Irrigating High and Low risk soils on the RNZ Uruti site

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1.0 Introduction

1.1 Background

Kay Consulting Ltd has been engaged by Remediation NZ Ltd (RNZ) to review the soils in the irrigation block at the Uruti site and provide

1.2 Project Scope

The scope of this report is confined to:

- The areas on the RNZ Uruti site which include the irrigation pond and irrigation blocks
- The existing irrigation equipment including the effluent pump, mainlines, travelling irrigator and sprinkler pods.

1.3 Qualifications of the Author

- B Ari Sc specialising in Agricultural Engineering
- Certificate in Advanced Sustainable Nutrient Management
- CNMA – Certified Nutrient Management Adviser

1.4 Soil Risk

This report discusses high and low risk soils and the importance of differentiation between these when considering irrigation practices on the RNZ Uruti site

"Risk" in this context relates to the risk of surface runoff or subsurface drainage occurring from the soil. Soils are assessed in the field against the Farm Dairy Effluent Design Code of Practice.

An important criteria is to assess the soil drainage class, and this was carried out by digging test pits into the irrigation blocks. Soil drainage classes are categorised into 4 sections:

1. Well drained
    a. No mottles
2. Moderately drained
    a. Few reddish-brown (rust-like) mottles
3. Imperfectly drained
    a. Mixture of 'rusty' and grey mottles
    b. But <50% of the upper subsoil colour
4. Poorly drained
    a. Dominated by grey mottles
    b. Rust-like mottles also present

Well drained and moderately drained soils are generally classified as low risk soils and imperfectly and poorly drained soils are generally classified as high-risk.

Irrigation onto high risk soils should occur only when there is a soil moisture deficit. This is referred to as deficit irrigation and is recognised as the key means of mitigating the risk posed by these soils.

Thirteen test pits were dug into the irrigation blocks. The soils in the lower irrigation blocks were assessed as being moderately drained, therefore low risk.

Six test pits were dug into the upper irrigation block and the soils were assessed as being Anthropic. Anthropic soils categorise soils constructed by or drastically disturbed by human activity. This 5 ha area was subjected to a major development in 2019 which involved stripping off the topsoil and levelling the area by spreading fill across the area. The test pit showed the soil profile subsoil comprising a mixture of brown soils and papa. The subsoil showed a compacted soil structure and was assessed as having a low infiltration rate. This would indicate the soil would be assessed as high risk.

1.5 Irrigation onto high and low risk soils

The objective of a well-designed irrigation system is to retain the irrigated effluent in the plant root zone. This will allow the effluent suitable residence time in the root zone to allow the plants to attenuate the potential contaminants. An Irrigation Designer will achieve this by adjusting the irrigator application rate and depth to match the soil. The soils at the RNZ Uruti site have been assessed against the criteria for High and Low risk soils and confirmed to be a combination of high and low risk. For this reason, discussion and detail is provided in relation to best practice irrigation onto high and low risk soils.

1.6 Application Depth

The volume of water applied during irrigation is referred to as the application depth. Farmers will make reference to the amount of rain in their rain gauge in mm. For example, there was 4 mm of rainfall yesterday. This relates to the formula 1mm of rain falling on 1 ha equals 10,000 litres. Using the example of 4mm of rainfall, this would equate to 40,000 litres of rain falling on each ha of land.

Using the above example during irrigation, an irrigator could report that they applied 40,000 litres (onto one ha) or 4mm, both relate to the same measurement.

1.7 Application Rate

Application rate refers to the volume of water applied in any given time period. Using the irrigation example in 1.6 above, if the 40,000 litres was applied to 1 ha over a 2-hour period the application rate would be 2 mm/hr.

1.8 Irrigation Equipment

Liquid from the irrigation pond is spread onto the irrigation block using a travelling irrigator and sprinkler pods.

Figure 1:Irrigation pond, pump, and manifold

Figure 2:Travelling Irrigator

Figure 3:Sprinkler Pod

2.0 Low risk soils

In low risk soils soil water flows through the soil profile under the influence of gravity. Soil water tends to drain through the soil profile in a relatively even manner, wetting the whole soil profile, and is termed matrix flow. This is often referred to as a piston flow effect where soil surface inputs displace and drain water situated deeper in the soil profile.

When designing the irrigation system for a low risk soil, an Irrigation Designer will calculate the water holding capacity of the soil and restrict the volume of applied irrigation so that the water or effluent will remain in the plant root zone. This will allow the effluent suitable residence time in the root zone to attenuate the potential contaminants. Deficit irrigation is not required for low risk soils because there is low risk of preferential flow in low risk soils (hence the term 'low risk') and the soils ability to hold water in the root zone can be relied upon. This is explained further below.

2.1 Soil drainage in low risk soils

Soils contain a number of pores which range from small micropores which tend to hold water to larger macropores which convey water very quickly when saturated.

When a soil profile is wetted (from rainfall or irrigation) the smaller micropores fill up with water until they are all full and have reached a state referred to as field capacity (FC). At FC there is no or negligible drainage as the soil water is held in the micropores by a process called capillary action.

If further rainfall or irrigation is applied to the soil the larger macro pores full up until all the soil pores are full and this state is referred to as soil saturation. Any further rainfall or irrigation will cause surface ponding.

When the rainfall or irrigation stops the macropores will rapidly drain and after a short period of time the soil will revert back to field capacity and any further soil drying will be from evapotranspiration.

This shows why it is important not to irrigate effluent past the soils field capacity as any excess water will rapidly drain through the soil profile and could potentially contaminate the subsurface water table. This subsurface drainage cannot be seen by the naked eye and must be considered in any risk mitigation process.

2.2 Soils in the low risk areas at RNZ Site

The soils in the Uruti effluent blocks were classified by BTW Company in the June 2015 report as Orthic brown soils from the Whangamomona Complex loams. A field survey by BTW Company using soil augers identified the topsoil as Light brown grey silty clay and the subsoil as Light grey silty clay.

The soil texture was assessed by feel[1] during the site visit as a silty loam as shown in Figure 1.

Figure 4:Test Pit

2.3 Application Depth for low risk soils at RNZ Site

8 ha at the Uruti Site are able to be managed as Low Risk Soils.

The principal applied to irrigation of low risk soils is that it is important that the volume of effluent applied during each application does not exceed the water holding capacity of the soil in the plants root zone (otherwise ponding will occur). The soil's Profile Available Water in the top 30 cm (PAW_{30}) describes the maximum amount of water that can be held in the soil that is extractable by plants (i.e. plant available water).

The soils PAW_{30} was calculated for the RNZ Uruti site using the methodology from the Farm Dairy Effluent Design Code of Practice FDEDCOP at 60 mm.

[1] Undertaken in general accordance with methodology described in 'Soil Description Handbook' Milne et al. (1995)

Industry good management practice is to restrict irrigation depth to less than 50% of PAW_{30} .

Therefore, the maximum application depth for the RNZ Uruti site is 30 mm.

As the irrigator at the site does not distribute effluent evenly over the entire wetted area, in order to prevent over irrigating, the application depth is reduced by the distribution uniformity coefficient (DU). The FDEDCOP requires irrigators to achieve a DU of 1.25.

Using a DU of 1.25 this gives an adjusted maximum application depth **(Dt) of 25.0 mm.**

2.4 Application Rate for low risk soils at RNZ Site

The Farm Dairy Effluent (FDE) Design Code of Practice states that the maximum application rate must not exceed the soil infiltration rate. If effluent is applied at a rate greater than the soils infiltration capacity, effluent will pond on the soil surface and there is a risk of run off into surface water ways.

The soil infiltration rate for the subject site was calculated using the methodology from the FDE Design Code of Practice at 15 mm/hr when using a watering time of 20 minutes.

The application depth for areas assessed as low risk should not exceed **Ra = 15.00 mm/hr**

2.5 Recommendations for irrigating onto low risk soils at RNZ Site

- The irrigation equipment used at the Uruti site should be capable of irrigating at ≤ 15.00 mm/hr.
- An application depth test (bucket test) on the irrigators should be carried out annually.
- The irrigation system should be operated so that the volume of effluent applied does not exceed 25 mm on any soil.
- The design application rate should not exceed 15.00mm/hr.
- Irrigation should not be applied to low risk soils that are at or above soil saturation.
- The Standard Workplace Instruction SWPI_RU-740-020-A provides instructions on how to operate the irrigation system so to achieve the design application depth and rate specific to the areas of high and low risk soil.
- Training is to be provided to all staff who operate the irrigation system, to ensure they understand the difference between high and low risk soils and why they are managed differently.

3.0 High risk soils

High risk soils comprise:

- **Coarse textured soils** – example sandy soils where soil water is not readily held in the soil profile and rapidly drains.
- **Soils with fine textured soils** – example soils with high clay content in which soil cracks may occur as result of the wetting and drying cycles. Soil water favours movement down these cracks when the soil is draining. This is called preferential flow or commonly referred to as bypass flow.
- **Soils with subsurface drainage**.
- **Soils with impeded drainage or low infiltration rate**.
- **Soils with slope exceeding 7°.**

Irrigation onto high risk soils should occur only when there is a soil moisture deficit. This is referred to as deficit irrigation and is recognised as the key means of mitigating the risk posed by these soils.

Soils dry out via a process referred to as evapotranspiration (ET) being a combination of evaporation from the soil surface and transpiration from the plants. In summer ET can be as high as 5mm per day. This means that on high risk soils the irrigation of, for example, 10mm must be delayed by two days after heavy rainfall.

3.1 Soil Drainage in High Risk Soils

The movement of soil water in high risk soils is referred to as preferential flow or commonly referred to as bypass flow. Water favours movement down preferred pathways when the soil drains and as a result large proportions of the soil matrix is bypassed. This occurs in soils with coarse soil structure such as sandy soils, fine soils such as clay soils with soil cracks as a result of the wetting and drying cycles and preferential flow paths induced by the installation of artificial drainage.

3.2 Soils in the high-risk areas at RNZ Site

Six test pits were dug into the upper irrigation block and the soils were assessed as being Anthropic. Anthropic soils categorise soils constructed by or drastically disturbed by human activity. This 5 ha area was subjected to a major development in 2019 which involved stripping off the topsoil and levelling the area by spreading fill across the area. The test pits showed the soil profile subsoil comprising a mixture of brown soils and papa. The soils assessed across the test pits did not show a consistent soil texture and this relates to the source of fill used to level the area. Pits 9, 11 and 13 contained papa and showed a compacted subsoil which were assessed as high risk. Pits 10 and 12 showed mainly brown soils and were assessed as low risk.

The upper irrigation block is considered to be a single management block and for the purposes of irrigation management the area is assessed as being high risk.

The major reasons the soils across the upper irrigation block were assessed as high risk is because the soil incorporated papa and had been compacted during the site development. Mechanical aeration of this area is recommended to speed up the recovery process by improving drainage, air diffusion and root exploration.

It is recommended that RNZ carry out annual soil survey on the upper irrigation block to review the risk status of the soil as it transitions to low risk.

3.3 Application depth for high risk soils at RNZ Site

5 ha at the Uruti Site are able to be managed as High-Risk Soils.
The principal applied to irrigation of high-risk soils is that it is important that the volume of effluent applied during each application does not exceed the soil water deficit.
The soil water deficit is calculated using a portable moisture probe.

The maximum application depth for high risk soils was calculated using the methodology from the FDE Design Code of Practice as:
The maximum application depth using a high rate irrigator (Travelling Irrigator) **(Dt) = 10 mm**
The maximum application depth using a low rate irrigator (Sprinkler pods) **(Dt) = 25 mm**

3.4 Application rate for high risk soils at RNZ Site

The Farm Dairy Effluent (FDE) Design Code of Practice states that the maximum application rate must not exceed the soil infiltration rate. If effluent is applied at a rate greater than the soils infiltration capacity, effluent will pond on the soil surface and there is a risk of run off into surface water ways.

The soil infiltration rate for the subject site was calculated using the methodology from the FDE Design Code of Practice at 10 mm/hr.

The application depth for areas assessed as high risk should not exceed Ra **= 10.00 mm/hr**

3.5 Recommendations for irrigating onto high risk soils at RNZ Site

- The irrigation equipment used at the Uruti site should be capable of irrigating at < 10.00 mm/hr.
- An application depth test (bucket test) on the irrigators should be carried out annually.
- The irrigation system should be operated so that the volume of effluent applied does not exceed ~~the~~ soil water deficit.
- The design application rate should not exceed 10.00mm/hr
- High Risk soils should only be irrigated when there is a soil water deficit, and no irrigation should occur within two days of heavy rainfall greater than 10 mm in a 24 hour period. Climate data and soil moisture probes should be used to inform this decision.
- The Standard Workplace Instruction SWPI_RU-740-020-A provides instructions on how to operate the irrigation system so to achieve the design application depth and rate specific to the areas of high and low risk soil.
- Training is to be provided to all staff who operate the irrigation system, to ensure they understand the difference between high and low risk soils and why they are managed differently.