7 December 2023

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Ratana WWTP s92 - Groundwater Microbial Reductions

5-P1472.06

Dear Blair,

Background

WSP provided an assessment of the effects of microbial contamination on groundwater from the proposed irrigation of treated wastewater at Ratana (Appendix D of the original consent application – Section 3.2.3). This assessment explained that most of the microbial load would be attenuated in the soils and that there would be further attenuation within the saturated sand. The assessment also indicated that based on the groundwater flow model, irrigated water is expected to take up to 6 years to reach the receiving environment (marine) and therefore any microbial contaminants that were not attenuated in the surface soils would die off before they reached the receiving environment.

A calculation of the likely inactivation of e.coli was presented separately that used reported inactivation rates taken from John and Rose (2005) of between 0.07 and 0.1 log10/day. Assuming the most conservative end of that range (i.e. least rapid attenuation) of 0.07 log10/day inactivation rate, a daily reduction of 15% was calculated. Based purely on the inactivation of e.coli, at this rate (15% per day) the calculation showed a reduction in e.coli from 1000 cfu/100mL to <1 cfu/100mL after 45 days. Assuming groundwater velocity of 0.8 m/day this equated to approximately 36m. Adding a "factor of safety" of 3, this distance from site increased to 108m.

Following submission of the Resource Consent Application, Horizons Regional Council (HRC) have raised the following Section 92 notice:

s92 – Groundwater 4. Please provide further information on bacterial reductions with distance from the site. This information should use a quantitative estimate based on likely reductions within the saturated zone only given that groundwater levels are very shallow at the site.

In response to this WSP S92 notice, WSP have prepared the following further analysis.

Assessment Method

WSP have used Function.xls to complete an initial assessment in response to the S92 notice. Function.xls is a freely available Microsoft Excel ® spreadsheet that includes programs for calculating mathematical functions and for evaluating analytical solutions in ground water hydraulics and contaminant transport (Hunt 2005 and 2012).

Due to the absence of site-specific microbial contaminant transport field trials, WSP's quantitative estimate of bacterial reductions in the saturated zone have been made using a simple one dimensional contaminant transport solution.

The specific function used for the assessment is the one-dimensional solution for a continuous source that is often used in laboratory experiments in which the concentration is kept constant at one end of a semi-infinite solution domain. In practice this is an extremely conservative way to model the likely fate and transport as it assumes:

1. No attenuation in the soil or unsaturated zone
2. No mixing or dilution under the site itself
3. No dispersion in the y or z axis.

The "base case" parameters and assumptions used in the calculation are:

- Retardation Factor = 1 (i.e. no retardation the aquifer – conservative assumption)
- Initial Concentration (C_O) = 1000 cfu/100mL)
- Groundwater velocity (μ) = 0.8m/day (based on previous calculation using hydraulic conductivity and groundwater contours interpolated from groundwater levels)
- Days of discharge = 243 days (based on September 1st to April 30) – Note this is again a conservative assumption as it is expected that the majority of the irrigation season will involve deficit irrigation.
- Decay Constant (λ) = 0.15/day (calculated from John and Rose (2005))
- Dispersion coefficient = 10% of the distance from site (i.e. scale dependant dispersion)

The result of the calculation is presented in Figure 1 below.

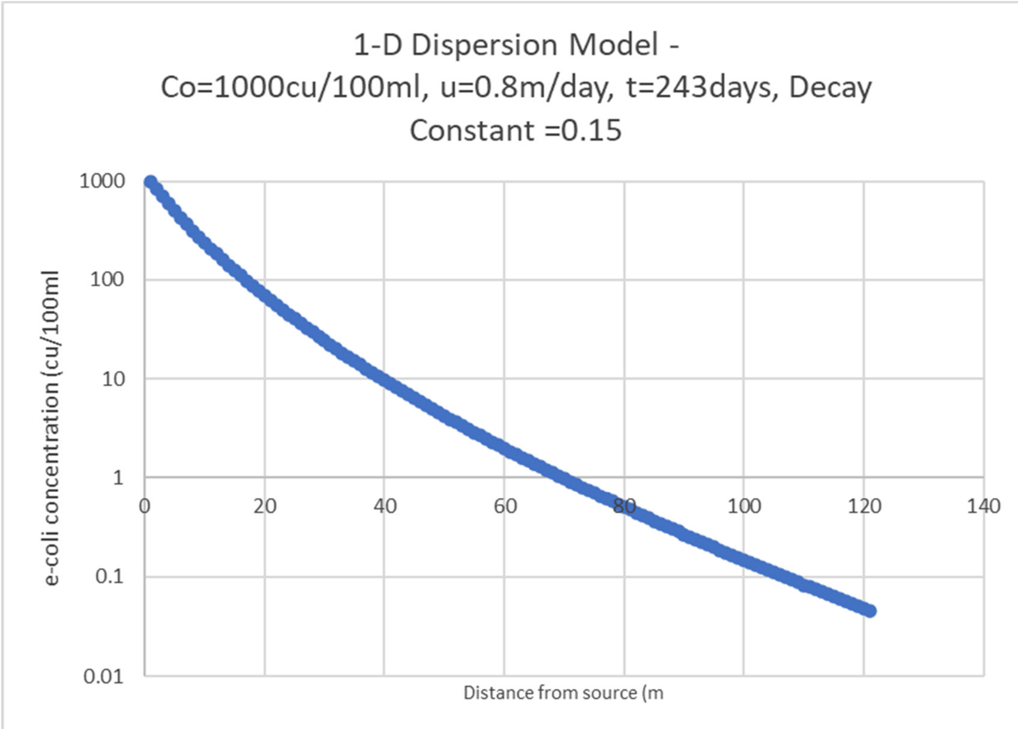

Figure 1 – Reduction in E-Coli with Distance from Site.

As shown in Figure 1, the concentrations in groundwater would be expected to reduce to less than 130 cfu/100mL (swimming water standard) at a distance of 15m from the site and to <1 cfu/100mL (drinking water standard) at approximately 70m from the site boundary respectively.

Sensitivity to parameters chosen

As many of the parameters used in the calculation are based on conservative assumptions rather than field data, the calculation's sensitivity to the different parameters chosen has been assessed as detailed below.

Sensitivity to Initial Concentration

The assumed starting concentration of 1000cu/100mL is considered a reasonable estimate of the level of contamination after the treatment plant. However, it is recognised that the actual numbers are likely to be variable and further that additional e.coli from other sources (ducks, geese etc) may be added to the effluent whilst it is ponded. Also, if there is a problem with part of the treatment plant there could be a temporary spike in microbial levels.

Figure 2 below shows the resulting reductions from the site at different initial concentrations of up to 3 additional orders of magnitude higher than the "base case" (i.e. 10,000, 100,000 and 1,000,000 cfu/100ml).

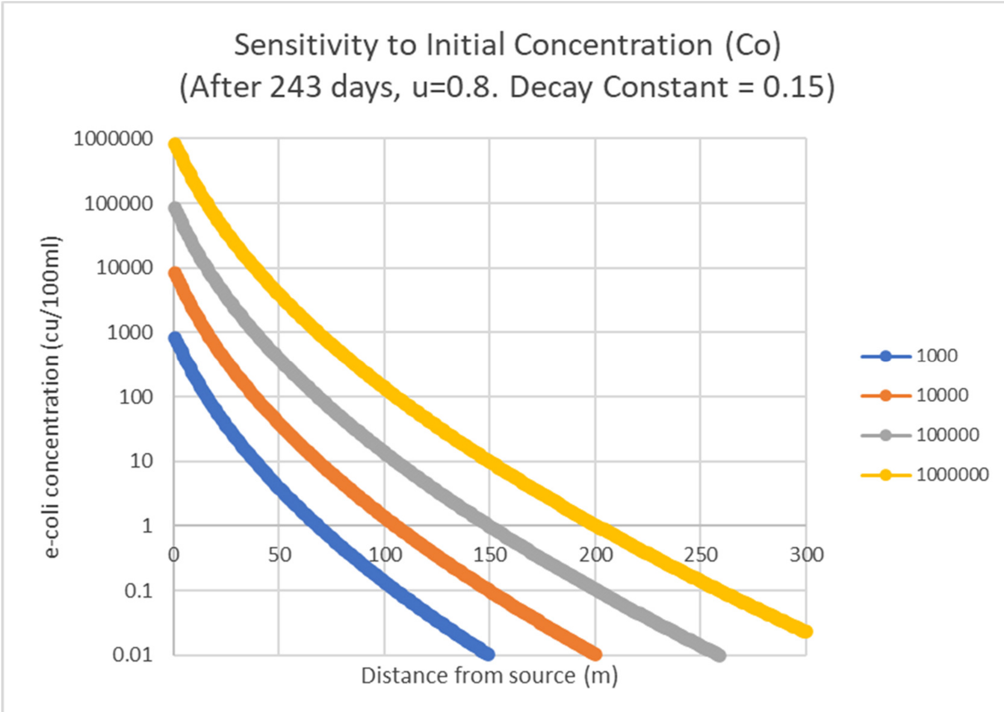

Figure 2: E. coli reductions with distance with higher initial concentrations

Figure 2 demonstrates that even with an initial concentration 3 orders of magnitude higher than expected, concentrations would be expected to drop to less than the swimming water standard of 130 cu/100mL at approximately 100m from site and the drinking water standard of <1cu/100mL at 200m from site.

Sensitivity to groundwater pore velocity

The base case assumed groundwater pore velocity of 0.8m/day was taken from the previous calculation presented for microbial die off. To test the sensitivity of the reduction in concentrations with distance from the site to the pore velocity the calculation was run with groundwater pore velocities of 10%, 50%, 200% and 1000% of the base case. Figure 3 shows the output of this sensitivity analysis.

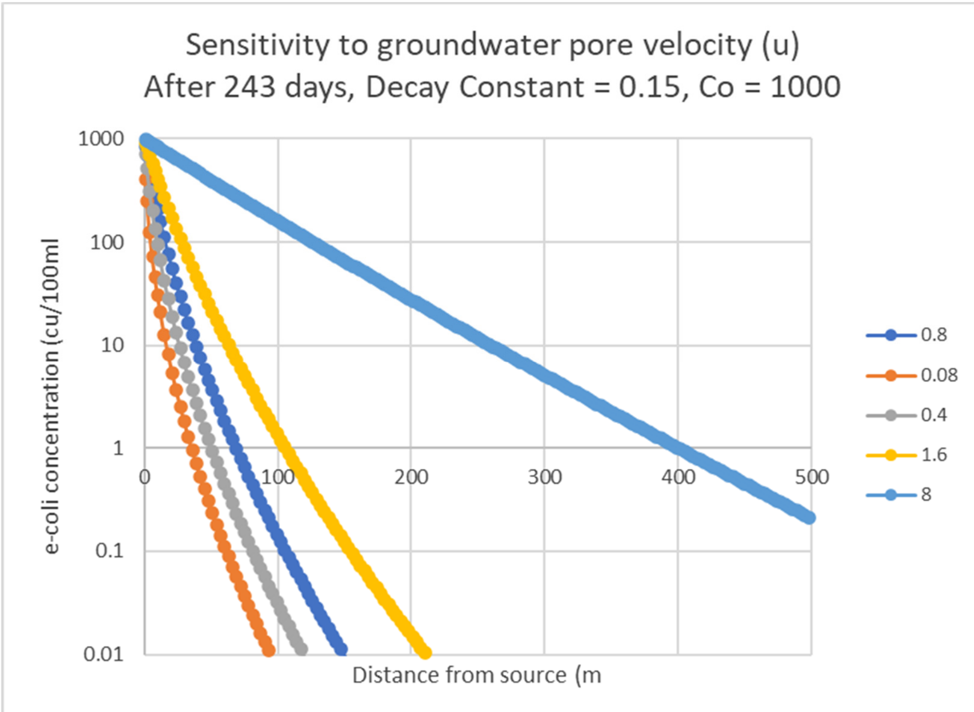

Figure 3: E.coli reductions with distance with different pore velocities

Figure 3 demonstrates that at lower pore velocities, concentrations will fall below the relevant swimming and drinking water standards closer to the site boundary. At a pore velocity of 0.4m/day the DWS of <1cu/100mL is reached at a distance of 50m (as opposed to 70m for the base case of 0.8m/day). At double the base case pore velocity (1.6m/day) the DWS of <1cu/100mL is reached at a distance of 100m.

Sensitivity to Decay Constant

The Decay Constant the factor in the one dimensional dispersion model that allows for the die off or inactivation of the contaminant being modelled. A Decay Constant of 0 would indicate zero die off and would be an appropriate assumption for a contaminant that does not break down over time. Higher Decay Constants represent materials or microbes that break down readily in receiving environment. The base case assumed a decay constant for e.coli of 0.15 per day based on the conservative end of the range of inactivation rates published in John and Rose 2005. Figure 4 below presents the results obtained with different decay rates with some at the higher end of the reported range and some below the reported range. Although a Decay Constant of zero is not a realistic scenario it has been included in this sensitivity analysis to show the general effect microbial inactivation has in the transport equations.

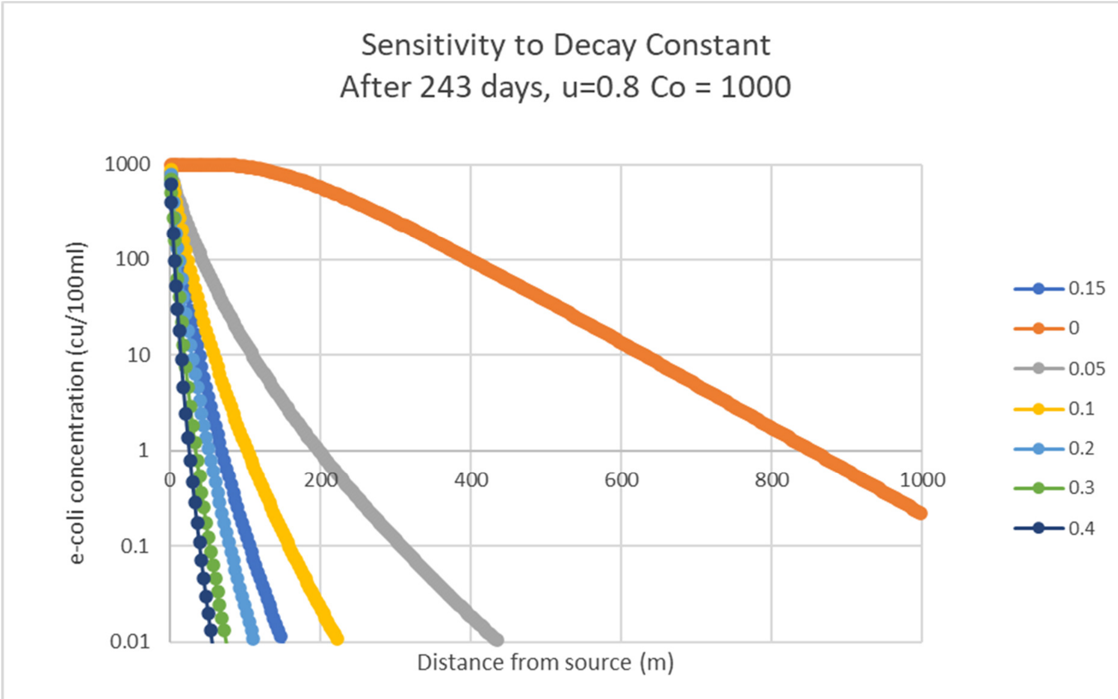

Figure 4: E.coli reductions with distance with different Decay Constants

Sensitivity to duration of discharge to groundwater

As detailed above, the base case conservatively assumes that 100% of the microbial load will enter groundwater for the duration of the irrigation season (September 1st to April 30th). It is expected however that the majority of the time irrigation will take place under deficit irrigation conditions meaning that the irrigated wastewater (and microbial load) would not reach the underlying shallow aquifer.

Figure 5 shows the effect on the bacterial reductions with distance based on durations of discharge of 14 days, 30 days and 243 days (base case).

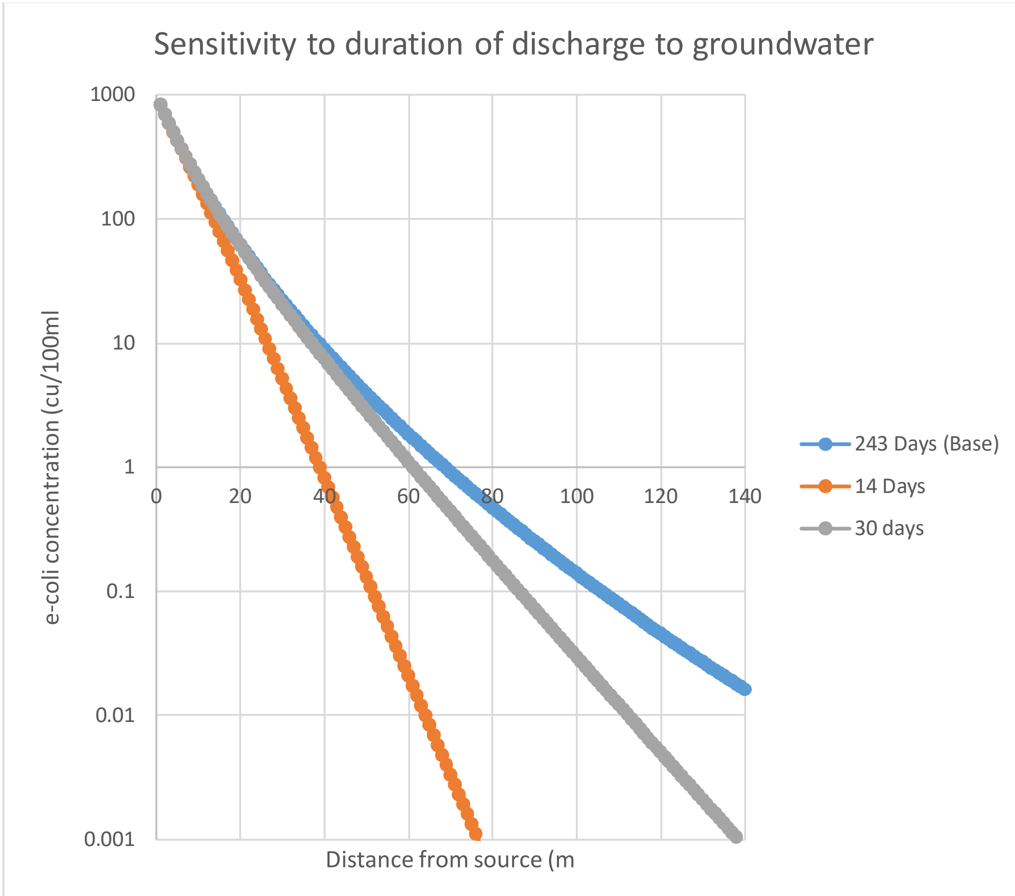

Figure 5: E.coli reductions with distance with different application durations

Figure 6 below shows the time required to return to background concentrations at a distance of 13.6m from the site (chosen as the point where e-coli concentrations are equal to the swimming water guideline value of 130cfu/100mL) following cessation of discharge after 30 days compared to if discharge to groundwater continued indefinitely. As shown on Figure 6, concentrations would be expected to return to background levels (<1) after a period of 27 days.

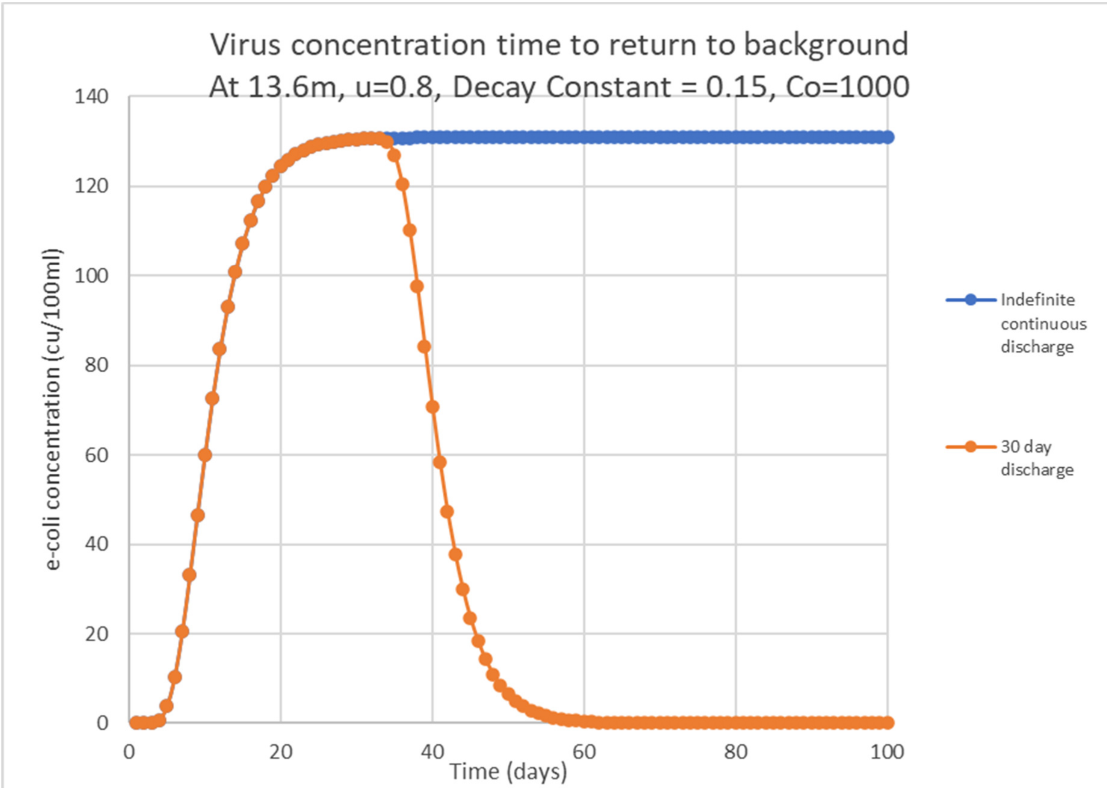

Figure 6: E.coli reductions with time following cessation of discharge to groundwater

Conclusion

In response to the HRC S92 request for "*a quantitative estimate based on likely reductions within the saturated zone only given that groundwater levels are very shallow at the site*" WSP has used Function.xls to demonstrate the expected reductions in groundwater with distance from the site.

It is noted that groundwater downgradient of the site is not used for drinking or stock watering and therefore there are no known receptors other than potential discharge to the coast which is located approximately 1km from the closest boundary of the proposed discharge site.

Previous assessments estimated microbial die off within approximately 100m of the site (allowing for a Factor of Safety of 3) based on reported die off rates for various bacteria in groundwater. Using the one-dimensional solution for a continuous source within Function.xls and the groundwater and contaminant parameters previously reported for the site, showed concentrations would be expected to reduce to less than 130cfu/100mL at approximately 15m from the site boundary and to less than 1cfu/100mL at a distance of approximately 70m from the site boundary. This is considered to be a very conservative estimate for the following reasons:

1. It assumes no retardation,
2. Mixing under the irrigation area is ignored,

3. Dispersion in the y axis and z axis is ignored,
4. The lowest point in the range of the literature values for decay rates was used,
5. Discharge was modelled as occurring for the entire irrigation season (not just when deficit irrigation is not possible),
6. The initial concentration of 1000 cfu/100mL was used – assuming no inactivation in the soil or unsaturated zones.

Regards

Campbell Ogilvie
Business Manager - Palmerston North

References:

Review of Factors Affecting Microbial Survival in Groundwater, David E. John and Joan B. Rose, Environ. Sci. Technol. 2005, 39, 19, 7345–7356

Visual Basic Programs for Spreadsheet Analysis, Bruce Hunt, Groundwater Volume 43, Issue 1, 2005 p138-141.

Groundwater Analysis Using Function.xls, Bruce Hunt, Civil Engineering Department, University of Canterbury, 14 January 2012

Disclaimers and Limitations

This report ('**Report**') has been prepared by WSP exclusively for Rangitīkei District Council ('**Client**') in relation to consenting the discharge to land from the Rātana Wastewater Treatment Plant ('**Purpose**'). The findings in this Report are based on and are subject to the assumptions specified in the project proposal dated June 2021. WSP accepts no liability whatsoever for any reliance on or use of this Report, in whole or in part, for any use or purpose other than the Purpose or any use or reliance on the Report by any third party.