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APPENDIX 'H'

Haehanga Catchment

- Preliminary Groundwater Investigation

[BTW Limited]

REPORT

Haehanga Catchment Preliminary Groundwater Investigation

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Haehanga Catchment Preliminary Groundwater Investigation

Remediation New Zealand

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Reviewed

Report Author

1-7-2015

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Date

Reviewed by

2-7-2015

[redacted] Environmental Advisor, BSc in Environmental Studies and Geology

Date

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TABLES

FIGURES

1 INTRODUCTION

1.1 Scope

This report has been prepared for Remediation New Zealand Limited by BTW Company. This short technical report summarises available information relating to groundwater investigations in the Haehanga Catchment, adjacent to the Remediation New Zealand Uruti Composting Facility.

For a full site description and environment setting, readers are directed to the Uruti Composting Facility Management Plan. This report is a follow up investigation to further detail groundwater interactions beneath the composting facility. The investigation comprised a desktop review of available information from the three monitoring bores on site combined with soil profiles and bore permeability tests undertaken on site.

1.2 Objectives

The primary objective of the investigation was to provide addition information to support management of the groundwater resource beneath the Uruti Composting Facility.

Specific objectives were to:

- Undertake a topographical survey of the site;
- Level survey the three monitoring bore heights in Mean Sea Level (MSL) to allow groundwater elevations to be calculated;
- Undertake bore permeability tests so that groundwater velocities could be determined;
- Make recommendations for future groundwater/hydrogeological monitoring to assist site management, and;
- Produce a preliminary or unconfirmed Conceptual Site Model

2 GROUNDWATER SITE WORKS

2.1.1 Monitoring Bore Description

In February 2011, three monitoring bores (GND 2188, 2189 & 2190) were advanced on site, using a 600mm solid stem auger attached to a hydraulic digger (Cowperthwaite, pers comms 2015). The bores were advanced to 4.10metres below ground level (mbgl) for GND 2188, 3.3 m for GND 2189 and 3.45 m for GND 2190. Slotted 51.8 mm diameter PVC pipe was installed in each monitoring bore.

Monitoring bore locations are shown on the site plan in Figure 2.1-2.3. Monitoring bore construction details are in Appendix A. Photographs of the well construction are presented in Appendix B.

Although the bores were advanced under a supervision of a hydrogeologist, bore logs and/or description of the soils and aquifer properties encountered were not recorded. From available site photos taken on the day of installation, the full length of the screen appears to be slotted. This is in contrast to the design specification in Appendix A. Details related to the filter pack, cementing and/or gravel around the screen are also not accurately known. The influence this data gap has on bore development, permeability tests and velocity calculations is uncertain.

Figure 2.1:Uruti Composting Topography Survey-lower part of site. Green dot denotes GND 2190 and reduced level

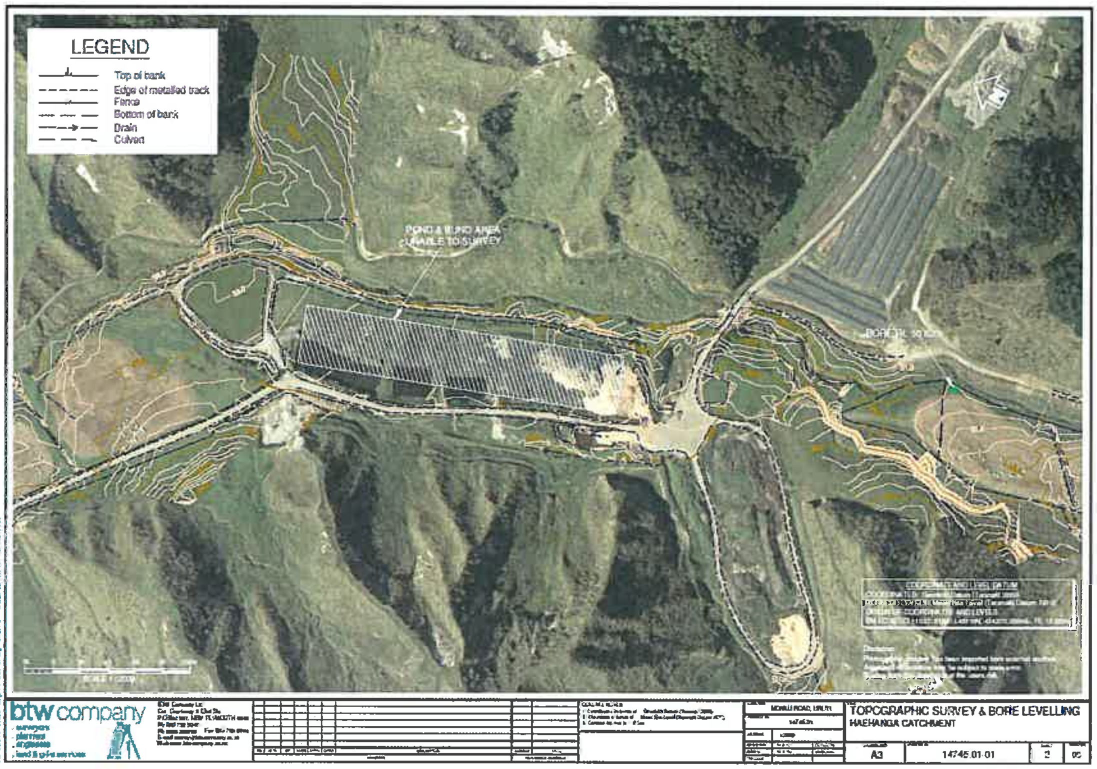

Figure 2.2:Uruti Composting Topography Survey-middle part of site. Green dot denotes GND 2189 and reduced level

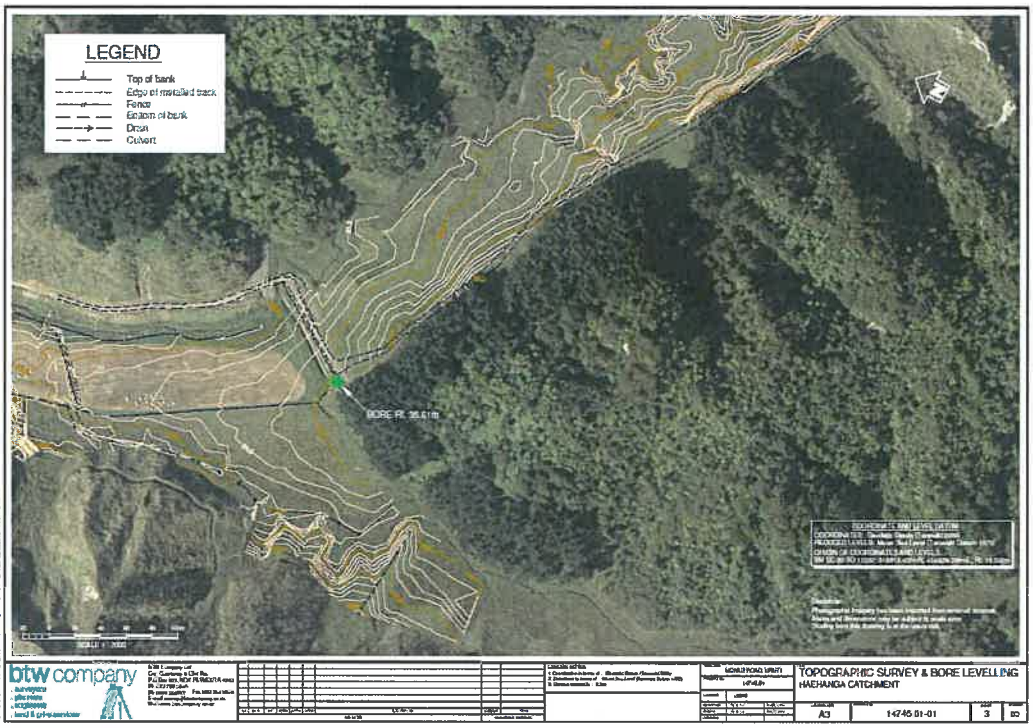

Figure 2.3:Uruti Composting Topography Survey-upper part of site. Green dot denotes GND 2188 and reduced level

2.1.2 Topographic Survey and Conceptual Site Model

GND 2188, GND 2189 and GND 2190 bores heights were surveyed by BTW Company surveyors on January 8th 2015. The survey established coordinates relative to Geodetic Datum (Taranaki 2000) and the elevation of the top of the casing relative to Mean Sea Level (Taranaki Datum 1970). BTW Company recorded spot heights adjacent each monitoring bores to corroborate surface elevation adjacent the bores.

The Topographic Survey formed the basis of the preliminary Conceptual Site Model (CSM) in Appendix D. The CSM was developed in Civil3E software, with all elevations in Mean Sea Level to the Taranaki 2000 Geodetic Datum. At present the CSM is unconfirmed and requires significantly more input to identify other potential contaminate sources and likely downstream receptors, both ecological and human. The preliminary CSM has however, defined the general hydrological setting in terms of hydraulic gradients down the Haehanga Stream, groundwater direction and hydrogeological interactions with the Uruti Composting Facility.

2.1.3 Soil and Aquifer Properties

For a description of the shallow soils encountered on the Uruti Composting Facility to two metres below ground level (mbgl), readers are directed to Section 2.3 in Uruti Composting Facility Management Plan. In brief, the soils encountered across the site were dominated by orthic brown/grey silty soils with increasing clay content at lower elevations across the site and with increasing depth. Surface soils to 250 mm deep were dominated by light brown loams and grey silty topsoil. However, between 250 mm and 1500-2000 mm, soils were characterised as silty clay with medium plasticity, traces of orange clay material, smaller particle sizes and soils were generally more friable. The shallow groundwater table was not encountered on the day of sampling but soils were generally damp below 0.5-0.75 mbgl.

Currently, detailed lithology of the site below 2000mm has not been determined as bore logs were not undertaken at the advancement of the monitoring bores. Subsequently, information which is critical to determining groundwater velocities including aquifer depth, confining structures and aquifer properties below 2000 mm deep were estimated from site visits, the topographic survey and observation of site staff during construction activities. The influence that aquifer properties below 2 metres have on groundwater velocities is uncertain, in terms of over and/or under estimating velocities. For the current groundwater velocity calculations, the aquifer properties were estimated as 'Silty Clay', with an effective soil porosity of 0.01 or 1% to the base of the aquifer (McWorter and Sunada 1977).

Well construction information is also limited but deemed critical to the analysis of slug test data, and as such several of the perimeters required for the Bouwer and Rice Method (1970) were estimated from the monitoring well schematic (Appendix A). These parameters were screen length, base of aquifer and the annular fill above the screen. It is therefore highly recommended that all future monitoring bores installed onsite, accurate bore logs and lithology below 2 m be described, along with accurate bore construction information as to allow recalculation of groundwater velocities.

2.1.4 Groundwater Level Gauging

The monitoring bores (GND 2188, 2189 & 2190) have been gauged for depth of water between 9 and 10 times, from February 2011 to January 2015. Groundwater level data is presented in Table 2.1 and 2.2.

Table 2.1:Haehanga Catchment Groundwater Gauging Data

Well ID	Date	Well TOC reduced level (m amsl)	Depth to water (m below TOC)	Groundwater Elevation (mamsl)
GND2188	4/02/2011	35.61	0.89	34.72
GND2189	4/02/2011	30.82	0.89	29.93
GND2190	4/02/2011	24.90	0.95	23.95
GND2188	11/02/2011	35.61	0.88	34.73
GND2189	11/02/2011	30.82	0.81	30.01
GND2190	11/02/2011	24.90	0.97	23.93
GND2188	19/08/2011	35.61	0.76	34.85
GND2189	19/08/2011	30.82	0.75	30.07
GND2190	19/08/2011	24.90	0.75	24.15
GND2188	26/04/2012	35.61	1.40	34.21
GND2189	26/04/2012	30.82	0.71	30.11
GND2190	26/04/2012	24.90	No data	No data
GND2188	21/11/2012	35.61	1.27	34.34
GND2189	21/11/2012	30.82	0.74	30.08
GND2190	21/11/2012	24.90	0.86	24.04
GND2188	14/06/2013	35.61	0.83	34.78
GND2189	14/06/2013	30.82	0.61	30.21
GND2190	14/06/2013	24.90	0.60	24.31
GND2188	14/01/2014	35.61	1.00	34.61
GND2189	14/01/2014	30.82	0.94	29.89
GND2190	14/01/2014	24.90	0.94	23.97
GND2188	15/05/2014	35.61	0.70	34.91
GND2189	15/05/2014	30.82	0.40	30.42
GND2190	15/05/2014	24.90		
GND2188	11/12/2014	35.61	0.43	35.18
GND2189	11/12/2014	30.82	0.28	30.54
GND2190	11/12/2014	24.90	0.24	24.67
GND2188	8/01/2015	35.61	1.22	34.39
GND2189	8/01/2015	32.80	1.06	31.74
GND2190	8/01/2015	24.90	1.30	23.60

GND2188	30/04/2015	35.61	0.703	34.91
GND2189	30/04/2015	30.82	0.553	30.27
GND2190	30/04/2015	24.90	0.71	24.19

Table 2.2:Seasonal Groundwater Levels in the Haehanga Catchment

GND2188	Min Groundwater RL	34.21	Max Groundwater RL	35.18
GND2189	Min Groundwater RL	29.76	Max Groundwater RL	30.54
GND2190	Min Groundwater RL	23.60	Max Groundwater RL	24.67
GND2188	Summer RL	34.60	Winter RL	34.85
GND2189	Summer RL	30.05	Winter RL	30.23
GND2190	Summer RL	24.15	Winter RL	24.23

2.1.5 Groundwater Velocity

To establish groundwater velocities through the shallow groundwater table, BTW Company staff undertook two bore permeability tests on the monitoring bores GND 2188 and GND 2190 (January 8th 2015).

The ‘slug test’ method requires removal of a set amount of water, where after recovery of water levels is timed with a stopwatch. The four litre ‘slug’ was removed by a high rate vacuum pump, and the recovering water level was determined with a calibrated electronic dip tape. Both monitoring bores did not fully recover to their initial water levels after 100 minutes. GND 2188 recorded sudden surges in water levels after several minutes, with erratic variability in water levels during the timed recovery phase. User error and dip failure were ruled out as both BTW Company technicians corroborated the water level measurements and operation of the electronic dip tape in a bucket of water. Groundwater levels in GND 2190 fluctuated in the initial three minutes after ‘slug’ removal but in the next one hour and 14 minutes water levels stabilised but never fully recovered to initial water level. However, final water levels only measured 10mm below the initial water level.

The erratic water levels in GND 2188 during recovery phase of the ‘slug test ’are represented in Figure 2.4.

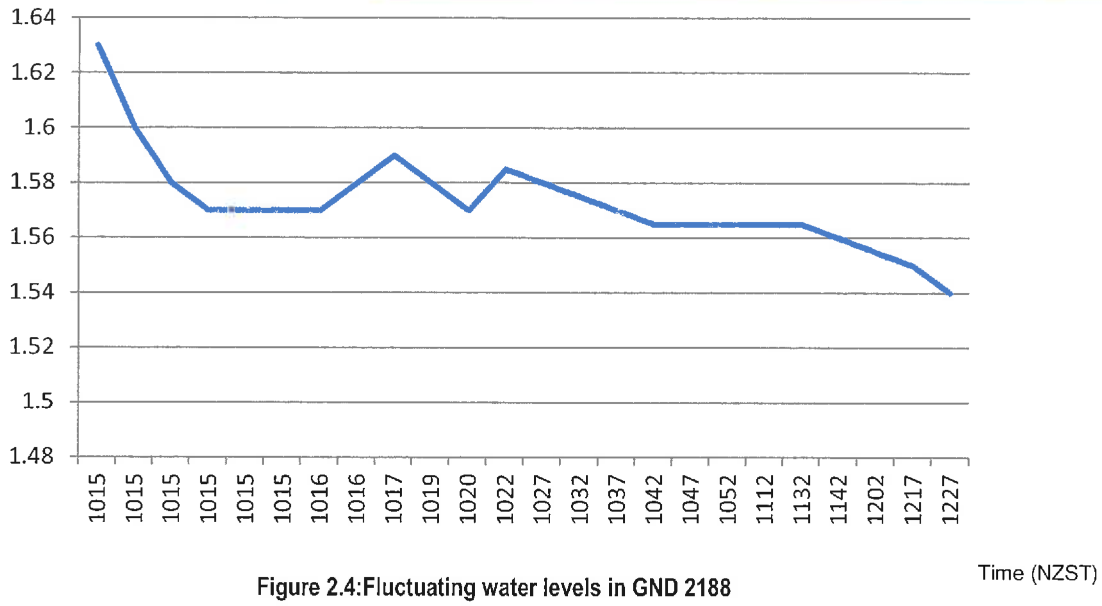

Figure 2.4:Fluctuating water levels in GND 2188

Due to the inconsistencies recorded in GND 2188, only permeability calculations were undertaken for GND 2190. These calculations were undertaken using the Bouwer and Rice method (1976) available from free software from the USGS website (http://pubs.usgs.gov/of/2002/ofr02197/index.html) and the online Bouwer and Rice calculator (http://www.groundwatersoftware.com/calculator_11_slugtest.htm).

The following calculations were then used to determine hydraulic gradient and linear groundwater velocity following Darcy's Law:

$$i = \frac{dh}{dl} = \frac{h_2 - h_1}{\text{length}}$$

where

i is the hydraulic gradient (dimensionless),

dh is the difference between two hydraulic heads (Length in metres), and

dl is the flow path length between the two piezometers (Length in metres)

Whereas

Groundwater velocity (v) based on Darcy's law and the velocity equation of hydraulics is given

by:

$v = Ki/n$

where;

K is hydraulic conductivity,

i is hydraulic gradient in the direction of groundwater flow

n is effective soil porosity (function of grain size and sorting).

Based on these parameters above, average hydraulic gradients and linear groundwater velocities have been estimated. Hydraulic gradients have be determined from the groundwater reduced levels in the monitoring bores GND 2188 to GND 2190 and distances between bores taken from the Topographic Survey (Figure 2.1-2.3).

Yielding:

K= 2.24* 10^{-6} or 0.00000224 m/sec

i= average 0.01196

n= 0.01 or 1 % for Silty Clay (McWorter and Sunada, 1977).

Table 2.3;Groundwater Velocities in the Haehanga Catchment

Hydraulic Gradient	Average velocity (m/day)
0.01196	0.2315

Table 2.3 above outlines average hydraulic gradients and average groundwater velocities adjacent GND 2190. Due to the limited groundwater gauging data for Winter and Spring months (3 occasions) it's as yet uncertain the impact what higher groundwater elevations have on hydraulic gradients across the Haehanga Catchment, and whether this impacts groundwater velocities. Furthermore, the velocities estimates in Table 2.3 are likely an underestimate for the middle to upper parts of the Haehanga Catchment, which has steeper topography therefore, higher hydraulic gradients and are overlain by more porous silty loamy/clay soils.

2.1.6 Groundwater- Surface water interactions

The interaction between the shallow groundwater table and the Haehanga Stream is a function of the elevation of the water table adjacent the Haehanga streambed. For example, if groundwater elevations in the monitoring bores are greater than the stream bed elevation, in all probability the stream will be gaining water from the shallow groundwater table. Conversely, streams can lose water from the groundwater table by outflow during periods of low groundwater levels when stream flows are high.

The degree of connection between the Haehanga Stream and the unconfined groundwater table changes laterally in space over differing reaches of the stream and over time. As the shallow groundwater table responds to recharge from rainfall, previously losing reaches become gaining reaches (Table 2.4). For example the reach of Haehanga Stream adjacent GND 2190 in December 11th 2015 and April 30th 2015 was probably losing to the Haehanga Stream. Both time periods coincided with 102 and 59 mm of rainfall in the preceding two days, with elevated soil moistures in the range of 44 and 45 %. Conversely, prior to January 8th 2015, Uruti received only 1 mm of rain in the previous eight days, with soil moistures at 32 %, this would have resulted in minimal outflow 'gaining' from the Haehanga Stream to the groundwater table.

Table 2.4:Stream and Groundwater Elevations (msl)

Date	Bore	Bore elevation	Stream Elevation	GW elevation	Groundwater Connectivity
30-04-2015	GND 2188	35.61	35	34.907	Gaining from stream
30-04-2015	GND 2189	30.82	30	30.267	Losing to Stream
30-04-2015	GND 2190	24.9	24	24.19	Losing to Stream
08/01/2015	GND 2188	35.61	35	34.39	Gaining from stream
08/01/2015	GND 2189	30.82	30	31.74	Losing to Stream
08/01/2015	GND 2190	24.9	24	23.6	Gaining from stream
11/12/2014	GND 2188	35.61	35	35.18	Losing to Stream
11/12/2014	GND 2189	30.82	30	30.54	Losing to Stream
11/12/2014	GND 2190	24.9	24	24.665	Losing to Stream

3 DISCUSSION

This preliminary groundwater investigation in the Haehanga Catchment recorded the clay soils form a semi-impervious shallow groundwater table overlain by more porous silty loamy-clays. The shallow groundwater table has been recorded between 0.25 metres below ground level (mbgl) at lower elevations of the site and 0.43 mbgl at higher elevations. The greatest depth to the groundwater table was recorded on GND 2188 on April 26th 2012 at 1.4 mbgl. The average depth to the groundwater table adjacent GND 2190 (most down-gradient bore) is 0.81mbgl. Therefore the shallow groundwater table is in almost constant interaction with the more porous loamy silty-clay's.

Seasonal differences are evident in groundwater elevations across the site, with the Winter-Spring months recording higher groundwater elevations. The groundwater flow pattern most likely is subdued to the overall topography, and flowing in a down valley gradient. Groundwater velocities have been estimated in the order of 0.2315 m/day. However, due to inconsistences in slug test data, only permeability calculation for one monitoring bore GND 2190 (lower part of the site) could be assessed. It must be noted that the Clay content of the soil profile was higher adjacent GND 2190 compared to the mid and upper parts of the site. Higher groundwater velocities would be expected through the more porous loamy soils adjacent GND 2189 and GND 2188.

The close hydraulic connection between the Haehanga Stream and the shallow groundwater has been documented as observed by Regional Council Staff. Rainfall recharge to groundwater is influenced by the hydraulic properties of the overlying soils, with the soils storage capacity the main characteristic to determine the recharge rate. At present rainfall recharge estimates which may influence potential contaminate loadings to the shallow groundwater table have not be made.

Appendix C goes some way to document how discharge/outflow events (i.e no rainfall, decreased soil moistures) and continued leachate irrigation results in elevated chloride concentrations in both the surface and groundwater resources. During these discharge events, where stream-flows are low over the summer months, the shallow groundwater table is most likely losing water to the Haehanga Stream. Therefore, limited water within the shallow groundwater table and the Haehanga Stream appears unable to attenuate the continued drainage losses of chloride through the soil profile as a result of continued irrigation.

Although outside the budgetary scope of the current investigation some consideration should be given to determine the 'time lag' of transport of chloride (and other contaminates) through the hydrological system as a response to outflow events in summer. At summer low flow periods, there is likely a greater potential of elevated chloride loadings to the Haehanga Stream and other downstream receptors. The downstream impact to stream biota has yet to be quantified as continuous 'time series' groundwater and surfacewater data are current unavailable.

The preliminary Conceptual Site Model has been developed (Appendix D) but as yet is not confirmed. The CSM has identified potential hydrogeological 'exposure pathways' for contaminates in the Haehanga Catchment, such as the chloride loaded porous surface soils being in direct contact with the shallow water table, and the reaches of Haehanga Stream 'gaining' water from the groundwater table, adjacent GND 2190 in the lower irrigation zone. However, considerable more information is required to confirm the CSM, in particular the identification of downstream receptors for all contaminates potential leaving the site, not only chloride but also metal and hydrocarbons contaminates.

4 RECOMMENDATIONS

The following recommendations aim to improve the management of water resources in the Haehanga Stream. These recommendations are additional to the recommendations made in the Uruti Composting Facility Management Report.

Specific recommendations include;

- Undertaking groundwater levels (and conductivity) measurements daily in the existing and proposed monitoring bores.
- Incorporate and align groundwater gauging data with surface water data (quantity and quality) with meteorological information to develop a Uruti Composting Facility Monitoring Plan.
- After 12 months of data collection, use the Monitoring Plan above as the basis for a catchment impact assessment, with the following goals
    1. Assess the potential adverse effects to downstream receptors in the Haehanga and Mimi River.
    2. Use the monitoring data to gauge the success of the previously recommended site improvements outlined in the Uruti Composting Facility Site Management Plan.
    3. Update and confirm the preliminary Conceptual Site Model with the monitoring data. The CSM will assist in future investigations on site, with emphasis on the transport of potential contaminates through the Haehanga hydrological system to important downstream receptors, such as the regionally significant Mimi Stream.
    4. Use the updated groundwater and stream flow monitoring and meteorological data to calculate rainfall recharge rates, and then model chloride 'fate and transport' through the soil profile to surface waters.
- Ensure that all future monitoring bores advanced onsite be done so by an approved drilling contractor, so that accurate bore logs and lithology can be determined.
- It is also recommended that the groundwater velocity calculation be updated once the lithology and bore construction data is ascertained for any bores advanced in the upper parts of the site.

4.1 Limitations

BTW Company has prepared this report for RNZ using available data sources, generally accepted practise and standards at the time it was prepared (June 2015). It is noted that the following limitations exist in the data potentially impacting on hydrogeological interpretation.

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- The lack of lithology data and bore construction information. It is accepted that bore logs are only an indication of inferred ground conditions at the specific location. However, without this data aquifer properties were estimated as clay to the base of the aquifer. For example, although the clay above 2000 mm appears continuous, uncertainty exists at greater depths to whether the clay forms a continuous layer or more permeable loamy/organic soils exist. However, in all probability the underlying papa mudstone would be a deeper confining layer across the catchment. Papa outcrops in the Haehanga Stream substrate are commonplace and observation of staff during construction activities suggest basement geology is between 3-6 metres deep.

- Therefore, the aquifer depths required to calculate the Bouwer and Rice Method (1976) were estimated from general site observations, and from interpreting spot heights from the topographic survey.

REFERENCES

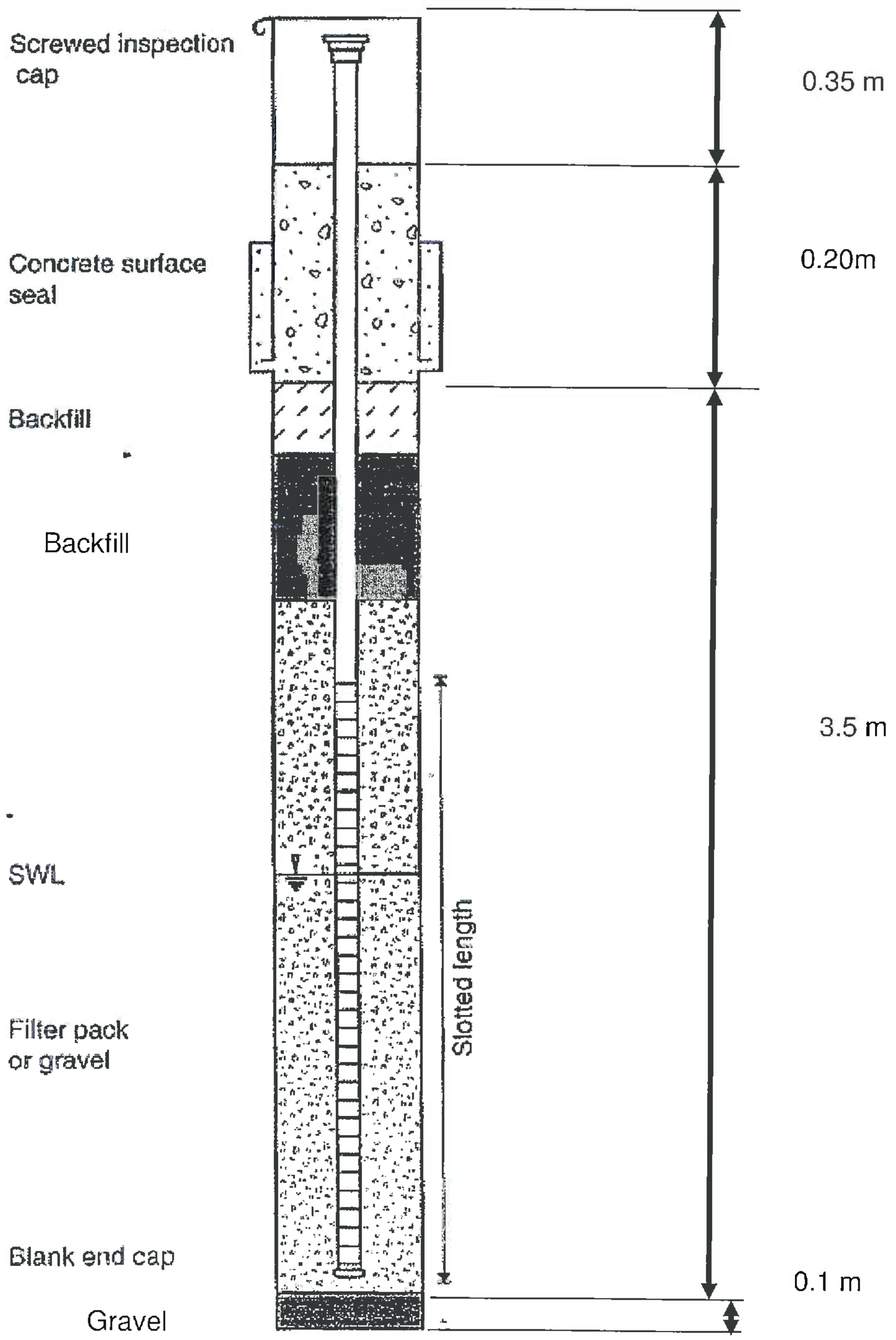
Bouwer, H. and R.C. Rice, 1976. A slug test method for determining hydraulic conductivity of unconfined aquifers with completely or partially penetrating wells, Water Resources Research, vol. 12, no. 3, pp. 423-428.

Cowperthwaite, S. 2015 Personal Communication with Author. Taranaki Regional Council, Scientific Officer

McWorter, D.B, Sunada,D.K 1977. Ground-Water Hydrology and Hydraulics. Water Resources Publications, Colorado.

APPENDIX A MONITORING WELLS- REMEDIATION NEW ZEALAND- URUTI

Monitoring wells – Remediation New Zealand - Uruti



CASING and SCREENS:
PVC: 51.8mm (2-in) satisfactory,
slotted screen.
Steel, Teflon

The location of the three monitoring wells are approximately at:

MW 1 – Baseline at 1732369 E – 5684631 N **GND2188**

MW2 – Irrigation area 1 at 1732302 E – 5684926 N **GND2189**

MW3 – Irrigation area 2 at 1731851 E – 5685677 N **GND2190**

Monitoring well installation

- Final depths should be measured and recorded
- The slotted portion of the pipe should start 0.2m below the ground level as per the schematic. This is not the case in all the bores.
- The top of the monitoring well should be capped to prevent contaminants entering the bore
- The top of the casing should be 300 mm above the ground and sealed so that potential contaminants or small animals cannot get in.
- A 2 meters perimeter fence should be erected around the monitoring well (i.e, 0.5 x 0.5 x0.5 x 0.5)

APPENDIX B MONITORING BORE INSTALLATION

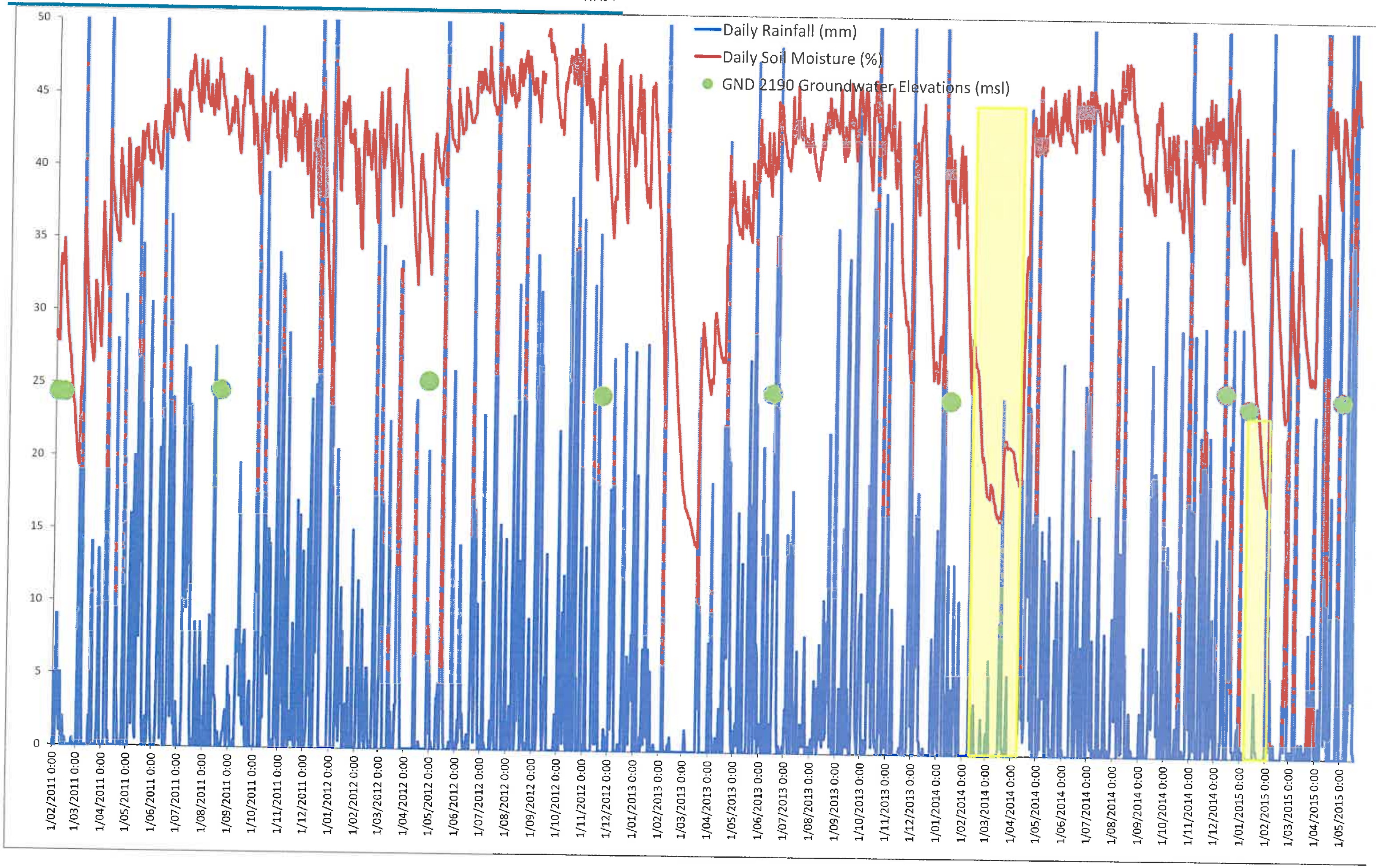
APPENDIX C SOIL MOISTURE AND RAINFALL RECHARGE ON CHLORIDE CONCENTRATIONS IN GROUNDWATER

Preliminary Summary

Examination of soil moistures (2003-2015), rainfall statistics, and available water chemistry data record elevated chloride within groundwater during periods of low rainfall and soil moistures (groundwater discharge to stream). During these periods groundwater levels (and most probably stream levels) are reduced (Table 2.1 & 2.2) and there is limited water within the hydrological system to attenuate the irrigated leachate. For example, the highly elevated chloride concentrations recorded in March 2014 in the Haehanga Stream and the monitoring bore GND 2190, coincided with the second lowest monthly rainfall total between 2003 and 2014, a very low soil moisture of 18% (yellow bars in figure below).

It is therefore, recommended that the following be considered:

- Once the water level recorder site has been installed in the Haehanga Stream, a full hydrogeological investigation should be undertaken in 12 months. This investigation should incorporate all the updated data streams including rainfall, soil moisture, groundwater elevations and Haehanga Stream discharge volumes. This will assist in quantifying potential drainage losses and/or adverse effects from the Uruti Composting Facility to surface water receptors downstream.



Uruti at Kaka Road Monthly Rainfall and Soil Moistures, yellow bars denote elevated Chloride concentrations in the Haehanga Stream and monitoring bore GND 2190

APPENDIX D PRELIMINARY UNCONFIRMED CONCEPTUAL SITE MODEL

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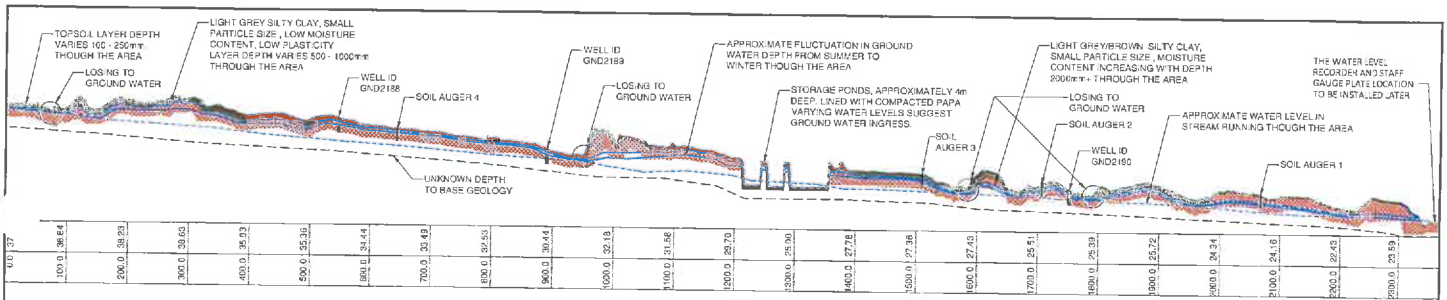

PROFILE
SCALE 1:6000 (A3) VERTICAL
SCALE 1:600 (A3) HORIZONTAL

PLAN
SCALE 1:6000 (A3)

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. planners
. engineers
. land & gis services

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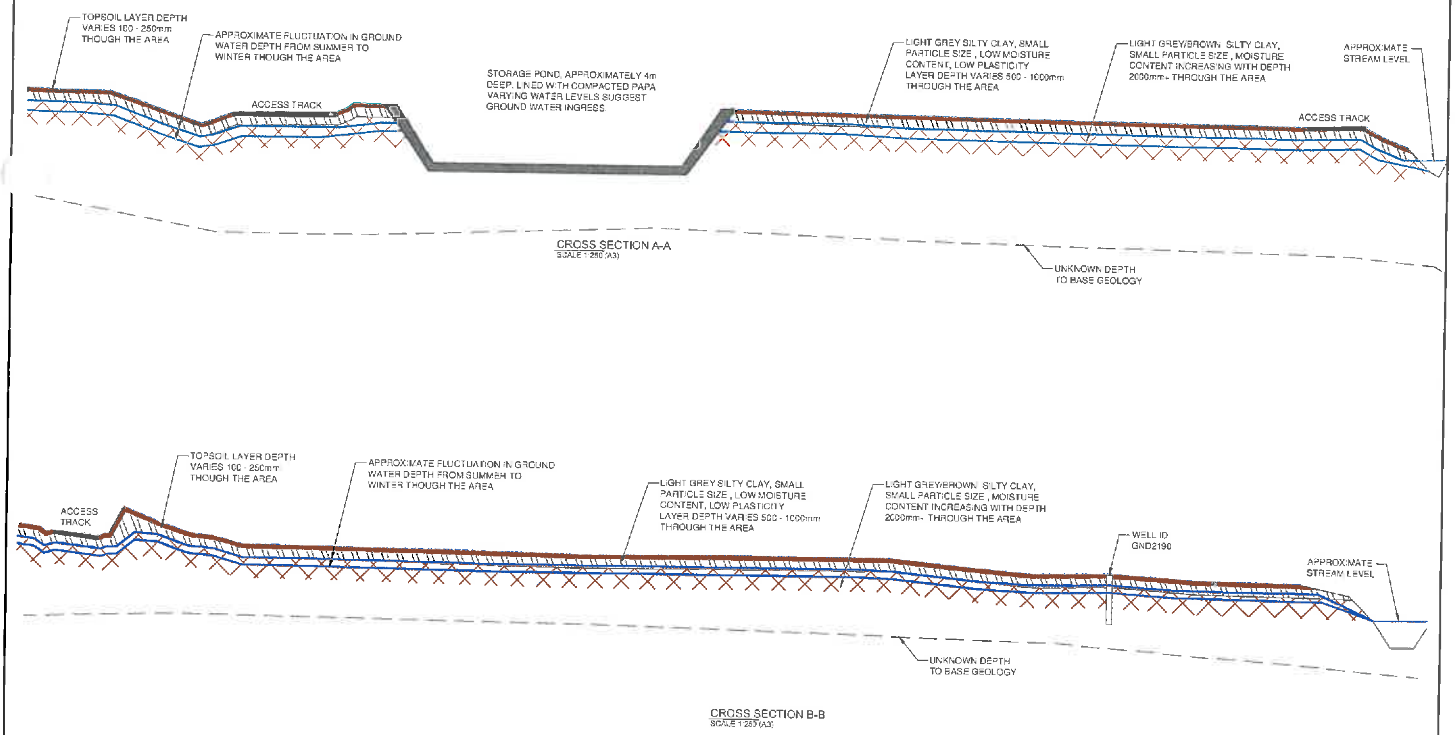
GENERAL NOTES
1. Coordinates in terms of : Geodetic Datum (Taranaki 2000)
2. Elevations in terms of : Mean Sea Level (Taranaki Datum 1970)
3. Contour interval is : 0.5m

LOCATION: MOKAU ROAD, URUTI
PROJECT No: 14745.01
A3 SCALE: 1:6000

TITLE: REMEDIATION (NZ) LTD
SOIL PROPERTIES
PLAN AND PROFILE

ORIGINAL SIZE: A3
DRAWING No: 14745.01-01
SHEET: 1
REVISION: 00



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Web www.btwcompany.co.nz

NO	DATE	BY	CHKD	APPR	APPR	DESCRIPTION	NUMBER	TITLE
REVISIONS							REFERENCE DRAWINGS	

GENERAL NOTES
1. Coordinates in terms of
2. Elevations in terms of
3. Contour interval is

LOCATION	MOKAU ROAD, URUTI	
PROJECT No.	14745.01	
A3 SCALE	1:250	
SURVEYED	TK & TD	25.03.2015
DRAWN	LV	24.06.15
CHECKED		

TITLE
REMEDIATION (NZ) LTD
SOIL PROPERTIES
CROSS SECTIONS

ORIGINAL SIZE	DRAWING No	SHEET	REVISION
A3	14745.01-01	2	00