GROUND WATER AND SOIL QUALITY ISSUES ASSOCIATED WITH THE ON-SITE DISPOSAL

OF

DOMESTIC SEWAGE EFFLUENT:

PROPOSED CHANGES TO

ENVIRONMENT WAIKATO'S TRANSITIONAL REGIONAL PLAN

2 ON-SITE SEWAGE

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EXECUTIVE SUMMARY

Environment Waikato have proposed changes to regional rules relating to the on-site disposal of domestic sewage effluent within the Transitional Regional Plan. This report addresses ground water and soil quality issues associated with the on-site disposal of domestic sewage effluent from a septic tank system, and the proposed regulations.

The report reviews the main contaminants that are likely to be discharged into the environment from an on-site sewage disposal system, and addresses some of the submissions made in response to the proposed rules.

Nitrogen, phosphorus and microbes are the main contaminants that are likely to be released to the environment through on-site sewage disposal.

Phosphorus is unlikely to be a contaminant of concern because it is readily bound onto soil particles and will become unavailable.

Microbes (bacteria, fungi, viruses, protozoa) may affect ground water quality and adversely affect ground water supplies. However, filtration, adsorption and die-off in soil and ground water limits microbe migration. The proposed rules, in conjunction with existing Council rules regulating the location and construction of ground water abstraction wells, are sufficient to avoid the microbiological contamination of ground water.

Nitrogen is a significant contaminant in surface waters and ground waters. In surface waters, ammoniacal-nitrogen may be toxic to freshwater animals, and nitrate-nitrogen may enhance weed and algal growth in the presence of phosphorus. Nitrate-nitrogen in ground water and surface water can cause adverse health effects at concentrations ≥ 10 g m^{-3}.

About 60 g d^{-1} of urea-nitrogen from urine and a relatively small, but unknown quantity of ammoniacal-nitrogen and nitrate-nitrogen from faeces is likely to be discharged into soakage from a septic tank sewage disposal system. In well drained soils, most of the urea-nitrogen will be converted into nitrate-nitrogen, which may then leach to the water table and contaminate ground water. In poorly drained soils, this is unlikely to occur, and nitrogen will remain bound to the soil, or liberated into the atmosphere.

The dilution of nitrate contaminated ground water is probably the only means through which the concentration of nitrate can be effectively reduced to manageable levels (< 10 g m^{-3}). Therefore, it is necessary to ensure that sufficient effluent dilution is achieved within the proposed effective disposal areas.

Nitrate concentrations in ground water of about 10 g m^{-3} to 15 g m^{-3} were modelled for effective disposal areas of 2500 m^2 and 800 m^2 respectively. However, these are considered to be conservative estimates and it is unlikely that the concentration of nitrate will exceed 10 g m^{-3} in most situations.

The modelling of nitrate contamination of ground water indicates:

i) that the discharge of sewage effluent into the ground from a septic tank system with an effective disposal area of 2500 m^2 is unlikely to adversely affect ground water quality and is also unlikely to produce cumulative adverse effects; and

ii) the discharge of sewage effluent into the ground from a septic tank system through an effective disposal area of 800 m$^:$ is probably appropriate for existing systems where no adverse effects from ground water contamination are identified.

In some instances, an existing or new system may not meet the requirements of the proposed rules due to variable site conditions or other reasons. In these circumstances, it is appropriate that the environmental impacts of the system are examined through a resource consent and consent monitoring procedure.

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1 INTRODUCTION

Environment Waikato have proposed changes to regional rules regulating the on-site disposal of domestic sewage effluent (proposed changes to Environment Waikato's Transitional Regional Plan, June 1993).

This report discusses ground water and soil quality issues associated with the proposed rule changes. The work has been undertaken in accordance with the brief given to the Natural Resources Section on 4 November 1993.

1.1 Scope

This report:

i) reviews the main contaminants that are likely to be discharged into the environment from an on-site sewage disposal system;

ii) assesses and quantifies some of the likely pathways that contaminants will take when discharged into the environment; and

ii) addresses some of the submissions made with respect to the proposed rules.

This report uses information and resource data collected within and outside the Waikato region. However, no data have been collected by Environment Waikato to specifically address the issues raised in the submissions.

1.2 Analysis of Submissions

An analysis of the submissions on the proposed rules have highlighted the following general concerns:

i) justification for the effective disposal areas of 800 m^2 and 2500 m^2;

ii) the environmental effects of the discharge on ground water quality: and

iii) the effects of variable site conditions.

These issues are addressed in body of the report.

2 ENVIRONMENTAL CONTAMINANTS

Several contaminants will be discharged into the environment from the on-site disposal of domestic sewage effluent. Nitrogen, phosphorus, and microbiological contaminants are the most likely contaminants to cause some adverse environmental effects, or have been identified as contaminants of potential concern in the proposed rules.

The likely pathways for contaminants to be dispersed to the environment are identified in Figure 1. Contaminants may be discharged into the air, soil or water through several means.

However, only the discharge of contaminants into ground water, and into soil are considered in this report.

2.1 Nitrogen

2.1.1 Introduction

Nitrogen (N) is a contaminant of significance to both surface waters and ground waters. In surface waters, ammoniacal-nitrogen may be toxic to freshwater animals and nitrate-nitrogen (nitrate-N) may enhance weed and algal growth in the presence of phosphorus. Nitrate-N can become significant to human health if ingested at concentrations in excess of 10 g m^{-3}. The New Zealand Health Department has stipulated 10 g m^{-3} nitrate-N as the maximum allowable level of nitrate in drinking water (New Zealand Department of Health, 1989).

The environmental chemistry of nitrogen is summarised in this section, and is presented in full in Appendix I.

2.1.2 Environmental Chemistry of Nitrogen

A healthy adult will normally excrete about 35 g of organic nitrogen per day in urine, of which up to 90% is urea (15 g urea-nitrogen). A household containing 4 adults will generate a total of 60 g of urea-N per day. In a septic tank system operating normally, this will be discharged directly into soakage.

A household of 4 adults may also generate about 6 g per day of organic-N in faeces. This may be converted into ammoniacal-N during anaerobic breakdown of organic-N in a septic tank. Ammoniacal-N may undergo relatively complex chemical reactions in a septic tank (e.g. nitrification of ammoniacal-N to nitrate-N then denitrification of nitrate-N to nitrogen and nitrous oxide). The nitrogen gases produced through these reactions are then lost to the atmosphere. A small but unquantified amount of ammonium-N and nitrate-N produced from the decomposition of the faeces will flow out of the septic tank and into the soakage area.

When urea-N reaches the soakage area, it will react with urease (microbial enzyme) no produce ammoniacal-N. In sandy soils, ammoniacal-N will be oxidised to form nitrate, which may then be readily leached to the ground water. In poorly drained soils, ammoniacal-N becomes bound to the soil, and undergoes slow nitrification to nitrate-N, then rapid denitrification to produce nitrogen and/or nitrous oxide. Therefore, in poorly drained soils, the leaching of nitrate into the ground water is insignificant.

2.2 Environmental Chemistry of Phosphorus

Phosphorus (P) is a contaminant of significance in surface waters where it acts as a nutrient that may enhance weed and algal growth.

About 2.5 g of inorganic phosphorus is excreted per day in human urine. A small quantity (0.3 - 0.7 g) of phosphorus is also present in human faeces in an organic form. Organic-P is transformed to inorganic-P (mineralised) only very slowly.
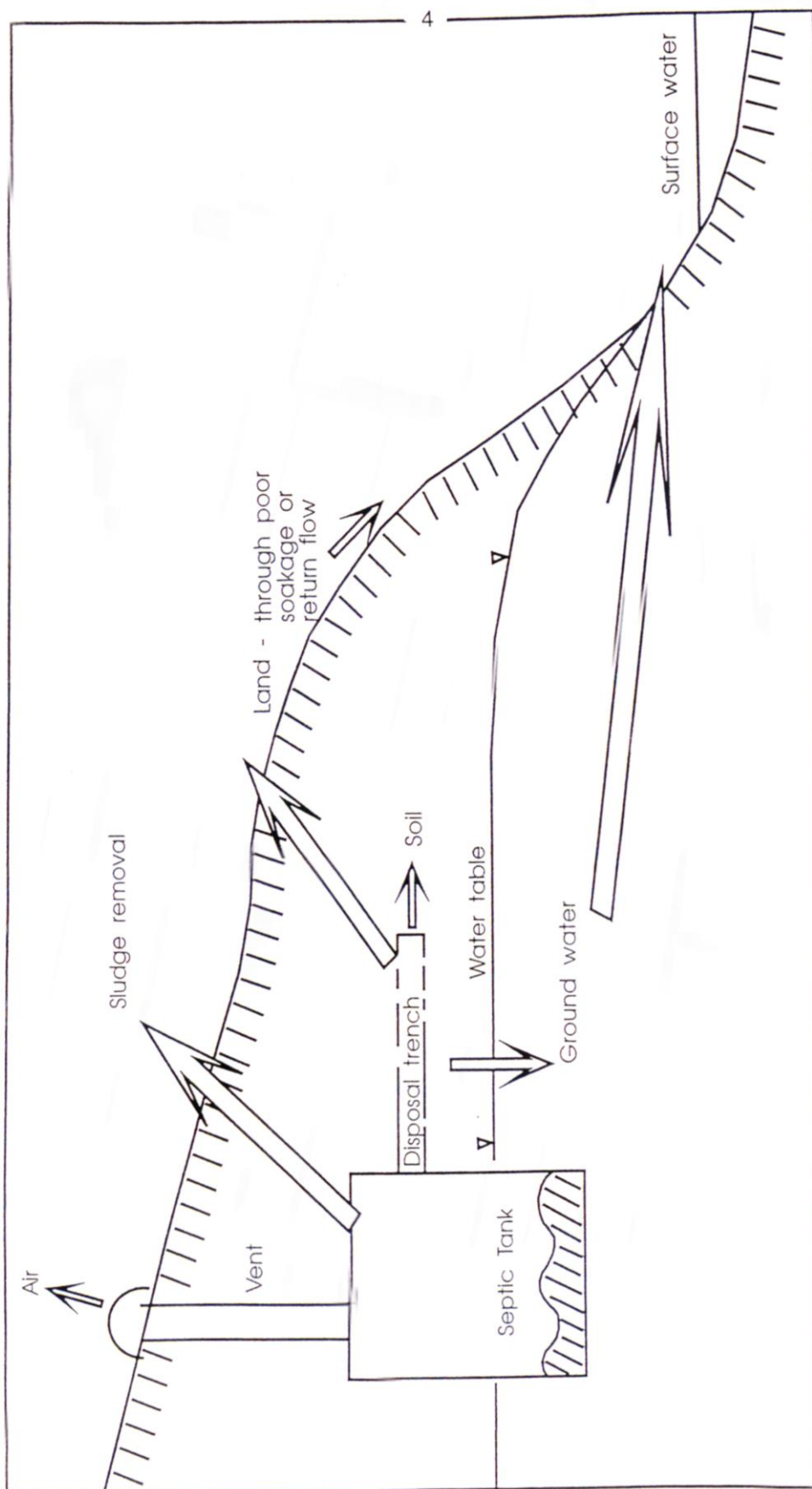
Figure 1. Likely contaminant pathways: Domestic household sewage waste.

Some detergents used in New Zealand contain inorganic phosphorus in the form of polyphosphates, which are discharged into septic tanks in small quantities.

Most soils, within the Waikato region have a significant capacity to immobilise phosphorus by binding it to soil particles and it is likely that all phosphorus discharged from a domestic sewage system will become attached to soils and made unavailable. Therefore, the threat of ground water contamination from the discharge of phosphorus in domestic sewage systems is considered minimal.

2.3 Microbiological Contaminants

Microbes are minute living beings which include protozoa, bacteria, fungi and viruses. A range of microbes are present in sewage effluent. Some microbes may be pathogenic (capable of causing disease) in water supplies, and therefore it is necessary to examine the likely behaviour of microbes in soil/ground water systems.

Soil and some geological materials have a capacity to remove microbes by filtering and adsorption in the soil or aquifer and/or die-off.

Microbes may migrate from a source of contamination in both soil and ground water environments. In unsaturated soils, microbes generally do not migrate more than about 5 m from the source of the contamination. However, in saturated conditions in a granular aquifer, microbes may survive and travel with the ground water for distances up to 30 m (Romero 1970). In circumstances where there are permanent fractures either in the soil or aquifer material, the movement of the effluent through the ground may be faster, and accordingly, microbes may be able to travel greater distances before die-off becomes significant.

Many regulatory authorities have adopted guidelines stipulating "safe" separation distances between sewage disposal areas and ground water supplies. These distances vary from 8 m in favourable conditions (where contamination is considered to be unlikely) to at least 30 m in unfavourable conditions (Romero, 1970; Fenner, no date).

In terms of Council functions and regulations, the effective separation of ground water abstraction wells and sewage outfall areas (to avoid microbiological contamination of ground water supplies) may be achieved through:

i) the implementation of **effective disposal areas** (as proposed); and

ii) the ongoing implementation of the Council's land use rule relating to the location and construction of ground water abstraction wells.

Both of these measures will help ensure that ground water supplies are not compromised by the discharge of sewage effluent into the ground.

2.4 Summary

i) Nitrogen, phosphorus, and microbes are all contaminants that may be discharged from a domestic on-site sewage system.

ii) Phosphorus is unlikely to be a contaminant of concern because it is readily bound onto soil particles.

iii) Microbes have the potential to be significant contaminants. However, filtration adsorption and die-off severely restrict microbial dispersion. The proposed rules, in conjunction with existing regulations, are likely to be sufficient to avoid microbial contamination of ground water supplies.

iv) Nitrate is the contaminant most likely to affect on ground water quality, potentially making ground water unpotable.

v) Nitrate contamination of ground water is more prevalent in permeable, well drained sandy soils. Nitrate contamination of ground water is unlikely to occur beneath poorly drained, fine-grained soils.

vi) The amount of nitrogen discharged from an on-site septic tank system is likely to be about 60 g m^{-3}.

3 NITRATE CONTAMINATION OF GROUND WATER

Nitrate contamination of ground water is an important issue in the proposed rules. However it is only likely to be significant in areas where permeable, well drained soils occur.

To achieve manageable levels of nitrate in ground water (< 10 g m^{-3} nitrate-N), some dilution of nitrate in ground water may be required. Therefore, it is necessary to ensure that sufficient dilution of nitrate is achieved within the proposed effective disposal areas.

3.1 Modelling of Contamination

Modelling nitrate contamination of ground water will help determine whether there is sufficient nitrate dilution to reduce nitrate concentrations to manageable levels. Modelling the contamination of ground water requires the establishment of a ground water model which often contain assumptions about the behaviour of a real ground water system. Some of these assumptions may not be met in real situations. However, despite these reservations, the modelling of ground water quality provides a tool through which the impact of sewage effluent disposal may be predicted/estimated.

3.1.1 Preliminary Analysis

The dilution of nitrate in ground water from a septic tank sewage disposal site depends on the quantity of ground water flowing beneath the site. The amount of dilution that is potentially available may be estimated using Darcy's law for ground water flow:

$$Q = AKi; \hspace{3cm} (1)$$

where

Q: Ground water flow through a porous, homogenous aquifer (m^3 d^{-1});
A: A cross-sectional area through which the ground water flows (m^2);
K: Hydraulic conductivity of the media (m d^{-1}); and
i: Hydraulic gradient (Figure 2).

Therefore, the concentration of nitrate in ground water may be calculated by:
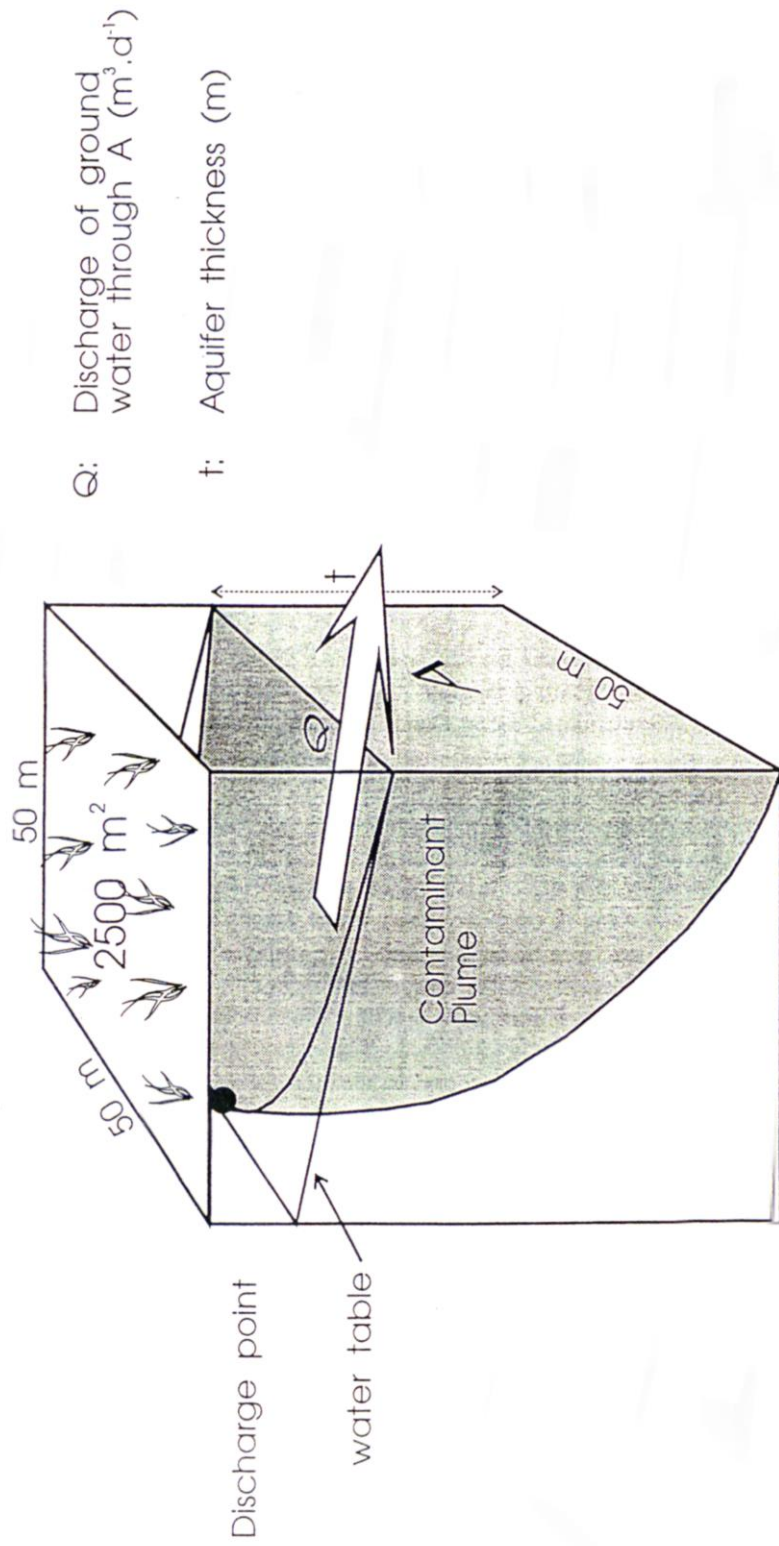
Q: Discharge of ground water through A ($m^3.d^{-1}$)

t: Aquifer thickness (m)

50 m

50 m

2500 m^2

50 m

50 m

t

Q

Discharge point

water table

Contaminant Plume

Figure 2. Conceptual model of a typical ground water contaminant system.

$$[NO_3] = NO_{3\text{septic tank}}/q; \qquad\qquad (2)$$

Where:

$[NO_3]$: Concentration of nitrate in ground water (g m^{-3});
$NO_{3 \text{ septic tank}}$: The amount of nitrate discharged into a domestic effluent disposal field (g);
q: Volume (m^3) of ground water through-flow per day, including about 1 m^3 discharged from the septic tank itself (i.e. $q = Q + 1$ m^3).

3.1.2 Computer Model

The preliminary assessment may be refined using a computer model. The computer model chosen for this assessment is an analytical two dimensional solute transport model (Plume-2D).

The model can calculate and plot the concentration of any chemical solute in ground water. It requires the establishment of a matrix or grid pattern, which in this case may be constructed to model the proposed effective disposal areas of 2500 m^2 and 800 m^2.

3.1.3 Hydrogeological Conditions

Characteristic regional hydrogeological information is required for both the preliminary analysis and the computer model of nitrate in ground water. As stated previously, nitrate contamination of ground water is only likely to be significant in areas where permeable, well drained conditions exist. Areas within the Waikato region that contain well drained soils include parts of the Hamilton Basin, southern Hauraki Lowlands, the Taupo Basin and some small coastal settings. Hydrogeological data collected from the Hamilton Basin and the Wairakei Catchment are used for both the preliminary analysis and the computer model (Appendix II).

3.1.4 Assumptions

Some of assumptions implicit in the preliminary analysis and the computer model, are listed in Appendix II. In addition, there are several other assumptions including:

i) a total discharge of 60 g of nitrate-N per day into ground water
ii) nitrate reduction only through dilution - no other nitrogen losses;
iii) a uniform, homogenous, and porous aquifer;
iv) complete mixing of effluent with ground water;
v) no rainfall recharge of the aquifer;
vii) uniform aquifer dispersion (computer model only);
viii) a point source of contamination (computer model only);
ix) square or rectangular effective disposal areas; and
x) steady-state conditions (i.e. no change of nitrate concentration with time).

3.2 Results

Results from the preliminary analysis and computer model are presented in Table 1. Figures A1 to A5 of Appendix II show that ground water nitrate concentrations decrease uniformly

away from a point source discharge. In real situations, this may only occur rarely, as physicalaquifer variations will control the dispersion of the effluent.

High nitrate concentrations are predicted in calculations 1 and 2 of the preliminary analysis and in run 1. However, the results reflect the likely **physical** conditions in a fine-grained aquifer (i.e. an aquifer composed of fine sands, with interbedded silt layers), which is typical of many settings within the Waikato region. Although the **physical** aquifer conditions are not conducive to nitrate dilution, it is likely that the **chemical** conditions in this setting are characterised by a reducing environment, and nitrate removal (denitrification) is likely to occur. Therefore, it is unlikely that nitrate contamination of ground water will be a significant problem in fine-grained aquifer systems.

The results from the other modelled situations (runs 2, 3, 4, and 5) show nitrate concentrations of 10 - 15 $g.m^{-3}$ at the boundaries of the effective disposal areas. A literature review of ground water quality beneath unsewered subdivisions show mean nitrate-N concentrations of about 4 $g\ m^{-3}$ which indicates that the modelling undertaken in this assessment is conservative, probably by about 50%.

3.3 Conclusions

The modelling presented in this report indicates that the concentration of nitrate-N in ground water at the boundaries of effective disposal areas of 2500 m^3 and 800 m^3 are likely to be about 10 $g\ m^3$ and 15 $g\ m^{-3}$ respectively. However, these estimates are likely to be conservative by about 50%.

The discharge of domestic sewage effluent is likely to be sustainable if the proposed effective disposal area of 2 500 m^2 is adopted.

There is less certainty regarding the sustainability of domestic sewage effluent disposal for an 800 m^2 disposal area, as the modelled nitrate concentrations are slightly higher. However, this effective disposal area is probably appropriate for existing areas where no adverse effects from ground water contamination have been identified.

It is likely that the cumulative impacts of sewage effluent disposal through new septic tank systems will be effectively managed through the proposed rules.

In some instances an existing or new system may not meet the requirements of the proposed rules due to variable site conditions or other reasons. In these circumstances, it is appropriate that the environmental impacts of the system are more thoroughly examined through a resource consent and consent monitoring procedure.

Table 1: Modelled concentration of nitrate in ground water.

Preliminary Analysis

Effective Disposal Area	2 500 m²			800 m²		
Calculation	1	3	5	2	4	6
Nitrate-N Concentration (g.m⁻³)	18	10	9	25	15	13

Plume -2D Computer Model

Effective Disposal Area	2 500 m²			800 m²	
Run	1	2	3	4	5
Maximum Nitrate-N Concentration (g.m⁻³)	105	31	43	53	54
Maximum Boundary Nitrate-N Concentration (g.m⁻³)	22	10	10	13	14

Maximum Nitrate Concentration refers to the concentration of nitrate at the septic tank outfall.
Maximum Boundary Nitrate Concentration refers to the maximum concentration of nitrate at the edge of the modelled disposal area.

4 SUMMARY

The environmental effects of the disposal of domestic sewage effluent from on-site septic tank disposal systems have been evaluated. This evaluation has been undertaken to support the proposed changes to regional rules for the on-site disposal of domestic sewage effluent.

Nitrogen, phosphorus and microbes are the main contaminants that are likely to be released to the environment through this disposal method.

Phosphorus is unlikely to be a contaminant of concern because it is readily bound onto soil particles.

Microbes have the potential to be contaminants of concern. However, filtration, adsorption and die-off in soil and ground water limits the migration of microbes in the ground. The proposed rules, in conjunction with existing regulations are sufficient to avoid the microbiological contamination of ground water supplies.

The contamination of ground water by nitrate leaching in well drained areas is the most significant issue relating to ground water quality in the proposed rules. The primary source of nitrate is from the conversion of urea-N in urine, with a small contribution from organic matter (e.g. faeces). A maximum of 60 g d^{-1} of nitrate-nitrogen is likely to be discharged into the environment from a septic tank disposal area.

Dilution of nitrate in ground water is the main means by which the concentration of nitrate contaminated ground water can be reduced to manageable levels (< 10 g m^{-3}).

The dilution of nitrate in ground water was modelled using hydrogeological information obtained from within the Waikato region.

Nitrate concentrations in ground water of about 10 g.m^{-3} to 15 g.m^{-3} were modelled for effective disposal areas of 2500 m^2 and 800 m^2 respectively. However, these are considered to be conservative estimates and it is likely that the concentration of nitrate will not exceed 10 g m^{-3} in most situations.

The information obtained from the ground water modelling indicates that the discharge of sewage effluent into the ground from a septic tank system through an effective disposal area of 2500 m^2 is unlikely to adversely affect ground water quality and is also unlikely to produce cumulative adverse effects.

The discharge of sewage effluent into the ground from a septic tank system through an effective disposal area of 800 m^2 is probably appropriate for existing systems where no adverse effects from ground water contamination are identified. However, it would be inappropriate to conclude that an 800 m^2 effective disposal area would be adequate for all situations throughout the Waikato region.

REFERENCES

Burden, R.J., (1982). Nitrate contamination of New Zealand aquifers: a review. New Zealand Journal of Science. 25: 205-220.

Fenner, F. No Date. Microbiological Pollution of Groundwater. Unpublished Technical Report, Centre for Resource and Environmental Studies, Australian National University.

Gibbs, M.M. Report on the Groundwater at the Acacia Bay Sewage Treatment Plant Site. 6pp.

Gibbs, M.M., (1977). Study of a septic tank system on a lake shore: Temperature and effluent flow patterns. New Zealand Journal of Science. 20: 55-61.

Gibbs, M.M., (1978). Report on the Groundwater Quality Along the Waitahanui Foreshore.

Ecology Division Report. Ecology Division. DSIR, Taupo. 7pp.

Gibbs, M.M., (1979). Groundwater input to Lake Taupo, New Zealand: Nitrogen and phosphorus inputs from Taupo township. New Zealand Journal of Science. 22: 235-243.

Hadfield, J.C., (1990). A Preliminary Evaluation of Piako Catchment Hydrology. Waikato Regional Council Technical Report 1990/24. 41pp.

New Zealand Department of Health, (1989). Drinking Water Standards for New Zealand.

Marshall, T.W.; Petch, R.A., (1985). A Study of Ground Water and Surface Water Resources in the Hamilton Basin. Waikato Valley Authority Technical Publication No. 30. 190pp.

Petch, R.A.; Marshall, T.W., (1988). Ground Water Resources of the Tauranga Group Sediments in the Hamilton Basin, North Island, New Zealand. Journal of Hydrology (N.Z.), 27: 81-98.

Robertson, W.D.; Cherry, J.A.; Sudicky, E.A., (1991). Ground-Water Contamination from two Small Septic Systems on Sand Aquifers. Ground Water. 29: 82-92.

Romero, J. C., (1970). The Movement of Bacteria and Viruses Through Porous Media. Ground Water. 8: 37-48.

Spalding, R. F.; Exner, M. E.; Lindau, C. W.; Eaton, D. W., (1982). Investigation of Sources of Groundwater Nitrate Contamination in the Burbank-Wallula Area of Washington, U.S.A. Journal of Hydrology. 58: 307-324.

Tinker, J. R., (1991). An Analysis of Nitrate-Nitrogen in Ground Water Beneath Unsewered Subdivisions. Ground Water Monitoring Review. 141-150.

Yates, M. V., (1985). Septic Tank Density and Ground-Water Contamination. Ground Water. 23: 586-591.

APPENDIX I: ENVIRONMENTAL CHEMISTRY OF NITROGEN AND PHOSPHORUS

A1 Chemistry of Nitrogen

An adult human who has normal protein intake will excrete about 35 g of organic nitrogen (N) per day in urine of which up to 90% is urea (15 g urea-N). Assuming that there are 4 adults living in a household, the total urea-N generated per day will be 60 g. Since the septic tank is saturated with solid and liquid waste at any given time, any liquid waste that reaches the septic tank will overflow into the soakage area.

A1.1 Reactions in the septic tank

Nitrogen in the faeces is in organic form. The amount of nitrogen in faeces varies with protein intake, but is generally small (about 1.5 g per adult per day).

During anaerobic breakdown of the faeces, organic-N can be broken down to ammoniacal form (Reaction 1).

$$\text{Organic-N (Protein)} \rightarrow \text{ammoniacal-N (NH}_3 + \text{NH}_4) \qquad (1)$$

Ammoniacal-N released from faeces will either diffuse to the surface of the septic tank or will be transported upwards during methane gas generation. A proportion of ammonium produced in the septic tank will be oxidised to nitrate (Reaction 2), subsequently denitrified and lost to the atmosphere. The balance of ammonium and nitrate produced from faeces will flow out of the septic tank.

$$\text{Ammoniacal-N + oxygen} \rightarrow \text{Nitrate (NO}_3) \qquad (2)$$

$$\text{Nitrate -organic-C} \rightarrow \text{N}_2 + \text{N}_2\text{O} \qquad (3)$$

Nitrification of ammoniacal-N (i.e. ammonium oxidised to nitrate form) occurs only at the surface of the liquid waste held in the septic tank, because of readily available dissolved oxygen at the interphase of the liquid and the septic tank head (i.e. dissolved oxygen is a prerequisite for nitrification).

Other main reactions that occur in the septic tank are organic carbon breaking down to methane and carbon dioxide, and sulphur compounds breaking down to hydrogen sulphide and mercaptans. These reactions will reduce the potential biochemical oxygen demand (BOD) in the septic tank.

A1.2 Reactions in the soakage area

When urea-N is released it reacts with urease (microbial enzyme) to produce ammoniacal-N (Reaction 4).

$$\text{Urea -urease} \rightarrow \text{ammoniacal-N (NH}_3 + \text{NH}_4) + \text{CO}_2 \qquad (4)$$
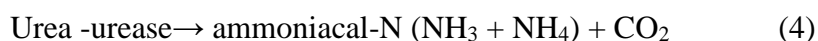
In sandy soils ammoniacal-N will be oxidised to form nitrate (Reaction 2), whilst in poorly drained soils the ammoniacal-N is held at the soil surface (exchange site). In poorly drained

soils, oxidation of ammoniacal-N occurs slowly and soon after the oxidation nitrate will be denitrified to produce gases such as dinitrogen (N_2) or/and nitrous oxide (N_2O) (Reaction 3). In well drained soils (e.g. sandy soils) the extent of denitrification is relatively low. Consequently, nitrate is more persistent in sandy soils.

A2 Phosphorus

About 2.5 g of inorganic phosphorus is excreted per day in human urine. A small (about 0.5 to 0.7 g per adult per day) quantity of phosphorus is also present in human faeces in an organic form. The rate of organophosphorus mineralisation is very slow (Reaction 5).

$$\text{Organic-P} \rightarrow \text{Mineral (inorganic)-P} \qquad (5)$$
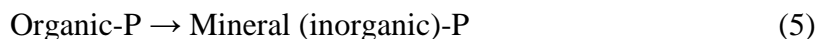
When mineralised, phosphorus reacts with aluminoferrous oxides and calcium present in soil and forms chemical complex. Inorganic phosphorus from urine also reacts in the same way. Since phosphorus has a high potential to react with soil components, it is generally not considered as a threat to ground water supplies.

Most detergents used in New Zealand household contain inorganic phosphorus in the form of polyphosphates. However, phosphorus present in detergents is unlikely to cause ground water pollution because very small quantities of detergents are used in households and because phosphorus derived from detergents is strongly bonded to soil particles (e.g. calcium and aluminoferrous minerals).

APPENDIX II: MODELLING OF DOMESTIC SEWAGE EFFLUENT IN GROUND WATER.

AII.1 Preliminary Analysis

Calculation	1	2	3	4	Hamilton Basin
Transmissivity ($m^2.d^{-1}$)	25	25	50	50	From Marshall and Petch, 1985
Aquifer thickness (m)	6	6	6	6	Assumed
K ($m^3.d^{-1}$)	4	4	8	8	Calculated
i	0.002	0.002	0.002	0.002	From Marshall and Petch, 1985; Hadfield, 1990
n	0.1	0.1	0.1	0.1	Assumed
Ground water velocity ($m.d^{-1}$)	0.08	0.08	0.16	0.16	Calculated
Aquifer cross section (m^2)	300	180	300	180	Estimated at 50 m x 6 m = 300 m^2 and 30 m x 6 m = 180 m^2 for 2 500 m^2 and 800 m^2 disposal areas respectively (Figure 2).
Q ($m^3.d^{-1}$)	2.4	1.44	4.8	2.88	Calculated
[NO_3] ($g.m^{-3}$)	18	25	10	15	Calculated

2 Wairakei			
Calculation	5	6	
Transmissivity (m^2 d^{-1})	50	50	Field information
Aquifer thickness (m)	60	60	Field information
K (m^3 d^{-1})	1	1	Approximately calculated
i	0.02	0.02	From Field information
n	0.05	0.05	Assumed
Ground water velocity (m d^{-1})	0.4	0.4	Calculated
Aquifer cross section (m^2)	300	180	Estimated at 50 m x 6 m and 30 m x 6 m for 2500 m^2 and 800 m^2 disposal areas respectively.
Q (m^3 d^{-1})	6	3.6	Calculated
[NO_3] (g m^{-3})	**9**	**13**	**Calculated**

AII.2 Plume 2D Model

Hydrogeology	Run 1	Run 2	Run 3	Run 4	Run 5
Velocity (m d^{-1})	0.08	0.2	0.4	0.2	0.4
Porosity	6	6	6	6	6
Aquifer Thickness (m)	0.1	0.1	0.05	0.1	0.05
Longitudinal Dispersivity (m)	10	10	10	10	10
Lateral Dispersivity (m)	3	3	3	3	3
Retardation	1	1	1	1	1
Half life (d)	0	0	0	0	0
No of discharge points	1	1	1	1	1
Area (m^2)	2500	2500	2500	800	800
Grid system					
x distance (m)	10	10	10	5	5
y distance (m)	5	5	5	5	5
No x nodes	11	11	11	9	9
No y nodes	6	6	6	5	5
Maximum nitrate concentration (g m^{-3})	**105**	**31**	**43**	**53**	**54**
Maximum boundary concentration (g m^{-3})	**22**	**10**	**10**	**13**	**14**

Figure A1: Nitrate Concentrations in Ground Water. Run 1: 2,500 m2.

☐	100-120
▦	80-100
☐	60-80
■	40-60
▦	20-40
☐	0-20
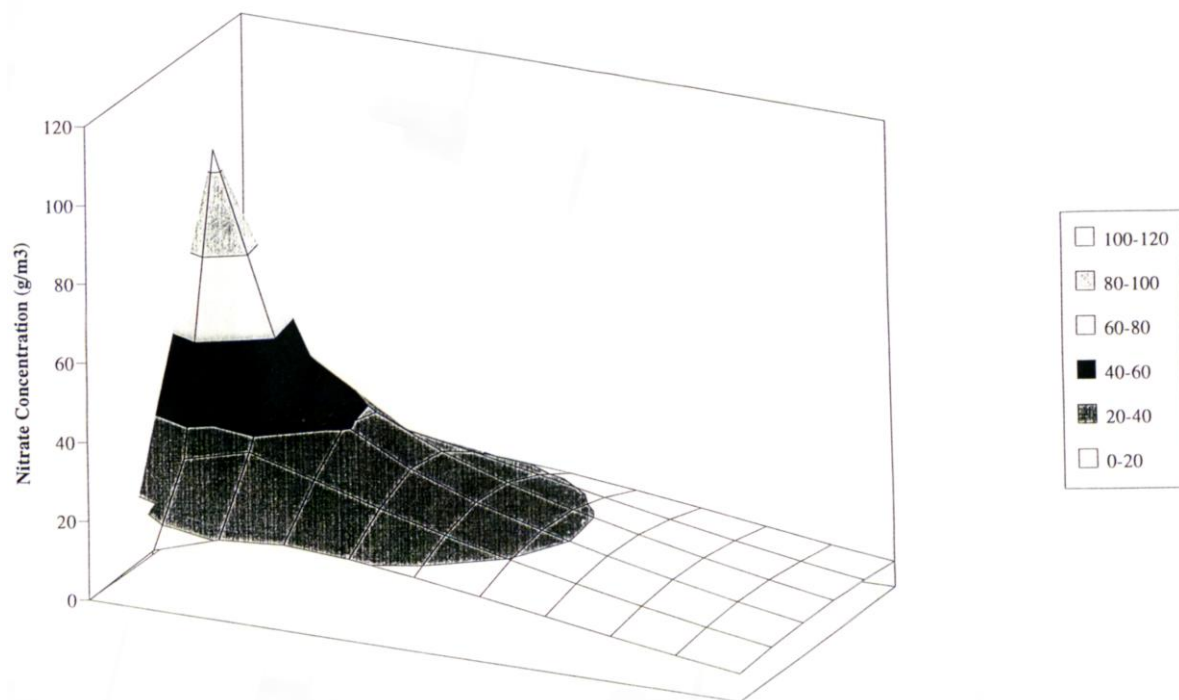
Figure A2:Nitrate Concentrations in Ground Water. Run 2: 2,500 m2.

■	30-35
☐	25-30
▦	20-25
☐	15-20
■	10-15
▦	5-10
☐	0-5
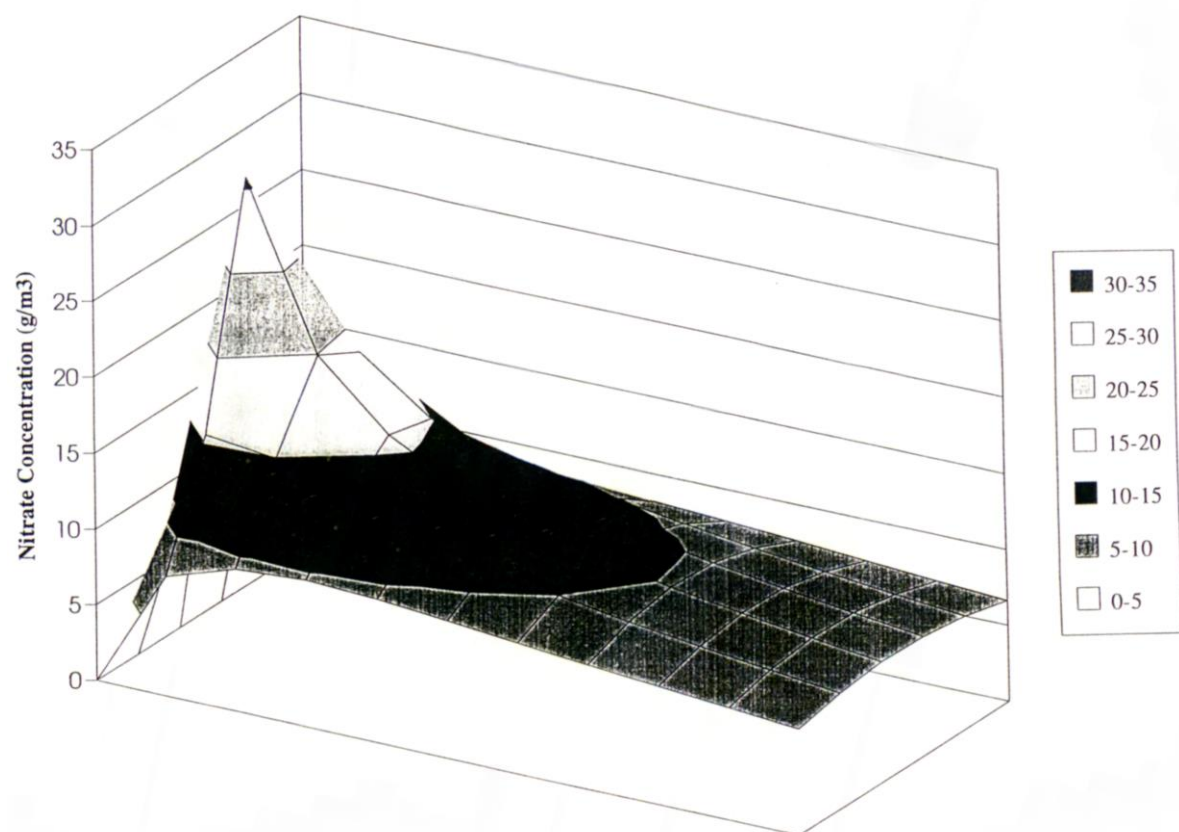
Figure A3: Nitrate Concentrations in Ground Water. Run 3: 2,500 m2.
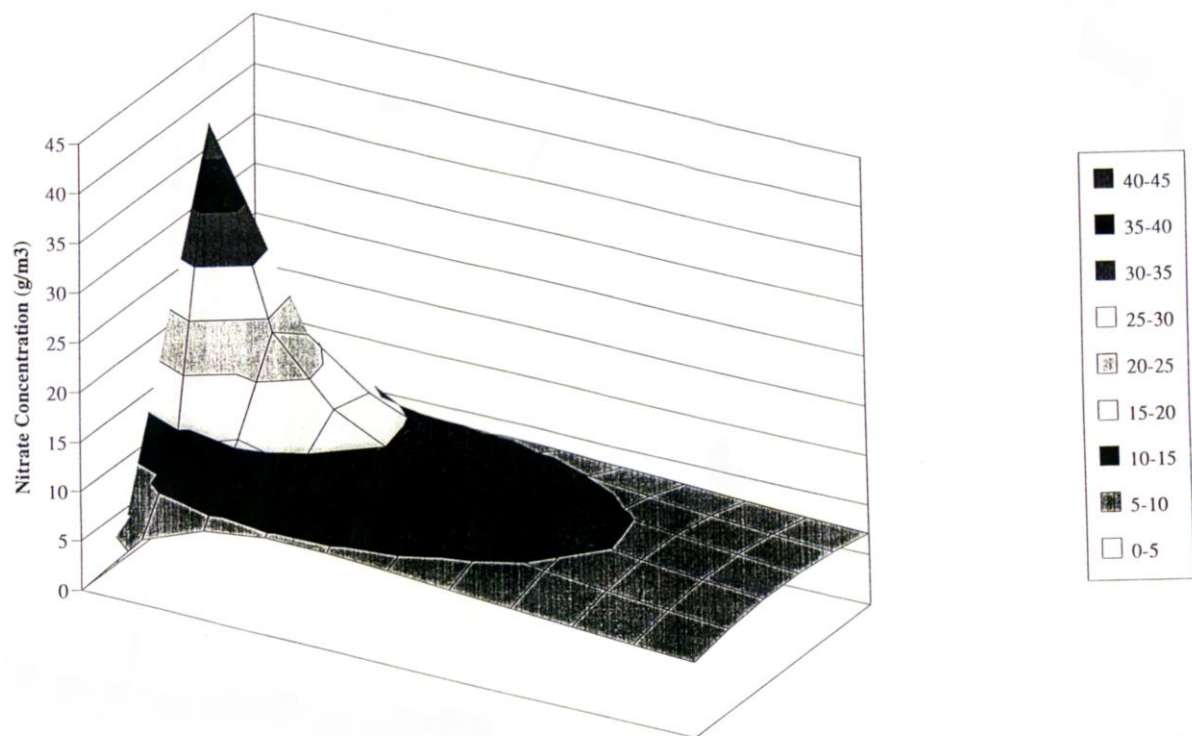

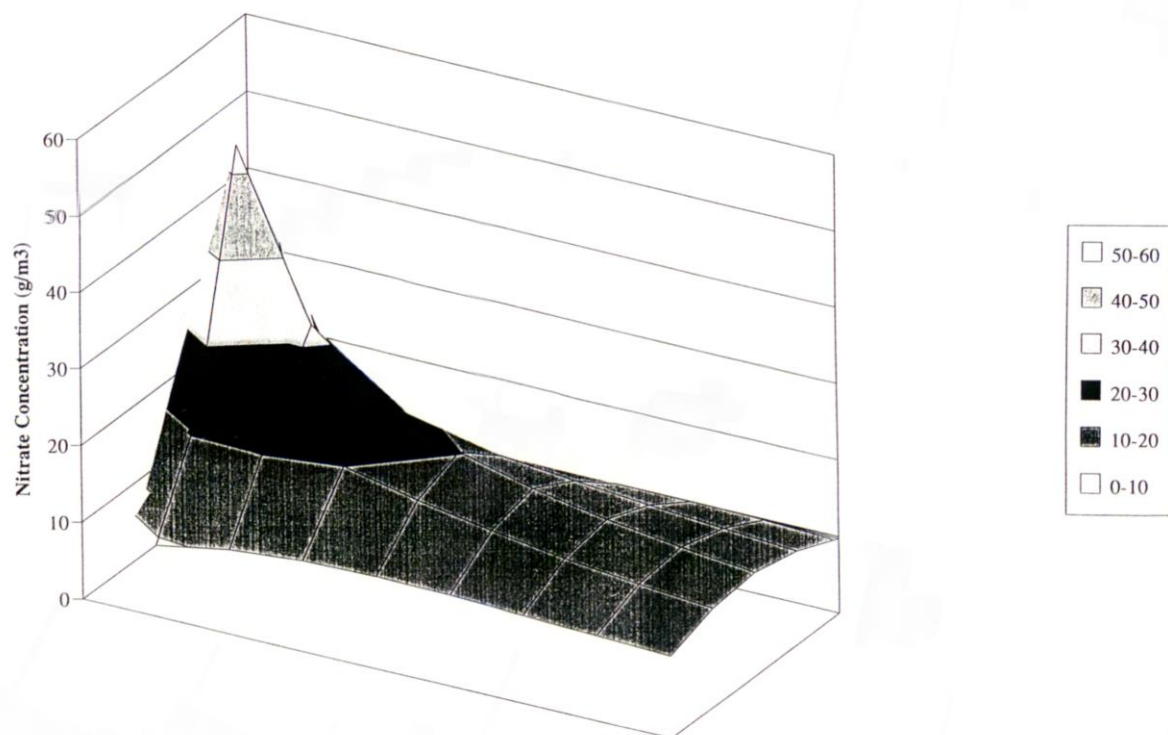**Figure A4: Nitrate Concentrations in Ground Water. Run 4: 800 m2.**

Figure A5: Nitrate Concentrations in Ground Water. Run 5: 800 m2.