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SUMMARY OF SOIL AND GROUNDWATER EVALUATIONS PARITUTU SITE, NEW PLYMOUTH NEW ZEALAND

GROUNDWATER
TECHNOLOGY

GROUNDWATER
TECHNOLOGY

Groundwater Technology New Zealand Limited
8 Leek Street, Newmarket, Auckland
PO Box 109-757, Newmarket, Auckland
Telephone: (09) 524 4447 Fax: (09) 524 4448

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SUMMARY OF SOIL AND GROUNDWATER EVALUATIONS PARITUTU SITE, NEW PLYMOUTH NEW ZEALAND

Prepared for:

DowElanco (NZ) Limited
89 Paritutu Road
Private Bag 1
New Plymouth
New Zealand

4 July, 1996
Our Ref: N1034R03

Prepared by:

GROUNDWATER TECHNOLOGY (NZ) LIMITED

Written/Submitted by:

Rgtt for DEW

David Whyte
Operations Manager

Reviewed/Approved by:

Ronald J Hicks

Ron Hicks
General Manager

Dedicated to Environmental Solutions

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1. INTRODUCTION

DowElanco (NZ) Ltd. (DowElanco) requested Groundwater Technology (NZ) Ltd. conduct environmental sampling (soils and groundwater) at the Paritutu Road site (Figure 1). The work follows an original site assessment by DowElanco during 1993 and 1994. The work was undertaken as part of DowElanco's ongoing environmental management program. The site layout is shown in Figure 2.

DowElanco's internal site assessment program was initially reported to Groundwater Technology (NZ) Ltd within a draft entitled "Consultant's Brief for Stage II Site Works at the Paritutu Road Site" 28 April 1994. Groundwater Technology undertook a program of work beginning May 1994. This work was directed at assessing soil and groundwater impact first detected at well #28 (Figure 2). This work involved the completion of nine soil borings, soil sampling, installation of seven additional groundwater monitoring wells and laboratory analysis of soil and groundwater samples. The work was completed by October 1994.

Groundwater Technology undertook additional works during 1995. These works included ground penetrating radar survey, 48 hour pump test, delineation of soil impacts around well #39, and well #16 and #16a (Figure 2), installation of up to six groundwater monitoring/recovery wells, determination of groundwater elevation contours, groundwater sampling, soil sampling, laboratory analysis of soil and groundwater samples, data analysis and reporting.

In June 1996 DowElanco requested that Groundwater Technology prepare a document (this report) summarising all the analytical and investigative work completed between 1993 and May 1996.

1.1 Background

DowElanco (NZ) Ltd, with assistance from offshore company resources, completed a 'desk top' assessment during April to September 1992 and this was reviewed in October 1992. Manufacturing has taken place on the Paritutu site since 1960. It has primarily been an agrichemical manufacturing facility for phenoxie herbicides. A plan was developed to determine the extent of any soil or groundwater contamination at the Paritutu site to determine

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SOURCE: N.Z. TOPOGRAPHIC MAP
NZMS 260
SHEET P19 NEW PLYMOUTH
EDITION 1 1984
MAP REPRODUCED WITH THE PERMISSION OF
THE DEPARTMENT OF SURVEY AND LAND INFORMATION, NEW ZEALAND

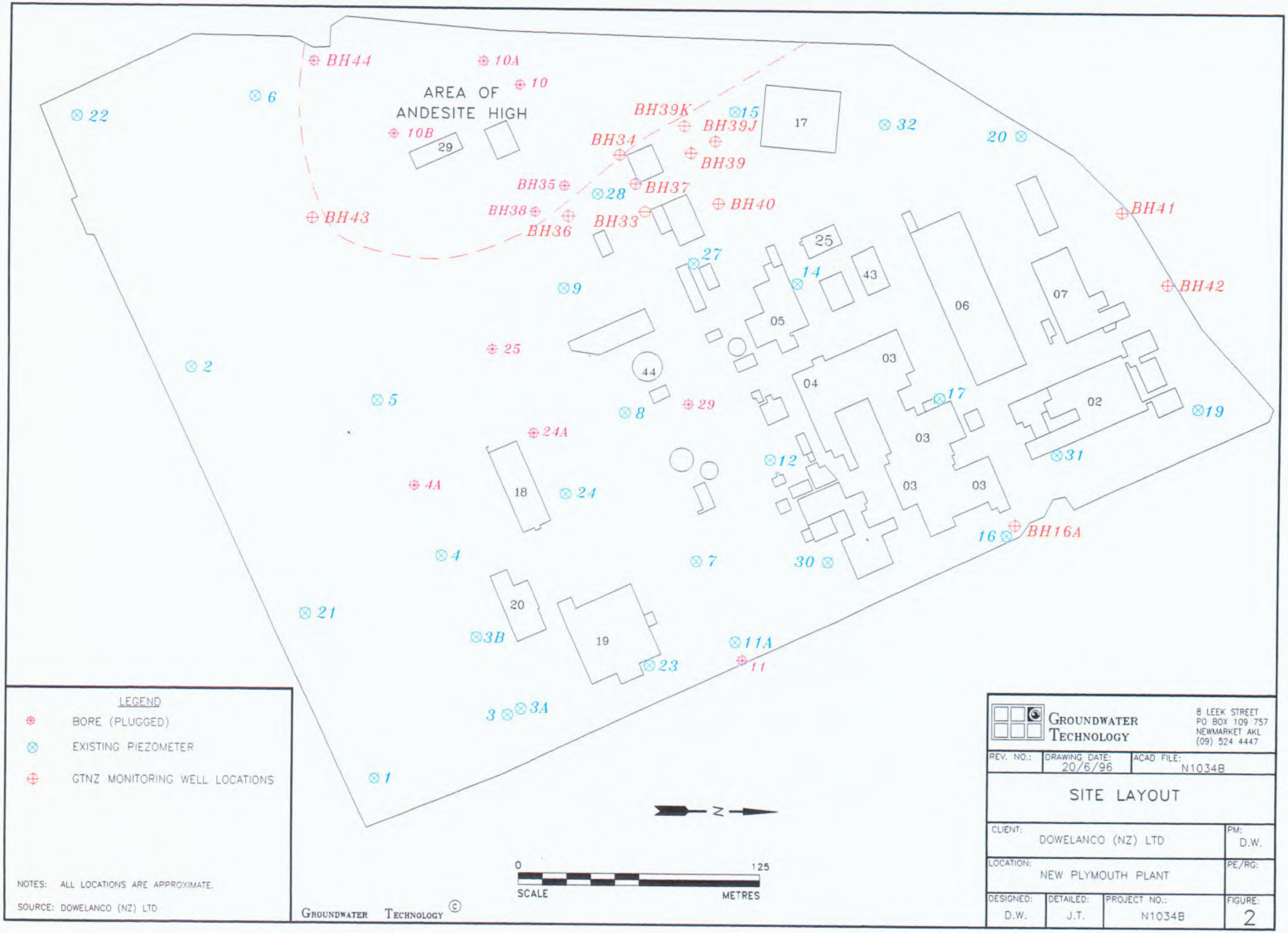
SCALE: 1:50 000

0 2000 4000

SCALE METRES

N

GROUNDWATER TECHNOLOGY PO BOX 109-757 8 LEEK STREET NEWMARKET AUCKLAND NEW ZEALAND (09) 524 4447	DESIGNED: W.J.S	SITE LOCATION	
	COMPILED: W.J.S.	CLIENT: DOW ELANCO (NZ) LIMITED	DRAWING DATE: 22/4/96
	PROJ. NO. N1035	LOCATION: PARITUTU ROAD NEW PLYMOUTH, N.Z.	FIGURE: 1



LEGEND

⊕ BORE (PLUGGED)

⊗ EXISTING PIEZOMETER

⊕ GTNZ MONITORING WELL LOCATIONS

NOTES: ALL LOCATIONS ARE APPROXIMATE.

SOURCE: DOWELANCO (NZ) LTD

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GROUNDWATER TECHNOLOGY

8 LEEK STREET
PO BOX 109 757
NEWMARKET AKL
(09) 524 4447

REV. NO.:	DRAWING DATE: 20/6/96	ACAD FILE: N1034B	
SITE LAYOUT			
CLIENT: DOWELANCO (NZ) LTD			PM: D.W.
LOCATION: NEW PLYMOUTH PLANT			PE/RG:
DESIGNED: D.W.	DETAILED: J.T.	PROJECT NO.: N1034B	FIGURE: 2

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the appropriate management option. There were four data collection activities that needed to be undertaken to provide the required information:

- Hydrogeological survey.
- Magnetometer survey.
- Groundwater monitoring program.
- Soil sampling program.

All data presented in this report relates only to the Paritutu site. The first part of this plan was "Physical Assessment #1" and involved conducting a hydrological and magnetometer survey of the Paritutu site.

DowElanco's internal site assessment program was reported to Groundwater Technology within a draft "Consultant's Brief for Stage II Site Works at the Paritutu Road Site" dated 28 April 1994. A site inspection and briefing were held on 12 May 1994.

The brief contained DowElanco's proposed scope of works for the "Physical Assessment #2" at the site which was to be completed in 1994. The brief is a detailed document covering soil and groundwater investigation, modelling, risk assessment and remedial alternatives which will need to be completed in subsequent stages of work. Subsequent to the site inspection and briefing, this scope of works was substantially modified.

The focus of these additional works was changed to investigate the presence of "stable" foam in monitoring well #28, and positive analytical screening results from water samples from well #28. Further analytical work to assess the level of communication between a shallow, perched groundwater body and a deeper aquifer system was performed in 1995.

Based on the results of the "Physical Assessment #1" works, and discussions of the Consultant's Brief, Groundwater Technology developed the further scope of works summarised below. The additional stages of work have essentially completed the investigation of any soil and groundwater "hot spots" identified in the initial "Physical Assessment #1" reports.

1.2 Objectives

The objectives of the various stages of work are summarised as:

- Further define by drilling and laboratory analysis, the nature and extent of contamination detected in well #'s 16, 28 and 39.
- Instigate a full round of macroion sampling of groundwater at the site.
- Determine through drilling and analysis the likely source or sources of contamination in the area around well #28.
- Use geophysical tools to determine:
  - i) The surface profile of the underlying andesite at the site boundary and hence, the most likely exit points for groundwater leaving the site.
  - ii) Better define the geological anomaly found in boreholes (BH) 10, 10a, 10b, 35, 38 and 44.
  - iii) Assist in locating future groundwater monitoring wells along the north-western and northern boundaries and recovery wells in the area of well #39.
- Conduct a 48 hour pump test in the vicinity of well #39 to better define aquifer hydraulic conductivity in the area of well #39.
- Install additional groundwater monitoring wells.
- Gauge wells to confirm groundwater levels and up date groundwater contour map.
- Collect groundwater samples from specified wells and analyse them for compounds of concern (chlorophenols and phenoxies).
- Collect groundwater samples from specified wells and analyse them for total organic chlorinated pesticides, organophosphates, solvents, total volatile chlorinated organics, total petroleum hydrocarbons (C_6-C_{36}), methane, ethane, ethylene, BOD_5, BOD_{20}, COD, TOC, pH, conductivity, TDS, arsenic, mercury, cadmium, chromium, lead, copper, iron, zinc, silver, nickel, magnesium and calcium.
- Collect soil samples from specified locations between well #42 and building 07.
- Develop a water balance for the site.
- Develop a groundwater flow model for the site.
- Develop a predictive fate and transport model for chlorophenol and phenoxies from the area of well #39.

1.3 Scope of Work

The scope of works completed between August 1994 and June 1996 is summarised under the following major headings:

GEOLOGY

- Drilling, logging and soil sampling from a total of 20 additional drillholes.
- Completion of a ground penetrating radar survey in the area extending from well #20 to well #6 to assist in better defining geological anomaly and to assist in locating future groundwater monitoring wells (Oct 1995).

HYDROGEOLOGY

- Collection of groundwater samples from all wells on site for macroion analyses (Aug 1994).
- Aquifer characterisation by pumping test from well #39 (Oct 1995).
- Installation of 12 additional groundwater monitoring wells (Aug 1994 and Oct 1995).
- All new and existing wells were gauged to measure groundwater levels and produce an up to date groundwater contour map.

DELINEATION

- Further definition of the vertical and lateral extent of compounds of concern in the area of well #28 involving the drilling of eight boreholes and installation of a further six monitoring wells (Aug 1994).
- Installation of well #16a (Aug 1994).
- Further definition of the vertical and lateral extent of compounds of concern in the area of well #39 with a further eleven soil borings and installation of monitoring well #'s 39j and 39k (Oct 1995).
- Installation of three additional boundary monitoring well #'s 41, 42 and 43 (Oct 1995).
- Further definition of the vertical and lateral extent of soil contamination in the area of well #16 by completing two soil borings to the water table (Oct 1995).
- Determination (in the field) of groundwater quality parameters pH, conductivity, temperature, and dissolved oxygen levels.

IMPACT ASSESSMENT

- Analysis of data including a preliminary (qualitative) risk assessment (Oct 1995).
- Soil samples collected from all soil borings were submitted to the DowElanco laboratory for the determination of concentrations of compounds of concern, including chlorophenols, phenoxies, solvents and organophospates.
- Groundwater samples were collected from new and selected existing wells and submitted to laboratories for determination of chlorophenols, phenoxies, macroions, total organic chlorinated pesticides, organophaspates, total volatile chlorinated organics, total petroleum hydrocarbons (C_6 -C_{36}), methane, ethane, ethylene, BOD_5, BOD_{20}, COD, TOC, pH, conductivity, TDS, arsenic, mercury, cadmium, chromium, lead, copper, iron, zinc, silver, nickel, magnesium and calcium.
- Development of fate and transport model for chlorpohenols and phenoxies (May 1996).
- Development of a groundwater flow model for the site (May 1996).
- Development of a water budget for the site (May 1996).

2. METHODOLOGY

2.1 Site Safety

All field work was completed in accordance with Groundwater Technology's Site Safety Plan. All fieldwork was supervised by DowElanco's nominated Site Safety Officer, and in accordance with standard DowElanco safety protocols. During the drilling program hard hats, steel cap boots, safety glasses, overalls and gloves were worn as protective clothing. During soil and groundwater sampling nitrile gloves were worn to avoid cross contamination and minimise the possibility of any contaminant coming in to contact with skin.

2.2 Drilling

Monitoring wells and soil borings were completed by Brown Brothers (NZ) Ltd using a Simco 5000 drilling rig. A 108 mm hollow stem auger incorporating a Laskey continuous soil sample/core recovery system was used. The drilling was conducted under the direct supervision of a Groundwater Technology geologist who logged the soil strata from the continuous core samples for each borehole/monitoring well.

Boreholes and monitoring wells were drilled to at least two metres into the water bearing strata or to where andesite rock was encountered. Soil samples were collected at 0.5 metre intervals or whenever a change in lithology was encountered. To prevent contamination from sample to sample, the sampling tubes and augers where cleaned in a decontamination solution and rinsed in potable water between each sampling event and well.

Soil borings not converted to monitoring wells were backfilled to within three metres of the ground surface with clean fill, then sealed to the surface with a bentonite grout mixture.

2.3 Soil Sampling

Soil samples were collected from the continuous core provided by the Laskey sampler to prevent up-hole contamination of soil samples. To avoid cross contamination and the possibility of any contaminant coming into contact with skin, a new pair of sterile nitrile gloves were used for each sample collected. For each sample event, the following methodology was used:

- The sample was sealed in a clip seal, air tight plastic bag and screened for volatile organic compounds (VOC's) on site using a photoionisation detector (PID). This sample was described for texture and mineralogy.
- A 250 ml glass jar with a teflon lined, screw top lid was filled, sealed and used for laboratory analysis of target analytes.
- Jars were stored on ice in chilly bins awaiting laboratory analysis. Cooling reduces volatile organic compound loss and bacterial degradation in the samples. Approximately three soil samples from each soil boring/monitoring well were submitted for laboratory analysis.

2.4 Monitoring Well Installations

Monitoring wells were constructed using threaded 3.0 metre lengths of 50 mm diameter, Class D, PVC screen with 0.75 mm machine slots, or stainless steel screen with 0.5 mm slots. The screen was sealed at the base with a 50 mm end cap. Sections of 50 mm PVC (or stainless steel) blank were installed above the screen, extending to the surface.

The annulus between the well and the borehole was backfilled with clean, graded sand pack to a height of 0.5 metre above the top of the screen. This sand pack reduces the impact of fine sediments on the well and enhances hydraulic connection with the aquifer.

A bentonite seal of at least 0.6 metres thickness was placed above the sand pack. The bentonite was wetted down during construction to ensure an immediate seal and to prevent downward migration of contaminated seepage water from overlying strata. If low levels of VOC's were detected by the PID during soil sampling, the cuttings were used to backfill the annulus above the bentonite seal. If VOC's were detected during soil sampling, the cuttings from the well were not used as backfill, but placed in to drums for disposal by DowElanco staff. Clean sand was then used to backfill the annulus. At the surface a concrete seal of at least 0.6 metres was placed above the cuttings or backfilled sand.

Wells were capped with a 50 mm end cap. Wells located on roads or access pathways were cut off at ground level and protected with a 150 mm cast iron flushing point cover. Diagrammatic details of well construction are shown on drilling logs (Appendix A).

Groundwater levels were noted during drilling. After well installation each well was developed by removing three to five well volumes of water with a Waterra hand pump. Well development reduces formation plugging and ensures free fluid movement and hydraulic continuity between the well and aquifer.

After well completion the well location and top of casing elevation was surveyed by BTW Associates Surveys. Well top of casing elevations are shown with well gauging data in Appendix B. All elevations surveyed on-site are related to a site datum. Groundwater levels in monitoring wells were gauged using an Interface Probe™.

2.5 Groundwater Sampling

The following protocol was adhered to during sample collection of groundwater from each monitoring well.

- The well was purged using a Wattera hand pump to remove three to five well volumes of water, or until pH, temperature and conductivity readings had stabilised.
- Sample bottles were rinsed first with water pumped from the well.
- Samples were collected in either glass or plastic sample bottles. A duplicate sample from each monitoring well was collected.
- Water samples were submitted to DowElanco Laboratory of determination of chlorophenol, phenoxie, and solvent concentrations.
- Samples were submitted to GTEL, Graysons or AMDEL Laboratories, for other specified analysis.

- New 16 mm diameter polyethylene sampling tube was used for each individual well to prevent cross contamination between wells during development and sampling.
- Samples were collected using either a stainless steel or disposable bailers.
- Typically, samples were not filtered in the field.
- Additional water samples from each monitoring well were collected by DowElanco personnel and submitted to the DowElanco laboratory for determination of chlorophenol, phenoxie and solvent concentrations.

2.6 Laboratory Analysis

Soil and groundwater samples selected for analysis of compounds of concern were submitted to the DowElanco laboratory. Water samples collected by Groundwater Technology (NZ) Limited were analysed for macroions (sodium, potassium, calcium, magnesium, chloride, sulphate and bicarbonate) by APHA "Standard Methods" 18th edition, 1992. Samples were submitted to Grayson Laboratories for analysis of macroions. Water samples analysed for total organic chlorinated pesticides, organophospates, total volatile chlorinated organics, total petroleum hydrocarbons (C_6 -C_{36}), methane, ethane, ethylene, BOD_5, BOD_{20}, COD, TOC, pH, conductivity, TDS, arsenic, mercury, cadmium, chromium, lead, copper, iron, zinc, silver, nickel, magnesium and calcium were submitted to GTEL and AMDEL Laboratories for analysis.

3. RESULTS

3.1 Geology

Considering information obtained from the soil boring program, ground penetrating radar and resistivity surveys (Appendix C), the geology at the site is interpreted as predominantly weathered air fall andesitic tephras and andesitic flows. Soils present at the site consist of fine sands and silty sands interbedded with silts and silty clays. Andesite rock is present at depth with an irregular topography. Our interpretation of the sub-surface geology at the site is summarised on cross-sections presented as Figures 3, 4, 5 and 6. The sequence of materials penetrated at each bore hole is depicted on the drilling logs (Appendix A). Construction details of each well are given on these logs.

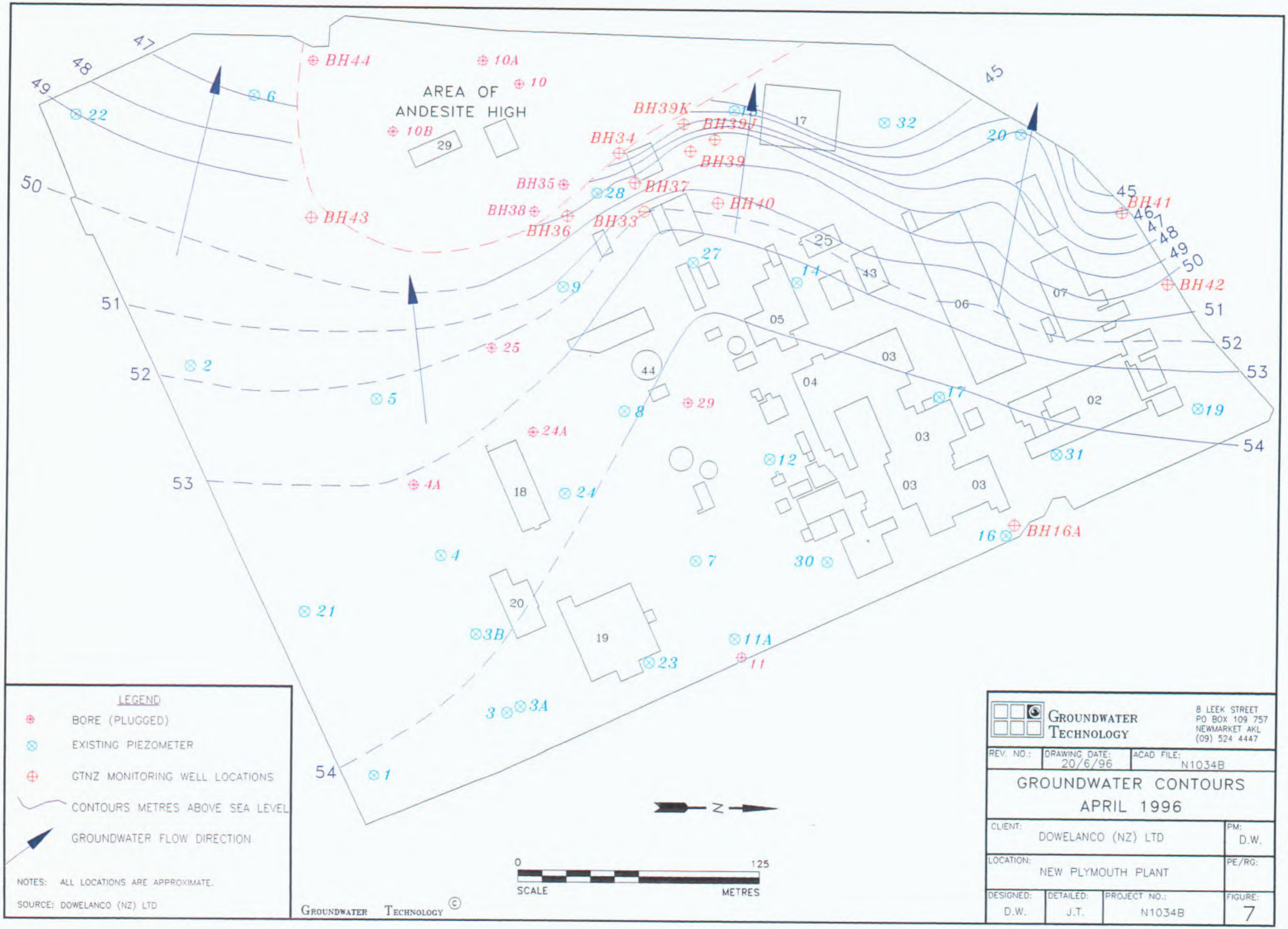
Results of the ground penetrating radar and resistivity surveys are presented in full in a report entitled "Additional Soil and Groundwater Evaluation, Paritutu Site, New Plymouth" and dated November 1995.

3.2 Hydrogeology

Groundwater within each of the wells was gauged on several occasions between 1993 and 1996. Initial water levels are shown on drilling logs presented in Appendix A. Gauging data is presented in Appendix B. Drilling and gauging data confirm that two aquifers are present on the site. A shallow "perched water table" aquifer and a deeper regional aquifer system. Interpreted groundwater elevation contours in the deep aquifer system are shown in Figure 7.

3.2.1 Shallow Perched Aquifer

In the south-eastern sector of the site, away from the area under investigation, previous work identified a "shallow perched water table" aquifer system (Hydrogeology Survey, February 1994). This report indicates groundwater flow is to the south-east. Water levels within this system are reported to be within 1.5 and 3.0 metres below the ground surface. No detailed aquifer characterisation has been attempted in this system. Average groundwater gradients are



LEGEND

⊕ BORE (PLUGGED)

⊗ EXISTING PIEZOMETER

⊕ GTNZ MONITORING WELL LOCATIONS

CONTOURS METRES ABOVE SEA LEVEL

GROUNDWATER FLOW DIRECTION

NOTES: ALL LOCATIONS ARE APPROXIMATE.

SOURCE: DOWELANCO (NZ) LTD

Groundwater Technology ©

GROUNDWATER TECHNOLOGY

8 LEEK STREET
PO BOX 109 757
NEWMARKET AKL
(09) 524 4447

REV. NO.:	DRAWING DATE: 20/6/96	ACAD FILE: N1034B

GROUNDWATER CONTOURS
APRIL 1996

CLIENT: DOWELANCO (NZ) LTD	PM: D.W.
LOCATION: NEW PLYMOUTH PLANT	PE/RG:

DESIGNED:	DETAILED:	PROJECT NO.:	FIGURE:
D.W.	J.T.	N1034B	7

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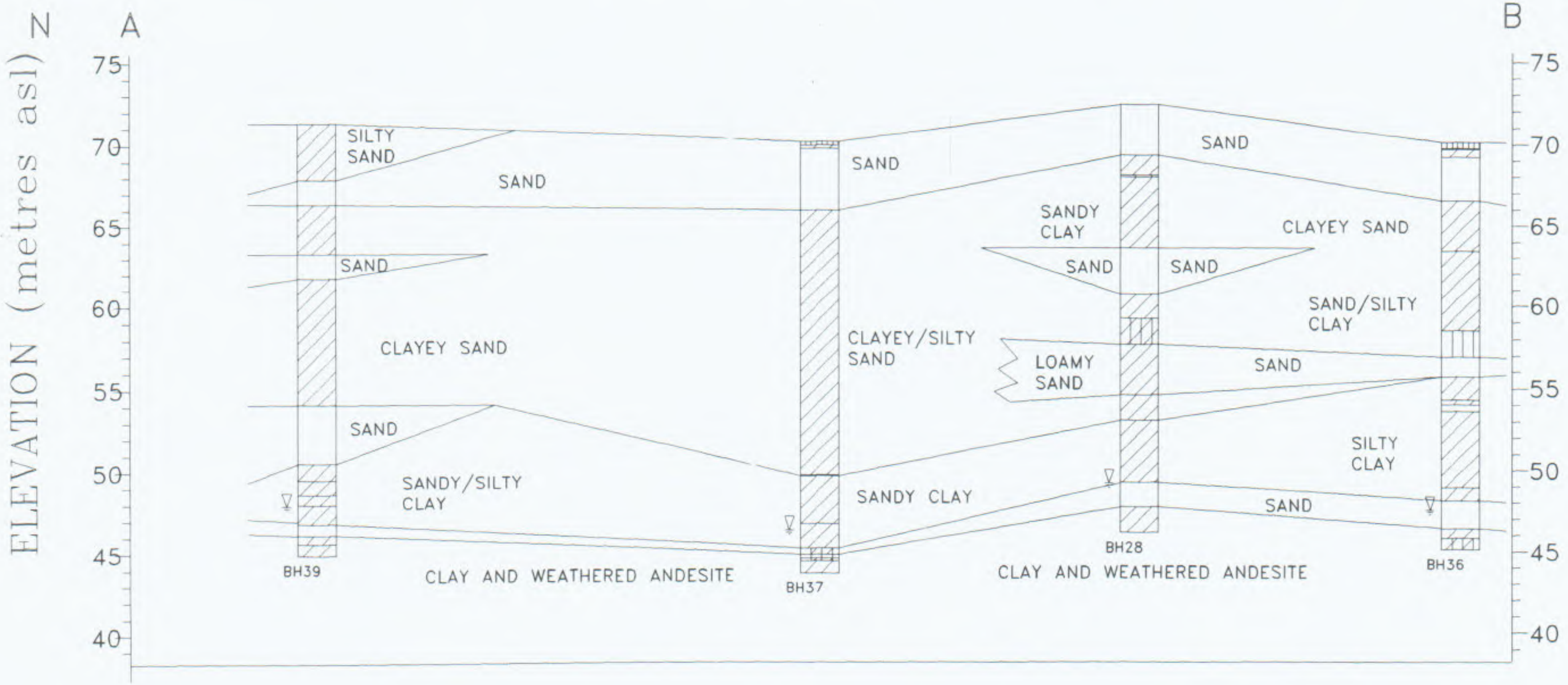
North – South Cross Section



HORIZONTAL SCALE = VERTICAL SCALE

NOTES: ALL LOCATIONS ARE APPROXIMATE

SOURCE: GROUNDWATER TECHNOLOGY FIELD SURVEY

GROUNDWATER TECHNOLOGY
8 LEEK STREET
PO BOX 109 757
NEWMARKET AUCKLAND NZ
(09) 524 4447

REV. NO.:	DRAWING DATE:	ACAD FILE:
3	07/11/95	N1034F5

CROSS SECTION A – B

CLIENT: DOWELANCO (NZ) LTD
PM:

LOCATION: NEW PLYMOUTH PLANT
PS:

DESIGNED:	DETAILED:	PROJECT NO.:	FIGURE:
M.A.	T.W.	N1034	3

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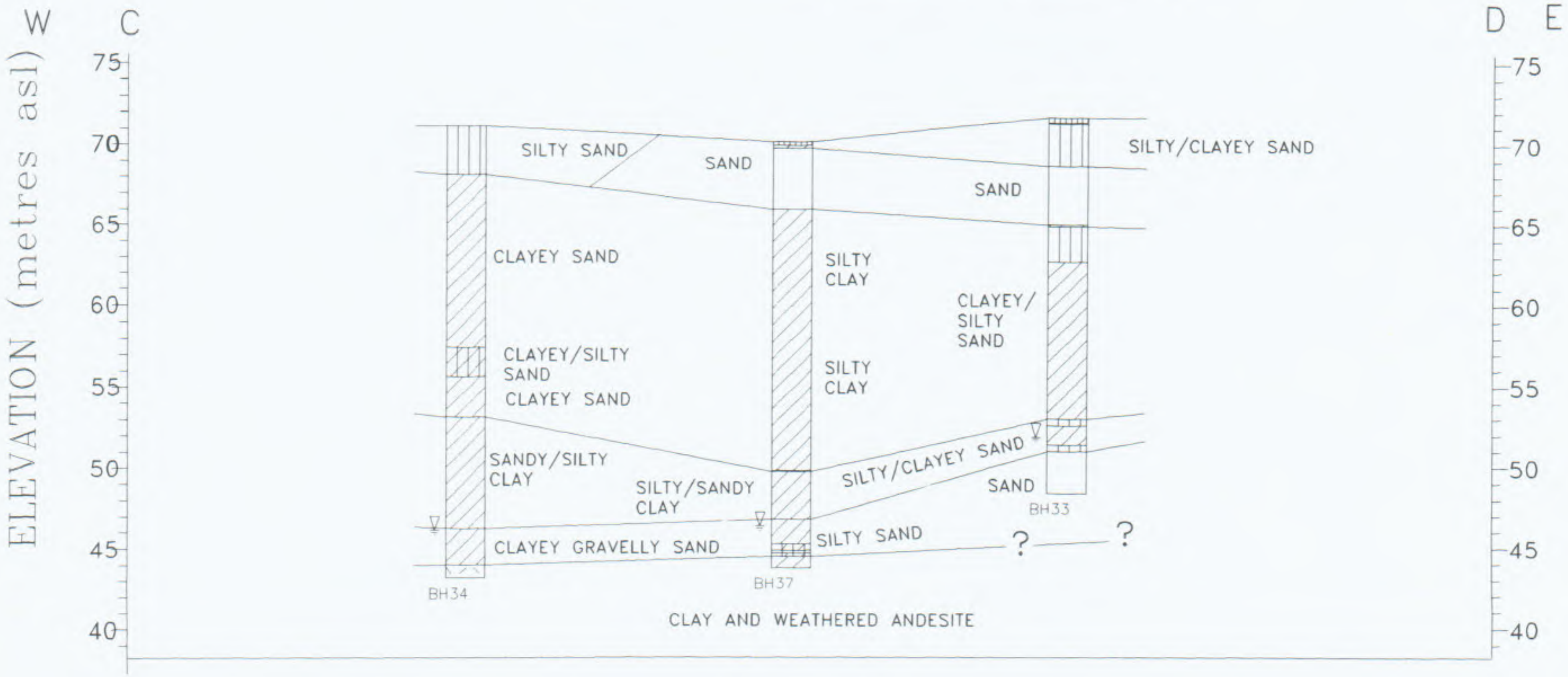
East West Cross Section



NOTES: ALL LOCATIONS ARE APPROXIMATE.

SOURCE: GROUNDWATER TECHNOLOGY FIELD SURVEY

HORIZONTAL SCALE = VERTICAL SCALE

0 20
SCALE METRES

GROUNDWATER TECHNOLOGY

8 LEEK STREET
PO BOX 109 757
NEWMARKET AUCKLAND NZ
(09) 524 4447

REV. NO.: 3
DRAWING DATE: 07/11/95
ACAD FILE: N1034F6

CROSS SECTION C – D

CLIENT: DOWELANCO (NZ) LTD
PM:

LOCATION: NEW PLYMOUTH PLANT
NEW PLYMOUTH, NEW ZEALAND
PS:

DESIGNED: M.A.
DETAILED: T.W.
PROJECT NO.: N1034
FIGURE: 4

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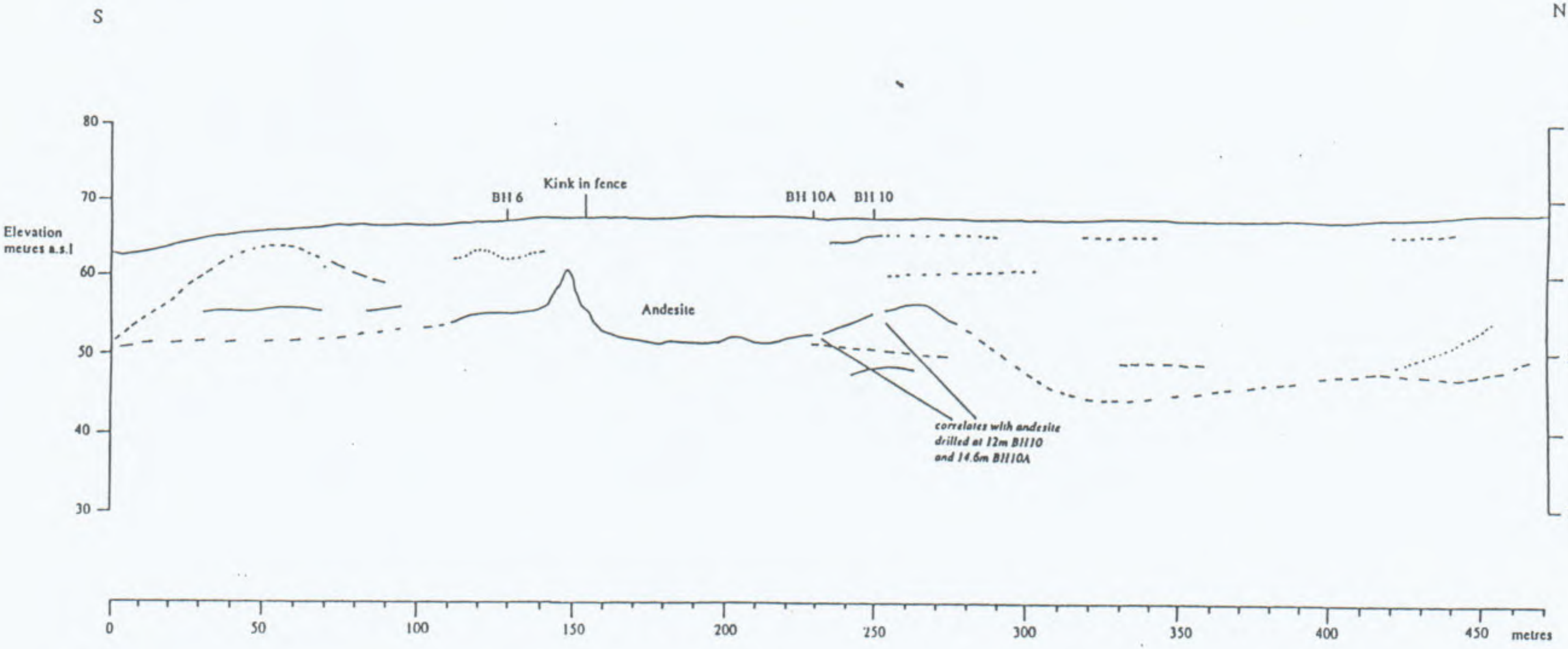

NOTES: ALL LOCATIONS ARE APPROXIMATE.

GROUNDWATER TECHNOLOGY

8 LEEK STREET
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NEWMARKET AUCKLAND NZ
(09) 524 4447

REV. NO.:	DRAWING DATE:	ACAD FILE:
3	07/11/95	N1034F5

LONG SECTION WESTERN BOUNDARY

CLIENT: DOWELANCO (NZ) LTD
PM:

LOCATION: NEW PLYMOUTH PLANT
PS:

DESIGNED:	DETAILED:	PROJECT NO.:	FIGURE:
M.A	T.W	N1034	5

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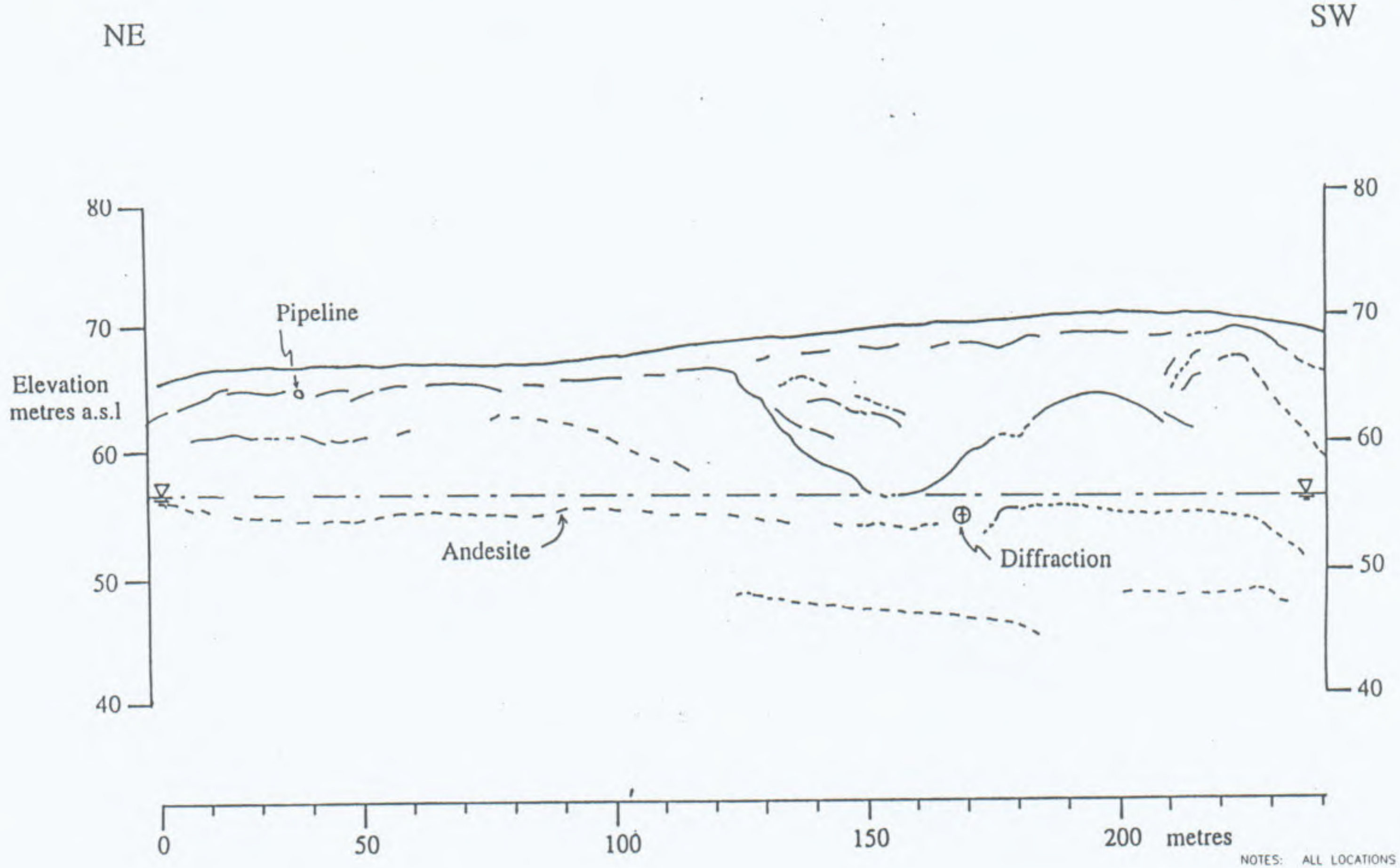

NOTES: ALL LOCATIONS ARE APPROXIMATE.

GROUNDWATER TECHNOLOGY

8 LEEK STREET
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(09) 524 4447

REV. NO.:	DRAWING DATE:	ACAD FILE:
3	07/11/95	N1034F5

LONG SECTION NORTHERN BOUNDARY

CLIENT: DOWELANCO (NZ) LTD

PM:

LOCATION: NEW PLYMOUTH PLANT

PS:

DESIGNED:	DETAILED:	PROJECT NO.:	FIGURE:
M.A.	T.W.	N1034	6

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calculated at approximately 1 vertical (v) to 80 horizontal (h). Assuming a similar range in transmissivity as determined for the deeper regional aquifer, ground water velocities are calculated to be in the range of 0.05 to 0.22 metres per day. To travel a straight line distance of 50 metres would take between 227 and 1000 days.

3.2.2 Deep Regional Aquifer

A deeper "regional" aquifer system is present across the entire site. Water levels within this system are between 14 and 27 metres below ground surface. Typically regional flows are towards the west and north-west, towards the coast. The majority of the sampling and aquifer characterisation has focussed on this aquifer system.

Within the regional groundwater system a localised disturbance in flow direction occurs. This is illustrated on Figure 7. Considering the results of drilling, ground penetrating radar survey and gauging data, groundwater flow in this area of the site is predominantly towards the north and northwest. However, south of well #36 groundwater flows towards the south and southwest. On the basis of our interpreted groundwater elevation contours the average hydraulic gradient is between 1v:5h to 1v:10h.

The localised disturbance in the groundwater flow is confirmed to be caused by the presence of andesite rock forming a boundary to groundwater flow. The depth to the underlying andesite rock varies across the site. West and south west of wells #28, 36 34 and 39k, drilling does not encounter groundwater above the andesite rock. Variations in the elevation of the upper surface of the andesite rock produces a change in groundwater flow direction. The irregular topography of the top surface of the andesite flow has been mapped by a combination of drilling and geophysical techniques including ground penetrating radar.

3.3 Aquifer Pump Test Results

Data on aquifer characteristics of the deep regional aquifer system have been collected by pumping tests conducted on well #39. Water levels were monitored in the pumped well and in surrounding wells. A small amount of draw down (32 mm) was measured in well #37, up and cross gradient from the pumped well.

Drawdown within the pumped well was measured at a maximum of 2.845 metres. Recovery data was collected for a short time following the termination of the pump test. The extraction rate was maintained as constant as practicable given the constraints imposed by pumping from a 50 mm diameter well with a limited aquifer thickness.

Draw down and recovery data are summarised in Figure 8, with data presented in Appendix D. Data was analysed and the transmissivity of the aquifer determined at between 2 to 10 m^2 per day. This equates to a hydraulic conductivity value of between 2×10^{-5} and 5×10^{-6} metres per sec. Since no appreciable draw down was measured in a well other than the pumped well it is not feasible to calculate a figure for aquifer storativity.

Draw down data from the pumped well (#39) was analysed using a programme called AQTESOLV.

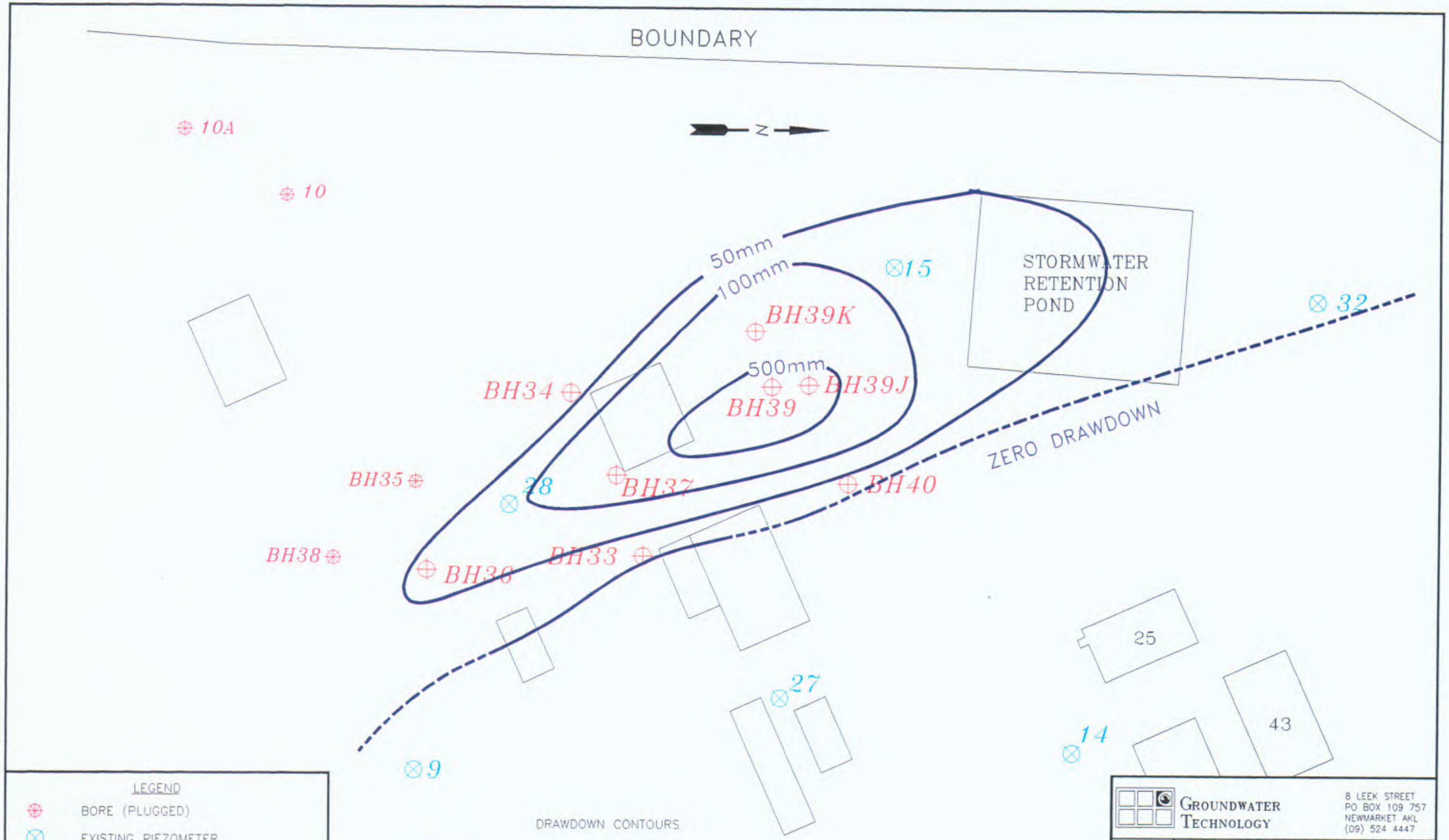
3.4 Groundwater Velocity

The velocity of groundwater flow can be computed knowing the hydraulic conductivity (K) and the hydraulic gradient (i).

$$\text{Velocity} = Ki$$

From pump test data collected from well #39 a transmissivity of 2 to 10 m^2 per day has been calculated. The saturated aquifer thickness in this well was measured at 3.93 metres. This gives a hydraulic conductivity of between 2×10^{-5} and 5×10^{-6} metres per sec. Groundwater gradients in the area have been calculated at between 1v:5h to 1v:10h.

Since velocity (V) = Ki, we can calculate average groundwater flow velocities. Calculated flow velocities are presented below in Table 1.



LEGEND

⊕	BORE (PLUGGED)
⊗	EXISTING PIEZOMETER
⊕	GTNZ MONITORING WELL LOCATIONS

DRAWDOWN CONTOURS

500mm DRAWDOWN
100mm DRAWDOWN
50mm DRAWDOWN

0 50
SCALE METRES

NOTES: ALL LOCATIONS ARE APPROXIMATE.

SOURCE: DOWELANCO (NZ) LTD

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GROUNDWATER TECHNOLOGY

8 LEEK STREET
PO BOX 109 757
NEWMARKET AKL
(09) 524 4447

REV. NO.: 2
DRAWING DATE: 1/11/95
ACAD FILE: N1004F2

MAXIMUM EXTENT OF DRAWDOWN

CLIENT: DOWELANCO (NZ) LTD
PM:
LOCATION: NEW PLYMOUTH PLANT
PE/RG:
DESIGNED: D.W.
DETAILED: J.T.
PROJECT NO.: N1034
FIGURE: 8

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TABLE 1 - AVERAGE GROUNDWATER VELOCITIES

Gradient	Hydraulic Conductivity (m/day)	Velocity (m per day)
i=0.1	K =1.728	0.173
	K= 0.432	0.346
i = 0.2	K =1.728	0.043
	K = 0.432	0.086

Based on these calculations the average groundwater velocity ranges from 0.086 metre per day to 0.346 metre per day. Thus to travel the shortest straight line distance of 50 metres to the property boundary will take between 144 and 581 days. To reach the coast, approximately 300 metres away will take between 867 and 3,490 days.

3.5 Groundwater Macro ion Data

Macroion analysis results are summarised in Table 2 and presented as a Piper Trilinear Plot in Figure 9. Data show that there is little difference in the geochemical signature between the water in the "shallow perched" system and the deeper "regional" system. This is to be expected since they are both likely to be recharged by rainfall and the geology of the two aquifers is similar. Residence times are also likely to be similar.

Examination of data plotted on a Piper trilinear diagram show no clear trends or patterns. Wells # 28 and 39 stand apart from the rest of the samples in that they have higher levels of carbonate-bicarbonate and lower levels of sulphate and chloride. Both these wells are know to contain impacted groundwater. However, this trend is not uniform since wells #36 and 37 are also know to contain impacted groundwater but both plot with the remaining wells.

DowElanco (NZ) Ltd.

FIGURE 9 CONFIDENTIAL

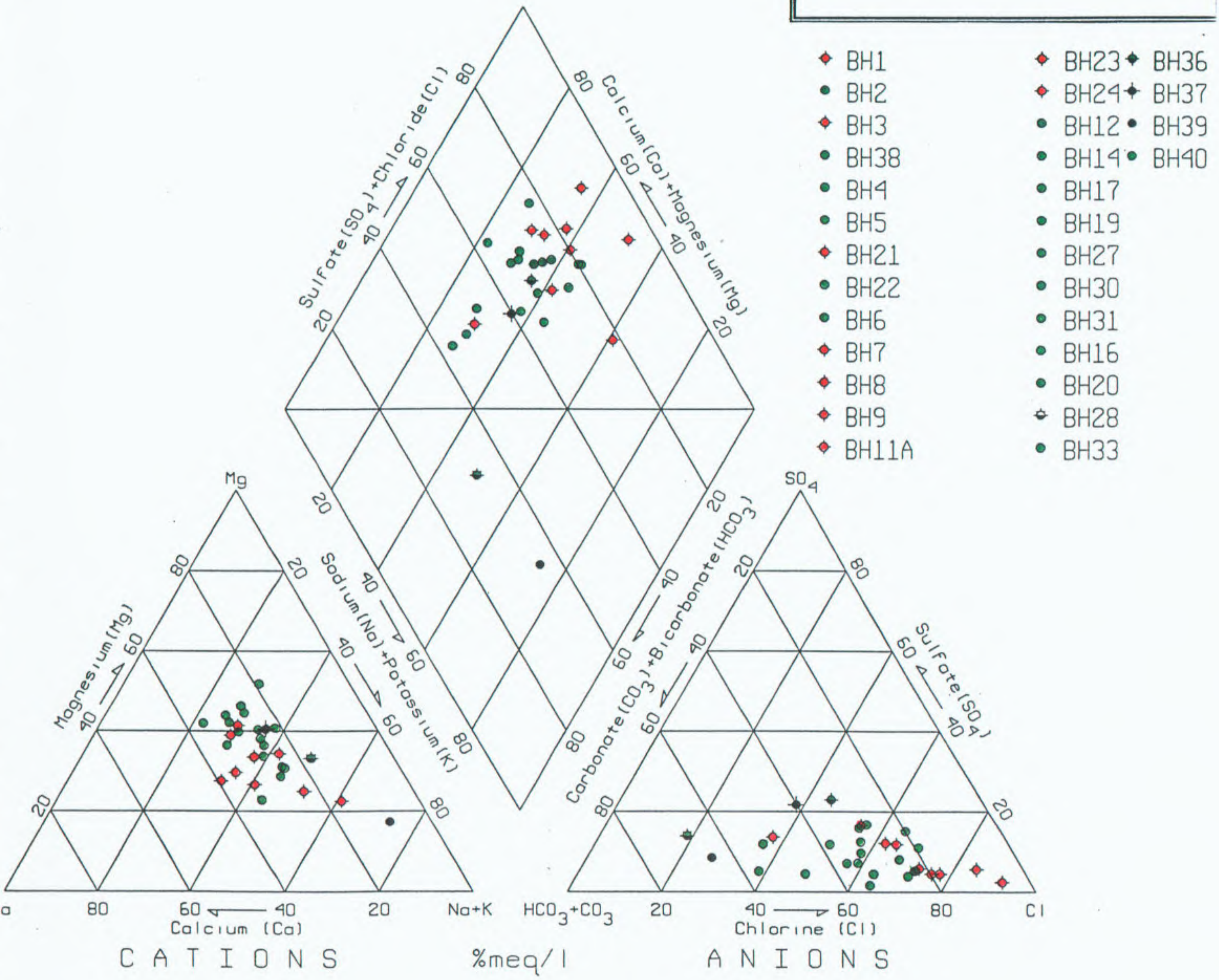
PIPER TRILINEAR DIAGRAM

MACRO-ION ANALYSIS

DOW ELANCO CHEMICAL PLANT

NEW PLYMOUTH

7 NOV 1994



NOTE: Solid or semi solid symbols indicate data from "hot" wells .
Red indicates data from "shallow perched" aquifer .
Green indicates data from "deeper" aquifer .

GROUNDWATER TECHNOLOGY

TABLE 2 - GROUNDWATER MACROION RESULTS SAMPLES COLLECTED BETWEEN 25 AUGUST AND 2 SEPTEMBER 1994 RESULTS IN PARTS PER MILLION

Date Collected	Well ID	Na^+	K^+	Ca^{2+}	Mg^{2+}	Cl^-	HCO_3^-	SO_4^{2-}	Fe^{Total}	Mn^{Total}
25.8.94	BH1	22	3.5	17	9	42	51	15	0.13	0.05
	BH2	28	3.6	13	5.2	42	46	9.2	53	0.92
25.8.94	BH3	72	9.3	45	19	152	105	16	130	2
	BH3B	20	3.2	12	3.1	35	32	15	27	0.59
	BH4	40	5.6	18	8.3	63	100	3	59	4.5
	BH5	40	3.6	17	7.9	35	29	9.3, [10]	13	0.36
	BH21	22	7.9	20	9.1	28	110	19	18	2.8
	BH22	45	4.3	20	14	63	66	6.4	68	1.2
26.8.94	BH6	38	3.2	27	18	49	140	8.4	27	0.36
	BH7	24	4.2	11	5.8	42	65	23	28	0.97
	BH8	17	2.4	16	4.1	42	45	14	26	0.95
	BH9	35	1.9	27	8.4	92	32	11	40	0.68, [0.61]
	BH11A	94	7.6	33	13	230	46	11	13	0.22
26.8.94	BH23	25, [26]	5.5	17, [14]	5.1	63	49	6.7	3.5	0.12
	BH24	32	3.1	6.8	3.4	63	56	9	22	1
27.8,94	BH12	33	6.7	30	12	54	87	22	120	5.4
	BH14	45, [46]	4.6, [6.5]	25, [21]	13, [13]	54	120	23	18	2
	BH17	34	5.5	44	19	61	117	14	54	0.52
	BH19	43	4.4	39	21	105	99	14	16	0.41
	BH27	29	3.7	16	7.3	43	70	13	170	4
	BH30	38	5.7	22	13	56	89	30	31	0.46
	BH31	32	4	22	14	58	100	13	6.2, [5.1]	0.1,[0.07]
31.8.94	BH16	64	7.1	48	24	109	163	14	5.4	1.8
	BH20	41	4	35	18	42	183	10	270	3.6
	BH28	93	6.5	26	18	28	299	38	41	2.3

NOTE: Cl^- = chloride, SO_4^- = sulphate, HCO_3^- = bicarbonate, Ca^{2+} = calcium, Mg^{2+} = magnesium,
Na^+ = sodium, K^+ = potassium, Fe^{TOTAL} = iron, Mn^{TOTAL} = manganese:
ND = Not detected [5.1] denotes duplicate sample.

Table continues next page.

Table continued

Date Collected	**Well ID**	**Na^+**	**K^+**	**Ca^{2+}**	**Mg^{2+}**	**Cl^-**	**HCO_3^-**	**SO_4^{2-}**	**Fe^{Total}**	**Mn^{Total}**
31.8.94	BH33	36	3.2	20	11	49	71	27	120	3.3
	BH36	59	5.1	30	19	60	126	56, [56]	110	1.8
	BH37	50	3.5	25	16	60	187	63	1, [100]	21
2.9.94	BH39	150	7.1	14	10	73	520	41, [42]	51	3.2
	BH40	41	4	21	21	52	220	31	170	5.9

NOTE: Cl^- = chloride, SO_4^- = sulphate, HCO_3^- = bicarbonate, Ca^{2+} = calcium, Mg^{2+} = magnesium,
Na^+ = sodium, K^+ = potassium, Fe^{TOTAL} = iron, Mn^{TOTAL} = manganese:
ND = Not detected [5.1] denotes duplicate sample.

4. ANALYTICAL RESULTS

This section summarises available laboratory soil and groundwater data collected from the site between 1994 and 1996. The information is presented in tabular format with soils data followed by groundwater data. Laboratory reports are presented in Appendix E

4.1 Soil Analytical Data

4.1.1 Chlorophenols and Phenoxies

TABLE 3 - SOIL ANALYTICAL RESULTS
SAMPLES COLLECTED 1994 TO 1996
RESULTS IN PARTS PER MILLION (MG/KG)

DateCollected	Well ID	Sample ID	Depth (mbgl)	Phenoxies (mg/kg)	Chlorophenols (mg/kg)
22 & 23.8.94	BH33	940823-3	1	ND	ND
		940823-1	18.7	ND	ND
		940823-2	20.2	ND	ND
23 & 24.8.94	BH34	940823-4	0.5	ND	ND
		940823-7	23.4	ND	ND
		940823-10	25.6	ND	ND
25.8.94	BH35	940823-16	0.5	ND	ND
		940823-13	9.6	ND	ND
		940823-19	23.4	ND	ND
26.8.94	BH36	940823-5	0.5	ND	ND
		940823-8	14.4	ND	ND
		940823-11	23.4	ND	ND
METHOD DETECTION LIMITS				1	1

NOTE: ND not detected above method detection limits.
mbgl metres below ground level:
All concentrations are in mg/kg
Concentrations in excess of method detection limits are shaded and in bold.
[25.7] denotes duplicate sample.

Table continues on next page

Table continued

DateCollected	Well ID	Sample ID	Depth (mbgl)	Phenoxies (mg/kg)	Chlorophenols (mg/kg)
29 & 30.8.94	BH37	940823-22	20.3	ND	ND
		940823-25	23.8	ND	ND
		940823-28	24.6	ND	ND
30.8.94	BH38	940823-29	6.5	ND	ND
		940823-27	12.7	ND	ND
		940823-30	18	ND	ND
31.8.94	BH39	940823-14	1.9	ND	**18.3**
		940823-15	6.5	**2.5**	**6.8**
		940823-17	9.6	**6.5**	**5.9**
		940823-18	12.6	**4.6**	**3.1**
		940823-20	15.7	**4**	**3.3**
		940823-21	17.2	**6.6**	**1**
		940823-23	20.2	**3.7**	ND
		940823-24	22	**2.5**	ND
		940823-26	24.8	**5.6**	ND
1.9.94	BH40	940823-32	0.9	ND	ND
		940823-9	2	ND	ND
		940823-12	20.3	ND	ND
		940823-31	21.8	ND	ND
10/10/95	BH39a	1	2.9	**74.56**	**129.71**
		2	5.5	**19.86**	**75.3**
		3	8.5	**2.11**	**7.92**
13/10/95		1	20.1	ND	ND
METHOD DETECTION LIMITS				1	1

NOTE: ND not detected above method detection limits.
mbgl metres below ground level:
All concentrations are in mg/kg
Concentrations in excess of method detection limits are shaded and in bold.
[25.7] denotes duplicate sample.

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Table continued

DateCollected	Well ID	Sample ID	Depth (mbgl)	Phenoxies (mg/kg)	Chlorophenols (mg/kg)
10/10/95	BH39b	1	0.5	ND	ND
		2	1.3	**39.58**	**77.47**
10/10/95	BH39c	1	2.7	**5 521.5**	**1 806.5**
		2	5.6	**6.3**	1.0
		3	8.6	**5.99**	**4.89**
10/10/95	BH39d	1	1.5	ND	**2.69**
		2	4.5	**2.99**	**48.21**
		3	8.5	**3.33**	**18.49**
11/10/95	BH39e	1	1.5	ND	ND
		2	5.5	ND	**2.07**
		3	8.5	ND	**5.4**
11/10/95	BH39f	1	0.5	**551.3**	**546.18**
		2	7.5	**57.1**	**17.8**
		3	9.7	**1.25**	ND
12/10/95	BH39g	1	0.5	ND	ND
		2	3.5	ND	ND
		3	7.5	ND	ND
12/10/95	BH39h	1	0.5	ND, [ND]	ND, [ND]
		2	1.5	ND	ND
		3	8.2	ND	ND
12/10/95	BH39i	1	0.5	**2 071.65**	**65**
		2	5.5	ND	ND
		3	8.2	ND	ND
METHOD DETECTION LIMITS				1	1

NOTE: ND not detected above method detection limits.
mbgl metres below ground level:
All concentrations are in mg/kg
Concentrations in excess of method detection limits are shaded and in bold.
[25.7] denotes duplicate sample.

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Table continued

DateCollected	Well ID	Sample ID	Depth (mbgl)	Phenoxies (mg/kg)	Chlorophenols (mg/kg)
20/10/95	BH39j	1	20.7	**1.03**	ND
24/10/95	BH39k	1	23.0	**12.17**	**12.47**
2/9/94	BH16a	940823-33	21.9	ND	ND
		940823-35	25	**2**	ND
		940823-36	27	ND	ND
		940823-37	29	ND	ND
19/10/95	BH16b	1	8.5	ND	ND
		2	11.3	ND	ND
		3	20.5	**2.21**	ND
13/10/95	BH16c	1	10.5	**22.03**	**67.86**
		2	14.45	**30.08**	ND
		3	20.5	**2.61**	ND
METHOD DETECTION LIMITS				1	1

NOTE: ND not detected above method detection limits.
mbgl metres below ground level:
All concentrations are in mg/kg
Concentrations in excess of method detection limits are shaded and in bold.
[25.7] denotes duplicate sample.

4.2 Groundwater Analytical Data

Groundwater samples were collected from all wells in 1993 and analysed for concentrations of chlorophenol (PCOC, 2,4-DCP, 2,4,5-TCP and 2,4,6-TCP), phenoxie (2,4-D, 2,4-T, MCPA and MCPB) organophosphate (Diazinon, Phosate and Chlorpyrifos) and solvents (including xylene, ethlybenzene, ethanol, methanol, Butoxyethanol, 1-Buthanol and n-Buthanol). Results are summarised in the following tables. Groundwater samples from later sampling events were predominantly analysed for chlorophenol and phenoxie concentrations.

Screening results (1993) for organophosphates and solvents were all no detect with method detection limits of 5 µg/l and 10 mg/l respectively.

4.2.1 Chlorophenol Concentrations

TABLE 4 - CHOROPHENOL CONCENTRATIONS 1993 TO 1996
RESULTS IN PARTS PER MILLION (MG/L)

WELL ID	CHLOROPHENOLS (mg/l) 1993	CHLOROPHENOLS (mg/l) 1994	CHLOROPHENOLS (mg/l) 1995	CHLOROPHENOLS (mg/l) 1996
1	ND	NS	NS	NS
2	ND	NS	NS	NS
3	ND	NS	NS	ND
3a	ND	NS	NS	NS
3b	NS	NS	NS	NS
4	ND	NS	NS	NS
4a	Well dry and plugged			
5	ND	NS	NS	NS
6	ND	NS	NS	ND
7	ND	NS	NS	NS
8	ND	NS	NS	NS
9	ND	NS	NS	NS
10	Well #'s 10, 10a & 10b all dry and plugged			
11	Well dry and plugged			
11a	ND	NS	NS	NS
12	ND	NS	NS	NS
13		NS	NS	NS
14	ND	NS	NS	NS
15	NS	ND	ND	ND, [ND]
16	ND	NS	NS	NS
16a		NS	ND	NS
Method Detection Limits	*0.1**	*0.1 **	0.03	0.03

NOTE: ND = not detected above method detection limits:
NS = not sampled:
[1.6] = Duplicate result
All concentrations are in mg/l unless stated otherwise.

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WELL ID	CHLOROPHENOLS (mg/l) 1993	CHLOROPHENOLS (mg/l) 1994	CHLOROPHENOLS (mg/l) 1995	CHLOROPHENOLS (mg/l) 1996
17	ND	NS	NS	NS
18		NS	NS	NS
19	ND	NS	NS	NS
20	ND	NS	NS	ND
21		NS	NS	ND
22	ND	NS	NS	ND
23	ND	NS	NS	NS
24	ND	NS	NS	NS
24a	Well dry and plugged			
25	Well dry and plugged			
26		NS	NS	NS
27	ND	NS	NS	NS
28	0.11	ND	ND	ND
29	Well dry and plugged			
30	ND	NS	NS	NS
31	ND	NS	NS	NS
32	NS	NS	NS	ND
33	Well not Installed	ND	**0.132 [0.133]**	ND
34	Well not installed	NS Well dry	ND	ND
35	Hole dry and plugged			
36	Well not installed	ND	ND	ND
37	Well not installed	ND	ND	ND
38	Hole dry and plugged			
Method Detection Limits	***0.1****	***0.1 ****	0.03	0.03

NOTE: ND = not detected above method detection limits:
NS = not sampled:
[1.6] = Duplicate result
All concentrations are in mg/l unless stated otherwise.

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WELL ID	**CHLOROPHENOLS (mg/l) 1993**	**CHLOROPHENOLS (mg/l) 1994**	**CHLOROPHENOLS (mg/l) 1995**	**CHLOROPHENOLS (mg/l) 1996**
39	Well not installed	**1.6, [1.1]**	ND	ND
39j	Well not installed until Nov 1995		NS	1.524, [1.36]
39k	Well not installed until Nov 1995		NS	0.298
40	Well not installed	ND	ND	ND
41	Well not installed		ND	ND
42	Well not installed		ND	**0.451,** **0.265, [0.446] Filtered** **1.434 Unfiltered**
43	Well not installed		ND, [ND]	NS
44	Hole dry and plugged			
Method Detection Limits	*0.1**	*0.1 **	0.03	0.03

NOTE: ND = not detected above method detection limits:
NS = not sampled:
[1.6] = Duplicate result
All concentrations are in mg/l unless stated otherwise.
Concentrations in excess of method detection limits are shaded and in bold.
* Method detection limits changed after 1994.

4.2.2 Phenoxie Concentrations

TABLE 5 - PHENOXIE CONCENTRATIONS 1993 TO 1996
RESULTS IN PARTS PER MILLION (MG/L

WELL ID	PHENOXIES (mg/l) 1993	PHENOXIES (mg/l) 1994	PHENOXIES (mg/l) 1995	PHENOXIES (mg/l) 1996
1	ND	NS	NS	NS
2	ND	NS	NS	NS
3	ND	NS	NS	ND
3a	ND	NS	NS	NS
3b		NS	NS	NS
4	ND	NS	NS	NS
4a	Well dry and plugged			
5	ND	NS	NS	NS
6	ND	NS	NS	ND
7	ND	NS	NS	NS
8	ND	NS	NS	NS
9	ND	NS	NS	NS
10	Well #'s 10, 10a & 10b all dry and plugged			
11	Well dry and plugged			
11a	ND	NS	NS	NS
12	ND	NS	NS	NS
13		NS	NS	NS
14	ND	NS	NS	NS
15		ND	ND	ND, [ND]
Method Detection Limits	***0.1*** *	***0.1*** *	0.03	0.03

NOTE: ND = not detected above method detection limits:
NS = not sampled:
[1.6] = Duplicate result
All concentrations are in mg/l.
Concentrations in excess of method detection limits are shaded.
* Note that method detection limits changed after 1994.

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WELL ID	PHENOXIES (mg/l) 1993	PHENOXIES (mg/l) 1994	PHENOXIES (mg/l) 1995	PHENOXIES (mg/l) 1996
16	ND	NS	NS	NS
16a		NS	0.11	NS
17	ND	NS	NS	NS
18		NS	NS	NS
19	ND	NS	NS	NS
20	ND	NS	NS	ND
21		NS	NS	NS
22	ND	NS	NS	ND
23	ND	NS	NS	NS
24	ND	NS	NS	NS
24a	Well dry and plugged			
25	Well dry and plugged			
26		NS	NS	NS
27	ND	NS	NS	NS
28	0.15	0.1	ND	ND
29	Well dry and plugged			
30	ND	NS	NS	NS
31	ND	NS	NS	NS
32	NS	NS	NS	ND
33	Well not installed	ND	**1.198, [1.208]**	ND
34	Well not installed	NS	**0.051**	**0.083**
Method Detection Limits	***0.1 ****	***0.1 ****	0.03	0.03

NOTE: ND = not detected above method detection limits:
NS = not sampled:
[1.6] = Duplicate result
All concentrations are in mg/l.
Concentrations in excess of method detection limits are shaded.
* Note that method detection limits changed after 1994.

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WELL ID	**PHENOXIES (mg/l) 1993**	**PHENOXIES (mg/l) 1994**	**PHENOXIES (mg/l) 1995**	**PHENOXIES (mg/l) 1996**
35	Hole dry and plugged			
36	Well not installed	**0.15**	ND	ND
37	Well not installed	**0.19**	ND	ND
38	Hole dry and plugged			
39	Well not installed	**2.3, [1.9]**	ND	ND
39j	Well not installed until Nov 1995		NS	**14.532, [14.377]**
39k	Well not installed until Nov 1995		NS	**2.741**
40	Well not installed	ND	ND	ND
41	Well not installed until Nov 1995		ND	ND
42	Well not installed until Nov 1995		ND	**1.848,** **2.887, [3.254] filtered** **6.509 Unfiltered**
43	Well not installed	NS	ND, [ND]	NS
44	Hole dry and plugged			
Method Detection Limits	*0.1 **	*0.1 **	0.03	0.03

NOTE: ND = not detected above method detection limits:
NS = not sampled:
[1.6] = Duplicate result
All concentrations are in mg/l.
Concentrations in excess of method detection limits are shaded.
* Note that method detection limits changed after 1994.

4.3 Modelling Data

The modelling objectives were:

- To collect baseline groundwater quality data for inclusion in fate and transport model.
- Develop a water balance for the site.
- Develop a groundwater flow model for the site.
- Develop a predictive fate and transport model for chlorophenol and phenoxies from the area of well # 39.

- Prepare a report summarising the findings of the groundwater modelling.

The following was completed to assist the modelling:

- Water level gauging in all specified wells.
- Purging and collection of groundwater samples from monitoring well #'s 3, 6, 15, 20, 22, 28, 32, 33, 34, 36, 37, 39, 39j, 39k, 40, 41 and 42, to provide baseline groundwater data.
- Establishment of groundwater balance from meteorological data and calculate the volume of water exiting the site at specified points.
- Using MODFLOW to generate a groundwater flow model of the site.
- Generate a fate and transport model for chlorophenols and phenoxies from the area around well #39.
- Analysis of data and preparation of this report.

4.3.1 Groundwater Modelling

Modelling is conducted in two parts. First, a groundwater flow model is developed using MODFLOW, a modular finite element flow modelling program developed by the USGS. Second, a predictive fate and transport model for the nominated chemical compounds is developed using the US Geological Survey model MOC (Method of Characteristics). MOC is used widely for contaminant fate and transport modelling around the world.

The following basic assumptions are used in the modelling

- Flow regions are of infinite extent in a longitudinal direction and of great extent in the lateral direction.
- Aquifer being modelled is homogenous, and isotropic.
- Flow within the aquifer is uniform and continuous in direction and velocity.
- Hydraulic properties of the aquifer do not vary with temperature or density of groundwater.
- Groundwater upgradient of source area is free of the contaminant.
- Contaminant adsorption is governed by linear and reversible equilibrium adsorption isotherm.
- Unsaturated flow (vadose zone) is steady and in a vertical direction only.

4.3.1.1 Groundwater Flow Model

MODFLOW solves for heads in the aquifer, and provides water budgets for both the entire site and any zone(s) selected within the modelled area.

The grid adopted for the MODFLOW analysis is centred on the site and comprises of 24 rows by 28 columns of cells, each 25m x 25m. Modelling results and input data are presented in Appendix F. Our analysis is for steady-state conditions, with the initial heads based on the estimated existing heads as determined by our latest gauging data. To provide through flow, groundwater is injected at the upgradient boundary and discharged at the downgradient boundary at rates that approximately maintained these heads. A no-flow zone is inferred at the projected location of the andesite, and boundaries to other no-flow areas are taken normal to the inferred equipotential (Figure 7). Zones used in the ZONE BUDGET module of MODFLOW, used to estimate the percentage of water discharging from the site between well #'s 15 and 20, are indicated on a figure in Appendix F.

An average aquifer transmissivity of 6 m^2 per day is used in the model, based on earlier pump test results. Recharge to the aquifer by rainfall infiltration is estimated from annual rainfall and evaporation figures for New Plymouth, as provided by the Meteorological Bureau. Total infiltration to the aquifer (in m/d) is taken as 30 per cent of the difference between average daily precipitation and the average daily evaporation over a typical year.

For the conditions modelled and the adopted heads, MODFLOW output provides a mass balance that agreed to ± 0.05%. ZONBUDEM uses cell-by-cell flow output from MODFLOW to estimate water budgets for sub-regions of the modelled area. To estimate groundwater flow between well #'s 15 and 20, ZONBUDEM data from zones 1 and 2 is used. The results of this analysis are presented in Appendix A. Data suggests that approximately 21.4 m^3 / day (50 per cent), of the volume of groundwater entering the site exits between these two wells. The volume of groundwater leaving the site between well #20 and the eastern boundary of the site (Zone 3) is estimated to be approximately 9.7 m^3 / day.

4.3.1.2 Fate and Transport Modelling

The grid adopted for the fate and transport analysis has 28 x 32 cells, each cell being 20 m x 10 m. The analyses are carried out using the USGS program, Method of Characteristics (MOC). A number of scenarios are modelled as part of this work. The scenarios modelled include:

- Effects of a continuous contaminant source.
- Effects on groundwater concentrations following capping of the source area in the overlying soil.
- Prediction of possible concentrations at various points on the site.

For this modelling the following input data was used for the area around well # 39:

- Initial concentrations are chlorophenols at 1.5 mg/L and phenoxies at 14.5 mg/L.
- Dispersivity is taken at 1.0 metre.
- Average degradation rate is assumed to be 4 x 10^6 seconds (half life).

Modelling results are very sensitive to the degradation rate used. Unlike radioative decay, biotic and/or abiotic degradation of organic compounds is site specific and depends on the nutrients and oxygen available.

Modelling results are presented as concentration contour plans in Appendix F.

4.3.1.3 Continuous Point Source

Under this worst case scenario (source material remains and rainfall infiltration active), of a continuous source of dissolved phase contamination entering the aquifer system. Results are summarised as concentration contours on figures presented in Appendix F and in Table 6.

TABLE 6 - MODEL PREDICTED AND ACTUAL CONCENTRATION

Distance from Source (m)	**Chlorophenol Concentration (mg/L)**		**Phenoxy Concentration (mg/L)**	
	Model	Actual (3/5/96)	Model	Actual (3/5/96)
0	1.5	1.5	14.5	14.5
25	0.97	ND (#15)	9.55	ND (#15)
50	0.42	ND (#32)	6.21	ND (#32)
75	0.4	ND (#20)	3.9	ND (#20)
100	0.25		2.4	
125	0.15		1.47	
150	0.05		0.89	
175	ND		0.46	
200	ND		0.12	
225	ND		ND	
250	ND		ND	
Method Detection Limits	0.03		0.03	

NOTE: ND Denotes not detected above method detection limits
(#20) denotes well groundwater sample from.

Our modelling suggests that chlorophenol concentrations will be below method detection limits within a distance of approximately 150 to 175 metres from a continuous source of contamination. Phenoxy concentrations will be below method detection limits with a distance of 200 to 250 metres. Our modelling suggests that:

- No contaminants of concern will reach the coast at concentrations greater than DowElanco laboratory method detection limits.
- A continuous point source will produce a plume of approximately 175 to 225 metres long.

Analytical data from groundwater samples collected over a four year period (1993 to 1996) shows that degradation rates at the site are faster than those assumed in our model. Analytical data shows that within a distance of not more than 100 metres concentrations of the contaminants of concern have fallen to less than DowElanco Laboratory method detection limits.

For a point source at well # 42, our model predicts that concentrations of the contaminants of concern will be below DowElanco method detection limits within a distance of 100 metres.

4.3.1.4 Capping of Source Area

This scenario assumes that the currently contaminated soil overlying the aquifer is capped with an impermeable seal preventing further rainfall infiltration. The location, size and contaminant concentrations within the plume are indicated for periods of one, three, six, nine and twelve months on figures presented in Appendix F. Data at the time step of 12 months following construction of the seal is presented in Table 7.

TABLE 7 - MODEL PREDICTED CONCENTRATIONS AFTER 12 MONTHS

Distance from Source (m)	Chlorophenol Concentration (mg/L)	Phenoxy Concentration (mg/L)
0	1.5	14.5
25	0.86	8.34
50	0.49	4.77
75	0.27	2.63
100	0.15	1.43
125	0.08	0.77
150	0.04	0.41
175	ND	0.22
200	ND	0.12
225	ND	0.07
250	ND	0.04
Method Detection Limits	0.03	0.03

Our model suggests that concentrations of contaminants will be at or below method detection limits within 250 metres from the source. Existing groundwater data indicate that the degradation rate at the site is faster than that assumed for the model. Existing water quality data shows that concentrations of the contaminants of concern are less than those predicted by this modelling.

4.3.1.5 Contaminant Concentrations at Specific Locations

Modelling suggests that groundwater concentrations above DowElanco Laboratory method detection limits may be present up to the property boundaries (well #39). Existing historical water quality data confirms that the contaminants of concern are decreasing in concentration over time and distance from the source areas at rates faster that predicted by the model. Actual data confirms that the input model parameters are conservative. Modelling has used conservative (low) degradation rates as reported in the literature. This difference can be related to a combination of factors including:

- Natural degradation of the contaminants of concern occurs at higher rates than assumed in the model.
- Groundwater flow is slower than that assumed in the model.

5. CONCLUSIONS

5.1 Site Geology

Based on information obtained from the soil boring program, the geology at the site is interpreted as predominantly weathered air fall andesitic tephras and andesitic flows. Soils present at the site consist of fine sands and silty sands interbedded with silts and silty clays. Andesite rock is present at depth. Our interpretation of the sub-surface geology at the site is presented in cross-sections (Figures 3 to 6). The sequence of materials penetrated at each bore hole is depicted on the drilling logs (Appendix A). Construction details of each well are given on these logs.

5.2 Site Hydrogeology

Initial groundwater levels are shown on drilling logs presented in Appendix A. Gauging data is presented in Appendix B. Interpreted groundwater elevation contours in the deep aquifer system are shown in Figure 7. Data indicates that two aquifer systems are present at the site. A localised shallow rainfall recharged upper aquifer (largely confined to the northeastern side of the site) and a deeper "regional aquifer".

In the south-eastern sector of the site, away from the area under investigation, previous work has identified a "shallow perched water table" aquifer system (Hydrogeology Survey, February 1994). This report indicates groundwater flow is to the south-east. Water levels within this system are reported to be within 1.5 and 3.0 metres below the ground surface.

A deeper "regional" aquifer system is present across the entire site. Water levels within this system are between 14 and 27 metres below ground surface. Typically regional flows are towards the west to north-west direction, towards the coast.

Within the regional groundwater system localised variations in flow direction occur. This is illustrated on Figure 7 which shows groundwater contours around well #28. Based on the results of this gauging, groundwater flow direction beneath this area of the site is predominantly towards the north and northwest. However, south of well #37 there appears to be groundwater flow towards the south and southwest. On the basis of the interpreted groundwater elevation contours the average hydraulic gradient is between 0.1 and 0.3 (1v:5h to 1v:3h).

A localised disturbance in the groundwater flow is known to be due to the presence of andesite rock forming a boundary to groundwater flow. The depth to the underlying andesite rock varies across the site. West and south west of wells #28, 36 and 37, drilling has not encountered groundwater above the andesite rock.

5.3 Impacted Soil Areas

Soil sample analytical results show that the majority of soil samples do not contain phenoxies or chlorophenols at concentrations above the method detection limits.

Soils recovered from hole #'s 16a, 16b, 16c, 39, 39a, 39b, 39c, 39d, 39e, 39f, 39I, 39j, and 39k are exceptions. Laboratory results indicate that the soils from these holes contain phenoxies concentrations ranging from 1.03 to a maximum of 5 521.5 mg/kg (#39c at 2.7 metres). In the same holes chlorophenol concentrations range from 1 to 1 806.5 mg/kg (#39c at 2.7 metres). Data indicates a consistent and rapid decrease in concentration within soils with depth.

5.4 Areas of Impacted Groundwater

Groundwater has been impacted by chlorophenol and phenoxie contamination at well #'s 15, 16a, 28, 33, 34, 36, 37, 39, 39j, 39k, 40, 41 and 42. These areas are consistently within or down gradient of known areas of soil impacts. Historical data indicates unless the well is pumped hard, concentrations decrease with time.

5.5 Modelling

Models are developed using the available data, but represent only one possible interpretation of the existing conditions. Assumptions specific to this project are outlined in this report. The models are calibrated to the existing head conditions, with an accuracy of ± 0.05%.

Considering our model results, using current gauging data and baseline water quality data Groundwater Technology (NZ) Limited conclude that under the conditions modelled:

i) No contaminants of concern (chlorophenols and phenoxies) will reach the coastline (at least 300 metres west of the western property boundary) at concentrations above the DowElanco Laboratory method detection limits of 0.03 mg/L, assuming a continuous point source.

ii) No contaminants of concern will be above DowElanco Laboratory method detection limits at any distance greater than 250 metres from the source areas (assuming that the source area at well #39 is capped with an impermeable barrier).

iii) Available groundwater data indicates that groundwater flow velocities are low, ranging between 0.076 to 0.164 metres per day.

iv) Contaminants of concern have relatively short half lives (averaging 46 days).

v) Existing historical water quality data confirms that the contaminants of concern are decreasing in concentration over time and distance from the source areas at rates faster that predicted by the model. Actual data confirms that the input model parameters are conservative.

vi) A groundwater flow model has been developed for the site with an accuracy of ± 0.05 %. This model calculates through flow at 41 m^3 / day. Of this approximately 75% or 31 m^3 / day exits between well #'s 15 and 19 (northwestern and western boundaries) with the remaining 25% exiting between well #'s 6 and 22.

6. REFERENCES

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