A review of information on the transportation of dairy effluent through soil and the associated on-farm practices.

A report prepared for the Kellogg Rural Leaders Programme

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Executive summary:

The "domestic licence to operate" relies almost entirely upon the dairy industry proving that they can minimise the risk of effluent and associated land use activities from degrading water quality. Compliance statistics must improve quickly to enable the industry to grow and avoid greater regulation.

Considerable resource put into educating dairy farm owners and staff but until recently has focused on why it is important to have good practices and the practical aspects of how to operate, maintain and manage effluent systems. There has been limited discussion with farmers on the basic principles of irrigation. Farmers, Council staff and rural professionals know that effluent applied in wet conditions can quickly reach a waterbody but they don't necessarily understand how effluent is transported through soil in order to prevent it.

Effluent must be applied in a way that ensures the nutrients and faecal micro-organisms in dairy effluent are retained in the root zone. Storing effluent in a pond (deferred irrigation) and applying it only when soil conditions are suitable and using equipment that can apply effluent to land at a low rate and depth are the two main tools for achieving Best Practice. This report focuses primarily on the latter.

Agresearch identified that linking soil drainage characteristics and slope to capability of the effluent irrigator to apply the correct application rate and depth is critical to driving the decision making on-farm and minimising the risk of contaminating surface and ground water. They developed a risk framework based on five landscape and drainage features.

1. Artificial drainage and coarse soil structure
2. Impeded drainage or low infiltration rate
3. Well drained flat land ($<7^0$)
4. Well drained but very stony flat land ($<7^0$)
5. Sloping land ($>7^0$).

Soil with poor drainage and coarse structure has a higher risk of being able to contaminate waterbodies because it tends to transport effluent, below the root zone, down preferred pathways such as cracks, worm channels and past large soil aggregates via preferential or bypass flow.

The risks of overland or surface run-off are also high on sloping land and soil that has been compacted or damaged by vehicle movement because it has a lower infiltration rate or ability to absorb the effluent through the surface. Overland flow can also occur if soil is saturated and all soil macro and micropores are full.

On well drained land the risk is much lower because matrix flow allows the effluent to drain through the soil profile, evenly wetting the whole profile and pushing existing water deeper similar to the movement of a piston. While surface ponding is difficult to create, the risk, particularly on stony soils, is the contamination of groundwater.

It is critical that the amount of effluent applied must be equal to what the soil can safely hold (must not exceed the available soil water deficit) and absorb (infiltration rate). Well drained land is the exception to this rule. All risks can be managed by applying the correct application depth and rate to suit the soil and slope features and conditions.

Application rate and depth of an irrigator is influenced by a large range of factors that require frequent assessment, maintenance, vigilance and operator skill to ensure the performance of the equipment remains at its optimum. Depth is easily controlled by how fast the irrigator travels or pulsing and is the principal means of managing the risk but depends upon knowing how much soil water deficit exists each day. To assist with the decision making, new guidelines have been developed that match irrigation equipment type to soil water deficit for each soil and landscape feature.

The reality is that very few farms have a soil moisture meter so the ability to achieve Best Practice is difficult. Intuition, making use of the weather and rainfall information, setting up the irrigation system correctly, regularly testing or installing alarms to ensure the system is operating at its optimum or simply being vigilant will minimise the risks. However the industry would make significant and rapid improvement to lift the compliance rates and lower the risk of effluent contaminating waterbodies by each farmer investing $2-3000 in a soil moisture metre to take the guess work out of the daily decision making process. Thinking like a person irrigating a summer crop and ask "is this the best time to apply effluent to the land" is important but it must be supported by good information and knowledge.

There are many issues to consider when choosing the right effluent management system for any farm. Being certain about what management and risk outcome is desired, knowledge of the soil drainage characteristics and land slope, good rainfall data and knowing the application rate and depth capabilities of irrigation equipment will be helpful.

Whatever the farm location, effluent irrigation equipment that can apply a low application rate of <10mm/hr and a depth of <5mm will significantly minimise the risk of dairy effluent being lost below the root zone and contaminating waterbodies. Low rate systems are more adaptable and flexible to a range of soil drainage characteristics, slope and climatic conditions, they avoid problems of palability, they grow more grass and they deliver greater peace of mind.

2. Introduction:

Politically and publicly it has been decided that water quality and quantity are fundamentally important for the future of New Zealand. While this appears to be an appropriate goal that fits with our Clean Green and Pure NZ slogans it overlooks the challenge that it imposes on the primary production sector. Finding the balance between public expectation (pristine water) and what is realistically achievable and affordable is the tension that dairy farmers are grappling with at present.

Effluent management and non compliance with Council rules have become the focus. While concerns existed in the 1990's about the success of applying dairy effluent to land it wasn't until 2003 before there was any significant investigation and scientific research. Dr David Houlbrooke and Dr David Horne at Massey University identified there were upwards of 80% loss of nutrients under existing practices and this was contributing to the contamination of streams, lakes and rivers. However loss of faecal and nutrient contaminants could be significantly reduced by storing effluent in ponds until the soil conditions were suitable and using low application rate systems.

These results coincided with increased monitoring, new rules and greater efforts by Regional Councils to improve effluent management practices and water quality outcomes. The Resource Management Act, Section 15 further strengthened the Council's position. In effect all Council have to prove is that contaminants, such as effluent, have the potential to discharge into a waterbody (ditch, creek, river, lake). Ponding on the surface is considered one of these situations along with direct discharges via surface run-off. The Environment Court endorses the public perception that water quality is a sacred cow and has continually increased fines to those prosecuted from $5000 in 2005 to in excess of $100,000 in 2010.

The regulatory system and public opinion has moved so quickly and significantly that farmers have been left wondering what is acceptable and affordable. In a wet winter and spring farmers will potentially need 5-6 months of storage and that in-turn requires a system that can pump large volumes in the small windows of good weather to prevent ponds overflowing.

Farmers remain unconvinced about the need for the "perfect system at all times" that can withstand all weather scenarios. This exert from the Otago Daily Times, 28 September 2010 reflects the difficulties facing farmers to find that social, environmental and economic balance.

"Lex Morris estimates he has two weeks' capacity left in his dairy-shed effluent ponds, which have been filling steadily because exceptionally wet weather has prevented him from irrigating it on to pasture.
Mr Morris, who farms near Clydevale, said it was a widespread problem, and he and other Otago farmers did not want to pollute waterways or fall foul of the Otago Regional Council's dairy-effluent rules, but were unsure what to do.
Jeff Donaldson, group manager of Otago Regional Council-owned Regional Services, said his staff would be "reasonable" with farmers' plights, but would not tolerate effluent entering waterways.
"We're not going to be unreasonable, but clearly we believe responsibility rests with landowners to manage their effluent wisely."
That could involve using tankers to empty ponds or irrigating it on to areas such as shelter belts.
The council would continue to inspect farms and investigate breaches, Mr Donaldson said.
Mr Morris said most years he would be applying effluent to his pasture by now, but that was not possible, as winter was particularly wet and the soil had had no opportunity to dry.
Building bigger ponds was also not an option now, but it raised the question of just how big the ponds needed to be".

Innovative engineering and electrical solutions that remove all the risks are now becoming available but some farmers question whether they can afford them. A few have invested upwards of $300,000 in the hope that their system will give them piece-of-mind, future proof their farming investment and withstand any changes to Council rules in the foreseeable future.

Managing effluent to an acceptable standard that captures all the benefits is a complex and costly task that changes from day to day and throughout the season. Each farm has its own specific climate, soils and circumstances that makes it unique and this will determine how effluent is managed every day, even when milking has stopped for the season (eg: to manage pond storage capacity).

Councils have recently engaged scientists to provide more information about the transportation of effluent in soil once it has been discharged to the land. While this information is very helpful for those developing new policies and regulation it requires the understanding of a lot of terminology and soil science before it can be fully understood and then integrated into on-farm practices. This underlies the complexity of safely applying dairy effluent to land.

There has been a lot of information provided to farmers about how to maintain, operate and manage effluent systems but dairy farmers and staff don't have a good understanding about what happens to effluent when it reaches the soil. Applying effluent is no different than irrigating a summer crop. The same principles apply. If Best Practice is to keep nutrients and microbes in the root zone then farmers have to know what happens in their particular soil when effluent is applied in order to achieve this outcome.

The purpose of this report is to;

1. review the available information on farm dairy effluent management with an emphasis on information that describes what happens to effluent once it is discharged to land,
2. summarise the basic principles and terminology associated with soil and irrigation that are relevant to keeping effluent within the root zone (ie achieving Best Practice),
3. identify the key factors and data that is required to achieve Best Practice,
4. link the findings to existing on-farm systems and provide practical guidance about applying effluent to land and choosing the 'right' effluent management system,
5. test the validity of the information and guidance by undertaking a case study,
6. provide information in a format that can used to develop regulations, Fact Sheets or educational material for rural professionals, Councils, AgITO and farmers.

3. Soil characteristics and landscape features:

When considering effluent management it is often best to start in the paddock and work back to the shed. It is clear that understanding the characteristics of the soil types on each farm is key to managing effluent well. Starting out in the paddock allows the critical soil component of the equation to be assessed first and allow other decisions to follow.

3.1 Soil drainage groups and risk framework

Dairying is occurring on numerous soil types but for research and reporting purposes they have been grouped them into categories based on drainage and slope features, according to their risk when receiving effluent. This provides information and guidance that covers all situations throughout New Zealand.

Table 1. Soil and landscape risk framework for farm dairy effluent management (courtesy of AgResearch, Houlbrooke and Monaghan)

Soil and landscape feature	Artificial drainage or coarse soil structure	Impeded drainage or low infiltration rate	Sloping land (>7°)	Well drained flat land (<7°)	Other well drained but very stony[X] flat land (<7°)
Application depth (mm)	< SWD*	< SWD	< SWD	< 50% of WHC[#]	≤10 mm
Instantaneous application rate (mm/hr)	N/A**	N/A**	< soil infiltration rate	N/A	N/A
Storage requirement	Apply only when SWD exists	Apply only when SWD exists	Apply only when SWD exists	24 hours drainage post saturation	24 hours drainage post saturation
Max N load	150 kg N/ha/yr	150 kg N/ha/yr	150 kg N/ha/yr	150 kg N/ha/yr	150 kg N/ha/yr

* SWD = soil water deficit,
[#]WHC = water holding capacity in the top 300 mm of soil,
[X]Very stony= soils with > 35% stone content in the top 200 mm of soil
** N/A = Not an essential criteria, however level of risk and management is lowered if using low application rates

Table 1 identifies that drainage capability and slope are the two key features that drive the decision making process for managing effluent in order to minimise the risk of contamination of waterbodies by nutrient and microbial losses. The level of risk is primarily influenced by managing the application depth, average application rate and storage requirements.

This Table forms the current scientific background information for managing the risks of applying effluent to the land. Councils are now using this information to develop their review their Plans and regulations under the Resource Management Act.

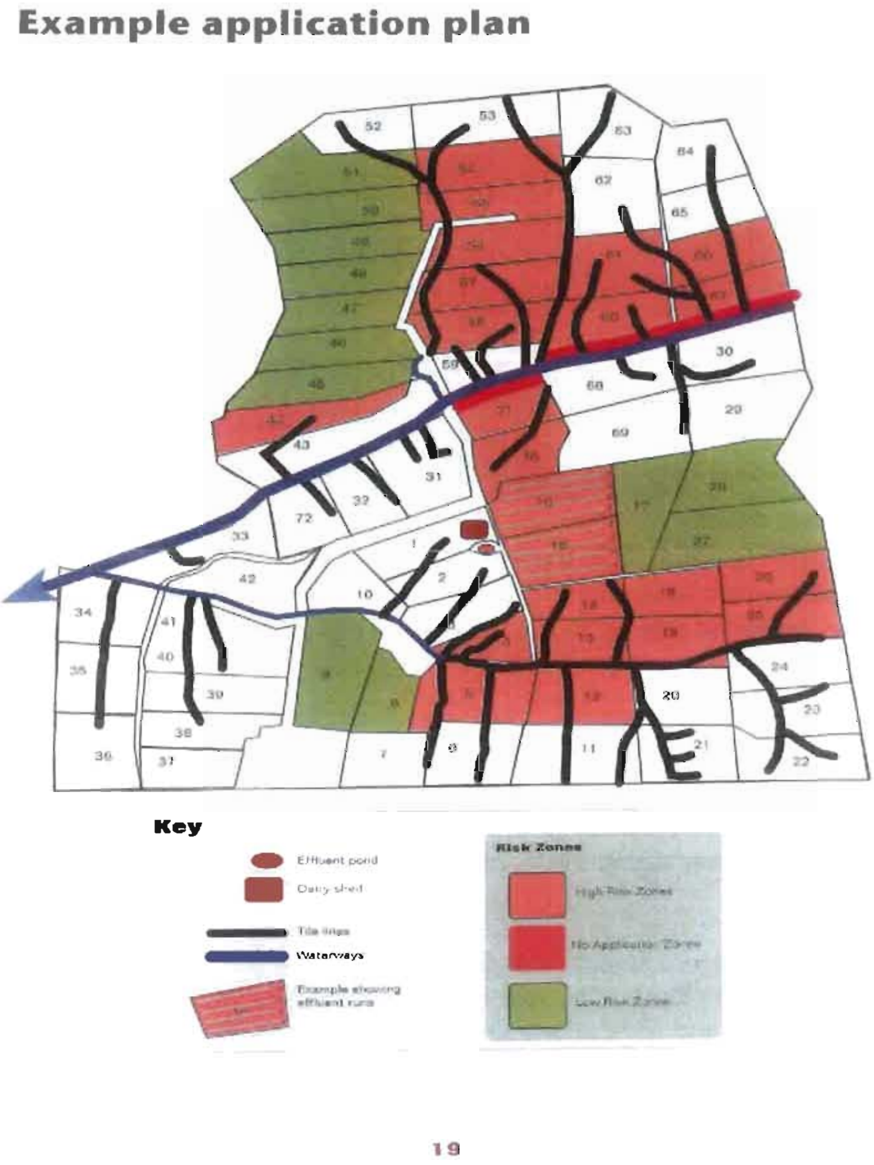
The adoption of these guidelines is different to adopting Best Practice (BP). Best Practice would aim to avoid the risks. For soils with artificial drainage the BP would be to apply effluent using only a low application rate system but it is realised that careful management using other systems can minimise the risks.

3.2 Drainage capability

The ability for water to move through the soil surface (infiltration) and down through the soil profile is just the same for effluent. Farmers applying effluent must think like a farmer irrigating a crop and ask the same question before they start the pump – is this the best time (to apply liquid to the soil) to get the maximum benefit?

Farmers and staff will instinctively group their paddocks according to their drainage capability. Ideally a farm map will identify features like drainage capability or risk as part of an effluent management plan. Figure 1 is an example of an effluent risk management plan and was developed by Otago Regional Council for farms with tile and mole drains on poorly drained land.

Figure 1: Risk management farm plan for dairy effluent. (courtesy Otago Regional Council)



Farmers will also know where pugging or vehicle damage has occurred and be aware that compaction has impeded drainage because surface water will take time to disappear. Coarse or blocky soil structures can also be an indication of impeded drainage characteristics and artificial drainage such as moles and tiles are frequently used to improve drainage on these soils.

Soils with impeded drainage and greater management risks are differentiated from free draining soils that have lower risks in Houlbrooke's risk management framework, Table 1. Free draining soils such as alluvial river terraces, commonly found in Canterbury, transport effluent differently down through the profile. While these soils may have a lower risk of causing ponding and surface runoff to waterways, the challenge facing farmers on these soils is to keep the effluent in the root zone and prevent it contaminating ground water.

3.3 Slope:

Slope is the second key feature when considering risk. The risk of environmental damage from effluent is heightened by increased slope. Flat land is defined in soil science and geographical terms as land with slopes less than 7-8 degrees. The majority of slightly undulating land is under the 7 degree threshold. It is surprising how steep a 7 degree slope is. However there is a good proportion of dairy farming also occurring on land that will exceed the 7 degrees. (eg; rolling country in Northland, Waikato, Otago).

Having slopes above the threshold doesn't mean effluent cannot be applied. It simply means greater care must be taken and equipment with the capability of applying low application rates is required. The risk on sloping land is run-off due to effluent being applied at a greater rate than the soil can absorb it. This may lead to travelling irrigators being deemed 'unsuitable' for use on rolling country – a concept that will no doubt take farmers considerable time to get their minds around and accept because it is a common practice at present.

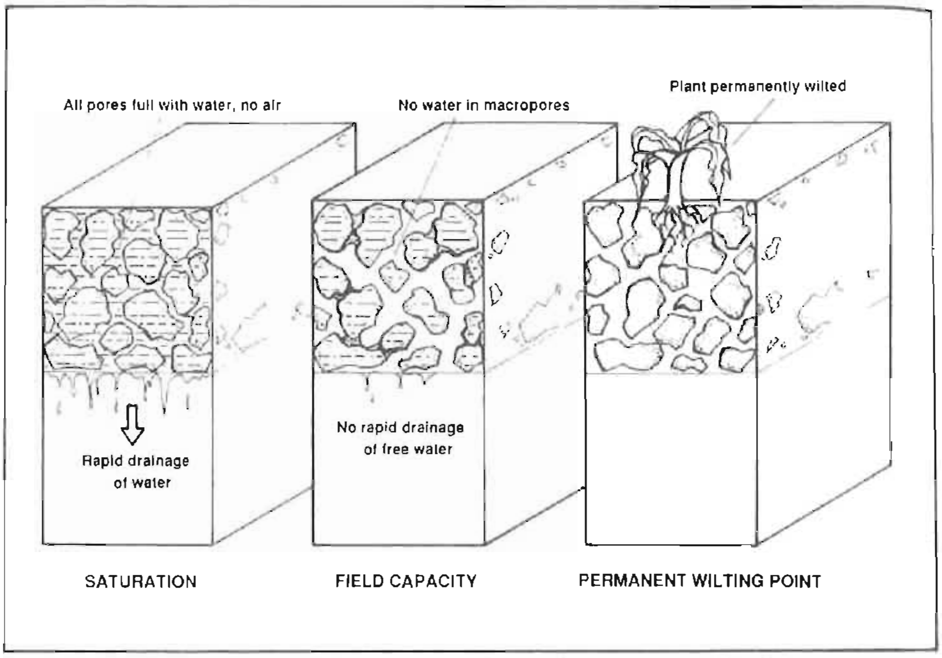
4. How is effluent transported in soils?

If effluent is applied in a way that exceeds the capability for the soil to receive it and hold it safely for plant uptake there is a high risk losses and contamination of waterbodies by nutrients and faecal micro-organisms. The risk of contamination of water is dependent on how effluent is transported through and across the soil. This varies for each soil category as described in Table 1 and represented in Figure 2.

4.1 Terminology:

Saturated soils are when all the soil pores are full of water and there is no air present.
When soils are saturated they can lose effluent as surface run-off to waterways, hollows, ditches, lakes and other water bodies.
A quick field test is to squeeze the soil. If water appears on the soil surface it is considered saturated.
Field capacity is the maximum water content of the soil once drainage has become negligible or stopped.
When the soil is at field capacity the larger pores (macropores) of the soil are filled with air and the small pores (micropores) are filled with water.
The quick field test is to squeeze the ball of soil. No water should appear on the soil surface but a moist outline of the ball is left on the hand. Another test is that the soil sticks to the thumb when rolled between the forefinger and thumb.

Figure 2: Representation of soil water content at saturation, field capacity and permanent wilting point. (McLaren and Cameron,1990)



Water holding capacity (WHC) is the amount of moisture that can be held by the soil. At field capacity the WHC increases as the soil particles get finer (silt and clay). Soils with <40mm per 300mm of soil depth (root zone) are considered to have low WHC, medium 40-50mm and high if >50mm WHC. (Refer Table 2)

Table 2: Estimated Water Holding Capacity for different soil classes. (adapted from Bloomer)

Soil class	WHC (mm/300mm) *
Clay loam	52.5 - 57
Silt loam, no stones or gravel	46.5 – 49.5
Silt loams, approx 35% gravel by volume	33 – 36
Sandy loam	19.5 – 33
Sand	13.5 - 16.5

* Note: Assumes same soil class to root depth of 300mm.

Drainage is when water is lost down through the soil profile below the root zone and potentially to groundwater. Soils drain excess water when the soil is totally saturated or has moisture content greater than field capacity.

Otherwise soils tend to hold the water in the soil pores. Exceptions to this rule are cracks and worm channels and excessive application rates. Drainage can quickly flow down these cracks and channels faster than soil can absorb it.

Knowing how effluent drains out of a soil is key to understanding why soil moisture content is an essential piece of information for managing effluent.

There are 3 mechanisms for transporting excess soil water and effluent:

1. Matrix flow
2. Preferential or by-pass flow
3. Overland flow

4.2 Matrix flow:

Matrix flow occurs when water drains through the soil profile evenly. It's preferred pathway is to wet the whole soil profile by getting into the small gaps and micrpores, displacing existing water and pushing it deeper down the profile similar to the action of a piston. Well drained sandy, pumice, river terrace and young ash derived soil exhibit matrix flow.

Drainage from these soils can often be rapid but matrix flow means that newly applied effluent does not immediately flow out the bottom, below the root zone, but is held in the soil profile for a reasonable length of time allowing nutrients and contaminants to be filtered for longer (attenuation) or taken up by the plants.

This mechanism provides major benefits for effluent management on well drained soils. The most important benefit is that free draining soils can often receive and hold effluent one day after the last rain or irrigation event. However, when soils are this wet, application depths should still be kept as low as possible (< 10 mm) i.e travelling irrigators running at fastest speed.

Matrix flow also means that effluent can be applied on flat land more frequently with minimal risk of contaminating surface water by direct discharge. As a result, less storage is required which is a substantial cost saving.

It is generally difficult to saturate free draining soils but they can become temporarily saturated (all marco and micropores are full of water) if a large amount of effluent is applied in prolonged wet periods. Direct discharge and by-pass flow could occur under these circumstances.

The more likely danger is contamination of groundwater caused by applying more effluent (depth) than the soil can filter or plants can uptake. However the amount of contamination from applied effluent is very small compared to the amount caused by cows naturally discharging effluent in the paddock during grazing. Controlling the amount of N losses on free draining soils is more about minimising the effects of autumn applied urine patches and wintering stock on shallow soils.

Caution is required on stony soils (>35% stones in top 200mm). Table 1 recommends <10mm depth of effluent is applied per application. For well drained soils with less stone content, the recommendation is < 50% of WHC depth is applied at all times to avoid groundwater contamination risks especially where effluent is being applied over shallow aquifers. Table 2 provides an indication of the Water Holding Capacity (WHC) for different soils types.

4.3 Preferential or by-pass flow:

Preferential or by-pass flow is when water or effluent flows down preferred pathways such as cracks, large pores spaces, root and worm channels when soils are draining. Freeze-thawing and wetting-drying cycles can also cause cracks especially in soils with fine texture (clays) and impeded drainage. In effect effluent can by-pass large portions or blocks / aggregates of soil and deliver contaminants quickly below the plant root zone.

Preferential flow paths can be created by installing tile and mole drains (artificial drainage). The drains are extremely efficient and can transport the effluent to waterways within minutes of the effluent being applied to the land.

Figure 3: Diagram illustrating artificial drainage and an example of preferential flow through a Pallic gleyed soil containing remnants of old mole drains. (courtesy AgResearch, Houlbrooke)

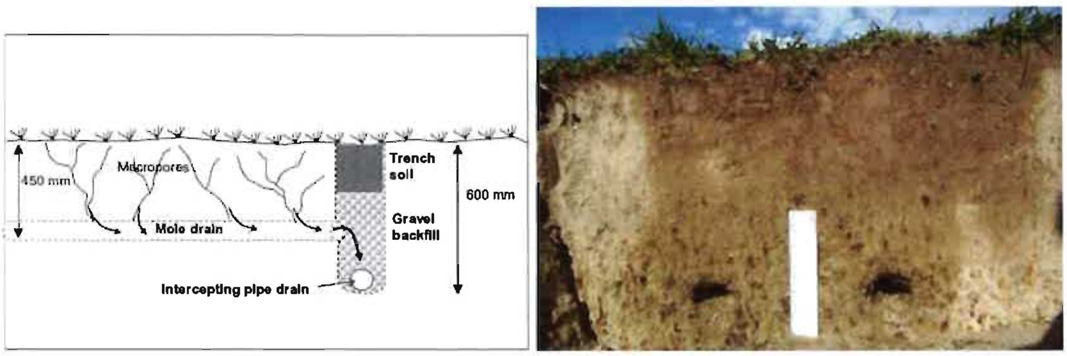


Figure 4: Photograph of soil (Waimea clay loam) illustrating mottling, blocky structure and gleyed appearance.

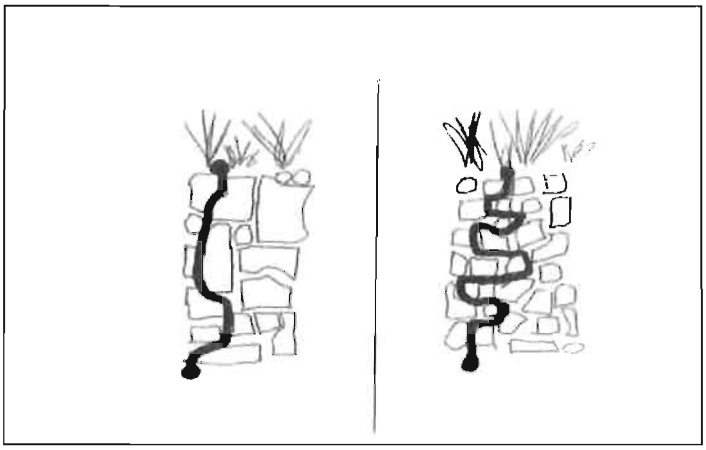
Soils that are peaty, mottled (brown-red patches), have coarse structure, a perched water table and or gleyed (often grey/yellowy) appearance all have high preferential flow risk.
Figure 4 is an example of a soil where preferential flow will occur.

If the amount of effluent applied is less than the soil water deficit (SWD) the risk of preferential flow is greatly reduced so long as application depths are low (i.e <10 mm).
If large depths are applied the SWD that is available in the micropores won't be able to soak up the high inflow of effluent so preferential flow will occur.

This highlights the need to have application equipment that can apply small precise depths of effluent and have a soil moisture meters, especially during the wetter times of the year, when minimal SWD often exists so only the correct amount is applied.

The distinct difference in risk between well and poorly drained soil is illustrated by the flow pathways in Figure 5.

Figure 5: Illustration representing the difference between preferential and matrix flow in soil.



Preferential flow Matrix flow

4.4 Overland flow:

Overland flow or surface run-off is the result of applying more than the land can absorb (even though the soil has the capacity to store it) or applying so much that the soil becomes totally full of water (ie; saturated). In both cases effluent can easily run across the soil surface and into a waterway.

The risk of overland flow increases significantly on sloping land and for soils with compaction or damaged structure. It is essential that the application rate is no greater than the infiltration rate to prevent run-off.

Soils with poor drainage are also vulnerable to overland flow because they are more prone to becoming saturated.

Overland flow is the most risky form of flow because it often results in direct discharge of effluent to waterbodies. Effluent practices must avoid this occurring.

5. What is "ponding"?

Ponding is when effluent or water stays on the soil surface for a period of time. There are two different ways in which "ponding' can occur. Infiltration and saturation excess ponding.

It is often not possible to immediately identify what type of ponding is occurring. The photographs in Figure 7 could be either infiltration or saturation excess ponding. However any ponding indicates that practices can be improved.

Figure 7: Photographs of ponding following effluent application by a travelling irrigator.

5.1 Infiltration excess ponding:

When surface ponding takes 30 minutes to one hour to disappear, this is called infiltration excess ponding. Such conditions imply that the soil is not full of water already and has pores that can store incoming water but the intensity at which the effluent is applied exceeds the soil's ability to absorb the liquid or infiltrate through the soil surface.

On flat land this occurs reasonably often. Infiltration excess occurs naturally when surface ponding follows a short heavy rainfall that disappears after a while. If effluent is applied like a heavy rainfall event the same thing happens. This is common on flat alluvial soils in Canterbury and while it is considered non compliant by existing Council rules, the risk to the environment on flat land, where no direct discharge to a waterway occurs, is very low. If an appropriate depth of effluent has been applied then all ponded effluent should be absorbed within one to two hours of application.

However, on sloping land (undulating land), ponded water will move downslope very quickly creating surface runoff or overland flow. This must be avoided. Compaction caused by heavy cows or vehicles and damage due to pugging, can also severely affect the ability of the soil to absorb effluent. On sloping land and where compaction or the like has occurred, the risks are much higher and irrigation equipment that applies effluent at an application rate greater than 10mm/hr will not be suitable. Preferably the application rate should be <5mmm/hr.

Figure 8: Photographs showing the difference in structure of soils that are compacted and not compacted. (courtesy of AgResearch)

Compacted soil (poor structure) Non compacted (well structured)

To prevent infiltration excess ponding apply effluent at a rate or intensity that the soil can absorb. In otherwords the application rate must not exceed the infiltration rate.

5.2 Saturation excess ponding:

The second process that results in ponding is known as 'saturation excess'. This occurs when soil is fully saturated, often as a result of a high water table or a slowly permeable subsoil layer that restricts drainage. When saturated soils are filled beyond field capacity to the point that all large macropores and normally air-filled pores are filled with water, the soil has no capacity to absorb further water through the surface and it ponds. This is saturation excess ponding.

Applying too much effluent (ie; the depth is too high) will cause soil saturation and saturation excess ponding. This is a more risky type of ponding because the excess effluent applied will not soak away until the soil losses some of its moisture by draining it deeper into the soil profile, into tile drains or by evaporation. Overland flow will stop once the effluent stops being applied but it indicates that preferential flow conditions will occur and that direct losses of nutrients and microbes will eventuate.

The solution to avoiding saturation excess ponding is to only apply effluent when the soil is dry enough to store the amount of effluent applied (ie; there is sufficient soil water deficit) and in all other times store effluent until conditions are suitable.

6. Application depth:

Application depth is probably the most important aspect of effluent management because it is the one thing that farmers and staff can control easily.

6.1 Definition of "application depth":

Application depth (mm) *is the amount of effluent applied to the land during one application.*
The "depth" is the same as measuring rainfall in a rain gauge.

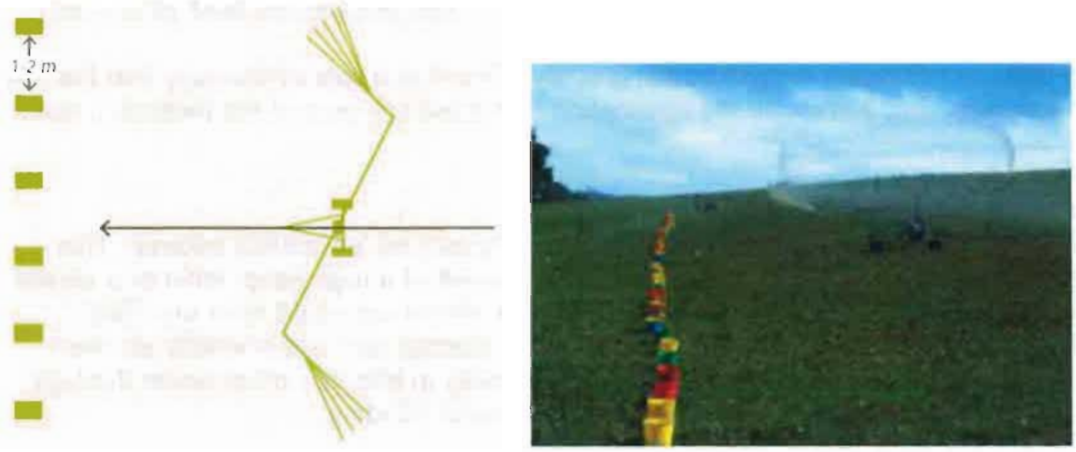
There are several makes and models of travelling irrigator on the market. The depth they can apply varies considerably between slightly less than 5mm to greater than 50mm but this is totally dependent on a large number of things that can affect performance. A <u>average</u> depth for a travelling irrigator varies considerably but could be between 10mm – 25mm. The depth that stationary sprinklers and pods apply is entirely dependent on how long effluent is applied but application depths are often less than 10mm and can be <2mm.

It is essential that the <u>depth</u> of effluent applied is <u>less than the soil water deficit</u>
The <u>only</u> exception to this rule is well drained soils on flat to undulating land.

6.2 Measuring application depth:

The simplest way to measure application depth is to place approximately 6-8 ice-cream containers about 1-2m apart across the path of the irrigator, collect the effluent and use a ruler to measure the depth collected in each container. Record the depth in each container and identify the maximum and average depth collected.

Figure 9: Diagram and photograph showing how application depth is measured for a travelling irrigator. (courtesy DairyNZ)



(Measuring Application depth instructions: Refer to DairyNZ Fact Sheet 6-9)

To measure depth more accurately the surface area of the top of <u>each</u> container and the volume of effluent collected is measured.

Example:
500ml effluent landed in a square ice-cream container with a surface area of 170mm width x 170mm length.

Depth = volume / area   1mm = 1 litre / m^2

$$\text{Depth} = \frac{500 \times 1000}{170 \times 170} = 17.3\text{mm}$$

If 500mls was collected in a round container with a smaller surface area for the effluent to fall onto (radius of 70mm) in one application the depth would be greater.

$$\text{Depth} = \frac{500 \times 1000}{3.14 \times 70 \times 70 \text{ (radius}^2\text{)}} = 32.5\text{mm}$$

6.3 How does irrigator speed affect application depth?

Some effluent applicators (pods and sprinklers) are stationary so speed is irrelevant. The majority of effluent in New Zealand is still applied by travelling irrigators that can have their speed easily adjusted. The faster the travel speed the lower the depth of effluent applied.

Not all travelling irrigators are geared the same or have the same distribution pattern so each one will deliver a different depth at different speeds. Therefore it is absolutely vital to know the depth of effluent applied at different speeds so that when the SWD changes, the speed of the irrigator can be adjusted with certainty that the depth applied will match the available SWD.

When soils are already close to field capacity (ie; the soil has a low soil water deficit) it is important to have the irrigator travelling as fast as possible. Even then it may not be fast enough to avoid applying so much effluent that runoff or saturation ponding occurs.

Example:
If the irrigator travels faster, less effluent will be collected in the containers because less time will be available for the effluent to be applied. In this example there is less volume collected in the container therefore less depth is applied than in the previous example above.

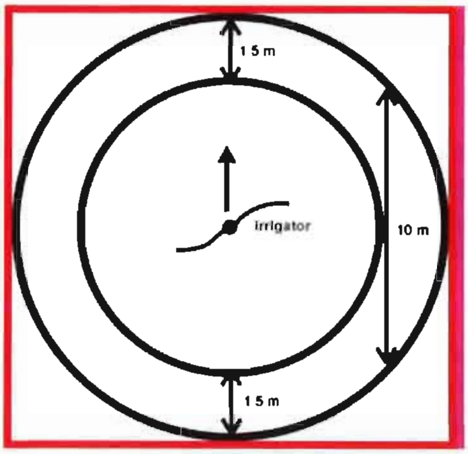
$$\text{Depth} = \frac{300\text{ml} \times 1000}{170\text{m} \times 170\text{m}} = 10.4\text{mm}$$

6.4 Uniformity and application depth

Distribution uniformity can be very poor on some applicators. If there is a wide variation between the minimum and maximum depths applied by the applicator then it is important to make decisions based on the <u>maximum</u> application depth (eg travelling irrigator: 25mm on outside, 10mm on inside of wetted area). If the variation is relatively narrow then matching the average depth to SWD is adequate.

Figure 10 illustrates the common 'donut' pattern problem with uniformity that travelling irrigators. The variation between the depth applied on the outside compared to the inside is obvious in the photograph.

Figure 10: Schematic diagram (courtesy of AgResearch) and photograph representing a common 'donut' distribution pattern for a travelling irrigator.



To measure the maximum and average application depth enough containers or trays must be placed across the diameter or width of the wetted area to capture the variation in uniformity of application.

Figure 11: Variation in application depth between different irrigators. (courtesy AgResearch)

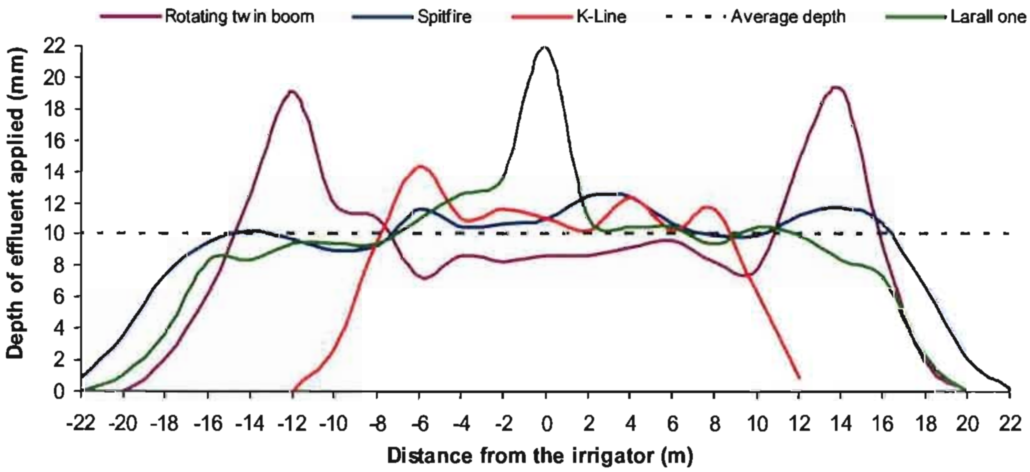


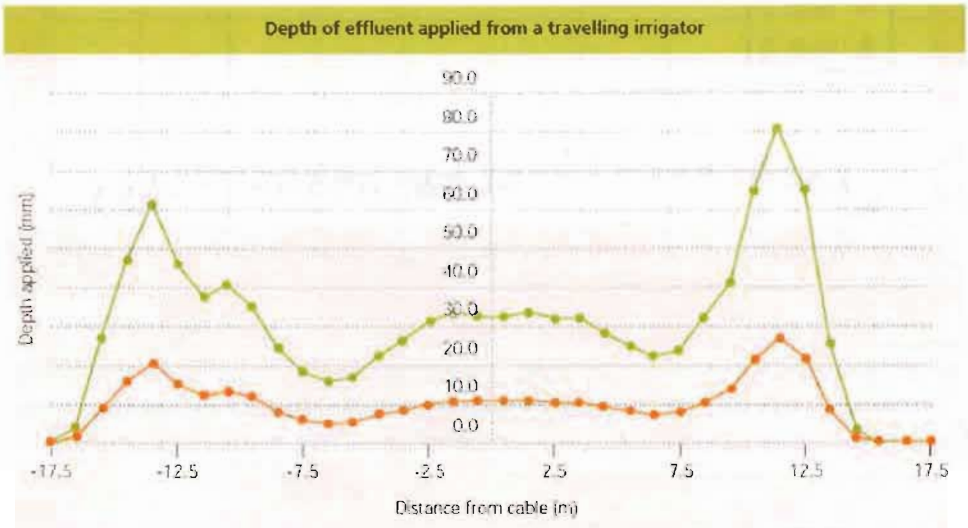
Figure 11 highlights the variation in application depth applied across the wetted area for different applicators. Note that while the average depth is 10mm some application depth peaks in Figure 11 are twice as high as the average depth and more if the minimum depth is considered. Where the maximum depth of effluent is applied is where ponding occurs first. This is why it is important to know at least the average depth and preferably what the maximum application depth is, and match it to the soil water deficit.

A higher depth can also be caused by wetted areas overlapping. If K line pods or sprinklers are not spaced far enough apart this can occur.
Figure 11 also highlights that applicators may have a peak that covers only a small percentage (0.3%) of the wetted area. (eg; Larall / Bosch sprinkler). In this case the peak should not be considered the maximum depth because it only covers a small proportion of the wetted area.

The uniformity of effluent applicators has improved considerably in recent years, especially for travelling irrigators. Travelling irrigators have traditionally had maximum depths of >15mm on their fastest speed but improvements on the new generation irrigators have reduced this to 5mm or less by engineering them to travel much faster and improving the spray pattern.

Figure 12 shows the effect on depth that occurs from ensuring the irrigator is performing at its optimum.

Figure 12: Depth of effluent applied before and after adjustment of travelling irrigator. (DairyNZ 2009)



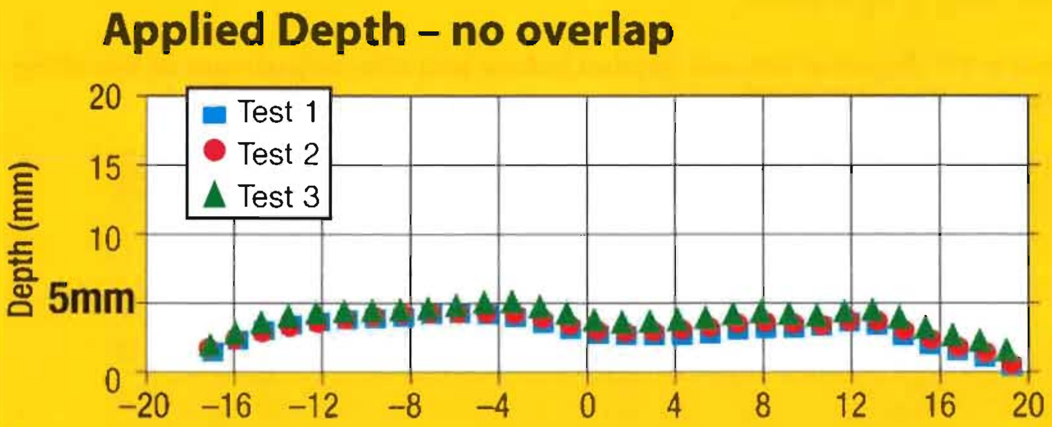
Numedic and Plucks (refer Figure 13) have recently modified their travelling irrigators to improve uniformity and application depth.

Figure 13: Information and test results for new travelling irrigator from Plucks Engineering Ltd, Rakaia website.

With a 300 Meter x 30 M run, the [redacted] can apply your effluent at a rain rate as low as 4.5mm per pass and as fast as 1.5 hours per run, if you want.

Which equals 45,000 litres in one run, spread so evenly that you will think it is only the *morning dew* on the ground, not where your effluent irrigator has been.

The new [redacted] finally brings to your farm a travelling irrigator that cannot leave dark strips on your paddock or doughnuts at the ends, because of its patented boom design, giving your LP35E a *super flat rain curve* (see graph).



Meaning it rains evenly right across the wetted width, so there is as much effluent rain falling in the middle of the wetted width as at the edges, instead of most of the effluent rain landing only at the outside edges of each run, creating dark strips up your paddock and over saturating the outer 3 to 8 Meters of width on both sides of the irrigator run, for the full length of the paddock, as other travelling irrigators currently do.

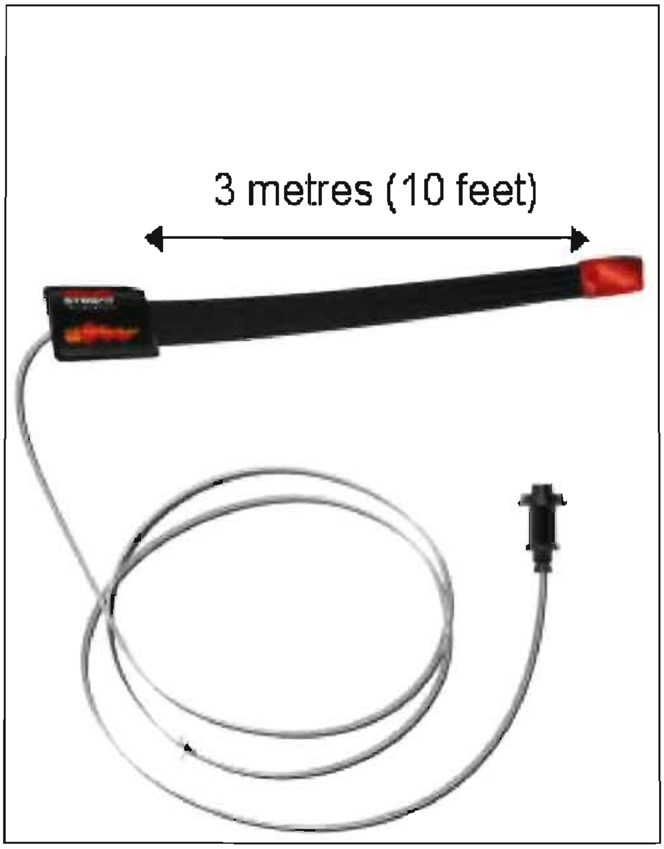
The new PLUCK'S [redacted] irrigator does not leave any puddles, or dark strips, or doughnuts patterns, but instead leaves your effluent run looking like a light *morning dew* has settled.

Uniformity or spray pattern is also highly affected by pressure. Most systems will have the pressure delivered to the irrigator checked following installation but very few systems have their pressure checked after that. Insufficient pressure is more common than people realise. A good indicator of low pressure is slow rotation of a travelling irrigator and effluent 'dribbling' out of nozzles (Figure 16). There are a number of different nozzles on the market and the spray pattern can be improved significantly by choosing the correct nozzle.

6.5 Measuring Soil Water Deficit (SWD)

Ideally all farms should have a metre or device (eg: Aquaflex tape, Figure 14) that continually records soil water deficit (SWD) and transmits that information automatically to the farm computer or a professional service provider. The software programmes or service provider will interpret the data and by knowing the maximum or average application depth of your applicator you can determine if it is appropriate to apply effluent. Some systems will send a text message advising if effluent can be applied or not (eg:ReGen).

Figure 14: Photograph of Aquaflex tape (courtesy Streat Instruments Ltd)

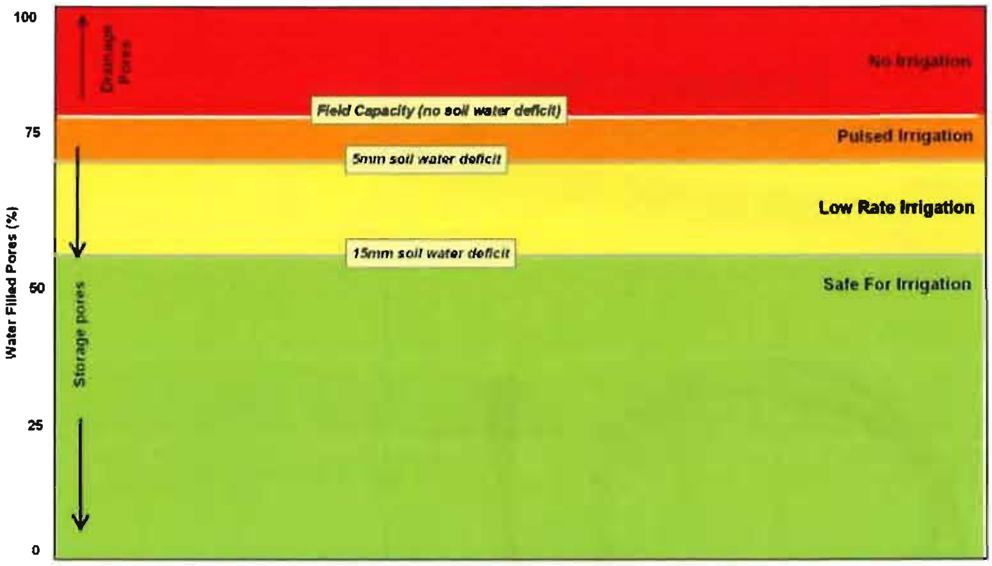


Investing in a soil moisture metre will cost about $2-3000 for an Aquaflex tape with radio link back to the computer or cheaper if data is downloaded with a handheld device. This is probably the most suitable and affordable metre on the market for farmers.

If only one metre is installed it must be placed in the soil type that represents the majority of the effluent block. Usually an effluent block often has more than one soil type so ideally a metre or device should be installed to monitor all soil types where effluent is applied. If installing only one metre but there are 2 or more soil types it is recommended to place that metre in the soil that has a higher water holding capacity (clays, silts), has artificial drainage (soils with tile drains) or sub soil pan impeding drainage (peat/ pakahi soil). The risk of over application is higher and more difficult to manage on these soil types than soils that drain more freely.

Some Councils websites have SWD information for different soil types and locations across their region which can also be a useful guide This information can only be used as an indication because the information is not recorded on each specific farm. Most farms will also have several different soil types and have received less or more rainfall than where the Council meter is located. The Environment Southland website (Figure 15) provides SWD and matches that with guidance on the method of irrigation.

Figure 15: Website screenshot providing dairy effluent application guidance based on soil water deficit (courtesy Environment Southland).



6.6 Precision farming and the practicalities of deciding how much effluent to apply:

Agriculture in New Zealand is rapidly demanding more precision in order to deliver efficient use of resources and profit but also to provide assurances that practices are compliant. The use of GPS for mapping, paddock layout, fertiliser applications, sowing and irrigation is now common practice. Effluent management is no different to irrigation and greater precision is likely to be required in the future especially for compliance purposes.

Being more precise will cost money but by using other tools such as Overseer, testing the nutrient content of effluent, good record keeping and GPS, the full benefits of more efficient fertiliser use will offset the costs and return a profit long term. In addition these tools will provide peace of mind and provide instant and accurate on-farm decisions. Farmers are now valuing this very highly given that Court imposed fines are $20 -100,000 or more.

In the future farms will invest in a soil moisture metre for effluent management but at present most farms do not have a SWD metre. Farmers and staff are currently making decisions with limited information about how much effluent to apply especially during the wetter months of spring and autumn.

On land where the risks associated with effluent application are higher (ie; sloping, poorly drained, tiles, compacted, clays) more precision is required because SWD is often minimal (less than 10mm) and often from July - Nov. The unfortunate fact is that many irrigators cannot apply less than 10mm average depth and that puts farmers at risk of enforcement action by Councils. The only way this can be overcome is to have more storage. With imprecise equipment and limited information, effluent should be stored until it is certain that sufficient SWD exists. This highlights the value of installing a soil moisture metre and having good equipment.

In the absence of a SWD metre there are practical indicators that can be adopted. If water is ponding on the surface in paddocks or water is splashing off the quad bike tyres in most instances the soils will be saturated with zero SWD. Effluent must not be applied in these circumstances. Water will drain from the larger macropores in the soil if there is no more rain or irrigation and the soil will reach a state of field capacity. Soils at field capacity feel slightly moist to touch and it normally takes 2-3 days after rain for soils to reach this state. It is important to allow another 2-3 days of dry, sunny weather with light breezes before applying effluent unless the irrigator can apply 5mm or less depth. This will ensure the soils will have dried out and sufficient SWD will exist. These are only general rules of thumb so if in doubt effluent should be stored rather than applied.

Eg:
SWD = 6-7mm,

If maximum average depth for travelling irrigator at fastest speed = 10mm
Effluent cannot be applied – store effluent.
If maximum average depth for travelling irrigator at fastest speed = 6mm
Effluent can be applied with caution.
If maximum average depth for K line pod system is 4mm effluent can be applied

SWD = 18mm,

Maximum average depth for travelling irrigator at fastest speed = 10mm
Effluent can be applied and the irrigator speed could be reduced slightly.
Maximum depth for K line pod = 5mm
Effluent can be applied for at least 3 hours without shifting the pod.

7. Application rate

Application rate is commonly confused with application depth. Understanding the importance of application rate is vital especially when the weather has been poor, slopes exist, soils are wet and conditions for applying effluent require more precision.

7.1 Definition of application rate

Application rate (mm/hr) *is the depth of effluent applied during one application within a certain time period.*
This is a measure of how intense or heavy the effluent has been applied.

7.2 Measuring application rate

The simplest way to calculate average application rate is to divide the average of the depths collected in each container by the time during which effluent was entering the containers (one complete pass over all containers).

$$\frac{\text{Average Depth}}{\text{time}} = \frac{18\text{mm}}{20\text{mins}} = 18 \times \frac{60}{20} = 54\text{mm/hr}$$

If the volume being delivered at the irrigator is known, then application rate is flow rate divided by the wetted area. Irrigation or pump specialists will generally use this method.

$$\frac{\text{Volume (litres / hr)}}{\text{Wetted area (m}^2\text{)}} = \text{Application rate (mm/hr)}$$

** **NB:** Remember that 1mm = 1 litre/m^2.

6 l/sec = 6 x 3600 (seconds in a hour) = 21600 litres / hr

If irrigator only applied effluent for 30minutes = 0.5 hrs
If the irrigator travels a short distance an applies this much effluent to an area of 250m^2

$$\text{Application rate} = \frac{21600 \times 0.5}{250} = 43.2\text{mm/hr}$$

For a stationary pod or sprinkler the application rate will be the same as the application depth. For K line pods this is approximately 4-5mm/hr. When using a gun, pods or sprinklers that are pulsed it is important to be aware that while the depth applied over a short period in any hour is low the intensity it has been applied at means the application rate (4mm/hr) will always be higher (eg; a K line pod can apply 1mm depth in 15min pulse, then switched off for 45 minutes but the application rate is 4mm/hr). This highlights the difference between application depth and application rate.

Application rates for a moving irrigator have traditionally been much higher than a sprinkler or pod but some new generation travelling irrigators have application rates below 10mm/hr and capable of applying depths of less than 6mm. Application rates have been reduced predominantly by improving the distribution pattern. Application depths have also been lowered to less than 6mm but this is due to speeding them up with new gears and cam designs.

Speeding up a travelling irrigator does not lower the application rate. Speed only lowers the application depth. Engineers have improved application rate by improving the spray pattern and uniformity with modification such as using diffusers and making one arm longer than the other.

7.3 The influence of pressure on application rate:

Application rate is dependent on how much pressure and volume produced by the system. If a travelling irrigator has low pressure, it rotates less often and consequently moves slower. This increases the depth applied and that increases the application rate. A low application rate is preferred therefore it is important to ensure pumps are operating at their optimum and no leaks exist in the mainline, hydrants or equipment. An example of pressure loss is when a nozzle is lost off the end of the boom. That will immediately reduce pressure and application rate increases significantly.

A common way that farmers overcome lower pressure on poorly configured or maintained systems (high pipe friction loss, or lack of pump capacity) is to block off one nozzle outlet on a travelling irrigator. This increases pressure, speeds up the irrigator and lowers depth and can also lower the application rate. However this can only be regarded as a temporary fix. Figure 16 provides examples of this.

Figure 16: Photographs showing how pressure can influence distribution pattern, application depth and application rate. (courtesy DairyNZ)

Sub optimal pressure or incorrect spacing can result in higher application depths and poor distribution patterns.

Systems operating at the correct spacing and pressure deliver lower depths and better uniformity.

8. Infiltration rate

8.1 Definition of infiltration rate

Infiltration rate (mm/hr) *is the rate at which effluent (or rainfall) can be absorbed by the soil.*
If effluent is applied at a greater intensity (ie: application rate) than it can be absorbed through the soil surface it will either pond on the surface or run-off into a hollow or waterway.

Table 3 details the variation in infiltration rates between different soil types in New Zealand. The finer textured clays have much lower infiltration rates than the coarse textured sands and sandy loams. Dairying occurs on all of these soil types and highlights the importance of knowing about the characteristics of soils where effluent is to be applied to avoid ground and surface water contamination and keep the nutrients in the root zone.

Farmers will usually know where water infiltrates the surface faster and where consolidation or compaction has occurred. It's important farmers use that local knowledge to make changes to how or where effluent is applied.

Table 3: Estimated maximum infiltration rates (mm/hr)

Estimated Maximum Infiltration Rates (mm/hour)

Soil Group	Slope 0^0 - 8^0	Slope $9^0 - 12.5^0$
Sands and light sandy loams uniform in texture	31	25
Sandy loams overlaying a heavier subsoil	20	16
Medium loams to sandy clays over a heavier subsoil	16	13
Clay loams over a clay subsoil	13	10
Silt loams and silt clays	10	8
Clays	6	5
Peat	16	-

(Adapted from NZS 5103:1973)

Courtesy Bloomer, 2010

8.2 Why is infiltration rate so important?

When the effluent hits the land the first factor that determines whether or not a good management outcome will occur is how well the effluent is going to soak or infiltrate through the soil surface. Until recently we have tended to ignore the importance of soil type and their associated infiltration rates when choosing the most appropriate effluent system but as monitoring is stepped-up by Councils and fines increase this is one factor that needs to be considered. Ponding is the easiest factor to see and monitor for a compliance officer.

Many of New Zealand's soil types are finer textured clays or silts, have impeded or imperfect drainage, are easily compacted or have mole and tile drains. Other factors that affect infiltration rate are the amount of vegetative cover, the slope, and the solids content of the effluent. Solids content refers to effluent from a feed or stand-off pad that has a lot of long fibres in it. If it isn't chopped or separated from the liquid prior to being applied to land, it can mat or blind the soil surface. This lowers the infiltration rate.

A high percentage of dairying occurs on soils with these characteristics and features which is one reason why it is difficult to manage the potential adverse effects of effluent discharged to land.

8.3 How is application rate associated with infiltration rate?

The infiltration rate of clays and silts is typically less than10mm/hr (refer Table 3). However given that the structure of clays and silts can be easily damaged by pugging and winter feeding or compacted by machinery and the weight of cows the infiltration rate can often be significantly reduced.

The application rate of many travelling irrigators is typically more than 40mm/hr so effluent is going to be applied faster than it can infiltrate the soil surface in many circumstances. Ponding or surface run-off can therefore easily occur, especially on sloping land. This is the principal reason why effluent applicators with application rates above 10mm/hr pose a higher risk and should not be used at all when soils are compacted, at field capacity, saturated or with low SWD.

On sloping land above 7^0 application rates must be less than the infiltration rate or at least <10mm/hr. Best Practice is to apply effluent at <5mm/hr for sloping land and soils with poor or impeded drainage characteristics. This is why K lines, Bosch sprinklers and other low application rate irrigators are better suited to sloping land or where infiltration rate is low. On flat land a low infiltration rate can be mostly avoided by applying a low depth of effluent but some ponding risk still may exist. Travelling irrigators should therefore be adjusted to their fastest speed.

For well drained or free draining soils (friable, small aggregates and matrix flow) infiltration rate is usually high (>20mm/hr) and on soils with a high stone content it is often higher. While this is great for compliance purposes because it is difficult to generate visible ponding, it comes with the danger that large amounts of effluent are likely to be draining down through the profile.

Farmers will usually know where water infiltrates the surface faster and where consolidation or compaction has occurred. It is important farmers use that local knowledge to make changes to how or where effluent is applied.

If infiltration rate is not a constraining factor then application rate is less important. Application **depth** is therefore critical to ensuring that contaminants and nutrients remain in the root zone on free draining soils.

Depths of no more than 25mm per application event is generally regarded as the maximum that should be applied. This equates to approximately 75kg/ha Nitrogen.

The flat, free draining, alluvial soils found on river terraces and many parts of the Canterbury Plains are suitable for higher rate (> 10mm/hr) applicators where controlling the depth by changing the speed will generally achieve good outcomes.

9. How much effluent should be applied and when?

9.1 Best Practice:

How much effluent and when it should be applied varies from farm to farm and day to day. In order to keep nutrients within the root zone and out of waterbodies, Best Practice is based on good information and systems that can accurately apply the right amount, every time. The formula for all soils is:

1. **Measure irrigator's application depth and rate at different speed settings at the furthest point from the pump**
2. **Identify the drainage characteristic of the soils in the effluent block and if the slope is <7^0 or not**
3. **Record daily soil water deficit (SWD)**

4. **Check the paddock conditions (grass cover, large cracks, compaction), check weather, adjust timer or speed, check irrigator is operating properly, check storage capacity**
5. **Apply the appropriate recommendations in Table 1.**

Consideration also has to be given to:

- specific farm consent conditions and what is required to be compliant
- the presence of artificial drainage (tiles and moles) and large cracks
- best timing (soil temperature and plant growth stage) to maximise the effluent nutrient value
- growing as much grass, clover and crop as possible (don't over apply and stall growth)
- avoiding palability issues caused by applying so much that it coats the pasture
- avoid having to apply effluent during calving to relieve stress on staff
- avoid potential mishaps when relieving milkers are used or at weekends or key staff are away on leave
- having the ability to cope with natural events like flooding, snow, frost or long periods of wet weather

Effluent should be applied when plants are actively growing. Grass will uptake the nitrogen in the effluent at temperatures above 8 degrees Celsius but if the aim is to maximise potassium uptake by clovers, the soil temperature needs to be 12 degrees Celsius or more. By applying effluent later in the season there is greater return on the investment in a well designed, installed, operated and maintained effluent system.

Tables 4, 5, & 6 provide Best Practice guidelines that match irrigator equipment type to soil water deficit (SWD) for each soil and landscape feature referred to in Table 1.

Table 4: Dairy effluent land application system and soil water deficit risk management framework

Features: **Soils with impeded / artificial drainage, coarse structure, low infiltration rate / compacted, < 7 degrees slope**

Effluent system	Slurry tanker	Travelling irrigator, av depth 10-20mm @ fastest speed	Travelling irrigator, av depth < 10mm @ fastest speed	Smart Hydrant, Larrall, K line, Uni Sprinkler, pulsed, < 5mm av depth
Saturation	X Do not apply X	X Do not apply X	X Do not apply X	X Do not apply X
Field capacity	X Do not apply X	X Do not apply X	X Do not apply X	X Do not apply X
SWD				
0 - 5mm	X Do not apply X	X Do not apply X	X Do not apply X	✓ Apply – caution X
5 – 10mm	X Do not apply X	X Do not apply X	✓ Apply – caution X	✓ OK ✓
10 – 20mm	X Do not apply X	✓ Apply – caution X	✓ OK ✓	✓ OK ✓
> 20mm	✓ Apply – caution X	✓ OK ✓	✓ OK ✓	✓ OK ✓
Notes:	Vulnerable to causing compaction and damage, can apply low depth	High application rate, higher average depth, older type irrigator, slower, poorer uniformity	New generation irrigator / Spitfire, faster speed, low average depths, good uniformity	Stationery, vulnerable to being left in one place, lowest appl rates and because pulsed very low depths.

Note: "Do not Apply" assumes that effluent will be held in storage.

Table 5: Dairy effluent land application system and soil water deficit risk management framework

Features: Well drained soils, < 7 degrees slope

Effluent system	Slurry tanker	Travelling irrigator / Spitfire, av depth 10-20mm @ fastest speed	Travelling irrigator, av depth < 5mm @ fastest speed	Smart Hydrant, Larrall, K line, Uni Sprinkler, pulsed, < 2mm av depth
Saturation	X Do not apply X	X Do not apply X	X Do not apply X	X Do not apply X
Field capacity	X Do not apply X	X Do not apply X	X Do not apply X	✓ OK ✓
SWD 0 - 5mm	X Do not apply X	X Do not apply X	✓ OK ✓	✓ OK ✓
5 – 10mm	✓ Apply – caution X	✓ Apply – caution X	✓ OK ✓	✓ OK ✓
10 – 20mm	✓ OK ✓	✓ OK ✓	✓ OK ✓	✓ OK ✓
> 20mm	✓ OK ✓	✓ OK ✓	✓ OK ✓	✓ OK ✓
Notes:	Limited by vulnerable to cause compaction and soil damage, but can apply low depth. Some ponding risk.	High application rate, higher average depth, older type irrigator, slower, poorer uniformity. Med – Hi risk of ponding.	New generation irrigator, faster speed, very low average depths, good uniformity. Some risk of ponding.	Stationary, vulnerable to being left in one place, lowest appl rates /hr and pulsing allows very low depths. Low ponding risk

Note: "Do not apply" assumes that effluent will be held in storage.

Table 6: Dairy effluent land application system and soil water deficit risk management framework

Features: Sloping land, > 7 degrees

Effluent system	Slurry tanker	Travelling irrigator / Spitfire, av depth 10-20mm @ fastest speed	Travelling irrigator, av depth < 5mm @ fastest speed	Smart Hydrant, Larrall, K line, Uni Sprinkler, pulsed, < 2mm av depth
Saturation	X Do not apply X	X Do not apply X	X Do not apply X	X Do not apply X
Field capacity	X Do not apply X	X Do not apply X	X Do not apply X	X Do not apply X
SWD				
0 - 5mm	X Do not apply X	X Do not apply X	X Do not apply X	X Do not apply X
5 – 10mm	X Do not apply X	X Do not apply X	X Do not apply X	✓ Apply – caution X
10 – 20mm	X Do not apply X	X Do not apply X	X Do not apply X	✓ OK ✓
> 20mm	X Do not apply X	X Do not apply X	✓ Apply – caution X	✓ OK ✓
Notes:	Limited by vulnerable to cause compaction and soil damage, but can apply low depth. Some ponding risk.	High application rate, higher average depth, older type irrigator, slower, poorer uniformity. Med – Hi risk of ponding.	New generation irrigator, faster speed, very low average depths, good uniformity. Some risk of ponding.	Stationary, vulnerable to being left in one place, lowest appl rates /hr and pulsing allows very low depths. Low ponding risk

Note: "Do not apply" assumes that effluent will be held in storage.

9.2 Current practices and reality:

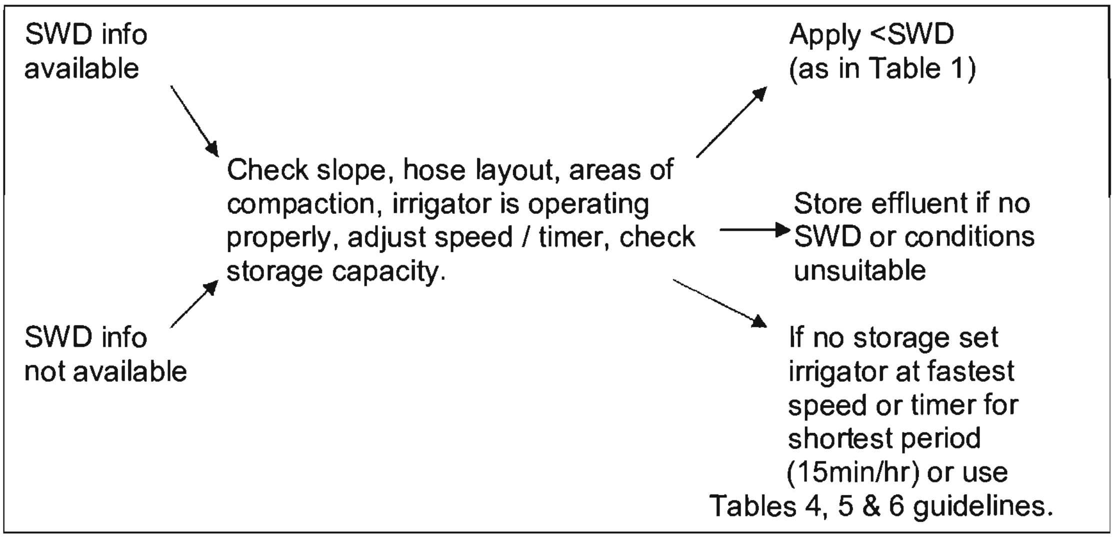
For many dairy farms in New Zealand the key is matching the SWD that exists each day to the system's application rate and depth capabilities. But the reality is that only a few farmers have a soil moisture metre at present. Without knowing the SWD the whole concept of achieving Best Practice for effluent application is difficult.

If application depth and rate are known for each speed or time period (pods / sprinklers) the general information in Figure 17 and Table 7 can be used as a guide.

If SWD information is not available paddock conditions must be assessed carefully and a more conservative approach taken. If soil conditions are marginal and there is any risk it is best not to apply any effluent. If effluent must be applied then apply the least amount possible by setting the irrigator on the fastest speed or timer on the shortest intermittent period (15 mins/hr) and check the paddock frequently.

For free draining soil do not apply any more than 20 - 25mm in a single application and cease application if overland flow occurs.

Figure 17: Simple guidelines for applying the right amount of effluent.



The technology is available to apply exactly the right amount of effluent every day but unless regulations or industry standards require this to happen it will be up to each individual to decide on the level of investment they are comfortable to operate with.

Table 7: General guidelines for how much dairy effluent can be applied to each soil type (courtesy of DairyNZ).

Soil type	Maximum application depth	Maximum application rate
Sand	15mm	32mm/hr
Loamy Sand	18mm	32mm/hr
Sandy Loam	24mm	20mm/hr
Fine Sandy Loam	24mm	17mm/hr
Silt Loam	24mm	10mm/hr
Clay Loam	18mm	13mm/hr
Clay	18mm	10mm/hr

Note: Figures for soils with 50% WHC prior to effluent application – not wet soils

9.3 Pulsing or intermittent application of effluent:

Intermittent application of effluent or pulsing is adopted by most temporarily stationary pods and sprinkler systems. It allows application depths of <2mm to be applied in many instances which enables the user to apply effluent when SWD is almost nil. This has the benefit of less storage being required because more opportunity exists for effluent to be applied.

With these systems the application rates are also very low which avoids ponding, the risk of runoff and ensures effluent can be held in the root zone for plant uptake.

The downside of pulsing is that the volume of effluent applied can be significantly reduced. This is overcome by setting up separate lines of pods or sprinklers and automatically switching between them so volume is being continuously pumped each hour. The Smart Hydrant also achieves this by having 6 guns and setting it to run for 10 minutes each hour. You could pulse a travelling irrigator but your still have the problem of applying less volume plus a travelling irrigator doesn't have the same ability to take advantage of situations when the SWD is less than 5mm.

10. Factors that influence irrigator performance:

Depth, application rate and the overall performance of an irrigator, especially a travelling irrigator, is significantly influenced by a multitude of factors either on their own or in combination. For example, the installation of a new irrigator may not deliver optimum irrigator performance because the pump is inadequate or the mainline is too small. Application rate and depth are often affected simultaneously by the same issue.

10.1 Standards and Codes of Practice:

Many systems are not designed well, installed and commissioned properly, operated or maintained well and have their performance assessed regularly. Unfortunately this is very common issue at present. DairyNZ are currently developing Farm Dairy Effluent Design Standards and Design Code of Practice. These will establish a means of measuring the adequacy of effluent systems and provide guidance for designers. It can also be used to provide assurances to farmers that systems and services are going to deliver what is expected or promised. In time this will form the benchmark and help to overcome some of these issues. Audit services are now starting to appear in some provinces and farmers will see the benefit of using them annually in the future.

10.2 Pump and mainline size:

It is vital to have a pump or irrigation specialist design and properly configure your pump to your length and size of pipeline. As herd sizes increase many farmers have extended their mainline without seeking specialist advice. This has often caused a reduction in pressure delivered at the irrigator (eg; due to increased pipe friction and head losses) and subsequently poor effluent management outcomes have occurred.

If solids are being separated from the raw effluent this will also influence decisions made on mainline and pump size because green water (effluent without the solids) is easier to pump than un-separated raw effluent. The pump / irrigation specialist will need to consider whether effluent is being separated or not when designing the system to ensure the correct pressure is being delivered to the irrigator. The consistency of the effluent or Dry Matter (DM) content will also change the pumping and setup requirements. If effluent is coming off a feed pad or from a wintering barn there will be a lot more fibre and the different consistency can cause a number of problems.

10.3 Pressure:

Sufficient pressure must exist at the point of discharge on the irrigator (ie; usually measured at the irrigator or at the first coupling before the irrigator) to ensure it operates at its optimum. If there is insufficient pressure the spray pattern, uniformity and distance effluent is applied (wetted area) is often adversely affected. Because travelling irrigators are driven by pressure turning the boom and activating the winch mechanism the pressure is the critical factor in determining the irrigator speed. Insufficient pressure and the speed of a travelling irrigator is slower. All of these factors are likely to increase the maximum application depth.

10.4 Nozzle size and shape

Nozzle size and shape can also affect pressure and spray pattern / uniformity. There are a number of different and innovative nozzle designs on the market.

Nozzles can easily be blocked by balls of grass or feed fibre, stones, ear tags, hair and pieces of hoof. Untidy practices at the shed can also lead to penicillin tubes, gloves and the like going through the effluent pump. A coarse filter, the weeping wall system and multiple storage ponds will prevent most of these problems. In the past nozzles would be slit and tips cut off to increase the nozzle diameter. This might have solved the blockage problems but it also caused other problems because the pressure is reduced. New designs have overcome some of the blockage issues and have improved spray pattern, uniformity and application rate.

The recently available hard plastic nozzles can apply lower depth and deliver good uniformity but operate better at high pressure. The disadvantage is that they block more easily. Rubber nozzles tend to 'balloon' or bulge under pressure and don't block as much but this increases the depth. Conical shaped nozzles certainly provide superior spray pattern and lower depth than the older flat 'petrol cap' nozzle.

Sometimes one nozzle on the travelling irrigator is blocked off. This is often done to increase pressure and makes the irrigator travel faster. While this will generally reduce the depth applied it will also reduce the volume of effluent applied which can then lead to sumps overflowing or other issues arising. Blocking a nozzle should be considered a temporary measure and a warning that the system needs urgent attention.

Figure 18: Different nozzles used for dairy effluent. ***(photos courtesy of DairyNZ and Russell Winter)***

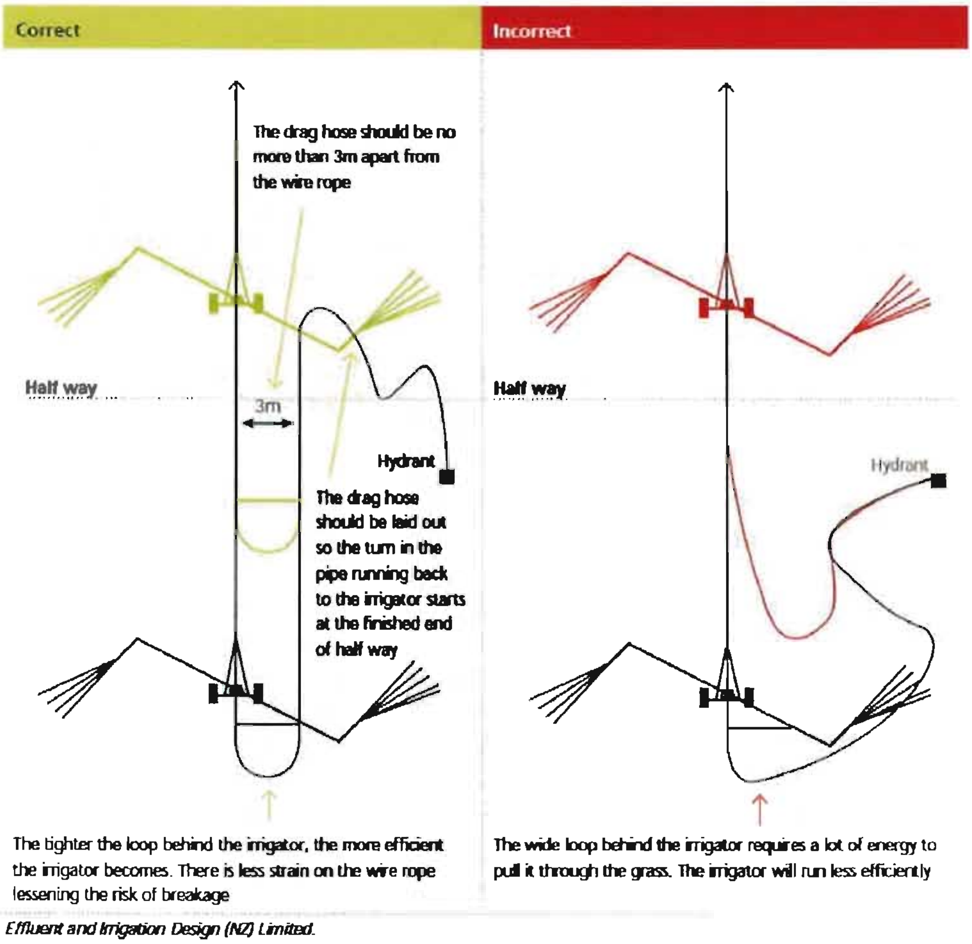
Plucks nozzle

Old style flat nozzle

10.5 Setup and operation:

One of the more common factors that affect speed of a moving irrigator is increased drag on the hose connected to the travelling irrigator. Long grass, uneven ground surface, stones and humps, incorrect layout of drag hose and consequently the amount of effort required to pull the, undulating or steep sloping land and incorrect gear selection. Incorrect layout can result in up to 50% more depth being applied.

Figure 19: Correct and incorrect layout of travelling irrigator drag hose. (courtesy of Effluent and Irrigation Design (NZ) Ltd)



Travelling irrigators (except those that can apply very low depths) should almost always be run on their fastest speed and some people weld the means of adjustment in the fastest speed setting so it cannot be altered. A travelling irrigator will not move at all if it comes to the end of the wire rope, the wire rope has slack in it when it starts up, the ratchet is not engaging the gears or a knot in the wire rope gets jammed. If a travelling irrigator stops moving but keeps applying effluent it takes less than a minute to cause major over application. This is due to the high application rate compared to a stationary applicator like a K line pod.

Figure 20: Photograph illustrating the "donut" application characteristics of a travelling irrigator and the consequences of it being stationary. (courtesy DairyNZ)

10.6 Maintenance and training:

In addition poor maintenance of equipment will also influence application depth. Flat tires, poor drag hose layout, the drag hose getting caught on obstacles, humps in the paddock or on long grass, worn seals and lack of grease, wire rope in poor condition tips on the irrigator boom at the wrong angle and damaged or worn out mechanical components (eg teeth on sprockets) can increase the depth applied mainly because they will slow the irrigator down.

For stationary pods and sprinklers there is far less to maintain. However leaks, blockages, lost nozzles and structural damage can still affect depth and application rate due to the lack of pressure.

Other things to check include blockages in the line, leaks at hydrants, pipe joins, couplings and where pipes get kinked.

Training is crucial. An effluent system is only as good as the staff operating it. Farm owners who operate their own system tend to have fewer compliance problems. Many South Island farms are owned by equity partnerships or corporations. Training, knowledge of responsibilities and an understanding about why they are being required to follow good practices is even more important under these ownership structures. Owners are often held more responsible for any non compliance, especially if a consent is required for land application, even if they have a contract that says the herd manager or sharemilker is responsible and the owner doesn't live on the farm.

GPS systems that record effluent application are one way for absentee landowners to monitor good practice and record where effluent has been applied for nutrient budgeting purposes.

Environment Southland developed 2 simple checklists (Figures 21 & 22) for assessing effluent systems and maintaining them that provide clear guidance for farm owners and staff.

Figure 21: Environment Southland effluent system assessment checklist and application guidance – How does my system stack up?

	Optimum	Okay	Take Action
Effluent Irrigation	☐ Irrigate from a deferred storage pond system	☐ Irrigate daily from a storage pond	☐ Irrigate direct from sump
Minimizing Effluent and Water Use	☐ Use <50L/cow/day; stormwater is diverted from storage ponds	☐ Use 70L/cow/day and stormwater is diverted from storage ponds	☐ Use more than 80L/cow/day and stormwater is diverted from storage ponds
System Design and Set-up	☐ Set up that has been designed in consultation with an expert specifically for the property	☐ A standard system ("off the shelf") that has been designed by an expert.	☐ Mix and match – a system that has been put together with no expert consultation or consideration for the specific property
Application Timing	☐ Irrigate only when soil moisture is low	☐ Irrigate only after one week since a significant rainfall event	☐ Irrigate daily or when storage facilities are full, despite weather conditions and soil moisture
Application Rates	☐ Application depth and rate are based on the soil properties (i.e. water holding capacity and root zone depth)	☐ Application depths are less than 15mm per application, applied at a rate slower than 10mm/hr	☐ Application depths are 15mm per application, applied at a rate of 10mm/hr
Application Area	☐ Effluent is applied to a farm area greater than 8ha/100 cows or is applied based on its N or K content	☐ Effluent is applied to a farm area of between 4-8ha/100 cows	☐ Effluent is applied to a farm area of 4ha/100 cows, or less
Storage	☐ Have 90 days storage with pond desludged annually	☐ Have 30 days storage with pond desludged regularly	☐ Have less than 30 days storage with pond desludged infrequently
Application Method	☐ Low rate application system	☐ Adjustable application rate system	☐ High application rate system
Training and Maintenance	☐ Skilled staff doing daily maintenance and checks	☐ Skilled staff doing regular maintenance and checks	☐ Untrained staff doing ad-hoc maintenance
Effluent Management Plan (EMP)	☐ EMP has been prepared, is on display and is used by staff on a regular basis	☐ EMP has been prepared but is not used on a regular basis	☐ EMP has not been prepared for the property
Nutrient Management	☐ You soil test regularly and prepare a nutrient budget, then strategically use supplemental fertiliser based on these results	☐ You manage nutrients by regular soil testing and applying supplemental fertiliser based on these results	☐ Effluent paddocks receives the same amount of fertiliser as the rest of the farm

Remember – if things go wrong the first priority is to stop the discharge then address the cause or contact Environment Southland as soon as possible.

Figure 22: Environment Southland effluent system maintenance schedule.

EQUIPMENT AND MACHINERY MAINTENANCE SCHEDULE

Person responsible:

Daily	Regularly	Six monthly to Annually
	☐ If over ground piping is used, ensure that the connection joints are kept clean. Dirt caught in the joints will move through the lines and block nozzles.	☐ Strip down the pump for oiling and cleaning as per manufacturer's instructions
☐ Assess whether the soil is dry enough to allow effluent application to the pasture without excessive ponding, runoff or leaching	☐ Tyres are inflated to the right pressure as under inflated tyres put pressure on the winch	☐ Check the pump seals as these are the components most susceptible to wear
☐ Check low-lying areas in the irrigator run. If effluent is ponding here then you are applying too much effluent or applying it too quickly.	☐ Flush clean water through the delivery line and sprinklers to keep them from blocking.	☐ Check the pump impeller and casing for wear
☐ Waterways and tile drains should be checked during and after irrigation to make sure effluent is not discharging into water.	☐ Check the hole on the rubber nozzle on the end of the irrigator arm is not split. This affects the efficiency of the irrigator and increases the amount of effluent being applied.	☐ Check the reticulation lines for leaks
☐ Check at the end of the irrigator run to make sure the irrigator switches off and effluent has not ponded	☐ Grease the applicator, ratchet drives and cable winch drums regularly. Grease nipples should be evident.	☐ General storage facility maintenance. Remove sludge from the storage facility and spray any weeds growing on storage ponds.
☐ Make sure the winch is in gear at the start of a new run and that the irrigator is anchored securely, with hose attached	☐ Check that the float switches are clear and working	☐ Check pump capacity
☐ Manage the irrigator drag hose to reduce the strain on the irrigator winch.	☐ Check that the nozzles are not blocked or damaged	☐ Have a nutrient analysis done on the stored effluent, soil and pasture.
☐ Irrigator is operated during daylight hours so the operation can be monitored	☐ Make sure the spray application system is not sending effluent into the water troughs	☐ Stormwater diversion is useful particularly in the off-season.
☐ Make sure the irrigator is clean and does not have a heavy coat of effluent on it	☐ Clean and clear the effluent stone trap and gratings	☐ Check anti-siphon valves for blockages
	☐ Shift the spray applicator system to a new area that has been recently grazed	

10.7 Alarms and Fail Safe systems:

In the last five years a lot more alarm and fail safe systems have come on the market to meet the growing demand for 'peace of mind' for farmers and staff. Gator Buddy, TIM (Travelling Irrigator Monitor), Farmworks and Tracmap are some of the brands available for travelling irrigators and cost approximately $5-6000. These systems monitor pressure, speed, and other factors. When performance reduces to a critical threshold it shuts the irrigator down and notifies the owner by text or sounds an alarm.

The need for performance warning systems has arisen because travelling irrigators are notoriously unreliable, they can discharge a large amount of effluent onto one spot very quickly, they are not checked frequently enough, they often cannot be seen from the shed, Council staff can turn up unannounced, the public and neighbours are watching more closely and large penalties are being issued for non compliance.

11. Choosing the 'right' effluent system for each farm

The choice of the most suitable effluent management system is primarily based on five key factors:

1) Objectives – compliance, nutrient value, future proofing against new standards, ownership and tenure
2) Soil type and drainage characteristics including risk of compaction, wintering and cropping practices.
3) Slope of land where effluent is applied
4) Climate – especially monthly average rainfall figures and any other information such as monthly soil temperatures and daily SWD records
5) What level of convenience and control is wanted – less labour, owner operator or staff managed.

After making the primary decisions a number of other factors require consideration before the final decision can be made on what the most suitable system is for each farm. They include:

- Site - location and topography
- Effluent type – dry matter content or consistency of effluent
- Cow numbers milked, seasonal or winter milk
- Wintering cows on or off-farm.
- Infrastructure – existing or new system, wintering barn, stand-off or feed pad, pumps and pipes
- Washdown facilities and systems – water used each milking
- Yard and concrete area that will capture stormwater and mix with effluent
- Stormwater diversion installed or not
- Shape and size of paddocks
- Proximity of waterways relevant to irrigator diameter of wetted area
- Volume of storage required and pond management
- Location – neighbours, existing buildings and laneways
- Affordability.

Once all of these factors are known, the technology and range of equipment that is available, at the time, must be investigated. The best way to see a lot of this equipment and system options in one place at one time is at the National Agricultural Field days at Mystery Creek, Hamilton. When a system(s) is chosen it is also valuable to visit a farm that is already using it to check on the pros and cons from a farmer's perspective. The final decision is usually based on affordability.

12. Conclusions:

- The majority of information about the movement of dairy effluent through soil and how to manage the risks of dairy effluent is contained in scientific reports. These reports provide valuable information and insight but require a level of background soil science knowledge and field experience to fully understand and integrate into farm systems and practices. To improve compliance and environmental outcomes improved guidelines and means of transferring this knowledge to people operating and monitoring dairy effluent systems is required to maximise the benefits and minimise the risks.
- Managing effluent to an acceptable standard while capturing all the benefits is a complex and costly task that changes from day to day and throughout the season. Each farm has its own specific climate, soils and circumstances that makes it unique and this will determine how effluent is managed every day, even when milking has stopped for the season.
- Best Practice is to apply dairy effluent to land in a way that avoids any loss of nutrients and faecal micro-organisms to surface and groundwater water bodies. Storing effluent in a pond (deferred irrigation) and applying it to land only when soil conditions are suitable and at a low application rate and depth are the two main tools for achieving Best Practice.
- Those making decisions on-farm and operating effluent equipment must think like a person applying irrigation water to a summer crop and ask the question each day "is this the best time to apply effluent to the land"?
- Soil drainage characteristics and slope are the two key land features that determine the level of risk of direct contamination from applying effluent to land and are represented by five major land categories.
- Improving the knowledge of how effluent is transporting through and across soil has the potential to drive better rules, practices, technology and decision making and therefore avoid or significantly minimise the risk of contaminating waterbodies.
- Knowing how much soil water deficit exists on the effluent block provides critical information that will drive improved decision making about when and how much effluent to apply. All farms would benefit from installing a soil moisture metre and using the information daily to take the guess work out of decisions.
- Being able to match the available soil water deficit to the correct application depth and rate is essential and requires all irrigation equipment to be regularly assessed at all speeds.
- Effluent management systems that can store effluent until soil conditions are suitable and apply both a low application rate and depth significantly minimise the risk of dairy effluent contaminating waterbodies because they are more adaptable and flexible to a range of soil drainage characteristics, slope and climatic conditions.

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Appendix 1: Case study 1

Dairy effluent management options for Brian and Hilary Ford, Appleby, Richmond, Nelson, Fonterra Supply No: 38052

As part of a wider strategic review of their dairy farming business the Ford's have requested guidance on the options for improving effluent management into the future.

The farm is situated on the outskirts of Richmond, within 5minutes of the town centre and surrounded by numerous lifestyle holdings, a busy state highway linking Richmond to Motueka and Golden Bay, Swamp Road, a large market gardening operation and borders another dairy farm. The farm has been in the family for several generations and is currently managed by the Ford's son Andrew Ford (Sharemilker).

Objectives:

1. To have a compliant effluent management system that caters for an average or slightly better year, in terms of climate.
2. To take advantage of the nutrient value in the dairy effluent as much as practicable and affordable.
3. To future proof future farming operations for potential new Fonterra and Council standards.
4. To consider a range of effluent management and storage options and associated matters based on several possible farming system scenarios that will give effect to 1,2 & 3.

Farm current details:

Cows:

Winter milking: 100 cows, starting calving in May, milking ends February
Seasonal milking: 220 cows at peak starting calving August, milking ends May/June.
Cows milked: 140 cows in May
100 cows in June / July
135 cows in August
220 cows Sept - April

Dairy shed and yard:

Herringbone shed
Yard area (approx): 270m^2 concrete with kerbing
Washdown is by hose and tipper buckets using approx 12,000 ltrs /day
Cows are on the yard on average 2 hours/day for 2 milkings /day - less in winter and more at season peak.

Cooling water is used to fill buckets and included in washdown water.
Vat wash is included in the washdown water that enters the effluent system

Standoff pad:

Area (approx): 900 m^2
Cows on pad for 2hrs on average as per above numbers for June, July, August and half of September. Pad not used for other times of the year.
No washdown with additional water. Pad is scraped to sump.
Feed (predominantly baleage) is provided in bins
Assumed that when cows on pad they produce same amount of raw effluent as on yard /hr being 5.4 ltrs /day.

Effluent system at present:
Effluent from the pad scraping and yard washdown, vat washThe system is divided into two sumps (one at edge of pad and one next to shed), with separate pumps to a travelling irrigator (un-modified older generation style). Effluent is not pumped from pad sump after ceasing use in September. Calculations take account of variable numbers during the year.

Stormwater:
The only stormwater that enters the effluent is rainfall.
Gutters on buildings divert water away from yard and pad.
Tasman District Council recorded rainfall at Nelson Airport are attached. Mean monthly figures are used in calculations.

Stormwater diversions:
None are currently in place.

Soils:
Information and map sourced from Tasman District Council. (See attached details).

Waimea clay loam:
- 75% (approx) of farm
- Granular and nutty topsoil layer above coarse blocky structured layer with mottles indicating imperfect drainage at a distinct layer of 0.3-0.5m overlying deeper gravels,
- moderate to slow permeability,
- good moisture holding capacity,
- slightly sticky.
- Vulnerable to compaction and saturation during winter / spring months.
- narrow lenses of free draining gravels
- Irrigated in summer.

Richmond clay loam, 25% (approx) of farm.

Poor drainage, blocky structure, lots of mottles in subsoil indicating poor drainage issues.

NB: For this assessment the Waimea clay loam is considered as imperfectly drained and the Richmond clay loam considered poorly drained.

Slope:
The land is generally flat former river flood plain with some small undulation <7 degrees in slope.

Infiltration of soil surface:
The soils are vulnerable to compaction. This will lower the ability for effluent to be absorbed through the surface and saturation and infiltration excess ponding can easily occur. A low application rate system <10mm will generally overcome this.

Farming systems scenarios:

To give regard to a range of possible choices that the business may choose to follow six farming system options are considered on the basis that storage is the key matter.

1. Winter milking only – store only the effluent during the months of June/ July and August.
2. Winter milking + - store the effluent during the months of June/ July and August and September with cows leaving the pad after only 15 days in Sept.
3. Winter milking ++ - store the effluent during the months of June/ July and August, September and October with cows leaving the pad after only 15 days in Sept.
4. No Winter milking. Seasonal milking only and store effluent August and Sept and use the pad for Aug and 15 days in September.
5. No Winter milking. Seasonal milking but increase cows numbers to 300 cows and store effluent August, Sept and use the pad for Aug and 15 days in September.
6. No Winter milking. Seasonal milking but increase cows numbers to 300 cows and store effluent August, Sept and Oct and use the pad for Aug and 15 days in September.

Table 1. Calculation of total volume of effluent for different farming system options

System options	shed Washdown	stormwater yard	stormwater pad	raw effluent yard	raw effluent pad	Total m3
Winter milk (WM) J/J/A	1080	65	216	56	56	**1473**
WM + J/J/A + S pad JJA and 0.5 S	1440	86	251	92	92	**1961**
WM ++ J/J/A/S/O pad JJA and 0.5 S	1800	108	251	129	129	**2417**
Seasonal A/S, pad A & 0.5 S	720	42	105	59	54	**980**
Seasonal Cows+ 200 Aug 300 Sept, pad A & 0.5 Sept	720	42	105	82	58	**1007**
Seasonal Cows+ 200 Aug 300 S /O, pad A & 0.5 Sept	1080	64	105	131	58	**1438**

Matters considered for choice of system and irrigator:

The choice of irrigator is based on:

a) Objectives – compliance, nutrient value, future proofing for new stds
b) Soil type and drainage characteristics including risk of compaction, wintering and cropping practices.
c) Slope
d) Effluent type - DM content or consistency of effluent
e) Shape and size of paddocks
f) Proximity of waterways relevant to irrigator diameter of wetted area
g) Volume of storage required – Winter milking requires more storage
h) Existing infrastructure or is it a totally new system
i) Location – neighbours, existing buildings and laneways, topography
j) How much information is available prior to and after installation of system – daily SWD, soil temperatures, rainfall data, soils info
k) What level of convenience and control is wanted – less labour, owner operator or staff managed.

Contract and level of commitment decisions

- Winter milking contracts may not continue in the future. Seasonal milking may be the only option. This might provide an opportunity to increase cow numbers.
- The level of investment and effluent management option chosen will depend on the length of commitment to dairying. If it is for a short term (2-5yrs) the aim might be to focus on being compliant but limiting the volume of storage to reduce the cost slightly and having a degree of risk some seasons. Note that building a slightly bigger storage pond may not be much more expensive. If it is longer than 5 yrs then Best Practice and taking greater advantage of the nutrient value will provide greater return on investment and reduce the risk of non compliance with both Fonterra and Council standards.

Washdown and minimising inputs:

- Washdown efficiency in the yard should be improved to reduce input into storage. Clearly it is the largest input. The tipper buckets create a lot of additional washdown water.
- Without further investigation a question arises about the size of the standoff pad. Is it the right size for the herd or can it be smaller? Some pads are having a roof installed to manage stormwater but whether either of these options are viable is uncertain.
- It is assumed all the water is captured by gutters from all the buildings. Minimising how much stormwater enters the system is essential with all options.
- Installing a stormwater diversion system will reduce the storage required but will need careful management to avoid effluent being diverted inapprpriately

Soil water deficit (SWD) and choice of irrigator:

- The soil is a clay loam with moderate to poor drainage. The DairyNZ table of recommendations for this soil type are 18mm max depth and 13mm/hr max application rate. This is when the soil has 50% Water Holding Capacity and not a wet soil situation.
- It appears to be a reasonably 'wet' farm, the soils are imperfectly drained, there are several ditches and waterbodies and SWD's are likely to be low or nil from June – October with short windows of opportunity. A low application rate system that is also capable of applying very low depths provides the flexibility throughout the season to apply effluent when low SWD's exist. This approach also reduces the amount of storage required. Being compliant will require equipment that is more precise (low rate and depth)
- The current travelling irrigator used at present probably applies about 20-25mm average depth although ideally the pressure and rate / depth of application should be assessed. There is enough knowledge about the soil drainage capability, risks and the equipment to be able to suggest that the most significant improvement is to replace it. A new generation Numedic or Plucks irrigator is one option.

Pumps and mainline:

- Assessing the pressure being delivered at the irrigator would provide a clearer picture about the suitability of the mainline and pumps. It is critical to have the correct pressure at the irrigator at all times. Mainlines with 90mm diameter are the norm but the mainline can be split to cover different ends of the effluent block allowing 75mm diameter mainlines. A pressure test will also identify if the pumps need maintenance or replacement.
- Pumping raw effluent with some standoff pad fibres requires a more powerful pump than one pumping green water with the solids separated. The ability to use existing pumps needs consideration in the final option along with the type of effluent being pumped.

- Lower kW pumps use less electricity. Green water pumps are often only 7.5kW (10hp)

Storage:

- Storage is required even if the aim is only to be compliant. How much storage is considered in the 6 different scenarios. Clearly all of the seasonal milking options have the least volume of effluent needing storage. Storage into October will allow greater uptake of potassium by the clovers when temperatures exceed 12 degrees. The nitrogen value can be utilised by the grass much earlier at temperatures above 8-9 degrees. If information was available about daily SWD's and soil temperatures then this would make the decision more informed. Temperatures this season are still about 11 degrees in mid Oct but the wet season and cool nights has probably kept it low to date.
- If the aim is just to be compliant with some risk then storage till the end of September is potentially suitable. There will be times from June – Sept to apply effluent at low depths and therefore keep the volume of storage available in control.
- Larger ponds have bigger surface areas for rainfall. All of the WM options require a larger pond.
- Any storage pond must be sealed. If clay is available and tested as being suitable it must be located on the farm close to the pond site. Carting clay is costly. The other option is to use a rubber or synthetic liner (Firestone or Skellerup). The earthworks for this are less than a clay liner but the cost of installation with suitable gas venting, safety ladder, and possibly a place for a stirrer to rest makes this more expensive generally. It does give a higher level of assurance that the pond is sealed and most likely to be favoured in the future by Councils.

Sumps:

- The new system may require new sumps to be installed or a sludge bed (if a weeping wall is chosen).

Paddock choices to manage risk:

- Are there any paddocks that are drier than others where effluent can be applied when Soil Water Deficits (SWD) are low?
- The Waimea clay loam has better drainage properties for effluent application than the Richmond clay loam. This does not suggest there is any advantage in extending the effluent system to this soil type in order to lower the risks.

Wintering and cropping practices:

- It is assumed that seasonal milking cows are wintered off the farm but young stock might be wintered on-farm.
- Winter milking does mean some cows will be on paddocks during the wetter months of the year and compaction and soil structure damage is a risk on these soils
- Not aware of any cropping programme – all grass at present but could have an impact on soil structure in the future.
- Compaction risks on this farm requires a low application rate applicator to prevent ponding due to low infiltration rates

Palability and growing more grass:

- A low application rate and depth system will grow more grass and allow effluent to be applied a shorter time prior to grazing. The low amounts applied coats the grass in less effluent preventing uptake and grows more grass because the soils are not soaked in liquid and cooled causing a lag.

Alarms and fail safe system:

- The new design code requires all systems to have an alarm. Some Councils are requesting all travelling irrigators must have an alarm. Travelling irrigators have a record of low reliability, slowing down, couplings coming undone, ropes failing or spike coming out. The fail safe systems and alarms include Gator Buddy, TIM, Farmworks, Tracmap and others and cost about $6000. They will switch off the irrigator within 3-5minutes if any monitored parameter drops below the set threshold.

Convenience vs more hands-on system:

- There are some hi-tech systems available that can make the daily decisions via text messages.

Operator:

- This farm is family owned and managed. More care usually occurs with owner operated systems. This can reduce the need for GPS tracking, and possibly the alarm/ fail safes.

Soil moisture meter:

- Where SWD's are low a moisture meter is essential. Cost is approx $2500 installed and linked to computer. Can get hand held ones but need to have them calibrated to soils. Otherwise have storage til at least end of Sept and use simpler hand testing methods.

Odour and neighbours:

- Some ponds can smell and the neighbours complain. It can be managed generally by regular emptying, stirring, and possibly by filling pond from a pipe above the surface dropping the effluent from a height (some aeration occurs). Separating the solids can reduce this risk but not always eliminate it.
- Siting the pond and managing it well will be vital on this farm

Pumping volume:

- All of the irrigation systems pump approx 20-25,000 ltrs /hr. For those systems that can apply low depths and rates via pulsing (on for 15mins and off for 45 mins) it can be difficult to apply sufficient volume to maintain free board in the pond. This can be overcome by newly developed systems that allow the automatic switching from one line of pods or guns to another so the volume continues to be applied.

Anti-siphoning device:

- There is a cheap anti-siphoning device now available. Especially good for pulsed K lines and Uni-sprinkler.

Risks for different scenarios:

- Councils will be monitoring more stringently and during wet periods. Fonterra are likely to be demanding systems with nil or very low risk for 365 days of the year in the near future as part of supply terms.
- Storage volumes must account for the volume of effluent / washdown / stormwater. It must also have sufficient free board and allow for rainfall hitting the surface. The batter must be at least 2:1 but often 3:1. Staff working on weekends, relief milkers and contingency for illness all need consideration. Peace of mind, unusually wet seasons and comfort are important.
- With WM there is no option but to have storage on this soil type to remain compliant. It is frequently too wet during these months to safely apply effluent although some short opportunities will exist for a precision irrigation system. Applying effluent during the winter provides no nutrient advantage and will create large losses. As Fonterra moves towards greater nutrient management standards within the next 2-3 years storage during winter will most likely be required. Storage for J/J/A reduces the risk of non compliance but still leaves the risk of a wet September.
- Having storage into Sept lowers the risk of non compliance but doesn't fully utilise the advantages nor does it give any level of comfort that storage til the end of October provides for potentially little extra cost.

Irrigator options:

1. High tech system (eg; Harmonics)
Too expensive for small farm. Not suitable.

2. Travelling irrigator – existing one or similar:
Not considered suitable. Application rate and depth too high for low SWD's. High risk of non compliance and more storage required because can't apply safely til higher SWD's available

3. Travelling irrigator – new generation with good distribution uniformity and low depth <5mm.
Reduced risk of non compliance, suitable for terrain, low depths but not as precise as other options, require more storage because require greater SWD before can safely apply effluent, higher application rate, bigger pump, no solids separation but pond will need stirrer or cleaning out regularly, higher application rate and may apply more than soil surface can absorb, requires an alarm, overall less flexible system, not normally pulsed. (Eg: Numedic / Plucks)

4. Smart hydrant:
Low application rates (<10mm) and low depths (<2mm) when pulsed, 4-6 guns mounted on central buggy that uses a control panel and diverter system to send effluent to each gun for a prescribed time (if you have 6 guns each one will run for 10mins before the control unit stops the flow and sends effluent to another gun, 14 -16mm nozzles, pump un-separated effluent, ponds need stirrer, bigger pump than K-line, trailer or buggy required for guns and hoses, has more opportunity to apply in low SWD windows but not as much as other systems, large wetted area, takes a bit more time to set-up.

5 LARALL:
Low Application Rate and Low Labour, Bosch sprinklers, 3-4mm application rate, 6-7mm nozzles, 36-40m diameter wetted area, 12 or more sprinklers operating at once, irrigate more than one paddock at a time, a system of hydrants is set-up around the effluent block and sprinklers shifted to another hydrant, in-ground hydrant system is more expensive to install but means minimal time is required to shift sprinklers good for irregular shaped paddocks, filter is used on suction pipe, pond needs cleaning because no sludge bed used.

6. Hi-Tech Uni-sprinkler:
Very low application rate and depth (<1mm) when pulsed using timer switch, one of lowest risk systems with great management flexibility for poorly drained soils, can take advantage of short windows of low SWD, pumps un-separated effluent, requires pond to be stirred, bigger pump than K line, requires trailer or something similar to transport pipes and pods around, pods are slighter bigger version of K line pod, 9mm nozzles with greater wetted area than K line at 30 – 40m diameter, could have 2 lines of pods to pump volume when SWD is suitable, excellent for irregular shaped paddocks, can have 2-4 pods in line and could have 2 lines to allow pulsing to pump volume, pods and buggy are more expensive compared to K line, easy to shift.

7. K-line pods:
Very low application rate and depth (<1mm) when pulsed using timer switch, one of lowest risk systems with great management flexibility for poorly drained soils, can take advantage of short windows of low SWD, must have weeping wall or solids separation. Sludge bed must be cleaned out annually with digger and muck spreader, no stirrer required, filter fitted in pond, small pump required (10hp), no trailer required to shift pods, 3-4mm nozzles, 15-20m diameter of wetted area, usually have one set of 12 pods but may need to have 2 lines of 12 pods to pump volume when SWD is suitable, excellent for irregular shaped paddocks.

Pond sizes required;

- Pond depth = 3m
- Pond shape = square
- Freeboard = 250mm
- Solids = variable from 75 -150 cu m
- Rainfall onto pond surface is taken into consideration. For seasonal milking scenarios no rainfall that falls onto pond in J/J/A has been included in calculations.
- When lining a pond especially with clay it is preferred to have 3:1 batters. This is possible in this location where mean annual rainfall is 890mm. If rainfall was much higher too much rainfall would fall onto the pond surface and a 2:1 batter would be necessary.
- For the seasonal options it is assumed that cows will be wintered off the farm and not on the pad.
- These calculations have been completed with the aim of not applying any effluent during the period being considered. This allows effluent to be applied when soil temperatures are high enough to capture the nutrient value especially for the seasonal milking only scenarios. The calculations have not been undertaken to account for the use of a low rate applicator being able to apply effluent in short windows of low SWD during the seasonal option periods. For example over the period Aug / Sept there might be opportunity to apply effluent on 5 -10 days. Approximately 16 m^3 of effluent is produced daily but more than this could be applied on one day. This would reduce the amount of storage required and could be calculated but may not make a significant difference to the amount of storage required. Farmers with storage at present comment that they wish they had more. Farmers in Southland required to have 90 days storage to meet Council rules comment that they need 120 -150 days storage to provide maximum benefits and peace of mind. It often doesn't cost much more to build a pond bigger once the digger is on-site.

Option	Batter 2:1	Batter 3:1
Winter milk (WM) J/J/A	33 x 33m	37 x 37m
	Vol = 2187m^3	Vol = 2352 m^3
WM + **J/J/A + S, pad JJA & 0.5S**	37 x 37m	41 x 41m
	Vol = 2883 m^3	Vol = 3072 m^3
WM ++ **J/J/A/S/O, pad JJA & 0.5S**	42 x 42m	50 x 50m
	Vol = 3675 m^3	5043 m^3
Seasonal **A/S, pad A & 0.5 S**	28 x 28m	31 x 31m
	Vol = 1452 m^3	Vol = 1452 m^3
Seasonal, Cows+ **200 Aug** **300 Sept, pad A & 0.5 Sept**	28 x 28m	32 x32m
	Vol = 1452 m^3	Vol = 1587 m^3
Seasonal, Cows+ **200 Aug** **300 S /O, pad A & 0.5 Sept**	32 x32m	36 x36m
	Vol = 2028 m^3	Vol = 2187 m^3

Summary:

The recommendations are:

1. Decide if winter milking is to continue – suggest that after June 2012 it may not.
2. Decide if dairying is to continue at all and if so for how long is the commitment?
3. If dairying is to continue decide what you want to achieve from applying effluent. Is it to be compliant or to be more than that.
4. If ceasing dairying after 2011-12 season then any investment is marginal. Perhaps consider purchasing a new generation travelling irrigator that can apply low depths and lower application rates to reduce risk of non compliance.
5. For longer periods in dairying a low application rate and depth irrigator is essential on these soil types to have a low risk of non compliance. This irrigator will also maximise the opportunity to keep the nutrients in the root zone and therefore produce more grass and return on investment.
6. The current infrastructure will need to be assessed. Any new system must configure the pump and mainlines to enable optimum pressure at all times to the irrigator, especially when furthest from the shed.
9. Seasonal milking only significantly reduces the storage requirements. Increasing cow numbers to 300 does not necessarily increase storage requirements. Lining a pond with Firestone liner will cost approx \$20/m^2
10. Once key decisions are made a more detailed assessment of costs for each system can be undertaken.

Dated: 15th October 2010