Land Treatment Systems – Diary of a Hydrogeologist

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ABSTRACT

Well designed and operated land treatment systems provide a sustainable regime for the treatment and disposal of wastewater. However, many land treatment systems operate under circumstances leading to uncontrolled leaching of contaminants and groundwater quality issues.

A comprehensive understanding of groundwater, interactions with a land treatment system and final receiving surface water is key to gaining long-term land discharge consents. Groundwater quality is a critical issue for all land treatment/disposal systems, especially where there is close connection between land and groundwater use. This connection can drive pre-treatment requirements to ensure groundwater quality protection.

Over the past two decades, the awareness and rhetoric surrounding management of groundwater quantity, quality and surface water interaction has changed. Legislation has been updated, namely the National Policy Statement for Freshwater Management (NPSFM (2014, revised 2017), and regional plans. Obtaining a land discharge consent in 2018 is a different ball game to 2008, and barely recognisable from 1998 in terms of the required depth and breadth of groundwater assessment. Hard lessons from the 2016 Havelock North incident have further highlighted the importance of groundwater knowledge and risk management.

This paper presents key groundwater considerations for today's land discharge including; assessment techniques, case-study outcomes and learnings from successful municipal and industrial projects across New Zealand.

Keywords: groundwater modelling, groundwater-surface water interaction, contaminant transport

INTRODUCTION

Changes in regulations around New Zealand resulting in more stringent water quality standards and requiring appropriate consideration of cumulative water quality effects, mean that in many parts of the country there is a requirement to improve the situation for the environment receiving wastewater discharge. This usually requires a higher standard of treatment than previous, even when land treatment is employed. With a general trend of increasing permanent or transient populations in most of New Zealand, together with growing industrial production, there is frequently the need to provide for increased discharge volumes to the environment while maintaining or reducing contaminant loads and effects on the receiving environment.

Wastewater discharge to land is often the preferred option, for both cultural and environmental reasons, rather than point discharges to surface water, so groundwater effects assessments are more frequently required.

The NPSFM (2014, revised 2017) directs councils to set limits for both water quantity and quality to meet set freshwater objectives in each region. The NPSFM recognises the interconnection between groundwater and surface water and importantly requires the councils to manage the resources in a manner that recognises this connectivity. While many regional plans already manage water resources conjunctively and require the interconnection to be addressed in resource consents, the NPSFM seeks to ensure consistency across the country. The linkage between a discharge to land and surface water quality needs to be made, with consideration of the pathways via groundwater, and any groundwater effects, appropriately addressed.

The regulatory changes are in part occurring as a result of, and in tandem with, a better understanding of the interaction between groundwater and surface water and improved tools to characterise this, together with improvements in the knowledge of the effects of long-term wastewater discharge to groundwater and surface water receptors.

The 2017 Government Inquiry into the Havelock North *Campylobacter* contamination event has highlighted how important source protection is for drinking water supplies, and it is expected that this will motivate a consistent and appropriate level of assessment and scrutiny of the potential risks from land treatment systems to all New Zealand’s drinking water supplies.

There are also improvements to be made in our understanding and assessment of microbial transport in groundwater as a result of the Havelock North incident. While the pathways between the source and receptor in that event were relatively short and there was an absence of a protective confining layer, research by ESR (2017) has provided further insight into the variable nature of microbial survival rates in groundwater and highlighted how the particular *Campylobacter* strain in that event has longer survival rates in groundwater than other strains (and could survive significantly longer if present in an anoxic groundwater setting). There is a temptation to focus on the transport of *E.Coli* from a land treatment source to a drinking water receptor, given that *E.Coli* sampling data for wastewater is usually available and there is a Maximum Acceptable Value (MAV) set for *E.Coli* in the Drinking Water Standards for New Zealand (MoH, 2005, revised 2008). However, consideration of the risks from specific bacteria, viruses and protozoa requires greater attention including an understanding of the potential concentrations at the source and receptor following processes involving die-off, filtration and dispersion.

In our work in the hydrogeology space, we consider a number of factors in our assessment of land treated wastewater effects on groundwater and groundwater receptors (surface water, supply wells), both for consent applicants and in our auditing of applications on behalf of regional councils. These include the following.

- Regulatory requirements, which vary from region to region. Commonly there is a drive for improvements in water quality, rather than simply seeking to prevent deterioration in water quality.
- The contaminant source:

    - Full characterisation of the waste stream (often iterative changes are made to the treatment process with wastewater engineers/the client as a result of the hydrogeological assessments)
    - Emerging/atypical contaminants including pharmaceuticals, industrial compounds, cleaning compounds and site specific contaminants – what are they in the particular waste stream, which ones do we need to be concerned with, how are these behaving within the hydrological system, do we understand the risks, if not what monitoring/plans are required?
- Contaminant pathways:
    - In the past, groundwater has been considered somewhat out of sight, out of mind by some, however, now the connectivity between groundwater and surface water is understood more widely. We need to understand where is groundwater flowing to and how long it takes to move through the system, will the proposed discharge alter the hydraulic regime and to what degree, what effect will anisotropy have and could preferential pathways increase potential effects?
    - How will the contaminant interact with the groundwater system and reduce in concentration away from the source (due to filtration, die-off, dispersion, denitrification and other attenuation processes).
    - How will the system hold up against climate change, are flood/inundation risks present creating direct pathways from source to receptor, will sea level rise and associated coastal groundwater level rise affect contaminant transport?
- Potential receptors:
    - Surface and groundwater quality - what impact will the discharge have on the existing groundwater and surface water quality and what are the cumulative effects from other land use/discharges?
    - Public health aspects - what is the risk to nearby bore/water users, what is the risk to seemingly more distal bore/water users, what happens in a 'worst-case' situation, what pathogens should be considered?
- Other considerations:
    - Uncertainty and knowledge gaps – additional site investigation work may be required to improve our understanding, but uncertainty in the predictions may still remain.
    - Is there a beneficial re-use element to the application?
    - How will the applicant manage and mitigate predicted effects – on-the-ground property surveys to find potentially pre-database bores, extensive monitoring plans and networks, incident response plans, emergency response plans, discharge consent review conditions, technology review conditions, etc.
    - Public consultation and consideration of local tangata whenua values. Communication of scientific information in a transparent and accessible way is crucial for stakeholder engagement.

A case study is presented below to illustrate application of some of these considerations to a specific project, followed by a discussion of learnings from other projects.

CASE STUDY – OMAHA WASTEWATER TREATMENT PLANT

PDP were involved in the replacement of the resource consents for treated wastewater discharges from the municipal Omaha Wastewater Treatment Plant ("Omaha WWTP"). The Omaha WWTP treats wastewater from Omaha, Point Wells and Matakana. At the site, treated wastewater is discharged solely to land at forestry blocks within the WWTP site itself, and to the Omaha Beach Golf Course. There is no direct discharge to surface water but the irrigation areas border a harbour/estuary and open coastline. At the golf course, treated wastewater is used for irrigation during summer-autumn via subsurface drip irrigation. The irrigation greatly benefits the golf course, reducing their freshwater and fertiliser usage.

PDP undertook an assessment of the potential effects on groundwater levels, flow paths and subsequently groundwater quality effects primarily using numerical groundwater models (developed in MODFLOW). The first stage in any groundwater assessment is to develop a conceptual hydrogeological model. This is illustrated in Figure 1, which shows the conceptualised key flow paths within and between the three main aquifers. Figure 2 illustrates the specific particle tracking model results, while Figure 3 shows the predicted rise in groundwater levels (mounding) on the Omaha flats.

One of the key concerns during the consent process was the potential transport of viruses. Modelling was based on norovirus, to address to concerns over the longevity of this virus in groundwater. Based on the particle tracking and travel times illustrated in Figure 2, and with appropriate consideration of model uncertainty, the risk of viruses reaching receptors (water supply bores, surface water and the marine environment) at a concentration that could cause a risk to public health was considered sufficiently low.

The modelling work helped demonstrate that no capital upgrades were required and consents were granted for the Omaha WWTP with 35 year durations.

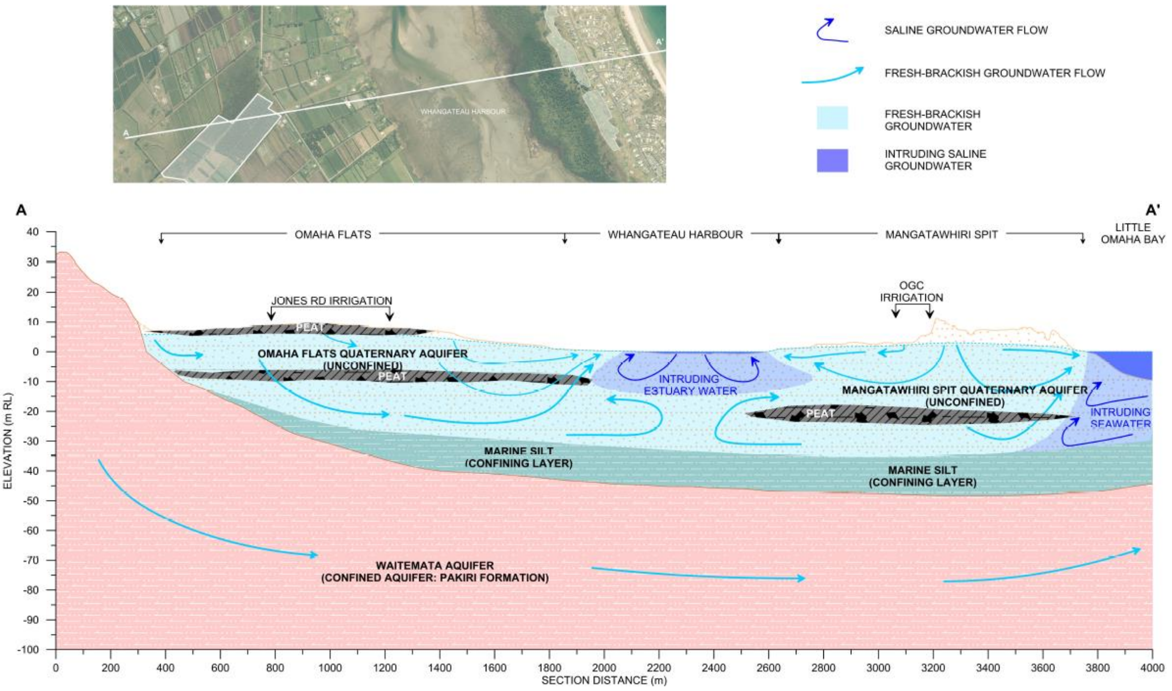

Fig. 1. Omaha Regional Conceptual Hydrogeological Model

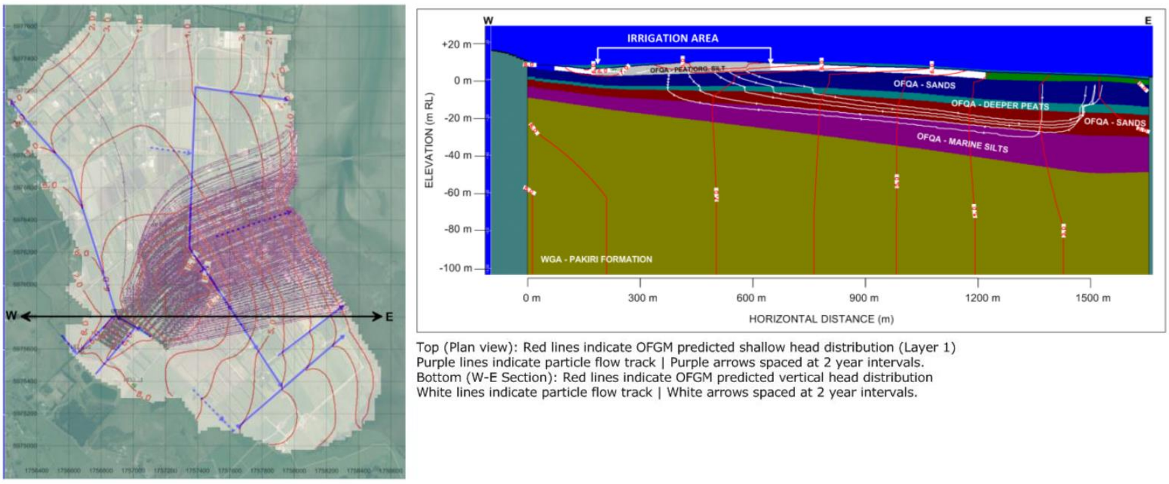

Fig. 2. Particle tracking Omaha Flats

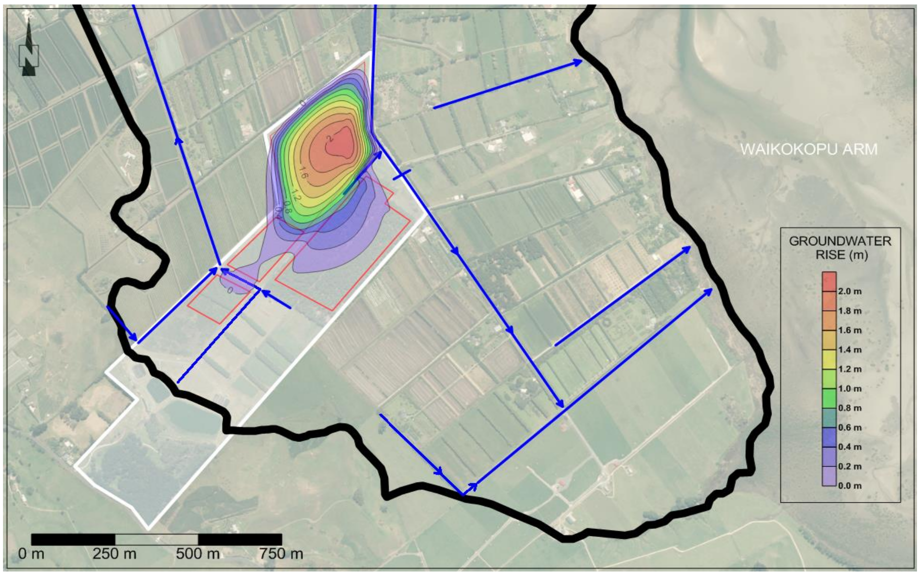

Fig. 3. Predicted groundwater rise (mounding) Omaha Flats

THE ROLE OF THE HYDROGEOLOGIST

The potential effects for each land treatment project clearly vary widely depending on the type and quantity of the wastewater/other waste and the receiving environment. Our role as hydrogeologists is to work closely with our wastewater engineers, ecologists and surface water quality scientists, external project team members and clients to guide the treatment options to ensure the environmental effects are maintained within acceptable limits, allowing for cumulative effects and other factors such as climate change. Some selected examples of this process include:

- Process wastewater from an Otago distillery was originally proposed to be treated and discharged to land on-site. The daily volume of the wastewater was low (<9 m^3/day) but expected nutrient contents were high (nitrogen >1,000 mg/L, phosphorus >100 mg/L). While our modelled effects on groundwater were within acceptable limits for drinking water, we predicted that the potential effects on the river receiving the impacted groundwater could exceed set limits. In light of this, conversations were held with a neighbouring farm and they now willingly accept land application of the beneficial waste via spreader truck to replace their previously imported fertiliser. This replaced the original proposal to discharge to land on-site and avoided the adverse effects on the river via the nutrient uptake provided by the pasture. Based on nutrient uptake modelling, including OVERSEER®, and further groundwater and surface water assessments, the solution was concluded to be environmentally sound and the discharge is now occurring with ongoing monitoring.

- A municipal wastewater treatment plant with final discharge via wetlands to ground on the Kapiti Coast required re-consenting at an increased design discharge volume. PDP were engaged to assess potential groundwater quality and surface water quality effects. Pathways to groundwater supplies and surface water receptors were considered. There was a wealth of water level and quality data available at the site. The assessments indicated that the current system was working well with limited observed environmental effects and that the increased discharge volume would be acceptable in terms of groundwater and surface water effects, with no additional upgrades required.

- A local authority required an assessment to be undertaken of the potential groundwater effects of an unsewered township in Canterbury serviced by septic tanks and on-site land disposal systems, to assist in their decision making on a reticulated system. Our groundwater assessment work showed that the microbial risks to groundwater were low due to the large unsaturated zone (> 70 m) and distance to the nearest supply wells. The effect on nitrogen concentrations in groundwater was concluded to be less than for a reticulated system with land disposal, due to the shift from a widely distributed contaminant load to a more concentrated load.

- Consent renewal work for a number of industrial clients has included reviews of existing water quality monitoring data, which has provided useful information on the existing impacts of the land treatment at each site. A review of groundwater quality information for a particular dairy factory discharge to land via irrigation indicated that the improved management practices that factory had implemented since 2009 were resulting in measurable improvements in nitrogen, as illustrated in Figure 4 below. A number of other factors that could have contributed to the decreasing trend in concentrations were considered to help isolate these management practice effects.

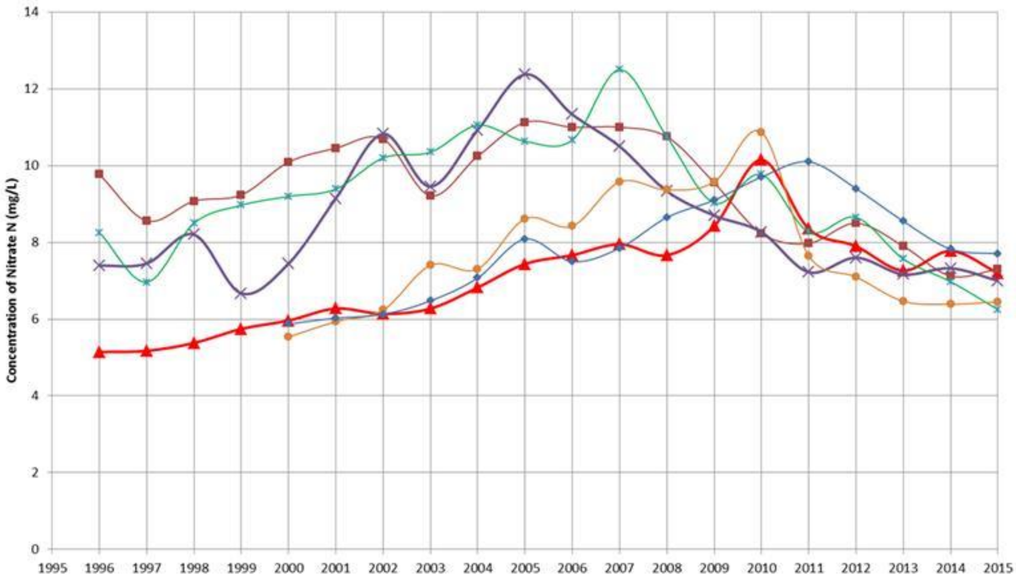

Fig. 4. Average annual nitrate-nitrogen concentrations in bores down-gradient of a dairy factory discharge

- We provided technical advice on the land disposal system associated with the East Rotoiti Rotomā Sewerage Scheme which was granted resource consent in 2017. A comprehensive drilling and testing programme was required to gather information to support the resource consent application and scheme design. The water table was found to be up to 65 m below ground level at the proposed site. The nitrogen loading rates to Lake Rotoiti were assessed and indicated that loading to Lake Rotoiti overall would be significantly reduced compared to current practice.

- Our work has also involved assessments for the disposal and 'treatment' of unconventional waste types – including cemeteries. In one of these projects, we advised a city council not to purchase land for a proposed cemetery as the microbial risks to groundwater were too high, due to a shallow water table and permeable strata not allowing for sufficient die-off and filtration of bacteria prior to the water reaching neighbouring supply bores. In another, we reviewed monitoring data and advised on including additional parameters more suited to identifying cemetery effects on groundwater (embalming chemicals and specific bacteria associated with decomposition) to aid in the management of the cemetery.

CONCLUSIONS

Successful land treatment systems require a good understanding of local groundwater conditions, interactions with the land treatment system and final receiving surface water. Particular consideration is required of the risks to groundwater and surface water drinking water supplies and other potential surface water quality effects.

A groundwater and surface water effects assessment in the planning stage of any land treatment project is key to developing an optimal treatment solution.

REFERENCES

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