Understanding Groundwater in Land Treatment Systems.

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ASTRACT

The design of a sustainable land treatment system relies on a good understanding of the environment which will be receiving the discharged material, whether effluent or sludge. For most systems the main mechanism for wastewater constituents to enter the wider environment is by leaching through soil and movement beyond the site boundaries in groundwater.

Shallow groundwater movement, localised to a land treatment site, is typically the least understood component of a land treatment system. The cost of developing a comprehensive groundwater understanding is prohibitive. As a result, groundwater information, in particular the movement of solutes derived from the discharge beneath and beyond the application site, is often estimated from limited groundwater data or by extrapolation from other receiving environments such as surface water. This risks missing a plume in the groundwater, and tends to apply high levels of conservatism to compensate.

A low cost piezometer installation method has been employed on near-coastal sand country to provide coverage of a 100 ha site. The site has complex hydrology due to the presence of interdunal lakes – both natural and man-made, drains and the influence of the coast located within 1.5 km of the site. The site has a number of activities occurring on it which may influence groundwater in the vicinity of the site. In addition, the catchment that the site is in has been highly modified by farming. While there are some surface water monitoring records near the site it has not been possible to separate the effects of the different activities on the site, or effects from other activities in the wider catchment. A better understanding of the groundwater movement in the vicinity of the site is been required.

A network of groundwater monitoring points and surface water level monitoring sites in the extensive drain network has been established on the site. Data from the monitoring points will provide information about the movement of waste derived constituents from the site and where those constituents enter the wider environment. The information obtained will enable the determination of effects on the environment from the activities on the site, and will ensure permanent sampling bores can be sited to intercept any solute plume from the activities on site.

This paper discusses the set-up, data collection and outcomes for the Manawatu sand country site and examines how the methodology can be applied elsewhere.

INTRODUCTION

An objective of land treatment is to discharge a material in such a way that improves its quality while deriving a benefit to the receiving environment and avoiding negative impacts. This objective can be achieved with diligent design. Design of a land treatment scheme, and design of a monitoring programme for the scheme, rely on an understanding of the behaviour and movement of discharge derived constituents once they enter the receiving environment.

The initial receiving environment for the discharged material is the soil and plant system. The highest degree of treatment to the material and the greatest benefit from the material occurs in the soil and plant system. In general, once the discharge derived constituents move beyond the rooting zone of the soil they are considered to be lost from the productive component of the land treatment system.

The main mechanism for loss of constituents to the wider environment is movement to groundwater by leaching, and transport off-site in groundwater. Direct overland flow of material is unlikely in a well-designed scheme.

In order to determine if and how much of a constituent leaves the site in groundwater an understanding of the movement of groundwater under the site is needed. There are very few locations where property scale hydrogeological information is available, and so for a new land treatment scheme there is likely to be a need to generate this information.

An initial estimate of groundwater conditions may be made from regional data. Following this a piezometer array is the main means to get site specific groundwater data. Developing a comprehensive groundwater understanding is a costly exercise. As a result, groundwater information, in particular the movement of solutes derived from the discharge beneath and beyond the application site is often estimated from limited groundwater data, or by extrapolation from other receiving environments such as surface water. This risks missing a plume in the groundwater, and tends to result in high levels of conservatism to compensate being applied. A low cost method for determination of groundwater properties is described below.

SITE DESCRIPTION AND ISSUES

A land application scheme has been operating since 1987 to discharge wastewater from the Levin community. Treated wastewater is reticulated to the site from Levin's WWTP. A 7 ha pond is located at the discharge site in which the treated wastewater is stored until it is discharged to a pine plantation.

The site is located on sand country within 1.5 km of the coast. The storage pond is located in a basin between dunes. The pond has no engineered liner, but there is expected to have been a degree of sealing due to sludge accumulation. The level of the pond is managed to enable water to accumulate over the winter/spring period to coincide with highest demand from the irrigated plantation over the summer/autumn period. The level of the pond varies by around 1 m. It is expected that the pond is poorly sealed over the zone that is seasonally dry. This seasonally dry pond wall area is likely to be large due to the shallow and broad shape of the pond. There is a potential that leakage from the pond may occur during periods of elevated wastewater levels and decrease when pond levels are lowered. This had not been confirmed previously.

At the time of site commissioning in 1987 the irrigation area was planted with pine trees. In the ensuing time tree mortality has occurred in patches over the site. As a result wastewater is irrigated over a combination of pine trees (now 25 years old) and pasture grazed by sheep. The rate of application to the site is around 75 mm/week irrigated once per week. While this would be considered a high rate of irrigation, the hydraulic rate is not considered to be problematic on what is effectively dune and beach sand.

In addition to the pond and the irrigation area, the site is consented to receive WWTP sludge from Levin's WWTP, so long as metal concentrations in the sludge are within consent limits. Under the conditions of the existing consent there is no monitoring required which would enable effects due to each of these activities to be separated. In considering the future operation of the site this creates a problem in that optimising the land application based on the impact it has on the environment cannot be done since the measured impact of what has occurred historically cannot be separated from other activities on the site.

The application site is located within the Waiwiri Stream catchment. The wider catchment is dominated by pastoral farming, including some dairying. Lake Papaitonga (DoC reserve) drains to the Waiwiri Stream and some small lifestyle blocks are present. Monitoring by a range of agencies (Cawthron, Horizons, HDC) have determined that high nutrient and coliform levels are present in the Waiwiri Stream throughout the catchment. Unsurprisingly, microbial source tracking of coliforms has identified bovine and ruminant sources for the measured coliforms. The catchment is extensively drained in low lying areas. Given the sandy texture, interspersed with accumulated peaty organic matter, this is expected to alter the groundwater flow directions near to drains. Monitoring of a drain in an assumed upstream position to the application site has indicated significant concentrations of measured parameters. However, the complex drainage network has made it difficult to determine whether the site is genuinely up-gradient of drainage from the application area or influenced by inland flowing groundwater resulting from mounding under the application area.

A better understanding of groundwater flow under the site is needed in order to:

- Enable future system optimisation;
- Identify the receiving environment for the wastewater applied to the site; and
- Determine the effects of the operation on the wider receiving enviornment.

METHODOLOGY

A programme was developed to map the groundwater flow under the site and its relationship with adjacent surface waterways. One of the key aims of the programme was to provide an initial wide coverage of the site with a large number of data points. These points were to primarily focus on depth to groundwater only, with the potential to add water quality sampling piezometers once more was known about the direction of groundwater flow.

There are 5 existing piezometers on the site and 20 standpipes with a 20-25 mm Ø were installed. In addition 12 surface water points were nominated. Using a modified hydraulic soil corer rig all the standpipes were installed in a day.

Figure 1 and 2: Standpipe installation.

The standpipe and surface water points were surveyed to a common datum. Standing water depth was measured following a settling period, from which a potentiometric contour map was produced.

RESULTS AND DISCUSSION

Three plots of the potentiometric surface were produced based on:

- Groundwater sites only;
- Groundwater and surface water sites; and
- Groundwater, surface water and wastewater pond.

The plots are shown as Figures 3, 4 and 5. The Waiwiri Stream runs from east to west in the lower part of the image. The coast is located around 1.5 km to the west.

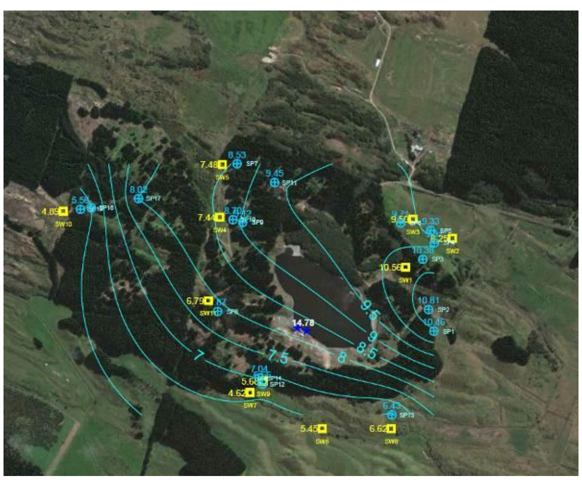

Figure 3: GW only

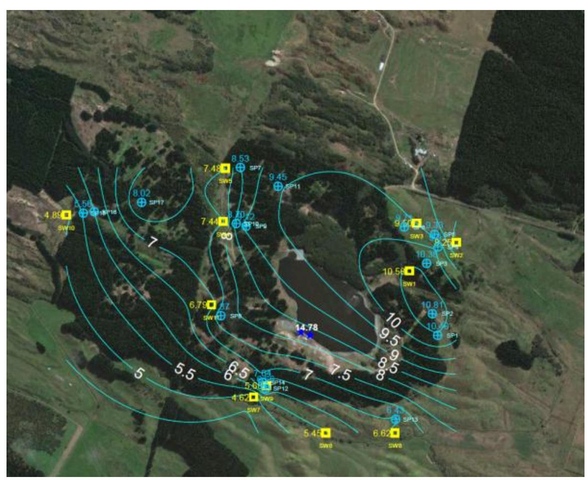

Figure 4: GW and surface water

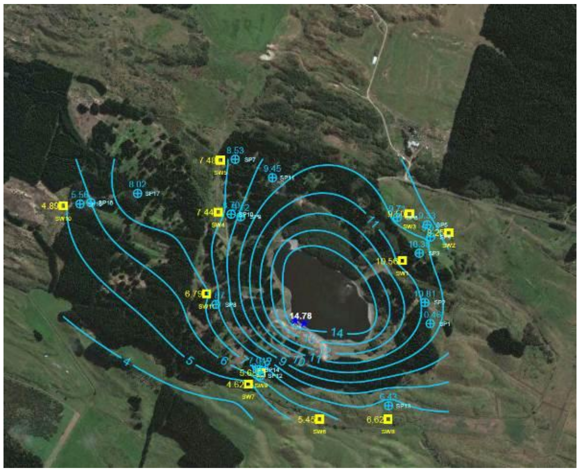

Figure 5: Ground water, surface water and pond

The potentiometric surface for both the groundwater only and surface water plus groundwater indicates that the groundwater gradient flows towards the coast (west) in the northern portion of the site, and flows south towards the Waiwiri Stream in the southern and eastern portions of the site. This is to be expected.

The inclusion of the wastewater storage pond water level in the groundwater model (Figure 5) suggests that there is considerable potential for mounding as by seepage from the pond. This causes groundwater to flow inland to the east, which can then be captured in surface drains. These eastern surface drains have historically flown past an up-gradient monitoring site. Consequently there is the potential that the historic upgradient site is actually influenced by mounding from the land application area and is in fact not upstream.

WHERE TO NEXT

Monitoring to date has identified additional sites for standpipe installation to confirm the relationship of the pond to the groundwater i.e. is seepage occurring.

Installation and water level monitoring to date has been undertaken while the pond levels are high. Continued water level monitoring will be carried out to determine if there is a seasonal relationship between pond water level, seepage from the pond and groundwater flow direction.

Permanent water quality sampling piezometers will be installed at sites determined from the investigation to be up-gradient and down-gradient of the site. The piezometers will enable nutrient losses from the site to be evaluated, and modification to the land application system design to be undertaken with some assurance of the activity's actual environmental effect.

APPLICATION TO OTHER SITES

The method for determination of groundwater at the Levin site has provided valuable information about the receiving environment for any discharge from the site. Relationships between the storage pond and groundwater can be established. Water movement following irrigation can be more accurately predicted result. The information gathered can be used to optimise system design while protecting the values of the receiving environment.

The methodology used to install monitoring standpipes and to monitor groundwater levels at the Levin site can be used for sites where groundwater is located within 6 m of the ground surface and is particularly well suited to silty soils, sandy soils and fine gravel. The determination of groundwater levels, gradient and flow direction have applications for site characterisation, pond seepage studies and land treatment leaching investigation.