BEFORE THE HEARINGS PANEL

IN THE MATTER of hearings on submissions concerning the Proposed One Plan notified by the Manawatu-Wanganui Regional Council

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SECTION 42A REPORT OF MR HAROLD IVAN BARNETT

ON BEHALF OF HORIZONS REGIONAL COUNCIL

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1. INTRODUCTION

My qualifications/experience

1. My name is Harold Ivan Barnett, and I am employed as an Environmental Scientist with the Regional Regulatory and Planning Group of Horizons Regional Council. I have held this position since January 1997. I have previously held the positions of Hydrologist, Planning Officer and Senior Environmental Officer with the Rangitikei-Wanganui Catchment Board and then the Manawatu-Wanganui Regional Council.

2. I have a Bachelor of Science Degree and a New Zealand Certificate of Science in Water Technology. I have worked in the hydrology, water and resource management fields with the former Ministry of Works, Catchment Boards and the Regional Council since 1966.

3. In my current position I report on resource consent applications for wastewater disposal to land. These include municipal, industrial, agricultural and domestic wastewater treatment systems. Over the last 10 years I have been involved with staff from the Territorial Authorities (TAs) in the promotion and installation of sustainable on-site wastewater systems in the Region. In particular I have worked closely with the Horowhenua District Council to develop a protocol to ensure that potential adverse effects from on-site wastewater systems are minimised.

4. I have read and agree to comply with the Code of Conduct for Expert Witnesses as contained in the Environment Court's Practice Note on Alternative Dispute Resolution, Expert Witnesses and Amendment to Practice Note on Case Management. In the case of this Proposed One Plan (POP) hearing, my duties under the Code to the Environment Court are replaced with duty to the Hearing Panel.

My role in the Proposed One Plan

5. I have been actively involved with the development of rules associated with the design and management of domestic on-site wastewater systems. I project managed/oversaw the preparation of the Manual for On-site Wastewater Systems Design and Management, with Mr Sandy Ormiston of Ormiston Associates, Auckland. The manual supports the POP rules. Following the release of the manual I facilitated consultation and attended meetings with TAs in the Region, wastewater system design consultants and suppliers of on-site systems.

Scope of evidence

6. My evidence covers the following topics to assist the Hearing Panel:

   i. Controlling discharges of contaminants to land. I introduce the concept of land treatment and beneficial use of nutrients rather than land disposal.

   ii. Comment on the scale of the discharges of contaminants from piggery operations to land and the appropriateness of POP Rules 13-7 and 13-8.

   iii. Comment on the scale of existing on-site wastewater systems in the Region and issues with their performance. I present steps taken to improve the management of on-site wastewater systems in the Region prior to the POP notification;

   iv. I introduce the Manual for On-site Wastewater Systems – Management and Design (together with Mr Sandy Ormiston, who is co-author). The Manual is designed to address the design and maintenance criteria set in the Proposed Rules for on-site wastewater – POP Rules 13-9, 13-10, 13-11, 13-12 and 13-13; and

   v. Finally, I will also make brief comment on the Ministry for the Environment's (MfE) Proposed National Environmental Standard (NES) for On-site Wastewater Systems (2008).

7. My evidence needs to be read in conjunction with evidence from:

   i. Dr Jon Roygard (Horizons' Science Manager), who provides the background for the discharge of contaminants to land and water;

   ii. Mr Barry Gilliland (Horizons' Policy Monitoring Officer) and Ms Clare Barton (Consultant Planner), who provide policy background and management options for land based wastewater application activities;

   iii. Ms Alison Russell (Horizons' Manager of Environmental Compliance) who provides details of land disposal activities associated with dairying and poultry rearing in the Region;

   iv. Mr Sandy Ormiston (of Ormiston Associates) who provides technical evidence on wastewater system design and management;

   v. Dr Brent Clothier (HortResearch) who describes the Nitrogen cycle in detail and the fate of nitrogen as it relates to land treatment. His evidence also covers the Soil-Plant-Atmosphere System Model (SPASMO) that Horizons used to demonstrate the impacts, including cumulative impacts, of on-site wastewater systems in the Horowhenua.

   vi. Drs Stewart Ledgard and David Houlbrouke (AgResearch) provide expert evidence on land treatment technologies in relation to modelling of specific farming activities; and

vii. Dr Roger Parfitt (Landcare Research) provides expert evidence on scenarios of future Nitrogen (N) inputs and outputs in New Zealand. He will also present models for Phosphorus (P) loss in the Upper Manawatu Water Management Zone and possible actions and monitoring programmes that will reduce P contributions to our streams and rivers.

8. To assist the Panel, I will refer in various parts of my evidence to material that is to be provided by my colleagues, with appropriate links.

2. EXECUTIVE SUMMARY OF EVIDENCE

9. My evidence relates to the issues and management of discharges of contaminants to land, specifically discharges of wastewater from municipal and industrial treatment plants, piggeries and on-site wastewater treatment plants.

10. Since the gazetting of the Resource Management Act in 1991, Regional Rules and public perception of environmental issues has forced a more effects-based examination of the activities associated with the discharge of contaminants to land where the discharge may reach water. Science and technology have made huge strides during this time in the understanding and managing of land application systems, assisted by better monitoring methodology and equipment.

11. My experience in this field, working with the Region's Territorial Authorities, consultants and with pig farmers, is that there is a slow but growing acceptance of the need to embrace technology and science in order to avoid adverse environmental effects. Any reluctance to move in this direction is generally related to the costs of implementing new technology and then monitoring the outcomes. These costs come on top of other increased costs faced by producers for inputs such as power, grain and rates, and poor receipts for their produce.

12. Good wastewater plant/system design with adequate capacity for peak loads, an awareness of soil and weather conditions (wind, soil moisture and rain), and effective day to day management are the keys to minimising adverse environmental effects from land application systems.

3. DISCHARGE OF CONTAMINANTS TO LAND – MUNICIPAL, INDUSTRIAL AND PIGGERY WASTES

13. Horizons is moving away from a focus on a land 'disposal' activity to a land 'treatment' regime where the objective is the beneficial use of the liquid and nutrient content in the waste stream. In such a regime land application is carried out by an appropriate system, at a rate that the soil and plant environment can assimilate without leaching contaminants through the soil profile. Such a regime requires application of waste to occur only when there is a sufficient soil moisture deficit; a wastewater storage facility is needed to hold the waste when the soil is at field capacity. The land application regime should also take into account the fate and storage of nutrients (nitrogen, phosphorus and potassium) in the soil profile over time, and to ensure any build up is managed to avoid break through issues. In some cases, other contaminants such as heavy metals and micro-organisms (pathogens) may also need specific management strategies.

14. For sewage effluent and biosolids, two publications are particularly useful in providing guidance on the design of land application systems. They are the *New Zealand Guidelines for Utilisation of Sewage Effluent on Land* (NZ Land Treatment Collective, 2000) and the *Guidelines for the Safe Application of Biosolids to Land in New Zealand* (NZ Water and Wastes Association, 2003).

15. For piggeries, two documents compiled by the Pork Industry Board provide guidance for members on calculating, treating and managing wastewater and odour. They are *Land-based and Pond-based Environmental Systems* (NZ Pork Industry Board, 1998) and *EnviroPork™: Pork Industry Guide to Managing Environmental Effects* (NZ Pork Industry Board, 2005). The latter publication provides information, management practices and a checklist for these to assist pig farmers to develop and manage infrastructure and activities at the piggery to meet requirements of Regional Rules.

4. DESIGN AND OPERATION OF ON-SITE WASTEWATER SYSTEMS

16. Provisions in Horizons' current Regional Plans for on-site wastewater (in the Manawatu Catchment Water Quality Regional Plan and the Land and Water Regional Plan) are not prescriptive as to the types of systems conforming to Permitted Activity status. In November 2000 Horizons produced the *On-site Wastewater System Guidelines for the Manawatu- Wanganui Region* with Mr Ian Gunn, of Auckland UniServices Ltd, Auckland, as Technical Advisor. This represented an attempt to assist TAs to ensure there was some consistency with sustainable wastewater systems across the Region. The publication, while helpful, allowed for a range of system designs that could suit any site

and as a consequence, regulatory staff from the TAs were left to make decisions on the appropriateness of proposed systems. The feedback was that some of the TAs did not have sufficient in-house expertise to make these decisions.

17. This became evident some years later when increased subdivision activity for coastal and lifestyle blocks, and an accompanying building boom, was experienced along the Region's western coast, particularly in Kapiti and Horowhenua districts). As a result, there was potential for a proliferation of septic tank type systems on small lots (in the vicinity of 2,000m^2). The cumulative impact of such development would adversely impact on the quality of the shallow groundwater system and on Lake Horowhenua, which was already displaying high nitrate levels. Groundwater in certain areas already had nitrate concentrations that exceeded the recognised World Health Organisation (WHO) standard for drinking water, ie. maximum allowable value of 50 mg/L NO_3, (Daughney *et al*, 2009; p 35).

18. In 2004, Horowhenua District Council – working with staff from Horizons – adopted a guideline under the Council's Minimum Engineering Standards, entitled *Minimum Requirements for On-Site Wastewater Systems in the Horowhenua District*. This Memorandum of Understanding (MOU) was loosely based on Auckland Regional Council's (ARC) Technical Publication No 58 (TP58), *On-site Wastewater Systems Design and Management Manual*. It provided for the installation of secondary treatment plants, a dose pumped land application rate of 3 mm/m^2/day for lots under 4,999m^2 (5 mm for larger lots), professional design and installation of systems, and maintenance under a service contract.

19. The MOU with the Horowhenua District Council has worked well and provided certainty as to the requirements for new on-site wastewater systems, as a Permitted Activity. The Horowhenua model has been modified for the Proposed One Plan. Mr Sandy Ormiston of Ormiston Associates, co author of ARC's TP58, was engaged as Technical Advisor for Horizons' Manual for On-site Wastewater System Design and Management (Barnett *et al*, 2007). This was notified as part of the POP in May 2007. Version II of the manual has now been prepared, incorporating comments made by Mr Ian Gunn (peer review), submitters and TA staff (expanding the maintenance section).

20. When the 'new' POP rules for on-site wastewater become operative it will give certainty and provide for improved management of treatments systems across the Region. Horizons staff have been working with the TAs for some time now to make this happen.

5. NATIONAL ENVIRONMENTAL STANDARDS FOR ON-SITE WASTEWATER SYSTEMS

21. In July 2008, the Ministry for the Environment (MfE) notified that it is proposing to introduce a National Environmental Standard (NES) for on-site wastewater systems. The objective was to have better performing systems across New Zealand to safeguard public health and the environment (surface water and groundwater quality). The discussion document provided for regular maintenance of all existing on-site systems under a three-yearly warrant of fitness type regime. Several consultation meetings were held across New Zealand and a number of concerns were raised by submitters. These related to underestimating the size of the project and its cost, some practicalities associated with the inspection regimes, and whether Territorial Authorities or Regional Councils were to implement the NES. MfE staff have summarised the submissions and will make a recommendation on the proposal to Cabinet, aiming to have the NES finalised by the end of 2009.

6. DISCHARGES OF CONTAMINANTS TO LAND

Background

22. Horizons advocates a preference for a 'managed' application regime for farm, industrial and municipal waste streams to land rather than to water, in order to ensure that groundwater and surface water quality in the Region is not compromised. This practice goes back to the mid-1980s when Horizons' predecessors, the Manawatu and Rangitikei-Wanganui Catchment Boards, and then the Central Districts Catchment Board, promoted a land application strategy.

23. There have been policy 'incentives' for land application systems, such as longer resource consent terms and lower management charges (involving compliance inspection and stream monitoring), in place for some time to ensure that the nutrients in wastewater were being beneficially utilised and thus mitigating detrimental impacts on surface water and groundwater quality.

24. To my knowledge, the earliest large-scale municipal land-based system in the Region was Horowhenua District Council's development of the 'Pot' in late 1986. The Pot is located in the forested western coastal zone, where Levin's wastewater is stored in an unlined artificial lake and then pumped on to 60 ha of pine forest. Prior to the development of the Pot, Levin's treated wastewater was discharged directly into Lake Horowhenua. The initial proposal for the Pot comprised both rapid infiltration and land

application components. About the same time (ie. late 1980s) the now mothballed Richmond Meat Processors & Packers meatworks at Oringi, near Dannevirke, was constructed with a land-based wastewater disposal system that used flood irrigation. This technique caused some environmental issues for the meatworks' operators, who then constructed a large pond and experimented with various methods of irrigating coppicing woodlots, with mixed success.

25. Since late 2005), resource consents for large municipal and industrial plants have been issued for land treatment regimes involving nutrient budgets and deficit irrigation. Examples are the processing wastes from the proposed plant for Effem Foods Ltd, trading as Masterfoods NZ, at Marangai, Wanganui, and a proposed upgrade for Feltex Wools' wool scour at Kakariki. For the record, Feltex Kakariki went into receivership in 2007 and the plant is no longer operational as a wool scour.

26. The Resource Management Act (RMA) was gazetted 1991 followed by the Regional Policy Statement (August 1998) and the Manawatu Catchment Water Quality Plan and Land and Water Regional Plan became operative in 1995 and 2003 respectively. Under these plans there is an emphasis on a sustainable discharge regime, with nutrient loading criteria, for the discharge of contaminants to land.

27. In the last 20 years more definitive science, increased public awareness and interest in the environment and advanced technologies in wastewater treatment and land application have lead to Horizons more actively promoting beneficial use regimes for wastewater at rates suited to the physio-chemical constraints of soils and crops, rather than just disposal to land.

28. The POP takes this objective a step further, phasing in the requirement for nutrient budgeting (inputs and outputs) for farming discharges to land in the various water management zones, from 2011 through to 2020. The concept of land treatment is more fully explained in the sub-section below.

KEY MESSAGES

1. Land treatment and beneficial use of water and nutrients is considered preferable to either discharge to water or a land 'disposal' regime.
2. Horizons' Regional Plans provide incentives for discharges to land rather than water.
3. Land-based disposal of municipal and industrial wastewater had occurred in some places in the Region since the late 1980s.
4. The science associated with wastewater treatment and land application techniques has improved to enable policy in this area to be refined.

Assessing the discharge of contaminants to land

29. Current Regional Rules (in the Manawatu Catchment Water Quality Regional Plan and the Land and Water Regional Plan) provide criteria for sustainable wastewater disposal regimes from agricultural and municipal sources as Discretionary Activities. In general terms, good environmental outcomes can be 'engineered' by having appropriately treated wastewater applied to good soils at conservative application rates, using best practical management practices with contingency plans for wet weather or treatment plant or equipment malfunction. Conservative application rates and good management are vital to ensure such regimes are sustainable. As always, there are costs associated with the treatment, land acquisition, irrigation infrastructure and storage facilities for the waste stream. Moral stewardship rarely pays the bills and often the decision about the degree and method of treatment hinges on what is affordable to meet environmental standards.

30. The following information is required to assess the actual and potential environmental impact of any wastewater application to land:

    i. The origin, volume and chemical nature (strength) of the wastewater stream.
    ii. The receiving environment – location and area of the activity, physio-chemical attributes of the soil (Land Use Capability[1], texture/structure, profile, permeability and water holding capacity), the constraints on the property such as proximity to rivers, lakes, wetlands or other sensitive sites, and the potential to contaminate groundwater.
    iii. Climate – monthly and seasonal rainfall patterns, and seasonal temperature variations.
    iv. Application rate (hydraulic load) – this is based on the daily volume, area to which it is applied and whether the waste is applied to pasture or a crop.

v. Nutrient concentrations, in particular Nitrogen, Phosphorus and Potassium associated with the application.

vi. Pathogens (E-coli).

vii. Metals – cadmium, copper, zinc, mercury, arsenic or persistent chemicals and pharmaceuticals.

viii. The method of applying waste onto land is also an important factor (ie. high rate application via travelling irrigators or lower rate via a K-line system, and ability to control application) to assess potential for creating odour or ponding and run-off issues.

31. Soil type and vegetation (pasture, crop or trees) at the land application area have an inherent capacity to renovate the contaminants in wastewater, provided the application regime is designed appropriately. By this I mean that the hydraulic and nutrient application rates, and any other contaminant of interest (eg. heavy metals), are suited to the soil type, soil moisture content and plant uptake so that beneficial use of the water and nutrients is maximised while leaching through the soil profile and potential for over application causing ponding and run-off are minimised.

32. To ensure a sustainable wastewater application regime, a robust evaluation of the physio-chemical characteristics of the soil at the proposed land application area is essential. This includes field measurements of the soil profile, texture, soil description (LUC category), drainage characteristics, depth to the high water table, and recognition of constraints in topography, aspect, vegetation and proximity to sensitive environments (rivers, lakes or wetlands) and other land application sites.

33. I have attached some notes on the soils' physical characteristics and how water and nutrients are transported in the soil profile via the hydrological (water), nitrogen and phosphorus cycles in Appendices 1 and 2. Agronomy fact sheets on the nitrogen and phosphorus cycles from Cornell University are provided. This is background reading material for the Hearing Panel.

34. The Panel will hear from Dr Jon Roygard, Horizons Regional Council's Science Manager; Dr Brent Clothier (Plant and Food Research); Drs Dave Houlbrouke and Stewart Ledgard (AgResearch); and Dr Roger Parfitt (Landcare Research) who will be presenting expert information on the various environmental cycles and the role of water and nutrients in the soil profile in relation to specific farming activities in the Region. My colleagues, Mrs Kate McArthur (Senior Water Quality Scientist) and Mr Hisham Zarour

(Senior Groundwater Scientist) will present expert evidence on the impacts of non-point source discharges of contaminants to land on surface water and groundwater quality.

35. Dr Clothier, in Sections 3 and 4 of his evidence, sets out and discusses the Soil Plant Atmosphere System Model (SPASMO) and its use to predict the need for irrigation for production and the hydrological impacts. In Sections 5, 6 and 7 he discusses the nitrogen cycle and uptake of nitrogen by plants and the fate of nitrogen compounds in the soil resulting from non-point source pollution by nutrients from farming activities. Dr Clothier and his colleagues has been have been the lead advisers to Horizons on these matters.

36. Soils that have higher iron and/or aluminium contents have the potential to absorb more phosphorus than other soils, and most faecal micro-organisms are retained within the top 5 cm of the soil profile.

37. Dr Parfitt, in his evidence, presents work he has done with phosphorus (P) losses in the upper Manawatu Water Management Zone and Horizons' implementation of its Sustainable Land Use Initiative (SLUI). In his paragraphs 59-65 Dr Parfitt discusses strategies to minimise P losses to water bodies. These include better managing dissolved P in point sources, planting trees on steeper slopes, keeping animals (cattle) from water bodies, using deferred irrigation methods for Farm Dairy Effluent (FDE) (NB this topic is further discussed by Dr David Houlbroke in his evidence), limiting P fertilisers, and using reactive phosphate rock (RPR) fertilisers where P fertilisers are used rather than more soluble P fertilisers. Dr Parfitt sets out his recommendations for further attention in paragraph 67 of his report.

KEY MESSAGES

1. The soil and plant system has the ability to assimilate and renovate agricultural and industrial wastewater via natural processes.
2. Land treatment is the beneficial use of the water and nutrients in wastewater by the soil and plant system to minimise leaching of these components.
3. Accuracy with the timing and application volume (hydraulic and nutrient loading) of wastewater is key to avoid exceeding the assimilation capacity of the crop and soil.
4. A well managed land treatment system limits wastewater application to rates that do not exceed the treatment capacity of the crop or soil, and minimises adverse effects on groundwater quality by all contaminants.
5. Storage capacity is a critical component of an efficient land treatment system.

Designing a land treatment system for municipal wastewater

38. In March 2000, the New Zealand Land Treatment Collective and Forest Research (now Scion) combined to release New Zealand Guidelines (in two parts) for the utilisation of sewage effluent on land. The publication was produced with financial assistance from the Ministry for the Environment under its Sustainable Management Fund. The preface notes that the guidelines are prepared to assist persons who design, consent, manage or monitor land treatment systems for municipal or domestic wastewater in New Zealand. Part 1, The Design Process, is intended to provide general guidance on methods and concepts involved in the process of designing land treatment systems. Part 2, Issues for Design and Management, provides supporting information, serving as a technical reference on key issues related to designing, operating and monitoring land treatment systems.

39. The guidelines are specific to design of systems where the final treatment of effluent occurs, or will occur, by irrigating onto a standing crop that is intended for harvest and economic return. Wetland systems and rapid infiltration basins and trenches are not addressed.

40. The guidelines were written by some of New Zealand's leading scientists working in the land treatment arena; they advocate the beneficial use of nutrients without compromising quality of soils or of surface water or groundwater. Although specific to the design and management of land treatment systems for sewage, the guidelines are based on soil, plant and atmosphere assimilation principles and I believe that they can be adapted for other waste streams. The guidelines build on the Department of Health's publication *Public Health Guidelines for the Safe Use of Sewage and Sewage Sludge on Land;* Public Health Services (1992).

41. Once the characteristics of the sewage stream in terms of volume, nutrient content, organic matter, toxic constituents and pathogens are identified, and field investigations have verified the site and soil constraints, a sustainable land application regime involving the beneficial use of the water and nutrient components can be designed. Such a regime would also require a robust monitoring programme to ensure environmental bottom lines are maintained.

42. I also bring to attention of the Panel to the existence of the publication entitled *Guidelines for the Safe Application of Biosolids to Land in New Zealand* (August 2003). This publication was produced by the New Zealand Water and Wastes Association (NZWWA) jointly with the Ministry for the Environment. The Guidelines were developed by a multi organisational project management steering group.

43. The two guideline documents are complementary. Together they demonstrate that land treatment systems for municipal wastewater specifically, and other wastes generally, can be designed in this Region using the principles advocated in the two documents

Discharges to land from piggeries

44. Intensive farming operations such as piggeries, poultry sheds and feedlots require shed capacity and necessary infrastructure to raise the animals, and best practice management strategies to deal with animal welfare, odour and the waste streams. The operations need to comply with the environmental constraints provided by Regional Rules. The scale of such operations dictates its environmental footprint and its proximity to developed housing (settlements or towns) or public facilities such as churches, marae and schools. The sometimes negative public perception of these operations can create opposition and consequently, more effort and cost may be required to secure the necessary resource consents.

Regional situation

45. Currently there are 23 piggeries in the Region with resource consents to discharge piggery wastewater to land (as recorded in Horizons' database). In comparison, there are approximately 920 dairy sheds and some 30 poultry farming operations listed in the Region.

46. Wang *et al* (2004) report that there has been a decline in the number of specialist pig farms (ie. a 50% decline) nationally between 1990 and 2002. The small New Zealand pig industry produces 700,000 pigs for domestic consumption. There is a trend towards intensified pig farms with farms housing more than 1,000 animals (ie. typically 100 sows) producing 56% of the pig population (MAF 2003).

47. Resource consents authorise the discharge of up to 624 cubic metres of piggery wastewater to land each day in the Region. Five of these consents also authorise the discharge, from time to time, of either piggery solids or composted bedding material to

land associated with cropping regimes. It is not possible to accurately define the nutrient loads applied to land as the degree of treatment afforded to piggery wash water can be quite variable.

48. I have not included in the piggery count the consent (No 103569), that was granted to Coastal Lakes Station (CLS), located between Himatangi and Foxton beaches on the west coast. This consent, granted in September 2008 for a 15-year term, was for the establishment of a 4,800 sow piggery in two stages with state-of-art housing and wastewater treatment technology as practised overseas. To meet the nutrient loading requirements, most of the increased waste under Stage II of the development was to be applied to properties off-site. CSL was advised that the activity would require further consents from Horizons and that the necessary consents were to be in place prior to pig numbers being increased as part of the Stage II development. This consent is currently under appeal.

Effluent

49. I attach a table below that shows calculation of the nutrients (nitrogen (N), phosphorus (P) and potassium (K)) produced from a 250-sow intensive piggery. It is taken from the NZ Pork Industry Board publication *EnviroPork^{TM}: Pork Industry Guide to Managing Environmental Effects* (2005).

Table 1. Nutrient values of fresh, untreated effluent from a 250-sow intensive piggery

Type of pig	Total number of pigs for a 250 sow piggery	Total solids output per pig kg/yr	Nutrient output of one pig kg/year			Total Nutrient output kg/year		
			N	P	K	N	P	K
Boars	8	186	15	5.3	3.8	120	42	30.4
Dry sows/ mated gilts	204	186	13.9	5.2	3.7	2835.6	1060.8	754.8
Gilts	14	197	12	4.6	4	168	64.4	56
Lactating sows plus litters	46	422	50	13	11	2300	598	506
Weaners	670	54	3.9	1.1	1.1	2613	737	737
Porkers	777	108	9.2	3	2.4	7148.4	2331	1864.8
Baconers	444	181	15.8	5.1	4.1	7015.2	2264.4	1820.4
Total	**2,163**					**22,200**	**7,098**	**5,769**

Source: EnviroPork™ (2005): Pork Industry Guide to Managing Environmental Effects.

Reference: Australian Pork Limited - National Environmental Guidelines for Piggeries.

50. The 250-sow unit as above produces approximately 22,200 kg of nitrogen in its fresh, untreated waste in a year. If this untreated waste was to be applied to land at the rates prescribed by Horizons' two operative Regional Plans (200 kg-N/ha/yr in the Manawatu Catchment Water Quality Plan and 150 kg-N/ha/yr in the Land and Water Plan) a land application area of 111-148 ha would be required. Note that if the wastewater was to be treated in an efficient pond system, the nitrogen concentrations would be considerably reduced, thus requiring a much smaller land application area to meet the operative regional rule requirements.

51. The 250-sow piggery described above would generate 21,600-43,300 litres (21.6 to 43.4 m^3) of wastewater each day, based on an allowance of 10-20 litres per pig, that would need to be treated and applied to land or water an environmentally sustainable manner. If the wastewater is applied to between 111-148 ha (to meet the nutrient loadings above), the depth of application would be:

Table 2. Annual application depth of wastewater from a 250-sow piggery to land

Daily volume (m^3)	Annual volume (m^3)	Applied to 111 ha	Applied to 148 ha
21.6	7,884	7.1 mm	5.3 mm
43.4	15,841	14.3 mm	10.7 mm

52. Piggery waste is generally high in pH and nutrients – nitrogen (high ammonium–N content), phosphorus, potassium and sodium, and could contain amounts of heavy metals associated with the pigs' diet. Waste is highly variable depending on animal age and species, type of diet, production practice and the immediate environment in which the pigs are raised (ie. type of housing and cleaning practices). Traditionally, piggery wastewater is treated using waste stabilisation ponds and sometimes the waste stream is pre-screened. While ponds can effectively reduce carbon and Biochemical Oxygen Demand (BOD) loading, they are ineffective in reducing nutrient concentration. Piggery effluent is therefore a rich source of nutrients in a beneficial use land application regime.

Table 3. Piggery effluent. Average values of nutrients and micro-nutrients (Laurenson *et al.*, 2006)

Average Values	N kg/m^3	P kg/m^3	K kg/m^3	Ca kg/m^3	Mg kg/m^3	Na kg/m^3	S kg/m^3
Slurry	2.1						
Screened slurry	1.5	0.2	0.5	0.4	<0.1	0.2	<0.1
Screen plus pond	0.5	0.1	0.4	0.1	<0.1	0.1	<0.1

Ponds	0.2	0.1	0.2	0.1	<0.1	0.1	<0.1

53. The table above provides average concentrations in kilograms/cubic metre (kg/m^3) for piggery effluent following processing by various treatment systems. The nutrients include total nitrogen (N), phosphorus (P) and potassium (K) while the micro-nutrient suite includes calcium (C), magnesium (Mg), sodium (Na) and sulphur (S).

54. Laurenson *et al.* (2006) state that piggery waste is characterised by high pH and high ammonium-N content, which influences the transformation of N in soils differently compared to various other sources of organic N. Piggery waste also contains sloughed stomach lining and has higher numbers of micro-organisms than farm dairy effluent (FDE).

Table 4. Comparison of the nutrients and micro-nutrients associated with piggery and dairy effluents (sourced from Laurenson *et al.*, 2006 - Tables 1 and 2)

Effluent source		Total solids	Total C	Total N	$NH4^+$	$NO3^-$	pH	Reference
Piggery	Untreated		820	1420	1200	0	7.5	Cameron *et al*., 1995
			1,987	1628	1026	0		Carey *et al*., 1997
	2-pond	154		85	72	13		Bolan *et al*., 2004a
		358		230	170	17	7.8	Lowe, 1993
Dairyshed	Untreated	7,400	2,247	246	58	0.5	7.6	Di *et al*., 2002
		13,400	3,880	363	95	0.5	8.3	Di *et al*., 1998
	2-pond	185		110	95	15		Bolan *et al*., 2004a

55. Laurenson *et al* (2006) also note that pig diet in modern piggeries comprises mainly agricultural grains and cereal. Phosphorus in these foods is not bio-available to monogastric animals (ie. pigs) and total P in pig manure is higher than that for cattle on a dry matter basis; 29.1gPkg-1 in pig manure compared to 6.7gPkg-1 for cattle. A knowledge of the nutritional value and therefore nutrient load of the slurry is therefore important when designing a sustainable and productive agricultural system with reuse of piggery wastes as a nutrient source.

56. Technology associated with pig rearing has advanced so that some piggeries now house their growers in eco-barns on litter comprised of sawdust or straw. The sheds are designed to have good air flow (some with an open side) thus eliminating some of the potential issues with odour. There are now food supplements available for the pigs that

suppress ammonia. The use of eco-sheds has also either eliminated or minimised the liquid waste stream. The litter in these sheds requires replacing at 1-3 month intervals and the spent litter material is high in nutrients, and can either further composted or applied directly to land to increase the organic matter of the soil in cropping operations.

Odour

57. Odour from pig rearing operations is largely unavoidable but can be mitigated by good management practices. Odour can emanate from buildings housing the pigs, wastewater collection and treatment facilities (ie. sumps and pond system), or from the land application activity. Efficient and timely washing of the housing areas, the use of diet supplements that inhibit odour production, and odour masking agents for the wastewater are some methods of mitigating odour. A clean and tidy operation, with screen planting and good buffers to dwellings and other public areas goes a long way to managing the odour issue.

58. Horizons' records show that since January 2003, the Council received 95 odour complaints with regard to activities associated with piggeries (ie. averaging 10 complaints a calendar year). There were 29 complaints in 2003 with the next highest being 19 in 2005. In other years complaint numbers just reached double figures.

59. To summarise then, effective day-to-day management is the key to a successful piggery operation. From a council perspective, such a piggery would have, and the owner/s would be able to demonstrate, the following:

    i. Infrastructure to adequately cater for the number of pigs on the property, with good buffer distanced to dwelling and public access areas with the boundaries, preferably screen planted. Clean and ventilated pig housing areas, and sufficient capacity for effective waste collection, treatment and disposal systems (ie. solid screening, ponds and land application area).
    ii. An awareness of actual and potential environmental issues arising from managing the piggery waste stream – avoiding run-off and ponding arising from excessive irrigation, complying with nutrient application limitations, managing odour from housing areas and treatment facilities, and having contingency plans and/or back-up equipment for system malfunctions or break-downs.
    iii. Employing best practice procedures for activities at the piggery, such as beneficial use of water and nutrients via land treatment, animal welfare and inspection, maintenance and upgrade regimes. A comprehensive site management plan is always helpful.

iv. Good and open communication with neighbours and the Council is desirable. This is particularly important for providing advance notice if there is a malfunction at the piggery that is likely to create off-site effects.

v. A good compliance record with the consent conditions and management plan. This will make consent 'renewals' a much easier and less costly process.

Assessing consent applications for existing and new piggeries under the Proposed One Plan

60. To my knowledge, all consents for pig effluent disposal activities issued by Horizons have conditions controlling nutrient loading to between 150-200 kg N/ha/y. A piggery within the lower Manawatu River Catchment operates under Manawatu Catchment Water Quality Regional Plan (MCWQRP) Rule 13 that authorises a nitrogen application rate of up to 200 kg/ha/y as a Controlled Activity west of the Ruahine Ranges. A piggery outside the Manawatu catchment operates under the Land and Water Regional Plan where DL Rule 4 authorises a nitrogen application rate of up to 150 kg N/ha in a 12-month period, not exceeding 50 kg N/ha in any 24-hour period, also as a Controlled Activity. The rules provide for the application of the piggery waste onto land, subject to buffers to dwellings, marae, churches, schools and public recreational areas as well as water bodies, and management of waste applications to ensure ponding, overflows and odour issues are avoided.

61. Currently, activities associated with discharges from piggeries (ie. the discharges of contaminants to land) are treated as Controlled Activity under the MCWQRP Rule 13, and Land and Water Regional Plan (DL Rule 4). A discharge of contaminants to air from factory farms, including intensive pig and poultry farming operations is permitted provided there is no objectionable odour, dust or noxious or dangerous airborne contaminants beyond the property boundary under the Regional Air Plan.

62. I believe it is appropriate that an existing piggery located on an adequately sized property in a rural setting, with the appropriate infrastructure (ie. pig housing and wastewater collection, treatment and disposal practices) and with a track record of effective management to operate sustainably is rewarded by having its 'renewal' applications treated under Controlled Activity status, as provided for in Horizons' current plans. Existing piggeries with either poor infrastructure or that are subject to poor management or mismanagement need to be upgraded to avoid negative environmental impacts before renewal of consent can be granted. Currently, new piggeries are also afforded Controlled Activity status under Horizons' current Regional Plans.

Proposed One Plan (POP)

63. Under Rule 13-6 of the POP, applications for the 'renewal' of discharge permits from existing piggeries are to be afforded Controlled Activity status. This is discussed in the evidence of Horizons' Consultant Planner, Ms Clare Barton.

64. Discharges to the environment (ie. land and air) from 'new' piggeries will be assessed as a Discretionary Activity under Rule 13-7 of the POP. This allows any application to be either granted with conditions or declined after a rigorous assessment of actual and potential environmental impacts. While this rule has met with opposition from the Pork Industry Board, in that it creates some uncertainty for its members, I believe that Horizons should have the discretion as to whether or not a piggery should be located in any particular location or what waste management (ie. collection, treatment and land application) standards are required.

65. The lack of a discretionary option for new piggeries became apparent in the proposed Coastal Lakes piggery case where application for consents for a very large piggery was proposed on a large coastal sand country block with sensitive coastal lakes and an existing large dairy herd. While the applicants proposed a new and modern piggery with high tech waste treatment by bioreactors and land application via pivot irrigators, there was no track record on which to base performance or management. Consequently only a 15-year term was granted.

KEY MESSAGES

1. There are 23 piggeries in the Region that produce up to 624 cubic metres of wastewater per day.
2. The largest existing piggery houses up to 700 sows with progeny reared to bacon stage.
3. In September 2008, Coastal Lakes Station, located between beach townships of Himatangi and Foxton, was granted a permit for the operation of a 4,800 sow piggery producing up to 450 cubic metres of CIGAR treated wastewater. This was to be applied to 1,100 ha of land. To my knowledge this proposal will not be proceeding at this scale.
4. Resource consents for existing piggeries are to be treated as Controlled Activities with no public notification under the POP Rule 13-6. New piggeries will be considered a Discretionary Activity.

7. ON-SITE WASTEWATER TREATMENT AND DISPOSAL

Introduction

66. This activity is associated with the collection, treatment and 'disposal' of wastewater onto and into land within a designated property. Generally the activity is associated with the wastewater from a single dwelling (ie. toilet, bathroom, kitchen and laundry) but is extended to cover schools, community halls, camping grounds, adventure and ski lodges and marae in the Proposed One Plan. Sewage and wastewater technology in developed countries has evolved over more than a century, moving from the small and basic septic tank (a settling chamber) and soak hole to package wastewater treatment plants (multi-chambered units with surface enhancing media for bacterial activity) and 'land treatment', where the contaminants in the treated wastewater (effluent) are applied into the soil at a 'designed' rate so that water, nutrients and pathogens are assimilated by plants and micro-organisms in the soil profile.

67. Domestic wastewater typically originates from the toilet, bathroom, kitchen and laundry areas of the house. Domestic wastewater includes human body wastes (faeces and urine), highly putrescible organic material, grease, oils, and detergents. Paint, hydrocarbons (grease, oil and petrol), weedkillers and insecticides can also be present. Wastewater generally contains millions of bacteria, some pathogens (disease causing) but can sometimes also contain organisms responsible for more serious diseases such as typhoid, dysentery and infectious hepatitis. Domestic wastewater is considered very objectionable (untreated it is culturally offensive to Maori) and potentially dangerous to public health.

68. Domestic wastewater typically is composed almost entirely of water (in excess of 99.9 %). It is only the other 0.1 %, which consists of both organic and inorganic material, that causes its objectionable and pollution causing characteristics.

Regional statistics

69. Horizons' Region is the fourth largest in New Zealand on the basis of area. It covers 22,215 km^2, or approximately 8% of New Zealand's land area, and includes quite diverse landforms and soil types. Soils range from windblown sands in the coastal strip on the West Coast (from Waikawa Beach to Wanganui), pumice soils in the Central North Island, to the impervious and heavy clay soils in and around Palmerston North and Tokomaru. Topography, soil type (particle size and permeability) and climatic conditions (rainfall and the groundwater table) are important criteria to be considered in

designing sustainable wastewater systems. This site and soil assessment is discussed in more detail in the Manual for On-site Water Systems Design and Management (Barnett *et al*, 2009)

70. The Region is divided into seven Territorial Authorities (TAs) – the Ruapehu, Rangitikei, Wanganui, Manawatu, Tararua and Horowhenua District Councils and the Palmerston North City Council. It also includes small parts of the Stratford and Otorohanga District Councils. The TAs provide service delivery functions to their ratepayers, ie. infrastructure associated with roading, potable water supply and wastewater reticulation (treatment and supply or disposal), solid waste collection and disposal (landfills). They are also responsible for the use, development and protection of land, including controlling subdivision and issuing and signing-off of building permits, and control issues associated with noise and hazardous substances. I have attached a map of the Region below showing the various TAs together with towns that are serviced by reticulated wastewater (sewage) systems.

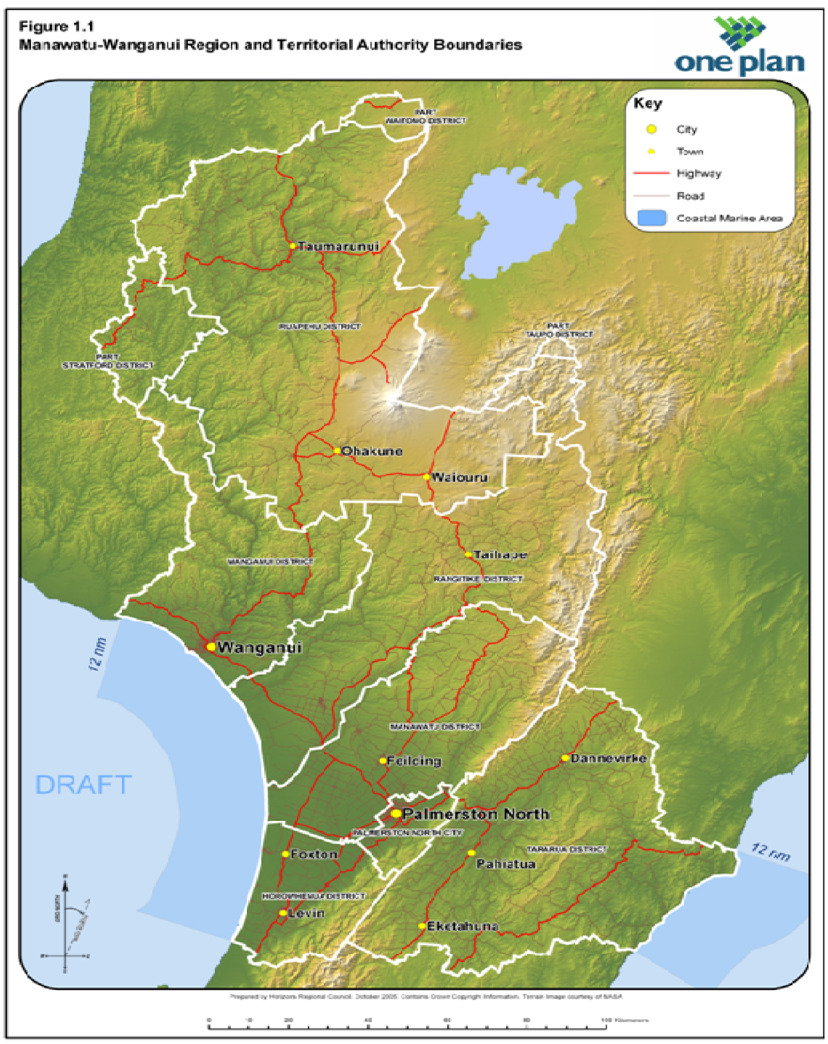


Figure 1.1
Manawatu-Wanganui Region and Territorial Authority Boundaries

71. The 2006 Census figures published by Statistics New Zealand provided the following population and dwelling demographics for the Region (Table 5 below)

Table 5. Regional Statistics for Population and Dwellings (Statistics NZ, 2006) for the Territorial Authorities within Horizons' Region

Local Authority	Population	Dwelling	Occupancy/dwelling
Ruapehu	14,739	6,888	2.14
Wanganui	43,719	18,651	2.34
Rangitikei	14,976	6,528	2.29
Manawatu	28,143	11,640	2.42
Tararua	17,538	7,662	2.29
Horowhenua	29,643	14,319	2.07
Palmerston North	76,722	29,700	2.58
Region - total	225,696	85,194	2.65

Note: The regional demographics are as published by the Statistics New Zealand as tables showing Changes in Census Night Population/Dwelling Count for Regional Councils. These figures contain random rounding so totals may not be completely accurate.

72. The Ministry for the Environment (MfE) has estimated that 20-30% of dwellings in New Zealand rely on on-site wastewater treatment and disposal (MfE, August 2008). Using this assumption, and numbers from Table 5 above, it can be assumed that 17,000-25,600 on-site systems operate in Horizons' Region. MfE has also estimated that that 30-40% of existing on-site systems are performing poorly or are in need of maintenance. Poorly performing systems adversely affect the receiving environment and can be a health hazard. This issue, and options for correcting problems, are discussed in the last section of my evidence under Proposed National Environmental Standards for existing on-site wastewater systems (from paragraph 102).

Selection and management of on-site wastewater systems in the region prior to notification of the Proposed One Plan

73. In this section I describe the components of an on-site wastewater system and document the process taken by Horizons in developing the Proposed One Plan strategy for managing on-site wastewater.

8. DOMESTIC ON-SITE WASTEWATER SYSTEMS – SOME DESIGN AND OPERATION FAULTS

Background

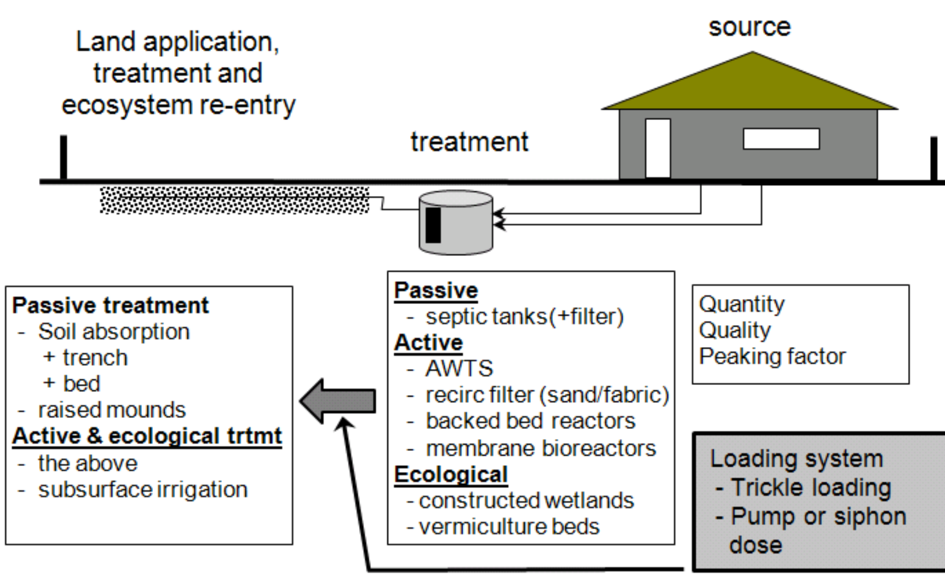
74. There are four key components to an domestic on-site wastewater system, namely:

i. The source of wastewater, ie. the size of the dwelling and the type of wastewater producing facilities (toilet cisterns, shower heads, washing machine(s) and other possible facilities such as spa baths), the number of occupants and their behaviour (ie. what is flushed and type of household products used such as cleaning agents);

ii. The treatment plant, which may be a simple septic tank/s or a more complicated package treatment plant;

iii. The land application method, which may be a gravity trench system or a dose loading system to the field using a pump, siphon or flout mechanism; and

iv. The land treatment component, which not only returns the treated wastewater to the local ecosystem but also provides additional treatment of the wastewater stream, ie. soil and plant interaction.



Source: ecoEng Ltd – Fact Sheet: OWMS 0904

Figure 1. Schematic diagram showing the key components of an a domestic on-site wastewater system

75. In order to design a system for long-term effectiveness, it is imperative to understand all four components together with any site constraints (ie. soil type and profile, the high groundwater level, topography and aspect, vegetation cover, size of property, and its proximity to neighbours and any sensitive environments). These factors provide guidance on the type of system best suited to the location. For example, is a secondary treatment plant with sub-surface drip line application of the wastewater required, or would primary treatment with a conventional trench or LPED bed suffice?

76. Wastewater inflows in the domestic situation fluctuate on a daily basis but a well designed treatment system, in particular a dose pumped system, will have the capacity to buffer the inflows. At the other end of the system, conditions in the land application area (LAA) can vary daily with rainfall and seasonally with soil moisture, temperature and plant growth. This affects the water and nutrient uptake. Therefore, wastewater application rates to land need be conservative (at least, worst case scenario plus buffer) to ensure that the soil and plants can assimilate load via natural processes at all times.

77. Inappropriate design or overloading will cause a system to fail. Installing trench or bed systems in tight soils with moderate to high loading rates is against good practice methodology and will fail in time. Similarly, under-estimating inflows will lead to poorly treated effluent entering the LAA, causing overloading or sealing of the trenches, beds or emitters. The application area or trenches will eventually become saturated and flood, potentially causing run-off to neighbouring properties or to water bodies. The LAA could cause odour issues due to anaerobic soil, and become a potential health hazard for humans, particularly children playing in water, and animals. It can also be expensive to fix as retrofitting is always much more expensive than doing it right the first time.

Chronological sequence of my involvement with on-site wastewater

78. My early involvement with wastewater systems was in the mid 1990s, investigating concerns with failures of on-site wastewater plants with trench systems in new lifestyle blocks in the Kelvin Grove area to the east of Palmerton North. The trenches were constructed in heavy clay soils. It became apparent that the systems were failing due to inappropriate design and that some guidance with system design was required. The Regional Council produced the On-site Wastewater System Guidelines for the Manawatu-Wanganui Region in November 2000, in conjunction with the Region's Territorial Authorities. Mr Ian Gunn of Uni-Tec Services, Auckland, a recognised wastewater expert, was the technical advisor for this document. Mr Gunn was also at the time involved in a joint Australia/New Zealand Committee looking at the update of

the Standard for the On-site Domestic Wastewater Management – AS/NZS 1547:2000. A workshop was held in early 2001 for Territorial Authorities, system designers and suppliers for implementation of the standard across the Region.

Horowhenua District

79. Horowhenua District occupies the narrow strip of land between the Tararua Ranges and the coast, to the south west of Palmerton North. It contains two nationally significant lakes – Horowhenua and Papaitonga. These two lakes also have cultural significance with local iwi. Several other coastal lakes and wetlands in the district also have regional significance. Parts of the district have been identified as having a problem with degraded groundwater quality (Bekesi, 1996; and Daughney *et al.*, 2009; pp 35). Groundwater in certain areas has nitrate concentrations that exceed the recognised World Health Organisation (WHO) standard for drinking water. This elevated nitrate problem has been attributed to historic dairy farming and market gardening activities, the prevalence of septic tanks, and the underlying geology. The evidence of Mr Hisham Zarour, Horizons' specialist Groundwater Scientist, will elaborate on this topic. In order to address some of these issues, Horizons produced the Lake Horowhenua and Hokio Stream Catchment Management Strategy (May, 1998).

80. In the early 2000s, the Horowhenua District started experiencing a boom in the demand for rural and coastal land and lifestyle blocks. Large areas of production land around Levin and on the West Coast of the North Island from Foxton to Waikawa Beach were being subdivided to meet this demand. The Horowhenua District Plan allowed subdivision down to 2,000 square metres lots. As these areas do not have reticulated services for either sewage or water, on-site systems are required for wastewater treatment and disposal.

81. Horizons had expressed concern for actual and potential impacts arising from the proliferation of on-site wastewater systems, the cumulative effects on the local groundwater, and the ability of the Horowhenua District Council to ensure the systems were maintained to perform effectively at all times. The District Council accepted this concern and, in collaboration with Horizons, produced a document 1.4.3.9 Minimum Engineering Standards – On-Site Wastewater Systems (May 2004). A copy is attached as Appendix 3. This document is a Memorandum of Understanding (MOU) between the two Councils on the standard, location and maintenance of on-site systems in the Horowhenua District. It was loosely based on Auckland Regional Council's Technical Publication No 58 (commonly recognised across New Zealand as TP58) with an

objective of raising the standard for wastewater management. I believe the strategy has met its objective.

Proposed One Plan strategy for on-site wastewater management

82. The Horowhenua experience was also being reflected in other districts in the Region. Palmerston North, Wanganui, Ruapehu, Rangitikei were facing similar subdivision and building booms. Other Regional Councils (eg. Environment Waikato, Environment Bay of Plenty and the unitary authority Tasman District Council) were also grappling with this issue. Horizons wanted to be proactive in promoting sustainable management of on-site wastewater. It engaged Mr Sandy Ormiston of Ormiston Associates Ltd, Auckland, to be Technical Advisor to produce the Manual for On-site Wastewater System Design and Management (Barnett *et al.,* 2007). Mr Ormiston is a co-author of Auckland Regional Council's (ARC) Technical Publication 58 (4^{th} Edition) (TP58) and is the current Chairman of the New Zealand Land Treatment Collective. Much of the design criteria in Horizons' manual has been adopted from TP58 with the approval of the ARC. The manual has been peer reviewed by Wastewater Engineer Mr Ian Gunn of UniTec, Auckland, who made some useful comments that have been incorporated into the second version.

83. Horizons' POP Rules and the contents of the manual were discussed with TA regulatory staff, planners, system suppliers and installers at three separate meetings (Palmerton North, Ohakune and Wanganui) in mid June 2007. Council staff (Policy Manager Richard Munneke and I) with advisor Sandy Ormiston, outlined the current and proposed Regional Rules and the possible implications, and answered question. The impression I took from these well attended meetings was that TA regulatory staff, suppliers and installers generally welcomed the prescription under the POP Rules but some wastewater engineers believed the prescription was too heavy handed.

84. Version 2 of the manual (Barnett *et al*., 2009) has been prepared to incorporate the comments and submissions that were justified in terms of technical and practical improvements, and to make the manual read better. Importantly, some modifications to POP Rules are also suggested to address the comments about 'heavy handedness'. I summarise the main changes below:

i. The term 'land disposal' had been replaced throughout the manual with 'land application'.

ii. Section 2.2 ‘percolation testing’ of a soil as an assessment for drainage has been withdrawn and ‘permeability’ measurement is suggested as a guide to determining a soil loading rate (soil category).

iii. Tables 4.3 and 4.4 (intermittent and recirculating sand filer design) have had some design sand size numbers and notes added.

iv. Section 4.8 dealing with greywater has had some additional notes inserted to exclude systems incorporating composting, vermiculture, peat beds and wetland systems from the scope of the manual.

v. Section 5.5 (Distribution Methods within the Land Application System) has had notes added on flood loading and dose loading, for completeness.

vi. Section 6.3 (Pressure Compensating Dripper Irrigation) now includes a section on Shallow Trenches and Low Pressure Effluent Distribution (LPED), including Table 6.5 LPED a worked example and a diagram (Figure 6.2). It is to be noted that Horizons’ preference is for trenches backfilled with aggregate.

vii. Section 7 (Maintenance and Management) has been expanded and now includes a new sub-section 7.4: Operation, Maintenance and Management that requires designers and suppliers to produce a maintenance manual for prospective owners of their systems. It also provides a checklist of components of an ‘on-site system’ that need to be inspected, and outlines the consequences of system failure.

Wastewater Users Group

85. Mr Hamish Lowe, Science Manager with the CPG Consulting (formerly Duffill Watts Group) established a local Wastewater Users Group in Palmerston North in August 2007. It is based on a similar group established in Hawkes Bay and provides a forum for interested parties (Territorial Authority and Regional Council staff, environmental and engineering consultants, planners, suppliers and installers) to meet informally to discuss issues of interest such as Regional Rules, MfE’s National Environmental Standard (NES) for On-site Wastewater Systems or any topics from the floor.

86. An updated version of the Manual for On-site Wastewater System Design and Management and the Proposed Regional Rules has been prepared. It will incorporate the changes suggested in submissions where we believe the integrity of the strategy is not compromised. Prior to the Hearing, this manual will be released and discussed with the Region’s TAs, wastewater system suppliers, system designers and submitters to narrow any points of contention. I am hopeful that this process will eliminate most of the issues raised by submitters in relation to on-site wastewater management in the Region.

By the time of the Water Hearing there should be only a few points of difference for the Panel to consider.

On-site wastewater – calculation of volumes, treatment & land application

87. Throughout this section I refer extensively to the Manual for On-site Wastewater System Design and Management (Barnett *et al.*, 2007). This is the 'old' version of the manual that was notified with the POP. Any proposed alterations/changes will be highlighted as track changes. In all cases I refer to this document as the manual and provide a page reference. A copy of the manual is provided in this evidence.

88. An assessment of wastewater production takes into account the occupancy and the per capita flow allowance. Occupancy depends on the type of facility, but for a dwelling is typically based on the number of bedrooms. The water supply (ie. roof water collection or unrestricted water bore or reticulated supply) and the type of water conservation measures installed influence per capita water consumption. Horizons recommends that a conservative design approach is adopted by the designer to provide a factor of safety in the system design.

Wastewater treatment

89. Wastewater in the domestic situation (ie. that is domestic in nature) arises from activities in dwellings, institutions, or commercial facilities. It consists of all-waste, greywater from wash basins, showers, laundry and kitchen, or blackwater from toilets. It does not include wastes from commercial or industrial processes, but sometimes does include grease, oil, paint and small quantities of herbicides and insecticides from home workshops. Wastewater is referred to as foul water in the New Zealand Building Code (Source: AS/NZS 1547:2000).

90. Effluent is defined as the liquid discharge from a processing step. The constituents found in wastewater can be classified as physical, chemical and biological. The constituents of most concern in wastewater are: suspended solids, biodegradable organics, pathogenic organisms, and inorganic characteristics including nutrients (eg. nitrogen and phosphorus). (Crites and Tchobanoglous, 1998).

91. Wastewater treatment refers to technologies used to retain and treat the components making up the wastewater stream prior to discharge to the land application system. The

land application system will also provide additional inground treatment of the treated effluent prior to it reaching and merging with groundwater.

92. There are four recognised levels of effluent treatment – primary (including improved primary), secondary, advanced secondary, and tertiary. They are defined in the manual. I have reproduced Table 4.1 from the manual below. It shows typical wastewater quality ranges for available treatment methodology.

93. Data showing the strength of typical domestic wastewater, with concentrations of the various contaminants and levels for different treatment options, is shown as Table 6 below.

Table 6. Typical domestic effluent quality ranges for various parameters and on-site treatment options (Source Auckland Regional Council TP58 (2004) Table 7.1)

Treatment Unit	**Typical Concentration g/m^3**						**FC**
	BOD_2	**TSS**	**NH_3**	**NO_3**	**TN** (Note 8)	**PO_4**	**CFU per 100 ml**
Raw Wastewater (Mixed value)	250 to 350	100 to 400	varies	<1	Varies	10 - 30	10^6 to 10^{10}
Raw Greywater	180 to 240	130 to 160					
Traditional Septic Tank							
Septic Tank (poor operation)	170 to 250	80 to 110	40 to 60	<1		10 - 20	10^6 to 10^{10}
Septic Tank (good operation)	to 150	50 to 70	20 to 30	<1	40 – 100 Typical	7 to 20	10^5
Greywater Tank (average operation)	50 to 80	30 to 50					
Digestive Tank (average operation)	60 to 100	40 to 60					
Two stage septic Tanks (in series)	70 to 120	40 to 60					
Septic Tank							
Septic Tank with Outlet Filter	70 to 120	30 (Note 3)			40 - 100		
S T plus [note 4] Intermittent Sand Filter	<10	<10		20 - 25	25 – 40	7	4 x 10^2 to 10^3 (Note 9)
S T plus Recirculating Sand Filter	<10	2 to 6	2 to 4	30 (average) [note 6]	15- 40 (note 7)	<1 to 10	10^2 to 10^4
S T plus Recirculating Textile Filter	<15	15	0 - 5	30 (average) [note 6]	30 – 60 (note 7)	5 to 15	10^3 to 10^4 99% reduction
Recirculating Sand filter with N reduction					75% reduction (note 7)		
AS –ATP [note 5]	20 to 50	20 to 100	<1	35	25 – 60 (Note 7)	4 - 10	3 x 10^3
AS-ATP Plus Sand Filter	<10	<10	<1	35			
Tertiary Disinfection							[note 10]

Notes:

1. The typical concentrations are to be used only as a guide as the concentrations of constituents in wastewater are highly variable.
2. Data based on indicative values from the literature (and in some cases on estimates) and NOT on recorded New Zealand information.
3. Total suspended solids level following an effluent outlet filter is dependent upon the type of filter and hydraulic flow. Some literature indicates TSS following some filter types may be significantly higher eg. up to 70 g/m^3.
4. ST refers to Septic Tank.
5. AS-ATP refers to activated sludge aerobic wastewater treatment plant.
6. The effluent quality obtained from the more sophisticated treatment system is reliant upon the system design, loading rate and being correctly operated and maintained.
7. Treated wastewater output quality can vary significantly from the above typical values and is dependent upon the influent concentrations.
8. Lower nitrate concentration can be achieved by following an additional nitrate reduction cycle.
9. The percent reduction with intermittent sand filters is better than that achieved by recirculating sand filter systems, due to the single pass and lower loading rate.
10. The level of disinfection and reduction in indicator organisms is dependent upon the level of and type of disinfection and is reliant on regular monitoring and maintenance.

94. The first column refers to the treatment technology used to retain and treat the components making up the wastewater stream prior to discharge to the land application area. The land application system will then provide additional inground treatment of the treated effluent prior to it reaching and merging with groundwater.

Application of the treated effluent to land

95. I believe this aspect is the key to sustainable on-site wastewater management. It requires the treated wastewater to be applied to land at a rate that provides for assimilation of the liquid, nutrients and bacteria components by plants (ie. uptake by grass, shrubs or trees in the land application area), micro-organisms in the topsoil, and the soil profile itself. If this facet is designed correctly – that is, to the worst case scenario – the integrity of surface water and groundwater should not be not be compromised.

96. A number of controlled loading devices and land application options are available that ensure best practice management of effluent. These devices and systems are detailed in Sections 5 and 6 of the manual (pg 37-57) (Barnett *et al.*, 2007).

97. Following the notification of the POP and the release of the manual (Barnett *et al.*, 2007), there was a series of meetings with the Region's TAs, wastewater system designers, system suppliers and installers to discuss the implementation 'strategy' and to get feedback on the proposed rules. My understanding from the feedback was that the strategy was considered good, the rules were too stringent for larger blocks (greater

than 5 ha) and that the proposed rules and the manual needed clarification on matters dealing with system maintenance and some small other technical matters.

98. Mr Sandy Ormiston, Horizons' consultant Technical Advisor for on-site wastewater systems, and I have since made modifications to the manual in an attempt to satisfy these comments.

Assessment of effects on the environment

99. An assessment of environmental effects (AEE) potentially arising from the proposed land application of wastewater is an essential part of every site assessment. Site assessment requirements are described in Section 2 of the manual. The section also includes guidance on minimum separation distance requirements that can be used to support the proposal and AEE.

100. The AEE should, at a minimum, include the following:

i. The anticipated treated effluent quality.
ii. Water conservation measures included in the dwelling.
iii. Impact on surface water (note separation distance provided in the design).
iv. Impact on groundwater (note the separation distance between the base of the land application system and highest seasonal groundwater level).
v. Flood risk (disposal system to be above the 1:20 year flood level). A flood risk assessment may not be required for all proposed systems and Horizons may have existing flood risk information available.
vi. Impact on soils (based on disposal system loading rate and proposed disposal method).
vii. Impact on vegetation.
viii. Presence of any historical sites.

101. More comprehensive assessment will be required for larger discharge volumes, where site or soil constraints are present or in areas in or close to a sensitive environment.

102. Additional details for assessment of environmental effects are available in ARC TP58 (2004) section 11.0.

Subdivision of land – size of lots

103. Until about 12 months ago, the Region had experienced approximately seven years of intense subdivision activity of farm land for lifestyle living. This was particularly the case in the Horowhenua and along the West Coast through to north of Wanganui. The demand was high and land prices reflected this demand. In the case of Horowhenua, the District Plan allowed subdivision down to 2,000m^2 lots.

104. The issue for Horizons was that all this land was not reticulated for wastewater, and there was likely to be a proliferation of on-site wastewater systems producing primary treated effluent into reasonably porous soils. The cumulative impact of discharges from the systems in terms nutrients and micro-organisms on groundwater was unknown. Horizons needed to determine and advocate a sustainable lot size to mitigate the potential off-site effects of wastewater systems from small lots.

105. Horizons engaged HortResearch (Drs Steve Green and Brent Clothier) to advise on the role and transport in soil of contaminants in domestic wastewaters. Dr Green used the Soil Plant Atmosphere System Model (SPASMO) to advise the risk of nitrogen, phosphorus and pathogens leaching from two large subdivisions proposed near Levin. The SPASMO model and results are discussed by Dr Clothier in paragraphs 10 and 11 of his evidence (Clothier, 2009; pp 26-30).

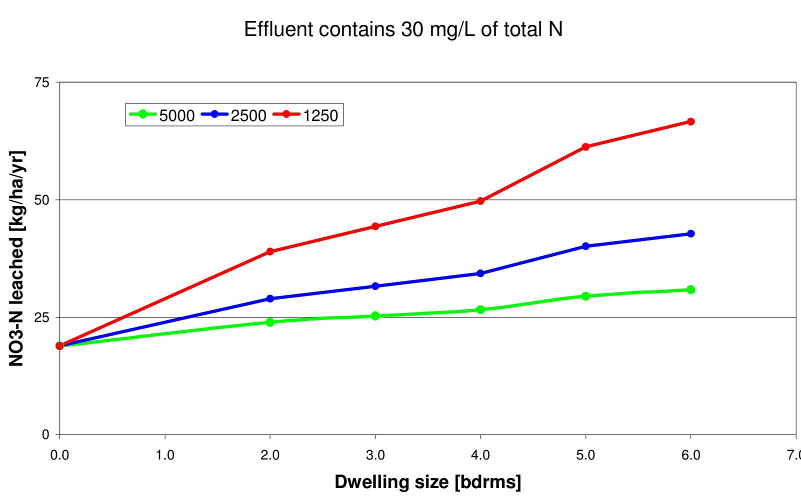


Figure 2. Showing annual leaching of nitrate-N averaged across a lifestyle block on Kawhatau stony silt loam near Levin as a function of dwelling size measured by the number of bedrooms and related to block size. The septic tank (wastewater treatment plant) considered here is a modern system providing secondary treatment (Figure 11.2 of Dr Clothier's evidence, 2009)

106. The results of this modelling (Figure 9 above) suggest that the only scenario to meet the Proposed One Plan nitrogen loss rule of 22kg-N/ha/yr (Table 13.2 POP; pp 13-4) was secondary treated wastewater from a 2 bedroom dwelling on a minimum lot size of 5,000m^2 in the subdivision under study. Phosphorus and *E. coli* would be treated in the soil profile.

107. While accepting of the fact that this study was for a single soil type (Kawhatau stony silt loam) it provides a good basis for the 5,000m^2 minimum lot size proposed in the POP Rule 13-11 d (i) for subdivisions, after the Plan becomes operative.

Regional rules

108. There are some suggested changes to the Proposed Regional Rules for On-site Wastewater Systems - POP Rules 13-9 and 13-10. They will be discussed in the evidence of Horizons' Consultant Planner, Mrs Clare Barton. The changes are recommended in an attempt to satisfy comment and concern expressed in written and oral feedback received in submissions following notification of the POP, and experience of day-to-day implementation of the proposed rules by regulatory staff from the Region's TAs, designers and system suppliers. The major change is in the reduction in the size of property that triggers the 'type' of on-site wastewater treatment required and land application rates. For example, for Permitted Activity status:

i. A property is now considered to be a 'farm' if its size is greater than 10 ha (reduced from 20 ha). There is no specific requirement on the type of wastewater treatment system so long as its design complies with the manual (Barnett *et al.*, 2007).
ii. For properties between 4 ha and 10 ha in size, the treatment plant can be either a primary treatment system (improved septic tank) or a secondary treatment plant with the effluent application rate to land no greater than 5 mm/m^2/day.
iii. For properties between 1 ha and 4 ha in size, the treatment plant needs to provide secondary standard effluent with an application rate to land no greater than 5 mm/m^2/day, based on a thorough site/soil assessment.
iv. For properties under 1 ha (10,000m^2) in size, the treatment plant needs to provide secondary standard effluent with an application rate to land no greater than 3 mm/m^2/day.

109. The other significant change is to the Maintenance and Management Section of the manual, where the operation, maintenance and management criteria have been made more explicit. This is shown in Version 2 of the manual.

110. I recommend that the suggested changes in the Regional Rules and the contents of Version 2 of the Manual for On-site Wastewater Systems Design and Management, as discussed in the evidence of Horizons' Planner be adopted for the following reasons:

i. The Regional Rules and the manual are complementary and will provide for sustainable on-site wastewater management across the Region.
ii. The changes remove some of the perception of over-regulation and heavy handedness with on-site systems.
iii. The proposed rules, with the degree of prescription suggested will simplify the TAs building consent process for on-site wastewater systems.
iv. The changes will reduce cost slightly for wastewater systems on larger properties.
v. The environmental bottom lines for surface water and groundwater will not be compromised by these proposed changes.
vi. Similar rules for managing on-site wastewater are in place in several other regions.

Proposed National Environmental Standard (NES) for existing on-site wastewater systems

111. National environmental standards are regulations issued under the Resource Management Act (RMA) by Central Government via the Ministry for the Environment (MfE). They prescribe technical standards, methods and other requirements for environmental matters to meet specific outcomes.

112. Local and regional councils must enforce these standards, or they can enforce stricter standards when the standard provides for this. In this way, national environmental standards ensure consistent minimum standards are maintained throughout all New Zealand's regions and districts.

Proposal for improving the performance of wastewater treatment systems

113. In early 2006, MfE announced that it was aware of, and concerned about, the performance – or more correctly the non-performance – of existing on-site wastewater systems operating around New Zealand. These issues arose from poor design, age of the infrastructure, possible overloading of the systems, and lack of maintenance. The tell-tale signs of poorly performing systems were odour (a 'rotten egg' smell), slowly flushing systems that backed up in toilets, saturated disposal fields, often with ponding of discoloured effluent and even run-off of the poorly treated effluent, with high BOD, nutrients and pathogens, either to neighbouring properties or water bodies. The poorly performing systems posed public health risks to both the people living in the dwelling

and also their immediate neighbours. Such adverse environmental effects were likely to be found in country areas (ie. farm houses) or small settlements with no wastewater reticulation. In recent years Horizons has become aware of, and concerned about, such effects in coastal townships where the cumulative effects of non-performing or poorly performing systems are affecting groundwater quality. Most residents in these areas fall into the poorer socio-economic class and for them to raise money for either upgrading of their current system or for a reticulated wastewater system was likely to cause them into further hardship, especially in the current economic downturn.

114. Following consultations with local and regional health and environmental authorities, MfE released a discussion document and a separate two-page summary setting out details of the proposed National Environmental Standard for public comment on 19 July 2008. The submission period ran for 10 weeks, ending on 26 September 2008.

115. The following extracts are sourced from the proposed NES:
It has been estimated that in some regions at least 20 per cent of homes rely on on-site wastewater treatment. This can include primary, secondary and tertiary treatment systems. Septic tanks are mainly primary treatment systems and represent the majority of on-site wastewater systems installed in New Zealand.

In many areas wastewater systems do not provide an adequate level of treatment and are adversely affecting human health and the environment. Failing systems can:

- *contribute to lakes, rivers, estuaries and beaches becoming unfit for swimming, gathering seafood and marine farming*
- *lead to contamination of groundwater and surface water supplies, affecting the quality of drinking water supplies, and may increase the occurrence of algal blooms.*

The aim of the proposed National Environmental Standard for On-site Wastewater Systems (the NES) is to improve the management and environmental performance of domestic on-site wastewater systems. In essence, the proposal is that:

- *Owners of properties with on-site wastewater systems in specific locations will be required to hold a current warrant of fitness that confirms their on-site system is functioning properly and is being maintained to an appropriate standard.*

The standard would authorise regional councils to require property owners with an on-site wastewater system to hold a current warrant of fitness (WOF) for their system. To *obtain a WOF, a system would be required to pass an inspection every three years. Regional councils would identify the areas where the standard would apply.*

These effects occur because of a range of factors, including poor maintenance, sensitive receiving environments (lakes, rivers, streams, etc), high-density residential areas, shallow groundwater and unsuitable soil types. Regular inspection and maintenance can play a significant role in improving the performance of wastewater systems.

In response, the Government is considering developing a national environmental standard (regulations) for the inspection and maintenance of on-site wastewater systems.

Source: Proposed National Environmental Standard for On-site Wastewater Systems (MfE, March 2008).

116. Following a series of workshops at 14 locations around New Zealand in August and September 2008, MfE sought submissions from parties interested in on-site wastewater management, ie. staff from territorial and regional councils, planners, consulting engineers, wastewater system suppliers, and the public. It received 135 submissions (40 from local government, 38 from community groups and householders, and 29 from industries involved with or affected by systems). A Summary Report on Submissions to the NES for On-site Wastewater systems was produced in mid April 2009.

117. For the interest of the Panel, I present below a schematic showing the NES development process, as produced by the MfE.

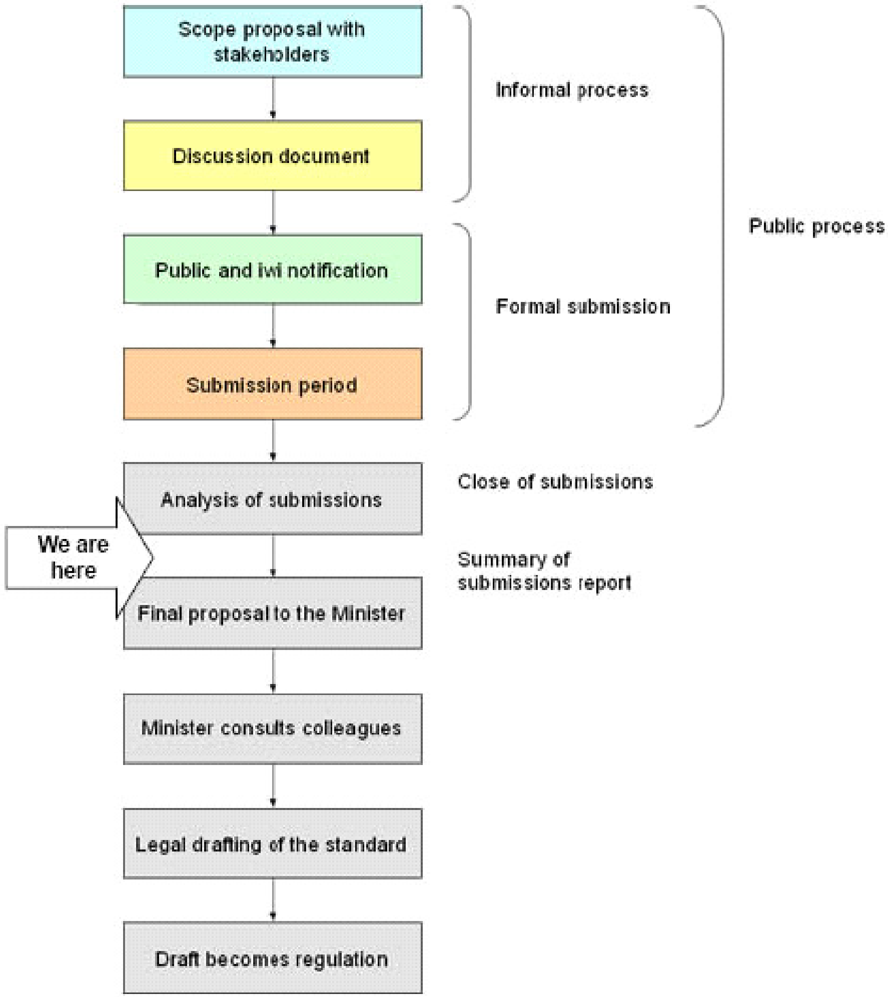


Figure 3. National Environmental Standards development process (MfE, 2009). Source: Ministry for the Environment Report, Proposed National Environmental Standard for On-site Wastewater Systems: Report on Submissions (April 2009).

118. Public involvement in the NES process has been completed and staff at MfE are in the process of preparing a final proposal for Ministerial consultation. While no further information has been received from MfE staff, my understanding from a recent publicity announcement is that an NES for existing on-site wastewater systems is likely by the end of 2009.

Discussion

119. I fully support the intent of the NES. I am of the opinion that if there is an on-site system installed, its design and performance should not compromise public health or the

environment. Its capacity to treat and apply the treated wastewater into the ground needs to examined from time to time, and ongoing maintenance is essential. These aspects, ie. design and maintenance, are provided for in Horizons' POP rules.

120. As most existing on-site systems were installed under Permitted Activity status, plans for their design and post-construction may not be readily available in the TA system (under the building consent process). Horizons does not get involved with system performance unless there is a complaint of a system discharging to water. At present, with the existing high workloads in Horizons' Compliance Team, there is no capacity to inspect all existing on-site wastewater systems in the Region.

121. As alluded to earlier, there are 'hot spots' in the Region where the cumulative impacts of poorly and non-performing on-site systems may be affecting public health and environment. Therefore, the NES provisions will be applicable in small unreticulated coastal townships or inland settlements.

122. To summarise, the POP (when it becomes operative) will provide for ensuring existing on-site wastewater systems are maintained. Such a programme will need to be prioritised and implemented, with poorly performing and non-performing systems targeted for maintenance or upgrade at cost to the homeowner. There will be time and cost for Council staff associated with the inspections, and significant cost to homeowners who need to upgrade their systems. It is unlikely in this economic climate that such a programme will be implemented in the short term in the Region.

123. The proposed NES, when in force, will require minimum standards for maintenance to be enforced throughout New Zealand by Regional Councils and TAs. The final decision on which councils will be involved, and the extent of the requirements (ie. whether just for on-site systems in selected 'hot spot' areas or across New Zealand), is still with the Government.

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Harold Barnett
August 2009

APPENDIX 1

(Appendix 2 of the Manual for On-site Wastewater Design and Management, Barnett *et al.*, 2009)

SOURCED FROM TP58 (2004) Auckland Regional Council Technical Sheet D-1
ASSESSMENT OF SOIL CHARACTERISTICS

FORMATION OF SOILS

Soils are formed as a result of weathering of the parent material from which they are derived. Five key factors determine the nature of the soil profile at any location:

- The type of parent material (which determines soil physical and chemical properties).

- Climate, particularly rainfall and seasonal temperature fluctuations, as these affect the rate and extent of weathering, and also the accumulation and breakdown of organic matter in the soil.

- Living matter such as vegetation and micro-organisms which have significant influence on the weathering process and contribute to the organic content of soil.

- Topography influences the effects of climate; elevated sloping areas drain better than low lying flat locations; slopes with a northern aspect have higher soil temperatures than those with a southern aspect; steepness affects erosion and deposition of soil layers.

- Soil age affects soil profile; older soils have well-developed profiles compared to younger soils (the soil forming process evolves over thousands of years of geological time, it being estimated that approximately 100 years of weathering is required to accumulate 25 mm of soil from a parent material).

SOIL TYPE AND PROFILE

The two main types of soils are "mineral" and "organic". Mineral soils are mainly weathered parent material with a small proportion of decayed plant and animal matter. For example, a silt loam soil suitable for plant growth would consist of 45% mineral particles, 5% organic matter, 25% air, and 25% water (by volume). Organic soils are those consisting of mainly decayed plant material such as occurs in swamps, bogs, marshland or peat lands.

The soil profile consists of the mainly unconsolidated material at the land surface that is utilised for growing crops and supporting structures, and which assimilates and transmits rainfall and constituents of wastes from animal and human activity. Three significant layers make up the soil profile:

The A Horizon – comprises the uppermost layer of most weathered material in which the bulk of the physical, chemical and biological activity in the soil takes place.

The B Horizon – is a transitional layer to which the very fine particles resulting from weathering will migrate and accumulate (eg. clays).

The C Horizon – is the unweathered layer which most resembles the original parent material from which the soil has been formed, and as such is the zone of least activity in the soil.

In any soil situation the actual soil profile may be made up of a range of horizons as affected by the time history of soil formation and the combination and dominance of the five soil-forming factors outlined above.

SOIL TEXTURE

Texture is determined by the proportions of the three principal mineral size fractions in soil - these fractions are clay, silt, and sand. The United States Department of Agriculture (USDA) classification of size fractions is the most commonly utilised in on-site wastewater practice. The USDA textural classification (Figure D1) is based upon the following particle size ranges:

Fraction Particle Diameter mm

Clay	less than 0.002
Silt	0.002 to 0.05
Very fine sand	0.05 to 0.10
Fine sand	0.10 to 0.25
Medium sand	0.25 to 0.50
Coarse sand	0.50 to 1.00
Very coarse sand	1.00 to 2.00
Fine gravel	> 2. 00

Either laboratory sieve analysis or a field method based upon "feel" of the soil can be used to determine texture. The following explanation of the "feel method" is taken from guidelines prepared by the University of Minnesota Agricultural Extension Service:

First, a large marble-sized portion of soil is moistened and then kneaded by hand until it has the consistency of putty. Then, the ball of soil is squeezed between thumb and forefinger so that by pushing the thumb forward over the forefinger a ribbon of soil is formed. The nature of any ribbon that forms (or does not form) indicates the soil textural class. Six general textural classes can be readily distinguishable by this technique –

Clay: Fine-textured soil that usually forms hard lumps or clods when dry and is quite plastic when wet. It can be very sticky when wet. When moist it can be squeezed into a long flexible ribbon. A clay soil leaves a "slick" surface when rubbed with a long stroke and firm pressure. Clay also tends to hold thumb and forefinger together due to its stickiness.

Clay Loam: Fine textured soil which usually breaks into clods or lumps that are hard when dry. When moist soil is squeezed, it will form a thin ribbon which will break readily, barely sustaining its own weight. The moist soil is plastic and will form a cast which will bear more handling. When hand kneaded it does not crumble readily, but tends to become a heavy, compact mass.

Silt Loam: When dry, may appear quite freely cloddy, but lumps are readily broken; when squeezed, it feels soft and floury. When wet, the soil readily runs together. Either dry or moist, it will form casts which can be handled freely without breaking, and when moistened and squeezed, it will not ribbon, but will have a broken effect.

Loam: Has a relatively even mixture of sands, silt and clay. A loam feels somewhat gritty, yet fairly smooth and highly plastic. Squeezed when moist, it will form a cast which can be handled quite freely without breaking, and it will not form a ribbon.

Sandy Loam: Contains much sand, but has enough silt and clay to make it somewhat sticky. Individual sand grains can be seen readily and felt. Squeezed when dry, it will form a cast which will fall apart. Squeezed when moist it will form a cast which will bear careful handling without falling apart.

Sandy: Loose and single grained. The individual grains can be readily seen or felt. Squeezed in the hand when dry, it will fall apart when the pressure is released and will not form a ribbon. Squeezed when moist, it will form a cast, but will crumble when the pressure is released.

Soil texture influences its permeability, aeration potential, and capacity to store water and nutrient salts, all of which affect the soils' ability to assimilate and rejuvenate wastewater components. Soil texture thus has a significant influence on determining design loading rates for on-site systems.

SOIL STRUCTURE

The hydrologic conductivity of a soil is significantly affected by its structure. Structure is the aggregation of soil mass into lumps known as "peds" which can be separated from each other by hand. The surfaces of "peds" will be planar in nature and void spaces between "peds" influence the passage of water through the soil, particularly in clayey soils. Common soil structural elements are "prismatic", "columnar", "blocky", "platy", and "granular". Structure may have a more significant effect on water movement in the soil than texture. For example "platy" structures are resistant to vertical water movement, but facilitate horizontal movement. "Blocky" structure in clay soils during dry weather shrinkage can provide high vertical transmission rates, but when wetted and swelled, will resist passage of water. Granular soils tend to be structureless and water movement is solely a function of texture. Aeration of subsoil is also affected by structure as is natural drainage through the subsoil.

WATER TABLE DETERMINATION

Soil colour and colour patterns are a good indication of the drainage characteristics of a soil and the seasonal variation in water table. Colour is influenced by the primary soil nature, the level of iron and manganese oxides present, and any organic content. Well drained soils above the water table are generally uniformly red, yellow, or brown in colour. Soils permanently (or nearly permanently) saturated are usually grey or blue in colour. Soils subjected to seasonal saturation can be speckled with different colours, known as mottles. Mottles indicate zones of saturated soil under winter conditions when complex biochemical reactions leach solubilised iron and manganese oxides from the soil, turning it grey in patches. Hence mottled soil under unsaturated conditions indicates periodic saturation. It should be noted, however, that not all soils show mottles under saturation, and landscape position and other soil characteristics may be needed to properly interpret the local situation.

Hence, although the water table depth may be fixed by borehole investigation, that result must then be interpreted relative to the season of the year, the degree of soil mottling from the soil profile, and landscape position.

SELECTION OF SOIL CATEGORY

The estimation of soil category for design purposes (Section 5.4 of TP58 and Section 4.3 of Appendix E of TP58) should be made on the basis of textural and structural assessment of the soil profile along with all other relevant site information. Traditional on-site practice has been to identify a suitable permeable layer of subsoil at depth below the A Horizon and to construct media filled trench (or bed) systems to load ponded effluent through the base of the trench (or bed) system.

It is now recognised that the biologically active A Horizon provides better opportunity for assimilation of effluent organic matter and nutrient salts while at the same time taking advantage of the infiltration and percolation capacity of the underlying subsoil, and the evapo-transpiration potential of planted vegetation. Design techniques which utilise the KISS (keep infiltration systems shallow) approach can take advantage of the disposal capacity of the upper soil/topsoil layer and match the selection of soil category for proposed disposal purposes with the design approach.

Figure D1: US Department of Agriculture Textural Classification for Soils

Source: *US Department of Agriculture, Textural Classification for Soils*

APPENDIX 2 SOIL – PHYSIO-CHEMICAL CHARACTERISTICS

These physio-chemical characteristics are explained further below.

Soil is porous mixture of:

- Organic material (decomposed plant and animal material, ie. humus)
- Mineral material (weathered rock, sand, silt and clay). The relative proportions of sand, silt and clay give the soil its texture
- Water
- Air
- Active organisms (bacteria, fungi, actimomycetes, plants and animals).

Soil texture and the relative proportions of sand, silt and clay vary within any given soil and from soil to soil. These differences are important when evaluating a soil for wastewater application. The non-solid or pore spaces are occupied by either water or air. A good fertile soil contains approximately 50% of pore space in its volume. Large pores (macropores) help drain out excess water from a soil. They are usually filled with air. Small pores are useful in retaining water in soils. The proportion of water and air in a soil are interrelated; as one increases the other decreases and vice versa.

Soil texture is an important characteristic because it gives a good indication of other soil properties such as water storage, drainage and nutrient supply. Soils with a 'uniform' mixture of sands, silts and clays are called loams and are most important for agriculture. Soils that have an extreme of one size fraction (ie. contain a very large proportion of clay or sand) are often more difficult to manage. Those with a dominant sandy texture (eg. sandy loam) are referred to as 'light' and those with a high proportion of clay as 'heavy'. These terms refer to the soil's ease for cultivation and not its relative density or mass of the soil particles.

I refer the Panel to Appendix 2 of the Manual for On-site Wastewater System Design and Management: Technical Report to Support Policy Development, May 2009 (Barnett *et al.*, 2009), entitled Soil Description, for further background information on the formation of soils, soil type and profile, soil structure, water table determination and selection of soil category.

The amount of pore space in the soil determines the volume of air or water that can occupy a given soil. As rainfall or wastewater is added to or lost from a soil, the amount of pore space occupied by either air or water will vary. The type and amount of solids determine the physical and chemical filtering capacity of the soil. This filtering capacity renders soil an excellent waste treatment medium.

Soil water storage

I now explain a few terms to describe the moisture status of soils that are important in scheduling irrigation or land application of wastewater regimes (From Chapter 6, McLaren and Cameron).

Consider a soil that has recently received a heavy application of water either as rainfall or irrigation.

Saturation (s)

At the end of the irrigation, water will have replaced almost all the air in the topsoil and drainage would be occurring through the macropores. Saturation can loosely be described as the amount of water in the soil 'when all the pores are full of water and no air remains in the soil'. For most soils this is a temporary state since drainage would be occurring and allowing air back in through the macropores.

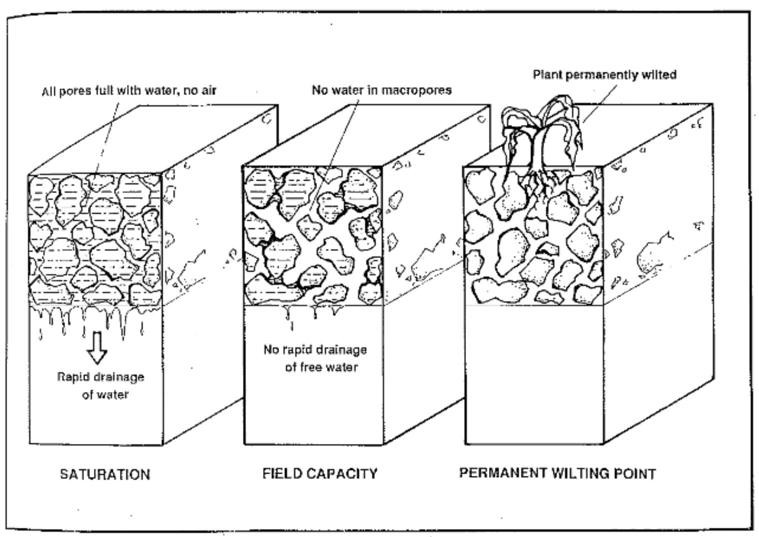


Figure 1. Illustration of soil water content at Saturation, Field Capacity and Permanent Wilting Point (from McLaren and Cameron, 1997)

Field capacity (FC)

When the application of water has stopped, the water in the largest pores begin to drain rapidly. After a period of time, often 1-2 days, the rapid drainage of macropores is complete and the soil is at a state called 'field capacity' (Figure 1). Although it is not possible to precisely define, field capacity is described as the state of the soil 'after rapid drainage has effectively ceased and the soil water content has become stable'. Field capacity is often related to the soil moisture content at a potential of -10kPa, although the most appropriate potential for a particular soil may be between -5 to -20kPa (equivalent to 0.05 – 0.2 bars suction)

Permanent wilting point (PWP)

Plant uptake of water and evaporation from the soil cause it to dry below field capacity (Figure 1). As water is removed, the water that remains in the soil becomes more and more difficult to abstract because it is held at greater suction. Initially the plant may start to wilt during the day, when the demand for water is at the highest, but eventually the plant will reach a point where it is wilted both day and night. This is the 'permanent wilting point' and can be described as the 'amount of water in the soil at which plants are permanently wilted'.

Like field capacity, the PWP is difficult to define precisely because it can vary with soil characteristics, such as depth, and with plant environmental conditions. The soil water potential at which the permanent wilting point occurs is generally taken to be -1500kPa (equivalent to 15 bars suction). The water remaining is held tightly in the small micropores and adsorbed to the soil particles. Some examples of the amounts of water at PWP in a range of New Zealand soils is presented in the table below:

Table 1. Approximate moisture content (%, v/v) of selected New Zealand soils (A horizon only). Adapted from Soil Bureau, 1968 and Gradwell, 1976. (McLaren and Cameron, 1996)

Soil Type (A horizons)	Field capacity[1] (%, v/v)	Permanent wilting point[2] (%, v/v)	Available water capacity (%)
Conroy sandy loam	29.4	7.0	22.4
Stratford sandy loam	51.5	28.4	23.1
Timaru silt loam	36.1	14.5	21.6
Marton silt loam	42.2	18.9	23.3
Templeton silt loam	33.8	15.5	18.3
Dannevirke silt loam	44.7	23.8	20.9
Temuka silt loam	47.0	23.9	23.1
Taita clay loam	42.3	20.8	21.5
Hamilton clay loam	36.3	18.5	17.7
Waiareka clay	51.6	32.1	19.4
Ruatangata clay	43.7	24.9	18.7
Egmont black loam	44.2	24.3	19.9

[1] Field capacity - Moisture content at 0.2 bar (-20 kPa)

[2] Permanent Wilting Point - Moisture content at 15 bar (-1500 kPa)

Available water capacity (AWC)

The available water capacity can be loosely defined as 'the amount of water which a soil can store for plant growth'. It is numerically equal to the amount of water held at field capacity (FC) minus the amount held at the permanent wilting pint (PWP):

AWC % = FC (%, v/v) – PWP (%, v/v)

Although the AWC can only be an approximate value, it allows useful comparisons to be made between soils (as shown in Table 1 above and Table 2 below) and on a day to day wastewater application basis it allows for calculation of irrigation depths. It is to be noted that all the water within the AWC range is not equally available to plants, but a lesser value defined as Readily Available Water Capacity (RAWC) provides an assessment of this figure. Water becomes more difficult for plants to absorb the closer the soil water potential moves towards the wilting point (-500 kPa).

Mr Hugh Wilde of Landcare Research in Palmerston North has provided a data for AWC and RAWC for a few selected soil types in the Manawatu and Horowhenua districts. This information is presented in Table 2 below.

Table 2. Available water capacities for some selected Manawatu-Horowhenua soils

Series	Type	AWC	RAWC	Data depth	Capacity to 70 cm depth (mm)	
		(%, v/v)	(%, v/v)	(cm)	AWC	RAWC
Foxton	black sandy loam	15.5	9.4	100	109	66
Pukepuke	black sandy loam	15.3	6.5	80	107	46
Kawhatau	stony silt loam	25.8	6.9	52	* 134	* 36
Tokomaru	silt loam	19.7	11	77	138	77
Kairanga	silt loam	26	6.6	100	182	46
Manawatu	silt loam	13.5	6.2	90	95	43
Marton	silt loam	15.2	11	100	106	77
Omanuka	peat	39.2	12	70	274	84
Taupo	sandy silt	14	-	70	168	-

* Depth to 52 cm

- Data not available

Notes:

Data from Otaki District soil survey and the Manawatu Soil Water and Measurement Programme.

No data is available for Makerua soils, so Omanuka soils (sandy peat soils) are given instead.

Source: Hugh Wilde, Landcare Research

I have attached some photographs of profiles of the soil types mentioned in Table 2 above, at the end of this Appendix. They will demonstrate to the Panel the variations between the soils, types of layering between the topsoil and subsoil/s, variations in particle size, texture, colour, organic matter content, rooting depth, and effects of groundwater such as mottling and gleying. Soil texture (resulting from the proportion of sand, silt or clay), presence of stones/gravel and vegetation (rooting depth) and the depth of groundwater table are the key factors in the ability of the soil to transmit or hold water.

As shown in Figure 1 below, in general, the finer the soil texture the greater the AWC. In sand, the difference between the FC and PWP is small, while in a clay the difference is large, giving a large AWC. As the figure shows, the greatest difference between the FC and PWP is for a silt loam texture. The silt loam has a greater AWC than the clay because it has a smaller PWP value, while having a similar FC value.

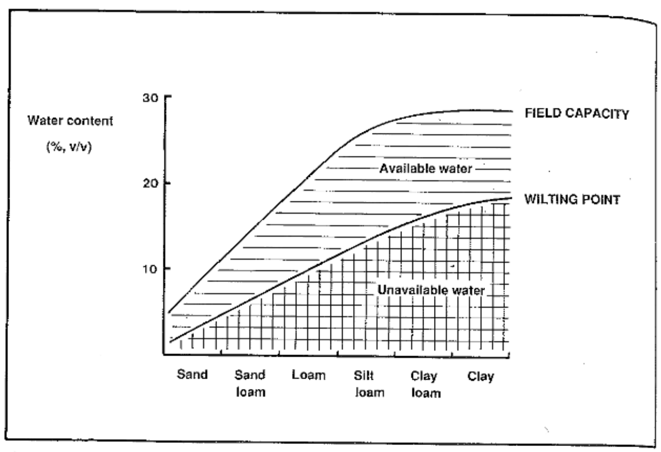


Figure 1. The relationship between soil texture and soil water content at field capacity and permanent wilting point (adapted from Cassel, 1983). Source: McLaren and Cameron, 1997.

The following factors have a major influence on the available water capacity (AWC) of a soil:

- Soil texture – finer the texture greater the AWC.
- A mineral soil with high organic matter content has a greater AWC than one with low organic matter level. While organic matter attracts water, due to surface charge this water is generally unavailable to plants and it is the beneficial effects of the organic matter on soil structure that is more important.
- The salt levels – high concentrations of salt in the soil solution in the soil lower the water potential, making it unavailable for plant uptake.

Rainfall and potential evapotranspiration

As New Zealand is surrounded by ocean, air masses moving over it tend to be moist. When this air when forced to rise over the central divide or via convection, it is subjected adiabatic cooling, condenses, forms clouds and often rain. The map of New Zealand below shows the annual rainfall distribution resulting from the prevailing westerly winds and the central ranges.

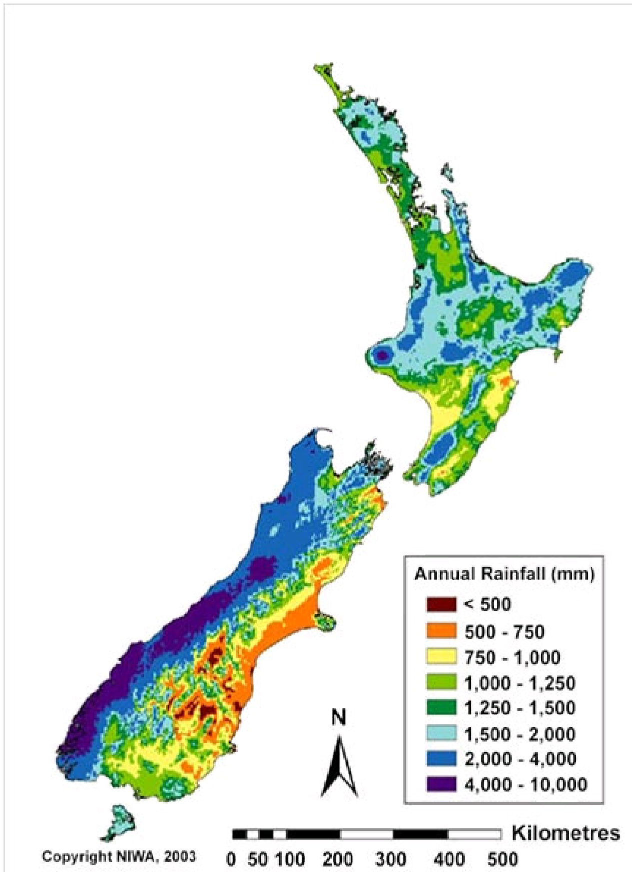


Figure 2. Rainfall distribution - average annual rainfall (mm) over NZ (NIWA, 2003)

New Zealand is considered generally lucky in terms of the amount of rainfall received and its reliability. Across the country rainfall patterns can be seasonal. There is a slight winter excess in the central and northern parts of the North Island but seasonal rainfall can vary between 40-50% in a 1 in 10-year event. Rainfall can also vary considerably over quite short distances, particularly if there are hills or mountains nearby. So, access to better than average annual or even monthly rainfall is required for managing irrigation of wastewater application regimes and this information (daily monitoring) needs to be collected from a station in close proximity to the activity.

Other climate information (temperature, wind and potential evapotranspiration) together with details of plant (trees, crops and pasture) uptake, and past and future land use, are factors for assessing options for land application regimes. This assessment determines how much land is likely to be required for a sustainable system.

To illustrate the variability between monthly mean rainfall and reference crop evaporation (also termed Potential Evapotranspiration[1] or PET). I include plots of these parameters for Palmerston North and Napier. The potential soil moisture deficit period has implications for both irrigation and land treatment (wastewater application) regimes.

Table 3. Average monthly rainfall and PET data for Palmerston North and Napier Airports

	Palmerston North (E05361)		Napier (D96481	
Month	**Mean Monthly Rainfall [1] (mm)**	**Mean Monthly PET [2] (mm)**	**Mean Monthly Rainfall[1] (mm)**	**Mean Monthly PET[2] (mm)**
June	81	17	92	22
July	89	20	79	24
August	78	33	75	38
September	82	55	70	63
October	73	84	53	99
November	62	108	48	126
December	91	126	74	145
January	64	131	51	151
February	60	107	60	117
March	71	82	90	92
April	65	50	71	57
May	81	26	67	33
June	81	17	92	22
Totals	**897**	**839**	**830**	**967**

Source:
1 Rainfall normals for NZ for the period 1961 to 1990 (NIWA Science & Technology Series No 3).
2 Long term mean monthly and annual reference crop evaporation (PET mm) calculated using Penmans (NZ Meteorological Service).

1 Potential evapotranspiration or PET is a measure of the ability of the atmosphere to remove water from the surface through the processes of evaporation and transpiration assuming no control on water supply.

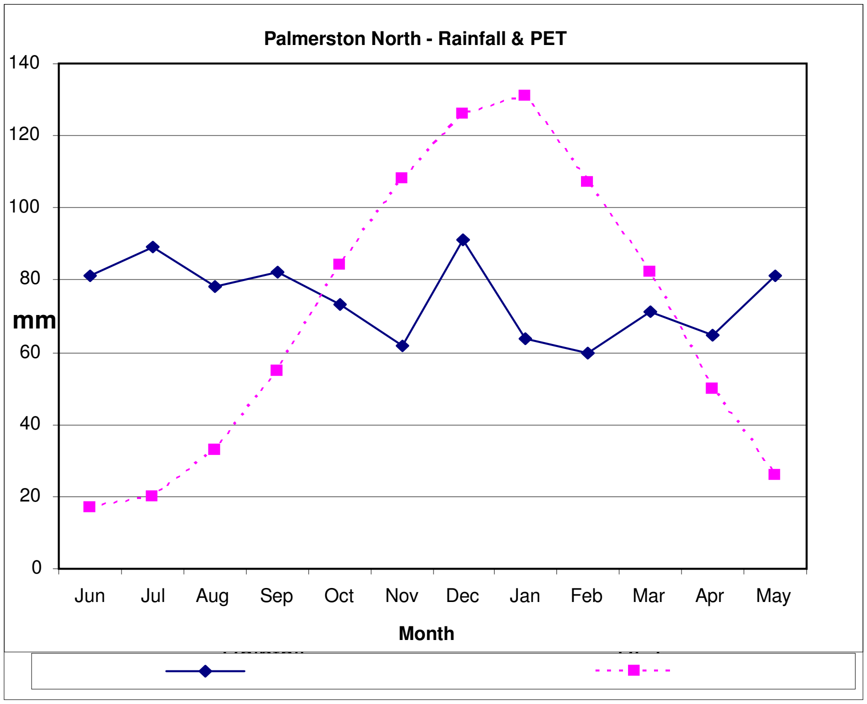


Figure 3. Plots of mean monthly rainfall and Potential Evapotranspiration (PET) for Palmerston North

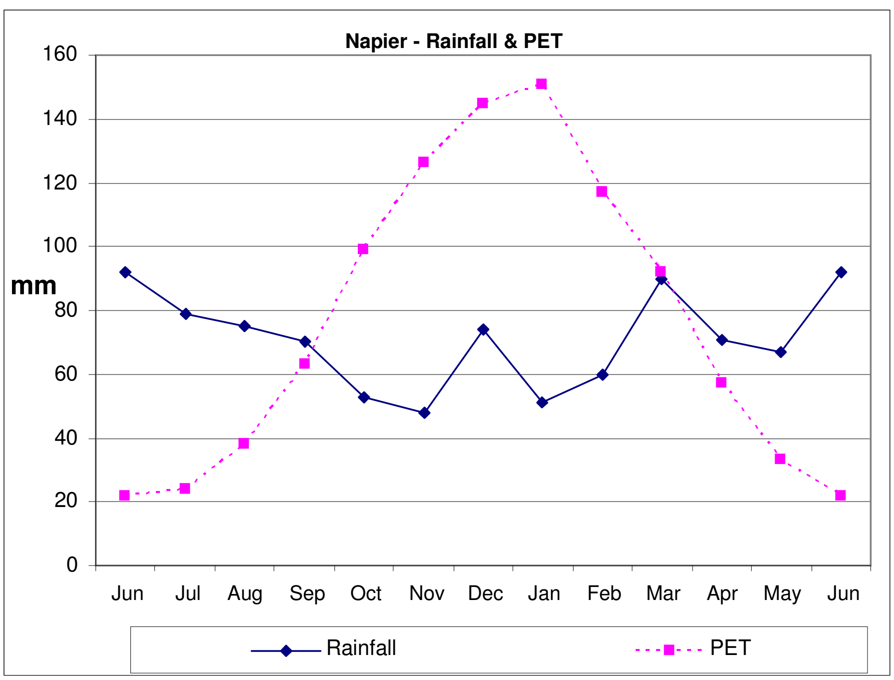


Figure 4. Plots of mean monthly rainfall and Potential Evapotranspiration (PET) for Napier

Water Table

The depth to the normal 'high' water table is also a key determinant in protecting groundwater quality under a wastewater application area. It is of particular concern in porous soils. A buffer between the high groundwater level and wastewater application level is desirable to ensure the soil layers, plant roots and organisms in the soil 'treat' the waste as it percolates through the down the profile.

The high ground water level can be obtained by monitoring an investigation borehole or can be deduced from soil colour and patterns in the soil profile. Detail is presented in Appendix 2 of the manual[2] (Soil Description). It is important to pragmatically differentiate between the high groundwater level and the 'short duration' perched water table that can becomes obvious at sites a short time after very heavy rainfall events.

A separation of 600-1500mm to the groundwater level is the conservative suggested buffer distance for providing effective land treatment for on-site domestic wastewater. The larger distance is suggested for primary treated wastewater in the manual (Barnett, 2009).

Vegetation

The type of vegetative cover (trees, crop or grass) is an integral part of the natural treatment of waste applied to land. A healthy vegetative cover, via its rooting system, is important for efficient treatment for the following functions:

- uptake of water and nutrients
- stabilising soil and preventing erosion
- providing food and habitat for soil micro-organisms to break down and use waste constituents.

Wastewater characteristics

Information requirements as to the nature and volume of the wastewater stream include:

- daily load (and peak load)
- availability for pre-application storage
- nutrient loading (concentrations of N, P, K, S)
- organic loading, dissolved salts (Na^+, Cl^-, DOM)
- suspended solids
- toxic elements (heavy metals, trace organic compounds)
- types and concentrations of micro-organisms (pathogens)

- oil and grease
- pH.

NOTE: An appreciation of how water and nutrients (nitrogen and phosphorus) behave in the environment is the basis of land treatment, ie. the water, nitrogen and phosphorus cycles. I attach Agronomy Fact Sheets Numbers 2 and 12 from Cornell University, USA. The fact sheets describe the nitrogen and phosphorus cycles.

Dr Brent Clothier (Plant and Food Research), Drs Dave Houlbroke and Stewart Ledgard (AgResearch), Dr Roger Parfitt (Landcare Research) and Horizons' Mr Hisham Zarour will be presenting information to the Panel with regard to the nitrogen cycle.

I briefly discuss the water cycle below.

The hydrological (water) cycle

The amount of water on earth is pretty much constant, but is mostly on the move. The main pathways water can take are shown is a simplified diagram below (Figure 5):

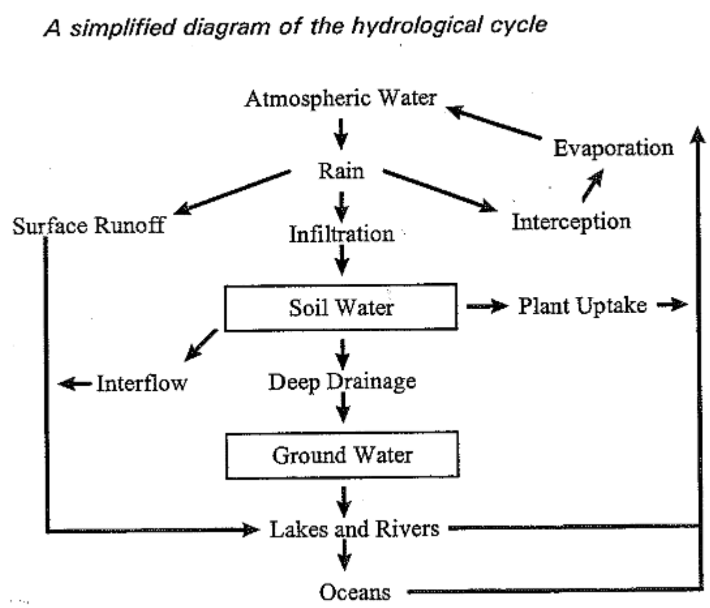


Figure 5. A simplified diagram of the hydrological cycle (Scotter, D., Massey University, 89.361 Transport Processes in Soils Study Guide)

The diagram shows that the soil is involved in two major branching points – each branching three ways. The first is at the soil surface. Here rainfall can soak into the soil (infiltration), pond on the surface and become run-off, or be caught by the foliage and evaporate directly from there (interception). Whether or not the rain reaching the soil soaks in or runs off depends largely on how heavy the rain event is, and how permeable the soil is. The permeability of the soil depends on the size and number of pores the soil.

The second branching point is within the soil, where the water can move laterally through the topsoil (interflow), move on downwards and out of the soil as deep drainage to become groundwater, or be stored in the soil to be later taken up by plants and lost as evaporation. The ability of the soil to store large amounts of available water for plants depends on the pore size distribution. The presence of large pores does not give a soil a low available water-holding capacity it is the absence of medium-sized pores.

A change in any part of the cycle has flow-on effects. Irrigation or the land application of wastewater can be thought of as short-circuiting the atmospheric part of the water cycle. Water from a stream or from the ground is extracted, pollutants added, and it then infiltrates into the soil. Inevitably, there will be more deep drainage, more interflow, and/or more plant uptake. Artificial drainage also changes the cycle. Drainage can be thought of as artificially inducing interflow, which in turn increases infiltration and reduces surface run-off.

Put in an equation format: Change in water storage = Inputs – Outputs

So a change of inputs to any part of the cycle will affect the amount of storage, and /or one or more of the outputs from that part of the cycle.

For example, take growth of pasture around Palmerston North over the year. Rainfall on average provides an input of 900 mm of infiltration. Plant (pasture) uptake and evaporation accounts for an output of approximately 840 mm annually. Over the year, the net change in storage is small with only a 60 mm excess of rainfall over evapotranspiration. This amount is lost as deep drainage or in artificial drainage, ending up in the groundwater or in the Manawatu River.

Dr Brent Clothier, in Sections 3 and 4 of his evidence, sets out and discusses the soil, plant atmosphere model (SPASMO) and its use to predict the need for irrigation for production and the hydrological impacts. In Sections 5, 6 and 7, he discusses the nitrogen cycle and uptake of nitrogen by plants and the fate of nitrogen compounds in the soil, resulting from non-point source pollution by nutrients from farming activities. Dr Clothier and his colleagues have been have been the lead advisers to Horizons on these matters.

If water-based effluent in excess of the PET is applied to pasture during dry periods in the summer months, plant uptake will increase, causing some of this extra water to be taken up by evaporation. The rest of the water and effluent applied will inevitably end up in either the groundwater or in the streams and in the Manawatu River. Therefore, managing the rate and volume of irrigation or the effluent application to uptake is fundamental to ensuring drainage does not adversely impact of the water quality of the Manawatu River.

I have also attached Cornell University Agronomy Fact Sheets Numbers 2 and 12 that describe succinctly how nitrogen and phosphorus and their compounds behave in the soil, plant and air environments. An understanding of basic soil science (physio-chemical characteristics of the particular soil) and the soil/plant system is fundamental to effective land treatment. Fact Sheet 2 is entitled Nitrogen Basics – the Nitrogen Cycle, and Sheet 12 Phosphorus Basics – the Phosphorus Cycle. The Sheets are from the Cornell University, Department of Crop and Soil Sciences, NY, USA.

Plants and the soil have a capacity to assimilate and renovate farm, municipal and industrial wastewater. This capacity will vary with location, topography, climate (temperature and rainfall) but specifically with the type of plants or vegetation, soil type (sand, clay or loam) and its moisture content, the quality of the wastewater, and its application rate.

By controlling the hydraulic and nutrient (nitrogen and phosphorus) loading rate within the constraints of the physio-chemical characteristics of the soil, and the ability of the plants or crops to uptake nitrogen, it is possible to minimise or even eliminate the leaching of nitrates to groundwater. This may mean no application to land at times when conditions are unfavourable, thus making storage of the potential waste stream a critical component of land treatment systems.

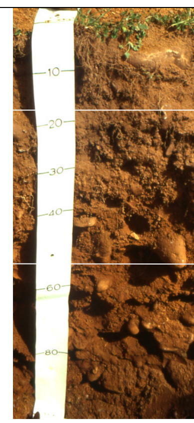
Photographs of some common soil profiles in Horizons' Region

(Source: Hugh Wilde, Landcare Research)

Foxton – black sandy loam

Pukepuke – black sandy loam

Ashhurst – stony silt loam



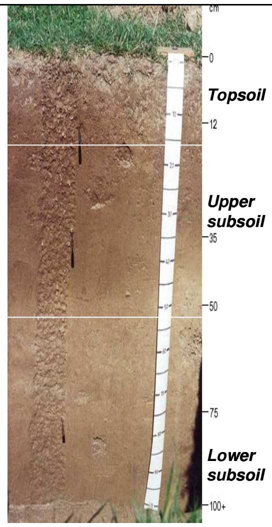
Kawhatau – stony silt loam

Tokomaru – silt loam

Kairanga – silt loam

Photographs of some common soil profiles in Horizons' Region

(Source: Hugh Wilde, Landcare Research)

	
Manawatu – silt loam	Marton – silt loam
	
Pukepuke – peaty loam	Makerua - peaty loam
	
Moawhango – volcanic loam (Taupo pumice and Tongariro ash)	Te Puke – volcanic sandy loam (yellow brown pumice)

Cornell University
Cooperative Extension

Agronomy Fact Sheet Series **Fact Sheet 2**

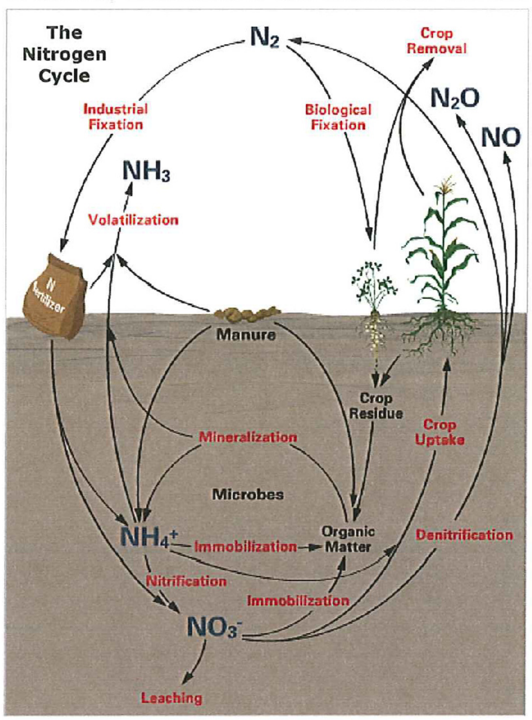
Nitrogen Basics – The Nitrogen Cycle

Nitrogen, Crops and the Environment

Nitrogen (N) is essential for the development of field crops. When N is deficient, root systems and plant growth are stunted, older leaves turn yellow and the crop is low in crude protein. Too much N can delay maturity and cause excessive vegetative growth at the expense of grain yield. Nitrogen fertilizer is expensive and losses can be detrimental to the environment. Efficient use of N by meeting crop needs while avoiding excessive applications of N is an important goal. This fact sheet provides a brief overview of the important components of the N cycle to aid in reaching that goal.

Nitrogen Cycle

The N cycle illustrates how N from manure, fertilizers and plants moves through the soil to crops, water and the air. Understanding the N cycle will help you make the best use of manure and fertilizers to meet crop needs while safeguarding the environment. In general, the N cycle processes of *fixation*, *mineralization* and *nitrification* increase



plant available N. *Denitrification*, *volatilization*, *immobilization*, and *leaching* result in permanent or temporary N losses from the root zone. Read on for specifics about each of the N cycle processes.

Fixation refers to the conversion of atmospheric N to a plant available form. This occurs either through an industrial process, as in the production of commercial fertilizers, or a biological process, as with legumes such as alfalfa and clover. Nitrogen fixation requires energy, enzymes and minerals, so if a plant available form of N is present, the crop will use it instead of fixing it from the air.

N_2	→	NH_3	→	$R\text{-}NH_2$
nitrogen gas		*ammonia*		*organic N*

- When legumes are tilled into the soil, the N stored in their roots is released and made available to the next crop or lost to the environment, depending on management.
- In mixed legume-grass stands, the grass can utilize N fixed by the legumes. If the stand has 25% or more legume, no additional N is needed.

Mineralization is the process by which microbes decompose organic N from manure, organic matter and crop residues to ammonium. Because it is a biological process, rates of mineralization vary with soil temperature, moisture and the amount of oxygen in the soil (aeration).

$R\text{-}NH_2$	→	NH_3	→	NH_4^+
organic N		*ammonia*		*ammonium*

- Mineralization readily occurs in warm (68-95°F), well-aerated and moist soils.
- In New York State, approximately 60—80 lbs of N per acre is mineralized on average from soil organic matter each year.

Nitrification is the process by which microorganisms convert ammonium to nitrate to obtain energy. Nitrate is the most plant available form of N, but is also highly susceptible to leaching losses.

NH_4^+	→	NO_2^-	→	NO_3^-
ammonium		*nitrite*		*nitrate*

- Nitrification is most rapid when soil is warm (67-86°F), moist and well-aerated, but is virtually halted below 41°F and above 122°F.

Denitrification occurs when N is lost through the conversion of nitrate to gaseous forms of N, such as nitric oxide, nitrous oxide and dinitrogen gas. This occurs when the soil is saturated and the bacteria use nitrate as an oxygen source.

NO_3^-	→	NO_2^-	→	NO	→	N_2O	→	N_2
nitrate		*nitrite*		*nitric oxide*		*nitrous oxide*		*dinitrogen gas*

- De-nitrification is common in poorly drained soils.

Volatilization is the loss of N through the conversion of ammonium to ammonia gas, which is released to the atmosphere. The volatilization losses increase at higher soil pH and conditions that favor evaporation (e.g. hot and windy).

$H_2N\text{-}\overset{O}{\overset{\parallel}{C}}\text{-}NH_2$	→	NH_4^+	→	NH_3
Urea		*ammonium*		*ammonia*

- Volatilization losses are higher for manures and urea fertilizers that are surface applied and not incorporated (by tillage or by rain) into the soil.
- Manure contains N in two primary forms: ammonium and organic N. If manure is incorporated within one day, 65% of the ammonium N is retained; when incorporated after 5 days the ammonium N will have been lost through volatilization. Organic N in manure is not lost through volatilization, but it takes time to mineralize and become plant available.

Immobilization is the reverse of mineralization. All living things require N; therefore microorganisms in the soil compete with crops for N. Immobilization refers to the process in which nitrate and ammonium are taken up by soil organisms and therefore become unavailable to crops.

NH_4^+ *and/or* NO_3^-	→	$R\text{-}NH_2$
ammonium *nitrate*		*organic N*

- Incorporation of materials with a high carbon to nitrogen ratio (e.g. sawdust, straw, etc.), will increase biological activity and cause a greater demand for N, and thus result in N immobilization
- Immobilization only temporarily locks up N. When the microorganisms die, the organic N contained in their cells is converted by *mineralization* and *nitrification* to plant available nitrate.

Leaching is a pathway of N loss of a high concern to water quality. Soil particles do not retain nitrate very well because both are negatively charged. As a result, nitrate easily moves with water in the soil. The rate of leaching depends on soil drainage, rainfall, amount of nitrate present in the soil, and crop uptake.
- The EPA has set the maximum contaminant level for drinking water at 10 ppm N as nitrate.
- Well-drained soils, unexpected low crop yield, high N inputs (especially outside of the growing season) and high rainfall are all conditions that increase the potential for nitrate leaching.

Crop Uptake is the prime goal of N management on farms. The greatest efficiency occurs when adequate N is applied at a time when the crop is actively taking it up. Efficient N use also depends on a number of other factors including temperature, soil moisture, pest pressure, and soil compaction.
- In the moist Northeast climate, nitrate remaining in the soil after the growing season will be lost to leaching or denitrification between crop harvest and the next planting season.
- Efficient N use during the growing season and the use of cover crops can minimize such losses.

Summary The ultimate goal of N management is to maximize N efficiency by increasing crop uptake and minimizing N losses to the environment. Crop N needs can be met through existing N sources (e.g. from soil organic matter, past sods and previously applied manure) and supplementary applications of N through manure and fertilizers. To make the most of existing N sources and purchased fertilizers, consider the N cycle facts, below:
- N released from killed sods, via mineralization and nitrification, can supply enough N for most, if not all, of the N needs of the following corn crop.
- The timing and method of manure and fertilizer applications determine the availability of nitrogen to the crop, but also the potential for loss. Spring applications with immediate incorporation will conserve ammonium from volatilization losses.
- Fall cover crops act as a "nutrient savings account" by taking up residual N from the growing season or fall manure applications and, thereby, reducing leaching losses. The nutrients in the cover crop become available for the next crop (by mineralization) after the sod is rotated.

For more information about N management in field crops (N guidelines, N calculators, etc.), see the "Nutrient Guidelines" section of the Nutrient Management Spear Program web site, below, or contact your local Cornell Cooperative Extension field crop educator.

For more information

Cornell University
Cooperative Extension

Nutrient Management Spear Program
http://nmsp.css.cornell.edu

Authors
Courtney Johnson, Greg Albrecht, Quirine Ketterings, Jen Beckman, and Kristen Stockin
2005

Phosphorus Basics – The Phosphorus Cycle

Phosphorus, Crops and the Environment

This agronomy fact sheet provides a brief overview of the important components of the phosphorus (P) cycle. Understanding the P cycle can help producers make decisions regarding P management on the farm, both for farm profitability and protection of the environment.

Most plants are only about 0.2% P by weight, but that small amount is critically important. Phosphorus is an essential component of adenosine triphosphate (ATP), which is involved in most biochemical processes in plants and enables them to extract nutrients from the soil. Phosphorus also plays a critical role in cell development and DNA formation. Insufficient soil P can result in delayed crop maturity, reduced flower development, low seed quality, and decreased crop yield. Too much P, on the other hand, can be harmful in some situations; when P levels increase in fresh water streams and lakes, algae blooms can occur. When algae die, their decomposition results in oxygen depletion which can lead to the death of aquatic plants and animals. This process is called "eutrophication" (see Agronomy Fact Sheet #13: Phosphorus Runoff, for additional information).

Crop Uptake

One goal with field crop management is to optimize crop uptake of available P. A typical corn silage crop will remove about 4.3 lbs of P_2O_5 per ton of silage (35% dry matter). Soil testing of available P can help avoid application of fertilizer P that is not needed for optimum production. Applying fertilizer beyond crop needs is a waste of time and money, and can be harmful to the environment.

Phosphorus Cycle

Phosphorus exists in many different forms in soil. For practical purposes, we can group these sources into four general forms: (1) plant available inorganic P, and three forms which are not plant available: (2) organic P, (3) adsorbed P, and (4) primary mineral P. The P cycle in Figure 1 shows these P forms and the pathways by which P may be taken up by plants or leave the site as P runoff or leaching. The general P transformation processes are: weathering and precipitation, mineralization and immobilization, and adsorption and desorption. Weathering, mineralization and desorption increase plant available P. Immobilization, precipitation and adsorption decrease plant available P.

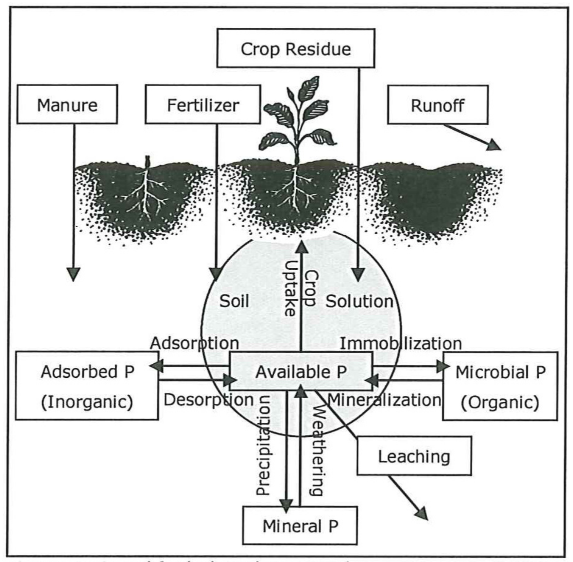


Figure 1: Simplified phosphorus cycle.

Weathering and Precipitation

Soils naturally contain P-rich minerals, which are weathered over long periods of time and slowly made available to plants. Phosphorus can become unavailable through precipitation, which happens if plant available inorganic P reacts with dissolved iron, aluminum, manganese (in acid soils), or calcium (in alkaline soils) to form phosphate minerals.

Mineralization and Immobilization

Mineralization is the microbial conversion of organic P to $H_2PO_4^-$ or HPO_4^{2-}, forms of plant available P known as orthophosphates.

Immobilization occurs when these plant available P forms are consumed by microbes, turning the P into organic P forms that are not available to plants. The microbial P will become available over time as the microbes die.

- Maintaining soil organic matter levels is important in P management. Mineralization of organic matter results in the slow release of P to the soil solution during the growing season, making it available for plant uptake. This process reduces the need for fertilizer applications and the risk of runoff and leaching that may result from additional P.
- Soil temperatures between 65 and 105°F favor P mineralization.

Adsorption and Desorption

Adsorption is the chemical binding of plant available P to soil particles, which makes it unavailable to plants. Desorption is the release of adsorbed P from its bound state into the soil solution.

- Adsorption (or "fixing" as it is sometimes called) occurs quickly whereas desorption is usually a slow process.
- Adsorption differs from precipitation: adsorption is reversible chemical binding of P to soil particles while precipitation involves a more permanent change in the chemical properties of the P as it is removed from the soil solution.
- Soils that have higher iron and/or aluminum contents have the potential to adsorb more P than other soils.
- Phosphorus is in its most plant available form when the pH is between 6 and 7 (Figure 2). At higher pH, P can precipitate with Ca. At lower pH, P tends to be sorbed to Fe and Al compounds in the soil.

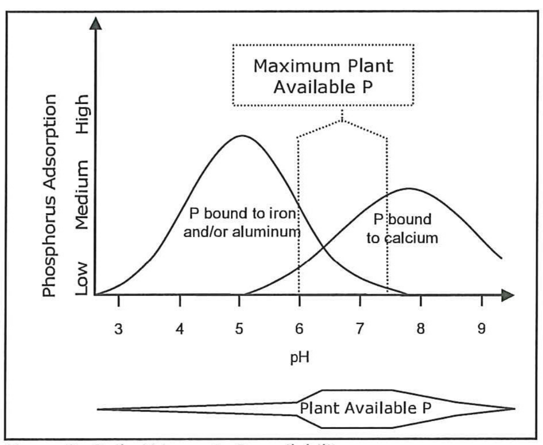


Figure 2: Soil pH impacts P availability.

- Every soil has a maximum amount of P that it can adsorb. Phosphorus losses to the environment through runoff and/or leaching increase with P saturation level.
- Precise fertilizer placement can decrease P adsorption effects by minimizing P contact with soil and concentrating P into a smaller area. Band application of fertilizer is a common example of this (see Agronomy Fact Sheet #8: Starter P Fertilizer for Corn).

Runoff

Runoff is a major cause of P loss from farms. Water carries away particulate (soil-bound) P in eroded sediment, as well as dissolved P from applied manure and fertilizers. Erosion control practices decrease P losses by slowing water flow over the soil surface and increasing infiltration.

Leaching

Leaching is the removal of dissolved P from soil by vertical water movement. Leaching is a concern in relatively high P soils (near or at P saturation), especially where preferential flow or direct connections with tile drains exist.

Summary

Crop uptake is the goal of applying P fertilizer or manure to the soil. If soil test P levels are already optimum, P additions through fertilizer or manure should not exceed crop removal. If additional P is needed (soils testing low or medium in P), P adsorption can be minimized by band applications and by maintaining an optimum pH. Naturally occurring immobilization of P by microbes can help ration plant available P to crops over the course of a growing season. Steps should be taken to reduce losses in order to maximize the efficiency of fertilizer and manure applications.

For more information

Cornell University Cooperative Extension

Nutrient Management Spear Program
http://nmsp.css.cornell.edu

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2005

APPENDIX 3

Document 1.4.3.9 Minimum Engineering Standards
On-site Wastewater Systems in the Horowhenua District

That any on-site wastewater system being installed, is to be to the approval and in compliance with requirements of Horizons Regional Council "Land and Water Regional Plan" (Oct 2003) and the Manawatu Catchments Water Quality Regional Plan (Oct 1998). Written approval of this shall be submitted to HDC and Issuance of the Project Information Memorandum & Building Consent is subject to approval of the wastewater disposal design by the MWRC. No works shall commence prior to issuance of the same. It is to be designed and installed by a professional and suitable qualified person experienced in onsite effluent disposal systems. The system is to be situated and installed so as to avoid any significant adverse effects on human health or the environment or a nuisance to neighbouring properties.

Minimum Requirements for an On-site Wastewater System.

Horizons Regional Council endorses the introduction and use of the Minimum Requirements for On-site wastewater systems as stated in the “Minimum Engineering Standards”. These should be used as a bullet point guide-line that people wishing to install and comply with Regional Councils requirements for an on-site wastewater system on their property in the Horowhenua.

- (Please contact the Horowhenua District Council or Horizons Regional Council if you need an explanation or clarification of the requirements detailed below)

Site Assessment, design, installation and compliance

- Site assessment to be carried out by a suitably qualified person.
- A suitable professional shall undertake the design and installation of the onsite treatment system.
- Preference is for secondary treatment.
- The property owner shall ensure that a test on the wastewater system is carried out by the installer or manufacturer within a 4-month period of its installation to demonstrate its compliance with AS/NZ 1547:2000. A copy of the compliance results is to be sent to Horowhenua District Council.
- On-site system capacity is to be designed to occupancy based on the number of bedrooms in the dwelling – as per Table 4.3A1 AS/NZS 1547:2000.
- Any on-site system is to have a capacity of not less than 4500 litres.
- The system is to include an outlet filter to a standard prescribed in AS/NZS 1547:2000.

- ❖ The system shall evenly distribute effluent to the entire disposal field by either pump or dosing siphon.
- ❖ Every system shall have a minimum 3-year service/maintenance contract with the supplier or its agent post installation.

Effluent Disposal Fields

Location requirements

- ❖ Have at least 20m separation distance between neighbouring disposal fields.
- ❖ Located no closer than1. 5 meters from any boundary.
- ❖ Located not closer than 20 metres from valley floors, storm drains, any type of open water body, or down-slope land boundaries, and 20m down-gradient (ie. with respect to groundwater flow) from drinking water bores.
- ❖ Located in an area where the ground surface is free of inundation in a 10-year flood event.
- ❖ The underside of the disposal bed is to be not less than 600mm above the highest water table.
- ❖ Preference is for disposal into the top soil.
- ❖ In a designated area free from slopes over 18 degrees (3 horizontal - 1 vertical)

Site requirements

- ❖ A primary effluent disposal field of not less than 250m2 (average 3 bedroom home)
- ❖ A ‘reserve area’ of equivalent size to the designed effluent disposal area shall be set-aside on the same lot for future expansion of replacement of disposal area.
- ❖ Maximum discharge to land not to exceed 1500 litres/day per primary disposal field.
- ❖ With suitable soils and groundwater conditions, for lot sizes under 4,999m2 the aerial effluent-loading rate shall not exceed 3.5 litres/m2/day
- ❖ With suitable soils and groundwater conditions, for lot sizes over 5,000m2 the aerial effluent-loading rate shall not exceed 5 litres/m2/day.

Others

- ❖ Suitable plants and shrubs shall be planted and maintained in the disposal field.
- ❖ Fencing of the disposal field from children and animals may be necessary as a protection for public health. (This will be identified and specified at time of application)
- ❖ Once the effluent disposal system has been installed, it the responsibility of the property owner to maintain. It is to be maintained to a standard and manner that avoids adverse effects on human health, the environment or a nuisance to neighbouring properties, and is to at all times to be in compliance with Horizons Regional Councils "Manawatu

Catchment Water Quality Regional Plan" (October 1998) and the "Land and Water Regional Plan" (October 2003)

- If at sub-division stage an existing effluent disposal system on any Lot within the proposed development is found to be more than 10 years old, it must then be proven by the owner to comply with the current " Minimum Requirements for Onsite Effluent Disposal" within the Horowhenua District adopted jointly by Horowhenua District Council and Horizons Regional Council

Document 1.4.3.9