in the matter of:	the Resource Management Act 1991
and:	submissions and further submissions in relation to proposed variation 1 to the proposed Canterbury Land and Water Regional Plan
and:	**Fonterra Co-operative Group Limited** *Submitter*

Statement of evidence of Robert John Potts (nutrients)

Dated: 29 August 2014

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CHAPMAN TRIPP

STATEMENT OF EVIDENCE OF ROBERT JOHN POTTS

A. INTRODUCTION

1 My name is Robert John Potts.

2 I hold the qualification of NZCE (Civil), BE(Hons)(Ag), Dip Hydrology(groundwater), CPEng and I have also completed the *Making Good Decisions* course. I am a Member of IPENZ, Water NZ (ex-Chairman of Small Wastewater and Natural Systems Group (SWANS), NZ Land Treatment Collective (ex-President) and Irrigation NZ. I am currently on the Water NZ Technical Committee, am Chairman of the On-site Wastewater System National Testing Programme and am on the Industry Review Panel for Unit Standards in On-site Wastewater Training.

3 I am currently employed by Lowe Environmental Impact Limited as an Environmental Engineer.

4 I have worked in the area of Agricultural Engineering since 1977, firstly with Ministry of Agriculture and Fisheries, then from 1989 until 1994 with Lincoln University, and from 1994 I have worked in private practice. I have assessed the effects of irrigation development and farm intensification in NZ, Australia, Pakistan, Algeria and Vietnam.

5 My involvement in the Fonterra Darfield project began in 2011 and I have undertaken numerous site visits. I understand the project, the soils, irrigation operation, nutrient loading and leaching assessments.

6 In preparing my evidence, I have also read the evidence of Mr **Ian Goldschmidt, Ms Sharon Dines** and **Mr Peter Callander** and the relevant parts of the Officers section 42A Report.

B. SCOPE OF EVIDENCE

7 In my evidence I have been asked to:

7.1 provide an introduction to the nitrogen (N) and phosphorus (P) cycles;

7.2 provide an outline of the he current lawfully permissible leaching load from the Fonterra Darfield operation, including third party farms;

7.3 provide a comparison of the lawfully permissible leaching load with the values provided in Loe (2013) that make up Table 11(i) in the proposed Plan;

7.4 provide a more accurate Table 11(i) for the proposed Plan (as it might support Fonterra's alternative relief);

7.5 discuss the most appropriate place in the Plan to allocate loads from farms used for industrial discharges; and

7.6 discuss how industrial wastes are used as a general 'farm fertiliser' on non-specified farms.

8 Although this is a Council hearing, I have read the Expert Witness Code of Conduct set out in the Environment Court's Practice Note 2011. I have complied with the Code of Conduct in preparing this evidence and I agree to comply with it while giving oral evidence before the hearing committee. Except where I state that I am relying on the evidence of another person, this written evidence is within my area of expertise. I have not omitted to consider material facts known to me that might alter or detract from the opinions expressed in this evidence.

C. INTRODUCTION

9 **Mr Goldschmidt** provides an overview of Fonterra and its Darfield operation in his evidence.

10 As discussed by **Mr Goldschmidt**, processing at the site produces various waste streams requiring treatment and disposal. These include process wastewater, clean process water, Dissolved Air Flotation (DAF) sludge, stormwater and domestic wastewater. These waste streams undergo various forms of treatment before they are tertiary treated via application to land on and around the site. The waste streams and their treatment methods are:

10.1 **Process Wastewater** - this is largely generated during the cleaning of the manufacturing plant. The wastewater contains mainly milk and dairy product residues (milk solids), and dilute concentrations of nitric acid, sodium hydroxide and dairy sanitisers used in the clean-in-place (CIP) system. It undergoes primary treatment via DAF, mainly to remove solids and fats, before land treatment via spray irrigation;

10.2 **Clean Process Water** - this is mainly the recovered water evaporated from the milk, also known as condensate water or COW Water. The condensate is a clean wastewater stream containing only traces of milk contaminants produced during the evaporation process. This stream does not require preliminary treatment prior to land treatment via spray irrigation;

10.3 **DAF Sludge** - this is not a specific waste stream but a by-product of the wastewater treatment system. It is treated by land treatment via soil injection 50 mm into the soil through a slot applicator;

10.4 **Stormwater** - this is runoff from impervious surfaces within the plant site. It is treated via land treatment through swales and then infiltration basins; and

10.5 **Domestic sewage** - this is the wastes from on-site toilets, wash facilities and kitchens. It is treated by a packed bed reactor (PBR) before land treatment via a sub-surface drip irrigation system.

11 Fonterra currently holds various consents associated with the above discharges to land. The consents that relate to land application of various waste streams from the site are illustrated in **Table 1** and attached to **Mr Goldschmidt's** evidence as his Annexure 1.

Table 1: Land Application Consents Details

Consent	**Description**	**Land Owner**	**Effective Farm Area**	**Irrigated Area**	**Volume Limit**
CRC103594	Process wastewater	Fonterra	635	492.1	2,360,000 m^3/yr
CRC140775	Clean process water	Gunn (third party)	191	121.3	500,000 m^3/yr
CRC140777	Clean process water	Gray (third party)	221	174.4	500,000 m^3/yr
CRC133976	DAF sludge	Multiple	N/A	498.8 [a]	20 m^3/ha/yr
CRC134753	Domestic sewage to Land	Fonterra	N/A	0.42	16 m^3/day
CRC103589.1	Stormwater to Land	Fonterra	N/A	1.11	N/A

a. The consent allows the area to be expanded without varying the consent provided certain conditions are met and it is approved by Manager Enforcement and Compliance.

12 The Fonterra Farm area is managed mainly as a cut and carry operation with limited grazing occurring. This means that most of the pasture dry matter is harvested and removed from the site as hay, silage or baleage and the stock carried for grazing are at low intensity to tidy up around fence lines, at less than 10 stock units/ha.

13 As part of the Stage 2 development, two additional areas of land were secured to enable irrigation of additional clean process water as shown on Figure 2 in **Mr Goldschmidt's** evidence. The two farms are contracted to take the clean process water and thus form part of the industrial site wastewater treatment system. They operate as pastoral grazing and cropping farms, with the clean process water providing an irrigation and minor nutrient source.

14 The Gunn Farm is managed by the owner with Fonterra staff operating the irrigation system. It is run as a support block for a neighbouring dairy farm, including the growing of crops for winter dairy grazing.

15 The Gray Farm is managed by the owner with Fonterra staff operating the irrigation system. It is run as a lamb finishing farm but also provides winter support to dairy farms on crops.

16 The DAF sludge is currently consented to be applied to 498.8 ha on five farms. The consent allows the area to be expanded without varying the consent provided certain conditions are met and the expansion is approved by Manager Enforcement and Compliance.

D. NUTRIENT CYCLES '101'

17 The movement of N and P through the soil to groundwater is very different. Commissioners at other hearings I have been involved with have found a brief introduction to the N and P cycles very helpful, so I have provided these below.

Nitrogen

18 Figure 1 provides a relatively simple N cycle. This does not show fertiliser being applied to the soil/plant interface, or in the Fonterra Darfield situation, fertiliser and wastewater on the Fonterra Farm, and fertiliser and clean process water on the Third Party Farms.

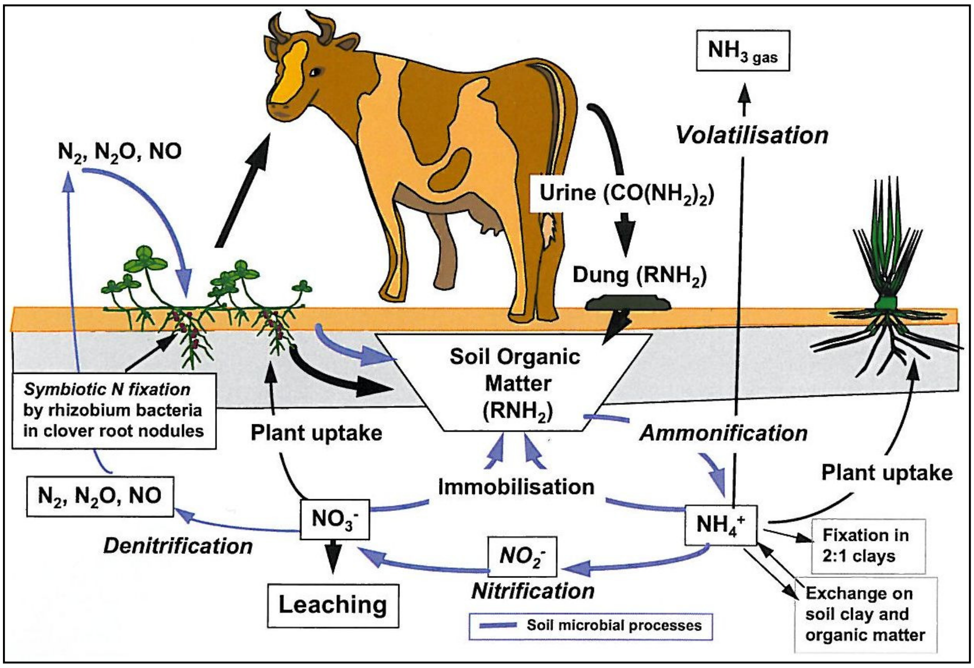

Figure 1: Nitrogen Cycle (Source: FLRC, 2012)

19 N can be in many forms (transformation of the forms is mostly by microbial processes as indicated in **Figure 1**):

19.1 **Organic N -** About 98% of the total soil N exists as a component of organic matter called the organic nitrogen fraction, which includes humus and soil organisms (RNH_2 in **Figure 1**). In organic forms, soil nitrogen is insoluble, unavailable to plants and described as immobilised.

19.2 **Mineral N (also referred to as soluble N, inorganic N or immediately plant available N)** - Around 2 - 3 % of the total soil N exists as ammonium (NH_4^+) or nitrate (NO_3^-) ions, called the mineral nitrogen fraction. Mineral N is formed through the decomposition of soil organic matter or from added fertiliser or wastewater containing NH_4^+-N or NO_3^-N. Mineral N is the form used by plants and soil microbes to make proteins. In the soil NH_4-N is strongly held to soil surfaces (particularly clays, humus and silts) while NO_3^-N is mobile (not strongly held) and prone to leaching.

19.3 **Gaseous N** - N exists in gaseous form as ammonia gas (NH_3), dinitrogen gas (N_2 which makes up 78% of the earth's atmosphere), nitrous oxide (N_2O) and nitric oxide (NO). N_2 gas can be "fixed" from the atmosphere by lightning strikes, but most fixation is done by symbiotic nitrogen-fixing bacteria such as Rhizobium that live in the root nodules of legumes. Gaseous N is also released from the soil. NH_3 gas can be produced during transformations of NH_4^+ in a process called volatilisation. N_2, N_2O

and NO are produced when NO_3^- is denitrified by soil bacteria in anaerobic conditions, i.e. water logged soils.

20 Nitrogen is also sometimes reported as Total Kjeldahl Nitrogen (TKN). TKN is the sum of organic nitrogen, ammonia (NH3), and ammonium (NH4+).

21 Nitrogen is a mobile essential plant nutrient, with numerous factors affecting transformation processes and distribution of nitrogen in the soil, such as temperature, crop type, soil texture, organic matter, soil depth, pH, gas losses, nitrification inhibitors and cultivation. Details of how these affect N in the soil are provided in **Attachment A**.

22 So what does the above mean for the Fonterra process wastewater and clean process water applied via spray irrigation?

23 The nitrogen forms of the Fonterra waste streams are shown in Table 2:

Table 2: Forms of N in Fonterra Waste Streams

	Organic mg/L (% Total Nitrogen (TN))	NH_4 mg/L (% TN)	NO_3 mg/L (% TN)	TN mg/L
Process Wastewater	60 (55%)	trace	50 (45%)	110
Clean Process Water	2 (99%)	trace	0.03 (1%)	2.03
Combine PWW and CPW	31 (55%)	trace	25 (45%)	56
DAF Sludge	7,000 (100%)	-	-	7,000
Bagged Fertiliser	N/A (50%)	N/A (50%)	-	-

24 The N is likely to be applied (and used or lost) in the following ways:

24.1 Virtually no N will be lost during spray application as there is minimal ammonia in the process wastewater and clean process water;

24.2 N from clean process water applied to the Third Party Farms is basically all organic with minimal nitrate-N and has very low concentrations (2 mg/L) and annual loading (24 kg N/ha/yr). This organic N has to undergo transformation to ammonium and then nitrate to be leached and this will only occur when soil temperatures are warm (see **Attachment A** regarding the effect of soil temperatures). Loading is such that it is likely to be less than plant requirements and additional nitrogenous fertiliser will be required to optimise plant growth;

24.3 Process wastewater applied to the Fonterra Farm is about 50:50% organic and nitrate-N, meaning that a portion is available for leaching if not used by plants. The process wastewater total nitrogen concentration is moderate (110 mg/L) and annual loading low for a partial cut and carry farm at 250 kg N/ha/yr. A significant amount of organic matter (carbon) is applied with the process wastewater and this will assist in reducing leaching and provide carbon for denitrification during wet conditions, probably in early winter;

24.4 Process wastewater and clean process water are applied little and often, evenly across the irrigated area and at controlled application rates and depths to match the soils infiltration and water holding characteristics. This maximises the potential for soil interaction with the nitrogen in the waste streams as it passes through the soil profile. In addition, when the soil is greater than 85% saturation, there is a 40% reduction in the application depth and storage at times of extreme weather.

24.5 Depending on the amount of cut and carry (harvesting of pasture and hay, silage and baleage), the N applied in wastewater is also likely to be insufficient and additional fertiliser will be required, particularly in spring.

25 Each year will be different. Climatic factors (rainfall, temperature and evapotranspiration) affect the rate of grass growth, the rate of mineralisation, the rate of denitrification and thus the amount of nitrate-N leached. The farming system also affects the amount of N leached and this may vary from year to year, particularly on the Third Party farms. The type of farm systems used on the three farms is outlined above in paragraphs 12 - 15.

Phosphorus

26 **Figure 2** provides a relatively simple phosphorus (P) cycle.

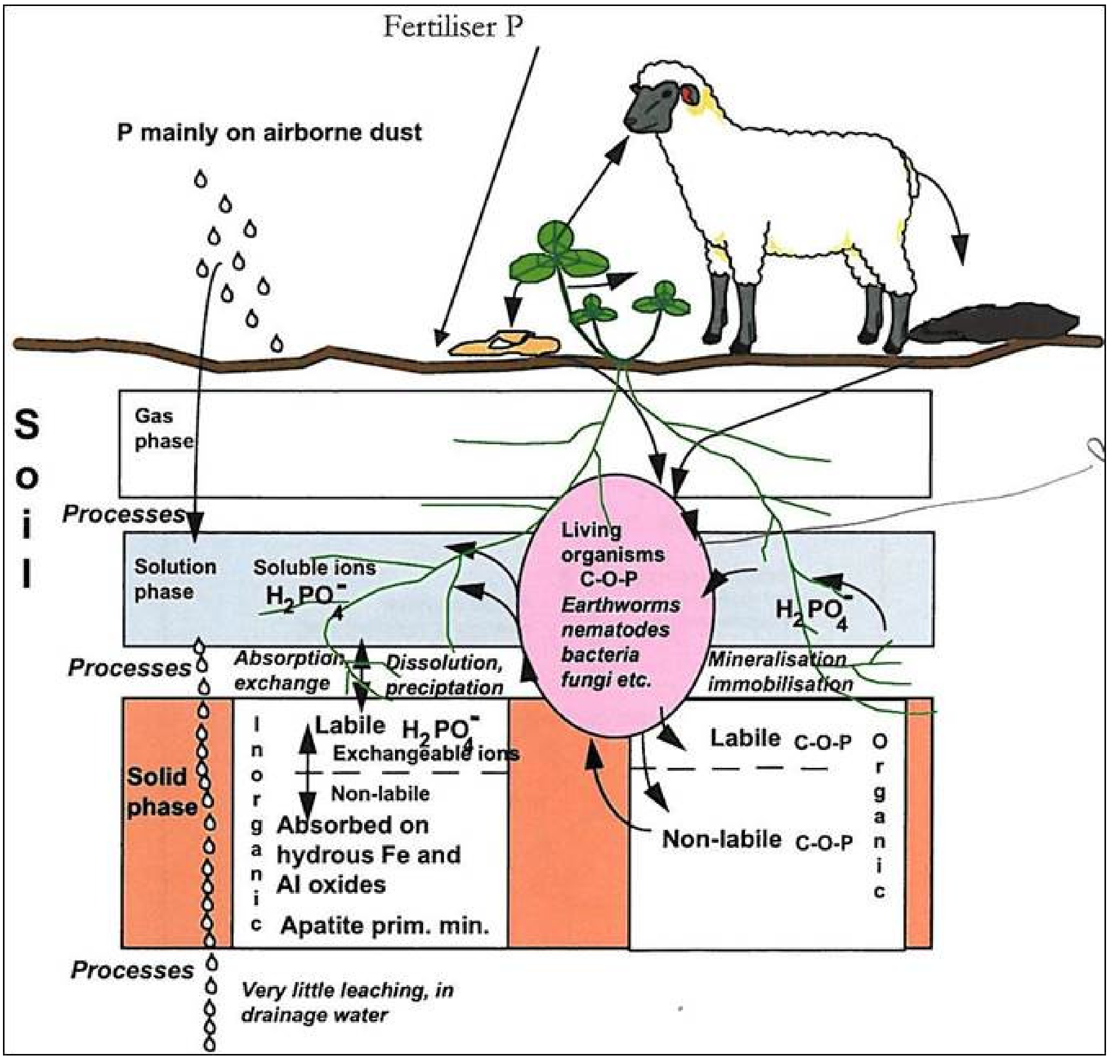

Figure 2: Phosphorus Cycle (Source: FLRC, 2012)

27 P exists in the soil as:

27.1 **Organic P** - The portion of organically bound P that is incorporated in the actively cycling plant and microbe system (i.e. easily degradable organic matter) is referred to as labile P and is responsible for most of the P released from organic matter. Eventually it becomes part of the more stable (non-labile) soil organic matter pool. Organic P is only slowly released back into the available P pool compared to P in solution and so is considered relatively immobile.

27.2 **Phosphate (also referred to as orthophosphate, soluble P or available P)** - Phosphate (PO_4^{3-}) is the form of P which is present in the soil solution (water held in the soil) and is available to be taken up by plants and microbes. As the phosphate is incorporated into the organic pool it is considered to be immobilised, and the process of releasing phosphate as organic matter breaks down is called mineralisation. The shape and charge ($^{3-}$) of the phosphate ion results in a strong physiochemical attraction to some soil clay minerals, particularly iron and aluminium oxides. This is called sorption and can result in the phosphate being only slowly available for uptake by plants and microbes. Phosphate in solution, when measured in water or wastes is referred to as dissolved reactive phosphorus (DRP).

27.3 **Mineral P** - Mineral P refers to the fraction of P which is part of soil minerals, in particular apatite[1]. Unlike nitrogen, the mineral P fraction is considered to be unavailable. Very small amounts are released into the soil solution as the minerals are weathered. This is referred to as dissolution.

28 Labile P refers to the portion of P that is actively involved in cycling between mineralisation and immobilisation and includes phosphate ions in solution, some organic P and some P that is bound to soil surfaces. Non-labile P refers to P which is unavailable, or very slowly available for plant or microbe uptake.

29 Because P binds to soil and organic matter it is not prone to leaching under most circumstances. The main mechanisms for loss of P from soil are product removal and loss in overland flow. Two components of overland flow which result in P loss are sediment loss where P is bound to the sediment, and loss of phosphate dissolved in the run-off water. P is not lost in gaseous form.

30 The availability of phosphorus in soil is affected by numerous factors including; amount of P sorbing clays, percentage of P sorbing sites that are full, contact between soil solution and soil particles, pH, climate, soil organic matter and cultivation. For further details, see **Attachment B**.

31 So, similarly, what does the above mean for the Fonterra Process Wastewater and Clean Process Water applied via spray irrigation?

32 Only Total P is measured in the waste streams as it will all be in the organic form – see **Table 3**:

[1] Apatite is a group of phosphate minerals, usually referring to hydroxylapatite, fluorapatite and chlorapatite, named for high concentrations of OH−, F− and Cl− ions, respectively, in the crystal.

Table 3: Forms of P in Waste Streams

	Organic P mg/L (% TP)	DRP or PO_4 mg/L (% TP)	TP mg/L
Process Wastewater	30 (100%)	-	30
Clean Process Water	0.2 (100%)	trace	0.2
Combine PWW and CPW	15 (100%)	trace	15
DAF Sludge	670 (100%)	-	670
Bagged Fertiliser	-	N/A (100%)	-

33 The P is likely to be applied (and used or lost) in the following ways:

33.1 No P will be lost during spraying as there is no gaseous phase;

33.2 P from clean process water applied to the Third Party Farms is organic and at a very low concentration (0.2 mg/L) and annual load of 2 kg P/ha/yr. Additional P fertiliser is likely to be required for optimal growth.

33.3 P from process wastewater applied to the Fonterra Farm will also be organic and has a moderate to high concentration at 30 mg/L (note sewage is in the order of 8 mg/L). The annual loading is around 50 - 90 kg P/ha/yr. This is usually considered above annual plant requirements in a grazed situation and is on the extremity of the acceptable range for a cut and carry system.

34 As described in **Attachment B**, the amount of P that is applied in excess of the plant needs will be held in the soil by immobilisation into organic matter or sorption to soil clay minerals. The application rate has been designed to maximise the contact of the solution with the soil, i.e. low event application depth and irrigation rate based on unsaturated soil conditions, resulting in a high rate of removal of P from the soil solution to the soil particles. This is particularly so for the soils at these three sites as the Lismore soils have a very strong P sorption due to the presence of aluminium and iron oxides.

35 As with N, each year will be different. Climatic factors (rainfall, temperature and evapotranspiration) affect the rate of grass growth and

P uptake, the rate of mineralisation and thus the amount of P available. The farming system also affects the amount of P that can be leached or can runoff with soil particles and this may vary from year to year, particularly on the Third Party farms with cultivation for cropping and dairy winter grazing – both of which expose soils to potential erosion. The type of farm systems used on the three farms is outlined above in paragraphs' 14, 16 and 17.

E. FONTERRA DARFIELD LAWFULLY PERMISSIBLE LEACHING

36 As set out above, the Fonterra Plant has 6 consents relevant to discharges to land and nutrient leaching. The stormwater and domestic wastewater are included for completeness but nutrient leaching from these two sources is minimal.

37 There are two areas that need to be considered when looking at applied nutrient loads and leaching masses, depending on the method used to calculate the mass leached. First, there is the irrigated area which is used to look at nutrient loading and plant uptake (kg N/ha/yr). Then second, there is the leaching value that results from OVERSEER modelling which is for the whole of the effective farm. This is because the unirrigated area forms part of the overall operation of the farming system along with the irrigated area and they are managed as one site, i.e. the whole area is fertilised at the same time and harvested at the same time. So where there is a limit on N leaching from a farmed area (e.g. 18 kg/ha/yr) then I consider that the effective farm area needs to be used in leaching calculations rather than the irrigated area only.

Nitrogen

38 The lawfully permissible leaching based on the current consent conditions are provided in **Table 4**.

39 The consented N load for the process wastewater onto the Fonterra Farm is an average of 250 kg N/ha/yr and the lawfully permissible leaching is 18 kg N/ha/yr. In comparison, OVERSEER modelling of the 2013/14 year predicted 14 kg N/ha/yr leached.

40 There is no N load limit on the Third Party farms and the lawfully permissible N leaching is based on an N concentration (as per the rules in the NRRP), i.e. at concentrations of > 8 mg/L an Environmental Management Plan is required, with a maximum concentration of 16 mg/L being allowed. No drainage figures are given in the consent conditions but a water balance carried out by Pattle Delamore Partners (and discussed in the evidence of **Mr Callander**) shows average drainage from the third party farms of 334 mm/year, an 80 percentile of 553 mm and a maximum over the 41 years of assessment of 718 mm. At a concentration of 16 mg/L, this equates to an average of 53.4 kg N/ha/yr, an 80 percentile of 88.5 kg N/ha/yr and a maximum of 115 kg

N/ha/yr allowed to be leached. In comparison, OVERSEER modelling of the 2013/14 year predicted 28 kg N/ha/yr leached from the Gunn Farm and 15 kg N/ha/yr from the Gray Farm.

41 This is much lower than regional predictions (Lilburne, et.al) for dairy support that are predicted to leach in the order of 18.75 mg/L with 350 mm of drainage in the Darfield area on light soils, i.e. 66 kg N/ha/yr.

42 The DAF sludge consent allows a load of 150 kg N/ha/yr to be applied. There is no leaching limit. OVERSEER modelling undertaken by Fonterra shows that adding DAF sludge in-place of fertiliser results in an additional 5 kg N/ha/yr being leached in a generic dairy farming situation, i.e. the sludge makes leaching worse and this is the opposite to what is expected. This is considered to be a conservative value, with the actual value likely to be less due to the way OVERSEER deals with slow release organic N.

43 The stormwater and domestic wastewater consents do not have leaching limits, so the values provided in the AEE or at the time of the hearing have been used.

44 The calculations in **Table 4** show that the consented Fonterra Darfield industrial discharges equate to an average of 36 tonnes and up to a maximum of 61.4 tonnes of N entering the groundwater system each year. If the DAF sludge is removed from this total as it is applied onto farms that are run as farms rather than as part of the industry, then the total is 33.5 – 58.9 tonnes N/yr.

Phosphorus

45 There are no consent conditions limiting phosphorus loads or leaching. Table 5 shows the P lost to water based on OVERSEER modelling.

46 The OVERSEER model has most of the P being locked up in the soil and this is likely to occur for many years.

47 The calculations in Table 5 show that the Fonterra Darfield industrial discharges equate to 0.53 tonnes of P entering the groundwater system each year. If the DAF sludge is removed from this as it is onto farms that are run as farms rather than as part of the industry, then the total is 0.28 tonnes P/yr.

Table 4: Lawfully Permissible N Loading and Leaching

Consent No.	Description	Land Owner	Effective Area (ha)	Consent N Loading (kg/ha/yr	Lawfully Permissible N Leaching	Lawfully Permissible Calculated Mass N Leached (kg/yr)
CRC103594	Process Wastewater to Land	Fonterra	635	250	18 kg/ha/yr	11,437
CRC140775	Clean Process Wastewater to Land	Gunn	191	-	16 mg/L	Avg 10,207 Max 21,965
CRC140777	Clean Process Wastewater to Land	Gray	221	-	16 mg/L	Avg 11,810 Max 25,415
CRC133976	DAF sludge to Land	Numerous	498.8	150	N/A	2,494 [a]
CRC134753	Domestic sewage to Land	Fonterra	0.42	110	N/A	1 [b]
CRC103589.1	Stormwater to Land	Fonterra	1.11	N/A	N/A	78 [c]
Total						**36,028 avg – 61,390 max**

a. Not based on consent but on OVERSEER modelling giving 5 kg/ha/yr leached above normal farming practice;

b. Not based on consent but on OVERSEER modelling giving 3 kg/ha/yr leached;

c. Not based on consent but on Stormwater AEE leaching rate for infiltration basins of 48 – 106 kg N/ha/yr.

Table 5: Lawfully Permissible P Loading and Leaching

Consent No.	Description	Land Owner	Effective Area (ha)	Consent P Loading (kg/ha/yr	Lawfully Permissible P Leaching	Lawfully Permissible Calculated Mass P Leached (kg/yr)
CRC103594	Milk Process Water to Land	Fonterra	635	N/A	N/A	113 [a]
CRC140775	Condensate to Land	Gunn	191	N/A	N/A	147 [b]
CRC140777	Condensate to Land	Gray	221	N/A	N/A	24 [c]
CRC133976	DAF sludge to Land	Numerous	498.8	N/A (13 in AEE)	N/A	250 [d]
CRC134753	Domestic sewage to Land	Fonterra	0.42	N/A	N/A	minimal
CRC103589.1	Stormwater to Land	Fonterra	1.11	N/A	N/A	minimal
Total						**534**

a. Based on OVERSEER modelling at 0.2 kg P/ha/yr to water

b. Based on OVERSEER modelling at 0.8 kg P/ha/yr to water

c. Based on OVERSEER modelling at 0.1 kg P/ha/yr to water

d. Based on OVERSEER modelling at 0.5 kg/ha/yr to water – this is no increase on normal dairy farming

F. COMPARISON WITH LOE (2013)

49 The figures used in Table 11(i) of CWLP v1 came from "*Selwyn-Waihora Catchment. Estimating nitrogen and phosphorus contributions to water from discharges of sewage effluent, from community systems, and milk processing wastewater. Report No, R13/8*" by Barry Loe of Loe Pearce and Associates, February 2013.

50 The report revised earlier estimates (Loe, 2012). It revised down the estimate of N leaching from milk processing from 210 to 61 t N/yr and increased the P estimate from 40 to 96 t P/yr.

51 The report separates out milk processing from meat processing and vegetable processing which are then combined together as one row in Table 11(i) of Variation 1. It also provides the detail of the separate entities producing the loads.

52 Mr Loe acknowledges there is still some uncertainty with the estimates, particularly where discharge occurs throughout the year. I concur with Mr Loe that the predictions are difficult and these will vary from year to year.

53 What I have calculated above is the N loading to groundwater based on consent conditions, i.e. the allowable leaching. This is not necessarily the same as actual leaching, which should be less in most years, as the allowable figure allows some margin of error and year to year changes due to seasonal variability.

54 The values reported in the Loe 2013 report for the Fonterra Darfield plant was just for consent CRC103594, i.e. the process wastewater onto the Fonterra Farm. The value reported for N was 19 t N/yr based on assuming leaching would be similar to that of dairy support of 45 kg N/ha/yr leached. This compares to my calculated consented value (**Table 4** above) of 11.4 t N/yr for the Fonterra Farm only. Mr Loe noted in his Table 7 that Fonterra figures provided in the AEE were 8 – 11 t N/yr.

55 However, the two Third Party Farms consents were not taken into account (CRC140775 and CRC140777), which equates up to a further 47.4 t N/yr. The domestic sewage and stormwater only add an additional 0.08 t N/yr and can be ignored. So in total, Fonterra's lawfully permissible leaching load is up to **58.9 t N/yr**, ignoring the DAF sludge that can go onto numerous farms; this is discussed further later in my evidence.

56 The P value reported by Loe was 50 t P/yr compared to that provided by Fonterra of 0.6 t/yr. Mr Loe's calculation was based on a loading of wastewater of 168 kg P/ha/yr, which was based on the

95 percentile annual volume and the maximum P concentration in the AEE (this may occur in some years). He also assumed all P in excess of 50 kg/ha/yr would be leached. As explained above regarding P in the soil, cut and carry operations export P from the soil system and the soil has enormous ability to retain P, thus leaching will be generally be minimal. However, eventually P sorption sites may be fully used and P will start moving down through the soil profile. Nevertheless, due to the depth of groundwater at Darfield (~100 m) and the soil's ability to retain P (even the subsoil), it will be 100's of years before P may enter groundwater.

57 The leaching figure provided by OVERSEER for the 2013/14 year was 0.1 - 0.8 kg P/ha/yr, which equates to a total of 0.28 t/yr, or 0.53 t/yr if the DAF sludge is included.

58 The OVERSEER P losses are what will happen in the next few years, so using a more simplistic approach as Loe did may provide the very long-term picture. At an average P loading of 70 kg P/ha/yr and plants exporting about 20 kg P/ha/yr for a partial cut and carry system and another 4 kg/ha/yr through livestock, then 46 kg/ha/yr will build-up in the soil until sorption sites are used up and then available for leaching. For the Fonterra Farm, this equates to 19 t P/yr and for the Third Party Farms, zero. So in total, Fonterra's long-term likely P leaching load is 19 t P/yr.

59 I note that there is no P limit in Variation 1 but an objective to reduce historical loads to Te Waihora by 50%. The likely long-term Fonterra P loading to Te Waihora will be less than 50% of the load calculated by Loe.

G. OTHER INDUSTRIAL USERS AND TABLE 11(I)

60 Twelve (12) other industrial users with consents to discharge nutrients to land have been identified on the Canterbury Regional Council database, including Synlait Milk Ltd.

61 I have not further analysed the consent information to ascertain whether the leaching loads calculated by Loe are correct. I will leave that to the individual organisations to provide in their submissions.

62 From assessing the section 42A report, the Officers are now recommending the removal of Industrial activities load allocation from Table 11(i) and I support this recommendation. However, should the Commissioners decide to retain Table 11(i), then I consider the nitrogen loads contributed by the major industrial users should be defined, either in the table, or in an appendix to Variation

1 to provide certainty to those users that their nitrogen leaching allocation will be available and does not get taken up by other users.

63 I also consider that sludges or other by-products do not need to be incorporated into Table 11(i) where they are consented as part of a "*global consent*" or the N in the sludge will replace fertiliser that would have been used by the farm. This is discussed further below in Section H.

64 My suggestion for Table 11(i) is provided below in Table 6:

Table 6: Table 11(i) of Plan

Catchment	Activity	Larger Industrial Discharges	Nitrogen Load (tonnes/year)	Limit/Target
Selwyn Waihora	Industrial or Trade Processes		Total	Limit
		Fonterra	58.9 or 61.4 with sludge	

65 Table 11(i) also provided additional allocation for future industrial discharges. I consider this is not likely to be necessary. Fonterra do not consider they need additional N leaching allocation as they believe they can manage their future expansions within their current allocation through further recycling within the plant, and/or by expanding the industrial activity onto neighbouring farms and taking over the farm's lawfully permissible leaching allocation, or else meet the 15 kg N/ha/yr leaching target.

66 As per above, I prefer the Officer's recommendation to remove the Industrial and Trade Waste component of Table 11(i) and instead rely on what is currently lawfully permissible through consents.

H. INDUSTRIAL DISCHARGES AND FARMING

Nutrient Allocation

67 There are two possible locations for nutrient load allocation for farms receiving industrial wastewater in Variation 1. These are either:

67.1 Farming; wastewater N would form part of the nutrient inputs for the farm.

67.2 Industrial; farms that are consented to receive wastewater are classed as part of that industrial activity.

68 However, due to industrial wastewater applications having to occur at times when the soil moisture is not in deficit, drainage is higher than a normal farm and thus N leaching can be higher. It will likely be difficult to manage the farm to limit N losses to the values suggested in the Plan. In addition, industrial wastewater disposal site are not run as normal farms, as wastewater has to be applied in the shoulder seasons when grass growth is slower and soil moisture deficits are less or non-existent. The land use and soil/plant/atmosphere systems become part of the treatment train (land treatment) for that industrial activity.

69 I consider that the industrial allocation block is the appropriate location for farms that form part of the industrial treatment system. Usually a significant assessment of effects (AEE) is submitted with the consent application to support the land treatment system. This assesses and addresses the effects on soils, plants, air, groundwater and surface water. Thus the effects of applying wastewater when the soil is not in deficit are usually remedied or mitigated. There are controls at the plant to assist, such as the extent of wastewater treatment (BOD and nutrient reduction), storage of wastewater during times of extreme weather, and there are controls at the land treatment site, such as the extent of cut and carry in association with extent of grazing.

70 Therefore, farm land that is used for industrial land treatment, and is consented as such, should not be double counted in the farm nutrient allocation block. More importantly, industrial land treatment farms that are lawfully permissible to leach > 15 kg/ha/yr should not be subject to the reductions required by Policy 11.4.14 by 1 January 2022 as they are not properly managed as farms but rather as part of the industrial treatment system.

Sludge Use as Fertiliser under Global Consents

71 Infrequent industrial discharges, such as DAF and other sludges that are by-products of wastewater treatment plants and which are spread onto farms only once or twice per year at low volumes, do not necessarily need to form part of the industrial nutrient allocation block. For example, if sludge does not have to be applied as it is produced, i.e. does not have to go onto a farm that very day regardless of soil moisture, land use and weather conditions then it becomes part of the optional fertiliser use regime for the farm. This is particularly so if the farm it is going onto has not had to be consented to accept the sludge, or is consented but in a very generic nature. For example in the Waikato, Fonterra have global consents to apply dairy by-products onto farms providing certain conditions are met. Fonterra have a similar consent for Darfield DAF sludge, where farms are specified in the resource consent but

additional farms can be added without an additional consent required providing they meet certain conditions and approval is given by the Manager of Enforcement and Compliance.

72 Fonterra Darfield DAF sludge is applied in 1 - 2 applications/year at a maximum volume of 20 m^3/ha/yr and 150 kg N/ha/yr. It is slow release and a valuable resource.

73 The sludge is applied to third party farms and as such Fonterra has limited ability to influence their operations. I therefore consider that sludge applied to farms in this context can form part of the farm fertiliser application as a substitute, managed by the farm receiving it and does not need to be accounted for in the industrial allocation.

I. COMMENTS ON SECTION 42A REPORT

74 I generally support the suggested changes to the following policies and rules on Variation 1 recommended in the s42A Report. I have some minor concerns about the following policy and rule wording, which I have explained below.

(a) Policy 11.4.10;

(b) Rules 11.5.25 and 11.5.26; and

(c) Policy 11.4.14.

75 **Ms Dines** provides amended wording to the policies and rules in Variation 1 in her evidence that address my concerns.

76 I consider the section 42A report recommended policy is now much simpler and has removed the need for industry to (unnecessarily) prove their lawfully permissible leaching prior to the plan becoming operative.

77 However, I have difficulty with "*Best Practicable Option*" (BPO). This definition used to be in the RMA but in my experience it has caused no end of argument as to what the "*Best Practicable Option*" actually is.

78 Wastewater treatment technology is changing all the time and what is considered "*the best*" will change from year to year and will differ depending on the wastewater engineer's opinion. Furthermore, more advanced wastewater treatment systems tend to add a lot of oxygen to the wastewater that oxidise the nitrogen to nitrate to enable it then to be denitrified to gases – this results in a net reduction in total N. However, the remaining N is in the nitrate form and therefore readily available for leaching (see section D above on

N cycle). Therefore more treatment at the plant can be detrimental to land treatment in the soil/plant system.

79 What is "practicable" also brings technical and financial viability into the mix, so whether an industry can afford the treatment technology or not comes into the equation.

80 Finally, the discharge system practicality is also subjective. Solid set systems, e.g. sprinklers on 20 x 20 m grid give best uniformity and control over application rates but can be 5 to 10 times more costly than a travelling irrigator system.

81 Accordingly, best practicable option creates considerable subjectivity regarding best treatment technology, best discharge system and financial affordability.

82 The word "*best*" was used in many places in the zone implementation plan, such as best nutrient management, best available science, best available information, and using best practice OVERSEER data input standards [2013]. These are likely to be more defined than best practicable option when it comes to wastewater treatment and discharge systems, although best nutrient management may also develop with time. The intent of the zone implementation plan is clear but policies and rules need to be clearer so that a Council Officer when assessing an application can decide or recommend.

83 Further I note that the Zone Committee recommend setting a catchment agricultural nitrogen load limit based on nitrogen leaching losses that would require all farming activities to perform at the mid-way point between losses under Good Management Practice and those under Maximum Feasible Mitigation. This was understood to mean that, if applied equally to all farming activities in the catchment, everyone would need to make a further 12.5% reduction in their nitrogen losses beyond good management practice loss rates.

84 The Zone Committee wanted better than Good but could see the difficulty with Maximum/Best. The policy and rules in the farming section of the plan were based on "*Good Management Practice*" and there are a number of tools farms can use to move from poor to better to good. However, when looking at the Sewage and Industrial section of Variation 1, the wording has changed to BPO.

85 I consider that also using "*Good Management Practice*" (*GMP*) for Sewage and Industrial discharges to be a more appropriate phrase as it does not have to be the 'best' (which is subjective), only 'good', which gives more options. Like with farming, "*good*" can be defined based on the overall effect, i.e. a combination of the

wastewater treatment system, land treatment operation and land use, e.g. GMP could be:

85.1 OVERSEER estimated leaching of less than 15 kg N/ha/yr; or

85.2 Annual N load to pastoral farming system of:

(a) 200 kg N/ha/yr and grazed with sheep; or

(b) 250 kg N/ha/yr and 50:50 grazed and cut and carry; or

(c) 350 kg N/ha/yr fully cut and carry.

86 I do not consider that GMP should try and set a concentration of N from a treatment plant as the lower this value is, the higher percentage nitrate-N it will be.

Rules 11.5.25 and 11.5.26

87 I generally support the changes to Rules 11.5.25 and 11.5.26 recommended in the s42A report. I have suggested a minor change.

88 I suggest that "sewerage" be changed to "sewage" as sewerage is the system, i.e. sewers transporting sewage, whereas sewage is the wastewater to be discharged.

89 My comments on BPO above also need to be accounted for in these Rules. **Ms Dines** suggests appropriate amendments in her evidence.

Policy 11.4.14

90 I note from the section 42A report that Policy 11.4.14 is recommended to be maintained as is. Although my evidence is involved with the industrial activities, I consider it important that Policy 11.4.14 differentiates that it is for general farming and excludes farms that are used for industrial wastewater land treatment. **Ms Dines** suggests appropriate amendments in her evidence.

J. CONCLUSIONS

91 Fonterra run an industrial activity with wastewater from that consented to be spread onto three farms. These farms form an integral part of the wastewater management strategy for the industrial plant and need to be considered industrial and not covered by policy and rules for farming, i.e. industrial land treatment farms that are lawfully permissible to leach > 15 kg/ha/yr should not be subject to the reductions required by Policy 11.4.14 by 1 January

2022 as they are not managed as farms but as part of the industrial treatment system.

92 Fonterra lawfully permissible nitrogen leaching (based on consent conditions and maximum drainage rates) is 61.4 t N/yr, or 58.9 t N/yr if the DAF sludge is not included.

93 Fonterra leaching losses are likely to be significantly less in most years than the permissible value as the N in their wastewaters is mostly in organic form and is thus slow release. Actual leaching losses are likely to be about 14 – 28 kg N/ha/yr but will vary year to year.

94 Fonterra's P loading from wastewater is all organic and slow release. With the high P retention soils, it is unlikely that any effect will be seen for many years and P leaching is calculated to be 0.53 t/yr.

95 DAF sludge is consented to be applied to a number of farms and the farm number can be increased without further consents being required. It currently accounts for leaching of 2.5 t N/yr. OVERSEER modelling predicts that using DAF sludge as a fertiliser replacement will result in an additional 5 kg N/ha/yr losses over normal fertiliser use. This is contrary to the likely result.

96 I consider sludge that is applied to farms as a fertiliser replacement does not need to be included in the industrial load allocation.

97 The calculation of the N leaching load from various industries is not required should Table 11(i) be removed from the Plan as recommended by the Officer. If the Panel decide to keep it in the Plan, then the values for industrial uses, based on lawfully permissible, will need to increase, as Fonterra's leaching load on its own is greater than the value of 61 t N in the Draft Plan. I support the Officers' recommendation to remove the Industrial component from Table 11(i).

98 With regard to Policy 11.4.10 and Rules 11.5.25 and 26, I have concerns to the use of Best Practicable Option. What is 'best' is so subjective in wastewater treatment and discharge systems. Treating wastewater to a higher quality can be detrimental to land treatment due to the changed form of the nitrogen. Instead, Good Management Practice allows more options for treatment and can be defined for industrial wastewater treatment/discharge systems based on meeting certain N loads for different land use activities or an acceptable N leaching value.

Dated: 29 August 2014

Robert John Potts

Attachment A: Further Details on Nitrogen Cycle

1 N can be in many forms (transformation of the forms is mostly by microbial processes as indicated in Figure 1):

1.1 **Organic N**. Chemical analysis of New Zealand topsoils typically shows that up to 5,000 kg of N is present per hectare. About 98% of the total soil N exists as a component of organic matter called the organic nitrogen fraction, which includes humus and soil organisms (denoted as RNH_2 on Figure 1). In organic forms, soil nitrogen is insoluble, unavailable to plants and described as immobilised.

1.2 Mineral N (also referred to as soluble N, inorganic N or immediately plant available N). Around 2 – 3 % of the total soil nitrogen exists as ammonium (NH4+) or nitrate (NO3-) ions, called the mineral nitrogen fraction. Mineral N is formed through the decomposition of soil organic soil matter or from added fertiliser or wastewater containing NH4+-N or NO3--N.

In most cases complex N compounds (organic matter, urea) are converted to NH_4^+-N (ammonification). Then if the NH_4^+-N is not used by plants and soil microbes, or volatilised (see below) it is transformed to nitrite (NO_2^--N) then NO_3^--N (nitrification). Collectively these processes are known as mineralisation. Mineral N is the form used by plants and soil microbes to make proteins.

In the soil NH_4^+-N is strongly held to soil surfaces (particularly clays, humus and silts) while NO_3^--N is mobile (not strongly held) and prone to leaching.

1.3 **Gaseous N.** N exists in gaseous form as ammonia gas (NH_3), dinitrogen gas (N_2 which makes up 78% of the earth's atmosphere), nitrous oxide (N_2O) and nitric oxide (NO). N_2 gas can be "fixed" from the atmosphere. Some fixation occurs in lightning strikes, but most fixation is done by free-living or symbiotic bacteria. Symbiotic nitrogen-fixing bacteria such as Rhizobium usually live in the root nodules of legumes (such as peas, lucerne, and clover). Here they form a mutualistic relationship with the plant, producing ammonia in exchange for carbohydrates. The other gas forms can also enter the soil mostly by atmospheric deposition.

Gaseous N is also released from the soil. NH_3 gas can be produced during transformations of NH_4^+ in a process called volatilisation. N_2, N_2O and NO are produced when NO_3^- is denitrified by soil bacteria in anaerobic conditions, i.e. water logged soils.

2 Fertiliser inputs, fixation of N by legumes, urea excreted in urine, leaching, product removal and volatilisation of nitrogen as ammonia and denitrification as nitrogenous oxides affects the equilibrium between organically fixed and plant available mineral N.

3 Nitrogen is a mobile essential plant nutrient, with numerous factors affecting transformation processes and distribution of nitrogen in the soil, such as:

(a) Temperature; No transformation occurs below 5 degrees C and maximum between 30 and 40 degrees, with temperatures really needed above 10 – 12 degrees, i.e. in colder areas, organic N conversion to ammonium and nitrate are very slow. So nitrate-N levels increase as the soil warms up after winter, accumulate in the soil during summer drought conditions and decrease with the onset of winter as soils become cold, rainfall may increase and leaching increases.

(b) Crop type; legumes as part of the crop will fix N but the amount of N fixing is usually reduced at high N loaded sites. Crop residues from early harvested crops which are cultivated into the soil before the onset of low winter temperatures release mineral nitrogen for utilisation by autumn sown crops.

(c) Soil texture; as above clay retains more nitrate compared to loamy soils, with sandy soils retaining the lowest concentrations. The risk of nitrate leaching is highest in sandy soils and soils with large cracks (natural or man-made).

(d) Organic matter; soils with a carbon content <2 % have half the nitrogen reserve compared to soils with >10 % carbon. This confirms that the potential to retain N in soils increases with increasing organic matter content.

(e) Soil depth; The conversion rate of ammonium-N to nitrate-N described as ‘nitrification’ decreases with soil depth and is linked to decreasing soil temperatures lower in the soil profile and less oxygen.

(f) pH; The rate of nitrification increases with increasing pH. Lime applied to soil to increase the pH, stimulates the microbial population and also the enzymes involved in the nitrification process.

(g) Gas losses; Loss of nitrogen as gaseous compounds from the soil takes place when nitrate is converted to

NO, NO_2 and N_2 through the process of denitrification, especially under anaerobic conditions due to soil compaction and/or waterlogging. Ammonia gas (NH_3) may be lost from surface application of urea as urine (particularly from dairy cows) or fertiliser.

(h) Nitrification inhibitors; Various nitrification inhibitors can be used to slow down the conversion of ammonium-N to nitrate-N. These are currently not used in NZ due to residuals found in milk. However, it is considered that they will be available some time again in the future.

(i) Cultivation: Aeration of soils through cultivation speeds up the rate of organic matter mineralisation and the supply of mineral nitrogen for the subsequent crop. Repeated cultivation for two or more seasons rapidly decreases the ability of the soil to provide N from the organic-N pool.

Attachment B: Further Details on Phosphorus Cycle

1 P exists in the soil as:

1.1 **Organic P.** Phosphorus is used in many biological processes and as a result it is taken up by plants and soil microbes. The portion of organically bound P that is incorporated in the actively cycling plant and microbe system (i.e. easily degradable organic matter) is referred to as labile P and is responsible for most of the P released from organic matter. Eventually it becomes part of the more stable (non-labile) soil organic matter pool which undergoes very little degradation. Organic P is only slowly released back into the available P pool compared to P is solution (see below) and so is considered relatively immobile.

1.2 **Phosphate (also referred to as orthophosphate, soluble P or available P).** Phosphate (PO_4^{3-}) is the form of P which is present in the soil solution (water held in the soil) and is available to be taken up by plants and microbes. As the phosphate is incorporated into the organic pool it is considered to be immobilised, and the process of releasing phosphate as organic matter breaks down is called mineralisation. The shape and charge ($^{3-}$) of the phosphate ion results in a strong physiochemical attraction to some soil clay minerals. As a result phosphate can become strongly attached to some clay minerals, particularly iron and aluminium oxides. This is called sorption and can result in the phosphate being only slowly available for uptake by plants and microbes. Phosphate in solution, when measured in surface water, groundwater or wastewater is referred to as dissolved reactive phosphorus (DRP).

1.3 **Mineral P.** Mineral P refers to the fraction of P which is part of soil minerals, in particular apatite. Unlike nitrogen, the mineral P fraction is considered to be unavailable. Very small amounts are released into the soil solution as the minerals are weathered. This is referred to as dissolution.

2 Labile P refers to the portion of P that is actively involved in cycling between mineralisation and immobilisation and includes phosphate ions in solution, some organic P and some P that is bound to soil surfaces. Non-labile P refers to P which is unavailable, or very slowly available for plant or microbe uptake.

3 Because P binds to soil and organic matter it is not prone to leaching under most circumstances. The main mechanisms for loss of P from soil are product removal and loss in overland flow. Two components of overland flow which result in P loss are sediment loss where P is

bound to the sediment, and loss of phosphate dissolved in the run-off water. P is not lost in gaseous form.

4 Availability of phosphorus in soil is affected by numerous factors including:

4.1 Amount of P sorbing clays; high amounts of clay minerals such as iron sesquioxides, allophane and imogilite result in large amounts of P removal from the soil solution. This is often measured using the P retention capacity or anion storage capacity of the soil. The amount of these minerals determines the number of soil sites to which the phosphate ion can bind. In contrast, a course sandy soil has very few sorption sites and so applied P is likely to move through the soil.

4.2 Amount of P sorption sites in the soil that are full; for soils with low capacity for retaining P, or soils where P is already sorbed to the soil, the equilibrium between the soil solution P concentration and the P binding sites will cause P to stay in solution i.e. as the phosphate ion.

4.3 Contact between soil solution and soil particles; because the sorption reaction is based on the equilibrium between the soil solution and soil particles, the two must be in contact for long enough for the exchange to take place. If the soil is flushed with water containing P there may not be sufficient contact to cause P to be sorbed to soil.

4.4 Soil pH; the pH of the soil affects the sorption of P where below pH 5.5 (sorbed to Al and Fe containing minerals) and between pH 7.5 - 8.5 (sorbed to Ca containing minerals) P is sorbed more strongly.

4.5 Climatic conditions; such as temperature and moisture levels affect P release from organic matter since in warm, humid conditions organic matter turnover occurs more rapidly resulting in more rapid release of P, while cold or dry conditions reduce the microbial activity in the soil and slow the release of P. In addition the chemical reaction that causes P to sorb to the soil is slower in colder conditions.

4.6 Soil organic matter; higher soil organic matter results in higher P availability. This is due to a relatively constant proportion of the organically bound P being released.

4.7 Cultivation; aeration of soils through cultivation speeds up the rate of organic matter mineralisation and the supply of P for the subsequent crop.