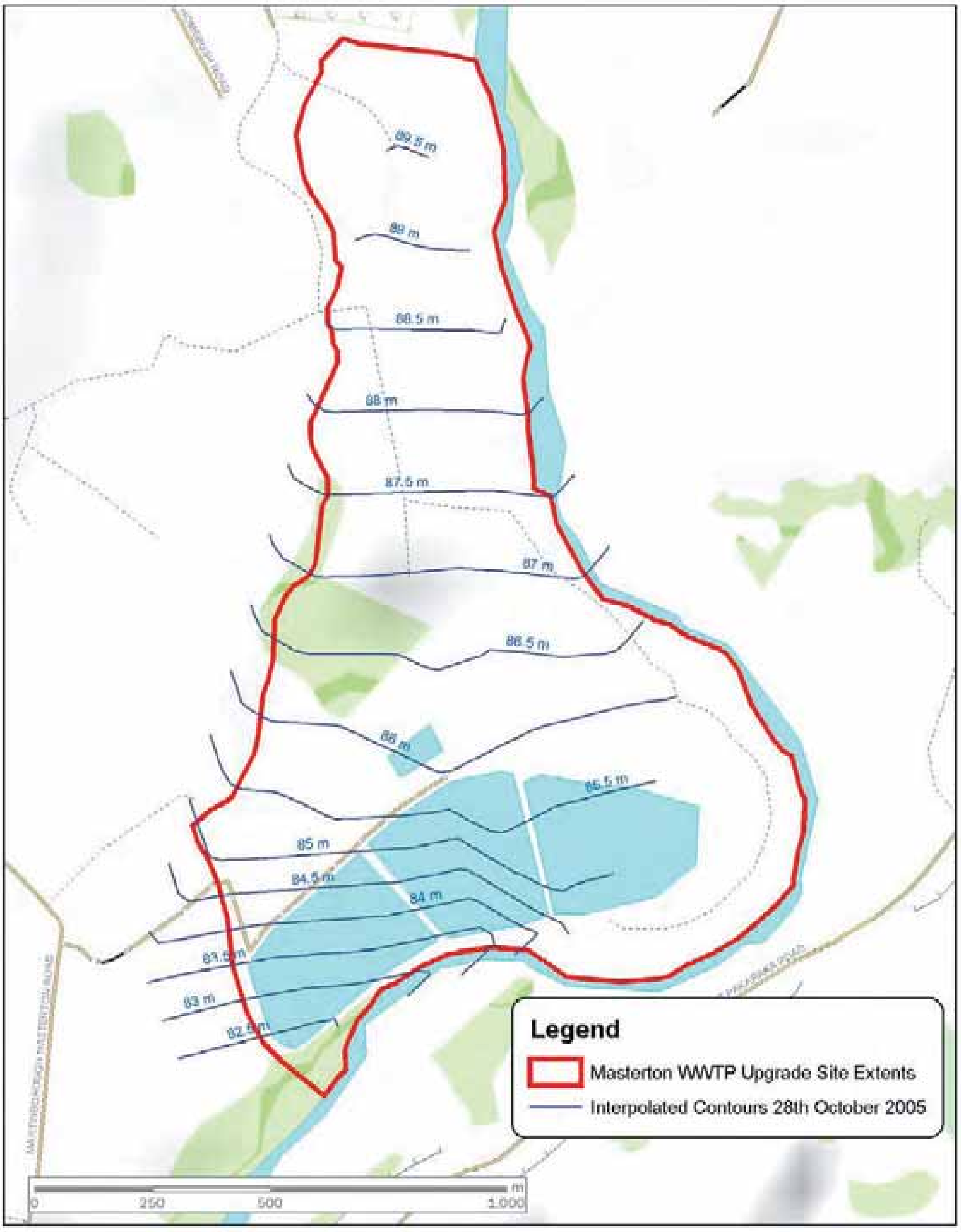


Figure 9: Piezometric contours interpolated from water level measurements on the 28th of October 2005

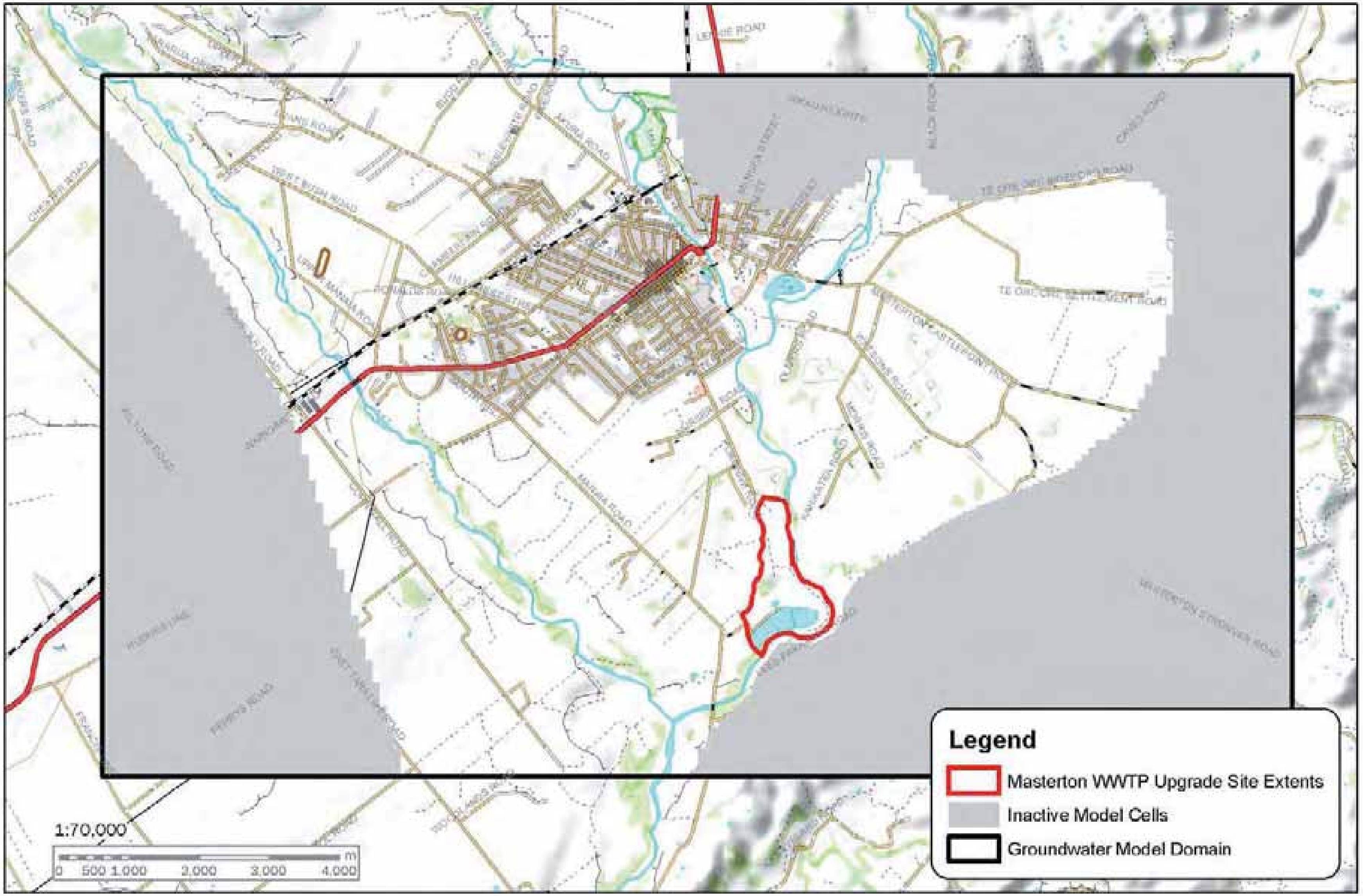


Figure 10: Area included in the Groundwater Model

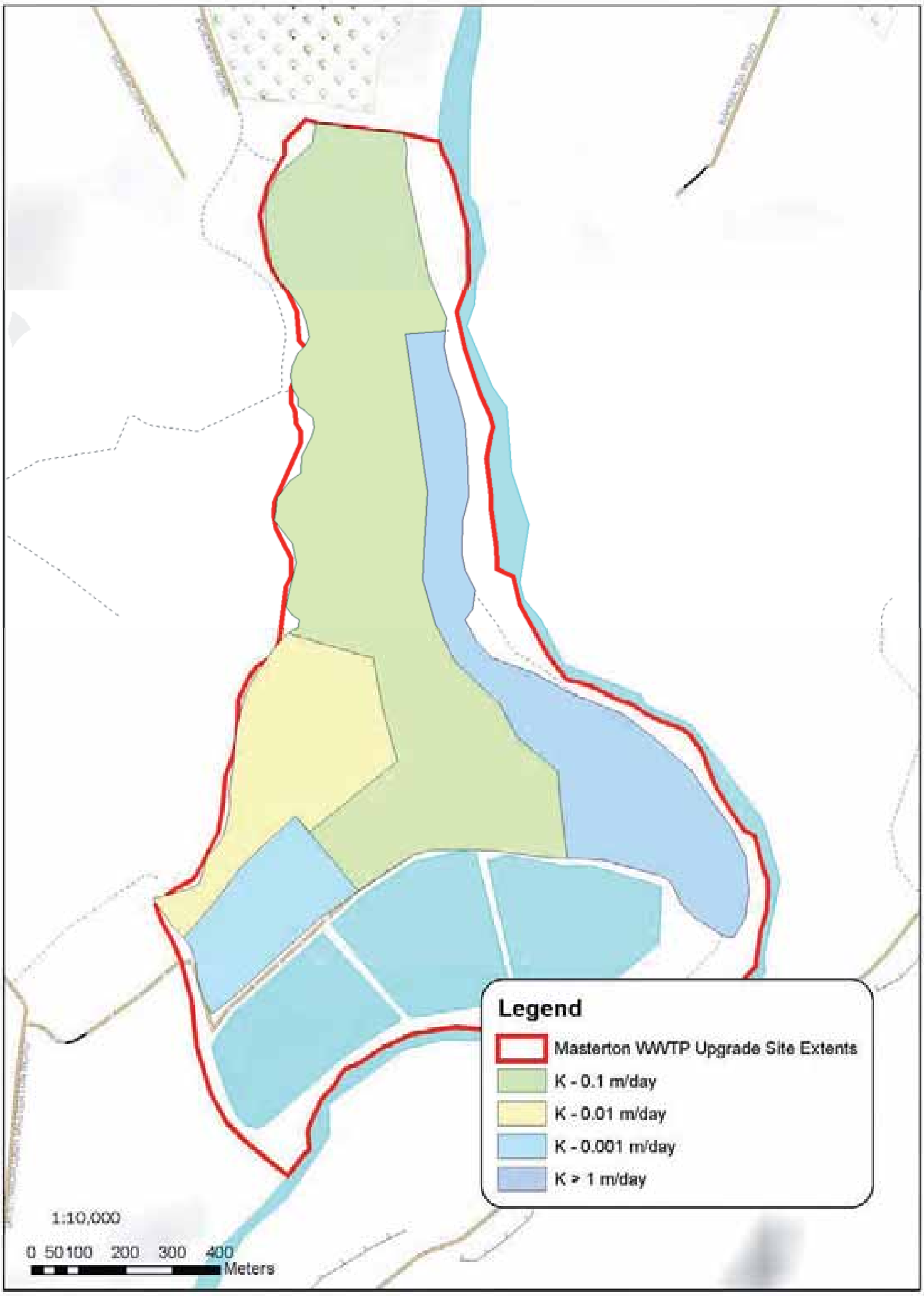


Figure 11: Hydraulic conductivity zones used in the modelling to represent the surficial confining sediments at the site

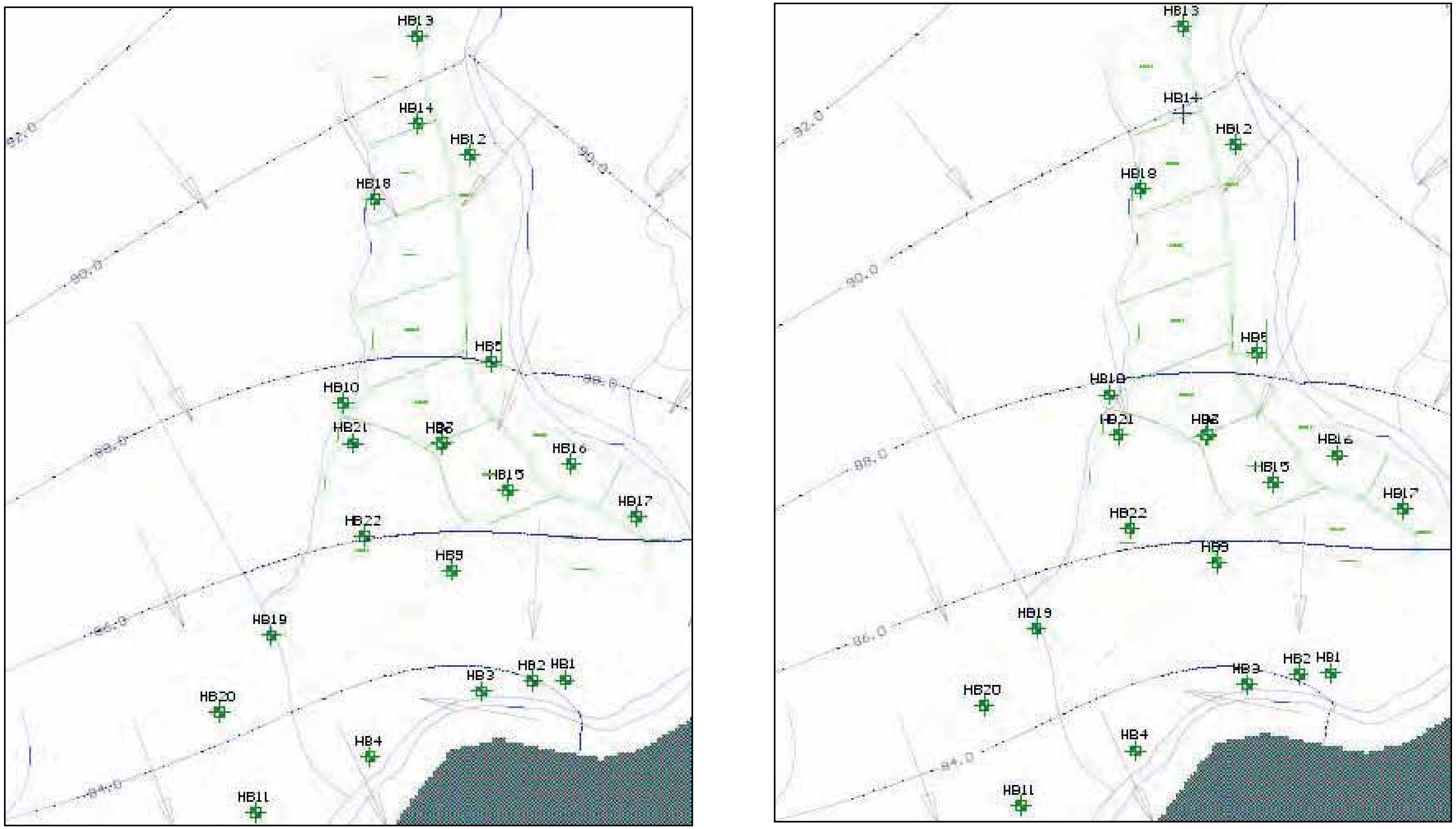


Figure 12: Modelled piezometric contours. The pre and post irrigation contours are shown in the left and right figures respectively.

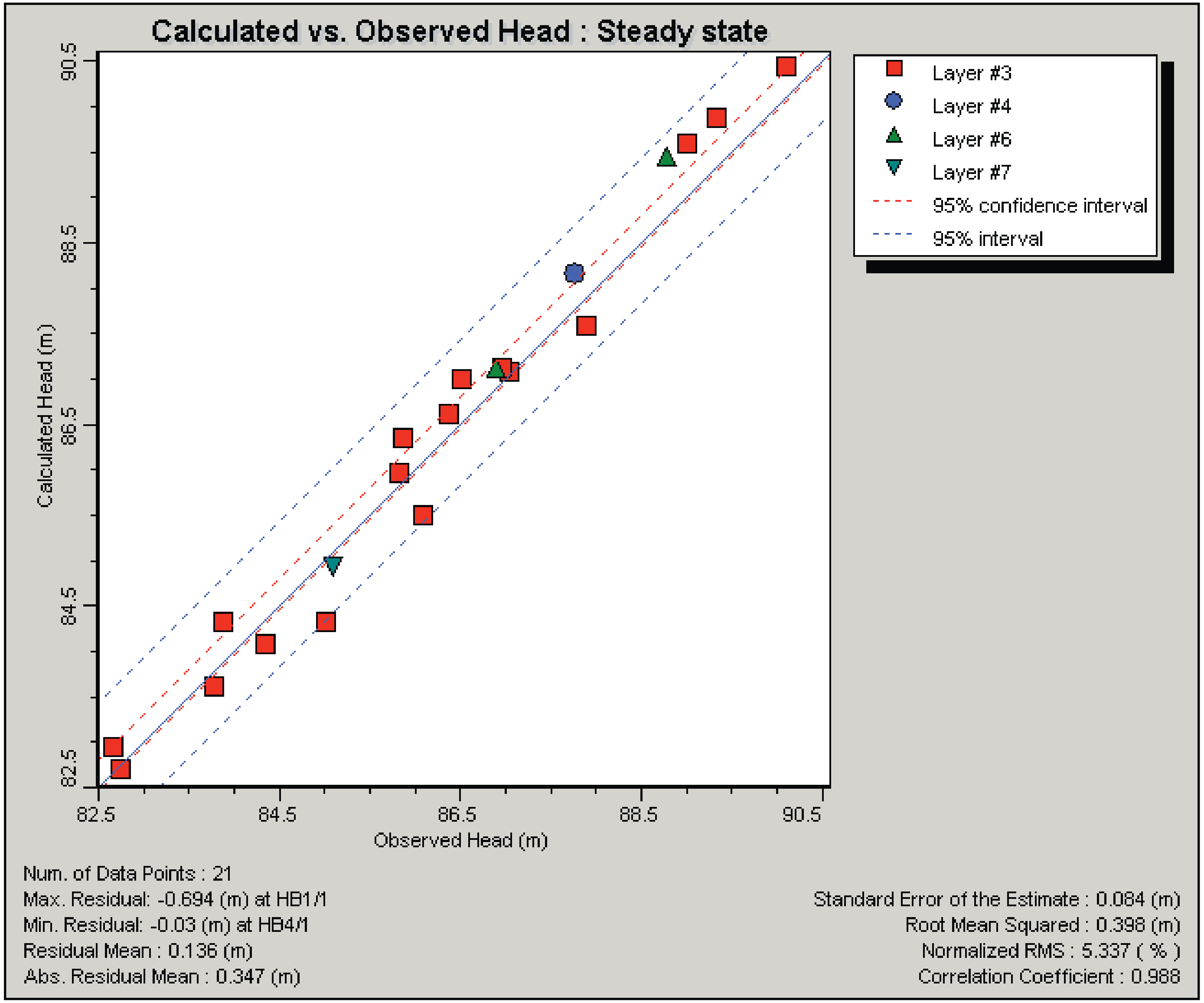


Figure 13: Plot illustrating degree of model calibration for the pre-irrigation steady state run

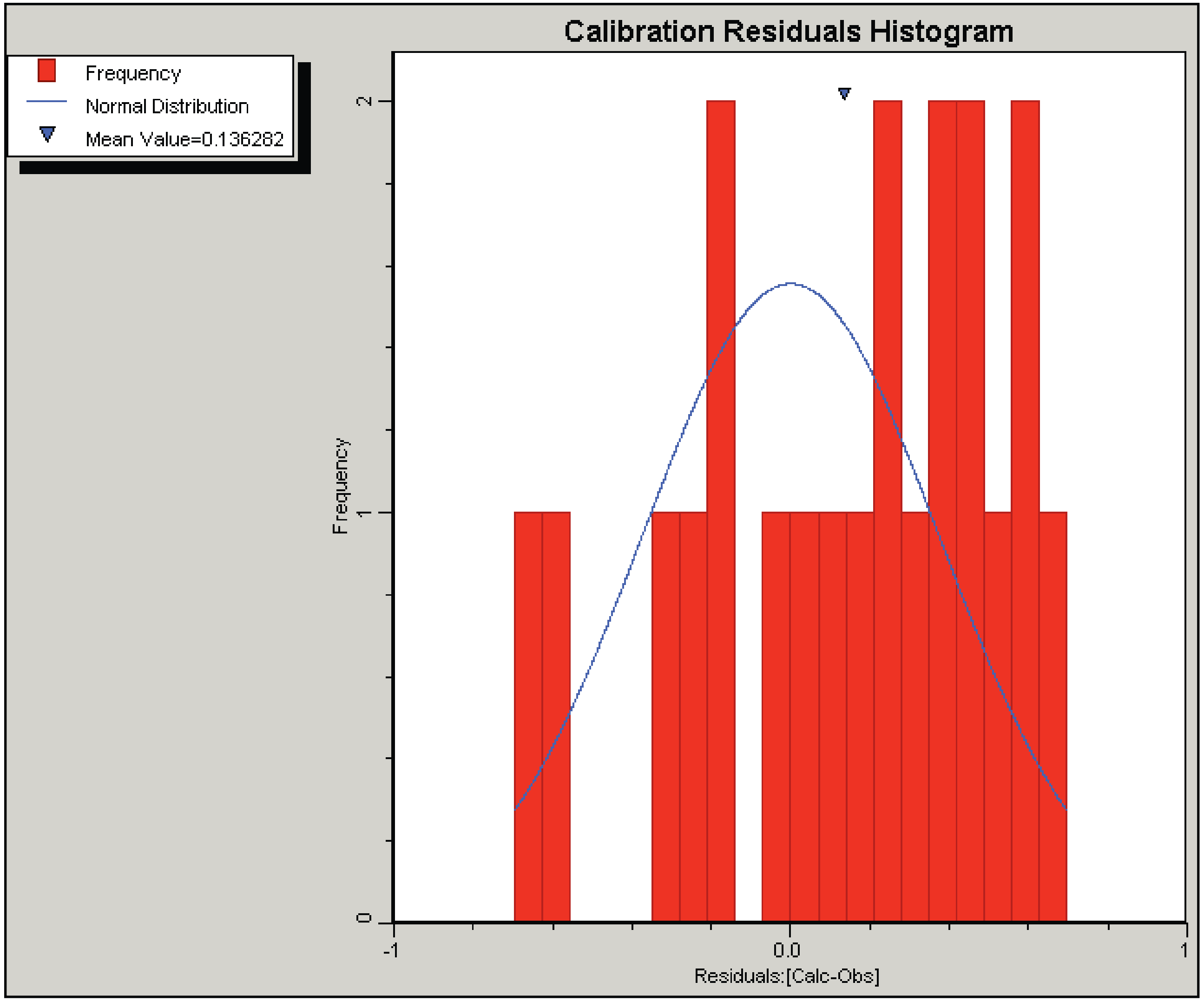


Figure 14: Histogram that illustrates that the modelled heads are slightly higher than the measured heads for the pre-irrigation steady state

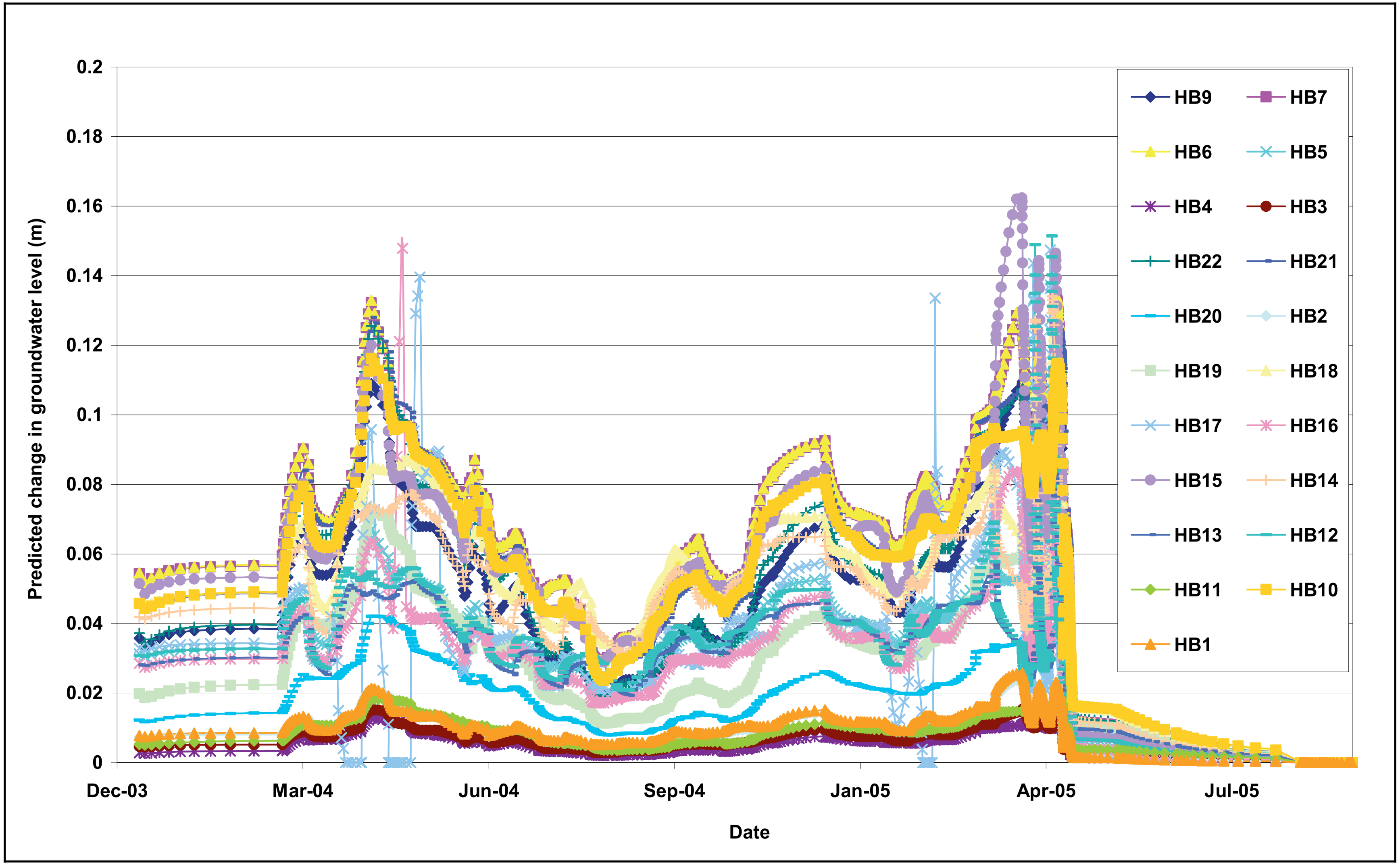


Figure 15: Simulated changes in groundwater levels for irrigation Option 6

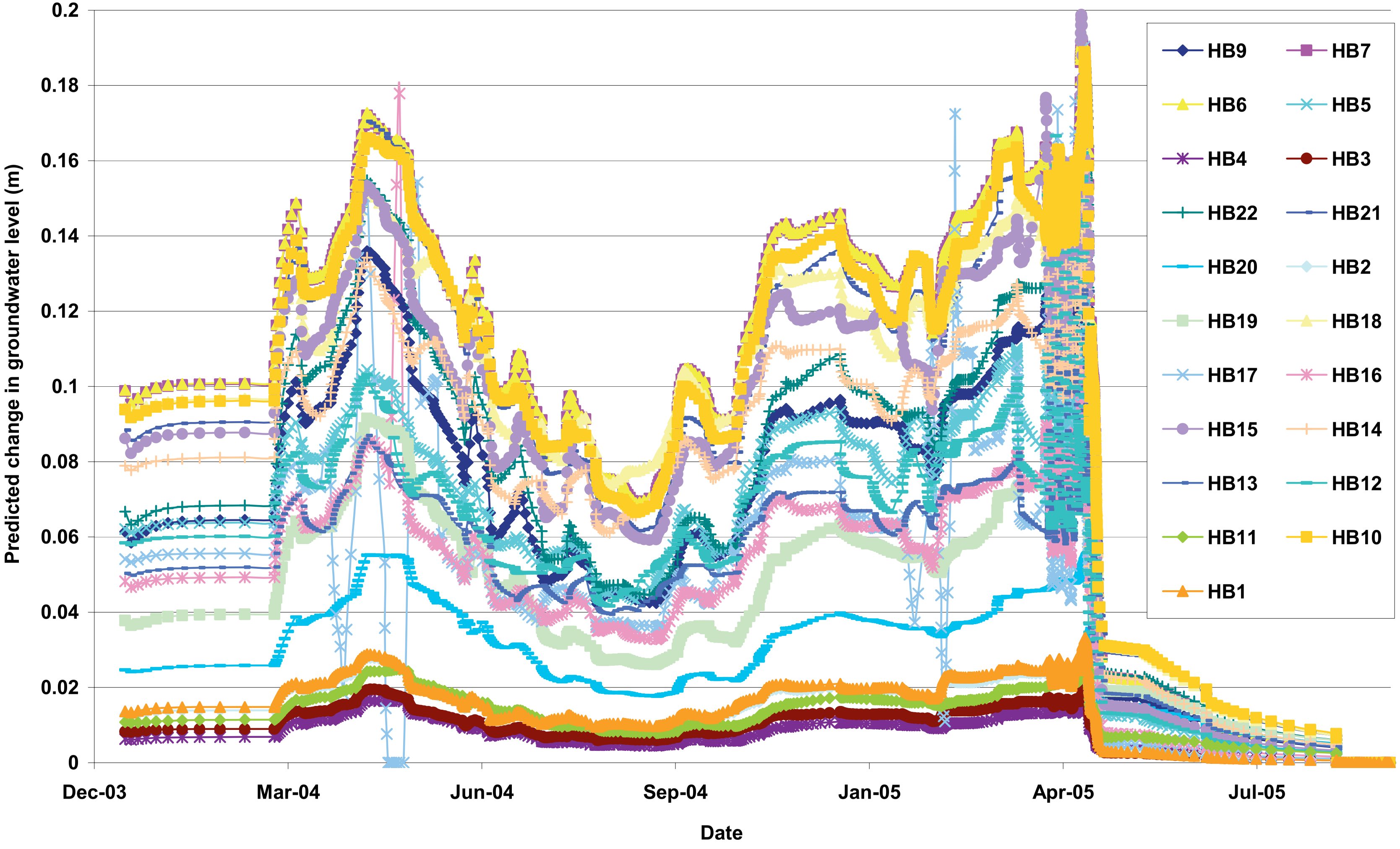


Figure 16: Simulated changes in groundwater levels for irrigation Option 3

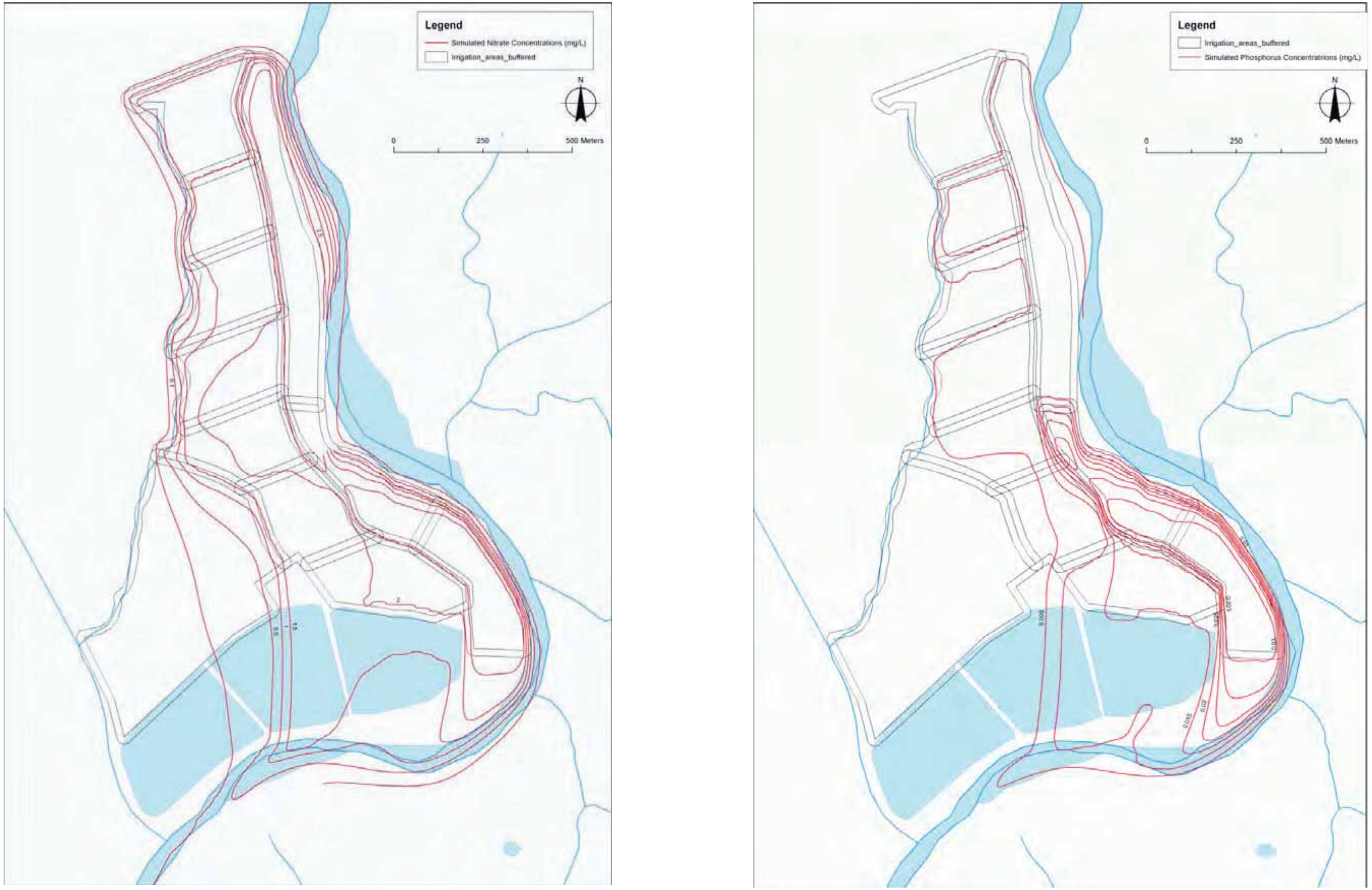


Figure 17: Plots of modelled nitrate and phosphorous concentrations for Option 6

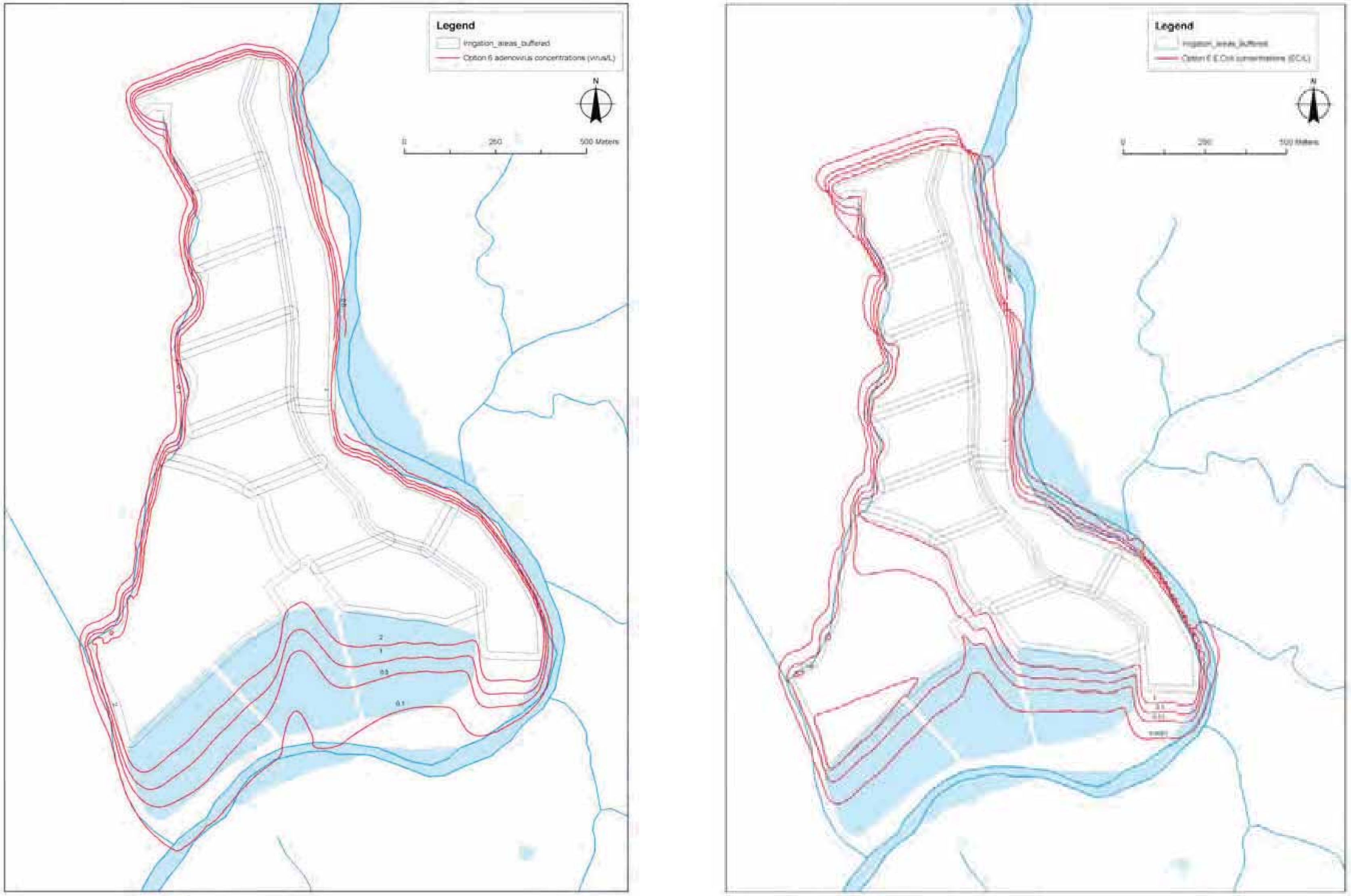


Figure 18: Plots of modelled adenovirus and E.Coli concentrations for Option 6

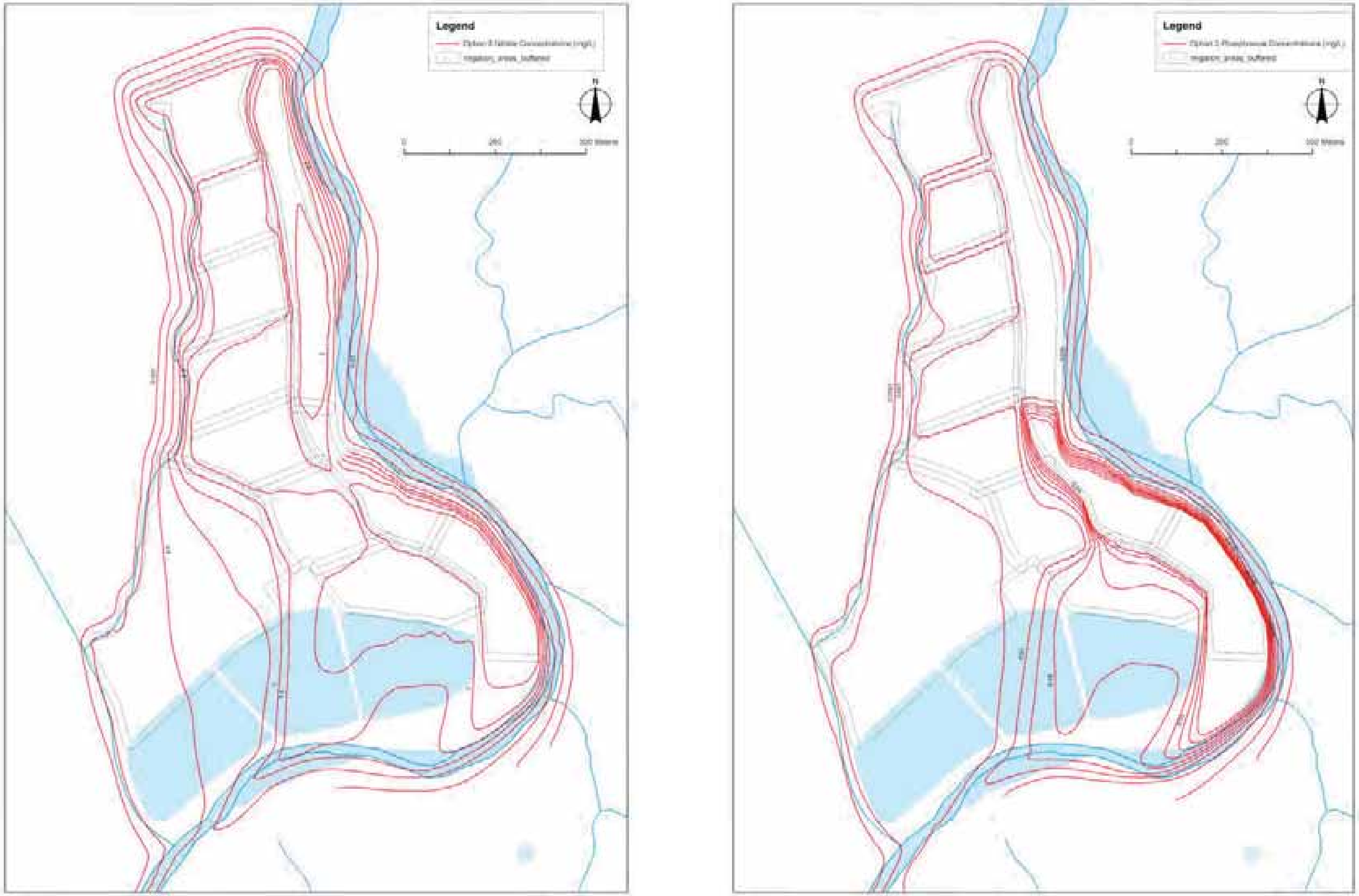


Figure 19: Plots of modelled nitrate and phosphorous concentrations for Option 3

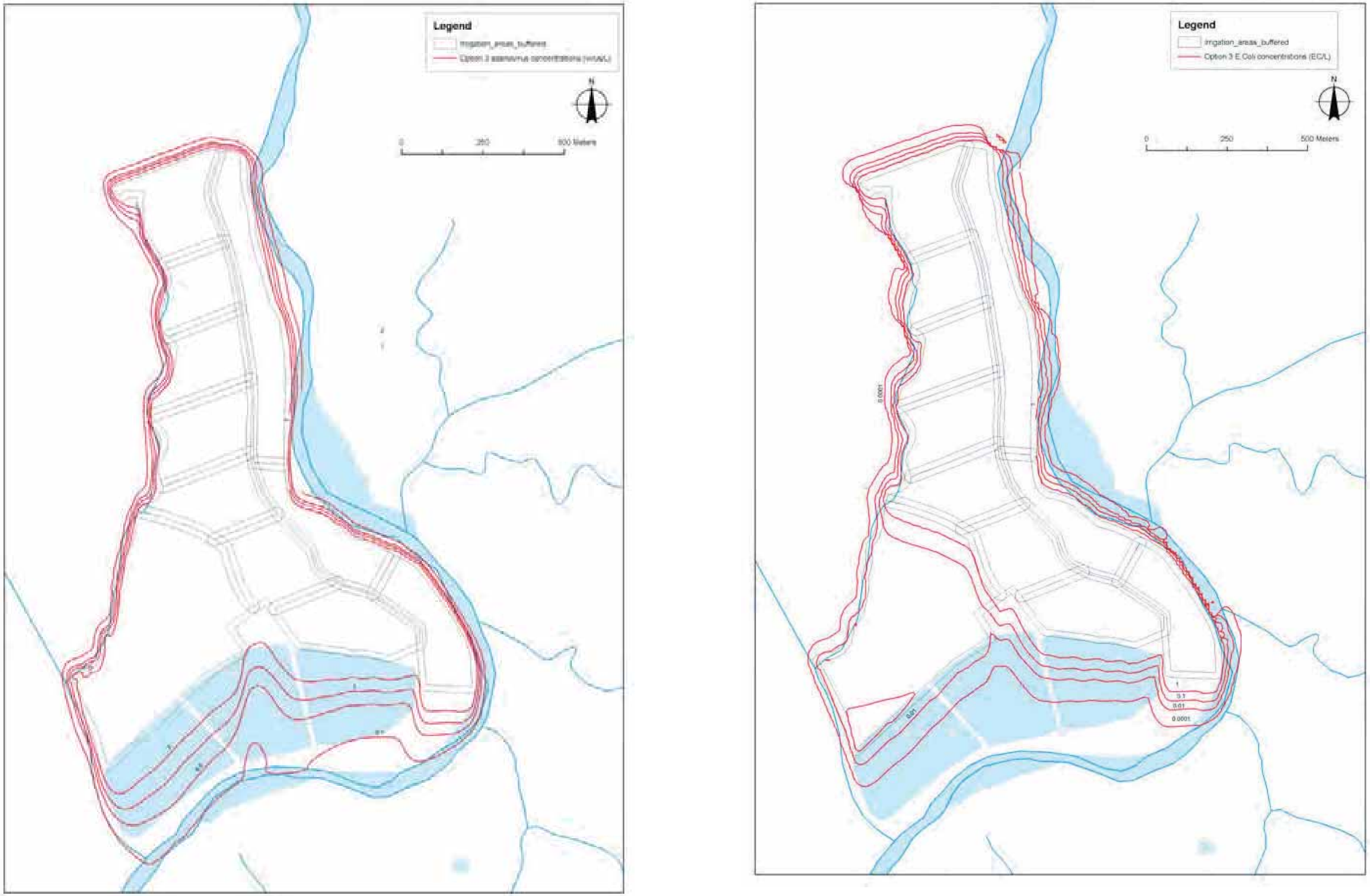


Figure 20: Plots of modelled adenovirus and E.Coli concentrations for Option 3

Appendix B: Borelogs

PATTLE DELAMORE PARTNERS LTD

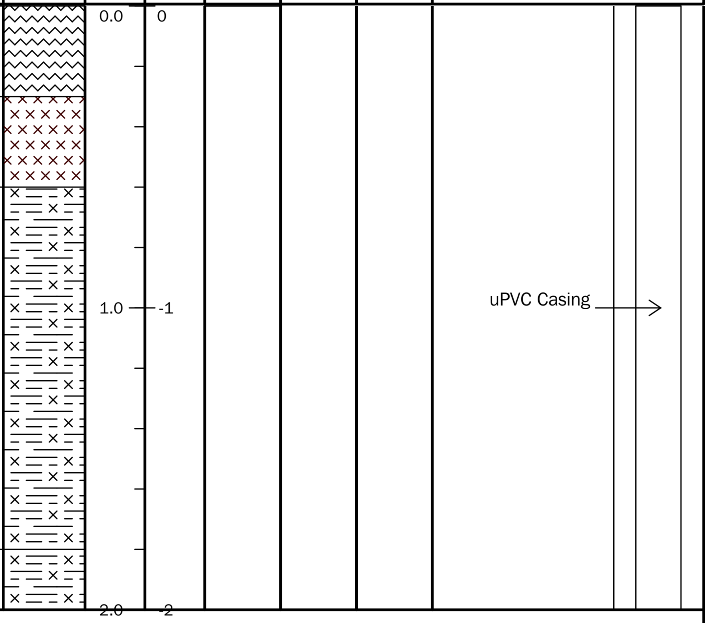
LOG OF BOREHOLE
Masterton Wastewater Phase 1

HOLE NO. **HA3**
JOB NO: WJ292_03

CLIENT: Beca Carter Hollings & Ferner Ltd		LOCATION: Masterton		
START DATE: 18/03/2004 END DATE: 18/03/2004	COORDINATES: 1825970 5458830	TOTAL DEPTH: 2.0 m	LOGGED BY: AB, PL	SHEET 1 OF 1

GROUND LEVEL: --
TOP OF CASING: --

INTERPRETATION	DESCRIPTION OF SOIL / ROCK (based on cuttings etc.)	DEPTH (m)	RL (m)	DRILLING DEPTH / DATE	WATER LEVEL GAIN / LOSS	SAMPLES / TESTS
	SOIL. silty soil with some clay, brown, damp	0.0	0			
	SILT. brown, damp					
	CLAY with some silt. firm, brown, damp	1.0	-1			
	CLAY with some silt. softer, damp to moist, brown	2.0	-2			



END OF BOREHOLE AT 2.0m

Notes:

KEY
Groundwater Level
Water Gain
Water Loss
● Grab sample

Drilled By:
Diameter: 32 mm
Method: Hand auger
Datum:

Filename: Logplot data Masterton piezo HA3

Logs based on New Zealand Geomechanics Society Field Description Guidelines (2005)

PATTLE DELAMORE PARTNERS LTD

LOG OF BOREHOLE

Masterton Wastewater Phase 1

HOLE NO. **HA6**

JOB NO: WJ292_03

CLIENT: Beca Carter Hollings & Ferner Ltd

LOCATION: Masterton

START DATE: 18/03/2004
END DATE: 18/03/2004

COORDINATES: 1825643 5459686

TOTAL DEPTH: 1.8 m

LOGGED BY: AB, PL

SHEET 1 OF 1

GROUND LEVEL: --
TOP OF CASING: --

INTERPRE-TATION	DESCRIPTION OF SOIL / ROCK (based on cuttings etc.)	GRAPHIC LOG	DEPTH (m)	RL (m)	DRILLING DEPTH / DATE	WATER LEVEL GAIN / LOSS	SAMPLES / TESTS	INSTALLATION
	SILT. hard, dry, brown		0.0	0				
	SILT with some clay. increasing clay content, brown							uPVC Casing →
	CLAY with some silt. brown		1.0	-1				
	CLAY. hard, brown							
	CLAY. moist, wet at end of drill							

END OF BOREHOLE AT 1.83m

Notes:

KEY
▽ Groundwater Level
← Water Gain
→ Water Loss
● Grab sample

Drilled By:
Diameter: 32 mm
Method: Hand auger
Datum:

Filename: Logplot data Masterton piezo HA6

Logs based on New Zealand Geomechanics Society Field Description Guidelines (2005)

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LOG OF BOREHOLE
Masterton Wastewater Phase 1

HOLE NO. **HA7**
JOB NO: WJ292_03

CLIENT: Beca Carter Hollings & Ferner Ltd	LOCATION: Masterton
START DATE: 18/03/2004 END DATE: 18/03/2004	COORDINATES: 1825755 5458814
TOTAL DEPTH: 1.2 m	LOGGED BY: AB, PL
SHEET 1 OF 1	

GROUND LEVEL: --
TOP OF CASING: --

INTERPRE- TATION	DESCRIPTION OF SOIL / ROCK (based on cuttings etc.)	GRAPHIC LOG	DEPTH (m)	RL (m)	DRILLING DEPTH / DATE	WATER LEVEL GAIN / LOSS	SAMPLES / TESTS	INSTALLATION
	SILT. brown, moist		0.0	0				
	SILT with trace of sand. brown, moist							
	CLAYEY SILT. brown, moist							uPVC Casing
	CLAY with some silt. hard, brown, moist		1.0	-1				

END OF BOREHOLE AT 1.2m

Notes:

KEY
- Groundwater Level
- Water Gain
- Water Loss
- ● Grab sample

Drilled By:
Diameter: 32 mm
Method: Hand auger
Datum:

Filename: Logplot data Masterton piezo HA7

Logs based on New Zealand Geomechanics Society Field Description Guidelines (2005)

PATTLE DELAMORE PARTNERS LTD

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LOG OF BOREHOLE

Masterton Wastewater Phase 1

HOLE NO. **HA8**

JOB NO: WJ292_03

CLIENT: Beca Carter Hollings & Ferner Ltd

LOCATION: Masterton

START DATE: 18/03/2004
END DATE: 18/03/2004

COORDINATES: 1825558
5459379

TOTAL DEPTH: 1.9 m

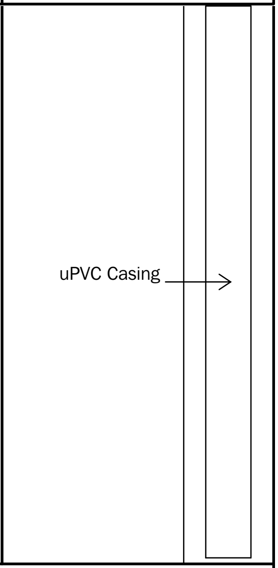
LOGGED BY: AB, PL

SHEET 1 OF 1

GROUND LEVEL: --
TOP OF CASING: --

INTERPRE-TATION	DESCRIPTION OF SOIL / ROCK (based on cuttings etc.)	GRAPHIC LOG	DEPTH (m)	RL (m)	DRILLING DEPTH / DATE	WATER LEVEL GAIN / LOSS	SAMPLES / TESTS
	SOIL. soil+silt, brown		0.0	0			
	SILT. semi-soft, damp to moist, brown						
	CLAY with some silt. hard, stiff, moist, brown		1.0	-1			
	CLAY. soft, moist to wet						

INSTALLATION



END OF BOREHOLE AT 1.85m

Notes:

KEY
- ⊽ Groundwater Level
- ← Water Gain
- → Water Loss
- ● Grab sample

Drilled By:
Diameter: 32 mm
Method: Hand auger
Datum:

Filename: Logplot data Masterton piezo HA8

Logs based on New Zealand Geomechanics Society Field Description Guidelines (2005)

PATTLE DELAMORE PARTNERS LTD

LOG OF BOREHOLE

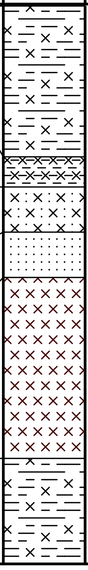
Masterton Wastewater Phase 1

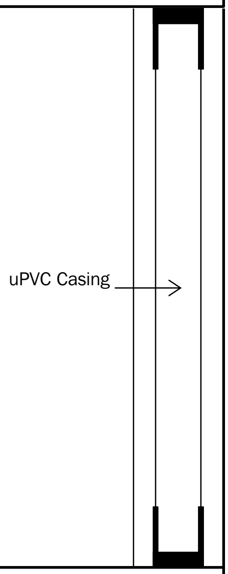
HOLE NO. **HA10**
JOB NO: Wj292_03

CLIENT: Beca Carter Hollings & Ferner Ltd
LOCATION: Masterton

START DATE: 18/03/2004
END DATE: 18/03/2004
COORDINATES: 1825678 5459494
TOTAL DEPTH: 1.9 m
LOGGED BY: AB, PL
SHEET 1 OF 1

GROUND LEVEL: --
TOP OF CASING: --





INTERPRE-TATION	DESCRIPTION OF SOIL / ROCK (based on cuttings etc.)	GRAPHIC LOG	DEPTH (m)	RL (m)	DRILLING DEPTH / DATE	WATER LEVEL GAIN / LOSS	SAMPLES / TESTS	INSTALLATION
	SILTY CLAY. dry, brown		0.0	0				
	CLAYEY SILT. moist, brown							
	SANDY SILT. dry, brown							
	SAND. medium-coarse, dry, brown							
	SILT. hard, brown, moist		1.0	-1				
	SILTY CLAY. soft, moist to wet							

END OF BOREHOLE AT 1.85m

Notes:

KEY

⊽	Groundwater Level
←	Water Gain
→	Water Loss
●	Grab sample

Drilled By:
Diameter: 32 mm
Method: Hand auger
Datum:

Filename: Logplot data Masterton piezo HA10

Logs based on New Zealand Geomechanics Society Field Description Guidelines (2005)

PATTLE DELAMORE PARTNERS LTD

LOG OF BOREHOLE

Masterton Wastewater Phase 1

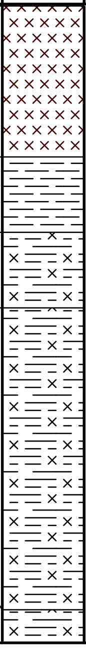
HOLE NO. **HA11**

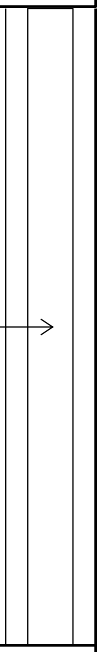
JOB NO: WJ292_03

CLIENT: Beca Carter Hollings & Ferner Ltd	LOCATION: Masterton
START DATE: 18/03/2004 END DATE: 18/03/2004	COORDINATES: 1825522 5459599
TOTAL DEPTH: 2.1 m	LOGGED BY: AB, PL
SHEET 1 OF 1	

GROUND LEVEL: --
TOP OF CASING: --

INTERPRE-TATION	DESCRIPTION OF SOIL / ROCK (based on cuttings etc.)	GRAPHIC LOG	DEPTH (m)	RL (m)	DRILLING DEPTH / DATE	WATER LEVEL GAIN / LOSS	SAMPLES / TESTS	INSTALLATION
	SILT. hard, dry, brown		0.0	0				
	CLAY. semi-soft, moist, brown							
	CLAY with some silt. semi-soft, moist, brown							
	CLAY with some silt. semi-soft, moist, brown, increasing clay content		1.0	-1				uPVC Casing
	CLAY with some silt. wet, brown		2.0	-2				





END OF BOREHOLE AT 2.11m

Notes:

KEY
- ⊽ Groundwater Level
- ← Water Gain
- → Water Loss
- ● Grab sample

Drilled By:
Diameter: 32 mm
Method: Hand auger
Datum:

Filename: Logplot data Masterton piezo HA11

Logs based on New Zealand Geomechanics Society Field Description Guidelines (2005)

JOB NO: WJ371
HB1

LOG OF BOREHOLE

Masterton Oxidation Ponds

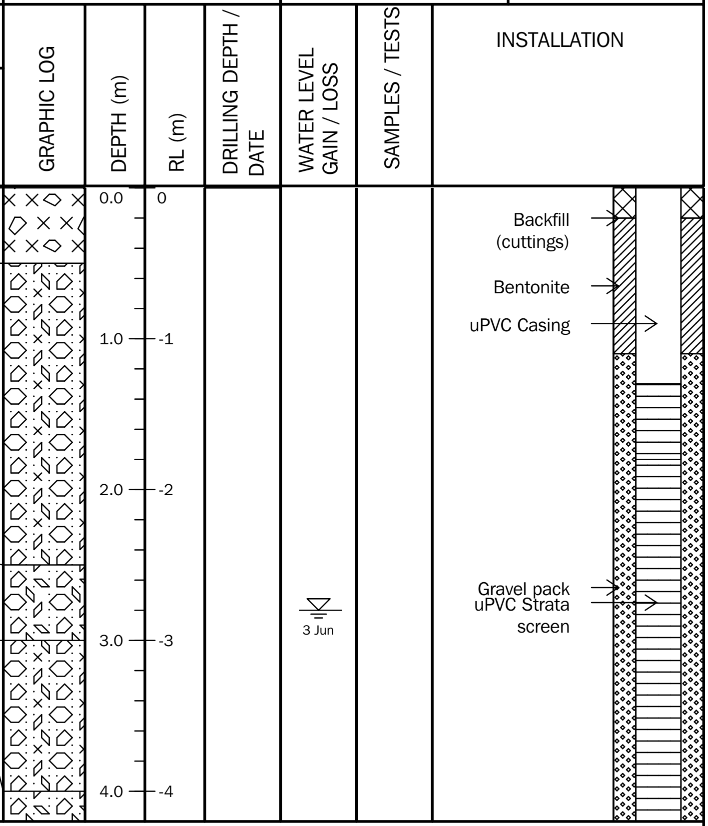
HOLE NO. **HB1**

CLIENT: Beca Carter Hollings & Ferner
LOCATION: Masterton

START DATE: 3/06/2003
END DATE: 3/06/2003
COORDINATES:
TOTAL DEPTH: 4.2 m
LOGGED BY: DA
SHEET 1 OF 1

GROUND LEVEL: --
RL TOP OF CASING: --

INTERPRE-TATION	DESCRIPTION OF SOIL / ROCK (based on cuttings etc.)
	GRAVELLY SILT. Light brown, dry. Gravel medium to coarse
	SANDY GRAVEL with some silt. Brown, loose, dry. Sand fine to medium, angular. Silt light brown.
	GRAVEL with minor sand. Grey, fine to medium, moist. Sand medium to coarse, angular.
	SANDY GRAVEL with minor silt. Grey, fine to medium. Sand coarse, angular
	GRAVEL with some sand. Grey, fine to medium. Sand coarse, angular. Minor silt.



END OF BOREHOLE AT 4.2m

Drilled By: Wairarapa Drilling
Diameter: 50 mm
Method: Air Rotary
Datum:
Notes:

KEY
⊽ Groundwater Level
← Water Gain
→ Water Loss
● Grab sample

PATTLE DELAMORE PARTNERS LTD

Logs based on New Zealand Geomechanics Society Field Description Guidelines (1988)

JOB NO: WJ371
HB2

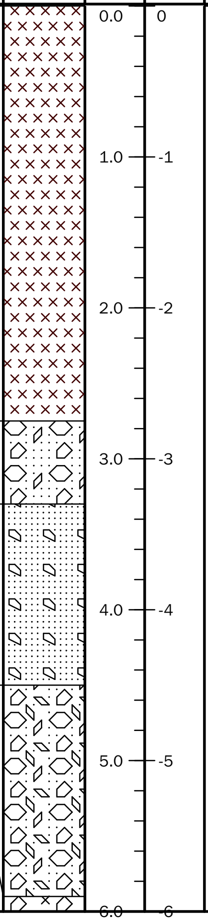
LOG OF BOREHOLE
Masterton Oxidation Ponds

HOLE NO. **HB2**

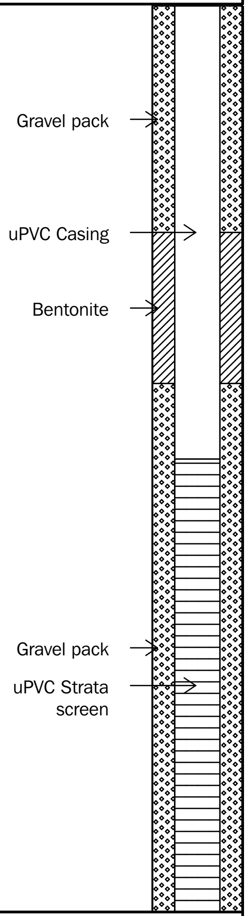
CLIENT: Beca Carter Hollings & Ferner	LOCATION: Masterton
START DATE: 3/06/2003 END DATE: 3/06/2003	COORDINATES:
TOTAL DEPTH: 6 m	LOGGED BY: DA
SHEET 1 OF 1	
GROUND LEVEL: --	RL TOP OF CASING: --

INTERPRE-TATION	DESCRIPTION OF SOIL / ROCK (based on cuttings etc.)	WATER LEVEL GAIN / LOSS
	SILT. Dark brown, dry with some minor wood	
	GRAVELLY SAND. Grey brown, loose, moist. Sand medium to coarse, angular.	
	SAND with some gravel. Dark grey, coarse, angular. Gravel medium to coarse.	3 Jun
	GRAVEL with some sand. Dark grey, medium to coarse. Sand coarse, angular	
	GRAVEL with some silt. Dark grey, fine to coarse. Silt grey, wet, plastic.	

GRAPHIC LOG / DEPTH (m) / RL (m) / DRILLING DEPTH / DATE / SAMPLES / TESTS



INSTALLATION



END OF BOREHOLE AT 6.0m

Drilled By: Wairarapa Drilling
Diameter: 50 mm
Method: Air Rotary
Datum:
Notes:

KEY
⊽ Groundwater Level
← Water Gain
→ Water Loss
● Grab sample

PATTLE DELAMORE PARTNERS LTD

Logs based on New Zealand Geomechanics Society Field Description Guidelines (1988)

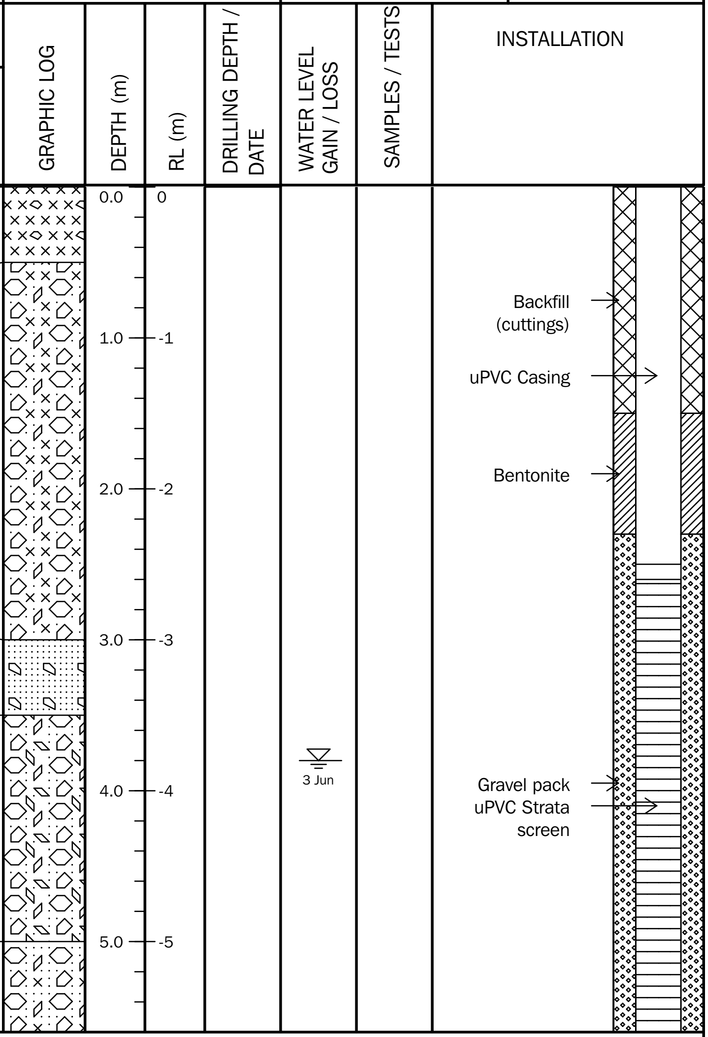
JOB NO: WJ371
HB3

LOG OF BOREHOLE
Masterton Oxidation Ponds

HOLE NO. **HB3**

CLIENT: Beca Carter Hollings & Ferner Ltd	LOCATION: Masterton
START DATE: 6/03/2003 END DATE: 6/03/2003	COORDINATES:
TOTAL DEPTH: 5.6 m	LOGGED BY: DA
SHEET 1 OF 1	
GROUND LEVEL: --	RL TOP OF CASING: --

INTERPRETATION	DESCRIPTION OF SOIL / ROCK (based on cuttings etc.)
	SILT with minor gravel. Light brown, dry. Gravel medium to coarse
	SILTY GRAVEL with minor sand. Brown, medium to coarse, dry. Sand fine to medium, angular.
	SAND with some gravel. Grey, medium to coarse, angular, moist. Gravel medium to coarse.
	GRAVEL with some sand. Grey, fine to medium. Sand coarse, angular
	GRAVELLY SAND with some silt. Dark grey, medium to coarse, angular. Gravel medium to coarse.



END OF BOREHOLE AT 5.6m

Drilled By: Wairarapa Drilling
Diameter: 50 mm
Method: Air Rotary
Datum:
Notes:

KEY
▽ Groundwater Level
← Water Gain
→ Water Loss
● Grab sample

PATTLE DELAMORE PARTNERS LTD

Logs based on New Zealand Geomechanics Society Field Description Guidelines (1988)

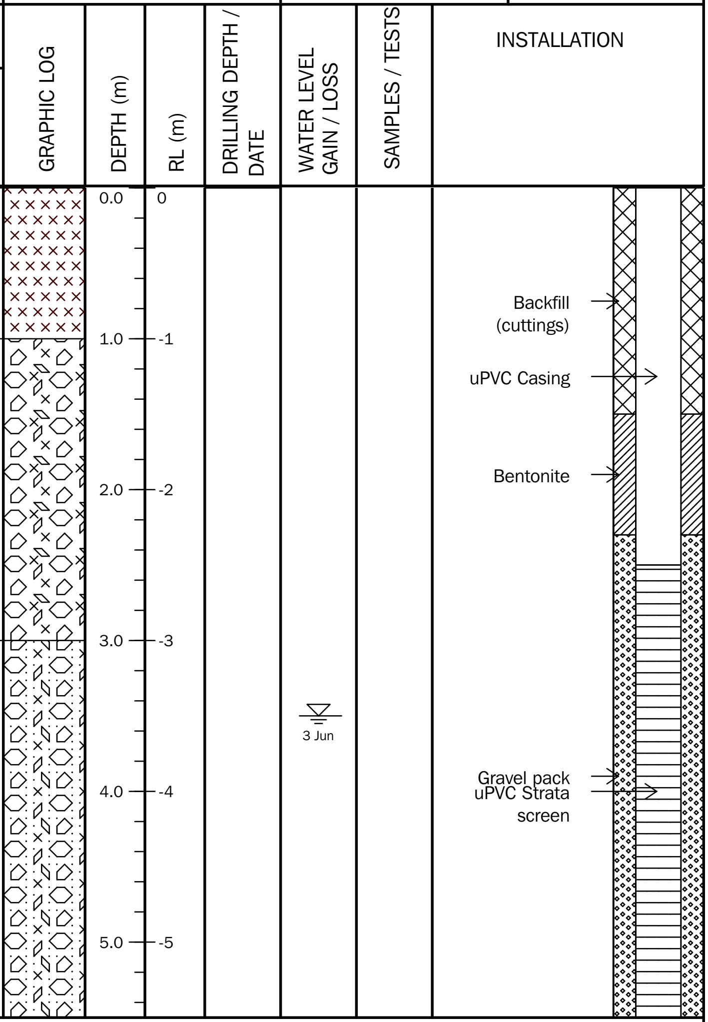
JOB NO: WJ371 WJ371 HB4	**LOG OF BOREHOLE** **Masterton Oxidation Ponds**	HOLE NO. **HB4**

CLIENT: Beca Carter Hollings & Ferner Ltd	LOCATION: Masterton

START DATE: 3/06/2003 END DATE: 3/06/2003	COORDINATES:	TOTAL DEPTH: 5.5 m	LOGGED BY: DA	SHEET 1 OF 1

GROUND LEVEL: --	RL TOP OF CASING: --

INTERPRETATION	DESCRIPTION OF SOIL / ROCK (based on cuttings etc.)
	SILT. Brown, moist, plastic
	GRAVEL with minor silt. Brown, medium to coarse, dry. Sand fine to medium, angular.
	SANDY GRAVEL with some silt. Grey, medium to coarse. Sand medium to coarse, angular.



END OF BOREHOLE AT 5.5m

Drilled By: Wairarapa Drilling
Diameter: 50 mm
Method: Air Rotary
Datum:
Notes:

KEY
⊽ Groundwater Level
← Water Gain
→ Water Loss
● Grab sample

PATTLE DELAMORE PARTNERS LTD

Logs based on New Zealand Geomechanics Society Field Description Guidelines (1988)

pdp

LOG OF BOREHOLE

HOLE NO. HB5 (was P4)

LOCATION: Homebush Wastewater Treatment Plant, Masterton.

JOB NO: WJ292

DATE: 31/7/00

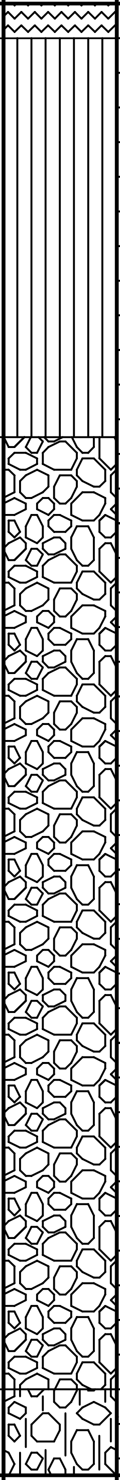
RL GROUND: -

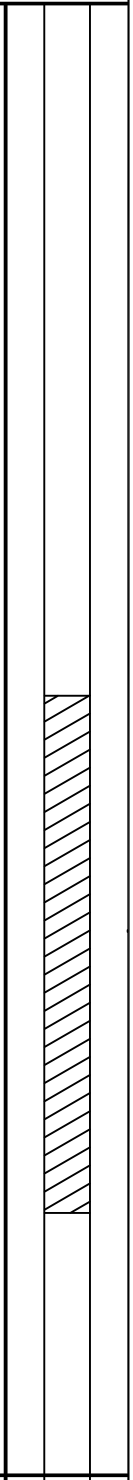
RL TOP OF CASING: -

LOGGED BY: D.A.

METHOD: -

DESCRIPTION OF SOIL	GRAPHIC LOG	DEPTH (m)	SAMPLE DETAILS	WATER LEVEL	INSTALLATION
TOPSOIL.					
SILTS, brown, plastic.		1.0 2.0			
GRAVELS, very loose, dark grey, sub rounded, clasts. Sand fraction 30% - 80% coarse/20% medium to fine. Rare clasts of chert. Average clast size approx. 10-20mm diameter. Some layers of hard clay at base of clean gravels.		3.0 4.0 5.0 6.0 7.0			
SILT BOUND GRAVELS. Very dirty water expelled. Gravels well rounded		8.0			
End of borehole at 8.5m					





REMARKS:

PATTLE DELAMORE PARTNERS LTD

D:\DATA\WELL\JOBS\WJ292

LOG OF BOREHOLE

HOLE NO. HB6 (was P2)

LOCATION: Homebush Wastewater Treatment Plant, Masterton.

JOB NO: WJ292

DATE: 26/7/00

RL GROUND: -

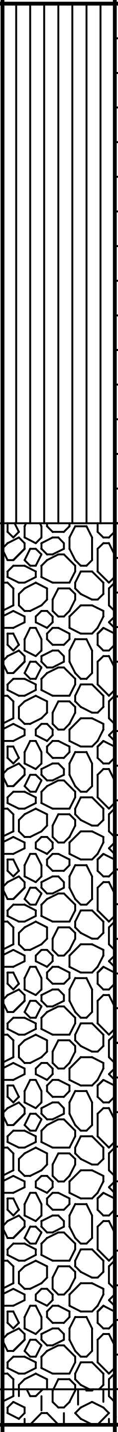
RL TOP OF CASING: -

LOGGED BY: D.A.

METHOD: -

DESCRIPTION OF SOIL	DEPTH (m)
SILT, dark greyish brown, moist, moderately plastic.	0 – 3.0
GRAVEL with some silt, light bluish grey, well graded, very loose. Gravel fine to coarse, sub rounded. Sand fraction 15% - 80% coarse/20% fine to medium. Rare quartz grains and chert clasts approx. 10mm.	3.0 – 8.0
SILT BOUND GRAVELS, clasts stained brown, sub rounded.	8.0 – 8.2
End of borehole at 8.2m	

GRAPHIC LOG

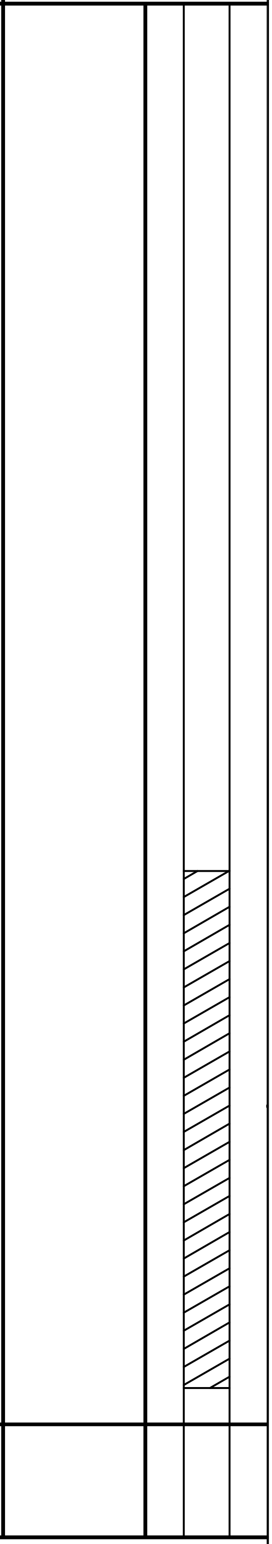


DEPTH (m)

SAMPLE DETAILS

WATER LEVEL

INSTALLATION



REMARKS:

PATTLE DELAMORE PARTNERS LTD

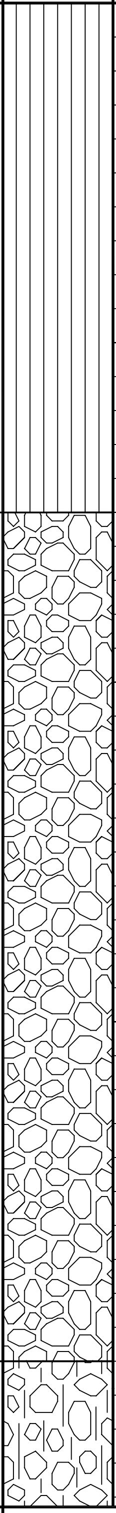
pdp **LOG OF BOREHOLE** **Page 1 of 3** **HOLE NO.** HB7 (was P3) top

LOCATION: Homebush Wastewater Treatment Plant, Masterton.

JOB NO: WJ292 DATE: 26/7/00 RL GROUND: - RL TOP OF CASING: -

LOGGED BY: D.A. METHOD: -

DESCRIPTION OF SOIL	GRAPHIC LOG	DEPTH (m)	SAMPLE DETAILS	WATER LEVEL	INSTALLATION
SILT, dark greyish brown, moist, moderately plastic.		1.0 2.0			
GRAVELS, very loose, dark grey. Average clast size 10x10x5mm, well rounded. Sand fraction 15 - 80%coarse/20% fine to medium. Rare quartz and chert.		3.0 4.0 5.0 6.0 7.0			
SILT BOUND GRAVELS, brown stained, sub rounded, clasts. Brown silt completely covers gravel clasts. Max. clast size 30x20x20mm. Sand fraction 15 - 80% coarse/20% fine to medium.		8.0			



REMARKS:

PATTLE DELAMORE PARTNERS LTD

D:\DATA\WELL\JOBS\WJ292

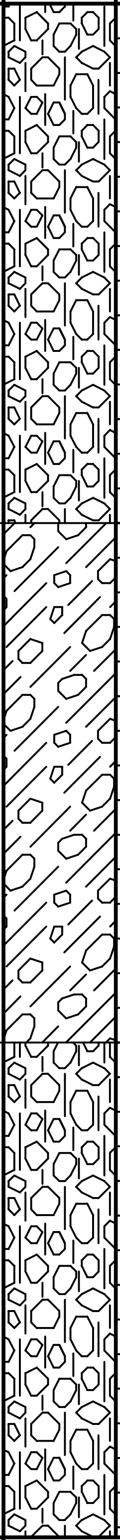
LOG OF BOREHOLE Page 2 of 3

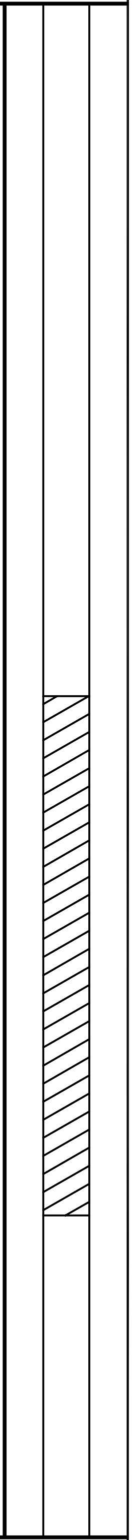
HOLE NO. HB7 (was P3)

LOCATION: Homebush Wastewater Treatment Plant, Masterton.

JOB NO: WJ292	**DATE:** 26/7/00	**RL GROUND:** -	**RL TOP OF CASING:** -
LOGGED BY: D.A.	**METHOD:** -		

DESCRIPTION OF SOIL	GRAPHIC LOG	DEPTH (m)	SAMPLE DETAILS	WATER LEVEL	INSTALLATION
SILT BOUND GRAVELS, brown stained, sub rounded, clasts. Brown silt completely covers gravel clasts. Max. clast size 30x20x20mm. Sand fraction 15% - 80% coarse/20% fine to medium.		9.0 10.0			
Hard pieces of clay interspersed with gravel.		11.0 12.0 13.0			
SILT BOUND GRAVELS, brown stained, sub rounded, clasts. Brown silt completely covers gravel clasts. Max. clast size 30x20x20mm. Sand fraction 15% - 80% coarse/20% fine to medium.		14.0 15.0 16.0			





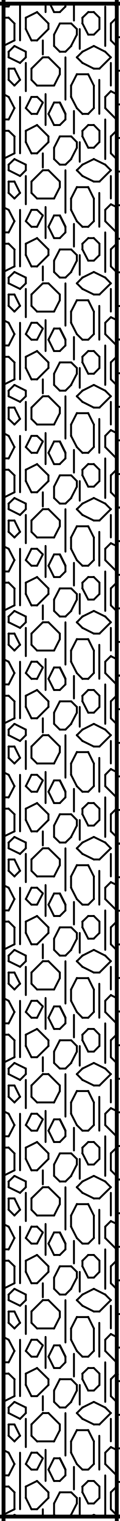
REMARKS:

PATTLE DELAMORE PARTNERS LTD

LOG OF BOREHOLE **Page 3 of 3** **HOLE NO.** HB7 (was P3)

LOCATION: Homebush Wastewater Treatment Plant, Masterton.

JOB NO: WJ292	**DATE:** 26/7/00	**RL GROUND:** -	**RL TOP OF CASING:** -
LOGGED BY: D.A.	**METHOD:** -		

DESCRIPTION OF SOIL	GRAPHIC LOG	DEPTH (m)	SAMPLE DETAILS	WATER LEVEL	INSTALLATION
SILT BOUND GRAVELS, brown stained, sub rounded, clasts. Brown silt completely covers gravel clasts. Max. clast size 30x20x20mm. Sand fraction 15% - 80% coarse/20% fine to medium.		17.0 18.0 19.0 20.0 21.0 22.0 23.0 24.0 25.0			
End of borehole at 25.0m					

REMARKS:

PATTLE DELAMORE PARTNERS LTD

D:\DATA\WELL\JOBS\WJ292

LOG OF BOREHOLE

Page 1 of 2

HOLE NO. HB9 (was P1)

LOCATION: Homebush Wastewater Treatment Plant, Masterton.

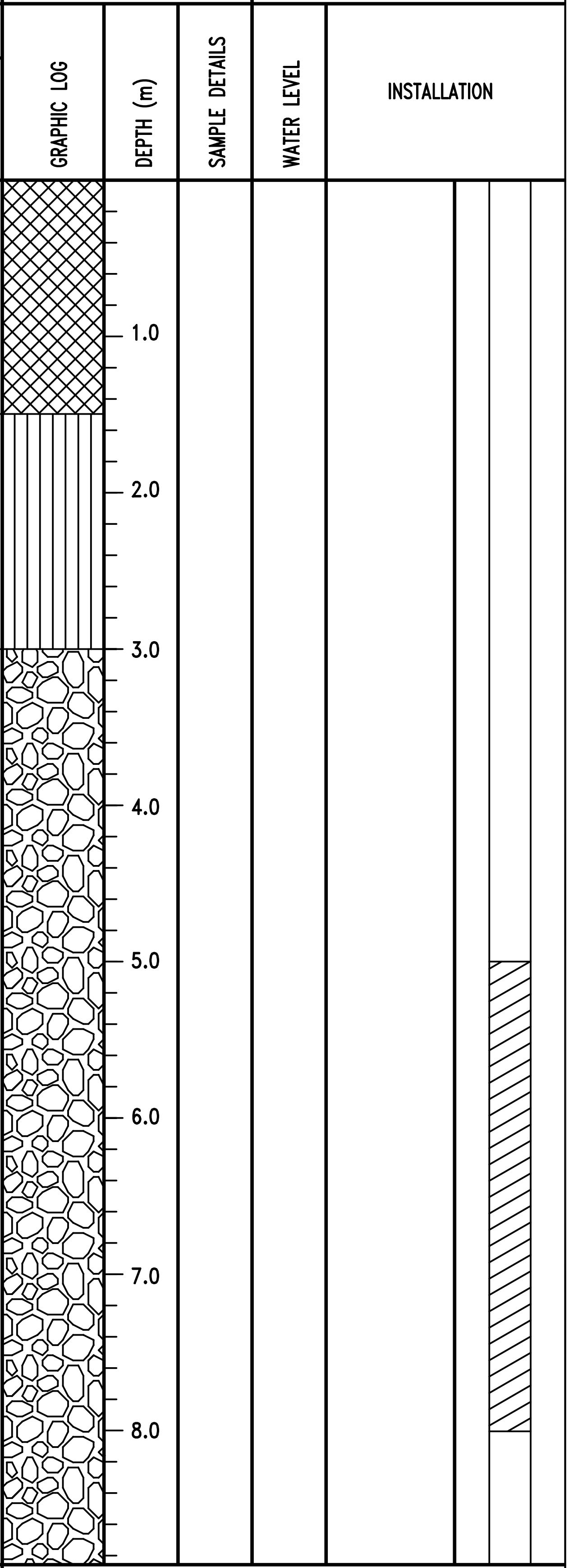
JOB NO: WJ292	**DATE:** 28/7/00	**RL GROUND:** -	**RL TOP OF CASING:** -
LOGGED BY: D.A.	**METHOD:** -		

DESCRIPTION OF SOIL

CLAY - GRAVEL. FILL.

SILT, dark greyish brown, moist, moderately plastic.

GRAVEL with some silt, light bluish grey, well graded, very loose.
Gravel fine to coarse, sub angular.
Sand fraction 15% - 80% coarse/20% fine to medium.



REMARKS:

PATTLE DELAMORE PARTNERS LTD

pdp

LOG OF BOREHOLE

Page 2 of 2

HOLE NO. HB9 (was P1)

LOCATION: Homebush Wastewater Treatment Plant, Masterton.

JOB NO: WJ292

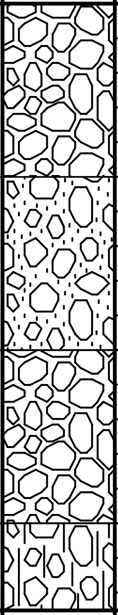
DATE: 28/7/00

RL GROUND: -

RL TOP OF CASING: -

LOGGED BY: D.A.

METHOD: -



DESCRIPTION OF SOIL	GRAPHIC LOG	DEPTH (m)	SAMPLE DETAILS	WATER LEVEL	INSTALLATION
GRAVEL with some silt, light bluish grey, well graded, loose. Gravel fine to coarse, sub angular. Sand fraction 15% - 80% coarse/20% fine to medium.					
GRAVEL, loose with sandy matrix. Sand fraction 50% - 25% coarse/60% medium/15% fine.		9.0			
GRAVEL with some silt, light bluish grey, well graded, loose. Gravel fine to coarse, sub angular. Sand fraction 15% - 80% coarse/20% fine to medium.		10.0			
SILT BOUNDED GRAVEL, clasts stained brown, sub rounded.		11.0			
End of borehole at 11.5m		12.0 13.0 14.0 15.0 16.0			

REMARKS:

PATTLE DELAMORE PARTNERS LTD

D:\DATA\WELL\JOBS\WJ292

PATTLE DELAMORE PARTNERS LTD

LOG OF BOREHOLE

Masterton Wastewater Upgrade

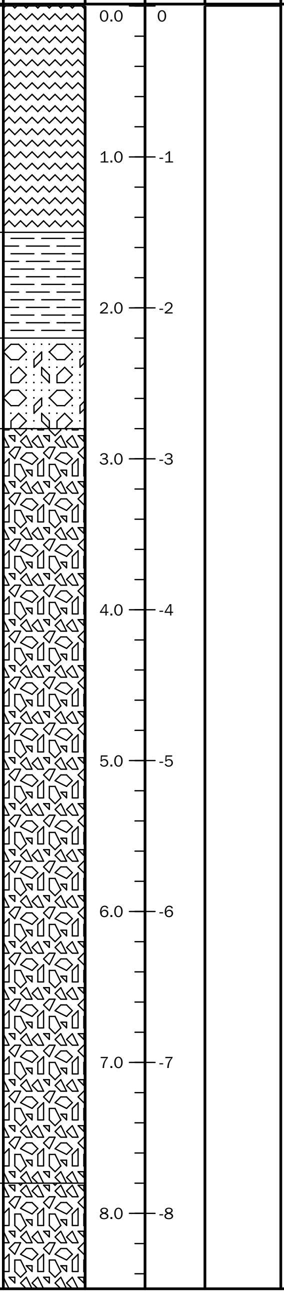
HOLE NO. **HB10 (Forbes)**
JOB NO:

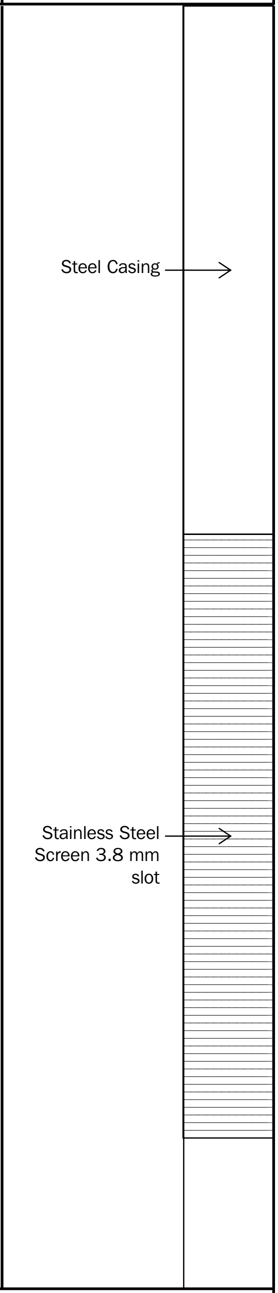
CLIENT: Beca Carter	LOCATION: Masterton
START DATE: Unknown END DATE:	COORDINATES: 1825355 5459150
TOTAL DEPTH: 8.5 m	LOGGED BY: G Butcher
SHEET 1 OF 1	

GROUND LEVEL: --
TOP OF CASING: --

INTERPRE-TATION	DESCRIPTION OF SOIL / ROCK (based on cuttings etc.)
	TOPSOIL
	CLAY Grey, firm with brown seams
	SANDY GRAVEL, gravel up to 10mm
	GRAVEL some WOOD, grey, rounded, size up to 100mm incr. with depth, incr. flow with depth
	GRAVEL grey/brown, tight, 80% loss of flow

GRAPHIC LOG | DEPTH (m) | RL (m) | DRILLING DEPTH / DATE | WATER LEVEL GAIN / LOSS | SAMPLES / TESTS | INSTALLATION





END OF BOREHOLE AT 8.5m

Notes: Redrawn from Water Permit Application Report

KEY
⊽ Groundwater Level
← Water Gain
→ Water Loss
● Grab sample

Drilled By: Wairarapa Drilling
Diameter: 300 mm
Method: Air Rotary
Datum:

Filename: HB10 (Forbes)

Logs based on New Zealand Geomechanics Society Field Description Guidelines (2005)

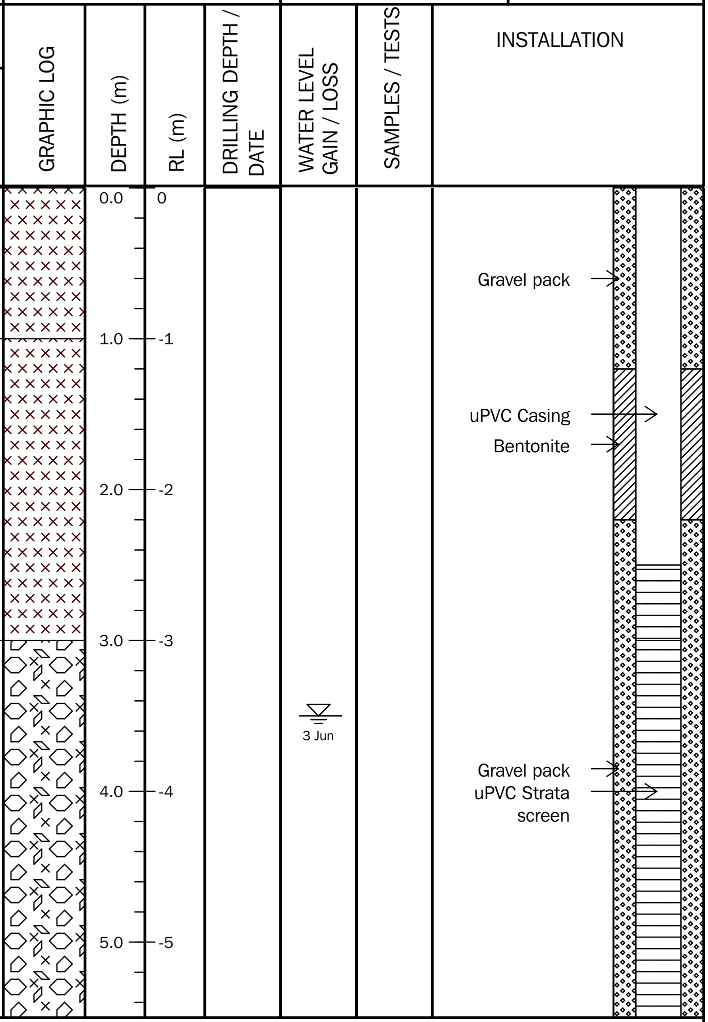
JOB NO: WJ371
WJ371 Steeby

LOG OF BOREHOLE
Masterton Oxidation Ponds

HOLE NO. **HB11 (Steeby)**

CLIENT: Beca Carter Hollings & Ferner
LOCATION: Masterton
START DATE: 4/06/2003
END DATE: 4/06/2003
COORDINATES:
TOTAL DEPTH: 5.5 m
LOGGED BY: DA
SHEET 1 OF 1
GROUND LEVEL: --
RL TOP OF CASING: --

INTERPRE-TATION	DESCRIPTION OF SOIL / ROCK (based on cuttings etc.)
	SILT. Light brown, dry with some minor wood
	SILT. Grey, moist, plastic
	GRAVEL with some silt. Grey medium to coarse. Silt brown.



END OF BOREHOLE AT 5.5m

Drilled By: Wairarapa Drilling
Diameter: 50 mm
Method: Air Rotary
Datum:
Notes:

KEY
⊽ Groundwater Level
← Water Gain
→ Water Loss
● Grab sample

PATTLE DELAMORE PARTNERS LTD

Logs based on New Zealand Geomechanics Society Field Description Guidelines (1988)

PATTLE DELAMORE PARTNERS LTD

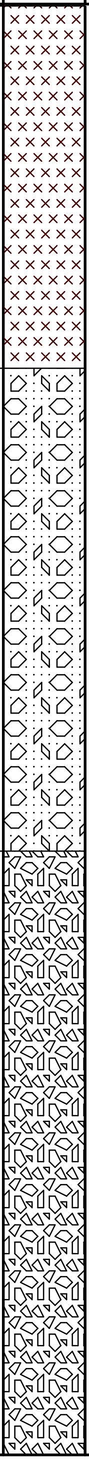
LOG OF BOREHOLE

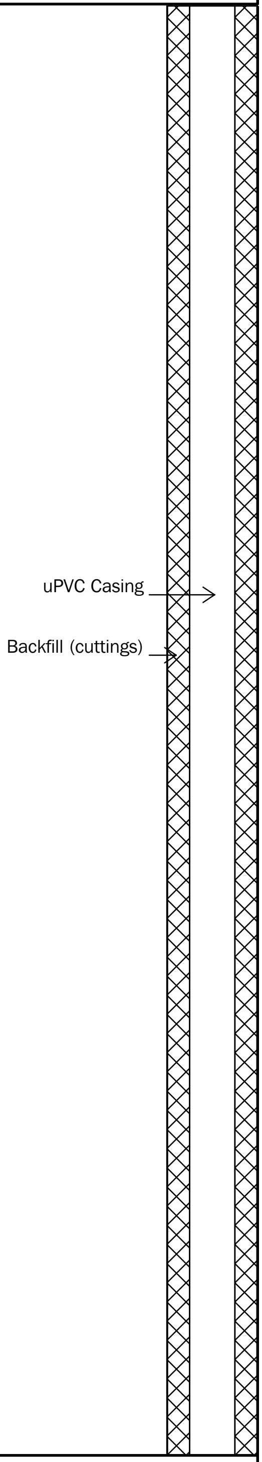
Masterton Wastewater Phase 1 Investigation

HOLE NO. **HB12**
JOB NO: WJ292_03

CLIENT: Beca Carter	LOCATION: Forbes Farm, Masterton
START DATE: 29/03/2004 END DATE: 29/03/2004	COORDINATES: 1825709 5459847
TOTAL DEPTH: 4.8 m	LOGGED BY: AB, PL
SHEET 1 OF 2	
GROUND LEVEL: -- TOP OF CASING: --	

INTERPRETATION	DESCRIPTION OF SOIL / ROCK (based on cuttings etc.)	GRAPHIC LOG	DEPTH (m)	RL (m)	DRILLING DEPTH / DATE	WATER LEVEL GAIN / LOSS	SAMPLES / TESTS	INSTALLATION
	SILT. River silts		0.0 1.0	0 -1				
	SANDY GRAVEL. Dry, Grey		2.0	-2				
	GRAVEL. Grey, increased flow with depth		3.0 4.0	-3 -4				





END OF BOREHOLE AT 4.8m

Notes:

KEY
- ∇ Groundwater Level
- ← Water Gain
- → Water Loss
- ● Grab sample

Drilled By:	Kerry Hare, Waiarapa Drilling
Diameter:	50 mm
Method:	Drilling
Datum:	
Filename:	Logplot data masterton well HB12

Logs based on New Zealand Geomechanics Society Field Description Guidelines (2005)

PATTLE DELAMORE PARTNERS LTD

LOG OF BOREHOLE

Masterton Wastewater Phase 1 Investigation

HOLE NO. **HB12**
JOB NO: WJ292_03

CLIENT: Beca Carter
LOCATION: Forbes Farm, Masterton

START DATE: 29/03/2004
END DATE: 29/03/2004
COORDINATES: 1825709 5459847
TOTAL DEPTH: 4.8 m
LOGGED BY: AB, PL
SHEET 2 OF 2

GROUND LEVEL: --
TOP OF CASING: --

INTERPRE-TATION	DESCRIPTION OF SOIL / ROCK (based on cuttings etc.)	GRAPHIC LOG	DEPTH (m)	RL (m)	DRILLING DEPTH / DATE	WATER LEVEL GAIN / LOSS	SAMPLES / TESTS	INSTALLATION

Notes:

KEY
⊽ Groundwater Level
← Water Gain
→ Water Loss
● Grab sample

Drilled By: Kerry Hare, Waiarapa Drilling
Diameter: 50 mm
Method: Drilling
Datum:

Filename: Logplot data masterton well HB12

Logs based on New Zealand Geomechanics Society Field Description Guidelines (2005)

PATTLE DELAMORE PARTNERS LTD

LOG OF BOREHOLE

Masterton Wastewater Phase 1 Investigation

HOLE NO. **HB13**
JOB NO: WJ292_03

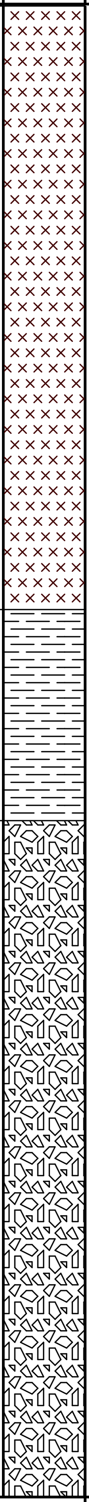
CLIENT: Beca Carter
LOCATION: Forbes Farm, Masterton

START DATE: 30/03/2004
END DATE: 30/03/2004
COORDINATES: 1825562 5460177
TOTAL DEPTH: 5.0 m
LOGGED BY: AB, PL
SHEET 1 OF 2

GROUND LEVEL: --
TOP OF CASING: --

INTERPRE-TATION	DESCRIPTION OF SOIL / ROCK (based on cuttings etc.)
	SILT. Top river silts
	CLAY. Grey, soft
	GRAVEL. Grey, increased flow with depth

GRAPHIC LOG



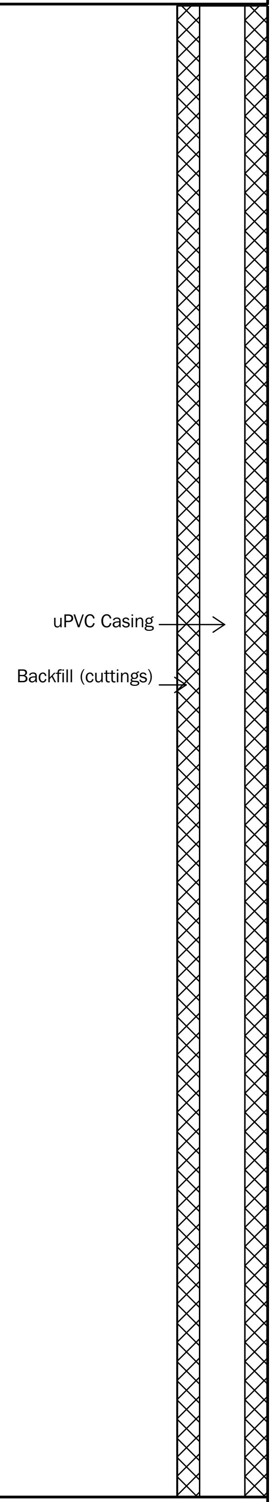
DEPTH (m)	RL (m)
0.0	0
1.0	-1
2.0	-2
3.0	-3
4.0	-4

DRILLING DEPTH / DATE

WATER LEVEL GAIN / LOSS

SAMPLES / TESTS

INSTALLATION



Notes:

KEY
- Groundwater Level
- Water Gain
- Water Loss
- ● Grab sample

Drilled By: Kerry Hare, Waiarapa Drilling
Diameter: 50 mm
Method: Drilling
Datum:

Filename: Logplot data Masterton well HB13

Logs based on New Zealand Geomechanics Society Field Description Guidelines (2005)

PATTLE DELAMORE PARTNERS LTD

LOG OF BOREHOLE

Masterton Wastewater Phase 1 Investigation

HOLE NO. **HB13**

JOB NO: WJ292_03

CLIENT: Beca Carter

LOCATION: Forbes Farm, Masterton

START DATE: 30/03/2004
END DATE: 30/03/2004

COORDINATES: 1825562
5460177

TOTAL DEPTH: 5.0 m

LOGGED BY: AB, PL

SHEET 2 OF 2

GROUND LEVEL: --
TOP OF CASING: --

INTERPRE-TATION	DESCRIPTION OF SOIL / ROCK (based on cuttings etc.)	GRAPHIC LOG	DEPTH (m)	RL (m)	DRILLING DEPTH / DATE	WATER LEVEL GAIN / LOSS	SAMPLES / TESTS	INSTALLATION
			5.0	-5				☒ ☒

END OF BOREHOLE AT 5.0m

Notes:

KEY
- Groundwater Level
- ← Water Gain
- → Water Loss
- ● Grab sample

Drilled By: Kerry Hare, Waiarapa Drilling
Diameter: 50 mm
Method: Drilling
Datum:

Filename: Logplot data Masterton well HB13

Logs based on New Zealand Geomechanics Society Field Description Guidelines (2005)

PATTLE DELAMORE PARTNERS LTD

LOG OF BOREHOLE

Masterton Wastewater Phase 1 Investigation

HOLE NO. **HB14**
JOB NO: WJ292_03

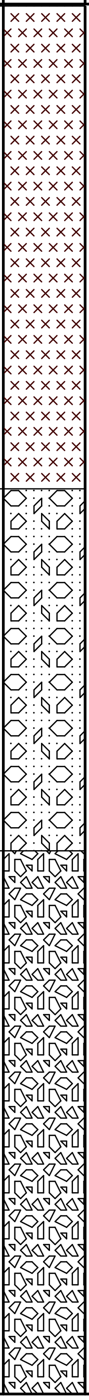
CLIENT: Beca Carter
LOCATION: Forbes Farm, Masterton

START DATE: 30/03/2004
END DATE: 30/03/2004
COORDINATES: 1825564 5459932
TOTAL DEPTH: 4.6 m
LOGGED BY: AB, PL
SHEET 1 OF 1

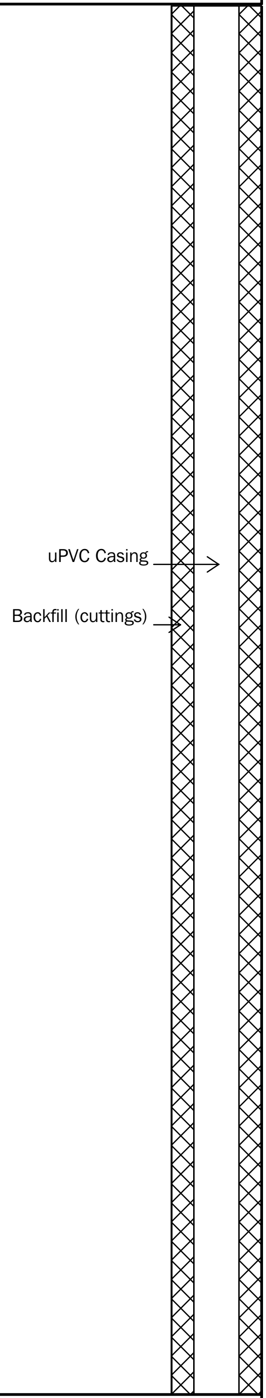
GROUND LEVEL: --
TOP OF CASING: --

INTERPRETATION	DESCRIPTION OF SOIL / ROCK (based on cuttings etc.)	DEPTH (m)	RL (m)	DRILLING DEPTH / DATE	WATER LEVEL GAIN / LOSS	SAMPLES / TESTS
	SILT. Top river silts	0.0	0			
		1.0	-1			
	SANDY GRAVEL. Grey, dry	2.0	-2			
	GRAVEL. Grey, up to 80mm, increased flow with depth	3.0	-3			
		4.0	-4			

GRAPHIC LOG



INSTALLATION



END OF BOREHOLE AT 4.6m

Notes:

KEY
▽ Groundwater Level
← Water Gain
→ Water Loss
● Grab sample

Drilled By: Kerry Hare, Waiarapa Drilling
Diameter: 50 mm
Method: Drilling
Datum:

Filename: Logplot data Masterton well HB14

Logs based on New Zealand Geomechanics Society Field Description Guidelines (2005)

PATTLE DELAMORE PARTNERS LTD

LOG OF BOREHOLE

Masterton Wastewater Phase 1 Investigation

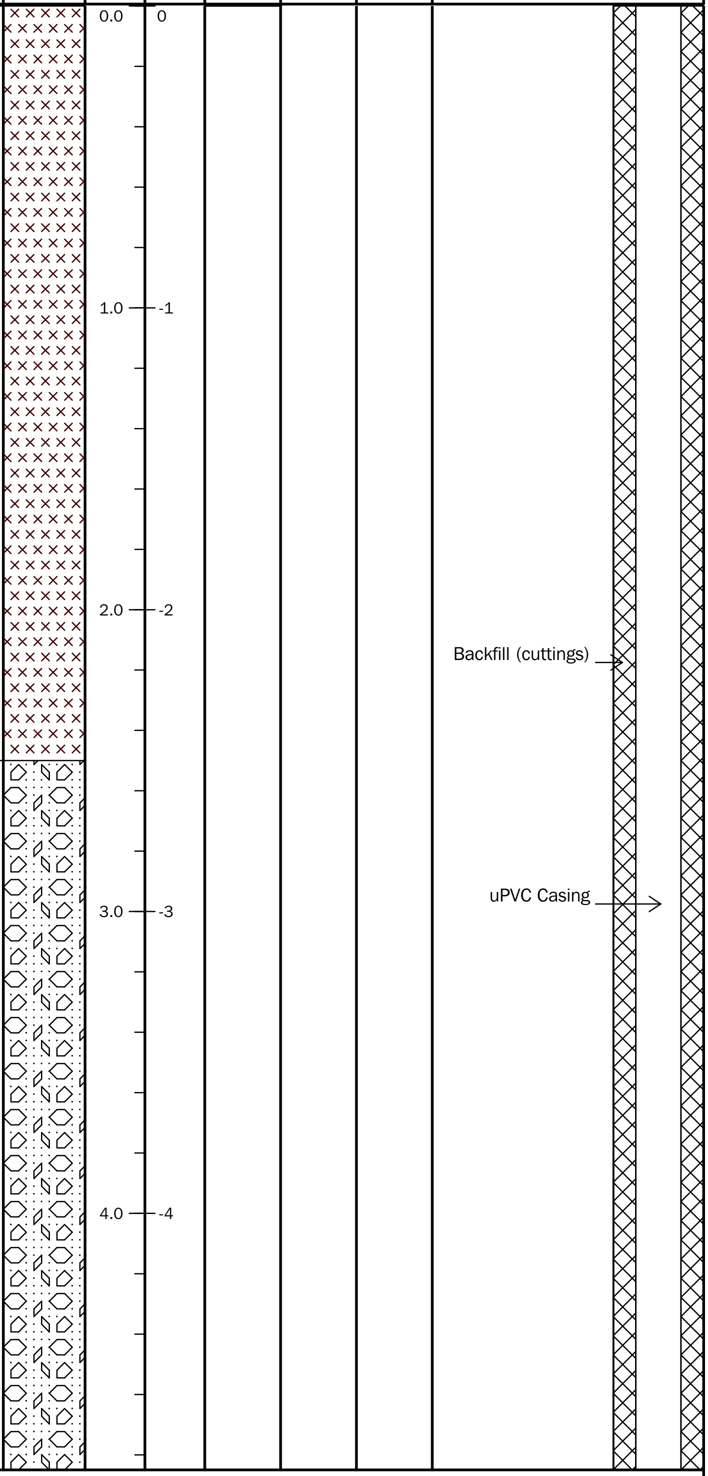
HOLE NO. **HB15**
JOB NO: WJ292_03

CLIENT: Beca Carter
LOCATION: Forbes Farm, Masterton

START DATE: 29/03/2004
END DATE: 29/03/2004
COORDINATES: 1825814 5458907
TOTAL DEPTH: 4.9 m
LOGGED BY: AB, PL
SHEET 1 OF 2

GROUND LEVEL: --
TOP OF CASING: --

INTERPRE-TATION	DESCRIPTION OF SOIL / ROCK (based on cuttings etc.)	GRAPHIC LOG	DEPTH (m)	RL (m)	DRILLING DEPTH / DATE	WATER LEVEL GAIN / LOSS	SAMPLES / TESTS	INSTALLATION
	SILT. Top river silts		0.0	0				
	SANDY GRAVEL. Grey, up to 50mm, damp							



END OF BOREHOLE AT 4.85m

Notes:

KEY
▽ Groundwater Level
← Water Gain
→ Water Loss
● Grab sample

Drilled By: Kerry Hare, Waiarapa Drilling
Diameter: 50 mm
Method: Drilling
Datum:
Filename: Logplot data Masterton well HB15

Logs based on New Zealand Geomechanics Society Field Description Guidelines (2005)

PATTLE DELAMORE PARTNERS LTD

LOG OF BOREHOLE
Masterton Wastewater Phase 1 Investigation

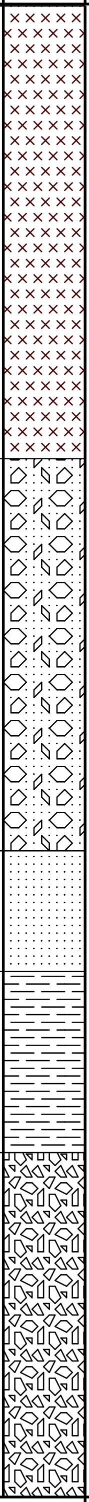
HOLE NO. **HB16**
JOB NO: WJ292_03

CLIENT: Beca Carter	LOCATION: Forbes Farm, Masterton
START DATE: 29/03/2004 END DATE: 29/03/2004	COORDINATES: 1825992 5458981
TOTAL DEPTH: 5.1 m	LOGGED BY: AB, PL
SHEET 1 OF 2	

GROUND LEVEL: --
TOP OF CASING: --

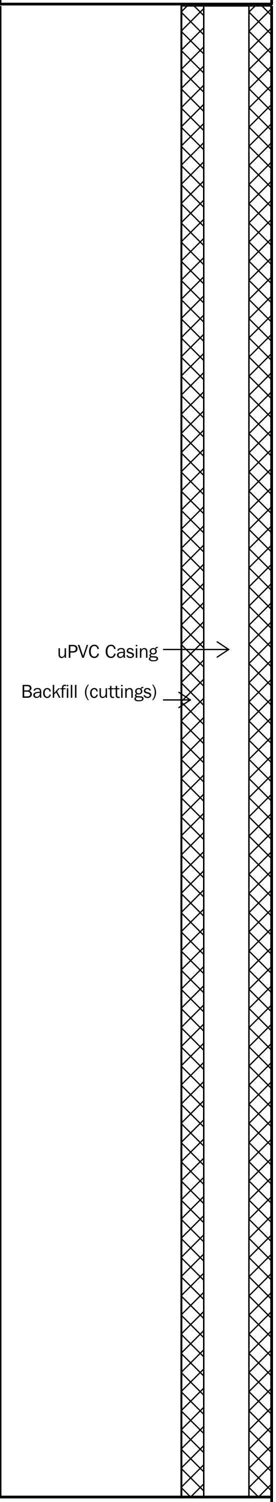
INTERPRETATION	DESCRIPTION OF SOIL / ROCK (based on cuttings etc.)
	SILT. Top river silts
	SANDY GRAVEL. Grey, dry
	SAND. Grey
	CLAY. Grey
	GRAVEL. Grey, gravels up to 80mm, increased flow with depth

GRAPHIC LOG



DEPTH (m)	RL (m)	DRILLING DEPTH / DATE	WATER LEVEL GAIN / LOSS	SAMPLES / TESTS
0.0	0			
1.0	-1			
2.0	-2			
3.0	-3			
4.0	-4			

INSTALLATION



Notes:

KEY
- ⊽ Groundwater Level
- ← Water Gain
- → Water Loss
- ● Grab sample

Drilled By: Kerry Hare, Waiarapa Drilling
Diameter: 50 mm
Method: Drilling
Datum:

Filename: Logplot data Masterton well HB16

Logs based on New Zealand Geomechanics Society Field Description Guidelines (2005)

PATTLE DELAMORE PARTNERS LTD

LOG OF BOREHOLE

Masterton Wastewater Phase 1 Investigation

HOLE NO. **HB16**

JOB NO: WJ292_03

CLIENT: Beca Carter

LOCATION: Forbes Farm, Masterton

START DATE: 29/03/2004
END DATE: 29/03/2004

COORDINATES: 1825992
5458981

TOTAL DEPTH: 5.1 m

LOGGED BY: AB, PL

SHEET 2 OF 2

GROUND LEVEL: --
TOP OF CASING: --

INTERPRE-TATION	DESCRIPTION OF SOIL / ROCK (based on cuttings etc.)	GRAPHIC LOG	DEPTH (m)	RL (m)	DRILLING DEPTH / DATE	WATER LEVEL GAIN / LOSS	SAMPLES / TESTS	INSTALLATION
			5.0	-5				☒ ☒

END OF BOREHOLE AT 5.1m

Notes:

KEY
Groundwater Level
Water Gain
Water Loss
● Grab sample

Drilled By: Kerry Hare, Waiarapa Drilling
Diameter: 50 mm
Method: Drilling
Datum:

Filename: Logplot data Masterton well HB16

Logs based on New Zealand Geomechanics Society Field Description Guidelines (2005)

PATTLE DELAMORE PARTNERS LTD

LOG OF BOREHOLE

Masterton Wastewater Phase 1 Investigation

HOLE NO. **HB17**
JOB NO: WJ292_03

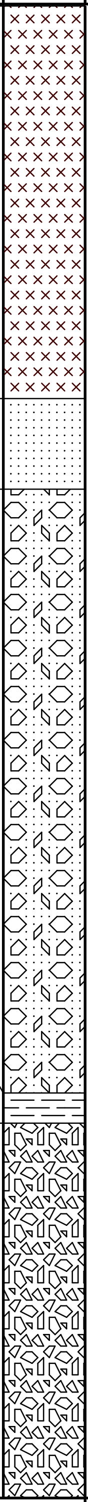
CLIENT: Beca Carter
LOCATION: Forbes Farm, Masterton

START DATE: 29/03/2004
END DATE: 29/03/2004
COORDINATES: 1826176 5458831
TOTAL DEPTH: 5.2 m
LOGGED BY: AB, PL
SHEET 1 OF 2

GROUND LEVEL: --
TOP OF CASING: --

INTERPRE-TATION	DESCRIPTION OF SOIL / ROCK (based on cuttings etc.)
	SILT. Top river silts
	SAND. Grey
	SANDY GRAVEL. Grey, gravels up to 50mm, damp
	CLAY. grey, dense
	GRAVEL. Grey, gravels up to 80mm, increased flow with depth

GRAPHIC LOG



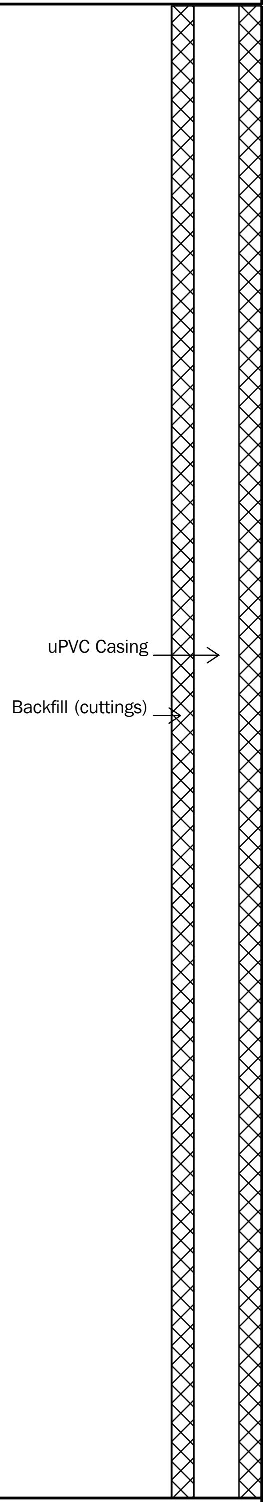
DEPTH (m)	RL (m)
0.0	0
1.0	-1
2.0	-2
3.0	-3
4.0	-4

DRILLING DEPTH / DATE

WATER LEVEL GAIN / LOSS

SAMPLES / TESTS

INSTALLATION



Notes:

KEY
Groundwater Level
Water Gain
Water Loss
● Grab sample

Drilled By: Kerry Hare, Waiarapa Drilling
Diameter: 50 mm
Method: Drilling
Datum:

Filename: Logplot data Masterton well HB17

Logs based on New Zealand Geomechanics Society Field Description Guidelines (2005)

PATTLE DELAMORE PARTNERS LTD

LOG OF BOREHOLE

Masterton Wastewater Phase 1 Investigation

HOLE NO. **HB17**
JOB NO: WJ292_03

CLIENT: Beca Carter
LOCATION: Forbes Farm, Masterton

START DATE: 29/03/2004
END DATE: 29/03/2004
COORDINATES: 1826176
5458831
TOTAL DEPTH: 5.2 m
LOGGED BY: AB, PL
SHEET 2 OF 2

GROUND LEVEL: --
TOP OF CASING: --

INTERPRE-TATION	DESCRIPTION OF SOIL / ROCK (based on cuttings etc.)	GRAPHIC LOG	DEPTH (m)	RL (m)	DRILLING DEPTH / DATE	WATER LEVEL GAIN / LOSS	SAMPLES / TESTS	INSTALLATION
		▨	5.0	-5				☒ ☒

END OF BOREHOLE AT 5.2m

Notes:

KEY
Groundwater Level
Water Gain
Water Loss
● Grab sample

Drilled By: Kerry Hare, Waiarapa Drilling
Diameter: 50 mm
Method: Drilling
Datum:
Filename: Logplot data Masterton well HB17

Logs based on New Zealand Geomechanics Society Field Description Guidelines (2005)

JOB NO: WJ29205

LOG OF BOREHOLE
Masterton Oxidation Ponds

HOLE NO. **HB18**

CLIENT: Beca Carter Ltd

LOCATION: East Bank of Makoura Stream

START DATE: 3/3/05
END DATE: 4/3/05

COORDINATES: 2735434.70 6021441.37

TOTAL DEPTH: 14.5

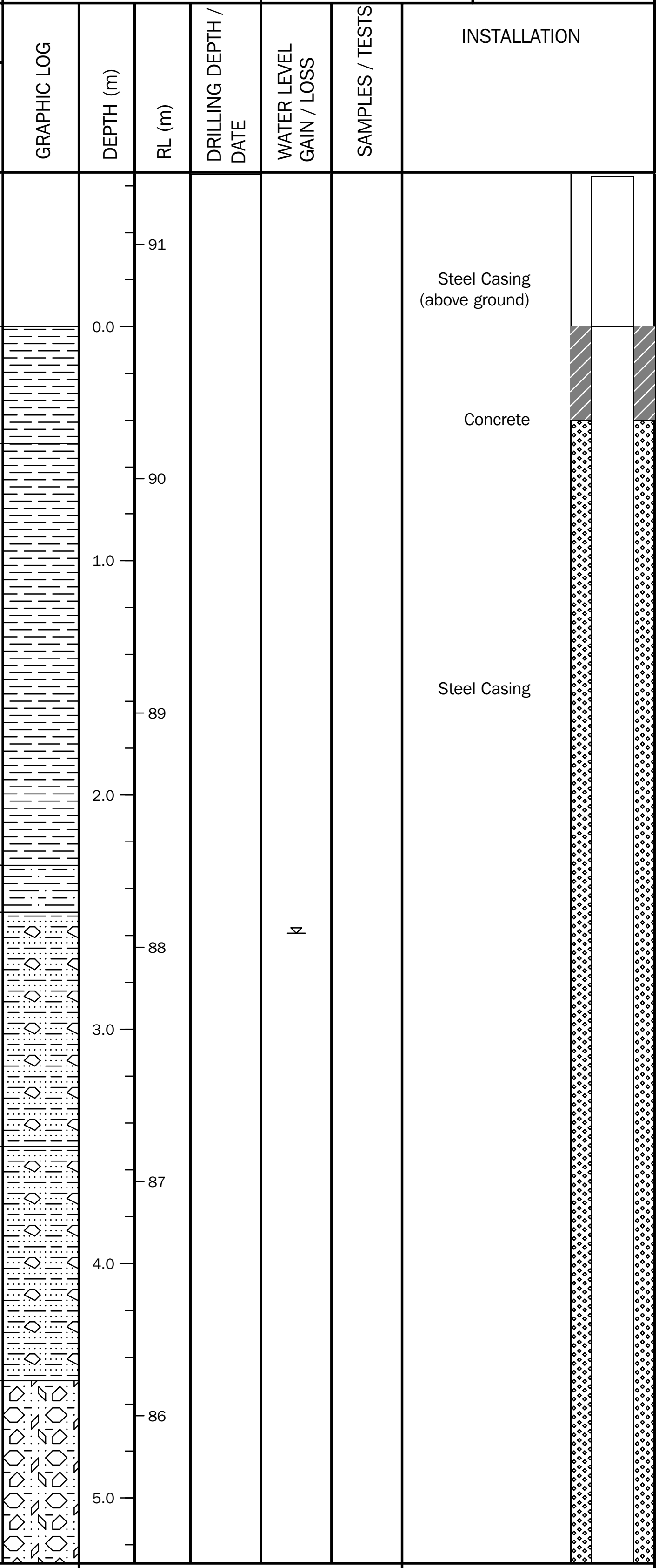
LOGGED BY: HL

SHEET 1 OF 3

GROUND LEVEL: 90.65

RL TOP OF CASING: 91.29

INTERPRE-TATION	DESCRIPTION OF SOIL / ROCK (based on cuttings etc.)
	CLAY. Light brown, soft, dry. TOPSOIL.
	CLAY. Light brown, soft, dry.
	CLAY. Brown, wet, plastic. Sand fine.
	CLAYEY SAND with some gravel. Brown, saturated. Sand fine to medium, sub-angular. Gravel sub-rounded, 5-20 mm, greywacke.
	CLAYEY SAND with some gravel. Brown, saturated. Sand fine to medium, sub-angular. Gravel sub-rounded, 5-20 mm, greywacke.
	SANDY GRAVEL with minor clay. Brown, saturated. Gravel fine-medium, 5-20 mm, sub-rounded, grewacke, some coloured stones. Sand fine-medium.



Drilled By: Wairarapa Drilling
Diameter: 150 mm
Method: Air Rotary Drilling
Datum: MSL
Notes:

KEY
Groundwater Level
Water Gain
Water Loss
● Grab sample

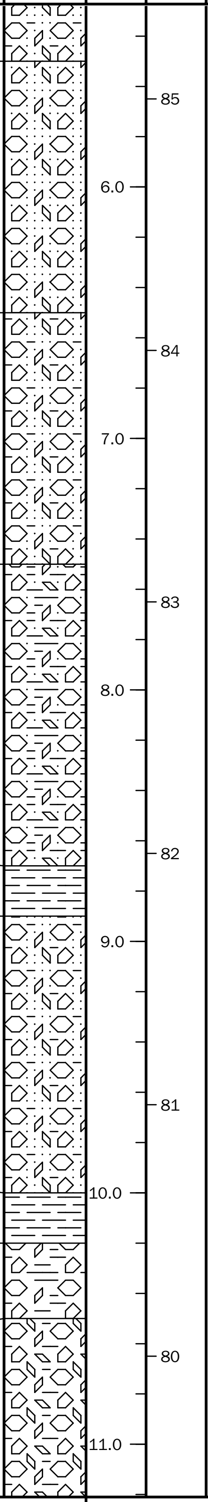
PATTLE DELAMORE PARTNERS LTD

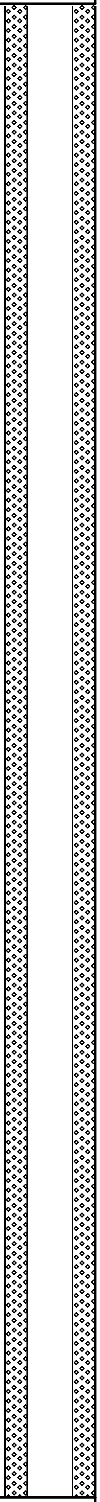
Logs based on New Zealand Geomechanics Society Field Description Guidelines (1988)

JOB NO: WJ29205	**LOG OF BOREHOLE** **Masterton Oxidation Ponds**	HOLE NO. **HB18**

CLIENT: Beca Carter Ltd		LOCATION: East Bank of Makoura Stream		
START DATE: 3/3/05 END DATE: 4/3/05	COORDINATES: 2735434.70 6021441.37	TOTAL DEPTH: 14.5	LOGGED BY: HL	SHEET 2 OF 3
GROUND LEVEL: 90.65	RL TOP OF CASING: 91.29			

INTERPRE-TATION	DESCRIPTION OF SOIL / ROCK (based on cuttings etc.)	GRAPHIC LOG	DEPTH (m)	RL (m)	DRILLING DEPTH / DATE	WATER LEVEL GAIN / LOSS	SAMPLES / TESTS	INSTALLATION
	SANDY GRAVEL. Blueish grey, saturated. Gravel 5-30 mm, sub-rounded, grewacke. Sand coarse.							
	SANDY GRAVEL with some clay. Blueish grey, saturated. Gravel 5-30 mm, sub-rounded, grewacke. Sand coarse.							
	CLAYEY GRAVEL with some sand. Blueish grey, saturated. Gravel sub-rounded, 5-15 mm, greywacke. Clay blue. Sand coarse. No water.							
	CLAY. Light brown, saturated, plastic, soft. No water.							
	SANDY GRAVEL with some clay. Blueish grey, saturated. Gravel 5-40 mm, sub-rounded, greywacke. Sand coarse. Clay blueish grey.							
	CLAY. Light brown, saturated, plastic, soft. No water.							
	CLAYBOUND GRAVEL. Blueish grey. Gravel fine-medium, 2-10 mm. Clay blueish grey.							
	GRAVEL with some clay. Grey, saturated. Gravels fine-medium, 2-10 mm. Clay blueish grey. Water-bearing.							





Drilled By: Wairarapa Drilling
Diameter: 150 mm
Method: Air Rotary Drilling
Datum: MSL
Notes:

KEY
- Groundwater Level
- ← Water Gain
- → Water Loss
- ● Grab sample

PATTLE DELAMORE PARTNERS LTD

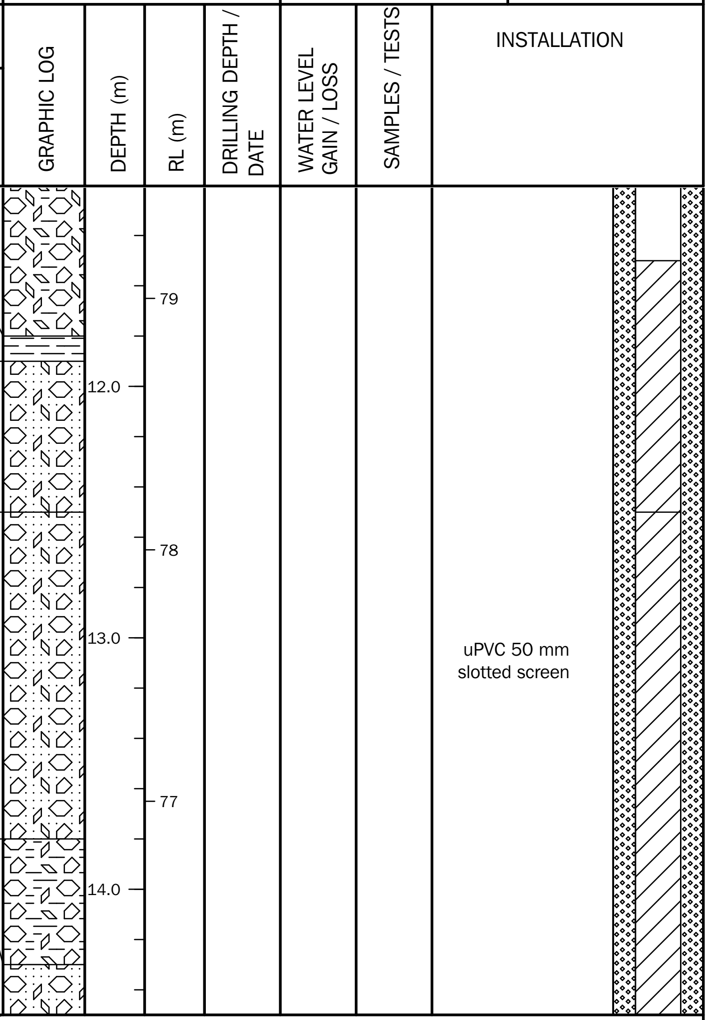
Logs based on New Zealand Geomechanics Society Field Description Guidelines (1988)

JOB NO: WJ29205	**LOG OF BOREHOLE** **Masterton Oxidation Ponds**	HOLE NO. **HB18**

CLIENT: Beca Carter Ltd	LOCATION: East Bank of Makoura Stream

START DATE: 3/3/05 END DATE: 4/3/05	COORDINATES: 2735434.70 6021441.37	TOTAL DEPTH: 14.5	LOGGED BY: HL	SHEET 3 OF 3
GROUND LEVEL: 90.65	RL TOP OF CASING: 91.29			

INTERPRE-TATION	DESCRIPTION OF SOIL / ROCK (based on cuttings etc.)
	CLAY. Light brown, saturated, plastic, soft. No water.
	SANDY GRAVEL. Grey, saturated. Gravels fine-coarse, 2-50 mm. Sand coarse. Gravel greywacke with some coloured stones. Water bearing.
	SANDY GRAVEL. Grey, saturated. Gravels fine-medium, 2-20 mm. Sand coarse. Gravel greywacke with some coloured stones. Water bearing.
	CLAYEY GRAVEL. Light brown, saturated. Gravel fine-medium, 2-20 mm, greywacke. No water.
	SANDY GRAVEL. Grey, saturated. Gravels fine-medium, 2-20 mm. Sand coarse. Gravel greywacke with some coloured stones. Water bearing.



END OF BOREHOLE AT 14.5 m

Drilled By: Wairarapa Drilling
Diameter: 150 mm
Method: Air Rotary Drilling
Datum: MSL
Notes:

KEY
⊽ Groundwater Level
← Water Gain
→ Water Loss
● Grab sample

PATTLE DELAMORE PARTNERS LTD

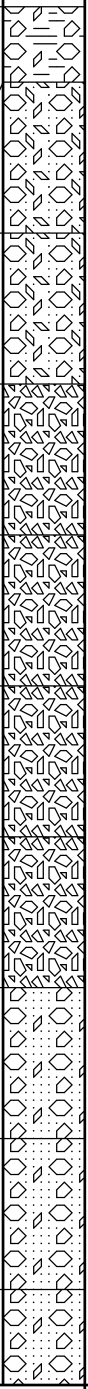
Logs based on New Zealand Geomechanics Society Field Description Guidelines (1988)

JOB NO: WJ29205	**LOG OF BOREHOLE** **Masterton Oxidation Ponds**	HOLE NO. **HB19**

CLIENT: Beca Carter Ltd		LOCATION: West Bank of Makoura Stream		
START DATE: 2/3/05 END DATE: 3/3/05	COORDINATES: 2735166.70 6020222.70	TOTAL DEPTH: 17.5	LOGGED BY: HL/MC	SHEET 1 OF 2
GROUND LEVEL: 85.65	RL TOP OF CASING: 86.37			

INTERPRETATION	DESCRIPTION OF SOIL / ROCK (based on cuttings etc.)
	GRAVELLY CLAY. Brownish grey, uniform grading, moist. Gravel sub-rounded, medium, 7-10mm,greywacke. Clay brown, large organic content.
	GRAVEL with some sand. Brownish grey, moist. Gravel sub-angular, medium, grain size 10mm. Sand very coarse.
	GRAVEL with some sand. Brownish grey, wet. Bi-modal (large grains up to 40 mm, small 2-5 mm). Gravel sub-angular to sub-rounded. Sand very coarse.
	GRAVEL. Clean, brown. Gravel medium (less than 15 mm), angular to sub-angular. Sand coarse.
	GRAVEL. Clean, brown. Gravel medium (less than 20 mm, average 5 mm), angular to sub-angular. Sand coarse.
	GRAVEL. Clean, brown. Gravel medium (average 10 mm), angular to sub-angular. Sand coarse.
	GRAVEL. Clean, brown. Gravel medium (average 10 mm), angular to sub-angular. Sand coarse.
	GRAVELLY SAND. Grey. Sand coarse. Gravel medium (average 5 mm).
	GRAVELLY SAND. Grey. Sand medium-coarse. Gravel medium (average 5 mm) angular to sub-angular.
	GRAVELLY SAND. Grey. Sand fine-coarse (poorly sorted). Gravel medium (average 5 mm) angular to sub-angular.

GRAPHIC LOG



DEPTH (m): 0.0, 1.0, 2.0, 3.0, 4.0, 5.0, 6.0, 7.0, 8.0, 9.0

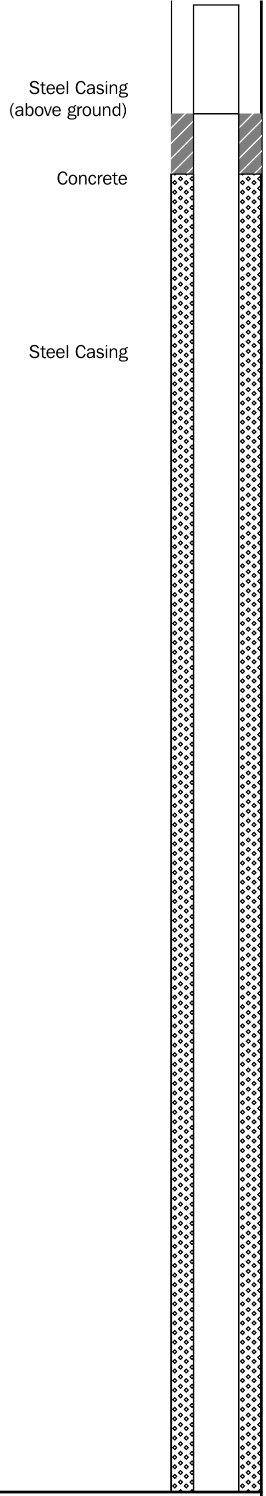
RL (m): 86, 85, 84, 83, 82, 81, 80, 79, 78, 77

DRILLING DEPTH / DATE

WATER LEVEL GAIN / LOSS: Water level 1.460 m below casing on 2/3/05

SAMPLES / TESTS

INSTALLATION



Drilled By: Wairarapa Drilling
Diameter: 150
Method: Air Rotary Drilling
Datum: MSL
Notes:

KEY
▽ Groundwater Level
← Water Gain
→ Water Loss
● Grab sample

PATTLE DELAMORE PARTNERS LTD

Logs based on New Zealand Geomechanics Society Field Description Guidelines (1988)

JOB NO: WJ29205

LOG OF BOREHOLE
Masterton Oxidation Ponds

HOLE NO. **HB19**

CLIENT: Beca Carter Ltd

LOCATION: West Bank of Makoura Stream

START DATE: 2/3/05
END DATE: 3/3/05

COORDINATES: 2735166.70 6020222.70

TOTAL DEPTH: 17.5

LOGGED BY: HL/MC

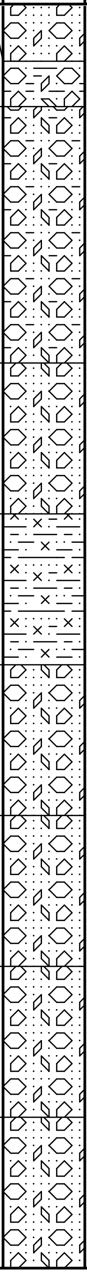
SHEET 2 OF 2

GROUND LEVEL: 85.65

RL TOP OF CASING: 86.37

INTERPRETATION	DESCRIPTION OF SOIL / ROCK (based on cuttings etc.)
	CLAYEY GRAVEL with some sand. Blueish grey, saturated. Gravel fine-medium, 3-15 mm, sub-rounded, greywacke. Clay blue. Sand coarse. No water.
	SANDY GRAVEL with minor clay. Brown, saturated. Gravel fine-medium, average 3 mm, sub-rounded, grewacke. Sand fine. Some brown clay.
	SANDY GRAVEL. Brown. Gravels medium, average 7 mm, sub-rounded. Sand medium-coarse.
	SANDY GRAVEL with minor clay. Brown, saturated. Gravel fine-medium, average 4 mm, sub-rounded, grewacke. Sand fine. Some brown clay.
	SANDY GRAVEL. Brown. Gravels medium, average 3 mm up to 20 mm, sub-rounded. Sand coarse.
	SANDY GRAVEL. Brown. Gravels medium, average 3 mm up to 20 mm, sub-rounded. Sand medium-coarse.
	SANDY GRAVEL. Brown. Gravels medium, average 3 mm up to 20 mm, sub-rounded. Sand medium-coarse.
	SANDY GRAVEL. Brown. Gravels medium, average 3 mm up to 20 mm, sub-rounded. Sand fine-coarse, poorly sorted.

GRAPHIC LOG



DEPTH (m): 10.0, 11.0, 12.0, 13.0, 14.0, 15.0, 16.0, 17.0

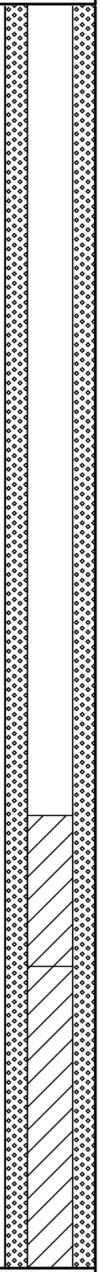
RL (m): 76, 75, 74, 73, 72, 71, 70, 69

DRILLING DEPTH / DATE

WATER LEVEL GAIN / LOSS

SAMPLES / TESTS

INSTALLATION



uPVC 50 mm
slotted screen

END OF BOREHOLE AT 17.5 m

Drilled By: Wairarapa Drilling
Diameter: 150
Method: Air Rotary Drilling
Datum: MSL
Notes:

KEY
Groundwater Level
Water Gain
Water Loss
● Grab sample

PATTLE DELAMORE PARTNERS LTD

Logs based on New Zealand Geomechanics Society Field Description Guidelines (1988)

JOB NO: WJ29205

LOG OF BOREHOLE
Masterton Oxidation Ponds

HOLE NO. **HB20**

CLIENT: Beca Carter Ltd

LOCATION: South of Access Road

START DATE: 1/3/05
END DATE: 1/3/05

COORDINATES: 2735023.58 6020007.25

TOTAL DEPTH: 4.8

LOGGED BY: HL

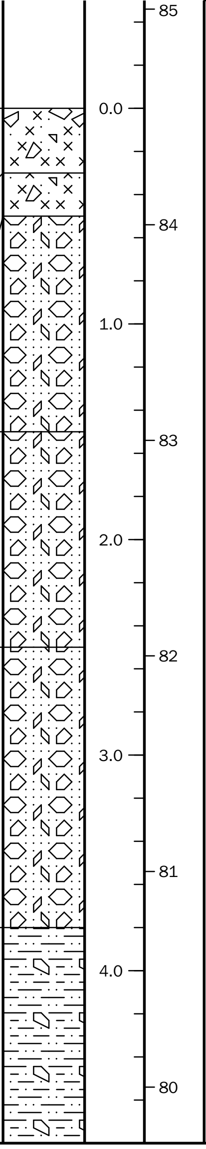
SHEET 1 OF 1

GROUND LEVEL: 84.54

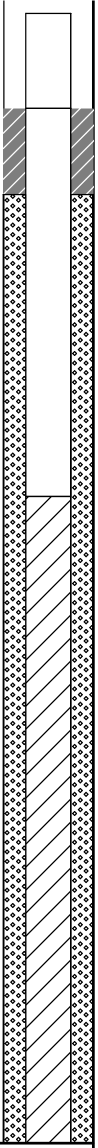
RL TOP OF CASING: 84.98

INTERPRETATION	DESCRIPTION OF SOIL / ROCK (based on cuttings etc.)	GRAPHIC LOG	DEPTH (m)	RL (m)	DRILLING DEPTH / DATE	WATER LEVEL GAIN / LOSS	SAMPLES / TESTS	INSTALLATION

	GRAVELLY SILT with sand. Dark browny grey. Gravel fine, well rounded. High organic content. TOPSOIL.
	GRAVELLY CLAY with sand. Grey, moist. Gravel fine, sub-rounded. Sand coarse. Clay plastic.
	SANDY GRAVEL. Grey, wet., gap-graded. Gravel sub-rounded, greywacke, 10-15 mm. Sand very coarse.
	SANDY GRAVEL. Grey, wet. Gravel sub-rounded, some coluored stones,greywacke, 10 mm. Sand very coarse.
	SANDY GRAVEL. Grey, wet. Gravel sub-rounded, some coluored stones,greywacke, 10 mm. Sand very coarse.
	SANDY CLAY with some gravel. Light brown. Gravel fine (5 mm), sub-rounded. No water.



Water level 0.945 m below casing on 3/3/05



Steel Casing (above ground)

Concrete

uPVC 50 mm slotted screen

END OF BOREHOLE AT 4.8 m

Drilled By: Wairarapa Drilling
Diameter: 50 mm
Method: Air Rotary Drilling
Datum: MSL
Notes:

KEY
▽ Groundwater Level
← Water Gain
→ Water Loss
● Grab sample

PATTLE DELAMORE PARTNERS LTD

Logs based on New Zealand Geomechanics Society Field Description Guidelines (1988)

JOB NO: WJ29205	**LOG OF BOREHOLE** **Masterton Oxidation Ponds**	HOLE NO. **HB21**

CLIENT: Beca Carter Ltd

LOCATION: At northern end of old stand of native trees

START DATE: 1/3/05
END DATE: 1/3/05

COORDINATES: 2735399.49 6020761.24

TOTAL DEPTH: 5.5

LOGGED BY: HL

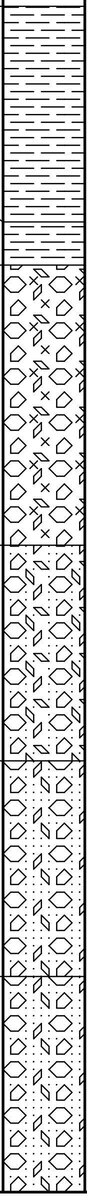
SHEET 1 OF 1

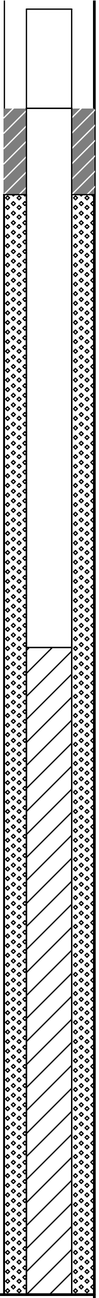
GROUND LEVEL: 88.04

RL TOP OF CASING: 88.50

INTERPRETATION	DESCRIPTION OF SOIL / ROCK (based on cuttings etc.)	DEPTH (m)	RL (m)	DRILLING DEPTH / DATE	WATER LEVEL GAIN / LOSS	SAMPLES / TESTS	INSTALLATION
							Steel Casing (above ground)
	CLAY. Light brown, dry, very fine and powdery. TOPSOIL.	0.0	88				Concrete
	CLAY. Grey, moist, plastic.	1.0	87				
	GRAVEL with some silt. Grey, saturated. Gravel gap-graded (20-30mm and 2-6 mm), sub-rounded, greywacke. Silt grey, wet, soft, plastic.	2.0	86		Water level 1.470 m below top pf PVC casing on 2/3/05		
	GRAVEL with some sand. Grey, saturated. Gravel gap-graded (10-15mm and 2-6 mm), greywacke with some coloured stones. Sand grey, very coarse.	3.0	85				
	SANDY GRAVEL. Grey, saturated. Gravel gap graded (20-30 mm, 2-6 mm), greywacke with some coloured stones. Sand grey and very coarse.	4.0	84				uPVC 50 mm slotted screen
	SANDY GRAVEL. Grey, saturated, some iron staining. Gravel gap graded (10-20 mm, 2-4 mm), greywacke. Sand grey and very coarse.	5.0	83				

GRAPHIC LOG





END OF BOREHOLE AT 5.5 m

Drilled By: Wairarapa Drilling
Diameter: 50 mm
Method: Air Rotary Drilling
Datum: MSL
Notes:

KEY
- ∇ Groundwater Level
- ← Water Gain
- → Water Loss
- ● Grab sample

PATTLE DELAMORE PARTNERS LTD

Logs based on New Zealand Geomechanics Society Field Description Guidelines (1988)

JOB NO: WJ29205

LOG OF BOREHOLE
Masterton Oxidation Ponds

HOLE NO. **HB22**

CLIENT: Beca Carter Ltd

LOCATION: North-west corner of paddock next to Pond 3

START DATE: 1/3/05
END DATE: 1/3/05

COORDINATES: 2735429.36
6020501.93

TOTAL DEPTH: 5.5

LOGGED BY: HL/MC

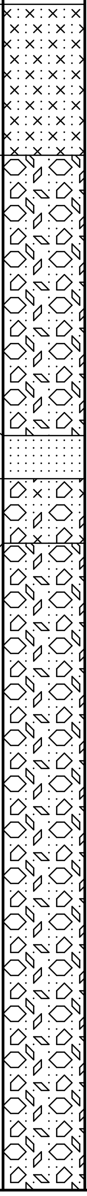
SHEET 1 OF 1

GROUND LEVEL: 86.65

RL TOP OF CASING: 87.16

INTERPRE-TATION	DESCRIPTION OF SOIL / ROCK (based on cuttings etc.)
	SANDY SILT with some gravel. Grey, very soft, moist, plastic. Gravel fine, greywacke.
	GRAVEL with some sand. Brownish grey, well-graded, moist. Gravel fine to coarse, sub-rounded greywacke. Sand coarse.
	SAND. Grey, wet, coarse.
	GRAVELLY SAND with some silt. Brownish grey, well-graded, wet. Sand coarse.
	GRAVEL with some sand. Grey, gap-graded, wet. Gravel sub-rounded, 10-15 mm, greywacke with some coloured stones. SAND grey, coarse.

GRAPHIC LOG



DEPTH (m): 0.0, 1.0, 2.0, 3.0, 4.0, 5.0

RL (m): 87, 86, 85, 84, 83, 82

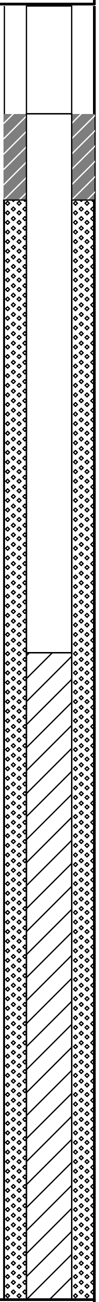
DRILLING DEPTH / DATE

WATER LEVEL GAIN / LOSS

Water level 1.105 m below top of PVC casing on 3/3/05

SAMPLES / TESTS

INSTALLATION



Steel Casing (above ground)

Concrete

uPVC 50 mm slotted screen

END OF BOREHOLE AT 5.5 m

Drilled By: Wairarapa Drilling
Diameter: 50 mm
Method: Air Rotary Drilling
Datum: MSL
Notes:

KEY
Groundwater Level
Water Gain
Water Loss
● Grab sample

PATTLE DELAMORE PARTNERS LTD

Logs based on New Zealand Geomechanics Society Field Description Guidelines (1988)