Selwyn District Council
Pines Groundwater Bore Monitoring

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1 Introduction

The Pines Wastewater Treatment Plant (WWTP) irrigates biologically treated, disinfected wastewater to land. As well as routine checks and monitoring of the discharge, a number of onsite bores (and one offsite bore) are monitored once per month to check for possible groundwater contamination from the WWTP discharge. Selwyn District Council (SDC) is required by Environment Canterbury to sample a number of private bores down hydraulic gradient of the WWTP for ten days if its own monitoring bores are found to be contaminated with coliforms or nitrogen. This report comments on the quality of the irrigated water, monitoring results of on-site and off-site bores, the level of nitrates in monitored bores, and any possible link between levels of E. Coli found in Council owned bores and private bores.

2 Description of Treatment, Irrigation, and Monitoring Requirements

The WWTP comprises a biological treatment process which removes solids and nutrients from the wastewater. Solids removal is achieved through settlement but the settled water, while appearing clear, still contains very high levels of faecal coliforms. To reduce the coliform count, disinfection of the wastewater is achieved by ultraviolet (UV) light. The treated, disinfected water is then discharged through two 400m diameter centre pivot irrigators (CP1 and CP2), which release the water sequentially ie when one irrigator completes a circle, the other unit starts. Irrigation takes place on land immediately adjacent to the WWTP.

The treated water is monitored monthly for Escherichia Coli (E. Coli) prior to irrigation. The consent also requires that a number of on-site bores (both up-gradient and down-gradient), and one off-site bore, be sampled monthly for E. Coli. If any of the down gradient bores are found to contain one or more E. coli units, then sampling of six private bores down gradient of the WWTP must be conducted, together with the Pines bores, for ten consecutive days following the last day a coliform unit is found in the on-site bores. The location of the bores is shown in Appendix 1, while Table 1 gives a brief description of the bore locations:

Table 1: Description of Selwyn District Council bore locations.

Bore number	Location
M36/7461	Up gradient of CP1 and CP2
M36/7462	Between CP1 and CP2
M36/7463	Approximately 110m down gradient of CP2
M36/7668	Approximately 70m down gradient of CP2
M36/7667	Approximately 35m down gradient of CP2
M36/7464	Off-site bore, approximately 600m down gradient of irrigation area

The consent requires the discharge to have a median of less than 500 cfu/100mL E. Coli, with a 95th percentile of 10,000 cfu/100mL.

3 Modelling of effects on groundwater

Modelling of the effect of the discharge on groundwater using the DISPSOLV was carried out during planning of the existing WWTP. The model was used to calculate the distance downstream from the contamination source before the faecal coliform concentration falls below 1 cfu/100 ml (the New Zealand drinking water standard requires zero cfu/100 ml, however for modelling purposes the nearest measurable value of 1 cfu/100 ml is used). In order to gain an indication of the probable and possible extent of contamination, two faecal coliform discharges were used in the dispersion model:

1. "Worst-case": 10,000 cfu/100 ml coliform concentration applied to land and 20% reduction in unsaturated zone. The 10,000 cfu/100 ml coliform concentration would only occur during a plant upset or problem with the UV system, and is not a normal condition.

2. "Likely": 500 cfu/100 ml coliform concentration applied to land and 90% reduction in unsaturated zone.

Other parameters used were based on Environment Canterbury's Groundwater Contaminant Modelling Guidelines (PDP, 2002). The inputs are summarised in Table 2 below:

Table 2: Groundwater Dispersion Modelling Input Parameters

Input:	"Worst Case" Discharge	"Likely" Discharge	Comment
Discharge volume	7,758 m^3/day	7,758 m^3/day	Maximum daily volume at design population
Concentration of faecal coliforms in effluent applied to land surface	10,000 cfu/100ml	500 cfu/100ml	95th %ile and median effluent concentration values.
Removal in unsaturated zone	20%	90%	See comments below
Initial concentration of faecal coliforms in aquifer*	8,000 cfu/100 ml	50 cfu/100 ml	Initial concentration calculated from removal in unsaturated zone.
Decay rate in groundwater	0.84 day^{-1}	0.84 day^{-1}	Sinton (1980)
Effective porosity of aquifer	0.2	0.2	Conservative (low) value (PDP, 2002)
Longitudinal dispersivity coeff. **Transverse dispersivity coeff.** **Vertical dispersivity coeff.**	0.03 0.003 0.0003	0.03 0.003 0.0003	Conservative (low) values (PDP, 2002)

*The DISPSOLV dispersion model assumes that all contaminants are discharged into the aquifer at a single point, which results in a very high initial concentration in the aquifer. In reality the contaminants are discharged over a large area, equivalent to many small point source discharges. In order to allow for this initial "dispersion", the contamination distances were corrected by subtracting the distance needed to achieve the "initial" microbe concentration in the aquifer. In other words, The model was used to "pre-dilute" the point source discharge to the correct initial concentration before reducing further to the NZ drinking water standard.

3.1 Model Results and Effect of Channels

A typical pore velocity of groundwater in Canterbury is estimated to be 2.9 m/day (Fietje, 1991) however groundwater velocities could be as high as 200 m/day in discrete highly permeable "channels" (PDP, ECan, 2002). The contamination distances for these two velocities, taken from the graphical model outputs, are shown in Table 3.

Table 3: DISPSOLV Groundwater Dispersion Modelling Results

	Contamination Distance[2]	
Groundwater Velocity[1]	**"Worst Case" Microbe Discharge**	**"Likely" Microbe Discharge**
200 m/day (worst-case)	1,240 m	395 m
2.9 m/day (typical)	60 m	30 m

1. Groundwater velocities represent worst-case and typical values used in ECan guidelines (PDP 2002, Fietje, 1991)
2. From DISPSOLV model - distance before groundwater faecal coliform concentration meets NZ Drinking Water Standard

It should be noted that, of the six private bores that may be sampled, the nearest is 1800m down gradient of CP2.

4 Results and Discussion

4.1 Final Effluent E. Coli

Figure 1 below shows the results of E.Coli in the discharge.

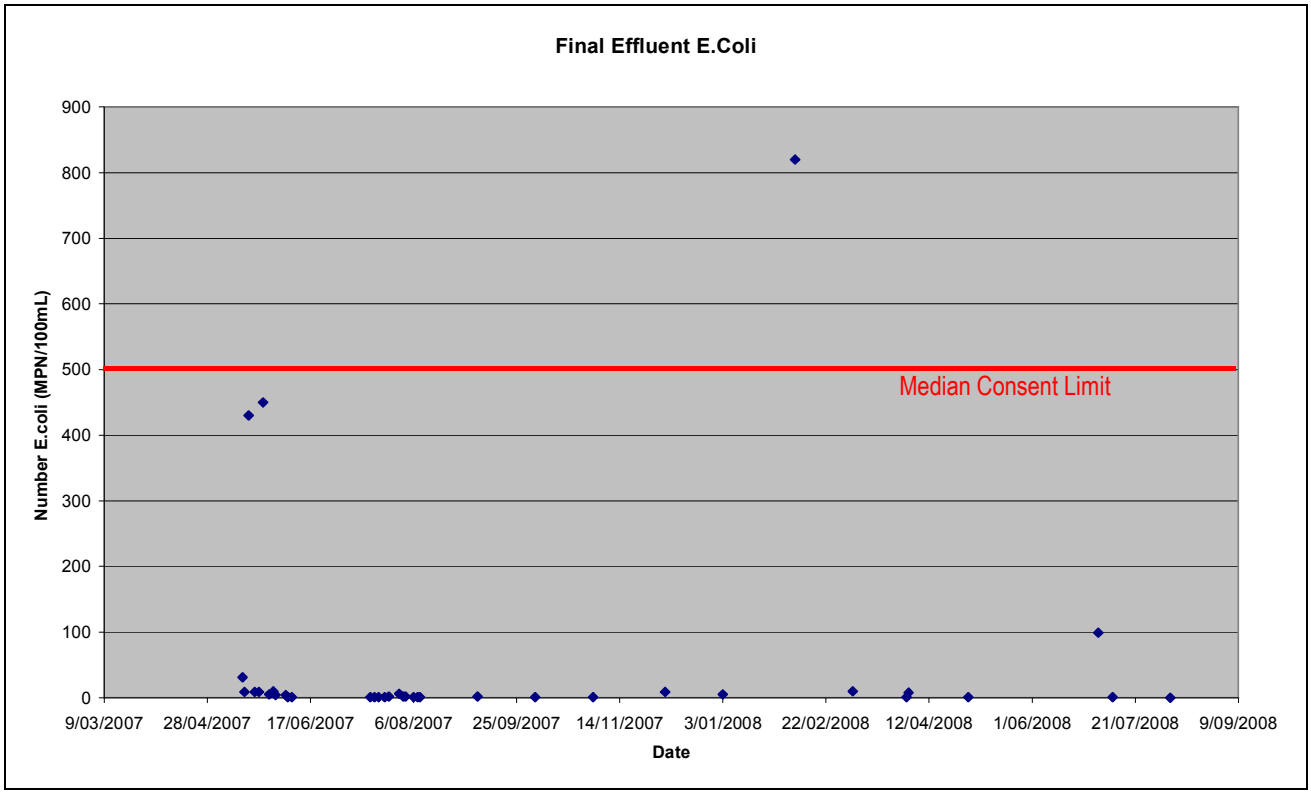

Figure 1 – Irrigated final effluent results

Note: A single high result of 31,000 MPN/100mL was found on 05 June 2008, which has not been plotted. It is thought that one of the UV banks was briefly lifted for maintenance, while the remaining bank had not turned on. No E.Coli were found in the monitoring bores during June, however.

The average E. coli count (excluding the outlier of 31,000 MPN/100mL on 05 June 2008) is well below 10 MPN/100mL. Figure 1 shows that very low levels of coliforms, typically less than 5 MPN/100mL, are consistently achieved. As a result, very few coliforms are discharged to irrigation and the risk of groundwater contamination is consequently low. The two high results in May 2007 were recorded during the plant optimisation phase. The high result of 820 MPN / 100mL in February 2008 was likely due to a small amount of solids carry over impacting the UV plant.

4.2 Results of on-site bore monitoring

4.2.1 Historical on-site bore monitoring for E. Coli

Prior to the operation of the WWTP and discharge through the irrigators, a number of groundwater samples were taken from (what was then to be) the irrigation area. Table 4 shows the results of these samples:

Table 4: Faecal Coliforms from bores within the Pines site (before plant construction)

Sample Date	M36/7461 MPN per 100ml	M36/7462 MPN per 100ml	M36/7463 MPN per 100ml	M36/7467 MPN per 100ml	M36/7468 MPN per 100ml
30-Aug-04	<9	<10	<10	<10	<10
13-Oct-04	<1	<1	<1	<1	<1
09-Nov-04	<1	<1	<1	<1	<1
14-Dec-04	<1	<1	<1	<1	<1
18-Jan-05	<1	<1	<1	<1	<1
01-Mar-05	NA	<1	<1	<1	<1
06-Apr-05	NA	<1	<1	<1	<1
16-May-05	NA	<1	<1	>1	<1
22-Jun-05	NA	2	1	<1	<1
20-Jul-05	NA	96	4	1	1
10-Aug-05	NA	<1	<1	<1	<1
12-Sep-05	NA	<1	<1	1	<1
12-Oct-05	NA	<1	4	1	<1
09-Nov-05	NA	<1	<1	<1	<1
06-Dec-05	NA	NA	NA	<1	<1
13-Jan-06	NA	NA	NA	<1	NA
24-Feb-06	NA	NA	NA	<1	NA
NA = not available					

The limit of 1 MPN/100mL faecal coliforms was reached or exceeded 14 times out of a total of 60 samples taken from the bores over the period August 2004 to February 2006. The presence of faecal coliforms implies that there are off-site sources of groundwater contamination. It may be noted that positive counts typically occurred at more than one location on a sample date. While a correlation with rainfall has not been checked, there is a trend of higher counts over winter, with no counts over what could be expected to be dry periods.

From the above data it can be concluded that positive counts above 1 MPN/100mL do occur from events that have no association with the irrigation of treated wastewater at the Pines.

4.2.2 On-site bore monitoring for E. Coli since commissioning

Since commissioning of the plant, monitoring of the six boreholes identified in Table 1 and Appendix 1 has occurred at least monthly and sometimes fortnightly. The full set of bore monitoring data since commissioning is given in Appendix 2. A count of one or more E. coli has been found nine times since irrigation began, and on two of these occasions the exceedance was from the upstream bore M36/7461. It could be contended that these occurrences are in line with the background observations, which supports the implication that there is an element of background contamination inherent in the area. According to the consent, an Excursion Response Plan (ERP) incorporating monitoring of private bores and the onsite bores must continue for ten days following any exceedance. This ERP has been enacted twice – in May 2008 and July 2008 (both due to a single E. Coli found in bore 7667), and the data set from these periods is shown in Appendix 3. It should be noted that rainfall

during the winter of 2008 was very high and the risk of coliforms being 'pushed ' rapidly through the soil zone and into the groundwater has been considered. This will be discussed in Section 5.

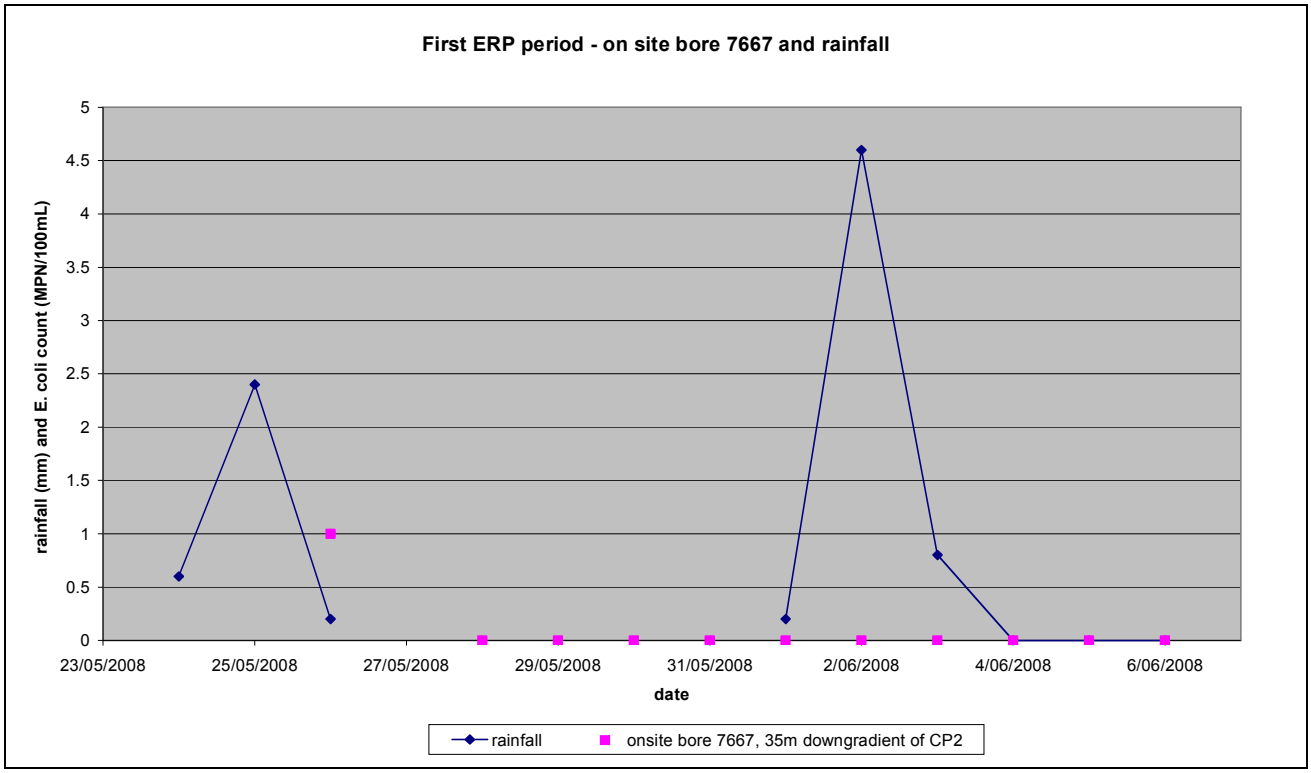

Figure 2 - Results from on-site bore monitoring during first ERP event
Note: During the first ERP, on-site bore sampling was only carried out at bore number 7667

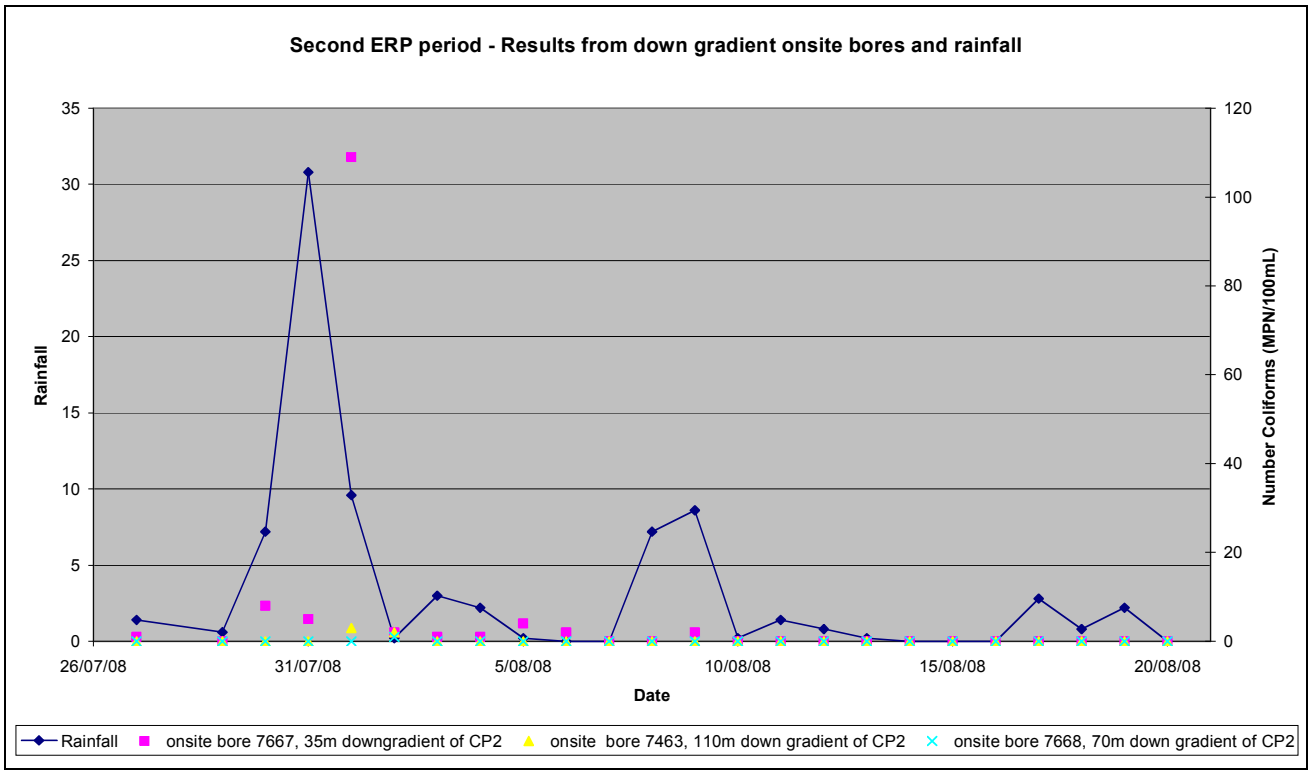

Figure 3 – Results from on-site bore monitoring during second ERP event
Note: The two on-site bores numbers 7461 and 7462, and downstream off-site bore, 7464 are not shown on this plot as no coliforms were found during the excursion response period.

The first point of note is that, following the finding of a single coliform in bore 7667 during May 2007, there were no further coliforms found over the ensuing 10 day ERP. Figure 1 shows that the pattern of E.Coli in the discharge leading up to this period was very low. Given that only a single coliform unit was found over eleven days of sampling, it is possible that the single result was due to variability in background water quality (as described in Section 4.2.1). It is also possible that there was contamination of the bore through spray drift, as bore 7667 is the closest of all the wells to either of the irrigators.

Figure 3 shows that there was a very high rainfall event towards the end of July, and this may have contributed to the high level of coliforms found in bore 7667, which is approximately 35m from the edge of the irrigation area. The effluent quality is required by consent to only be sampled once per month, so is not fully documented over this July / August period. A high result of <100 cfu/100mL was recorded in the final effluent on 3 July 2008, but this was 26 days before the high result in bore 7667 was found. However, very low results (1 cfu/100mL on 10 July 2008 and <1 cfu on 7 August 2008) were found in the final effluent close to the end of July. It is therefore difficult to make a link between any E. Coli in the discharge and E. Coli found in bore 7667.

Given the overall plant history of very low levels of E. coli in the discharge (refer to Figure 1), it would be reasonable to assume that this typically excellent performance has continued around the end of July. However, it is also possible that discharge in excess of 100 MPN/100mL has occurred, as indicated by the bore 7667 result on 1 August, which showed 109 MPN/100mL. Given the low E. coli trend about the single high sample on 1 August, it is reasonable to conclude that this is a rogue outlier and that there was an increase in E. coli that peaks at about 8 MPN/100mL, reducing to 1 MPN/100mL over the course of approximately four days. This pattern correlates with the heavy rainfall event at this time.

The Operator observed no ponding on either of the cetre pivot areas during the heavy rainfall period in July / August despite the fact that a total of 31mm rainfall plus 5.6mm of treated wastewater was irrigated during the heaviest rainfall on 31 July 2008. While it can be stated with some certainty that the soils were not fully saturated, it is likely that the depth of unsaturated gravels would have been less than normal. It is therefore feasible that the heavy rainfall has affected the level of coliforms in the bore nearest to CP2, but it appears that this affect is reasonably localised. Figure 3 shows that very few E. coli units were found in the more distant wells (ie 50m or greater from CP2). This is approximately in keeping with the modelling completed as part of the original Pines AEE (and as shown in Section 2), and is demonstrated graphically in Figure 4. This plot shows the average E. Coli count in the three on-site down gradient bores and the off-site bore over the period 30/07/08 to 09/08/08, when a high concentration of E. Coli was found in the bore nearest CP2 (number 7667). It is clear that the monitoring bore nearest the irrigator has recorded significantly more E. Coli than the other bores, and that there is a tendency, even in the wet conditions experienced over this period, for the concentration to decrease the further the bores are from the irrigator. It should be noted that flow was evenly split through the irrigators over this period ie both areas were irrigated every day.

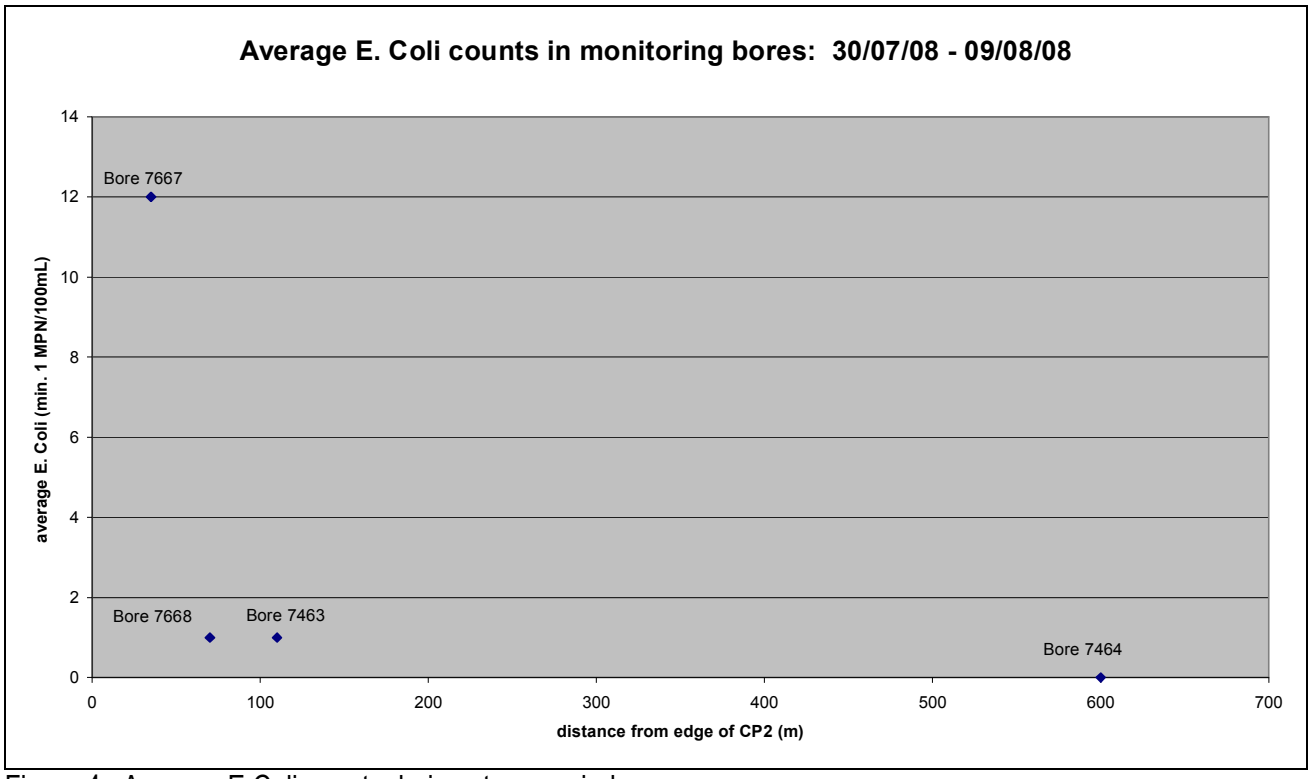

Figure 4: Average E.Coli counts during storm period

Note: Bores 7668 and 7463 recorded average E.Coli numbers of less than 1 but greater than 0 MPN/100mL. These are shown here as 1 MPN/100mL.

4.2.3 Summary of on-site bore monitoring

Based on information and data in the preceding sections, the following statements can be made with regard to the on-site monitoring bores:

- Contamination was really only noticeable at the down gradient bore approximately 35m from CP2
- Contamination at this bore appears to correlate with heavy rainfall events
- Beyond the 35m bore contamination drops off noticeably

- It is possible that contamination in the bore closest to CP2 is due to spray drift from the irrigators
- Contamination of the groundwater could also be due to reduced depth of unsaturated gravels during heavy rainfall events, background contamination from other activities in the area.

4.3 Off-site bore and private bore monitoring for E. Coli since commissioning

The Selwyn District Council samples only one off-site bore, but must also take samples from six down gradient private bores if a single coliform unit is found in any of its down gradient monitoring bores. The results from all these bores during the ERP periods of May and July/August 2008 are given in Appendix 3. The SDC off-site bore 7464 has only once recorded E. Coli (2 MPN/100mL in March 2008). It is possible that this is due to background concentrations as no E. Coli were recorded in the on-site bores during this time. It is also possible that this bore has been contaminated by other agricultural activities in the area. This is discussed in more detail in Section 5.

One particular private bore, number 4270 (located approximately 2,000m down gradient of CP2), has consistently recorded higher levels of E. Coli during the ERP monitoring, and is the subject of ongoing discussion between the bore owner and SDC. Figures 5 and 6 show the results from this bore compared to the SDC onsite bore during the ERP periods in May 2008 and July/August 2008:

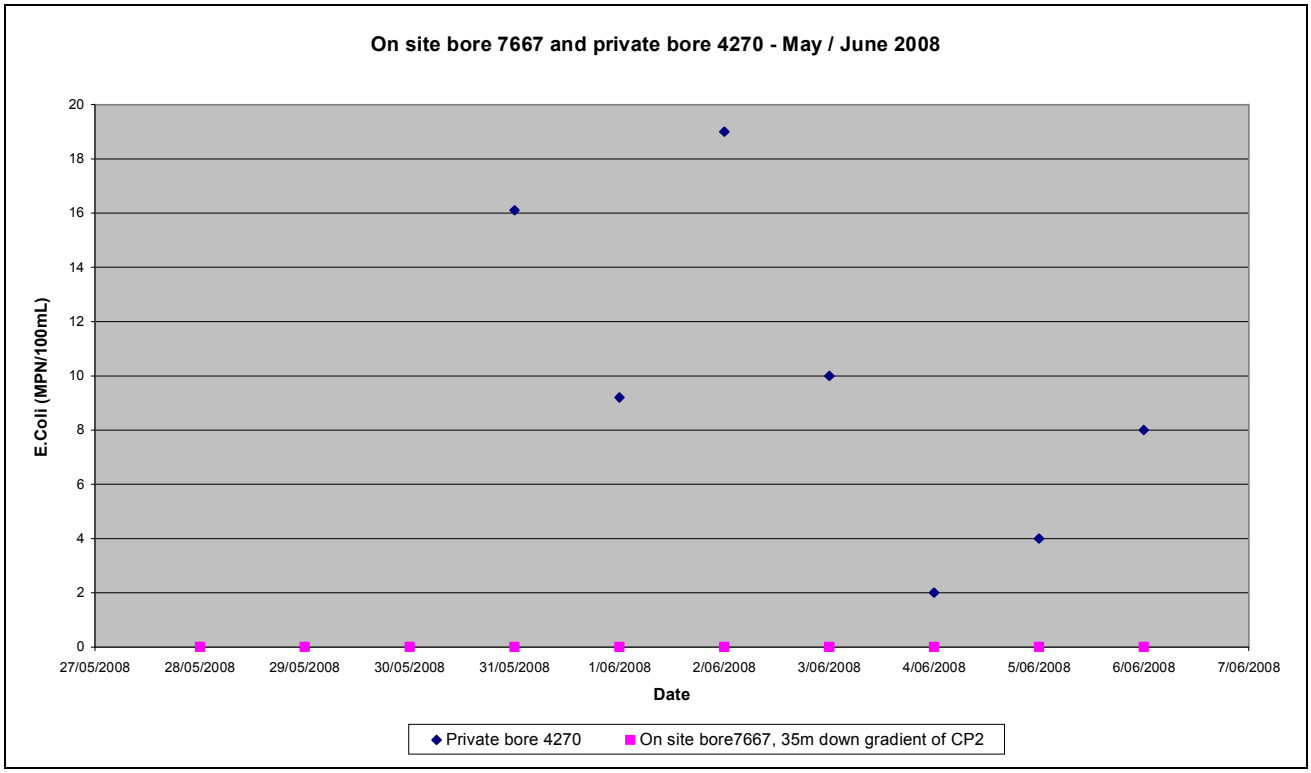

Figure 5: Private bore 4720 and onsite bore 7667 during first ERP period

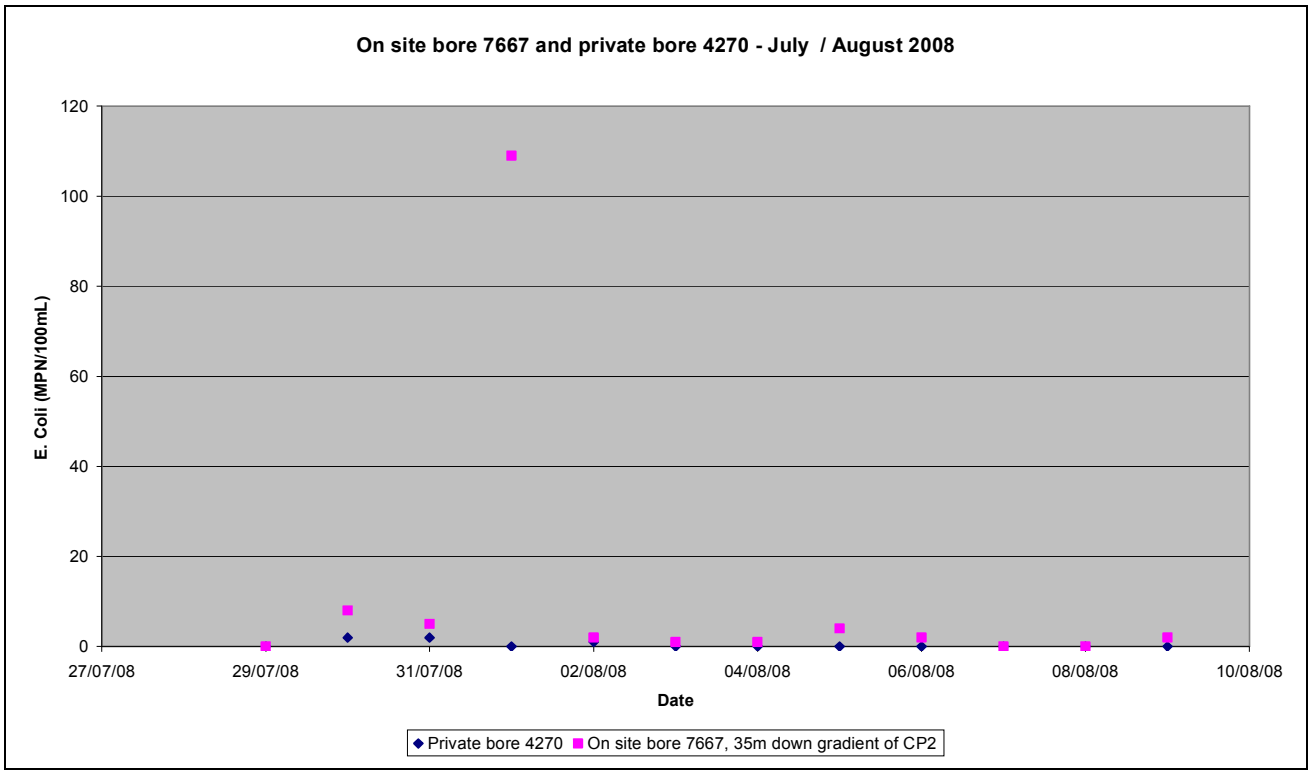

Figure 6: Private bore 4720 and onsite bore 7667 during second ERP period

Figure 5 shows that private bore 4270 recorded results well above the results measured onsite. Based on this data, there is no correlation during this period between the results measured at the onsite bore and the private bore.

The second ERP period (Figure 6) shows the high levels of coliforms found in on-site bore 7667 (also shown in Figure 3) but on only three occasions was private bore 4270 bore found to exceed <1 MPN/100mL. Again, the results are far from conclusive. While bore 4270 returned three high results at the same time as the onsite bore, there was a period of ten days following this when elevated results at the onsite bore were not matched by elevated results at the private bore.

It is very difficult, based solely on the above data, to prove any link between the on-site bore results and the results in bore M36/4270, due to the extent of available data, the potential for other sources of contamination, and that significant bacterial reduction can occur in the ground (refer to Sections 3 and 5). Furthermore, the off-site monitoring bore 7464 did not record any coliforms during the ERP periods. While there is the possibility of groundwater channelling around this bore, the results imply that any coliforms found in the onsite bores have been removed by the time the groundwater reaches the offsite bore.

4.4 Groundwater monitoring for nitrate

Under the consent, SDC must monitor its six bores for nitrate. If any of the down gradient on-site bores (ie bore numbers 7462, 7667, 7668, 7463) record a value greater than 8mg/L nitrate *and* is more than 30% greater than the up gradient monitoring bore (number 7461), then the ERP must be enacted. The results of monitoring for nitrate are given in Appendix 4, where it can be seen that the conditions whereby the ERP must be enacted have not occurred.

5 General Discussion

The potential for bacterial reduction through soils (primarily through filtration) has been well studied and documented, particularly for the Canterbury Plains (papers are available on request). In addition, natural decay will occur in the groundwater; E. Coli has been shown to have a 90% (T90) die off rate of between 2.6 and 3.2 days in the groundwater around the WWTP (Sinton, 1980).

Modelling using the DISPSOLV groundwater contaminant transport model was conducted as part of the original Pines Assessment of Environmental Effects (AEE), as shown in Section 3. This showed under worst case, extreme conditions (ie effluent irrigated at 10,000 cfu/100mL, 20% reduction of coliforms through the soil zone, groundwater channelling allowing a maximum velocity of 200 m/d, and a discharge rate of 7,758 m^3/d) it would take 1240m for the E. Coli concentration to be reduced to 1cfu/100mL. Unfortunately, in terms of verifying the model, the final effluent has been consistently low in E. coli. However, based on the present operation and data presented in Section 3.2.2, it appears that there is a relationship between the proximity of the bores to the irrigation areas and the levels of coliforms in the bores, and that bacterial die off through the groundwater is pronounced. Bore M36/4270 is located approximately 2,000m downstream of the irrigation area and has, on occasion, recorded high coliform concentrations. However, at the same time the on-site bores were frequently recording <1 cfu/100mL. Likewise, the final effluent is consistently low in E. coli. Based on this information, it is likely that the influence was not due to the irrigation of effluent at the Pines.

Figure 3 showed rainfall was extremely high over winter (an average of 4.37 mm/d fell at Pines WWTP in the months from April through to August, compared with a 20 year average of 1.92 mm/d over the same period at Burnham WWTP), with July recording the most rainfall. The levels of coliforms were highest in the onsite bores at the end of July / beginning of August. This is potentially as a result of partially saturated soil, resulting in reduced bacterial die-off. Saturated soils will generally allow more free passage of bacteria into the groundwater, and this can result in less bacterial kill than unsaturated conditions. However, even if the soil was saturated (and bacterial die off had been reduced) the fact that bore 7464 (600m down gradient of CP2), showed no coliforms suggests that bacterial die-off had occurred horizontally through the groundwater.

The presence of other sources of contamination in the area cannot be discounted in any analysis of effect on groundwater. For example, in addition to the background bore monitoring that showed contamination, it is known that piggery effluent is sprayed on to land adjacent to the Pines irrigation area. Inspection of the private bores has also shown that a number have poor well head security, and there have been clear signs of other animals such as rodents and chickens in the area. The risk of on-site contamination at these bores is therefore considered to be high.

6 Conclusions

Results of rainfall, on-site bore monitoring, and off-site private bore monitoring have been plotted and analysed. Based on the available data, the Pines discharge does not appear to have had a significant effect on groundwater quality for the following reasons:

- Final effluent discharged to land has been consistently low in E. Coli;
- The further reduction of coliforms vertically through the soil is well proven and supported by numerous studies;

- Should any coliforms reach the groundwater, there will be die-off of the coliforms as they move downstream. This is, again, supported by numerous studies and groundwater modelling conducted during the preparation of the AEE for the WWTP;
- An offsite monitoring bore located 500m downstream of the discharge area, and between the WWTP and Bore M36/4270, has only once recorded E. Coli;
- Analysis of monitoring bores during an ERP showed a general pattern of decreasing E. Coli concentrations with distance from the irrigation area, as predicted by modelling conducted during the AEE;
- Monitoring of groundwater on-site before the plant was constructed showed that the limit of <1 MPN / 100mL was exceeded nearly 25% of the time, suggesting that there are other sources of background contamination;
- There are other sources of potential contamination in the area, such as the spraying of piggery effluent and localised contamination at private bores.

If good effluent quality is maintained, then no effects beyond around 70m should be expected. Additionally, there is no information that does not indicate the groundwater modelling predictions are conservative, and remain appropriate for irrigation at the Pines site.

Elevated on-site E. Coli concentrations were found during a month where heavy rainfall occurred, and the possibility that this was due to the high rainfall cannot be dismissed. Down gradient monitoring of an offsite bore showed no coliforms, and significant bacterial kill is expected through the ground. Based on the data in this report it is considered very unlikely that, even during wet conditions, any E. Coli found in the onsite bore would be transported to the private bore 2,000m away.

Appendix 1 – Location of Onsite and Offsite Bores

Appendix 2 – SDC bore monitoring data

Appendix 3 – ERP bore monitoring results

Appendix 4 – Bore nitrate results