Determining minimum lot areas for sustainable on-site wastewater discharge

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ABSTRACT

Minimum lot sizes are an important aspect of onsite wastewater design for subdivisions. The designer not only needs to ensure that there is appropriate area for the discharge of wastewater, but also the cumulative effects of numerous systems operating within an area do not cause the degradation of the downstream environment. This paper summarises the modelling process that can be used for determining sustainable subdivision lot sizes for both on-site and decentralised communities, to ensure the downstream environment is not adversely affected. The process that has been established also allows the simulation of various design and operation modifications, and comparison with alternative land use. In particular the model allows the comparison of numerous scenarios of decreasing lot sizes and thus increasing population with the goal of determining a baseline lot size that would be the equivalent of the existing or an alternative land use. This paper presents the suitability of varying lot sizes based on the impact of nitrogen (other analytes could be used). Consideration is also given to the quality of effluent discharged. A case study is applied to the model is applied, with the results of this real scenario indicating that the quality of the effluent discharged has a significant impact on the minium lot size. For example secondary treated effluent can be assimilated on a lot size of approximately 2,000m^2 and have similar effects to the current land use. If only filtered septic tank effluent is used the minimum lot size increases to approximately 5,500m^2. The model provides a tool that can be used by developers and Regional Councils alike when considering the cumulative effects of proposed development and their effects on the down stream environment.

INTRODUCTION

It is well appreciated that cumulative effects need to be considered in cases where a number of separate on-site systems are located in close proximity (Auckland Regional Council TP58, 2004). Numerous systems operating in close proximity pose a greater potential risk to the receiving environment (EBOP 2006). Regional councils have responsibility for managing the potential cumulative effects of wastewater servicing (either on-site, cluster or centralised) on the natural land and water environment (MfE, 2003).

Currently, regulatory authorities are approaching the potential for cumulative effects of wastewater from subdivisions in a variety of ways, with many incorporating minium lot sizes for on-site wastewater discharges in their regional plans. Table 1 below outlines some of the varying approaches used by regulatory bodies aimed at limiting the cumulative effects of multiple-systems operation within a confined area.

Table 1. Minimum lot sizes for onsite wastewater treatment plants on site.

Regulatory Body	Parameters	Effluent quality	Minium Lot Size
Auckland Regional Council – Technical paper P58 (2004)			3,000m^2
Environment Waikato - On-Site Effluent Treatment Regional Plan (2006)	Standard Wastewater Treatment system	No Minium Limit	Effluent Disposal Area* <2,500m^2
	Improved Onsite sewage treatment	Pre-treatment of effluent to a standard not to exceed concentrations of 20g/m^3 of BOD_5 and 30g/m^3 SS	Effluent Disposal Area* >2,500m^2
Environment Bay of Plenty - On-Site Effluent Treatment Regional Plan (2006)	Within the lakes catchment	30 g/m^3 BOD_5 45 g/m^3 of TSS	Property title with a land area of less than 2 hectares will be subjected to minium performance conditions.
	Outside the lakes catchment	30 g/m^3 BOD_5 45 g/m^3 of TSS;	No Minimum Limit
Horizons Region Council -Proposed One Plan (2007)	New systems	BOD_5 20g/m^3 SS 30g/m^3 TN 30g/m^3	5,000m^2 2,500m^2
	Existing System for properties under 10 ha	No Minimum Limit	No Minimum Limit
- Land and Water Regional Plan (2003)	No Minimum Limit		
Greater Wellington Regional Plan for Discharges to Land (1999)		If Aerobically treated COD_5 does not exceed 20mg/L otherwise no minium limits	No Minimum Limit
Environment Canterbury-Proposed Canterbury Natural Resource Regional Plan (2004)		The effluent shall pass through a proprietary effluent filter before discharge to the land application system.	Minium Lot size is controlled based on the amount of effluent to be discharged ie 3 m^3/day on a property up to 8ha
Otago Regional Council – Water Plan 1999		No Minimum Limit	No Minimum Limit

*Effluent disposal area' means the area of land that is available for the infiltration and assimilation of effluent. The effective disposal area may extend beyond the property boundary provided an easement is registered on the title of the receiving property.

There are currently few models available that are able to predict the effects of lot sizes on the receiving environment and ultimately groundwater quality. Hence, the aim of this paper is to present the results of a basic modelling approach that examines the relationship between lot sizes, quality of effluent and their combined effects on total nitrogen concentrations within groundwater leaving the subdivision.

METHODS

Background

A variety of methods can be used to model the effect of a proposed landuse change on a property. The method undertaken depends upon the output required. DWG commonly utilise two methods of modelling: 1) the direct mass loading approach reaching groundwater and 2) a groundwater mass balance approach, which is essentially an addition to the first method. The main variation between these approaches is whether they take into account the effects of groundwater dilution.

The direct mass loading approach examines the amount of nitrogen loaded onto a site with comparisons drawn between the existing nitrogen loading (e.g. a dairy farm) and the proposed activity (e.g. a subdivision with onsite wastewater). Here existing models such as Overseer® and SPASMO can be utilised to predict nitrogen leaching rates from the current landuse. Calculations can then be undertaken based on population density and quality of effluent discharged to determine the proposed landuse effects relative to the existing landuse.

Care should be taken when using this approach as different models assume varying degrees of attenuation of nitrogen within the soil profile. To add a degree of conservatism, DWG often assumes no attenuation of nitrogen from wastewater being applied to a site i.e. discharged wastewater concentration is assumed to reach groundwater. Often this approach may be sufficient to determine if the proposed changes to nitrogen levels as a result of land change area acceptable. However, there are occasions where highly sensitive receiving environments may require further analysis and consideration of attenuation.

The second more refined modelling approach includes a groundwater mass balance to predict down-gradient effects of any nitrogen application. This requires consideration of groundwater characteristics and climatic factors. The volume of water recharging the aquifer over the area of the site needs to be determined. This includes both effluent and rainfall. While a relative assessment of increases can be made, knowing the upgradient groundwater concentration helps to refine the model output to predict the likely groundwater concentration downgradient of the site.

Baseline data

There are two forms of baseline that can be established. The first is the likely inputs that describe the current land use. The second is an artificial baseline scenario where there is no nitrogen input, under which the addition of rainwater will provide dilution of up-graident aquifer through-flow.

Introduction of mass

Once the baseline conditions are understood, the mass balance approach is undertaken to determine the amount of nitrogen proposed to be applied to a site. This includes nitrogen from wastewater and fertilizers. The first method considers the total mass of nitrogen over the site that may leach to groundwater. The second is a refinement that includes the mass of nitrogen in the groundwater system passing below the site. This is represented simply by the following equation:

Background N from groundwater (kg/d) + total N input from the site (kg/d) = Total N kg (kg/d)

The total N input from the site will vary depending upon nitrogen concentration of effluent application as well as the volume of effluent. These changes can be modelled and compared against the baseline data to determine the effects on groundwater nitrogen levels.

This simple mass balance approach allows a comparison between the proposed changes to the site and existing conditions. Depending on the system to be described, this process can involve the use the nitrogen outputs from the modelling tool Overseer®. Again a degree of conservatism is added into the model here as Overseer® assumes a leaching component enters groundwater with some attenuation occurring in the soils. In our simple mass balance approach it is assumed that discharge from treatment plants enter groundwater with no soil attenuation. As a result a worst case scenario from the wastewater is assumed. Further refinement of wastewater attenuation can be applied for sensitive catchments.

CASE STUDY

The following is an example of where the groundwater mass balance approach has been utilised. The property was located within the Horowhenua District, north of the Kapiti Coast. The primary reason behind using the adopted model was the perceived sensitivity of the receiving environment. The proposed subdivision was located within the catchment of Lake Horowhenua and Lake Papaitongia. Horizons Regional Council notes that the lake's within the region are currently in an "advanced state of eutrophication" (HRC 1998) and therefore controls on nitrogen inputs within the catchment zone were seen as appropriate. The approach used has been to adopt the second method where by the impact on groundwater is considered.

Site information and model inputs

The subdivision used for the model consisted of a total development area of 55.5 Ha. A significant area of these 55.5 hectares would be used for reserve areas and roads with only a total of 25.5 Ha available for lot development.

Current farming system

The site of the proposed subdivision was being used as a dairy farming. In order to provide comparisons with existing conditions on site, DWG used the AgResearch model Overseer® to describe the current pastoral system.

Wastewater characteristics

It was assumed that that an average of 5 people would inhabit each lot. Additionally, it was proposed that the site would host a café. Table 2 outlines the wastewater quantity parameters adopted for the each lot proposed for the site.

Table 2. Projected wastewater volumes per lot.

Facility	People per lot	Wastewater rate (L/p/d)	Volume (m^3/d)
Residential	5	200	65
Future Café	200	30	6
Total design flow			71

Varying effluent qualities can be used in this modelling approach. In this particular case two effluent variations were considered; a secondary treated effluent and filtered septic tank effluent.

Table 3. Effluent nitrogen concentrations used in the model.

Facility	Nitrogen Concentration (g/m^3)	Range (g/m^3)
Septic Tank with Outlet Filter	40	40-100 [a]
Secondary Treated	20	< 25 [b]

[a] ARC TP58 2004 and [b] Supplier specifications

Groundwater modelling

Recharge coefficient over the Levin urban area was estimated at 0.3 (Watts 2003). This coefficient takes into account that the surrounding area comprises impermeable surfaces (roads and buildings) and a diversion of stormwater runoff. As stormwater soakage was to be used as part of the development, this value was seen as a conservative value for recharge for the site i.e. a higher reacharge rate would have resulted in greater dilution and a lower concentration within the groundwater system.

Additionally the Table 4 outlines the various other parameters used to model the existing groundwater conditions to determine the volume of water that would flow under the site.

Table 4. Groundwater parameters.

Parameters		Units
Transitivity	60	m^2/d
Hydraulic conductivity	6	m/d
Aquifer gradient	0.005	
Aquifer depth	10	m
Site width	800	m
Cross sectional area	8,000	m^2
Aquifer through Flow	240	m^3/d

Results

The baseline results from the model were graphed into the following output, shown in Figure 1. This indicates the resulting groundwater concentration under the site. The graph shows the results of the current farming operation which uses output data from Overseer® and provides the current baseline for what is currently leaving the site, being 1,268 kg N/yr over the entire site or 22.8 kg N/ha/yr. For comparative purposes the World Health Organisation Guideline Drinking Water Threshold value for Nitrate Nitrogen has been added.

From the groundwater modelling we have also added the predicted background concentrations coming into the site as well as predicted concentrations leaving the site if no leaching of nitrogen was to occur on the site.

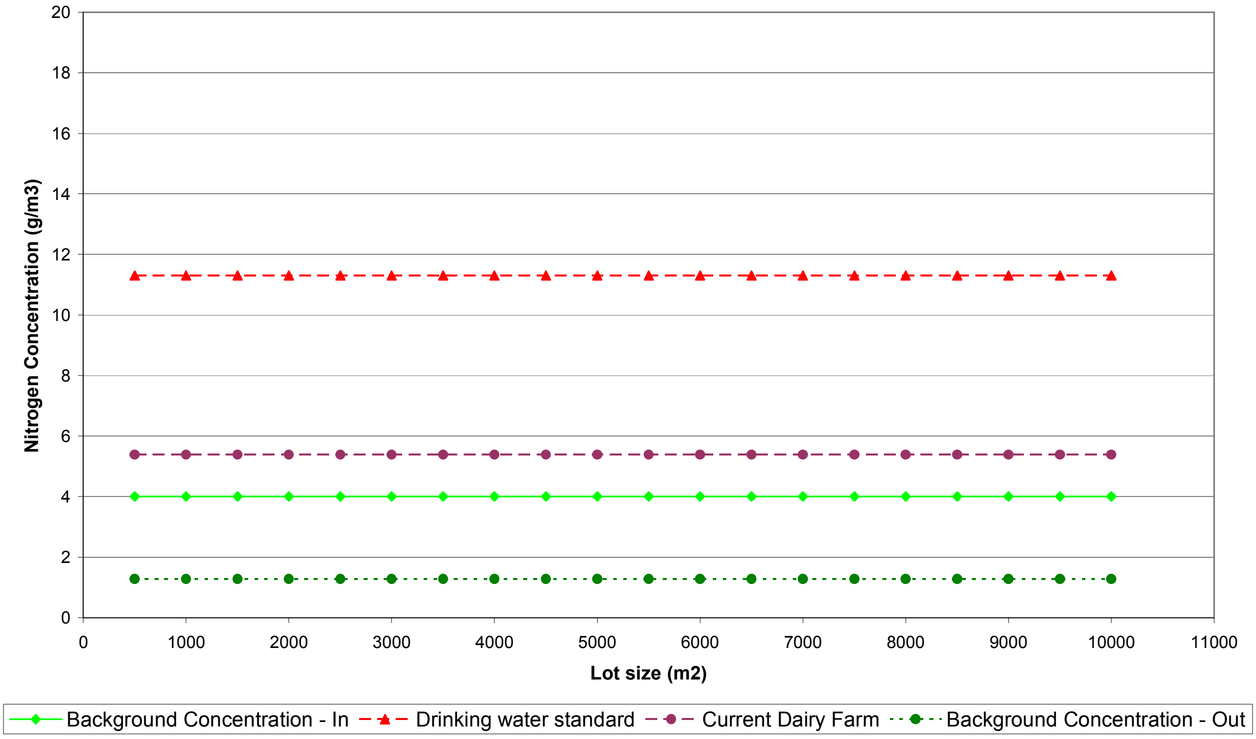

Figure 1. Baseline conditions.

The impact of the development can be imposed on the baseline data to determine the impact of varying lot size (Figure 2). The difference in wastewater treatment quality is also imposed on Figure 2, along with the effects of population density.

The model output, as described in the above Figures, can be then be used to examine the appropriate lot sizes so that the discharge will not increase nitrogen loading in the groundwater once the recharge of the site is taken into account.

For secondary treated systems the model indicated that a minimum lot size of approximately 2,000m^2 is appropriate to result in a groundwater nitrogen contribution equal to that of background groundwater nitrogen concentrations. Should a conventional septic tank and filter system be used, the minimum lot sizes for the area would increase to around 5,500m^2 to allow for no increase in groundwater nitrogen concentrations.

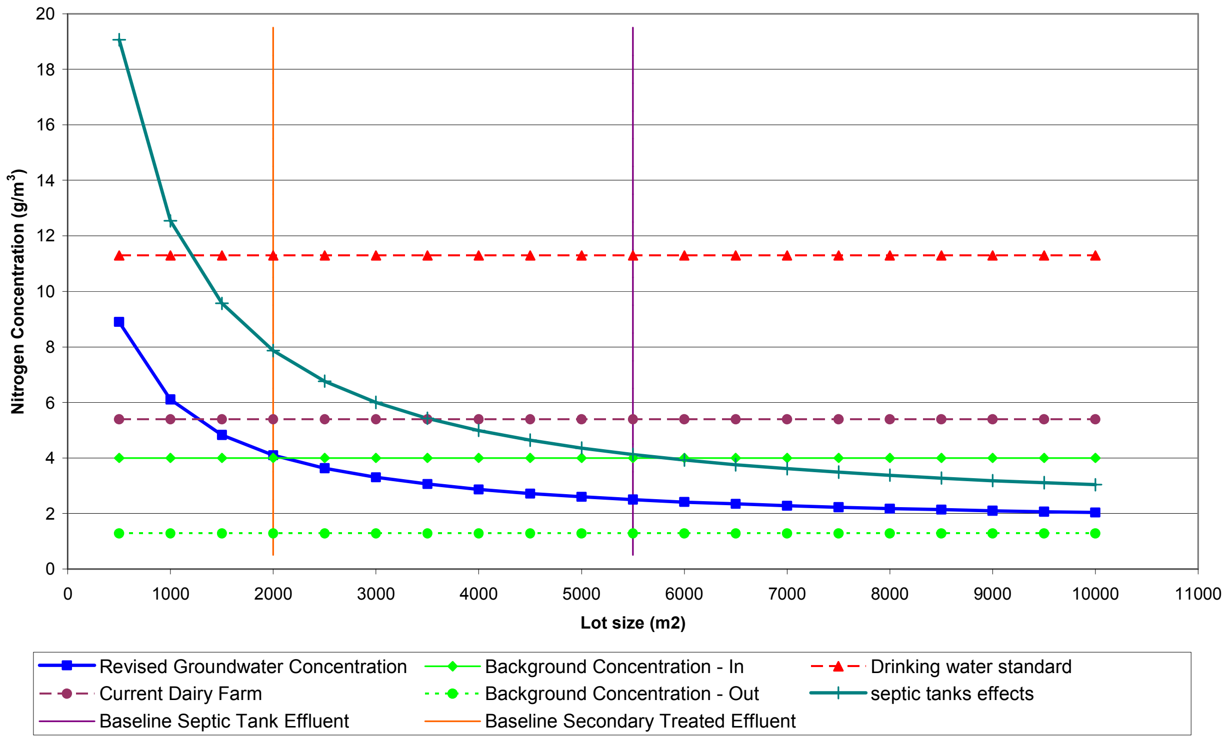

Figure 2. Projected effects of nitrogen with varying lot sizes.

CONCLUSIONS

Cumulative effects of numerous on-site wastewater systems need to be considered when undertaking planning for developments where on-site wastewater treatment and discharge systems are proposed. The same evaluation tool as used on a larger scale can be adopted on a smaller scale, with the combined effects of lots within a catchment considered collectively. This approach also allows for the consideration of decentralised systems.

The effects of multiple systems will vary greatly dependent upon the location of the site as well the sensitivity of the surrounding environment. The quality of the effluent will also influence the effects on the surrounding environment.

The model used in this study has its limitations. However, it does provide a useful basic tool in establishing the effects of lot sizes and their impacts on groundwater nitrogen concentrations. In this paper it has been used to demonstrate that if septic tanks and filters where installed on lots under 5,500 m^2 in size there would be an effect of increasing total nitrogen in groundwater above the existing baseline valued. However if an improved stranded of wastewater was used the lot sizes could be reduced to 2,000 m^2.

It should also be noted that this model is not solely restricted to nitrogen and can be applied to other nutrients. It should also be noted that receiving environment parameters will greatly impact on the effects of multiple systems.

REFERENCES

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