APPENDIX A:

THE RATIONALE FOR LAND DISPOSAL OF FARM DAIRY WASHWATER

1.0 BACKGROUND

Following the findings and the recommendations of the Waitangi Tribunal on the Manukau claim, the Auckland Regional Water Board (ARWB) prepared the Manukau Harbour Water Quality Management Plan (MHWQMP) (ARWB, 1990b) which summarised the findings of a 3 year comprehensive study of water quality issues in the Manukau Harbour catchment. Many of the findings of the MHWQMP were applicable to the region as a whole.

The research found that dairy farm discharges constituted the largest point-source of rural pollution in the Auckland region, particularly in terms of nitrogen and phosphorus loadings to the harbour. ARC Rural Pollution Abatement Officers have since found that similar nitrogen and phosphorus loadings from farm dairy washwater occur in all rural parts of the region.

During the preparation of the MHWQMP a concentrated effort was made to improve dairy washwater treatment on farms in the Manukau Harbour catchment. This was successful in reducing the percentage of direct (untreated) discharges from 36% to zero, but was less successful where treatment systems were in place, but were inadequate. Upon completion of the MHWQMP, 22% of farms still had treatment systems which were substandard in terms of MAF specifications at the time.

By the end of the Manukau Harbour Water Quality Action Plan, oxidation ponds were the most common form of treatment for farm dairy washwater, being used on approximately 56% of farms. Spray irrigation of washwater onto land was also common, being used by 27% of dairy farms. The remainder operated a variety of systems, including overland flow, tankering and barrier ditches.

A similar mix of farm dairy washwater treatment and disposal methods applies in all the region’s dairy farming areas, so that adverse effects from nutrient discharges on rural waterways are widespread throughout rural Auckland.

Consideration of the following matters led the ARC to conclude that land application of farm dairy wastes is the preferred option for the Auckland region:

- the estimated volumes discharged
- contaminants of concern and their likely concentrations in farm dairy discharges
- the ability of Auckland waterways to assimilate these contaminants
- the areas of land that would be needed to assimilate these contaminants without adverse environmental effects

Information about these is summarised below, followed by some examples to show how operators can work out the area of land they need to dispose of their farm dairy wastes in a way that complies with the rules of this Plan.

2.0 ACCEPTED AVERAGE WASHWATER VOLUME FROM FARM DAIRIES

The volume of the washwater produced by farm dairies depends on different variables for each farm. The residence time of cows on the yard is a primary factor which is in turn determined by other factors like the time of year, type of milking system, yard and shed design, milking plant type and labour availability. Other secondary factors include the level of stress on the cows whilst being milked or waiting to be milked, the type of plant wash down system and milking management.

Measured volumes range from 40 - 70 litres per cow per day but from discussions with operators and observations of ARC staff, there is a decreasing marginal rate of washwater produced per cow as herd size increases. For example, a herd of 500 cows has a washwater volume that may be as low as 30 litres/cow/day.

The ARC has adopted a figure of **50 litres/cow/day** as a representative volume, given the research outlined below. This rate is the best estimate to date from available data, and is therefore the rate assumed in this Plan. The following is a review of the average washwater volumes discharged per cow from farm dairies.

2.1 Dairy Shed Oxidation Pond Effluent Quality in the Auckland Region, Working Report No. 57, ARWB, 1990

From this survey of 20 farms in the Franklin District, the average dairy washwater volume was estimated from six of the farms as follows.

2700 l/90 cows	=	30 l/day
5000 l/115 cows	=	43 l/day
4500 l/90 cows	=	50 l/day
10000 l/150 cows	=	67 l/day
3300 l/70 cows	=	47 l/day
8000 l/130 cows	=	61.5 l/day
Average	=	**50 l/cow/day**

2.2 Agricultural Livestock Waste Production Figures, Massey University, Agricultural Engineering Department

The figure used is based on data collected from the Massey University dairy units and is **65 l/cow/day.**

2.3 Effluent Characteristics of Dairy Shed Oxidation Ponds and their Potential Impacts on Rivers, Hickey C W, et al, 1989

In this report, the authors assume a volume **80 l/cow/day** based on previous work by Drysdale and Painter (1983), Warburton (1983) and Vanderholm (1984). This rate assumes the use of reverse-flow washdown systems in each case.

2.4 Agricultural Waste Manual, Vanderholm, D H, et al, 1984, NZ Agricultural Engineering Institute

In this manual, a discharge rate of **50 l/cow/day** is used, and where there is a reverse-flow washdown system employed, a rate of **80 l/cow/day** is assumed.

2.5 Cowshed Effluent Survey 1993 - 1994, Northland Regional Council, 1994

This survey measured the same volume as Hickey et al (1989) of **80 l/cow/day.**

2.6 Proposed Changes to Environment Waikato's Transitional Regional Plan - Dairy Shed Effluent, Environment Waikato, 1993

Environment Waikato undertook a survey of six dairy farms, from which they found that the average washwater volume was **45 l/cow/day.** As a result of this survey and with consideration of data by Vanderholm et al (1984), the figure of **50 l/cow/day** was adopted for the purposes of the Draft Environment Waikato Regional Plan.

2.7 Kay's Stream Report - A Study of the Impact of Dairy Shed Wastes on a Small Rural Auckland Stream, ARWB, 1989

In this report, the average volume for this one farm was measured to be approximately 8,140 litres from a herd of 185 cows equating to a volume of **44 l/cow/day.**

2.8 Land Application of Farm Wastes, NZ Land Treatment Collective, Technical Review No. 9, October 1993

This review bases volumes of waste water produced on Vanderholm et al (1984), that is **50 or 80 l/cow/day.**

2.9 A review of monitoring results of dairy effluent systems in the Auckland region visited by MAF between June and September 1997 indicates a mean washdown volume of 30 l/cow/day (range 9-75). The individual data from which this mean is derived are rough estimations of washdown volume from the operator and/or the MAF Inspector.

3.0 CONTAMINANTS OF CONCERN AND THEIR LIKELY CONCENTRATIONS IN FARM DAIRY DISCHARGES

The MHWQMP identified that discharges from oxidation ponds frequently cause significant water quality degradation, especially when there is little dilution available in the receiving water. This is supported by a DSIR national survey of oxidation pond discharges (Hickey et al 1989), which revealed that massive dilution is necessary mainly to avoid ammonia toxicity to sensitive organisms in the receiving water. This is based on the United States Environmental Protection Agency (USEPA) ammonia toxicity criteria (USEPA, 1986). Ammonia was identified as the critical contaminant in oxidation pond discharges.

There is generally a lack of documented data on the levels of nutrients flowing off dairy yards in New Zealand. Recent research (unpublished) by Dr AHC Roberts of AgResearch Ruakura indicated that the concentration of nitrogen in dairy washwater off the yard is much higher than previously documented. Average levels of 23 gN/cow/day off the yard have been measured compared with 10 gN/cow/day previously reported by Vanderholm et al (1984). On this basis, the minimum land area for applying effluent must be increased accordingly. However a large proportion of the total nitrogen is likely to be nitrified and volatilised between the yard and being applied to the land, the proportion depending on the time of the year and weather conditions. Generally, a nitrogen loss of about 20% is estimated between untreated washwater collection and spreading onto land (Vanderholm et al, (1984).

The ARC has adopted the rate of **20 gN/cow/day** mainly on the basis of Dr Roberts' results, rounded down in light of the Agricultural Waste Manual data (Vanderholm et al, 1984). Also Jersey Cattle Breeders Association of NZ requested that Regional Councils take into consideration the lower stock unit values of Jersey cattle compared with Friesians when making assumptions about nutrient output.

4.0 THE ABILITY OF AUCKLAND WATERWAYS TO ASSIMILATE NITROGEN

As a result of the findings of the MHWQMP, the ARC commissioned a report (ARC, 1992a) on the suitability of USEPA criteria for assessing ammonia toxicity levels in the New Zealand fresh water situation. This report by the New Zealand National Institute of Water and Atmospheric Research concluded that the use of USEPA criteria is appropriate for New Zealand fresh waters. The dilutions required to achieve the USEPA salmonoid criteria vary from the median of 97 fold to 95 percentile of 248 fold dilution, (Hickey et al 1989). A further dairy oxidation pond study undertaken by the ARWB in 1990 (ARWB, 1990b) indicated similar dilution requirements for ammonia as that found by Hickey et al (1989), namely a range from a median of 92 fold to the 95 percentile of 244 fold dilution.

A stream flow of approximately 50 l/sec would therefore be required to achieve the minimum dilution necessary for a stream to assimilate ammonia from a pond discharge rate of 0.5 l/s for 50% of the time. The required dilution increases to 124 l/sec if the water course is to be protected 95% of the time.

The ARC proposes to use one-in-five year low-flow to determine available dilution in the summer period. While many water bodies may be able to achieve these dilutions during winter flow conditions, few will have enough volume during the summer, especially when abstractions are taken into account.

The ARC then commissioned a further investigation (ARC, 1992b) of the efficacy of systems to augment the treatment efficiency of conventional oxidation ponds by removal of ammonia. Most of the options studied were expensive and required a high degree of operator involvement. The report concluded that most feasible add-on systems were overland flow and spray irrigation. The next most feasible systems were rotating biological contact units but these are costly to install, require power to the site and need regular maintenance. The use of constructed wetlands was not covered in this study, as results from trial constructed wetland systems to date have not achieved sufficient or consistent ammonia reduction.

As a result of the above findings, the ARC concluded that ammonia toxicity and nitrogen concentrations generally in farm dairy washwater and the lack of dilution in most of Auckland’s waterways indicated that, for Auckland, land disposal is the preferred option.

However, applying excessive nitrogen onto land can also have adverse environmental effects, so the ARC needed to investigate acceptable levels for land application.

5.0 ACCEPTED NITROGEN LEVELS FOR THE DISCHARGE OF FARM DAIRY WASHWATER ONTO LAND

The ARC’s objective in setting a nitrogen limit is environmental protection as required by the Resource Management Act 1991. Excessive nitrogen applications are a possible threat to underground aquifer systems. Degradation of aquifers compromise the suitability of groundwater for potable, stock and irrigation supply and can result in contamination of spring flows into waterways.

A considerable amount of investigative work has been undertaken by the Waikato Regional Council in setting the appropriated nitrogen application rate for their region. Its primary focus was the protection of near-surface groundwater for potable water supply from a public health point of view. The ARC considers that this approach is applicable to the Auckland region where protection of aquifer systems for potable supply is the objective.

The ARC’s adopted nitrogen application rates for disposal of dairy sludge and washwater are:

(a) at a rate not exceeding the equivalent of **150 kgN/ha/year** and **30 kgN/ha/day** in the following areas:

  (i) those areas underlain by aeolian sands (Awhitu, Kaipara, Tapora, Pakiri, Omaha Flats);

  (ii) those areas underlain by volcanic basalt (Pukekohe, Puni, Waiuku, Bombay, Mangere);

(b) at a rate not exceeding the equivalent of **200 kgN/ha/year and 50 kgN/ha/day,** on low permeability clay soils of low vulnerability due to poor groundwater quality/yield.

The following is a literature review and discussion of the levels of nitrogen adopted for the Auckland region.

5.1 Literature Review

5.1.1 Agricultural Waste Manual, Vanderholm, D H et al, 1984

The authors of this manual suggest that as an upper limit to excess nutrient application, up to twice the plant's requirements for nutrients could be applied without serious effects on plant growth and groundwater quality. The average uptake of nitrogen in grazed pasture is cited as 200 kgN/ha/year, and so a corresponding upper limit for nitrogen application of 400 kgN/ha/year could be promulgated.

5.1.2 Forestry Bulletin CGGREF April 1993, No 35. French Ministry of Agriculture and Forestry

The EEC proposes that for identified risk zones or risk areas, the maximum annual nitrogen application from animal wastes on land should be 200 kgN/ha/year, reducing to 170 kgN/ha/year after 1995. The main considerations in identifying the risk areas are potable water quality and eutrophication of water bodies and coastal waters.

The protection of potable groundwater is of prime importance. Lowland streams recharged from groundwater are susceptible to compromised water quality from excess nitrate levels (eutrophication) in the soil profile.

5.1.3 Regional Plan - Dairy Shed Effluent: Operative Plan, Environment Waikato (1994)

Environment Waikato has adopted a maximum nitrogen rate of 150 kgN/ha/year across the region in the above plan, based on research and a review of information by Dr N Selvarajah. However, compared with the Auckland groundwater resources, Waikato groundwater resources are generally shallow and unconfined and groundwater quality is more subject to impact from surface activities. The application rate reflects this high contamination risk.

The Waikato maximum limit was also based on research into clover suppression from excessive nitrogen application and research into the rates of application of nitrogen applied to stony soils from piggery effluent.

However, Environment Waikato's redrafted plan change for farm dairy effluent disposal also states that nitrogen can be applied at a higher rate than 150 kgN/ha/year provided there is no elevation of groundwater nitrogen concentrations such that existing or reasonably foreseeable uses of the receiving groundwater or surface water would be compromised.

5.2 Discussion

The ARC's rural groundwater monitoring information shows that for much of the region near-surface groundwater is not used for potable supply to any great extent. This is mainly because of the poor quality of this resource due to high iron levels and more importantly, sustainability at the time of greatest need, during the summer months. Exceptions are the Southern Manukau volcanic aquifers and the sand systems of the Awhitu and Kaipara Peninsulas. In many areas deeper groundwater systems are heavily utilised for water supply, however most of these systems are confined or semi-confined, that is, there is little or no connection between the upper poor quality aquifers and the underlying groundwater system, so they are less vulnerable to contamination from surface activities.

Auckland Aquifers can be divided into the following broad groupings:

Aquifer Type 1 = sandy soils which are vulnerable due to their high permeability;

Aquifer Type 2 = volcanic soils which are vulnerable due to their high permeability and heavy abstractions;

Aquifer Type 3 = deeper aquifers connected to type 2 aquifers; and

Aquifer Type 4 = low permeability clay soils of low vulnerability due to their poor water quality or low yield.

Potential risks to groundwater quality can be established for these different aquifer types as follows:

Nitrogen loading rate (kgN/ha/year)	**Aquifer types (See above for type of Aquifer)**		
	1	**2 & 3**	**4**
100	minimal	minimal	minimal
150	minor	minor	minimal
200	moderate	moderate	minor
200+	major	major	moderate

The ARC has adopted a precautionary approach[1] and used nitrogen application rates which pose a minimal/minor risk to groundwater quality. The risks include a wide range of factors both environmental and physical which influence nitrogen uptake and mobility.

[1] The 'precautionary approach' is detailed in the *Proposed Auckland Regional Policy Statement.*

The ARC considered managing these application rates by producing regional maps delineating zones where the different rates would apply. However, the difficulty with this approach is that farm boundaries often cross several different soil types. The ARC's preferred approach utilises the operators' knowledge about their specific context to use the appropriate application rate.

The above evaluation assumes that the land where washwater is applied also receives input of nitrogen from normal farm grazing practices. Alternative land uses such as cropping can sustain considerably higher nitrogen loading, but such proposals will require consideration from the ARC on a case-by-case basis.

Some examples of how to apply the ARC's recommended nitrogen application rates are given below.

6.0 HOW TO WORK OUT YOUR ANNUAL AND DAILY NITROGEN APPLICATION RATES

In order to prevent short term over-application within the maximum annual application rate, the ARC promulgates daily maximum application rates for nitrogen of:

- 50 kgN/ha/day for clay soils; and
- 30 kgN/ha/day for sandy soils

These limits have been set to guard against potential adverse effects of increased levels of nitrogen in potable surface and groundwater, notwithstanding the limitations of the other standards. The maximum rates of 30 and 50 kgN/ha/day are based upon reasonable nitrogenous fertiliser applications to ensure economic benefit and to reflect standard practice (AgResearch 1994). With nitrogen application rates greater than these, the economic benefit in terms of added kilogram dry matter per kilogram nitrogen decreases at a marginal rate as the nitrogen application rate increases and the risk of nitrate leaching increases.

Nitrogen loading occurs from land disposal of farm dairy:

- treatment system sludge
- washwater

6.1 Sludge Application

For farms with clay soils, the application rate = 50 kgN/ha/day
= 60,000 litres/ha/day of sludge.

For farms with sandy soils, the application rate = 30 kgN/ha/day
= 36,000 litres/ha/day of sludge.

These both assume that the mean total nitrogen component of sludge is 0.166% (*pers comm* AHC Roberts, AgResearch) and that only 50% of the nitrogen component is the mineralised organic fraction immediately available for plant uptake. The remaining fractions are the organic and residual components which become mineralised in subsequent years.

A further safeguard against excessive nitrogen application is that at least 20% of nitrogen in the mineralised fraction will be lost through volatilisation during and after application, thus diminishing the risk of nitrate leaching to groundwater (Hart and Speir, 1992).

The above application rates of nitrogen are regarded as strategic applications for boosting pasture production. As such, effluent should be applied when pasture is actively growing, normally Autumn and Spring. Operators would apply sludge to land at these times in any case, when soil conditions allow the passage of heavy machinery.

6.2 Washwater Application

6.2.1 Worked examples for a farm on clay soil

(a) Annual rate

The maximum annual nitrogen application rate is 200 kgN/ha. Assuming a nitrogen concentration of 20 gN/cow/day in the washwater off the yard (untreated), for a range of herd sizes and lactation lengths, the minimum total irrigation area can be represented in the following table:

Minimum annual irrigation area requirements for farm dairy washwater application (ha)

	Herd size(H)			
Lactation days (L)	**100**	**150**	**200**	**250**
220	2.2 ha	3.3 ha	4.4 ha	5.5 ha
240	2.4 ha	3.6 ha	4.8 ha	6.0 ha
260	2.6 ha	3.9 ha	5.2 ha	6.5 ha

The above minimum areas can be calculated for any herd size and lactation length using Formula A-1 below:

Formula A-1 **Clay Soils**	Minimum annual irrigation area for farm dairy washwater application $= \dfrac{\mathbf{H \times L}}{\mathbf{10,000}}$

(b) Daily Rate

The minimum daily irrigation area needed depends on whether irrigation is sourced:

- directly from the yard, or
- from a holding or oxidation pond/s.

(i) Daily irrigation from yard washdown

Base the daily minimum area on **20gN/cow/day** through the yard.

For example:

100 cows x 20 gN/cow	=	2 kg N
The nitrogen limit	=	50 kgN/ha/day
Therefore the minimum area needed	=	2 / 50
	=	0.04 ha/day
	=	400 m^2 /per day
Therefore for 200 cows	=	0.08 ha
	=	800 m^2 /per day

Rule of Thumb:	**at least 4m^2 per cow**

(ii) Periodic irrigation from a holding pond system

Base the daily minimum irrigation area on an assumed nitrogen concentration of **0.04%**.

For example, if you wish to empty 100,000 litres (100 m^3) of effluent from a holding pond onto land on one day:

100,000 litres @ 0.04% N	=	0.04 / 100 x 100,000
	=	40 kgN
The nitrogen limit	=	50 kgN/ha/day
Therefore the minimum area needed	=	40 / 50
	=	0.8 ha
	=	8,000 m^2

Rule of Thumb:	**no more than 125m^3/ha/day**

6.2.2 Worked examples for a farm on sandy soils

(a) Annual rate

The maximum annual nitrogen rate on sandy soil is 150kgN/ha. Assuming a nitrogen concentration of 20gN/cow/day in the washwater off the yard (untreated), for a range of herd sizes and lactation lengths, the minimum total irrigation area can be represented in the following table:

Minimum annual irrigation area requirements for farm dairy washwater application (ha)

	Herd Size (H)			
Lactation Days (L)	**100**	**150**	**200**	**250**
220	2.9 ha	4.4 ha	5.9 ha	7.3 ha
240	3.2 ha	4.8 ha	6.4 ha	8.0 ha
260	3.5 ha	5.2 ha	6.9 ha	8.7 ha

The above minimum areas can be calculated for any herd size and lactation length using formula A-2 below:

Formula A-2 **Sandy Soils**	Minimum annual irrigation area for farm dairy washwater application $= \dfrac{\mathbf{H \times L}}{\mathbf{7{,}500}}$

(b) Daily Rate

The minimum daily irrigation area needed depends on whether irrigation is sourced:

- direct from the yard, or
- from a holding or oxidation pond/s.

(i) Daily irrigation from yard washdown

Base the daily minimum area on **20gN/cow/day** through the yard.

For example:

100 cows x 20gN/cow	=	2 kg N
The nitrogen limit	=	30 kgN/ha/day
Therefore the minimum area needed	=	2 / 30
	=	0.07 ha/day
	=	700 m^2 per day
Therefore for 200 cows	=	0.14 ha
	=	1400 m^2 per day

Rule of Thumb:	**at least 7m^2/cow**

(ii) Periodic irrigation from a holding pond system

Base the daily minimum irrigation area on an assumed nitrogen concentration of **0.04%**.

For example, if you wish to empty 100,000 litres (100 m^3) of effluent from a holding pond onto land on one day:

100,000 litres @ 0.04% N	= 0.04 / 100 x 100,000
	= 40 kgN
The nitrogen limit	= 30 kgN/ha/day
Therefore the minimum area needed	= 40 / 30
	= 1.3 ha
	= 13,000 m^2

Rule of Thumb:	**no more than 75m^3/ha/day**

Note: These calculations are only based on the nitrogen application rate condition. Other conditions such as avoiding run-off at any time must also be considered when applying washwater to land.