Environmental Management Group

Internal Report

Environmental Monitoring Section

Hawke's Bay Dairies: Effects of Dairying Activity on Nitrate Concentrations in Groundwater Interim Report

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HBRC Publication No. 4887
Report No. RM16-68

August 2000

EMT00/04

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Environmental Management Group
Technical Report
ISSN 1174 - 3077

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Hawke's Bay Dairies:

Effects of Dairying Activity on Nitrate Concentrations in Groundwater Interim Report

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August 2000
EMT 00/04
HBRC Plan Number 2909

Abstract:

Water Quality Monitoring of Hawke's Bay Dairies

The following report summarises the information collected to date on nitrate levels within the shallow unconfined aquifer at Crownthorpe including sites impacted by the operation and development of Hawke's Bay Dairies (HBD).

Results from the groundwater monitoring to date identify increasing nitrate levels with time at Bore 2 and 3. A comparison of Bore 3 nitrate concentrations before and after a change to whole farm effluent disposal has identified a significant increase in groundwater nitrate concentrations associated with that change. Furthermore nitrate levels are shown to be significantly different at Bores 1 and 2 in comparison to the upstream control site (Bore 4). Nitrate levels within the property boundary are typically greater than the 11.3 mg/l of nitrate nitrogen recommended in the NZ Drinking Water Standards as being suitable for a potable water supply. Based on the information to date the results indicate a significant rise in nitrate levels in comparison to the upstream control site beneath the Hawke's Bay Dairies property.

We recommend installing a further monitoring bore downstream of the Hawke's Bay Dairies property boundary, to provide additional information to assist in the review of the resource consent in 2001.

Contents:

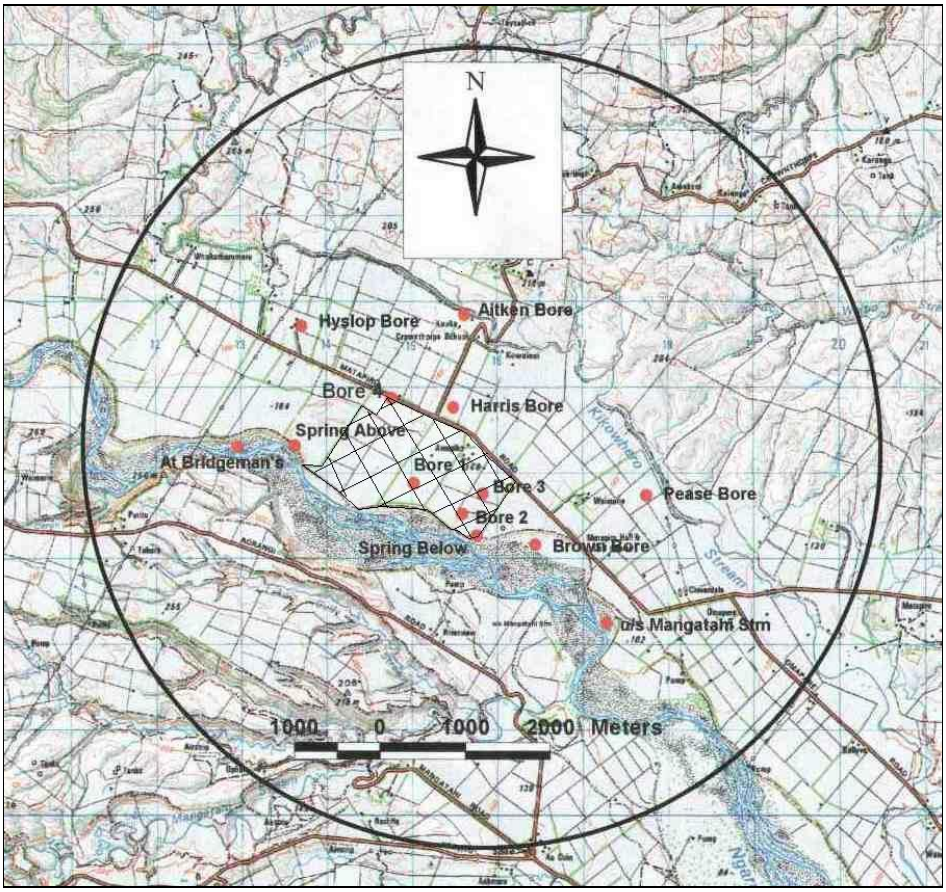
1 Background:

HBD is situated on the northern bank of the Ngaruroro River on a large terrace approximately 40 metres above the river (Figure 1). The general slope of this area is to the east towards the Kikowhero Stream. To the southwest of the farm is a low-lying terrace. The predominant land use in the area is pastoral farming. A small lifestyle block is located west of HBD, a vineyard to the northwest and a tree nursery on the neighbouring property to the east. Groundwater from both shallow and deep wells in the surrounding area is utilised for irrigation, stock and domestic purposes (Osbaldiston, 1997), although currently no shallow downgradient bores are used for domestic supply.

The soils in the area comprise the Takapau series. These soils have a high permeability. However ponding occurs in places after rainfall, because of plugging and sealing of soil pores on open pasture (Osbaldiston, 1997). The soil is deposited over a layer of gravels, locally known as "red metal", approximately 10 metres thick (Thorpe, 1990). This layer yields a modest water supply with a free water table probably recharged by rainfall percolating downwards through the soil. A confining layer of blue papa sits below the "red metals" layer. A deeper aquifer exists below the confining papa exerting an artesian influence.

The depth and permeability of the unconfined layer (and hence potential contamination of the shallow aquifer) makes it particularly susceptible to nitrate and faecal contamination, (Osbaldiston, 1997).

Figure 1 Location of monitoring bores.



The following Table 1 and Figure 2 identify the monitoring sites investigated to date for nitrate concentrations and Tables 2, 3 and Figures 3, 4 detail the results obtained from field and laboratory measurements.

Table 1 Description of sites for water quality monitoring at Crownthorpe (past and present).

HBRC Site #	Site Description	Easting	Northing	Established	Comment
2263	Harris Bore, Crownthorpe	2815489	6174752	14-Oct-97	Discontinued
2264	Aitken Bore, Crownthorpe	2815620	6175837	14-Oct-97	Discontinued
2265	Hyslop Bore, Crownthorpe	2813713	6175705	14-Oct-97	Discontinued
2266	Spring Above Hawke's Bay Dairies	2813631	6174308	14-Oct-97	Discontinued
2267	Ngaruroro River @ Bridgman's, upstream of springs	2812957	6174291	14-Oct-97	Discontinued
2268	Spring Below Hawke's Bay Dairies	2815752	6173256	14-Oct-97	Current
2269	Pease Bore, Crownthorpe	2817741	6173732	14-Oct-97	Discontinued
2270	Brown Bore, Irrigation bore, Crownthorpe	2816442	6173157	14-Oct-97	Discontinued
2372	Hawke's Bay Dairies Investigation Bore 1	2815096	6173989	26-Aug-98	Current
2373	Hawke's Bay Dairies Investigation Bore 2	2815916	6173909	26-Aug-98	Current
2374	Hawke's Bay Dairies Investigation Bore 3	2814898	6173989	26-Aug-98	Current
2506	Hawke's Bay Dairies Investigation Bore 4	2814760	6174860	3-Nov-99	Current

2 Current knowledge on the shallow unconfined aquifer:

Groundwater flow – According to an investigation carried out by Larry Luba, (past Geohydrologist of HBRC), the groundwater flow is likely to be parallel and towards the river. This in part has been supported by the surveying of the bores on Hawke's Bay Dairies (Bores 1, 2 and 3) and the monitoring of groundwater levels, and is consistent with information reported by Thorpe 1990. Due to the nature of the substrate and permeable layers preferential flow paths are likely to exist. Springs exiting the embankments at or about 15 metres below the lower terrace land are evidence for the existence of these preferential flow paths.

The geomorphology of underlying substrate (limestone and papa pans, which also acts as an aquaclude) is fluted (Larry Luba pers. com.) forming preferential flow paths under certain groundwater conditions. These flutings may also restrict progression of groundwater towards the river in certain circumstances e.g. low groundwater table. This could also influence the degree of dilution and dispersion in the underlying groundwater and create localised 'spikes' or 'troughs' dependant on the location of the sampling bore in relation to the 'flutings'.

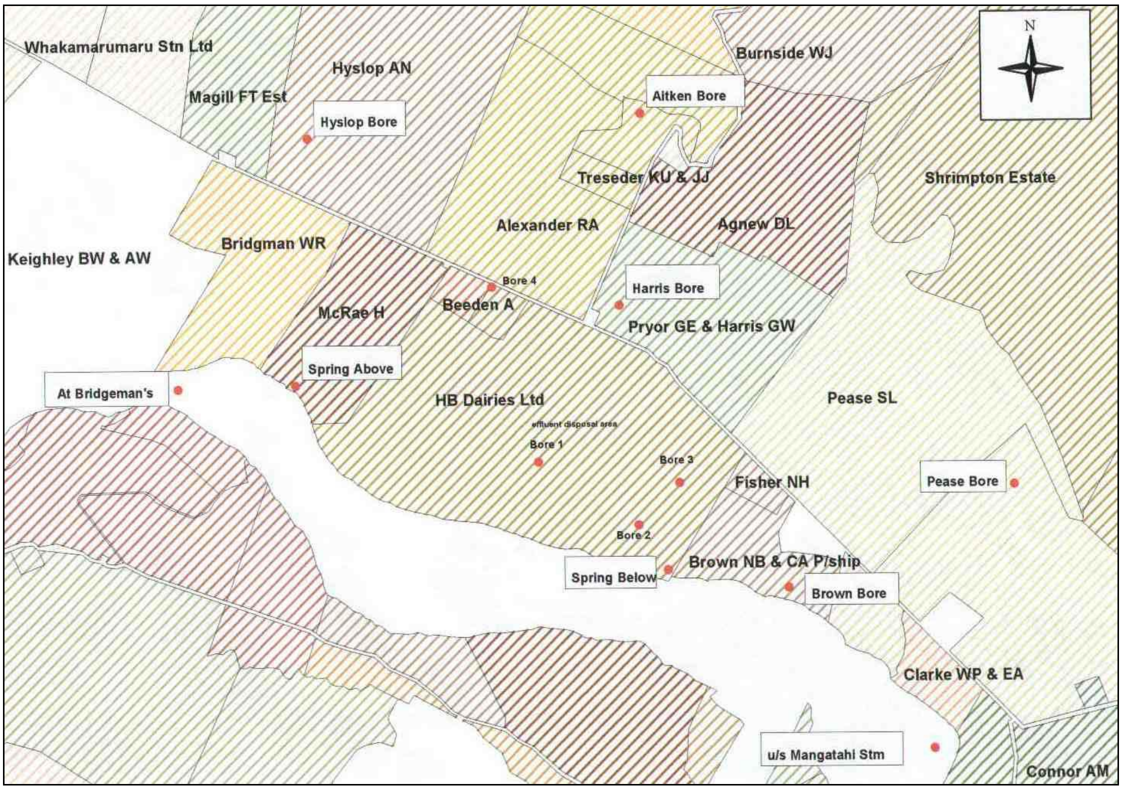
Table 2 Range of Groundwater depths for each bore (metres).

Bore	**Bore 1**	**Bore 2**	**Bore 3**	**Bore 4**
Range	-8.75 to -14.83	-10.81 to -15.08	-14.39 to -23.7	-12.72 to -15.76
Maximum depth	-14.9	-15.1	-25.0	-15.8

(also see Figure 4)

Problems occur when sampling from Bore 1 and 2 during dry periods. The ability to obtain a representative sample by purging becomes restricted as groundwater levels approach 13.5 - 14.0 metres below the ground surface. Accordingly results are likely to become unrepresentative of the aquifer as the maximum bore depth is reached, sediment interference may also cause analytical problems contributing to bias. Identification of outliers that may have occurred as a result of these problems was performed on all sites using WQStat Plus. Only one outlier (not representative of the results) was detected (bore 1, 15/12/98), which was not included in the analysis.

Figure 2 Map identifying property boundaries in relation to water quality sampling sites.



3 Current knowledge on groundwater quality:

Monitoring of the groundwater commenced in 1997 in response to concerns over contamination of the aquifer as a result of HBD's dairy feedlot operation. Concerns were in part addressed during the consent process with reviews of the likely effects of the operation being discussed in the AEE (EMS, 1998), and specific reports of Sparling 1997, 1998 and Roberts et al 1998. Some knowledge on the effects of dairying have been documented suggesting that on intensive dairy farms degradation of groundwater will occur through nitrate contaminated soil water percolate (Ledgard et al 1996). Concerns over the location and integrity of the bores and in response to recommendations by NIWA[1] (Cooke, 1998) resulted in 3 monitoring bores being installed in January 1998.

A review of the existing network of bores was also carried out during the processing of the resource consent (DP980370L), this resulted in only purpose built monitoring bores being utilized for the sampling of nitrate levels within the groundwater, (the integrity and construction of the existing bores being considered inappropriate). As a requirement of the issuing of DP980370L a fourth bore to assess upstream quality was installed in October 1999 (samples being taken from November 1999 onwards).

[1] Review of groundwater monitoring and well network by NIWA 1998.

Sampling was in accordance with condition 31 of DP980370L, at a frequency of monthly for a term of 24 months prior to the establishment of trigger levels (review condition 5 of the consent to be undertaken in September 2001).

Consequently only bores 1 to 4 and the downstream spring are currently monitored. 1 to 4 in accordance with the conditions of HBD's consent for discharge onto land of dairy effluent and the spring below by HBRC due to growing concerns over increases in contamination of the groundwater. The spring below has only been recently reinstated for monitoring after being discontinued for a period of 6 months due to its susceptibility to contamination/interference from overlying activities, (stock grazing and the risk of nitrate increases due to direct fertilizer application). This spring is being used in lieu of an appropriate downstream bore. It should be noted that during the consent process thought was given to having an off site bore (beyond the boundary) downgradient to the HBD operation, although this was consequently not considered necessary at that time.

It was predicted during the consent process that up to 78 kg/nitrogen/ha/year could be lost to the aquifer. The actual effect on the aquifer was not able to be estimated by the applicant consultants, although an independent consultant (Glasson & Potts Group) for the Regional Council noted that this may be in the order of 0.1 – 3 mg/l increase in nitrate levels within the aquifer. This being dependant on groundwater flow characteristics, (Potts, 1998).

As previously noted the HBRC stipulated as a consent condition that sampling would occur for 24 months (from the issuing of the consent) at the HBD site to determine the change in groundwater nitrate levels on site. The rationale of this monitoring was that it would allow identification of nitrate trigger levels and hence provide a basis for avoidance and mitigation. Ten sets of results from bores 1 to 4 are currently available (from November 1999). This report analyses those results.

4 Results:

Intensive monitoring of the Crownthorpe groundwater (shallow aquifer) has occurred since 1997. During this time changes to the number and location of sites being monitored have occurred, resulting in four bores and one spring now being routinely monitored. The following tables and graphs display the data collected since 1997.

Some caution needs to be exercised in interpreting these results as at least one land management change has occurred that has influenced the results namely the increase in stock numbers. The extent of this influence or indeed the extent of those changes is not clearly known. In some cases the short duration of sampling to date reduces the statistical 'power' of the interpretation (e.g. bore 4).

Table 3 shows the nitrate results obtained to date from the HBD onsite bores, and dpwngradient spring. A full set of groundwater results for Nitrate and Faecal coliform concentrations found in the HBD and Crownthorpe area are appended in Appendix 4.

Table 3 Nitrate concentrations in groundwater since monitoring of resource consent DP980370L.

Date sampled	Spring d/s	Bore 1	Bore 2	Bore 3	Bore 4
08/10/99		17.3	16.3	13.2	
03/11/99		16.2	17.3	13.1	11.3

30/11/99		15.5	17.5	12.8	10.4
22/12/99		15.6	20.7	14.3	11.3
26/01/00		14	17.3	13	11
23/02/00		15.3	19.7	13.7	12
22/03/00	11.4	18.8	18.7	14	11.7
27/04/00	11.3	11.9		14.1	12.2
24/05/00	10.8			16.7	11.8
28/06/00	11.3			14.5	12.2
26/07/00	10.3	17.9	23.2	13.9	10.4

Figures 3 and 4 show graphically the changes in the concentration of nitrate within the groundwater. Figure 4 plots the groundwater levels against the nitrate concentrations identified in bore's 1 to 4. This is to assist in interpretation of the changes of nitrate concentrations within the aquifer.

Figure 3 Nitrate concentrations in the Crownthorpe groundwater.

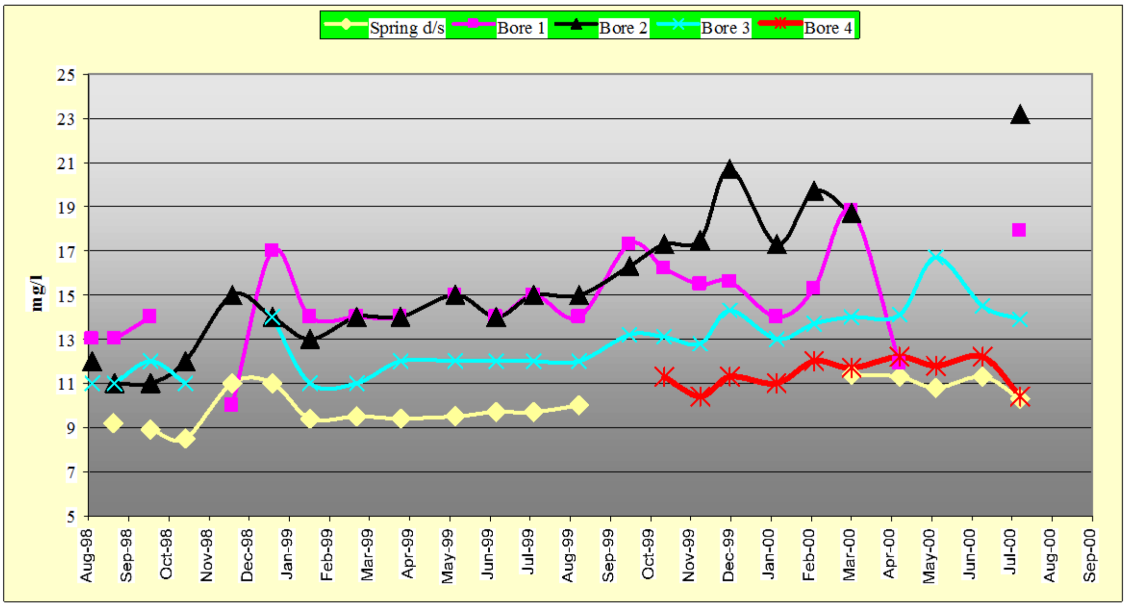


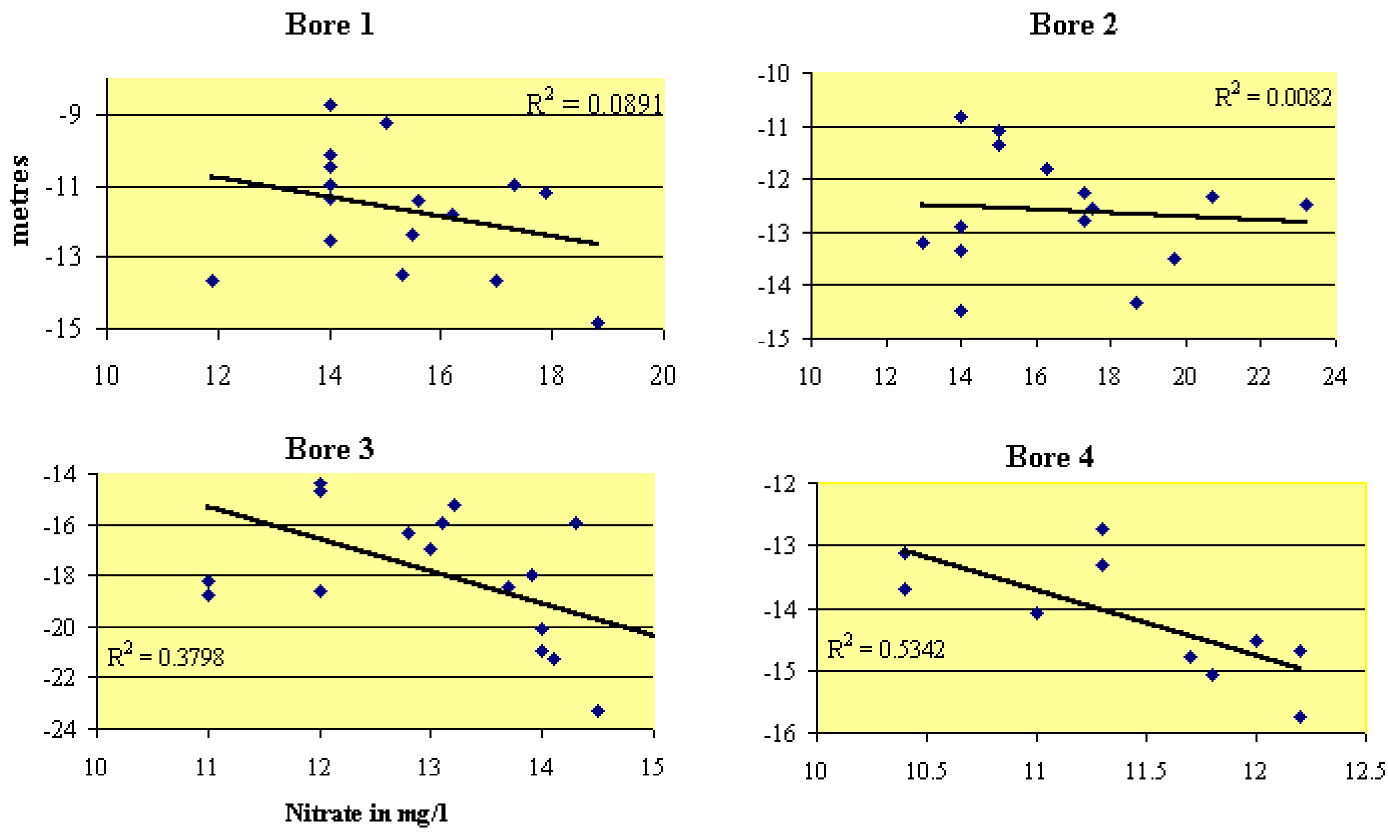
Figure 3 indicates an increase in nitrate concentrations over time within the aquifer. The results having been plotted from October 1998 – July 2000 (Fig. 3). During this period there have been farm management changes that may have had an effect on these results. The most significant management change coincided with the issue of the latest resource consent for the HBD discharge to land activity in October 1999. This changed the effluent disposal area from a selected ~ 41 hectare area (ungrazed and not irrigated further) to 140 hectares (grazed and irrigated). This management change in association with increasing stock levels have coincided with the continued increase in onsite nitrate levels.

The results show an increasing level of nitrate in the groundwater from the initiation of sampling.

Figure 4 has been included to show the fluctuations in groundwater level against nitrate concentrations. The sample size is not sufficient to allow analysis for seasonal or annual trends, Figure 12 in appendix 4 however is included to show the fluctuations shown to date in the groundwater levels.

The plots for Bore 3 and 4 (Fig. 4) identify an increasing concentration with depth trend, this is consistent with less dilution of contaminated (high in nitrates) soil water percolate with that of the aquifer. Bore 1 and 2 have weak trends, with both bores being recorded dry in the early winter period.

Figure 4 Nitrate concentrations vs Groundwater levels at Crownthorpe.



5 Discussion:

5.1 Changes in Median concentrations and Trends in Nitrate.

Small changes in the groundwater nitrate concentrations were expected to occur beneath the HBD property (EMS 1998). Our analysis of the monitoring data helps clarify what change can currently be detected, and may assist in predicting what further changes may be expected.

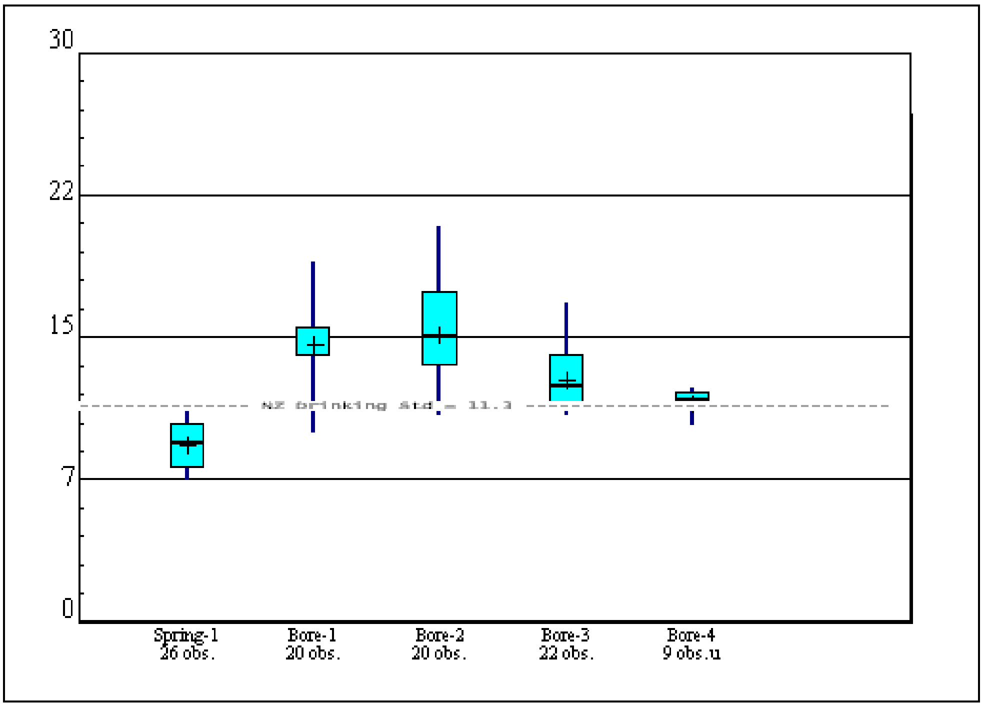
Statistical interpretation was carried out using WQStatplus (IDT 1998) and Ward et al 1988[2].

The box-whisker plot shown in Figure 5 suggests that some of the differences in median concentrations between bores are significant.

The box whisker plot graphically locates the median as the centerline and the interquartile range (25th and 75th percentile) as the ends of the boxes. The "whiskers" extend to the minimum and maximum values of the data set. The plus sign represents the sample mean.

[2] Groundwater Quality: A data analysis protocol

Figure 5 Box-Whisker Plot of Nitrate concentrations (mg/l).



The box whisker plot also shows that Bores 2 and 3 have the greatest variability, and to date appear the most influenced by changes in groundwater levels (as evidenced by difficulty in sampling).

An analysis of the significance of the trends and variation in median values between sites is contained in Appendix 2 and 3. Appendix 1 gives further detail on the statistical approach utilised in this report.

Table 4 identifies the significance of the median background data (Bore 4) in relation to the impact data (Bores 1 to 3 and spring below) using the Kruskal-Wallis Statistic, only paired data has been used for this analysis (10 observations).

Table 4 Contrast table using the Kruskal-Wallis statistic.

Station	Difference	Contrast	Significantly Different?
Spring	-3.000	13.999	No
Bore-1	19.786	12.595	Yes
Bore-2	26.000	12.595	Yes
Bore-3	12.350	11.430	Yes

Where the "Difference" of a station is greater than the "Contrast" (critical value) the hypothesis of a single population should be rejected.

In summary, the conclusions reached in Appendix 2 and 3 identify a significant variation in the median concentrations of nitrate in Bores 1, 2, and 3 (at the $\alpha = 0.05$ significance level).

Significant upward trends in nitrate concentrations are noted in Bores 1, 2, and 3.

5.2 Changes between two sampling periods (Bore 3).

Bore 3 data has been used to identify whether changes in the HBD farm management (restricted farm effluent disposal to whole farm effluent disposal), has attributed to changes in groundwater nitrate levels. Comparison of the nitrate concentrations from before October 1999 to that obtained after is shown in Table 5 and Figures 6 to 8. The box-whisker plot indicates a significant difference between the medians of the two sample periods.

Figure 6 Box-whisker plot of Bore 3 nitrate concentrations.

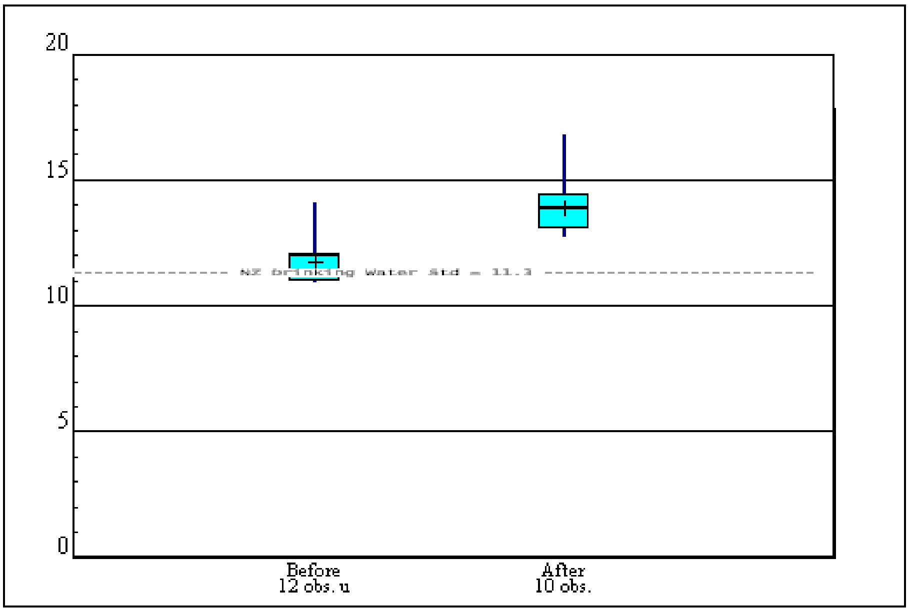
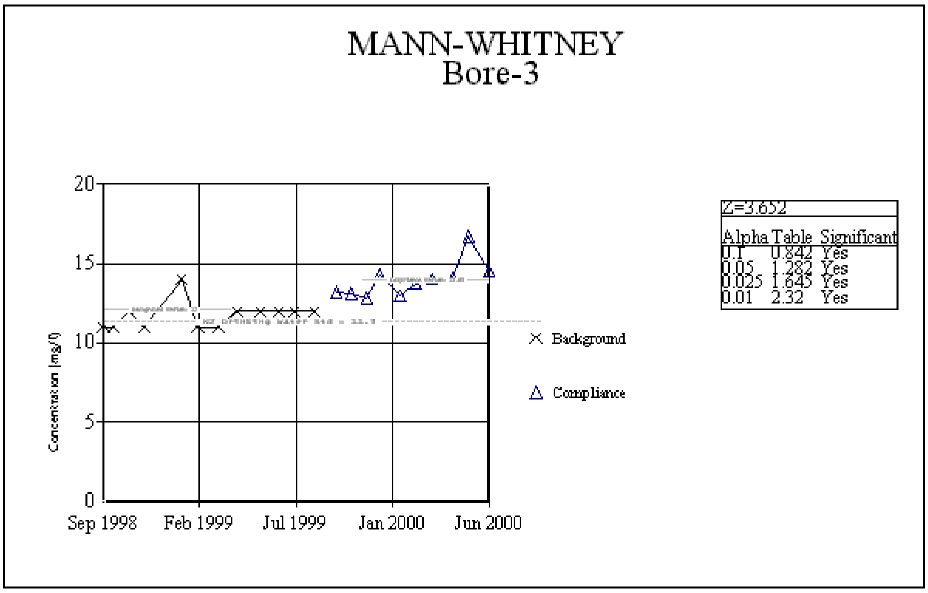


Figure 7 Time series nitrate data from Bore 3.



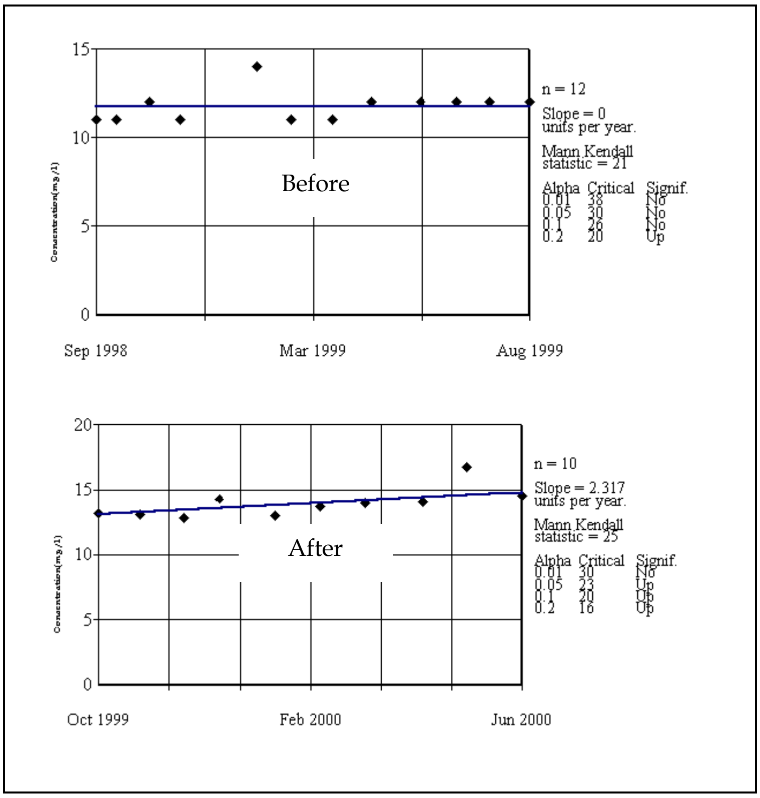
This is confirmed by using the Kruskal-Wallis test, (at the α = 0.05 significance level) and identifies that a significant change in the groundwater has occurred between the two dates (Table 5).

Table 5 Comparison of nitrate medians on Bore 3 (before & after) using ANOVA (Kruskal-Wallis test).

Station	Difference	Contrast	Significantly Higher?
After	9.992	4.573	Yes

Analysis of the two data sets (Figure 8) shows that there is an upward trend in nitrates after the change in farm operation to that before (Mann-Kendall at the α = 0.05 significance level).

Figure 8 Analysis of Bore 3 trends in (before and after farm management changes) nitrate concentrations.



What we can expect in the way of final nitrate concentrations beneath the HBD property is not clear as an increasing trend is still being observed. Further monitoring needs to be carried out to identify the variation under the current farming regime.

6 Conclusions:

Bores 1 to 4 were installed to represent the effect that HBD is having on the aquifer. The monitoring results from these, as detailed above, are consistent with a downgradient effect from the HBD operation. In all 3 of the onsite bores (1, 2 & 3) a significant increase in nitrate levels in comparison to background is noted.

With the collection of more data the interpretation of these results will become more robust, a cautionary approach should therefore be taken in the interim to the interpretation of the analysis where comparisons to bore 4 are made.

This trend in declining water quality is of a concern as concentrations identified in the groundwater are in excess of the NZ Drinking water standard (11.3 mg/l). More importantly however, (in view of groundwater not being abstracted for human consumption in the immediate vicinity of the potentially contaminated area), the nitrate concentrations are greater than that anticipated during the consent application and assessment of effects. What appears to have happened though is that the change in effluent disposal and associated land management practices to the whole farm has intensified the land use.

Although no estimate of the actual effect on the aquifer has been undertaken, apart from estimates of soil moisture percolate entering the aquifer, the assumption was that this would be negligible and not significant beyond the boundary. Results at hand suggest that this may not in fact be the case but the earlier estimates of the soil water reaching the aquifer (up to 48 mg/l of NO3-N, Sparling 1996) may be appropriate. This brings into question the original estimates made in 1998 utilising the "Overseer" model (AgResearch), the parameter estimates may need to be readdressed, as farm activities and stocking rates may have departed significantly from the original numbers (740 cows, from EMS 1998).

The question that remains to be answered however is "what is the effect beyond the boundary?" Currently no downstream bore has been installed; instead sampling of the downstream spring has been reinstated as an initial step. Results from this site since sampling recommenced suggest an elevation above previous levels. This is academic in some respects as this spring is not utilised as a water supply but rather drains to the Ngaruroro River, the effect on this system would not be identifiable.

However the spring does give an indication that concentrations have increased which now puts into question what effect is occurring in groundwater at the boundary, bearing in mind that groundwater flows are parallel and towards the river.

7 Recommendations:

It is recommended that a further bore be installed to gauge the effect beyond the boundary from the HBD operation. At present the information suggests that this effect may be significant and groundwater will continue to decline in water quality.

The whole farm nitrogen balance as presented using the "Overseer" model appears to be critical in identifying nitrate leachate potential. The ongoing requirement for annual reassessments of the nitrate leaching using "overseer" will assist in establishing whether the original calculations are still valid and hence the premise of trigger levels in response to increased nitrate formation within the shallow aquifer beneath HBD.

Bores are established to the east of the HBD property at a site likely to receive contaminant groundwater flow beyond the boundary. Location downstream of Bore 3 is likely to be appropriate subject to hydrogeological investigation. A minimum of one bore should be established with consideration for piezometric bore placement on the HBD property to identify soil water nitrate levels below the root zone (~ 1m). This will assist in establishing the trigger levels for nitrate attenuation in the underlying shallow aquifer. Consideration should also be given to identifying the flowpaths and velocities through the HBD property and beyond, to allow for a more detailed analysis at the completion of the monitoring program.

Review of the upstream bore (4) location in light of the dairy development on the Alexander property that has come to my attention during the analysis of the current monitoring results.

8 Acknowledgements:

I would like to acknowledge the following for their contribution to the sampling analysis and assistance in this programme. Kerson Laboratory Services (HB) Ltd, Analytical Research Laboratories, Team Data Collection (HBRC), The Compliance Team and especially Terry Jamieson (Team Leader), Fay and Gordon Edgecombe (HBD), and HBRC Scientific Officers Susie Osbaldiston, Nicola Gibellini and Jim Cooke (NIWA) for undertaking the review of this report and providing many valuable suggestions.

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Appendix 1 Data Analysis Protocol

The following is an example of the procedure followed in the analysis of the Crownthorpe groundwater data, (from Ward et. al, 1998).

Figure 9 Data Analysis protocol.

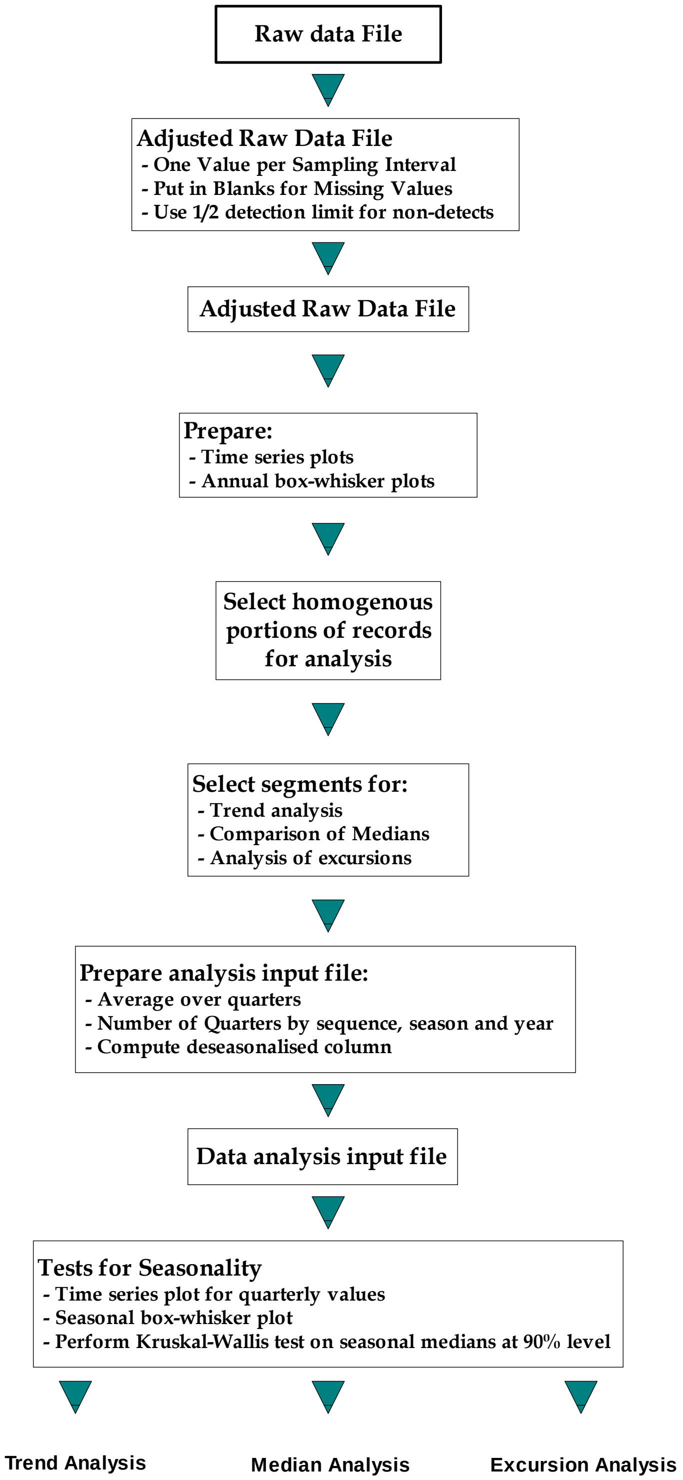
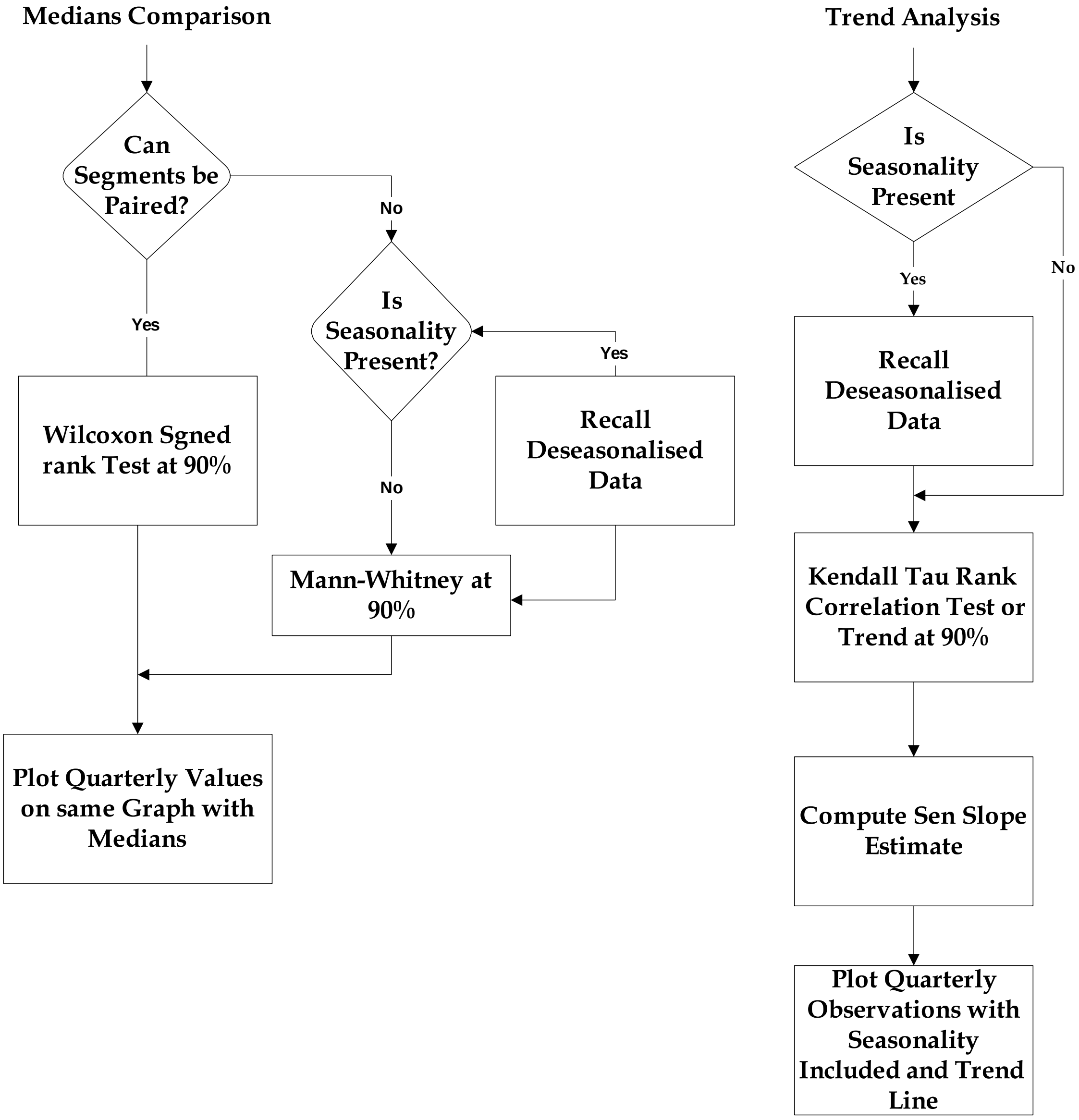


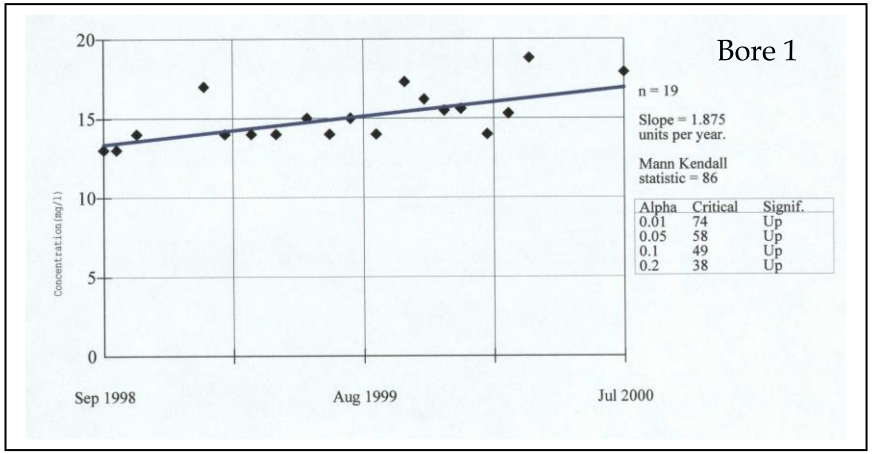
Figure 10 DAP – Trend and Median Analysis.

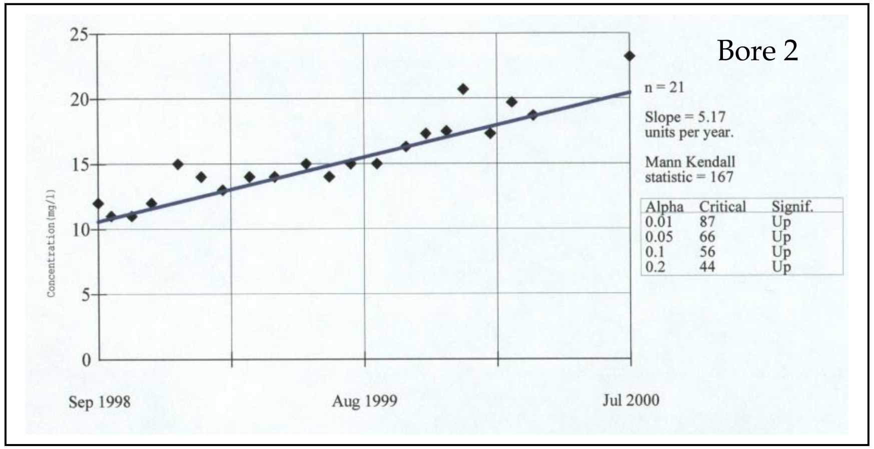
From Ward et. al, 1998.

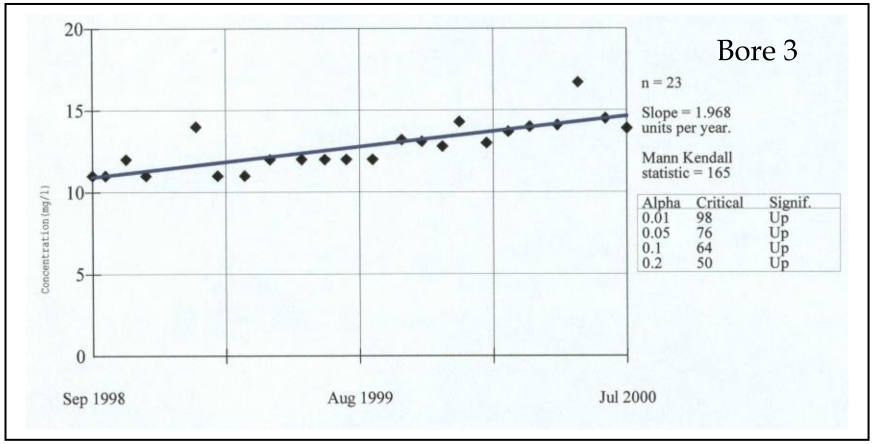


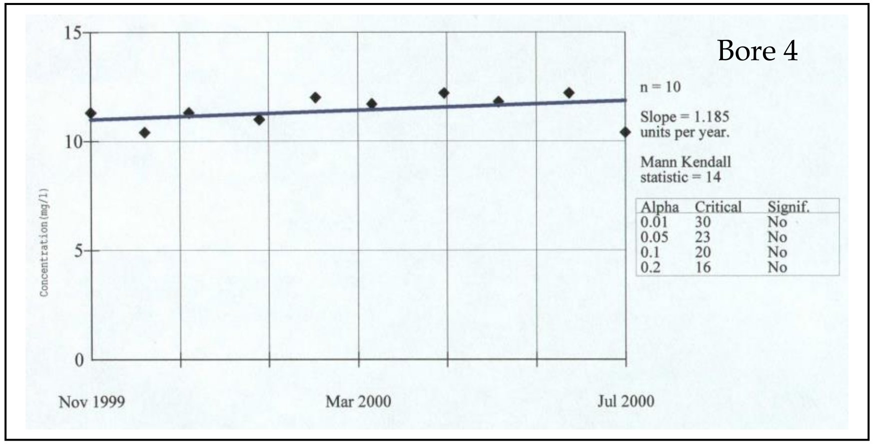
Appendix 2 Trend Analysis of nitrate levels from the monitoring bores at Crownthorpe

From WQSTAT PLUS 1998 – Sen Slope Estimate.









Appendix 3 Analysis of median nitrate levels from the monitoring bores at Crownthorpe

Non Parametric ANOVA, (From WQSTAT PLUS 1998).

Constituent: Nitrate (mg/I).

For observations made between 03/11/1999 and 26/07/2000 the nonparametric analysis of variance test indicates a DIFFERENCE between the medians of the background (upstream bore {4}) and compliance data at the 5% significance level. Because the calculated Kruskal-Wallis statistic is greater than the Chi-squared value, we conclude that at least one station has a significantly different median concentration of this constituent when compared to another station.

Calculated Kruskal-Wallis statistic = 33.305

Tabulated Chi-Squared value = 9.488 with 4 degrees of freedom at the 5% significance level.

There were 5 groups of ties in the data, consequently the Kruskal-WalIis statistic (H) was adjusted. The adjusted statistic (H′) was utilized to determine if the medians were equal.

Kruskal-Wallis statistic (H) = 33.258.

Adjusted Kruskal-Wallis statistic (H′) = 3.305.

The contrast test was performed to determine if any compliance station concentration was significantly higher than the background concentration. The contrast test indicates statistical significance in 3 of the compliance stations. The critical (contrast) value was computed with 4 degrees of freedom, 4 compliance stations, and a 1.25% error level for each station comparison.

Contrast Table:

Station	Difference	Contrast	Significantly Higher?
Spring	-3.000	13.999	No
Bore-l	19.786	12.595	Yes
Bore-2	26.000	12.595	Yes
Bore-3	12.350	11.430	Yes

Where the "Difference" of a station is greater than the "Contrast" (critical value) the hypothesis of a single population should be rejected.

Appendix 4 Faecal coliform bacteria, nitrate concentrations (in groundwater), and groundwater levels in the Crownthorpe area monitored to date.

Table 6 Faecal coliform bacteria (cfu/100mls).

Date Sampled	Harris	Aitken	Hyslop	Spring u/s	Spring d/s	Bore 1	Bore 2	Bore 3	Bore 4
22/10/97	<1	<1	<1	<1	<1				
17/11/97	160	1	<1	<1	<1				
16/12/97	10	<1	<1	4	<1				
28/01/98	2	<1	<1	<1	4				
09/03/98	<1	<1	<1	<1	<1				
31/03/98	<1	<1	<1	50	<1				
13/05/98	<1	<1	<1	3	<1				
16/06/98	<1	<1	<1	5	<1				
07/07/98	<1	<1	<1	<1	<1				
13/08/98	<1	1	1	4	2				
01/09/98						100	57	2	
17/09/98	<1	1	<1	<1	<1				
18/09/98						<1	11	1	
15/10/98	<1	<1	<1	6	<1	13	50	2	
10/11/98	<1		<1	70	<1		<1	<1	
15/12/98	<1	<1	<1	<1	<1	<1	<1		
14/01/99	<1		<1	64	<1	<1	<1	<1	
11/02/99	9		<1	<1	8	4	< 10	1	
18/03/99	<1	4	<1	<1	<1	59	4800	4	
20/04/99	<1	<1	<1	<1	<2	4	42	3	
31/05/99	<1	12	3	<1	5	20	71	<1	
30/06/99	11	36	<1	<1	<1	5	38	<1	
28/07/99	<1	5	<1	12	8	15	260	<1	
31/08/99	<1	1	<1	<1	<1	<1	2	<1	
08/10/99						<1	1	<1	
03/11/99						15	5	<1	210
30/11/99						<1	<1	<1	<1
22/12/99						3	3	<1	<1
26/01/00						1	1	<1	<1
23/02/00						1	4	<1	<1
22/03/00					8	6	6	<10	<1
27/04/00					<10		<10	<10	7

Table 7 Nitrate concentrations (mg/l).

Date sampled	Harris	Aitken	Hyslop	Spring u/s	Spring d/s	Bore 1	Bore 2	Bore 3	Bore 4
22/10/97	10	8	6.7	13	8.6				
17/11/97	10	10	7	14	8.1				
16/12/97	9.8	9.7	6.2	13	7.5				
28/01/98	10	9.5	5.8	12	7.5				
09/03/98	11	10	5.7	12	8				
31/03/98	11	10	5.8	12	7.9				
13/05/98	12	10	5.8	12	8.4				
16/06/98	11	10	5.6	11	8				
07/07/98	12	10	5.4	11	7.7				
13/08/98	12	9.7	5.4	12	10				
01/09/98						13	12	11	
17/09/98	12	9.4	6.3	12	9.2				
18/09/98						13	11	11	
15/10/98	13	9.8	6.2	12	8.9	14	11	12	
10/11/98	12		6.2	12	8.5		12	11	
15/12/98	14	8.4	5.9	13	11	10	15		
14/01/99	14		6.6	14	11	17	14	14	
11/02/99	13		5.5	13	9.4	14	13	11	
18/03/99	14	6.7	5.9	12	9.5	14	14	11	
20/04/99	13	9.5	5.6	12	9.4	14	14	12	
31/05/99	13	9.2	5.5	12	9.5	15	15	12	
30/06/99	10	7.8	5.5	13	9.7	14	14	12	
28/07/99	9.5	8.1	5.4	13	9.7	15	15	12	
31/08/99	9.8	8.9	5.9	13	10	14	15	12	
08/10/99						17.3	16.3	13.2	
03/11/99						16.2	17.3	13.1	11.3

30/11/99						15.5	17.5	12.8	10.4
22/12/99						15.6	20.7	14.3	11.3
26/01/00						14	17.3	13	11
23/02/00						15.3	19.7	13.7	12
22/03/00					11.4	18.8	18.7	14	11.7
27/04/00					11.3	11.9		14.1	12.2
24/05/00					10.8			16.7	11.8
28/06/00					11.3			14.5	12.2
26/07/00					10.3	17.9	23.2	13.9	10.4

Figure 11 Nitrate concentrations vs time from all sites surveyed to date in the Crownthorpe area.

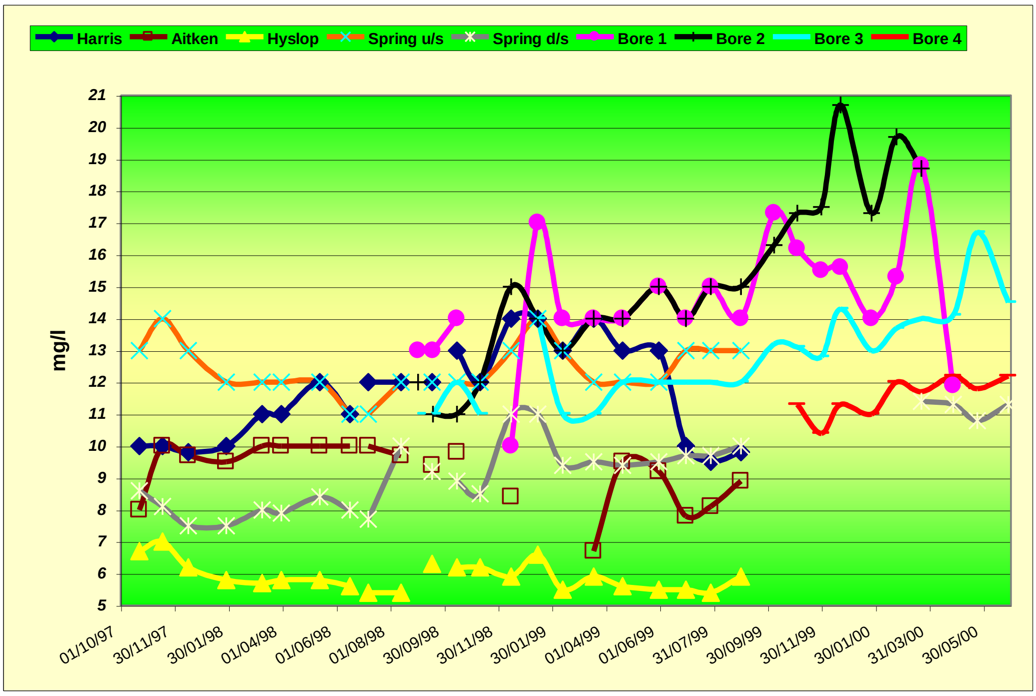


Figure 12 Groundwater depth vs nitrate concentrations over time at the four onsite bores at HBD.