# Sustainable Irrigation Management Plan V16

Prepared for
Veolia Environmental Services (Australia) Pty Ltd

Under direction of
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Prepared by

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# Document Registration

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The assistance of Raymond Choy, Jordan Gavel and Ines Fernandez is gratefully appreciated.

The anticipated permeate attributes were provided by Paul Mcparland

# EXECUTIVE SUMMARY

The Veolia Woodlawn Operations Site processes over 40% of Sydney's 'red' bin waste. The treatment process results in excess water that leaches out of the processed product.

The treated leachate water contains elevated concentrations of sodium, chloride, nutrients and potentially toxic elements and compounds. It requires major reductions in salinity, the concentrations of nutrients and the concentrations of potentially toxic elements before the water can be safely returned to the environment.

It is proposed to use a double Reverse Osmosis (RO) process to remove a proportion of the contaminants[1]. The feed water is pressurised and is forced through a semi permeable membrane. This process will produce water (hereafter referred to as permeate) that is suitable for pasture irrigation. The retentate that does not cross the semi permeable barrier consists of water with an increased contaminant load.

Table 1 shows the anticipated double Reverse Osmosis permeate attributes.

**Table 1. The typical attributes of the double RO permeate and their compliance compared with ANZG (2023a) long term irrigation threshold values.**

| Attribute | Units | Pass 2 permeate (estimated) | Short term irrigation (20 years) | Long term irrigation (100 years) | Comment |
|---|---|---|---|---|---|
| pH | pH Units | >6.5 | | within range of 5 to 9 | The 5 to 9 pH range helps prevent corrosion and fouling of irrigation equipment |
| Escherichia coli | CFU/ 100mL | 0.002 | | | Not an issue as no human contact is proposed. |
| Thermotolerant Coliforms | CFU/100 mL | 0.002 | | | Not an issue as no human contact is proposed. |
| Electrical Conductivity | µS/cm | 600 | Low and not an issue | Low and not an issue | OK for irrigation (0.6 dS/m or 384 mg/L of total dissolved solids ('salt') |
| Total dissolved solids | mg/kg | 384 | | | See above |

[1] This is the same process used at Kurnell to produce potable water for Sydney from seawater.

| Attribute | Units | Pass 2 permeate (estimated) | Short term irrigation (20 years) | Long term irrigation (100 years) | Comment |
|---|---|---|---|---|---|
| Phosphorus - Total | mg/L | 0.35 | Up to 12 | 0.05 | To minimise clogging of irrigation equipment only. 0.5mg/L in 1.83 ML of permeate irrigation /ha/y is 0.9 kg/ha/y. A typical 12 T/year Perennial pasture will accumulate 36 kg P/ha/y NSW Agriculture 1997). So, the permeate will supply <3% of the anticipated demand. |
| Total Nitrogen in water | mg/L | 60 | <125 | <5 | A perennial ryegrass pasture will accumulate an indicative 420 kg/ha/y of Nitrogen.(NSW Agriculture (1997). Applying 183 mm/year containing 60 mg/L N will supply 110 kg/ha/y of N. This is 26% of the pasture N demand. |
| Ammonia as N in water (operational max based on repeated sampling) | mg/L | 0.10 | | | Ensure there is no permeate runoff to streams. See above comment in relation to total N being 26% of pasture demand. |
| Nitrate as N in water (operational max based on repeated sampling) | mg/L | 50 | | | Ensure there is no permeate runoff to streams. See above comment in relation to total N being 26% of pasture demand. |
| Nitrite as N in water (operational max based on repeated sampling) | mg/L | 11.25 ug/L | | | OK |
| Sodium Adsorption Ratio | - | ? | Water with an SAR>6 AND salinity <600 uS/cm can create structurally | Add dissolved Calcium to the permeate | Check soil Exchangeable Na % every 3 years. Add 5T/ha of gypsum to the soil if Exch Na%>5%. |

| Attribute | Units | Pass 2 permeate (estimated) | Short term irrigation (20 years) | Long term irrigation (100 years) | Comment |
|---|---|---|---|---|---|
| | | | unstable soil following irrigation. | | |
| Arsenic-Dissolved | µg/L | 3.2 | 20000 | 100 | OK |
| Aluminium-Dissolved | µg/L | 20 | 20000 | 5000 | OK for irrigation. Ensure that there is no permeate runoff. |
| Aluminium-Total | µg/L | 24 | 20000 | 5000 | OK for irrigation |
| Antimony-Dissolved | µg/L | 0.8 | | | OK for irrigation |
| Boron-Dissolved | µg/L | 340 | 750 to 1500 | 500 | OK for short term irrigation. Raising the soil pH to>7 and increase to soil organic matter content will increase sorption of B . |
| Cadmium-Dissolved | µg/L | <0.1 | 50 | 10 | OK for irrigation |
| Calcium - Dissolved | mg/L | 0.52 | | | |
| Calcium - Total | mg/L | 1.2 | | | |
| Cobalt-Dissolved | µg/L | 0.94 | 100 | 50 | OK for irrigation |
| Copper-Total | µg/L | 1.7 | 5000 | 200 | OK for irrigation |
| Copper-Dissolved | µg/L | <1 | 5000 | 200 | See above |
| Fluoride, F | mg/L | 0.014 | 2 | 1 | OK for irrigation |
| Lead-Dissolved | µg/L | 0.24 | | | |
| Lead-Total | µg/L | 1.2 | 5000 | 2000 | OK for irrigation |
| Manganese-Dissolved | µg/L | 2.5 | | | |
| Manganese-Total | µg/L | 16 | 10000 | 200 | OK for irrigation |
| Mercury-Dissolved | µg/L | 0.005 | | | |
| Mercury-Total | µg/L | 0.005 | 2 | 2 | OK for irrigation |
| Molybdenum-Dissolved | µg/L | 0.1 | | | |
| Molybdenum-Total | µg/L | 0.13 | 50 | 10 | OK for irrigation |
| Nickel-Dissolved | ug/L | 3 | | | |
| Nickel-Total | µg/L | 3 | 2000 | 200 | OK for irrigation |
| Selenium-Total | µg/L | 0.1 | 50 | 20 | OK for irrigation |
| Sodium - Dissolved | mg/L | 18 | | | OK for irrigation |
| Sodium - Total | mg/L | 25 | | | OK for irrigation |
| Vanadium-Dissolved | µg/L | <4 | | | |
| Vanadium-Total | µg/L | 1 | 500 | 100 | OK for irrigation |
| Zinc-Total | µg/L | 120 | 5000 | 2000 | OK for irrigation |
| Zinc-Dissolved | µg/L | 21 | | | No runoff of permeate to local streamlines. |

| Attribute | Units | Pass 2 permeate (estimated) | Short term irrigation (20 years) | Long term irrigation (100 years) | Comment |
|---|---|---|---|---|---|
| Free Chlorine | mg/L | 0 | | | Chlorine reacts with organic matter and is inactivated. The combination of pasture biomass and organic matter in soils will rapidly inactivate the chlorine so that it is not an issue. |
| Total Chlorine | mg/L | 0.1 | | | Not an issue |

Based on the above results, it is reasonable to conclude that based on the chemicals tested, the double RO permeate is suitable for pasture irrigation.

# The proposal

Veolia initially wish to apply the double RO permeate onto 16.8 ha of paddock to the west of their effluent ponds. A critical issue is how much irrigation can occur without salinisation or increased contaminant loss to the environment.

The double RO water attributes of the permeate also meet the ANZG (2023a) Irrigation Guidelines. The water is 'non-saline' so the risk of salinisation of the site, the groundwater or local streams is negligible. Further, the predicted annual irrigation rate is 183 mm/year (1.83ML/ha/y). This is less than the difference between average annual rainfall and the potential evapotranspiration (709 mm rainfall, and potential evapotranspiration (FAO 56). Of 1056 mm or a moisture deficit of 347 mm/year).

The proposed irrigation areas are on low hills. The geology is largely volcanic, with some surface rocks being metamorphosed siliceous bedrock (see Espade v2.2 ).

The initial development will be concentrated in area 2 within the NW portion of the Veolia Property. See Woodlots and Wetlands (2023).

A series of irrigation models were examined to address the impacts. These were then assessed to determine the most suitable strategy.

The difference between average annual rainfall and actual evapotranspiration is low (<1mm/day on average). In the typical winter there is only a small difference between potential evapotranspiration and rainfall. A fixed deficit irrigation, say 10mm trigger, does not 'work' under these conditions.

The recommended irrigation strategy is therefore to apply a small quantity of irrigation (0.5 mm) each day when the predicted rainfall is <10mm. The 10mm irrigation cutoff threshold for predicated rainfall is less than the rainfall runoff threshold of 17mm/day (USDA model). See Appendix 2 for MEDLI Model outputs.

The irrigation is to be applied via fixed sprinklers. A total of 16.8 ha of irrigation is expected to be installed in the first phase. Assuming 0.5 mm/day irrigation the volume of permeate required is 84.6 cubic m/day. This is a 24 hr flow rate of 0.97 L/sec. A 2 L/sec design flow would be provided in approximately 12 hrs. If the average daily irrigation was applied as per the modelling, the annualised rate would be 30.7 ML/y.

The recommended model has 12 days/year when irrigation will not occur due . Note that in summer, the irrigation rate can be doubled to 1mm/day on 12 dry warm days to 'make up' for the 12 days/ average year with zero irrigation. The total application rate would be still be 183 mm/year.

**Table 2. The water balance components with and without 183 mm of permeate irrigation in the average year.**

| Water balance component | Zero irrigation | 0.5mm/day if <10 mm of rain predicted | Change (mm/y) |
|---|---|---|---|
| Rainfall (1980 to 2023) mm/y | 703 | 703 | 0 |
| Permeate irrigation mm/y | 0 | 183 | +183 |
| Soil evaporation. mm/y This assumes a thick pasture cover | 0 | 0 | 0 |
| Evapotranspiration mm/y | 593 | 798 | +205 |
| Rainfall runoff mm/y | 21 | 21 | 0 |
| Irrigation runoff mm/y | 0 | 0 | 0 |
| Deep drainage mm/y | 91 | 186 | +95 |
| Average available water (mm) | 40 | 58 | +18 |

The proposed irrigation protocols had no increase in surface runoff as table 2 shows. However deep percolation was increased from 91 mm/year without irrigation, to 186 mm/year for a scenario of 0.5 mm/day of permeate unless there was at least 10mm of rainfall predicted.

The key result from permeate irrigation is a 205mm/y increase in evapotranspiration and 95 mm/year increase in deep percolation. The average available water content increased from 40 mm to 58 mm.

The MEDLI modelling shows there is no accumulation of 'salt' anywhere in the profile. The reasons for this are that the soils are non - saline and there is a low concentration of salt in the permeate compared with typical Australian Irrigation Water.(see data in table 1, above).

## Salt addition due livestock

Cows typically consume some 40 gm of 'salt' a day from salt licks and from stock watering points (Duran, 2020). Assuming 1 beast/ha and 90% of the 'salt' is lost in urine, faeces and sweat, the site will receive some 36 gm/ ha/day of dissolved 'salt'. This is equivalent to 13 kg/ha/y of 'salt'.

## Salt addition via rainfall and dust

The MEDLI Model estimated salt addition via rainfall and dust to be 134 kg/ha/y (see MEDLI Model output in Appendices 2 and 3).

## Total salt balance

The salt balance components are:
Rainfall (134 kg/ha/y) PLUS
Irrigation (702 kg/ha/y) PLUS
stock watering and salt licks (13 kg/ha/y)

That is, an annual salt addition of 847 kg/ha/y of which 83% comes from the irrigated double RO permeate. See table 3.

Some buffer storage will be needed to ensure the supply of irrigation water can keep 'pace' with the irrigation demand of the proposed system.

The current MEDLI Model was used to assess salinisation.
According to model outputs in Appendix 2, salinity is not an issue. Table 3 shows the salt balance components of irrigated and non-irrigated lands.

**Table 3. Water, nutrient and salt balance components with and without the proposed irrigation regime 0.5 mm/day if there is <10mm of rain predicted). The anticipated salinity of the permeate is 600 uS/cm. See tables above. Data set : 1970 to 2021. Date Source: MEDLI model output in appendices 2 and 3.**

| Component (All in mm/y unless specified). | Zero irrigation | 0.5 mm irrigation each day when the predicted rainfall is <10mm. Annual average irrigation is 1.83 ML/ha |
|---|---|---|
| Salt load (kg/ha/y) Assumes a permeate salinity of not more than 0.6 dS/m (or 600 uS/cm). Salt concentration is 384 mg/L (assuming 1000 uS/m= 640 mg/L of salt). | 134 (in rainfall)<br><br>PLUS<br>Grazing animal addition (13 kg/ha/y)<br>=146 kg/ha/y. | 134 (in rainfall)<br><br>PLUS<br>Grazing animal addition (13 kg/ha/y)<br>PLUS<br>Irrigation (1.83 mm/y, is 702 kg/ha/y)<br>=850 kg/ha/y. |
| Nitrogen load (kg/ha/y) based on 60 mg/L and 183mm/year | <1 | A perennial ryegrass pasture will accumulate an indicative 420 kg/ha/y of Nitrogen (NSW Agriculture (1997). Applying 183 mm/year containing 60 mg/L N will supply 110 kg/ha/y of N. This is 26% of the pasture N demand. |
| Phosphorus load (kg/ha/y Based on 0.5 mg/L and 183 mm/year | <0.1 | 0.5mg/L in 1.83 ML of permeate irrigation /ha/y is 0.9 kg/ha/y. A typical 12 T/ha/year Perennial pasture will accumulate 36 kg P/ha/y (NSW Agriculture 1997). So, the permeate will supply 3% of the anticipated demand. |

The proposed irrigation regime increased transpiration by 205mm. Run off change is minimal (4mm additional loss in the average year). Note that the MEDLI modelling, below in Appendix 2, shows there is no prediction of phosphorus or nitrogen accumulation in the soil profile. Applying 183 mm/year containing 60 mg/L N will supply 110 kg/ha/y of N. This is 26% of the pasture N demand (420 kg N/ha/y, see table 3). The phosphorus application rate is 1 kg/ha/y (0.5mg/L*1.83 ML/ha/y), or <3% of the pasture demand for phosphorus.

That is, the contribution of the nitrogen and phosphorus in the irrigated permeate applied to the pasture will make a positive contribution to the pasture's nutrient demand. The pasture should be foraged harvested to ensure the demand is maintained in the long term.

Permeate irrigation increased salt load by 702 kg/ha/y. Over the 16.8 ha of irrigation, this is equivalent to approximately 0.145% of the salt load added to the Lake George Catchment in rainfall. That is, the proposed irrigation regime will have virtually no impact on the catchment salt load. Further, the MEDLI Modelling predicts that there will be little, if any, salt accumulation in the soil. Consequently, there is no impact of salt on pasture growth, and therefore none on pasture evapotranspiration rate.

## Is the sodium concentration in the irrigation water 'toxic' to agricultural plants?

**Table 4. Sodium concentration (mg/L) causing foliar injury in crops of varying sensitivity**

| **Sensitive** <br> **<115** | **Moderately sensitive** <br> **115-230** | **Moderately tolerant** <br> **230-460** | **Tolerant** <br> **>460** |
|---|---|---|---|
| Almond | Pepper | Barley | Cauliflower |
| Apricot | Potato | Maize | Cotton |
| Citrus | Tomato | Cucumber | Sugarbeet |
| Plum | | Lucerne | Sunflower |
| Grape | | Safflower | |
| | | Sesame | |
| | | Sorghum | |

[a] After Maas (1990)

Table 1 shows that the predicted sodium concentration is approximately 25 mg/L. Table 4 shows that the most sensitive crops require sodium concentrations to be less than 115 mg/L to avoid foliar injury. That is, the predicted sodium concentration is less than 22% of the injury threshold for the most sensitive agricultural crops.

Rhodes (1992) identified various water classes based on salinity. Water with an electrical conductivity of less than 700 uS/cm is non saline. Table 1 shows that the salinity of the double RO water is predicted to be 600 uS/cm at 25$^{o}$C. This is some 86% of the upper threshold for non saline water. The water is non-saline.

Forage harvesting will be essential to maintain pasture growth and evapotranspiration. External fertiliser will be needed to maintain satisfactory growth.

# Contents

# 1. BACKGROUND

## The project

Veolia Environmental Services (Australia) Pty Ltd, hereafter Veolia, processes some 40% of Sydney's putrescible wastes at its Woodlawn Site. The waste treatment process generates excess leachate. Currently this leachate treated then retained in effluent storage dams. However, higher than average rainfall in recent years has resulted in the need to safely dispose of excess water.

Irrigation onto lands within the Woodlawn site was explored as an option.

The chemistry of the treated leachate is a major constraint to reuse. The treated leachate was extremely saline, having salinity approximately 1/3 of sea water. It is unsuitable for irrigation. Application of treated leachate to land would kill off most vegetation as well as lead to loss of soil structural stability. See table 1, above, for details of the irrigation water chemistry resulting from double reverse osmosis (double RO) of the leachate.

A reverse osmosis (hereafter RO) plant is proposed as a way of removing contaminants that make the treated leachate unsuitable for irrigation. A sequence of 2 RO membranes is used to achieve permeate that is compliant with Australian Guidelines for irrigation as table 1 shows. It is proposed to irrigate nearby pastures with the permeate. Management of the retentate is under investigation.

The proposed irrigation area is currently used for sheep grazing. Major pasture plants on site include fescue and phalaris. However, weeds dominate the pastures[2].

A 2 pass RO system can reduce salinity from 13 to 17 dS/m to 0.6 dS/m[3] (table 1). Fescue and phalaris can tolerate irrigation water with 3 to 4 dS/m of salinity (ANZECC, 2000, Table 4.2.5). The Double RO permeate would be suitable for some legumes including Berseem clover, strawberry clover and some lucerne varieties (ANZECC, 2000).

It is concluded that the predicted permeate is suitable for pasture irrigation.

The current document is concerned with sustainable irrigation management of the permeate. It also provides detailed guidance on managing the irrigation project.

## References consulted


- DEC 2004. NSW Environmental Guidelines, Use of Effluent by Irrigation.
- NRMMC, EPHC, et al 2006. Australian Guidelines for Water Recycling : Managing Health and Environmental Risks. Phase 1.
- QDPI 2023. MEDLI model handbook
- ANZECC & ARMCANZ 2018. Australian and New Zealand Guidelines for Fresh and Marine Water Quality
- ANZG 2023. Water Quality for Irrigation and General Water Uses: Guidelines. Australian and New Zealand Guidelines for Fresh and Marine Water Quality. Australian and New Zealand governments and Australian state and territory governments, Canberra.


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[2] Efficient eradication of weeds is critically important to producing high quality, saleable fodder.
[3] 1000 uS/cm= 1dS/m

- Woodlots and Wetlands 2023. Suitability of four potential irrigation areas at the Veolia Woodlawn Operations Site to sustainably receive treated process leachates. V11
- Woodlots and Wetlands 2025. Impact of double reverse osmosis on permeate quality

# Report author

Peter Bacon has over 35 years' experience in investigating nutrient and water dynamics. In this time, he has published over 300 articles, ranging from expert systems to international reviews of major ecological processes.

In the 1970s he lectured to irrigation science Students at Yanco Agricultural College.

Following the untimely death of the Soil Chemistry Lecturer, he lectured in Soil Chemistry to Second and fourth Year Agricultural Science Students at the University of Sydney.

Since 2007 he has been a Fellow of UTS and guest lectured in environmental risk and on wetland design to manage waste waters.

In 1992 he was awarded a Churchill Fellowship to study effluent management and the environment in South Africa, Israel, Portugal and the USA. Specific aspects included modelling effluent quality changes to soil and water, the effects of land management on aquatic ecosystems, biosolids reuse in forests and the environmental effects of effluent reuse. In 1994 he founded Woodlots & Wetlands, an environmental consultancy, specialising in stormwater, wastewater management and eco engineering.

He has undertaken over 300 effluent and waste management projects including ones for food processing facilities, tanneries, abattoirs, chicken sheds, piggeries, dairies, wineries, industrial sites, cities, prisons and individual resort and institutional developments. He has also undertaken compliance investigations for waste food processing and for processing of treated grease trap wastes. Since 2005 he has provided expert witness in several Land and Environment Court cases involving waste management.

# 2. THE PROPOSED PERMEATE PRODUCTION RATES

## Reverse osmosis process

RO (reverse osmosis), operates by forcing pressurised water through a semi permeable membrane, leaving the residual water, with the suspended and dissolved contaminants, behind.

The water with the reduced concentration of contaminants is referred to as 'permeate'. The residual water and contaminants are referred to as 'retentate'.

The current proposal is for a 2-pass system, involving treated water undergoing 2 passes in sequence through separate, semi permeable membranes.

## RO production rates

Veolia expects to initially produce 1 L/sec of permeate from a proposed RO plant. This production rate was selected as the permeate produced could be accommodated in the 16.8 ha selected for the first phase of the project. Table 2.1 shows the consequent volumes of permeate water available for irrigation.

**Table 2.1. The volumes of RO permeate based on production of 1 L/sec (84 cubic m/24 hr day. The ha of irrigation land required, assuming 183 mm/y of irrigation, is also shown.**

| L/sec | L/ 24 hr 'shift' | Cubic m/day | ML/y if an average of 0.5 mm/day is applied | Irrigation land required (ha) based on maximum irrigation 183 mm/y. |
|---|---|---|---|---|
| 1 | 86400 | 86.4 | 32 | 16.8 |

## Permeate quality

The RO plant is designed to have a two pass system, with the permeate being subject to double RO.

Table 1 in the executive summary shows the anticipated attributes of the permeate after double RO. Woodlot and Wetlands (2025) details the changes in permeate chemistry due to the double RO process.

Key features of the permeate include a salinity of 0.6 dS/m, a pH of above 6.5 and a SAR[4] of less than 8.

The combination of a relatively high SAR and low salinity can facilitate soil dispersion. The relationship between SAR, salinity and risk of soil dispersion is shown below.

[4] SAR: Sodium Adsorption Ratio used to establish the likelihood of soil dispensing when irrigated with the combination of high SAR / low salinity irrigation water.

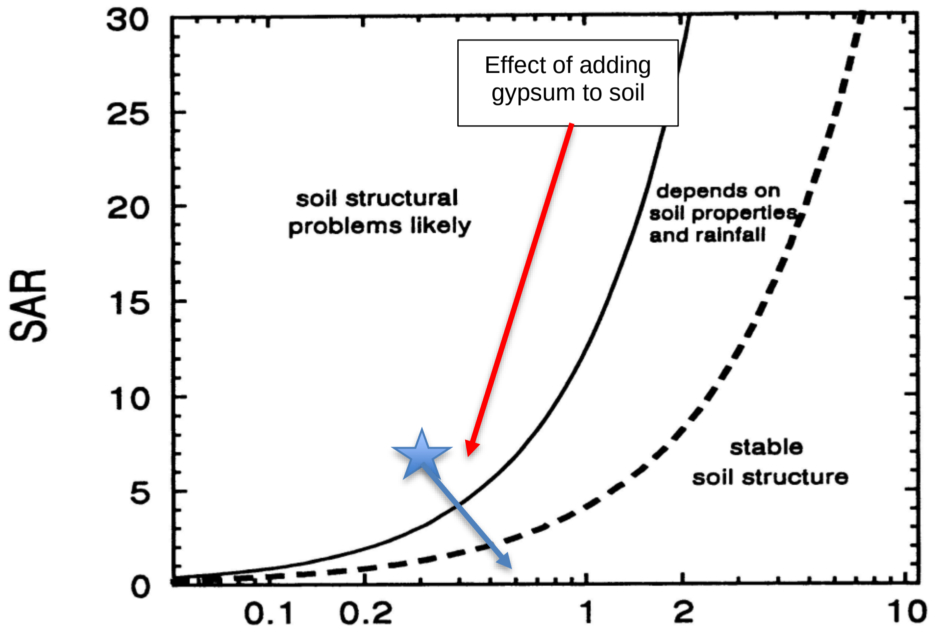


**Figure 2.1. Relationship between SAR and EC of irrigation water for prediction of soil structural stability (copied from DNR 1997b. note that 1 dS/m = 1000 uS/cm). Adding sufficient gypsum has two effects; it reduces the SAR and it increases to ionic strength of the soil water. Both these changes increase soil structural stability.**

The figure above is a copy of figure 4.2.2 in ANZECC (2000). The blue star shows that the anticipated combination of permeate electrical conductivity (0.6 dS/m) and SAR (8) could facilitate soil structural instability.

A combination of lime and gypsum must be used to address this issue[5]. Gypsum addition reduces the SAR and increases soil electrical conductivity. Both these processes reduce risk of soil structural problems developing. The lime will also reduce acidity. However, gypsum is more efficient than lime as the soil becomes neutral to alkaline.

Adding at least 20 mg/L of dissolved Ca to the final permeate or at least 5T/ha of gypsum to the soil will reduce risk of soil structural instability.

# Potential for changes in the RO permeate quality

Permeate water quality is discussed in detail in the report
***Woodlots and Wetlands (2025) Impact of double reverse osmosis on permeate quality***

At the Woodlawn site, the retention of the permeate in pondage over a number of years has resulted in some evaporation. This has concentrated the dissolved constituents. Assuming the current proposal succeeds there will be a reduced storage time in the Woodlawn Dams. In turn, this will reduce the dissolved chemical load in the raw feed

[5] NOTE that soil organic carbon can reduce the impacts of relatively high SAR. Soil with high concentrations of organic carbon usually have a large and varied microfloral population. The microflora produces mucus and gums. These act as soil particle binders. The dense root system under permanent pasture at Woodlawn also assists in soil stabilisation.

water.  This suggests there will be a gradual; improvement in the permeate chemistry over time.

# Critical control points

The pump system is a critical control point.  It can be shut down

Membrane ruptures and aging can result in decreased permeate quality.

Monitoring of the permeate salinity is a simple, continuous way of monitoring permeate quality.  The anticipated Electrical Conductivity of the feed water is some 23,000 uS/cm. The anticipated double RO permeate is expected to have a salinity of around 0.6 dS/m. The salinity sensors can readily be alarmed and the system shut down, if for example, the salinity exceeds 800 uS/m[6].

pH can be used as another readily measured control point.  A suggested alarm trigger is pH<6 and >8.

A flow meter downstream of the RO system is essential to monitor flow to the irrigation system.  Pressure sensors can be used in conjunction with solenoid valves to alert the operators to system leaks.

Any significant changes in permeate chemistry will be included in the reports required by the EPA.

The proposed double RO process is predicted to produce permeate that meets that ANZECC (2000) criteria for irrigation, except for Boron.  However, the site is Boron deficient, and Boron is mobile, so much of the Boron will be leached into the subsoil.

The double RO water attributes also meet the ANZG (2023a) Irrigation Guidelines.   The water is 'non-saline' so the risk of salinisation of the site, the groundwater or local streams is negligible.

The default guideline concentration for boron in irrigation water is 0.5 mg/L. The site specific guideline value is 0.75 to 15 mg/L. Boron is not normally considered an issue except in arid areas with saline soils. These conditions do not apply at Woodlawn.

The permeate quality is compliant with both ANZECC Guidelines For Irrigation and the Australian 2011 Drinking Water Guidelines .

The soils are acidic, so they must receive lime as part of the site preparation for irrigation (see below for details). Increasing soil pH to near neutral values will assist water quality management by precipitation of potentially toxic metals. It will also facilitate soil organic matter accumulation. This, plus raising the soil pH, will assist in boron retention.

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[6] Note the need to allow for temperature fluctuation between winter and summer conditions.

# 3. WATER BALANCE

A daily time step soil water balance was used to determine the volume of water that can be sustainably irrigated onto the site. The water balance model is based on a 5km*5km gridded data set derived from the SILO website (www.longpaddock.qld.gov.au).

The time duration of the modelling is 43 years, from January 1, 1980 to 13 June 2023. The most recent 43 year period was selected to reflect recent changes in rainfall and potential evapotranspiration that are likely to reflect recent impacts of climate change[7].

The model inputs/ assumptions are:

- Rainfall data is for a 5km*5 km grid centred on the Veolia site.
- The daily rainfall is based on a 2 dimensional simulation using nearby meteorological stations.
- The potential evapotranspiration (PET) is based on the FAO 56 model.
- The land use is assumed to be pasture with forage harvesting plus low to moderate sheep grazing pressure.
- The soil is assumed to be a well-structured ferrosol. Having a clay loam topsoil, with a low permeability clay subsoil.
- Runoff commences when the daily rainfall exceeds 17.8 mm (USDA, 1984)[8].
- Available water holding capacity in the root zone is 90mm.
- Once the combination of available soil water content + infiltration exceeds 90mm, the excess water percolated below the root zone. NOTE that this drainage is assumed to happen over the following 24 hrs. In practice, the clay subsoil is likely to take a minimum of 2 days. This creates opportunity for increased evapotranspiration. That is, the model is ‘conservative’.
- Plant water use ((evapotranspiration rate, or Et) is 100 % of PET until 50% of WHC (45 mm of available water), then a linear fall in Et as the available soil water content falls to zero.
- The recommended irrigation strategy is to apply 0.5 mm of irrigation each day when the rainfall is predicted to be 10mm or less.
- That is the cut off rainfall/irrigation day was >10mm of predicted rainfall.
- The final design RO flow is 1 L/sec. 24 Hrs/day, 365 days/year.
- The irrigation area totals 16.8 ha.
- Irrigation efficiency is 95%. That is 5% of the permeate is lost via spills, uneven distribution and evaporation.
- Average annual rainfall (1980 to 2023) is 709 mm
- Average annual potential evapotranspiration (1980 to 2023) is 1056 mm (FAO,56 model).
- Average annual runoff 21 mm (Based on USDA, 1984)
- Deep drainage without irrigation averages 91 mm/year. Applying 183 mm/year of permeate irrigation increases that by 85 mm to 188 mm/average year.
- A range of scenarios were examined.
- The recommended one is
  - Apply 0.5mm every day when the predicted rainfall on the irrigation day is not more than 10mm.
- The pre irrigation water balance was modelled to provide a base line condition.

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[7] Climate change in SE Australia is expected to increase potential evapotranspiration and to reduce rainfall. These changes will increase irrigation demand.

[8] In wet soils, runoff will commence once the infiltration capacity is less than the rainfall intensity. In saturated soils, the infiltration rate can approach zero. Therefore, irrigation must NOT occur on saturated soil

Figure 3.1 shows the initial irrigation area. It is a minimum of over 100m to the headwaters of a first order streamline. Figure 3.1. The area 2 proposed initial irrigation covers 16.8 ha. There is a buffer over 100m wide between the SW corner of the irrigation area and the headwaters of the nearest streamline. There is also a tree lined buffer between the irrigation area and Collector Road.


.**Figure 3.1. The area 2 proposed initial irrigation covers 16.8 ha. There is a buffer over 100m wide between the SW corner of the irrigation area and the headwaters of the nearest streamline. There is also a tree lined buffer between the irrigation area and Collector Road.**

Figure 3.1 shows the initial irrigation area. It is a minimum of over 100m to the headwaters of a first order streamline

## Minimising environmental risk from permeate irrigation

The Approach to minimising environmental risk to local watercourses include:

1. Double Reverse Osmosis (the same process used to produce drinking water at Sydney's desalination plant in Kurnell).
2. Irrigation at extremely low rates (0.5mm/irrigation) to minimise the possibility of runoff.
3. Not irrigating on days when 10mm or more rainfall is predicted
4. Each morning undertake a visual inspection of area 2 boundaries to determine if runoff is occurring. Do not irrigate if there is evidence of saturation (which would likely result in runoff).
5. Maintain a minimum of 100m between the edge of the irrigation area and any drainage line

The table below sets out the recommended separation distances between the outer edge of the irrigation areas and the nearest water bodies.

A separation distance of 50m is recommended between effluent irrigation systems and natural waterbodies. See table 3.1 below.

The proposed distance is over twice this distance.

**Table 3.1. Recommended buffer distances from effluent irrigation areas to water resources and public areas (copy of DEC, 2004, table 4.9).**

| Sensitive area | Separation distance (low strength effluent) | Separation distance (medium to high strength) | Impact of concern/comments |
|---|---|---|---|
| Natural waterbodies (e.g. rivers, lakes) | 50 m | 50 m | Protection of water quality and aquatic ecosystems. Supplementary requirements may be included for human sourced effluent to protect public health in recreation areas. |
| Other waters (e.g. artificial waters with beneficial uses, small streams, intermittent streams, water distribution and drainage channels, farm dams) | Site-specific | Site- specific | Protection of water quality for most sensitive water uses of the potentially affected waterbody. |
| Domestic well used for household water supply | Site-specific | 250 m | Groundwater quality for domestic human uses protected. |
| Town water supply bores | Site-specific | 1000 m | Water and groundwater quality for drinking water supply protected. Town bores generally pump at high rates and draw water from a large area. |
| Where spray irrigation gives rise to aerosols near houses, schools, playing fields, roads, public open space and waterbodies | 50 m[1] | 50 m | Avoidance of spray drift of effluent containing pathogens offsite. Buffers for odours and noise have separate assessment criteria and these are assessed on a site-specific basis. |
| Other sensitive areas (e.g. waters in drinking water catchments, aquatic ecosystems with high conservation value, wetlands, native stands of vegetation) | Site-specific | 250 m | Greater buffer distances and management may be required in some circumstances to protect drinking water (e.g. within the Sydney Drinking Water Catchment the Sydney Catchment Authority would seek a buffer of 100 metres in the absence of other evidence of a neutral or beneficial effect on water quality). |

**Notes:** 1. Recommended in ARMCANZ, ANZECC and NHMRC (2000) for the spray application of reclaimed water from sewerage systems.

# Impact of the proposed permeate irrigation regime on the water balance components

Table 3.2 shows the average  area 2 water balance components with and without the proposed irrigation regime.

**Table 3.2.  The water balance components with and without 183 mm of permeate irrigation in the average year. Based on daily data between January 1980 and June 2023.  Assumes soil water holding capacity in surface 500 mm is 90mm.**

| Water balance component | Zero irrigation | 0.5mm/day if <10 mm of rain predicted | Change (mm/y) |
|---|---|---|---|
| Rainfall (1980 to 2023) mm/y | 703 | 703 | 0 |
| Permeate irrigation mm/y | 0 | 183 | +183 |
| Soil evaporation. mm/y  This assumes a thick pasture cover | 0 | 0 | 0 |
| Evapotranspiration mm/y | 593 | 798 | +205 |
| Rainfall runoff mm/y | 21 | 21 | 0 |
| Irrigation runoff mm/y | 0 | 0 | 0 |
| Deep drainage mm/y | 91 | 186 | +95 |
| Average soil available water (mm) | 40 | 58 | +18 |

The key results from permeate irrigation are

- An increase in infiltration into the soil,
- An increase in evapotranspiration, and
- An increase in deep percolation.

The MEDLI modelling in appendix 3 shows there is no accumulation of ‘salt’ anywhere in the profile.  The reasons for this are that the soils are non - saline and there is a minimal quantity of salt in the permeate (see data in table  above).

The permeate availability is dependent on the RO process rate.  The initial assumption was 1L/sec 24/7.  This is equivalent to 31.5 ML/year. See table 3.2, below.

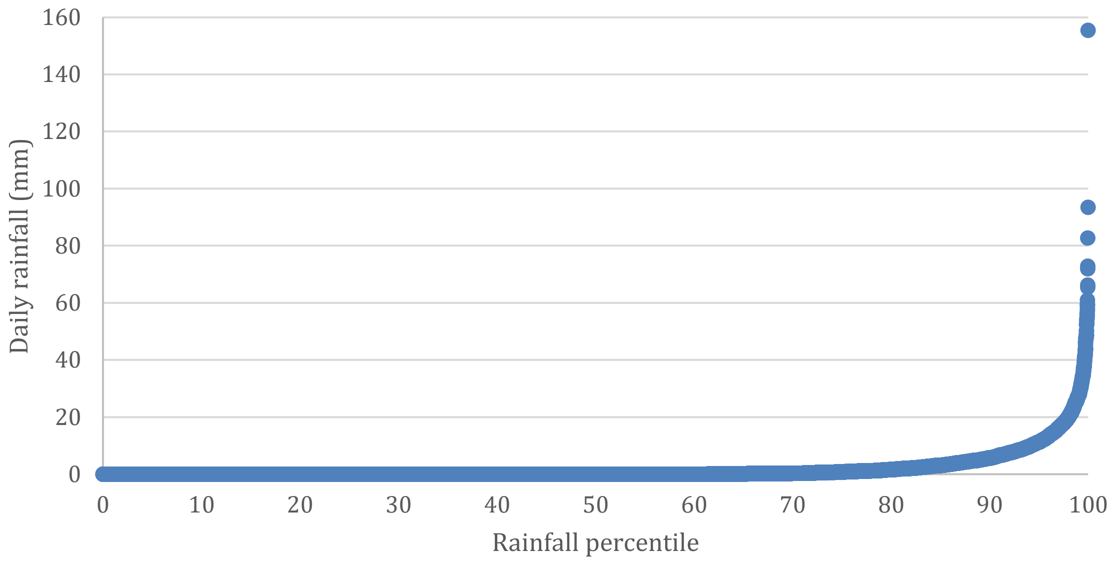
**Table 3.3.  The range of permeate production rates expressed as L/sec, cubic m/day and ML/year. The irrigation rate is shown in mm of permeate/year.**

| Design RO permeate production Rate (L/sec) | Daily (cubic m) | Annually (ML) if irrigated every day at 0.5mm/day | Irrigation onto 16.8 ha (mm/y) if irrigated 365 days/y at an average of 0.5mm/day[9] |
|---|---|---|---|
| 1 | 86.4 | 31.5 | 183 |

The irrigation rate can be increased to 1 mm/day during warm, dry summer days. This 'compensates for the 21 days in the average year when >10mm of rainfall precludes irrigation on that day. This higher rate on an average of 21 day per summer is designed to increase the annual application rate to an average rate of 0.5mm/day or 183 mm/year.

Figure 3.2 shows the percentile distribution of daily precipitation (mm/day).

**Figure 3.2 Rainfall percentile exceedance for daily total precipitation (mm) between Jan 1980 and June 2023.**




The percentile rainfall data is summarised in table 3.2.

**Table 3.4. The rainfall quantity (mm/day) as percentile frequency of days between January 1980 and June 2023.**

| Rainfall (mm of rainfall in a 24 hr period | **0** | **4** | **8** | **10** | **12** | **15** | **20** | **30** | **40** |
|---|---|---|---|---|---|---|---|---|---|
| Frequency (%) of exceedance of these rainfall events | 61 | 13 | 8 | 6 | 5 | 4 | 2 | 0.8 | 0.3 |
| Days / average year when rainfall threshold is reached | 223 | 47 | 29 | 21 | 18 | 12 | 7 | 3 | 1 |

Table 3.3 shows that there is no rainfall on 223 days in the average year. Some 6% of days have more 10 mm or more rainfall. That is, 21 days per average year will not be irrigated.

The USDA (1984) rainfall/ runoff/model suggests the runoff threshold for the Woodlawn conditions is 18 mm. Obviously if the ground is very wet then runoff will occur with less rainfall. However, this figure has been used to design the irrigation system specifications.

# Irrigation threshold

The 0.5 mm irrigation will only occur if there is less than 10mm of rainfall predicted for the irrigation day. This is an extremely small depth of irrigation water. Most of this 0.5mm will be retained then evaporated from the leaf surfaces. However, we have assumed to all of the 0.5mm will enter the soil. This is a very conservative approach.

The aim is to irrigate with minimal risk of permeate runoff.

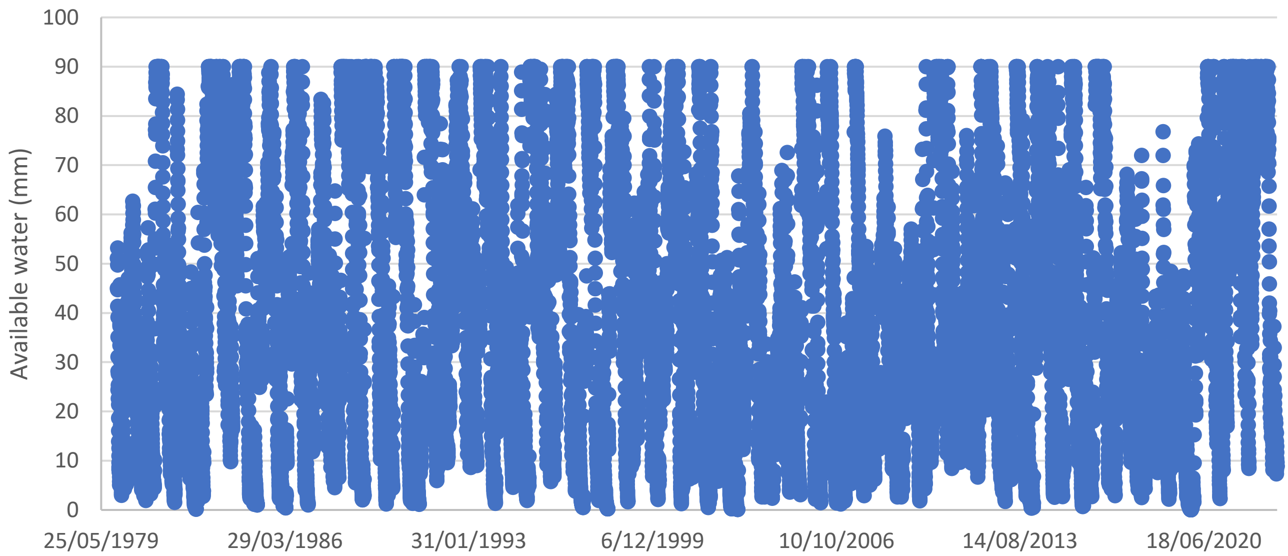
It is emphasised that irrigation must NOT occur if there is evidence of saturated soil and runoff is occurring. Daily inspection of the site is essential to verify that no runoff is occurring.

# Available soil water quantity without irrigation

A daily available soil water content model was used to predict the available soil water content. The available soil water content (ASWC) is the water content, in mm, between field capacity and permanent wilting point in the surface 500m of soil. The soil investigation of area 2 showed that the topsoil is a clay loam. While the subsoil is a medium clay. The soil water holding capacity (SWHC) in the bulk of the root zone was assumed to be 90mm (Geeves, et al, 2007).

The plant and soil water model used assumes 100% of Potential Evapotranspiration (PET) down to 50% of water holding capacity (45 mm). Then a linear fall in evapotranspiration (Et) as the available soil water content falls to zero

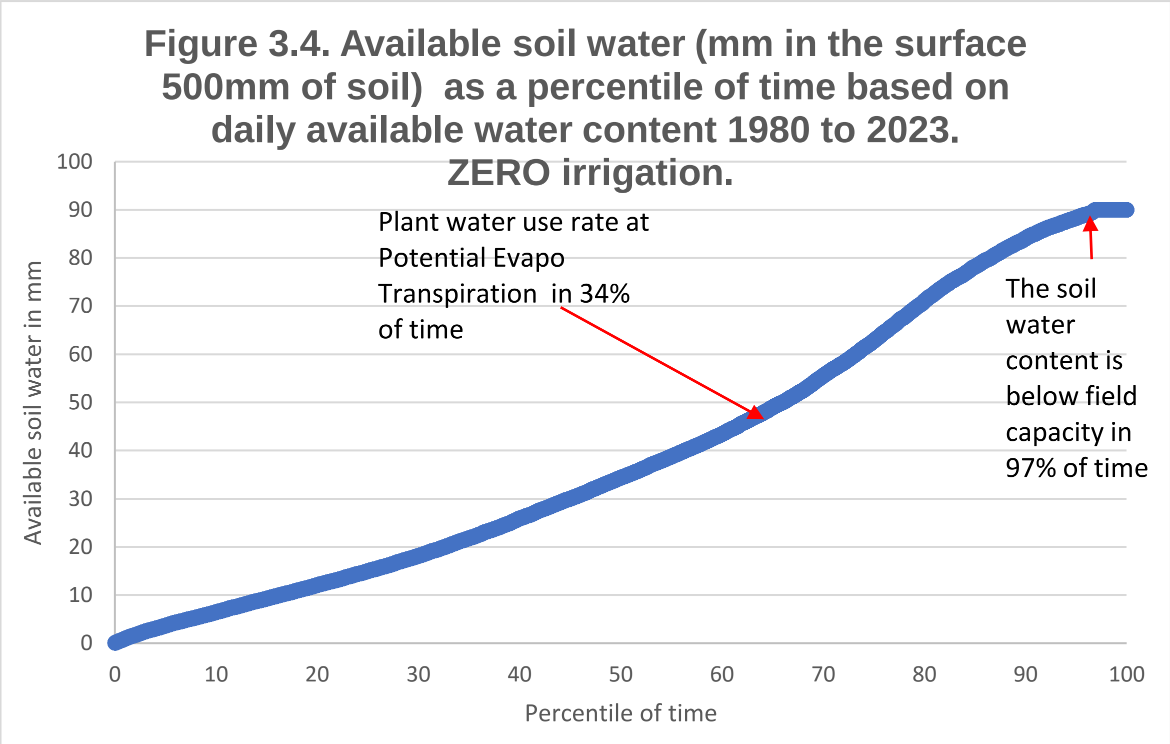
**Figure 3.3. Available soil water (mm) in the surface 500 mm of soil between January 1980 and June 2023. The assumed maximum available soil watrer is 90mm.**




It is obvious from figure 3.3 that there are numerous periods when available water content approaches zero.

Figure 3.4 shows the available soil water content falls to less than 10% of the maximum Water Holding Capacity in 16% of time.

In 97% of time the profile is not ‘full’.  In 95% of days the profile soil water content is at least 2mm below the water holding capacity (90mm).  That is, in some 97% of days it is possible to irrigate a small quantity of permeate (0.5mm), without exceeding the soil water holding capacity.




Note that in periods when the antecedent day had heavy rainfall, the soil water content could still be above 90mm as the water drains into the subsoil.

The strategy is therefore to apply an extremely low irrigation rate of 0.5 mm/day, and only when the model suggests that there is a moisture storage capacity available in the soil.

# Irrigation strategy

The irrigation strategy is:

- Ensure the permeate has very low salinity, so that there is minimal risk of salinisation of the soil and water.
- Maximise the volume of permeate that is used on the pastures within the subject property.
- Do NOT irrigate if the paddock is saturated and runoff is occurring.
- Apply the permeate via a low application rate/day to minimise the risk of runoff. That is: Apply irrigation at 0.5 mm/irrigation day
- Only irrigate on days when rainfall is  less than the likely runoff threshold of 18mm. The threshold for no irrigation was set at 10 mm of rain.
- Use warm dry summer days to increase the application rate to 1mm/day on an average of 21 days per year.  This will compensate for the zero irrigation on the average of 21 days per year.
- That is the annual rate is 365.25*0.5 mm/day = 183mnm/year.

## The irrigation model components

- The rainfall at which no irrigation occurs on that day is : 10mm.
- That is, the system will be overridden and not irrigate if 10mm or more rain is predicted on the irrigation day.
- The daily irrigation rate is 0.5 mm/ irrigation day (except for 21 warm dry summer days when irrigation was applied at 1mm/day). This extra volume of water is to 'compensate' for an average of 21 days/year when predicted rainfall will exceed 10 mm.
- The assumed irrigation area was 16.8 ha

# Zero irrigation

Zero irrigation was used as a 'base line' condition.

**Table 3.3. Site water balance with zero irrigation.**

| Rainfall (mm) | Actual evapotranspiration (mm) ET | Runoff (mm) | Irrigation (mm) | Deep drainage (mm) | Average available soil water (mm/500mm) |
|---|---|---|---|---|---|
| 703 | 593 (zero irrigation) | 21 | 0 | 91 | 40 |

This table provides the base line conditions. It is taken from the MEDLI Model for zero irrigation. See appendix 3.

# Water balance when 0.5 mm of permeate irrigation is applied when there is not more than 10 mm of rainfall predicted.

The full MEDLI model output for this scenario in shown in appendix 2.
Table 3.4 shows the impact of applying 0.5 mm/day of irrigation whenever there was less than 5mm of rainfall predicted for the same day.

**Table 3.4. Water balance when 0.5mm of permeate irrigation applied when there is not more than 10 mm of predicted rainfall on the irrigation day. The irrigation area is 16.8 ha. The design flow is 1 L/sec or 86.4 cubic m/day.**

| Component | Based on 0.5 mm/d for 344 days plus 11 days at 1mm/day |
|---|---|
| Number of irrigations /y | 344 |
| Potential evapotranspiration (PET), based on FAO 56 Model, | 1056 |
| Irrigation (mm/y) (344 days with 0.5 mm/day (170.5 mm) PLUS) PLUS 12 summer irrigations with 1mm of irrigation to allow for wet days with no irrigation). That is 170.5 +12 = 183 | 183 |
| Irrigation water demand (cubic m/irrigation day) of 0.5mm of permeate per day (86.4 cubic m/irrigation day) PLUS .13 warm dry days with 1 mm/day (173 cubic m/day). | 86.4 |
| Annual irrigation demand (ML/y) over 16.8 ha | 30.5 |
| Actual evapotranspiration (mm) ET | 802 |
| Deep drainage (mm/y) | 188 |
| Average water available (mm 90 mm max) | 58 |

The 0.5 mm of permeate / irrigation day will require a 24 hr flow of 1 L/sec of permeate. Obviously if the permeate production rate is increased to 2 L/sec, the irrigation period is halved. It is prudent to have a buffer tank capable of holding sufficient water to allow for the irrigation system demand and also for minor maintenance shutdown of the RO system. A tank capacity of 87 cubic m is required to adequately buffer inflow and outflows and also allow for short term maintenance shutdowns.

The average annual demand based on 183 mm/year irrigation per year is 30.5 ML.

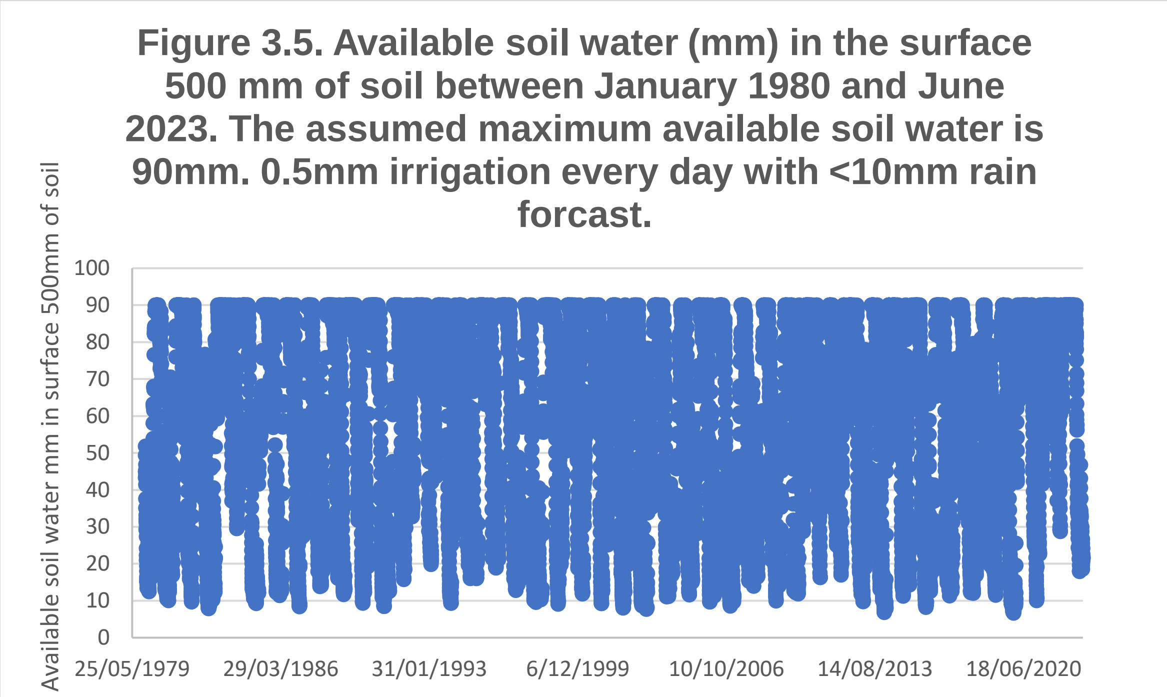



Figure 3.5 shows that the 0.5mm/day irrigation strategy results in soil available moisture content not falling to zero as per figure 3.3.

The average available water content in the surface 500mm was 58 mm compared with 40 mm for the zero irrigation condition.

# The recommended approach for area 2

- 16.8 ha of fixed sprinkler irrigation
- Applying 0.5mm/irrigation day IF predicted rainfall is not more than 10 mm.
  AND
- The site is not already saturated or runoff is occurring.
- The permeate production can be adjusted to suit the available area.
- Irrigation can be increased to 1mm/day during the summer in order to achieve an annualised average of 0.5 mm/day (183 mm/y).

# Calculation of soil salinisation

ANZECC (2000), chapter 4, gives methodology to predict soil salinity based on the salinity of the irrigation water and the leaching fraction[10]

The predicted salinity of the irrigation water is 0.6 dS/m

[10] The proportion of the applied water that is leached below the root zone

The soil salinity data on page 11 of Appendix 2 shows that the salinity of the soil solution at the base of the root zone is predicted as being 0.05 dS/m.

Table 4.2.4 in ANZECC (2000) shows soils with less than 0.95 dS/m average root zone salinity can support ‘salt sensitive’ plants.

It is therefore concluded that salinity is not an issue.

# Irrigation management

The proposed irrigation regime is based on an understanding of soil water dynamics and daily check of evapotranspiration data and rainfall prediction.

The aim of a typical irrigation system is to remove, or at least minimise, plant moisture stress as a limitation on plant growth.

In the current situation, maximising plant growth and leaf production will increase plant evapotranspiration. The zero irrigation pasture has an estimated ET of 593 mm/year. The pasture receiving an average of 0.5mm/day (183 mm/year of permeate) has a predicted ET of 798 to 802 mm/year. This indicates an increase in transpiration of 205 to 209mm/ year. This is 27mm (or 3% higher) more than the estimated irrigation application rate. Comparison for figures 3.3 and 3.5 show that a key benefit of the irrigation is that it prevents the soil water content from reaching zero (and therefore no transpiration). This suggests that the water use efficiency is higher in the pasture receiving a small amount of irrigation in every day except when rainfall exceeds 10 mm. In turn, the maximised plant water demand will facilitate maximum utilisation of the RO permeate.

The Potential Evapotranspiration (PET) based on the FAO 56 model, is estimated as 1056 mm/year. The actual ET is predicted as being 798 to 802 mm/year. This is some 76% of the PET. The reason for this is that the PET is much higher than the irrigation plus rainfall in the summer months. It may be possible to increase the irrigation rate in the summer, however this will depend on the ability to adjust the pressure of the feed water against the semi permeable membrane. Additional irrigation in summer, will assist in reaching the target of 183 mm/year.

# Output of the MEDLI Model

Table 3.5 shows the water balance components when an average of 177 mm of permeate per year is applied.

**Table 3.5. The irrigated land water balance based on the MEDLI Mode. See appendix 2**

| Name | Value |
|---|---|
| Rain | 709.3 |
| Effluent irrigation | 176.6 |
| Soil evaporation | 0.0 |
| Transpiration | 644.4 |
| Rain runoff | 9.5 |
| Irrigation runoff | 0.0 |
| Deep drainage | 232.3 |
| Delta soil water | -0.4 |

The rainfall is 709 mm/year. The potential evapotranspiration is 1056 mm/year. Therefore, there is a moisture deficit of 347 mm/yr (note that this will vary among years).

The actual evapotranspiration is 644mm/year. This is lower than the FAO model. At least some of the difference is due to allowing heavier irrigation during warm dry weather in the FAO model.

The pasture growth response to irrigation is typically 20 to 30 kg/ha/ mm of additional water. Therefore, assuming an additional 25 kg/ha of dry matter/mm of rainfall/year, the additional 177 mm of water will increase pasture production by a modelled 25*177= 4425 kgs of dry pasture mass/ha/year.

A set of relatively simple measurements/ observations are established to guide the operator.

# 4. THE IRRIGATION AREAS

The suitability of the site for  irrigation was based a field sampling and evaluation plus laboratory analyses of soil from 39 pits in the area.  Twelve pits were excavated in the 16.8ha of area 2.
The Australian Soil and Land survey Field Handbook (NCST, 2009) was used as a template to describe site conditions.

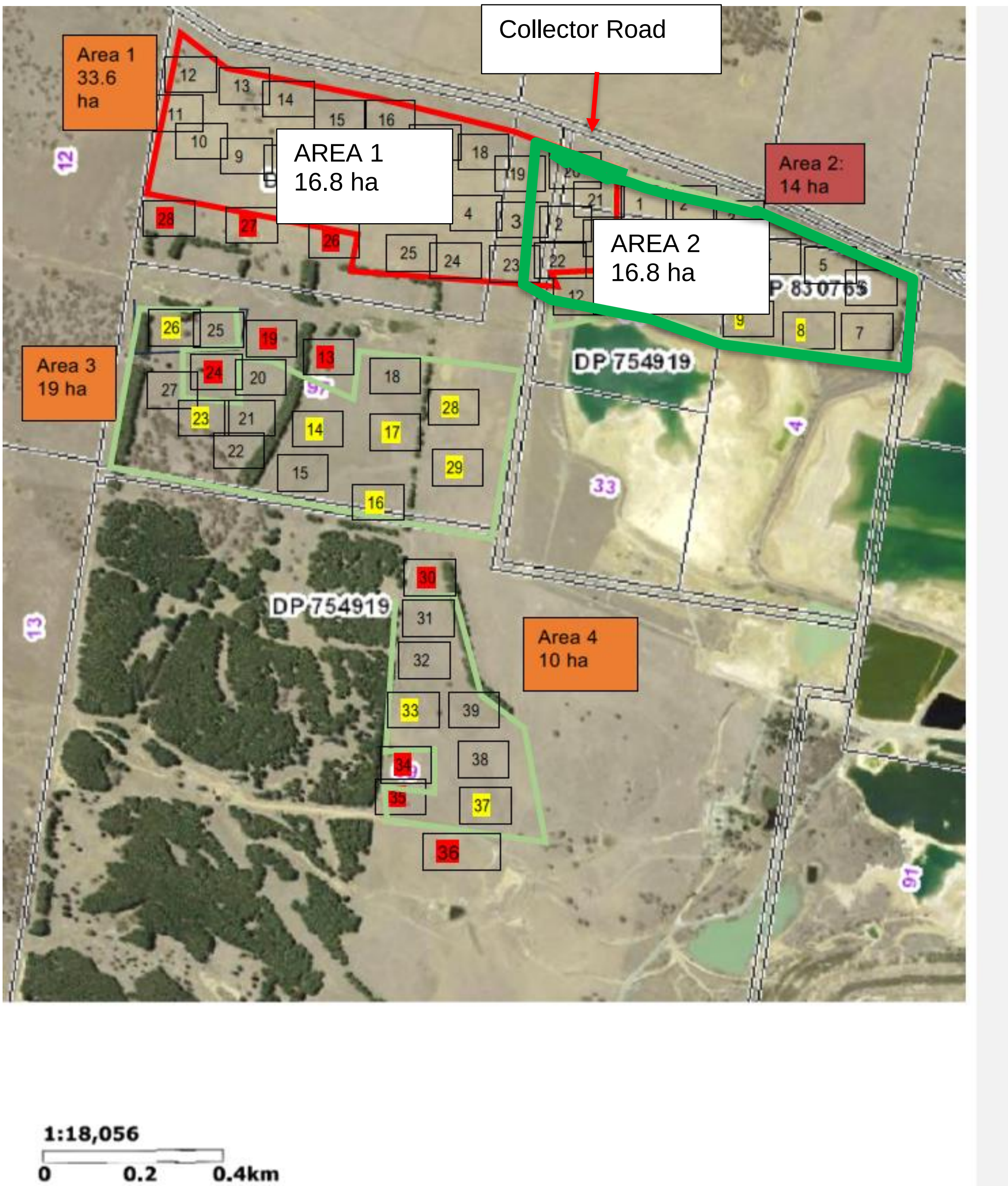



**Figure 4.1.  The soil sampling and landform assessment points within each of the four areas (image source: NSW Gov).  NOTE ONLY area 2 is proposed at this stage.12 of these pits were in the 16.8 ha of area 2 that is the subject of this report.**

NOTE that the areas shown are the maximum extent of each area. The irrigatable areas are considerably less. The RED highlighted areas are NOT suitable for irrigation. The YELLOW areas have SOME constraints.

There was a total of 36.3 ha of suitable irrigation areas in areas 1 and 2. Areas 3 and 4 had at total of 20.5 ha of irrigatable land. Areas 1 and 2 had 'better' soil than areas 3 and 4, so this study concentrated on areas 1 and 2[11].


**Figure 4.2. A back hoe was used to excavate observation pits, to determine soil depth and to facilitate soil sampling. Note the thick pasture cover.**

Landforms and irrigation suitability within each area is described detail in ***Suitability of four potential irrigation areas at the Veolia Woodlawn Operations Site to sustainably receive treated process leachates (Woodlots and Wetlands (2023).***

Section 5, below tabulates the key attributes of the irrigation areas.

[11] NOTE that only area 2 is proposed for development in the initial stage. Further development should be based on the performance of area 2.

# 5. SITE SUITABILITY FOR IRRIGATION

Site suitability for irrigation is based on a combination of physical, chemical and biological attributes.

**Table 5.1. The key considerations determining the suitability of the proposed irrigation areas. NOTE only area 2 is proposed for irrigation at this stage. See figure 4.1.**

| Attribute | Issue | Comment |
|---|---|---|
| Site infrastructure | Nearness to roads and power lines | Area 2 is adjacent to Collector Road. The separation distance requirement depends on the quality of the water (Especially potential pathogen load). NOTE the permeate does not contain pathogens, so this is not a significant consideration for the proposed system<br>The existing power line through area 2 limits the full potential of centre pivot systems.<br><br>Fixed sprinklers are preferred as they will not impact on power lines. A total of 36.3 ha is available in area 1 plus area 2.<br><br>It is proposed that Area 2,which has 16.8 ha of irrigatable land, will be developed first. |
| Ecological values | Some area on the northern portion of the irrigation area has been excluded because of the ecological values in this area | This reduces the potential irrigation area to 16.8 ha based on area 2.<br>Note that some buffering is required to minimise risk of vehicles on Collector Road being sprayed. So, some of the lands excluded on ecological grounds would already need to be excluded because of nearness to Collector Road. Note that there is a treed vegetative buffer zone between area 2 and Collector Road. This may need to be extended to the west to minimise spray drift risk in the western portion of area 2. . |
| Climate | Heavy rainfall can cause water logging and runoff | Irrigate frequently (at 0.5mm/day) subject to predicted rainfall being less than 10mm on that day. |
| Landform | Run-on from higher elevations could result in excessive leaching.<br>Locating the irrigation areas downslope of the dams could result in seepage into the irrigation area. | Areas 1 and 2 are located on a ridge line extending in a WNW direction roughly parallel to Collector Road.<br>The irrigation areas are at a higher elevation than the storage ponds. Therefore, seepage is NOT an issue. |
| Slope | Increased slope can increase runoff risk. In turn this can result in convergence zones which can by saturated for long periods. | Avoid irrigating obvious wet areas.<br><br>Runoff convergence areas can have little or no ability to utilise run-on water.<br><br>Area 2 is largely ‘flat’. |

| Attribute | Issue | Comment |
|---|---|---|
| | Fixed sprinklers can operate at up to 15% slope | Fixed sprinklers are recommended for area 2. |
| Soil depth | Shallow soils overlying rock can become waterlogged under heavy rainfall or irrigation | Area 2 has a 'wet' area in its SE corner. Avoid irrigating this area. There is a total 16.8 ha of irrigatable land in area 2. |
| Soil chemical instability | Unstable surface soil can develop a crust that inhibits water penetration.<br><br>An unstable B horizon can act as a choke inhibiting water movement in the soil. | Gypsum addition can assist in improving soil structure. However, the key issue is to maintain good surface soil structure. A combination of gypsum and dense pasture cover is recommended. Keep soil disturbance, especially cultivation to a necessary minimum. Wet soil tolerant pasture species such as phalaris and cocksfoot should be included in the pasture mix. |
| Low nutrient status | | Area 2 soils are based on volcanic rock. These soils are typically fertile. They have good nutrient retention capacity. |

**Key recommendation**

**1. Develop area 2 first, using fixed sprinklers able to deliver 0.5 mm/day.**

# 6. SOIL LANDSCAPE TYPES

Irrigation areas 1 and 2 are largely on the Duckfield Hut Variant ‘B’ soil landscape as figure 6.1, on the next page shows. These are reasonably fertile soils with slopes less than 10% and low local relief, being in the 5 to 30m range.

Irrigation areas 3 and 4 as shown in figure 6.1 are on the main type of Duckfield Hut Soil Landscape. This soil landscape has steeper slopes with some areas over 10% gradient.

Travelling irrigators operate at up to 8% slope and 3% cross slope. Fixed sprinklers can operate on slopes of 15%, provided they are well designed.

All of the irrigation area within areas 1 and 2 have less than 15% slopes

The key landform limitation for areas 3 and 4 will be slope.

Only area 2 is included in the current proposal. Fixed sprinklers are recommended.

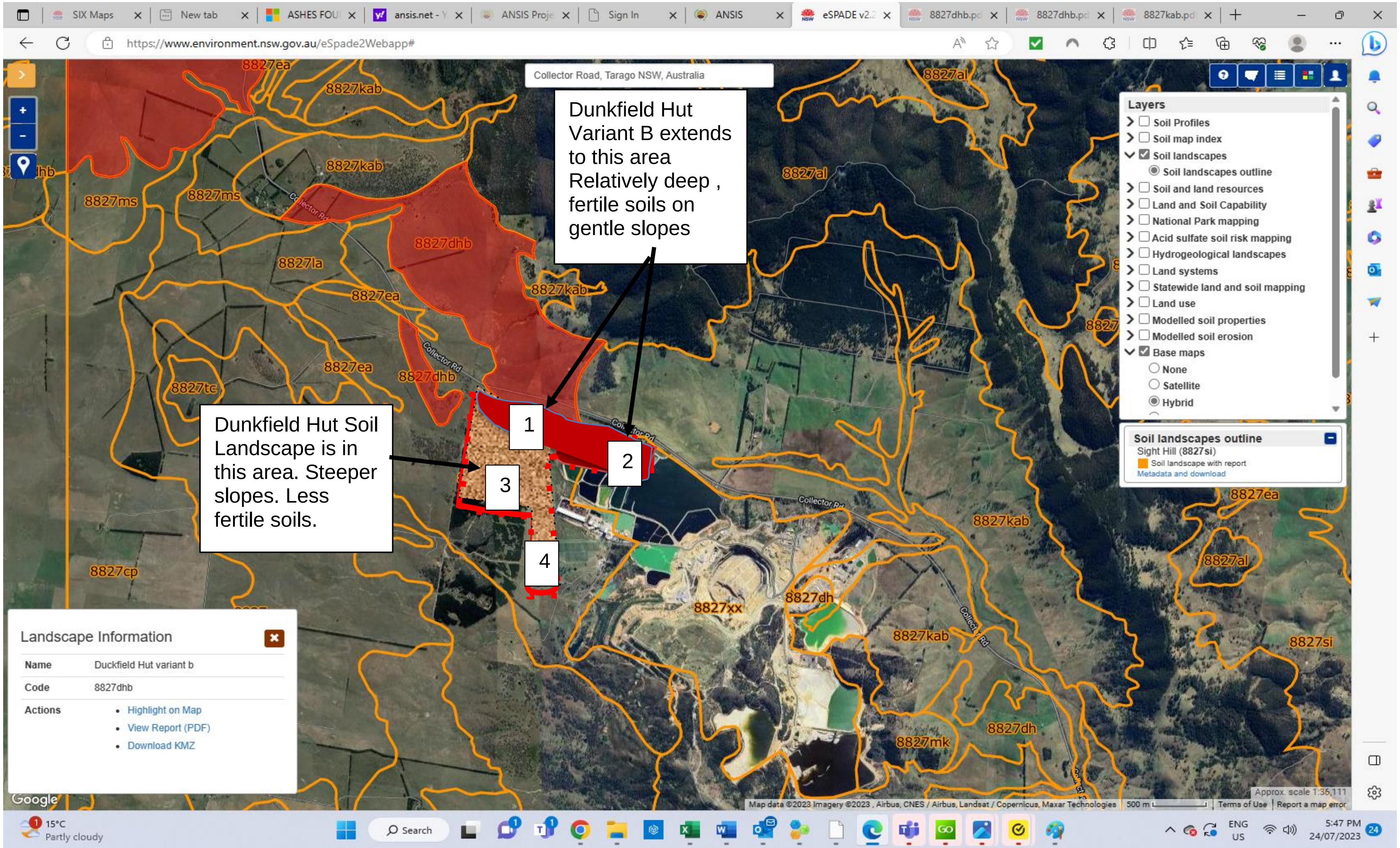



**Figure 6.1. The areas surveyed along Collector Road were part of the Duckfield Soil Landscape Variant b. These are within the currently proposed irrigation area 2. Irrigation areas 3 and 4 to the south were part of the Duckfield Soil Landscape. These are not included in the current documents.**

# 7. SITE MANAGEMENT

The paddocks, the soils and the pastures need to be well managed in order to maximise the productive use of permeate without creating environmental issues.

## Soils

The soils in area 2 are acidic, with low fertility, but structurally strong.

The fertility can be addressed by adding fertilisers as discussed above
Add a minimum of 50 kg/ha of phosphorous. DAP is suitable. It has 20% P, so 50 kg of P/ha will require 250 kg/ha of DAP. This will also supply 90 kg/ha of nitrogen. This should be applied annually once the improved pasture is established. The future rate of fertilisation should be based on leaf and soil analyses results.

There is a need to raise the soil pH. This can be achieved with 2 T/ha of lime. The application rate is based on the quantity of Exch Al present in the soil. It is expected that the quantity of lime per ha required will fall over time.

It is also strongly recommended that 2 T/ha of gypsum be applied in alternative years.

The soils have relatively low potassium. Check potassium concentrations in green leaves after 2 years and apply the equivalent of 50 kg of K/ha if required. The soils are boron deficient, so the boron in the permeate will improve soil fertility and therefore increase pasture growth and transpiration.

Note that if the soil structure is improved, it may be possible the register the site for soil carbon sequestration.

Soils in areas 3 and 4 are less favourable than those in areas 1 and 2. Gypsum will be essential. Additionally agricultural lime will be required. This document is designed to support approval for area 2.

## Management of pasture

Ideally the pasture would be grown for fodder The key reason for this is that sheep and cattle pug wet soils, and this reduces infiltration rate. Note that fodder growing will remove the need to allow for salt licks for cattle[12]. In turn this will reduce the salt addition to the irrigation areas.

Using forage harvesting when the soils are slightly dry will allow harvest without impacting on the soil.

The height at which the vegetation is harvested will depends on the dominant species. In autumn, a lower cut can be taken as it will assist white clover to reestablish. The cutting height should be around 75 to 100 mm, depending on pasture thickness.

Herbicide will be required to manage thistles and other weeds. Spray only as recommended on the drum. Contract spraying is an option.

[12] Cattle can damage fixed sprinkler systems so sheep are preferred.

# Pasture species

The species need to by winter active and able to tolerate wet conditions.

Species mix should include

- White clover
- Sub clover
- Perennial Ryegrass
- Tall Fescue (use Mediterranean variety)
- Phalaris

**Table 7.1. Pasture species and sowing rates under irrigation (derived from NSW Gov publications).**

| Species | Sowing Rate |
|---|---|
| Phalaris | 4 kg/ha |
| Tall Fescue | 15 kg/ha |
| Perennial Ryegrass | 2 kg/ha |
| Sub Clover | 4 kg/ha |
| White Clover | 1 kg/ha |

The cultivars change over time. Consult with a rural produce merchant such as Bungendore Rural for advice.

The NSW DPI produced a brochure containing the text below:

It sets out the pasture establishment actions:

# Eight steps to successful perennial pasture establishment

Reliable establishment is vital to ensure high levels of production and longevity from perennial pastures. Perennial pasture seeds are generally small with seedlings that are delicate and slow growing compared to most crops and many weeds. Greater care and attention to detail is therefore necessary to establish perennial pastures successfully.

**The following checklist of eight critical steps will help you achieve successful establishment and reduce the risk of failure.**

Optimum sowing times and species will vary with regions but the principles embodied in these eight steps will remain the same.

## A. Select, assess and plan early - start at least 8-12 months before sowing

### Key check: Assess the existing pasture, soil fertility, weed and pest risk

- Are the current pasture varieties well adapted and productive or should they be replaced?
- What livestock enterprise and potential pasture use is planned? – match these with appropriate species.
- Is a current soil test result available? – it can provide vital information to assist decision making.
- Is the soil pH and fertility level suitable for the proposed pasture? If not, reassess paddock selection, species, fertiliser, and need for lime or gypsum.
- What weed and insect pests need to be controlled? Competition from annual grasses is the major cause of poor establishment. Some weeds may need to be controlled over several years before sowing.
- Are any herbicide residues present that could affect the species being sown?
- Sowing equipment – ensure equipment capable of placing seed accurately is available and in working order.
- Budget carefully for the appropriate inputs – paddock preparation and sowing, herbicides, insecticides, seed, and fertiliser. Budget for fertiliser in subsequent years and extra livestock to make use of the extra feed grown.

## B. Weed and pest control in preceding year(s)

### Key check: Reduce weed seed reserves in the soil and insect pests by using techniques such as spray-graze, spray fallow, pasture-topping, spring fodder crops and integrated pest management procedures. This step must commence in the previous spring for autumn/winter sowing to prevent annual weed seed set.

- Is the boomspray calibrated and operating correctly?
- Are broadleaf weeds a problem? – consider the spray-graze technique.
- Are annual grass weeds a problem? Spray fallowing is preferred to spray topping because windy spring weather can prevent spraying at the correct time so that annuals still set sufficient seed to cause establishment failure during the following autumn.
- What insect pests are present or likely to be present that may affect establishment? Strategic spraying in spring, to reduce the adult population that produces over-summering eggs, is very effective in reducing red legged earth mite activity the following autumn but may not be as effective for blue oat mites. Insecticides may be added to the spray fallow or other herbicide applications provided the strategic timing of the insecticide is not compromised and is consistent

with label directions. Other pests of seedling pastures such as lucerne fleas, scarabs etc. will require different control measures.

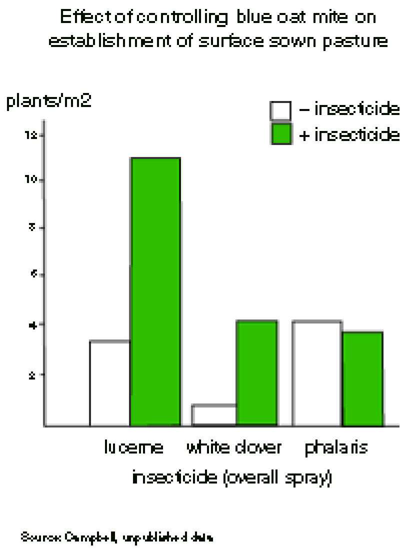
# C. Pre-sowing cultivation or grazing

**Key check: Manage the paddock for 3-4 months prior to sowing to reduce trash and maximise weed germination.**

- Conventional sowings – use cultivation in conjunction with herbicides.
- Direct drill or surface sowings – graze leading up to the sowing period to keep pasture only 1–2 cm tall when using sheep or 3–4 cm tall with cattle.

# D. Absolute weed & pest control - the most important factor for success

See example below:



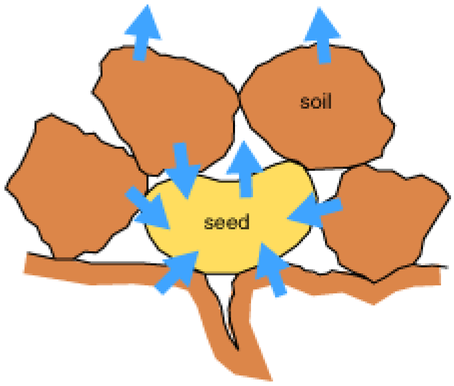

Effect of controlling blue oat mite on establishment of surface sown pasture (no insecticide versus insecticide)

**Key check: Allow full weed germination after the break of the season. Either cultivate or graze to keep weeds small while waiting for optimum sowing conditions. Remember both red legged earth and blue oat mites hatch after the autumn break especially when maximum day temperatures are below 20°C. They start producing eggs 6-8 weeks later.**

- As a rule, don't sow on the first rain of the season (as subsequent weed germination is likely to be a problem).
- Identify what weeds are present or likely to be present.
  – either use the appropriate herbicide at label rates, or
  – cultivate to achieve a firm, fine weed-free seedbed.
- Identify what pests are present or likely to be present and apply the appropriate insecticide. For earth mites, spray 4 weeks after the autumn break. This often coincides with the knock-down herbicide application prior to sowing.
- Where sowing into a dry seedbed is the only practical option (e.g., direct drilling cracking clay soils), good weed control in the previous season is paramount.

- Preferably sow without cover crops – these compete with the young pasture for moisture and light just like weeds.

# E. Adequate soil moisture - enough for quick germination and survival of the sown pasture




Source: PS Cornish 1984

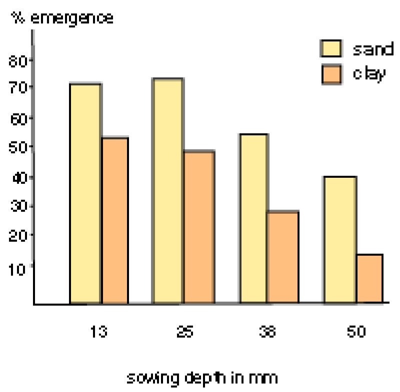
There must be adequate soil moisture around and above a seed

## Key check: Moisture extending from the surface to at least 20 cm

- Provide a firm, moist seedbed. This allows close contact between the soil and the seed. Seeds can then absorb moisture, germinate and emerge more quickly and reliably. (Arrows indicate direction of moisture flow.)
- Sow when conditions are best for germination and survival
  – temperate perennials: from autumn through to early spring (depending on the district)
  – sub tropical species: sow late spring to early autumn.
- Generally, avoid dry sowing as it increases the risk of failure. Where dry sowing has been successful, competition from weeds has been minimal and germinating rainfall has been sufficient for seedling survival until follow-up rain has fallen.
- For temperate species which can be sown in the cooler months, adequate soil moisture is more important than time of sowing.

# F. Accurate seed placement - neither exposed nor buried too deep

Emergence of lucerne as a percent of viable seed sown. Seeding success of lucerne declines with increased depth, particularly on clay soils.




Source: JM Sund et al. 1966

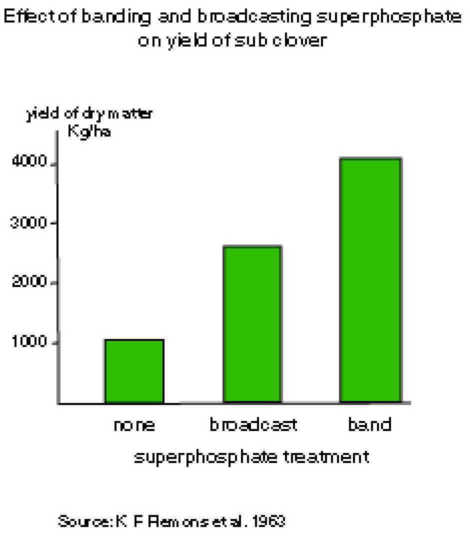
Seeding success of lucerne by depth and by soil type (sand versus clay)

**Key check: For direct drill sowings of most small seeded species, 5% of seed/fertiliser should still be visible in the row; for ploughed seedbeds, tilth over the seed should be no more than 1 cm deep.)**

- Direct drilling
  – Average furrow depth 25 mm, provided the furrow remains open, with 1–2 cm of loose soil over the seed.
  – Use inverted 'T' sowing points when direct drilling.
  – Don't use harrows or rollers.
- Conventional sowing
  – Beware of sowing too deep especially when the seedbed is loose and fluffy.
  – Rolling can enhance seed-soil contact but beware of surface crusting in some soils.
- Use seed that is certified or quality assured wherever possible and check its germination and purity.
- Use sufficient seed to ensure a dense pasture.
- Be aware of specific requirements of some species e.g., Rhodes grass, lovegrass and wallaby grass require very shallow sowing.
- Be aware that some soil types such as heavy cracking clays can lose moisture quickly after sowing while other clays are prone to surface crusting or frost lift in ploughed seedbeds.
- Ensure legume seed is inoculated with the correct strain of rhizobia and where necessary, lime pelleted. Molybdenum, insecticides and fungicides can be applied to seed to enhance establishment in many situations.
- Provide good nutrition – Apply adequate phosphorus, sulphur and molybdenum at sowing time.

  Use nitrogen fortified (compound) fertilisers for direct drill sowings (maximum rate, 20 kg N/ha). Banding fertiliser near the seed is four times more efficient than broadcasting.

## G. Monitor weeds & pests regularly after sowing




Effect of banding and broadcasting superphosphate on yield of subclover

**Key check: Look for pests and weed seedlings at 10-14 day intervals after sowing. This check is most often overlooked.**

- Check pastures for pests regularly. For earth mites this may require close inspection on hands and knees and using glasses if needed for reading. Treat young pastures immediately if mites are found – many mites will probably not be seen.
- The likelihood of insect pests being present is generally greater in direct drilled than conventionally sown new pastures.
- Control weeds with selective herbicides or possibly with grazing in grassy situations.
- In direct drilled pastures under warm, moist spring conditions, slugs may be a problem. Slugs can be detected by placing wet paper under bags or boards at several sites. A registered insecticide is available for use at or after sowing if they pose a significant threat.

## H. Initial & subsequent grazing

### Key check: Are grasses 10-15 cm tall and well anchored and is there good soil moisture?

- Once grasses are 10–15 cm tall and under good growing conditions, a quick grazing will enhance tillering and root development. Graze heavily but quickly down to 2.5 cm then rest.
- Always allow grasses to set seed in the first year. Hay cutting is never recommended in the first year.
- Never graze newly sown pastures early under dry conditions or if grasses are poorly developed.
- Avoid grazing aerial or surface sown pastures before they set seed. They are rarely well anchored and are easily pulled out. Stock moderately in the following growth season (e.g., autumn for temperate species, spring for sub tropicals).
- Some pastures have specific grazing requirements (e.g., lucerne and chicory require rotational grazing for good persistence).
- Recent research suggests perennial grasses will be more persistent when rested, especially under adverse conditions i.e., given some form of rotational grazing at least for part of the year.
- The most efficient grazing system for any farm will generally involve a combination of set stocking and some form of rotational grazing.

**Remember the most expensive pasture is the one that fails to establish properly.**
Such pastures have reduced productivity and carrying capacity, are more prone to weed invasion and have a reduced capacity to combat various aspects of soil degradation. These deficiencies continue throughout the entire life of the pasture. It rarely pays back the cost of establishment and it eventually has to be re-sown.

# Vegetation between the neighbouring properties and along Collector Road

The vegetation should inhibit any spray drift. The ideal would be a mix of species that have vegetation right to the ground. The vegetation can provide a shelter belt for sheep. However grazing should not be allowed as it can interfere with the wind break functions.

# 8. MODELING OF IRRIGATION SYSTEM PERFORMANCE USING MEDLI V2.5

## Background

MEDLI is an irrigation model developed within the Queensland Government. Recent improvements have been made to increase model flexibility. MEDLI is now able to model a wide range of scenarios.

The current model is Version 2.5. This was released in July 2023.

The key model outputs are shown in Appendices 2 and 3. NOTE the model was run over area 2 and assumes an area of 16.8 Ha under fixed sprinklers.

# 9. IRRIGATION MANAGEMENT

The following steps are required

- Establish ‘chain of responsibility’.
- Make phone numbers and email addresses of key contacts available to operator.
- Establish what contractors will be used.
- Ensure sufficient training from the irrigation equipment supplier so that the person responsible for the system understands how to operate the system. Specifically, how to react to changing conditions, e.g. a sudden storm.
- Arrange the contractors to prepare the sites (remove sheep, herbicide, apply lime and gypsum, prepare seed bed).
- Apply second round of herbicide to ensure weed kill.
- Arrange to sow the proposed seeding mix in autumn (check with Bungendore Rural regarding sowing times).
- Note that the irrigation can be used to create a favourable germination environment.
- Plough in the fertilizer (e.g DAP). NOTE some seeders allow sowing both seed and phosphate fertilizer. Avoid using ammonium based fertiliser with the seed.
- Sow the seed
- Commence the irrigation system.
- The RECOMMENDED regime is to irrigate 0.5mm/ day each day when not MORE than 10 mm rainfall is predicted.
- NOTE up to 25 warm dry summer days can be irrigated with 1mm/day of permeate. This is to compensate of loss of irrigation opportunities due to wet weather.
- Do NOT irrigate during heavy rain periods where runoff is obviously occurring.
- Do NOT irrigate when the ground is obviously saturated (when the soil surface has free water on it).
- DO a DAILY check to verify that there is no runoff from area 2. This is especially critical in the SW corner as there is to be no runoff to the headwaters of a small drainage line to the SW of area 2.
- Maintain the daily regime unless there are major issues, e.g damage to the RO system or heavy antecedent rainfall is causing widespread runoff.
- Make sure the operator identifies when he/she wants leave, go on holidays or is ill, etc. Arrange training for a replacement operator BEFORE the main operator departs on leave or resigns.
- The operator to keep a LOG BOOK recording
    - Daily check with RO plant to ensure it is operational AND how much water is available for irrigation.
    - Record occurrence of the daily visual check to ensure no runoff from area 2.
    - Irrigation quantities for the irrigation area (0.5 mm over 16.8 ha is 84.6 cubic m/day.
    - Days when irrigation was not applied
    - Cumulative irrigation volume each day
    - The on and off times each day
    - Any breakdowns, leaks or damage. AND responses.
    - The general condition of the pastures. This includes height, ground cover (look to replant areas where establishment is poor),
    - Identify the more suitable fodder harvesting schedules. Delay harvest if the soil is wet and the machinery will damage the soil via compression wheel rutting.
    - Identify and record apparent pasture health, and any evidence of insects or diseases
    - Check for pasture species change.
    - Record apparent need / closeness to forage harvesting.
    - Keep contractors up to date.

## Pre development investigations.

Predevelopment investigations are presented and discussed in
***Suitability of four potential irrigation areas at the Veolia Woodlawn Operations Site to sustainably receive treated process leachates. Woodlots and Wetlands (2023).***

The double RO process is predicted to produce permeate that meets that ANZECC (2000) criteria for irrigation. It also largely meets the Australian Drinking Water Guideline 2022 thresholds. This is essential in order to ensure the environmental impact is kept to an absolute minimum.

It is noted that the climate is cool and moist, especially in winter. Between April and late September, the rainfall approximates the potential evapotranspiration, so there is minimal irrigation demand. The irrigation scheduling is based on a visual assess of surface soil wetness and the predicted rainfall on each day. Apply 0.5mm if the trigger threshold of 10mm of rainfall predicted is not reached.

Close assessment was undertaken in some 40 soil excavation pits to a minimum of 1m.along a ridge line parallel to Collector Road. The total area investigated was some 42 ha. Of this 36.3 ha were considered suitable for irrigation. In the initial stage only 16.8ha will be developed. These are within the area 2 as per figure 4.1.

The soil characteristics that made the sites suitable for irrigation were:

- Ferrosol soil type.
- The combination of ferrosol chemistry/ minerology and permanent pasture that means the soils have good structure, good internal drainage and good ability to retain nutrients and any potential toxicants.
- Soil depth at least 0.8m and preferably >1m deep
- Surface soil loams to pedal clay loams (facilitating rapid infiltration of water)
- Structurally stable clay subsoils (facilitating moderate infiltration below the root zone and large ability to retain nutrients, contaminants and water).
- <8% grade and <3% cross grade. Sprinkler irrigation can be used at least to 15% grade.

The proposed irrigation area drains to Lake George. Lake George is a closed basin. The proposed irrigation areas are on rolling low hills. The geology is largely volcanic.

The soils were analysed for pH, EC, Available P, N, C, exchangeable cations, available Zn, Mn, Fe, Cu, B and Si. The soils were acidic non-sodic and non-saline. The soils were nutrient deficient but with adequate concentrations of micro nutrients, except for B which was very deficient. The soil structure was strong. The relatively high concentrations of soil organic carbon plus the contributed to the moderate to strongly pedal physical condition of the soil. A combination of long term pasture, liming, gypsum and NPK fertilisation will maintain soil physical, chemical and biological fertility.

In summary, the soils adjacent to Collector Road in the NW portion of the site are suitable for irrigation. There was some 35.3 ha that could be used for the proposed permeate irrigation. Of this 16.8 ha in area 2 will be developed in the initial stage.

## Irrigation schedule

Each morning, check the BoM website for today's predicted rainfall
Record results in log book.
If there is less than 10 mm of rain forecast, commence irrigation.
Record start and finish time for each subset of fixed sprinklers in the log book.

# Management and reporting schedule

## Daily

- Check with security for any breaches of the plant or the irrigation area, e.g sprinkler head theft.
- Check RO flow and RO water in storage. Record each start and finish time

- Record volume of RO water used each day
- Any observations of problems and issues.  For example, bogging of equipment, areas where runoff is apparent, leaks from the irrigation system.
- Check for irrigation area runoff. DO NOT IRRIGATE if there is any evidence of runoff from Area 2.

## Weekly

- Pasture inspection: weeds, areas of poor growth (check for irrigation pipeline leaks), insects and diseases.
- Check and lubricate sprinklers as necessary,
- Check along irrigation area' boundaries for evidence of runoff.
- Check plant height to predict forage harvesting date
- Check weekly forecast.  Make sure the irrigation system is NOT used whenever there is more than 10 mm of rain predicted
- Make sure the records are up to date.  If there is no irrigation, note incident (this includes prediction of >10mm of rain on the irrigation day).

# 10. SITE MONITORING

## The water flow and quality monitoring program

- Automatic continuous monitoring of the RO plant for flow and basic quality, especially pH and salinity.

  Automatic and continuous system for pressure differential within the RO system (designed to detect pinhole development within aging RO membranes).

  Also use change salinity of the permeate to identify loss of efficiency in the system.

  Automate the system as much as reliably possible. Test the alarms regularly. Record and non-compliances in the log book.

## Permeate volumes and chemistry.

Record weekly cumulative flow to the irrigation area.

- permeate chemistry 3 monthly at the RO outlet . PLUS sampling following significant maintenance / repairs of the RO system. Follow DEC (2004), table 5.1 schedule for pH, EC, SAR, Total N, Total P, Metals.
- See table 1 in the executive summary, above, for the anticipated constituents for the double RO permeate. These provide a guide for the likely concentrations in the permeate. The actual concentrations need to be compared with the ANZECC guidelines (2000) . RECORD to results of any analyses. The chemistry of the irrigated permeate will be compared with the ANZECC Guidelines, for freshwater as well as the stock water guidelines. PROVIDED the actual chemistry of the permeate, is similar to the predicted values, it is reasonable to continue irrigation. Serious non-compliance requires system shut down AND investigation.

- **Water courses downslope of the irrigation area**: Sample water annually in spring for pH, EC, SAR, Total N, Total P.
- **A small farm dam in SE of area 2**: Sample annually in spring time. Record pH, EC, SAR, Total N, Total P.
- **Install shallow piezometers along the ridge top**[13] to enable collection and testing of ground water chemistry. Record presence of water, depth to water, and sample annually for pH, EC, nitrogen, phosphorus, major cations and anions.
- Another emerging issue is potential contamination of agricultural waters sources by persistent organic pollutants such as per and poly fluoroalkyl substances (PFAS). PFAS are environmentally persistent and can accumulate in plant and animal produce, either directly or indirectly via fodder consumption. PFAS are very mobile in the environment and can migrate large distances from source sites in groundwater and surface waters. At present PFAS guidelines are not included and the NEMP guideline should be referred to (HEPA 2020). Guidance in these cases must consider likely transfer rates from the irrigation water or stock water into plants and animals, with the objectives of preventing adverse impacts on human health, produce quality or animal health. Due to the range of PFAS compounds potentially present, these assessments will likely be site specific. NOTE no guidelines for irrigation at present (August, 2024). NEMP guideline should be referred to (HEPA 2020) for guidance.

  Current (2024) soil investigation concentrations are PFOS + PFHxS 0.01 mg/kg and PFOS 0.1 mg/kg for Class 'A' residential lands. Site with minimal contact (Class 'B' lands) have a threshold of 2 mg/kg for PFOS + PFHxS and 20 mg/kg PFOS (EPA, 2020). The anticipated double RO water meets the thresholds for 80% protection of aquatic species. However, these thresholds are for freshwaters. The use of the thresholds for irrigation water is very conservative as any of the irrigation water that could eventually reach a surface water body will be extremely diluted by the

[13] The aim of the piezometers is to detect accumulation of salinity and potential contaminants in the shallow water table. 4 test bores are required along the ridge top to detect any salinisation or contaminant accumulation.

surrounding ground and surface waters. The current (2024) thresholds for freshwater with protection for 80% of biota are 31 ug/L for PFOS and 1824 ug/L for PFOA (HEPA (2020))[14].

## The pasture monitoring program involves

- Undertake plant sampling each year in late spring. The sample harvest to be at ground level and just before forage harvesting. A minimum of 1 sample/4ha (5 samples) to be taken. The sample points to be geo-located and site NOT resampled.
- Recording the number and type (s) of bales harvest at each cut for each of the 4 areas.
- Do an annual dry mass estimate based on typical samples.
- Annually sample the fodder and obtain chemical analyses to identify nutrient export. PLUS moisture content.
- Assess the pasture species and indicative dominant / major species at the flowering stage.
- Note need, if any, for weed and pest management.

## The soil management program involves

- **After 12 and 24 months**: Sampling a minimum of 1 sample point per 5 ha (4 in area 2).
  Areas 2: 4 sample points. Depth 0-10 cm. Geo-position and avoid repeating sampling of the same position. Analise the 4 samples for pH, EC, Available P, total P, total N, Organic carbon, Exch Cations, pesticides, heavy metals and boron.

- **Every 3rd year:** Sample a composite soil sample of 40 soil cores per 5 ha (a 4 locations in a total of 16.8 ha), taken at a depth of 0- 10 cm. For pH, EC, Available P, total P, total N, Organic carbon, Exch Cations, pesticides, heavy metals, PFAS and boron.

  **Every 10th year:** Composite soil samples from 4 sites in area 2 (1 per 5ha), each containing 5 cores at four depth intervals to 1 metre, within a 5 metre diameter plot. The four depths should fall within 0–20, 20–40, 40–70 and 70–100 cm depth increments, and positioned within major soil horizons or layers.
  - Sampling to 1m or to rock
  - Note topsoil depth (cm), the presence of a bleached A2 horizon and the depth to rock.
  - Sample all four depths for pH, EC, P sorption capacity, major cations and boron.

ADDITIONALLY, Sample a composite soil sample of 40 soil cores per 5 ha (4 locations in total in area 2), taken at a depth of 0- 10 cm. For pH, EC, Available P, total P, total N, Organic carbon, Exch Cations, pesticides, heavy metals, PFAS (check on initial samples to see if PFAS sampling is required).

[14] In November 2024 there was interest in reducing threshold PFOS family chemicals in drinking water. These lower thresholds may eventually apply to all freshwaters.

# 11. REFERENCES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# APPENDIX 1. WATER QUALITY FOR PRIMARY INDUSTRIES (COPIED FROM ANZECC, 2018).

The quality and quantity of water resources are critical for agriculture in Australia and New Zealand, and water quality is important to protect human consumers of agricultural food products.

Growth of primary industries, together with expanding urbanisation and other industrial development, has increased the demand for good quality water and exerted escalating pressure on the quality of available water resources. Water quality for primary industry enterprises must take into account:

- productivity issues
- possible adverse effects on downstream activities and water quality.

Irrigation and livestock watering are the largest agricultural uses of water. Minor amounts are used for other production purposes, such as the mixing of pesticide, fertiliser, veterinary formulations and livestock dietary supplements. Irrigated agriculture and livestock production industries in Australia rely heavily on the use of groundwater and surface water resources. Groundwater is an important source of stock water in parts of New Zealand.

We provide guidance and default guideline values (DGVs) for primary industries that are applicable to both surface water and groundwater quality, where appropriate. DGVs for general on-farm water use are included with the irrigation DGVs and cover topics such as corrosion and fouling of pipes and fittings.

We revised guidance for livestock drinking water quality in the Water Quality Guidelines. Other guideline values for primary industries published in the ANZECC & ARMCANZ (2000) guidelines have been retained, including water for aquaculture and the production of foods for human consumption, and water for irrigation.

## Livestock drinking water quality

Good water quality is essential for successful livestock production. Poor quality water may reduce animal production and impair fertility. In extreme cases, stock may die.

Contaminants in stock drinking water can produce residues in animal products (e.g. meat, milk and eggs), adversely affecting their saleability and sometimes creating human health risks.

Livestock production operations and meat processing plants may impair downstream water quality (e.g. through faecal contamination), highlighting the need for an integrated approach to land and water management in rural catchments.

Refer to Primary Industries — Livestock Drinking Water Guidance (Table A) for revised advice and DGVs for biological, physiochemical and radiological characteristics of water quality that may affect animal health.

DGVs are thresholds within which there should be minimal risk of adverse effects to animal health. If a parameter does not meet a DGV, we recommend further investigation to determine the level of risk.

## Irrigation and water for general on-farm use

An important goal of water quality for irrigation and general use is to maintain the productivity of irrigated agricultural land and associated water resources, in accordance with the principles of ecologically sustainable development and integrated catchment management.

The quality of the water available or the cost of treating it so that is fit for purpose should be a consideration in any irrigation strategy — alongside soil and crop type, climate and yield — to fully understand economic viability.

Refer to Primary Industries — Irrigation Guidelines for guidance and default guideline values applicable for the assessment of surface water and groundwater quality for irrigation water in Australia and New Zealand. Includes guidance on biological parameters, salinity and sodicity, inorganic contaminants (specific ions, including heavy metals and nutrients), organic contaminants (pesticides) and radiological characteristics of irrigation water.

DGVs are thresholds within which there should be minimal risk of adverse effects to animal health. If a parameter does not meet a DGV, we recommend further investigation to determine the level of risk.

# Aquaculture and aquatic foods

Aquaculture covers the production of food for human consumption, fry for recreational fishing and natural fisheries, ornamental fish and plants for the aquarium trade, raw materials for energy and biochemicals, and a number of items for the fashion industry.

With wild fisheries approaching maximum sustainable levels and many already overexploited, aquaculture is globally important as a source of aquatic food and other products.

Adequate water quality is needed for maintain viable aquaculture operations. Poor water quality can:

- result in loss of production of culture species
- reduce the quality of the end product.

Aquaculture production is reduced when influent water contains enough contaminants to impair development, growth or reproduction and potentially result in death.

Product quality is reduced when low levels of a contaminant cause no obvious adverse effects but gradually accumulate in the culture species to the point where it poses a potential health risk to human consumers.

Both production and product quality need to be considered if useful and usable guideline values are to be provided for the aquaculture industry.

## Influent and source water quality

Refer to Primary Industries — Livestock Drinking Water Guidance (Tables A to AA) for advice and DGVs for influent (incoming water) or source water quality. This addresses the safety of aquatic foods for human consumers, whether the foods be produced by aquaculture or commercial, recreational or indigenous fishing.

## Aquaculture and human consumption of aquatic foods

Guidance for aquaculture and human consumption of aquatic foods in the Water Quality Guidelines has not been revised since the ANZECC & ARMCANZ (2000) guidelines. Most of these guideline values should be used with caution as few are based on a critical assessment of a wide dataset. The aquatic ecosystem guideline values can be used as additional indicative information as they will generally be protective of aquaculture species.

In addition to guideline values for the protection of aquaculture species, refer to Primary Industries — Livestock Drinking Water Guidance (Tables B to BB) for faecal coliforms, biotoxins and off-flavour compounds in aquatic foods for human consumption produced via aquaculture.

### Wild fish stocks

The Primary Industry Guidelines for protecting the health of commercial fish species do not apply to recreational and commercial fisheries based on wild populations of aquatic organisms. Wild fish stocks are dependent on healthy ecosystems to support them throughout their life cycle (e.g. feeding, breeding, habitat). For the protection of wild fish stocks, it is best to apply our guidance for managing aquatic ecosystems.

### Seafood production

Food Standards Australia and New Zealand (FSANZ) sets out food safety and suitability requirements for seafood generally from pre-harvesting production of seafood up to, but not including, manufacturing operations.

## Other sources of water quality guidance

Some water quality issues were considered out of scope for the revision of the Water Quality Guidelines because advice can be found elsewhere.

- Use by agriculture — refer to documents published in conjunction with the National Water Quality Management Strategy; for example, Australian Guidelines for Water Recycling.
- Farmstead water supplies for domestic use
    - Australian Drinking Water Guidelines 6 (2011) — Updated 2016
    - Drinking-Water Standards for New Zealand
    - Guidelines for Drinking-Water Quality Management for New Zealand.
- Washing of farm produce or dairy water supplies — refer to local health and hygiene regulations and the Australian and New Zealand Food Standards Code.
- Aquaculture and human consumption of aquatic foods
    - physical and chemical stressor, toxicant guideline values and guidance on chemicals in water that can taint aquatic organisms in the ANZECC & ARMCANZ (2000) guidelines
    - food safety and suitability requirements for seafood generally from pre-harvesting production of the seafood up to, but not including manufacturing operations, stipulated by Food Standards Australia and New Zealand.

## References

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# APPENDIX 2. OUTPUT FROM THE MEDLI MODEL

## ZERO IRRIGATION

General Information

## SCENARIO REPORT: Full run

### General information

Enterprise: Woodlawn double RO 06.09.2024 ZERO irrigation
Client: New client
MEDLI user: PETER-DELL\Peter

### Description:

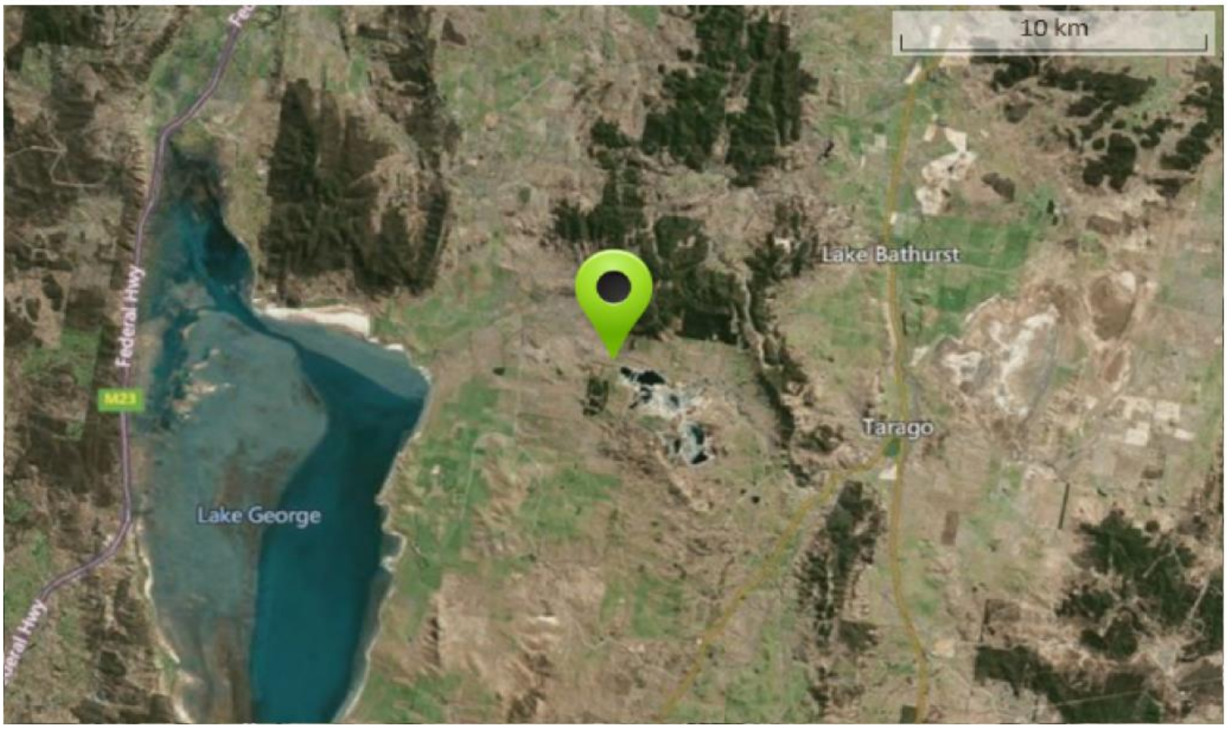
New description

### Scenario details:

NO irrigation .

### Map of location:

Note: If the map above appears as a dark box, check that the network is accessible and that the coordinates are not for a location in the ocean.



## Climate information

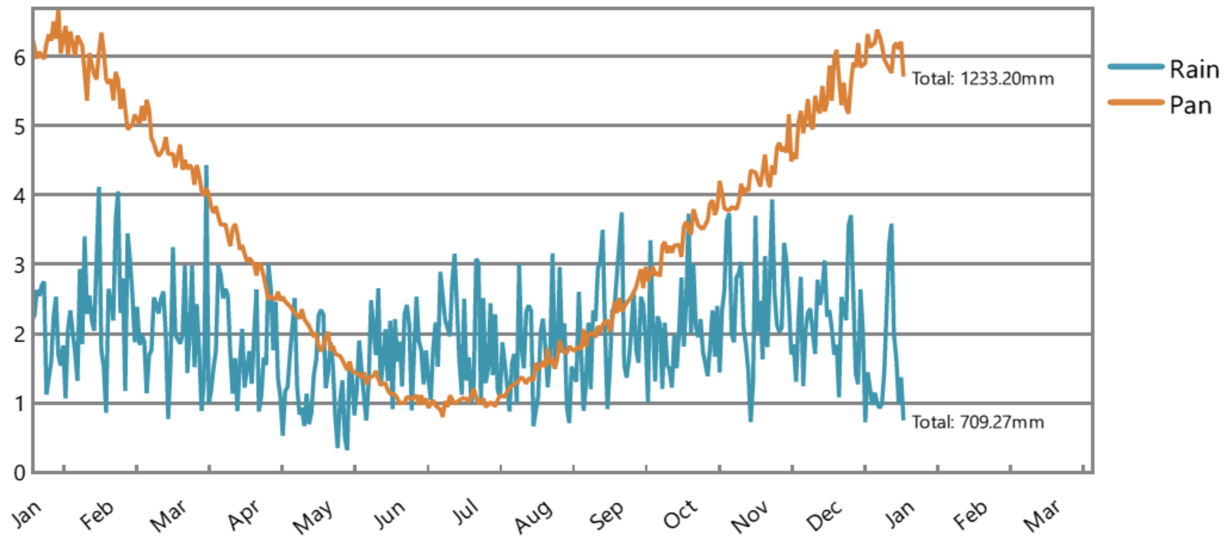
Climate Data Location: Veolia, -35.05°, 149.55°
Run Period: 01/01/1970 to 31/12/2021 ( 52 years )

## Climate statistics

| | 5th Percentile | | 50th Percentile | | 95th Percentile | |
|---|---|---|---|---|---|---|
| Rainfall (mm/year) | (Year 1979) | 469.0 | (Year 1987) | 684.9 | (Year 1978) | 975.2 |
| Pan evaporation (mm/year) | (Year 1974) | 995.1 | (Year 2003) | 1216.9 | (Year 1979) | 1537.0 |

## Climate data

Daily average across run period:



Description

## Wastestream information

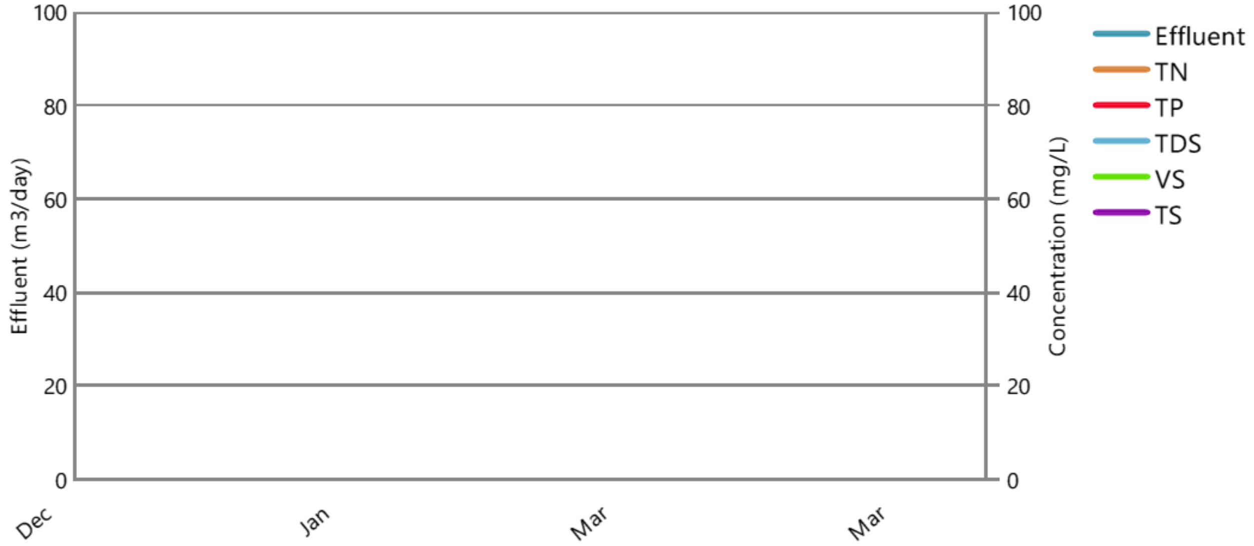
Wastestream Name:  - New generic system

## Wastestream production description

Daily New generic system data supplied for a representative year. This wastestream is not separately pretreated.

## Wastestream

Average Daily Quantity and Flow-Weighted Average Quality:




## Wastestream

Effluent Quantity: 0.00 m3/year or 0.00 m3/day (Min-Max 0.00 - 0.00)

Flow-Weighted Average (Min - Max) Daily Effluent Quality Entering the Pond System:

| | Concentration (mg/L) | Load (kg/year) |
|---|---|---|
| Total nitrogen | 0.00 (0.00 - 0.00) | 0.00 (0.00 - 0.00) |
| Total phosphorus | 0.00 (0.00 - 0.00) | 0.00 (0.00 - 0.00) |
| Total dissolved salts | 0.00 (0.00 - 0.00) | 0.00 (0.00 - 0.00) |
| Volatile solids | 0.00 (0.00 - 0.00) | 0.00 (0.00 - 0.00) |
| Total solids | 0.00 (0.00 - 0.00) | 0.00 (0.00 - 0.00) |

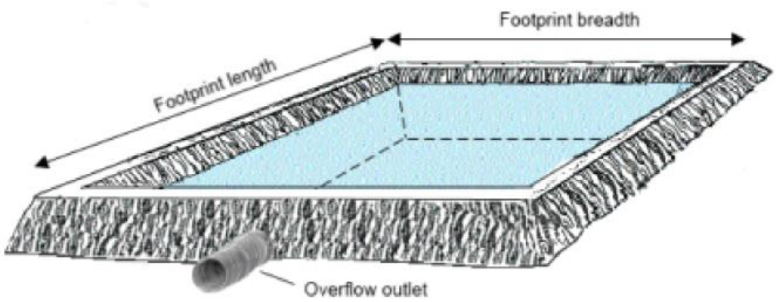
Description

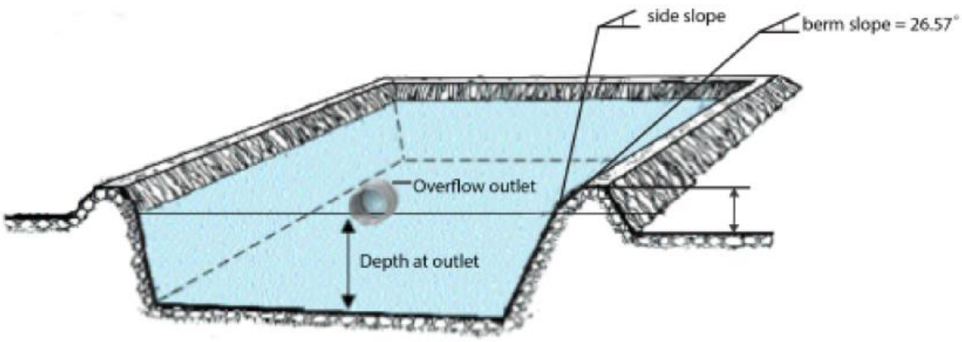
## Pond system information

Pond System Configuration: 1 closed (sludge-free) storage tank

## Pond system details

| | Pond 1 |
|---|---|
| Maximum pond volume (m3) | 1000000000.00 |
| Minimum allowable pond volume (m3) | 249740880.49 |
| Pond depth at overflow outlet (m) | 4.00 |
| Maximum water surface area (m2) | 250345582.19 |
| Pond footprint length (m) | 27405.05 |
| Pond footprint width (m) | 9135.02 |
| Pond catchment area (m2) | 250345582.19 |
| Average active volume (m3) | 762350709.75 |




## Irrigation pump limits

| | |
|---|---|
| Minimum pump rate limit (ML/day) | 0.00 |
| Maximum pump rate limit (ML/day) | 1.00 |

## Shandying water

| | |
|---|---|
| Annual allocation of fresh water available for shandying (m3/year) | 0.00 |
| Maximum rate of application of fresh water (ML/day) | 0.00 |
| Nitrogen concentration (mg/L) | 0.00 |
| Salinity (dS/m) | 0.00 |
| Minimum shandy water is used | No |

Description

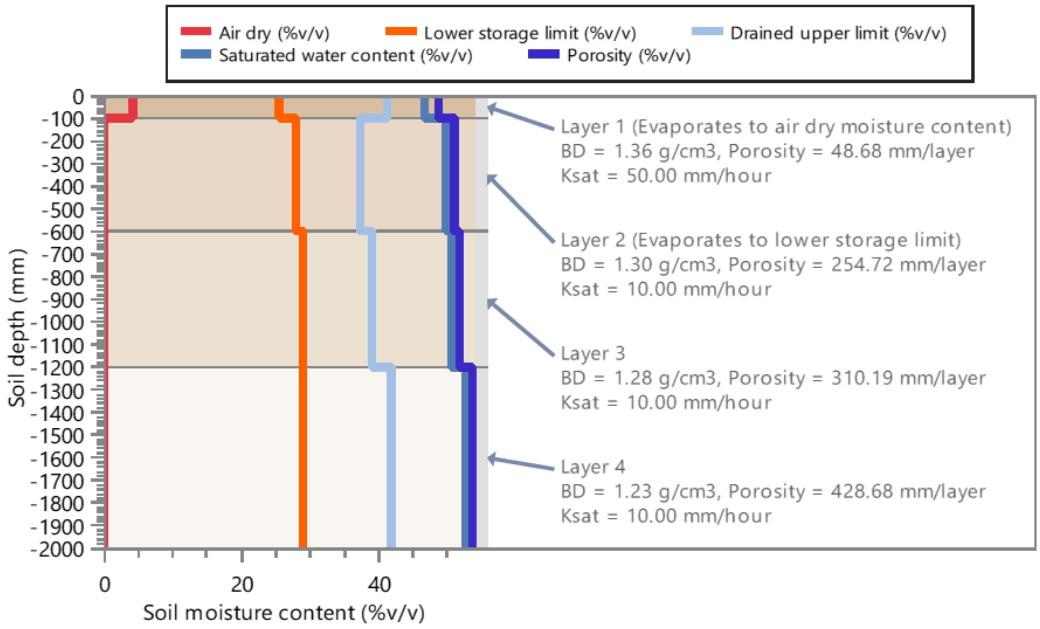
## Paddock information

Paddock: Areas 1 and 2, 36.3 ha

### Soil type: Red ferrosol, 2000.00 mm defined profile depth

| | |
|---|---|
| Profile porosity (mm) | 1042.26 |
| Profile saturation water content (mm) | 1020.80 |
| Profile drained upper limit (or field capacity) (mm) | 796.10 |
| Profile lower storage limit (or permanent wilting point) (mm) | 571.00 |
| Profile available water capacity (mm) | 225.10 |
| Profile limiting saturated hydraulic conductivity (mm/hour) | 10.00 |
| Surface saturated hydraulic conductivity (mm/hour) | 50.00 |
| Runoff curve number II (coefficient) | 78.00 |
| Soil evaporation U (mm) | 6.00 |
| Soil evaporation Cona (mm/sqrt day) | 3.50 |

### Profile




### Planting regime: Monthly Green Covers - New cover species

| | |
|---|---|
| Average monthly cover (fraction) (minimum - maximum) | 1.00 (1.00 - 1.00) |
| Maximum crop factor at 100% cover (mm/mm)<br>(Maximum crop coefficient 0.9 x Pan coefficient 0.8) | 0.72 |
| Dead cover (if Mthly Covers) or Tot. cover left after harvest (fraction) | 0.00 |
| Potential rooting depth in defined soil profile (mm) | 500.00 |
| Salt tolerance | Tolerant |
| Salinity threshold (dS/m soil saturation extract) | 3.00 |
| Proportion of yield decrease per dS/m increase (fraction/dS/m) | 0.00 |

### Irrigation rules: Fixed sprinkler

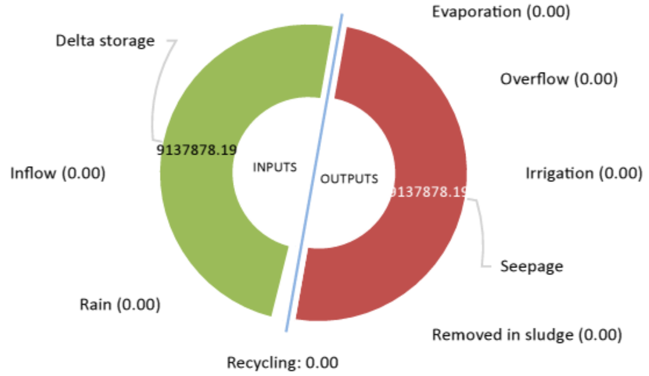
| |
|---|
| Rule 1. Irrigation triggered every 1 days and rainfall is less than or equal to 0.00 mm |
| Rule 2. Irrigate a fixed amount of 0.00 mm each day |
| Rule 3. Irrigation window from 1/1 to 31/12 including the days specified |
| Rule 4. A minimum of 365 days must be skipped between irrigation events |

Performance

## Pond system information

Pond System Configuration: 1 closed (sludge-free) storage tank (wet weather storage pond: 1000000000 m3)

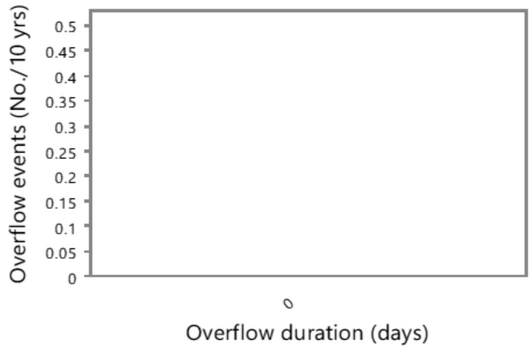
## Pond system water balance (m3/year)

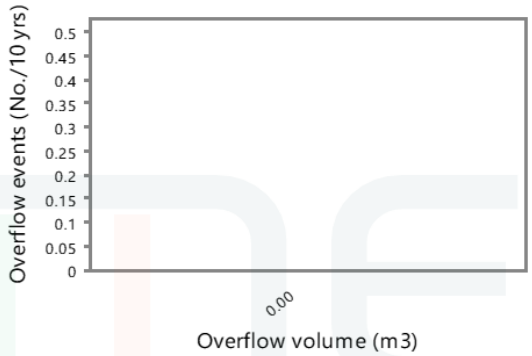


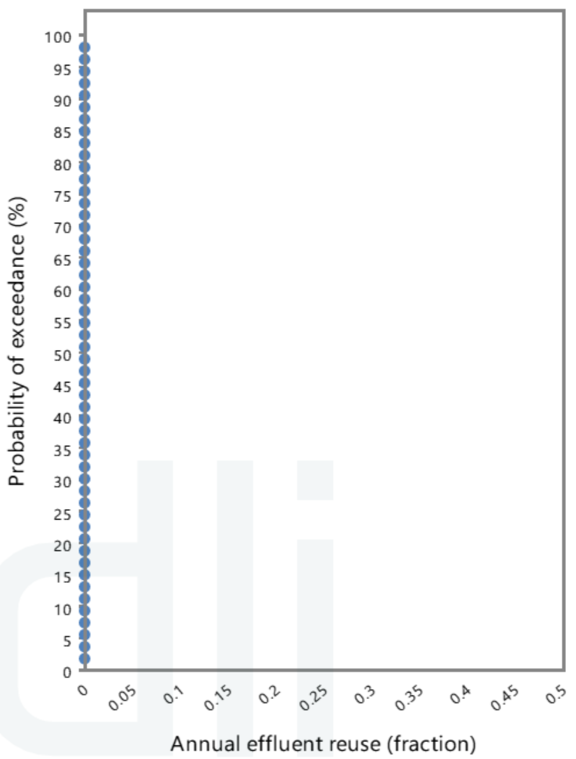

| Name | Value |
|---|---|
| Rain | 0.00 |
| Inflow | 0.00 |
| Recycling | 0.00 |
| Evaporation | 0.00 |
| Overflow | 0.00 |
| Irrigation | 0.00 |
| Seepage | 9137878.19 |
| Removed in sludge | 0.00 |
| Delta storage | -9137878.19 |

## Overflow and reuse diagnostics

| Metric | Value |
|---|---|
| Total volume of overflow (m3/10 years) | 0.00 |
| Total number of overflow events (events/10 years) | 0.00 |
| Total number of pond overflow days (days/10 years) | 0.00 |
| Probability of at least 90% effluent reuse (%) | 0.00 |
| Effluent reuse (Proportion of inflow + net gain in rain that is irrigated) (fraction) | 0.00 |



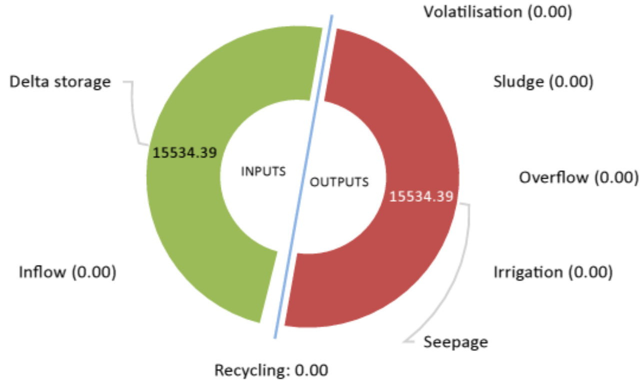



Performance

## Pond system information

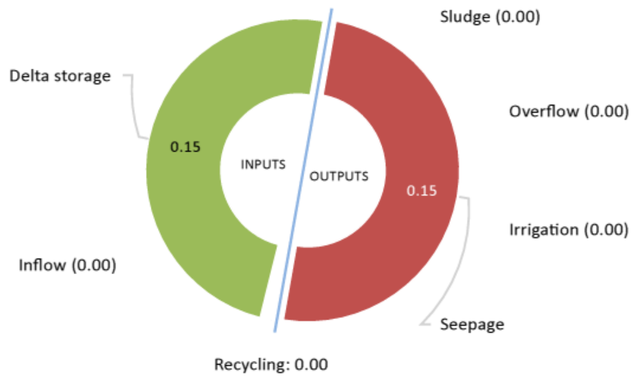
Pond System Configuration: 1 closed (sludge-free) storage tank

## Pond system nitrogen balance (kg/year)



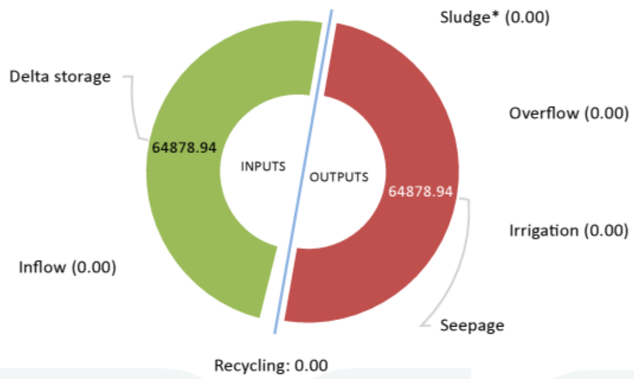

| Name | Value |
|---|---|
| Inflow | 0.00 |
| Recycling | 0.00 |
| Volatilisation | 0.00 |
| Sludge | 0.00 |
| Overflow | 0.00 |
| Irrigation | 0.00 |
| Seepage | 15534.39 |
| Delta storage | -15534.39 |

## Pond system phosphorus balance (kg/year)




| Name | Value |
|---|---|
| Inflow | 0.00 |
| Recycling | 0.00 |
| Sludge | 0.00 |
| Overflow | 0.00 |
| Irrigation | 0.00 |
| Seepage | 0.15 |
| Delta storage | -0.15 |

## Pond system salt balance (kg/year)




| Name | Value |
|---|---|
| Inflow | 0.00 |
| Recycling | 0.00 |
| Sludge* | 0.00 |
| Overflow | 0.00 |
| Irrigation | 0.00 |
| Seepage | 64878.94 |
| Delta storage | -64878.94 |

* Salt removal in sludge is not calculated from the pond salt balance. However if salt could be assumed to be present in the sludge at the same concentration as in the pond supernatant (up to a maximum of salt added in inflow) - then salt accumulation in the sludge could be 0.00 kg/year

**Pond system sludge accumulation:** 0.00 kg dwt/year

Performance

## Pond system information

Pond System Configuration: 1 closed (sludge-free) storage tank

## Pond nutrient concentrations and salinity

| Average across simulation period | Pond 1 |
|---|---|
| Average nitrogen concentration of pond liquid (mg/L) | 1.70 |
| Average phosphorus concentration of pond liquid (mg/L) | 0.00 |
| Average salinity of pond liquid (dS/m) | 0.01 |

| Value on final day of simulation period | Pond 1 |
|---|---|
| Final nitrogen concentration of pond liquid (mg/L) | 1.70 |
| Final phosphorus concentration of pond liquid (mg/L) | 0.00 |
| Final salinity of pond liquid (dS/m) | 0.01 |

## Water use (assumes 100% irrigation efficiency)

| Metric | Value |
|---|---|
| Pond water irrigated (m3/year) | 0.00 |
| Average shandy water irrigation (m3/year) (minimum - maximum) | 0.00 (0.00 - 0.00) |
| Total water irrigated (m3/year) | 0.00 |
| Proportion of irrigation events requiring shandying (fraction of events) | 0.00 |
| Proportion of years shandying water allocation of 0 m3/year is exceeded (fraction of years) | 0.00 |
| Average exceedance as a proportion of annual shandy water allocation (fraction of allocation) (minimum - maximum) | 0.00 (0.00 - 0.00) |

## Irrigation quality

| Metric | Value |
|---|---|
| Average nitrogen concentration of irrigation water - before ammonia loss during irrigation (mg/L) | 0.00 |
| Average nitrogen concentration of irrigation water - after ammonia loss during irrigation (mg/L) | 0.00 |
| Average phosphorus concentration of irrigation water (mg/L) | 0.00 |
| Average salinity of irrigation water (dS/m) | 0.00 |

## Irrigation diagnostics (No effluent irrigation occurred!)

| Metric | Value |
|---|---|
| No. periods/year without any irrigable effluent in the wet weather storage pond (periods/year) | 0.00 |
| Average length of such periods (days) | 0.00 |

## Irrigation triggering and application

No. Days without Irrigation Applied per Year: 365.25 (with fixed irrigation applied set to zero [217.54], rain exceeding specified rainfall threshold [140.69] and day below minimum time set between irrigations [7.02])
No. Days without Irrigation Applied per Year: 365.25 (with no demand - no application [217.54] and not triggered [147.71])
No. Days with Irrigation Applied per Year: 0.00
No. Days with Irrigation Triggered per Year: 217.54

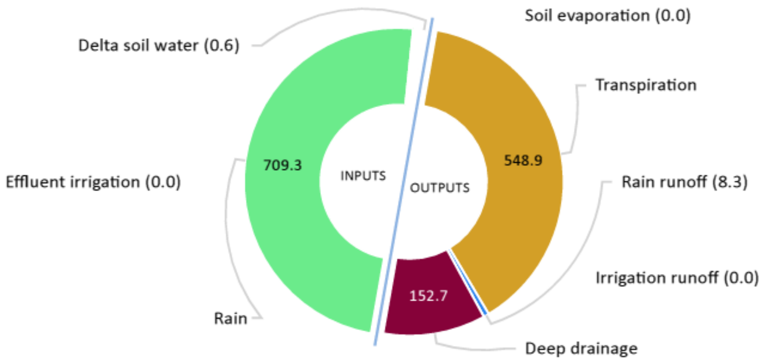
Performance

## Paddock information

Paddock: Areas 1 and 2, 36.3 ha

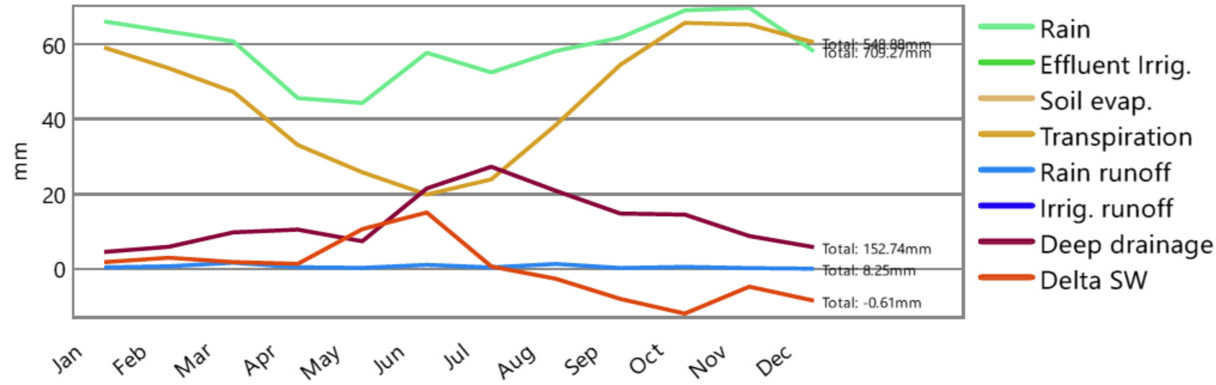
Soil Type: Red ferrosol, 53.30 mm PAWC at maximum root depth

## Soil water balance (mm/year)

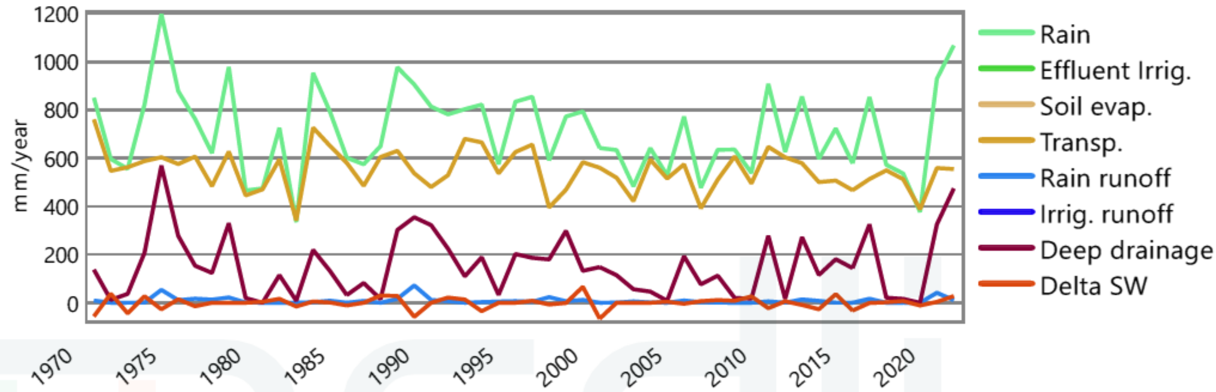



| Name | Value |
|---|---|
| Rain | 709.3 |
| Effluent irrigation | 0.0 |
| Soil evaporation | 0.0 |
| Transpiration | 548.9 |
| Rain runoff | 8.3 |
| Irrigation runoff | 0.0 |
| Deep drainage | 152.7 |
| Delta soil water | -0.6 |

## Average monthly totals (mm)




## Average annual totals (mm/year)



Performance

## Paddock information

Paddock: Areas 1 and 2, 36.3 ha
Soil Type: Red ferrosol
Irrigation Ammonia-N Volatilisation Losses (kg/ha/year): 0.00
Proportion of Total Nitrogen in Irrigated Effluent as Ammonium-N (fraction): 0.10
Nitrogen Added by Irrigation: 0.00
Phosphorus Added by Irrigation: 0.00
Planting Regime: Monthly Green Covers - New cover species

## Plant salinity tolerance

| Metric | Value |
|---|---|
| Salt tolerance | Tolerant |
| Salinity threshold (dS/m soil saturation extract) | 3.00 |
| Proportion of yield decrease per dS/m increase (fraction/dS/m) | 0.00 |
| No. years assumed for leaching to reach steady-state (years) | 10.00 |

## Soil salinity

| Metric | Value |
|---|---|
| Average Infiltrate Salinity (dS/m) | 0.03 |

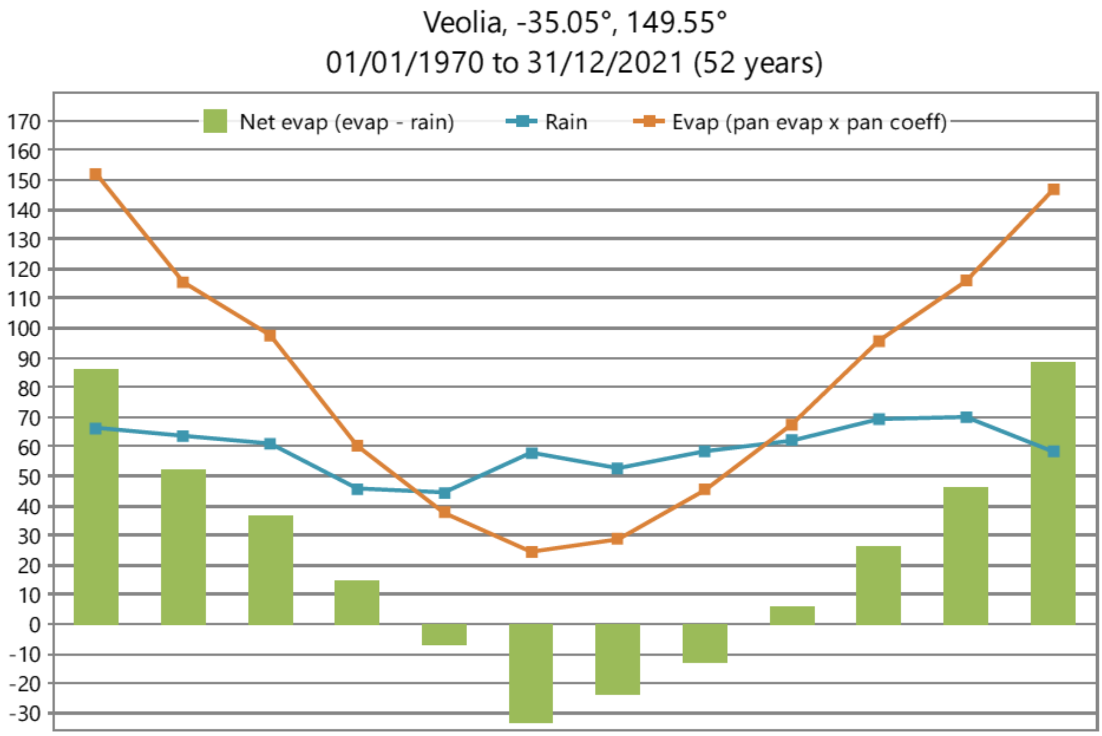
No salinity calculations as no irrigation occurred.

Diagnostics

## Scenario information

Enterprise: Woodlawn double RO 06.09.2024 ZERO irrigation

## Climate long-term monthly averages (mm)




| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Year |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Rain | 66.3 | 63.6 | 60.9 | 45.8 | 44.5 | 57.9 | 52.6 | 58.4 | 61.9 | 69.2 | 69.9 | 58.3 | 709.3 |
| Evap | 152.0 | 115.5 | 97.5 | 60.2 | 37.5 | 24.4 | 28.6 | 45.2 | 67.5 | 95.7 | 115.8 | 146.6 | 986.6 |
| Net evap | 85.7 | 51.9 | 36.6 | 14.4 | -7.0 | -33.5 | -24.0 | -13.1 | 5.6 | 26.5 | 45.9 | 88.3 | 277.3 |
| Net evap/day | 2.8 | 1.8 | 1.2 | 0.5 | -0.2 | -1.1 | -0.8 | -0.4 | 0.2 | 0.9 | 1.5 | 2.8 | 0.8 |

Diagnostics

## Pond system information

Pond System Configuration: 1 closed (sludge-free) storage tank

Effluent Type: - 0.00 m3/year or 0.00 m3/day generated on average

## Effluent entering pond system after any pretreatment and recycling

*Average (Minimum-Maximum) influent quality calculated for 0.00 non-zero flow days/year.*

| Constituent | Concentration (mg/L) | Load (kg/year) |
|---|---|---|
| Total nitrogen | 0.00 (0.00 - 0.00) | 0.00 (0.00 - 0.00) |
| Total phosphorus | 0.00 (0.00 - 0.00) | 0.00 (0.00 - 0.00) |
| Total dissolved salts | 0.00 (0.00 - 0.00) | 0.00 (0.00 - 0.00) |
| Volatile solids | 0.00 (0.00 - 0.00) | 0.00 (0.00 - 0.00) |
| Total solids | 0.00 (0.00 - 0.00) | 0.00 (0.00 - 0.00) |

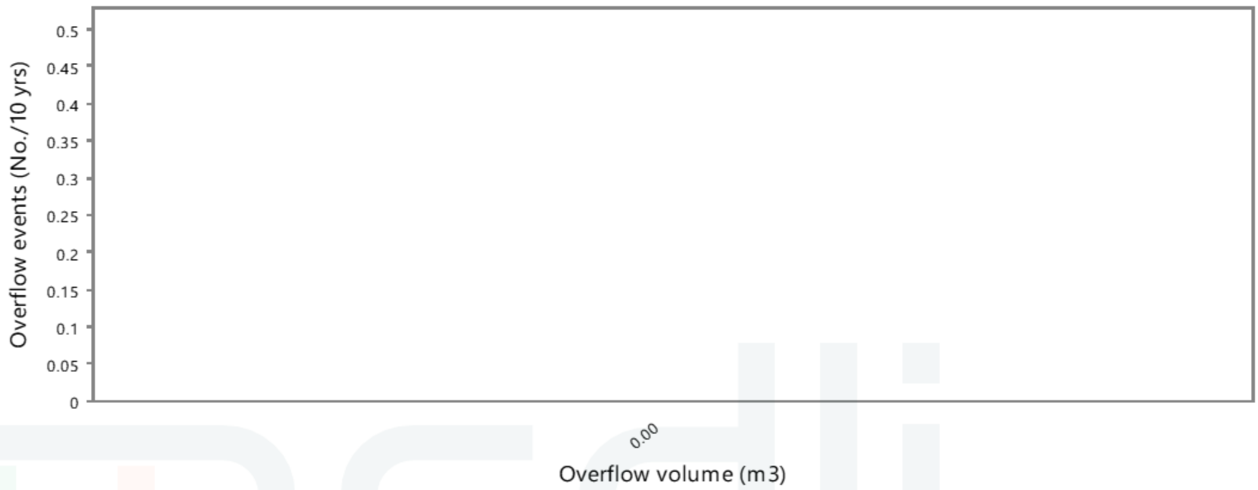
## Ammonia-N loss from pond system water surface area: 0.00 kg/m2/year

## Last pond (wet weather store): 1000000000.00 m3

| Metric | Value |
|---|---|
| Theoretical hydraulic retention time (days) | 0.00 |
| Volume of overflow (m3/year) Average (minimum-maximum) | 0.00 (0.00 - 0.00) |
| Volume of overflow per day (m3/day) Average (minimum-maximum) | 0.00 (0.00 - 0.00) |
| No overflow days - Average per year (Total in run period) | 0.00 (0) |
| No. overflow events per 10 years exceeding threshold of 250345.582 m3* (events/10 years) | 0.00 |
| Average overflow event recurrence interval (years) | 0.00 |
| Average duration of overflow (days) | 0.00 |
| Probability of at least 90% effluent reuse (%) | 0.00 |
| Effluent reuse (proportion of inflow + net rain gain that is irrigated) (fraction) | 0.00 |
| Average salinity (dS/m) | 0.01 |
| Salinity on final day of simulation (dS/m) | 0.01 |

* The threshold is the volume equivalent of the top 1 mm depth of water of a full pond

## Volume distribution of the overflow events



## Scenario information

Area irrigated: 36.3 ha total area

## Loading to whole irrigation area: (assuming 100% irrigation efficiency)

| | Quantity/year | Quantity/ha/year |
|---|---|---|
| Total irrigation applied (m3) | 0.00 | 0.00 |
| Total nitrogen applied (kg) | 0.00 | 0.00 |
| Total phosphorus applied (kg) | 0.00 | 0.00 |
| Total salts applied (kg) | 0.00 | 0.00 |

## Shandying

| Metric | Value |
|---|---|
| Annual allocation of fresh water for shandying (m3/year) | 0.00 |
| Average shandy water irrigation (m3/year) (minimum - maximum) | 0.00 (0.00 - 0.00) |
| Average exceedance as a proportion of annual shandy water allocation (% of allocation) (minimum - maximum) | 0.00 (0.00 - 0.00) |
| Minimum shandy water is used | No |

## Irrigation issues

| Metric | Value |
|---|---|
| Number of days without irrigation (days/year) | 365.25 |

Diagnostics

## Paddock information

Paddock: Areas 1 and 2, 36.3 ha

## Irrigation: Fixed sprinkler with 0.2% ammonium loss during irrigation

| |
|---|
| Irrigation triggered every 1 days and when rainfall is less than or equal to 0.00 mm |
| Irrigate a fixed amount of 0.00 mm |
| Irrigation window from 1/1 to 31/12 including the days specified<br>A minimum of 365 days must be skipped between irrigation events |

## Soil water balance (mm): Red ferrosol, 53.30 mm PAWC at maximum root depth

| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Year |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Rain | 66.3 | 63.6 | 60.9 | 45.8 | 44.5 | 57.9 | 52.6 | 58.4 | 61.9 | 69.2 | 69.9 | 58.3 | 709.3 |
| Efflt. irrg. | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Soil evap | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Transpn. | 59.3 | 53.8 | 47.5 | 33.2 | 25.9 | 20.0 | 24.0 | 38.6 | 54.7 | 65.9 | 65.4 | 60.7 | 548.9 |
| Rain runoff | 0.5 | 0.8 | 1.7 | 0.5 | 0.4 | 1.1 | 0.5 | 1.4 | 0.3 | 0.6 | 0.3 | 0.1 | 8.3 |
| Irr. runoff | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Drainage | 4.6 | 6.0 | 9.9 | 10.6 | 7.5 | 21.6 | 27.4 | 21.0 | 14.9 | 14.6 | 8.9 | 5.9 | 152.7 |
| Delta SW | 1.9 | 3.1 | 1.9 | 1.4 | 10.7 | 15.2 | 0.7 | -2.6 | -8.0 | -11.9 | -4.7 | -8.4 | -0.6 |

## Planting regime: Monthly Green Covers - New cover species

| | |
|---|---|
| Average monthly cover (fraction) (minimum - maximum) | 1.00 (1.00 - 1.00) |
| Average monthly crop factor (fraction) (minimum - maximum) | 0.72 (0.72 - 0.72) |
| Dead cover (if Mthly Covers) or Tot. cover left after harvest (fraction) | 0.00 |
| Average rooting depth in defined soil profile (mm) | 500.00 |

## Soil salinity - plant salinity tolerance: Tolerant

*Assumes 1.0 dS/m Electrical Conductivity = 640 mg/L Total Dissolved Salts*
*All values based on 10 -year running averages.*

No salinity calculations as no irrigation occurred.

# APPENDIX 3. OUTPUT FROM THE MEDLI MODEL BASED ON APPLYING 0.5 MM/DAY OF IRRIGATION



## SCENARIO REPORT: Full run

### General information
Enterprise: 25.04.2025 Woodlawn double RO 0.6dS.m
Client: New client
MEDLI user: PETER-DELL\Peter

### Description:
New description

### Scenario details:

### Map of location:

Note: If the map above appears as a dark box, check that the network is accessible and that the coordinates are not for a location in the ocean.


General Information

Description

## Climate information

Climate Data Location: Veolia, -35.05°, 149.55°

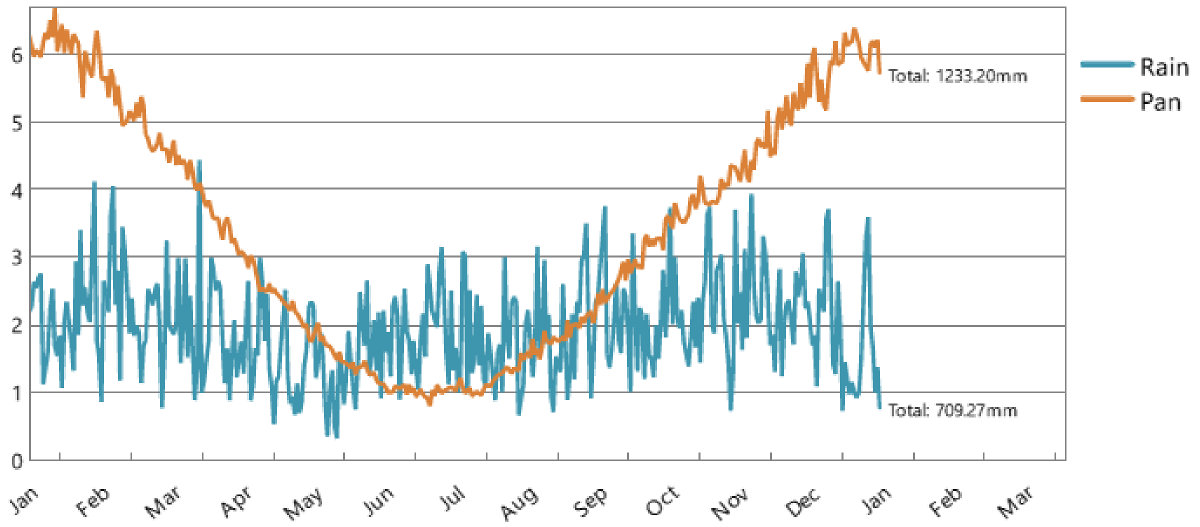
Run Period: 01/01/1970 to 31/12/2021 ( 52 years )

## Climate statistics

| | 5th Percentile | | 50th Percentile | | 95th Percentile | |
|---|---|---|---|---|---|---|
| Rainfall (mm/year) | (Year 1979) | 469.0 | (Year 1987) | 684.9 | (Year 1978) | 975.2 |
| Pan evaporation (mm/year) | (Year 1974) | 995.1 | (Year 2003) | 1216.9 | (Year 1979) | 1537.0 |

## Climate data

Daily average across run period:



Description

## Wastestream information

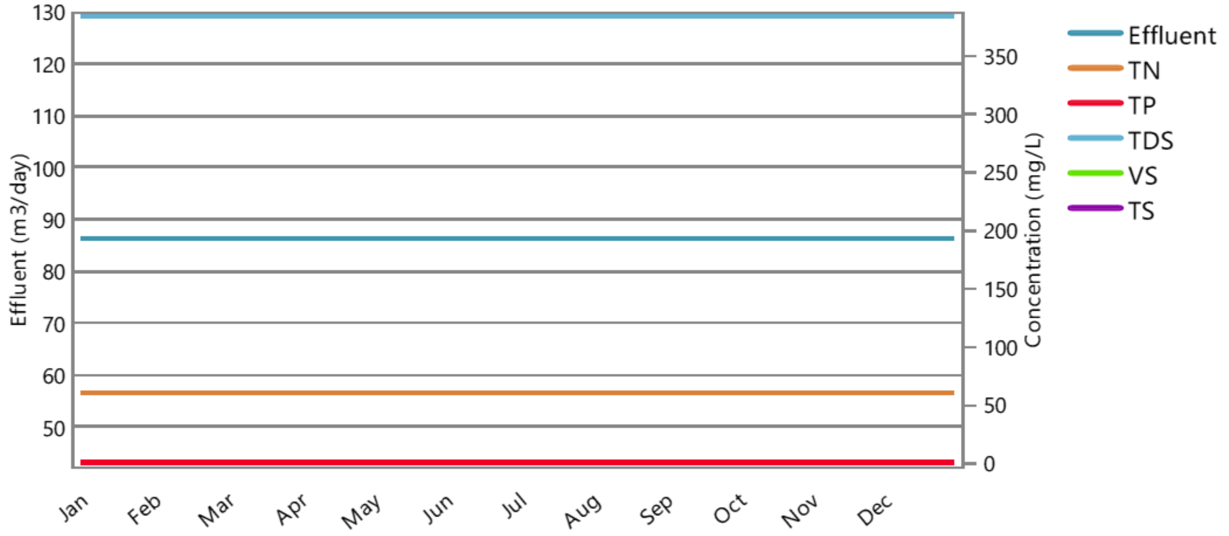
Wastestream Name: - New generic system

## Wastestream production description

Daily New generic system data supplied for a representative year. This wastestream is not separately pretreated.

## Wastestream

Average Daily Quantity and Flow-Weighted Average Quality:




## Wastestream

Effluent Quantity: 31557.60 m3/year or 86.40 m3/day (Min-Max 86.40 - 86.40)

Flow-Weighted Average (Min - Max) Daily Effluent Quality Entering the Pond System:

| | Concentration (mg/L) | Load (kg/year) |
|---|---|---|
| Total nitrogen | 60.00 (60.00 - 60.00) | 1893.46 (1892.16 - 1897.34) |
| Total phosphorus | 0.50 (0.50 - 0.50) | 15.78 (15.77 - 15.81) |
| Total dissolved salts | 384.00 (384.00 - 384.00) | 12118.12 (12109.82 - 12143.00) |
| Volatile solids | 0.00 (0.00 - 0.00) | 0.00 (0.00 - 0.00) |
| Total solids | 0.00 (0.00 - 0.00) | 0.00 (0.00 - 0.00) |

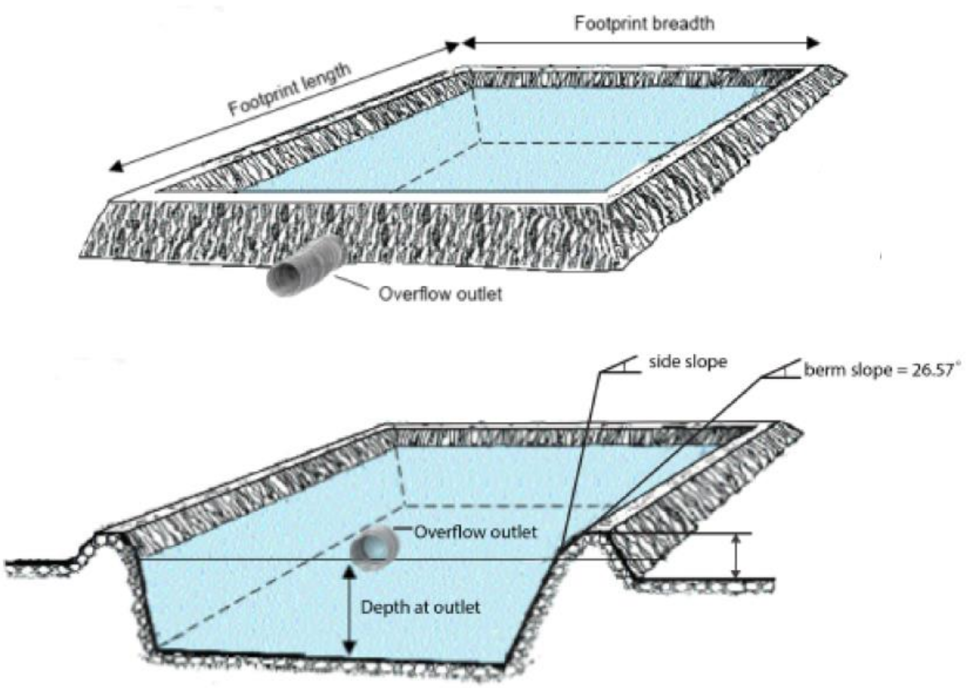
Description

## Pond system information

Pond System Configuration: 1 closed (sludge-free) storage tank

## Pond system details

| | Pond 1 |
|---|---|
| Maximum pond volume (m3) | 100000.00 |
| Minimum allowable pond volume (m3) | 79907.25 |
| Pond depth at overflow outlet (m) | 5.00 |
| Maximum water surface area (m2) | 20115.97 |
| Pond footprint length (m) | 245.66 |
| Pond footprint width (m) | 81.89 |
| Pond catchment area (m2) | 20115.97 |
| Average active volume (m3) | 99920.85 |




## Irrigation pump limits

| | |
|---|---|
| Minimum pump rate limit (ML/day) | 0.00 |
| Maximum pump rate limit (ML/day) | 1.00 |

## Shandying water

| | |
|---|---|
| Annual allocation of fresh water available for shandying (m3/year) | 0.00 |
| Maximum rate of application of fresh water (ML/day) | 0.00 |
| Nitrogen concentration (mg/L) | 0.00 |
| Salinity (dS/m) | 0.00 |
| Minimum shandy water is used | No |

Description

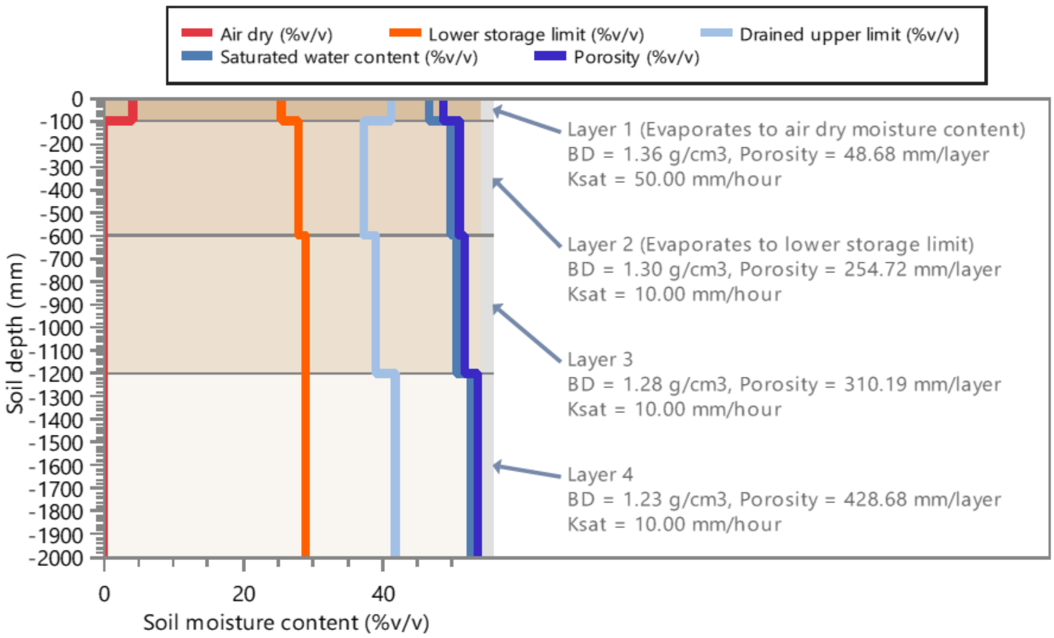
## Paddock information

Paddock: New paddock, 16.8 ha

## Soil type: Red ferrosol, 2000.00 mm defined profile depth

| | |
|---|---|
| Profile porosity (mm) | 1042.26 |
| Profile saturation water content (mm) | 1020.80 |
| Profile drained upper limit (or field capacity) (mm) | 796.10 |
| Profile lower storage limit (or permanent wilting point) (mm) | 571.00 |
| Profile available water capacity (mm) | 225.10 |
| Profile limiting saturated hydraulic conductivity (mm/hour) | 10.00 |
| Surface saturated hydraulic conductivity (mm/hour) | 50.00 |
| Runoff curve number II (coefficient) | 78.00 |
| Soil evaporation U (mm) | 6.00 |
| Soil evaporation Cona (mm/sqrt day) | 3.50 |

## Profile




## Planting regime: Monthly Green Covers - New cover species

| | |
|---|---|
| Average monthly cover (fraction) (minimum - maximum) | 1.00 (1.00 - 1.00) |
| Maximum crop factor at 100% cover (mm/mm)<br>(Maximum crop coefficient 0.9 x Pan coefficient 0.8) | 0.72 |
| Dead cover (if Mthly Covers) or Tot. cover left after harvest (fraction) | 0.00 |
| Potential rooting depth in defined soil profile (mm) | 500.00 |
| Salt tolerance | Tolerant |
| Salinity threshold (dS/m soil saturation extract) | 3.00 |
| Proportion of yield decrease per dS/m increase (fraction/dS/m) | 0.00 |

## Irrigation rules: Fixed sprinkler

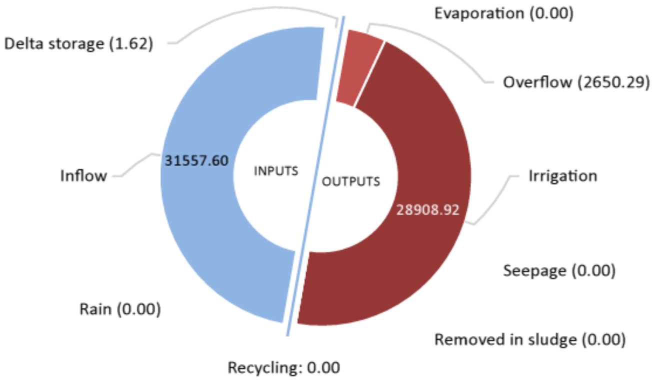
| |
|---|
| Rule 1. Irrigation triggered every 1 days and rainfall is less than or equal to 10.00 mm |
| Rule 2. Irrigate a fixed amount of 0.50 mm each day |
| Rule 3. Irrigation window from 1/1 to 31/12 including the days specified<br>Rule 4. A minimum of 0 days must be skipped between irrigation events |

Performance

## Pond system information

Pond System Configuration: 1 closed (sludge-free) storage tank (wet weather storage pond: 100000 m3)

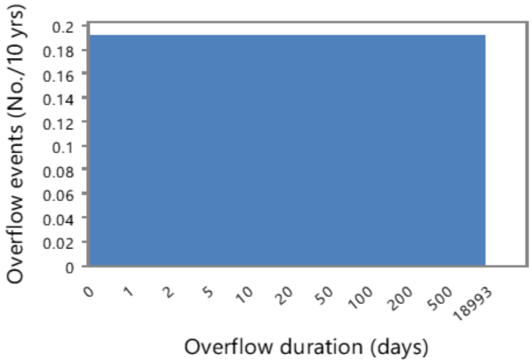
## Pond system water balance (m3/year)

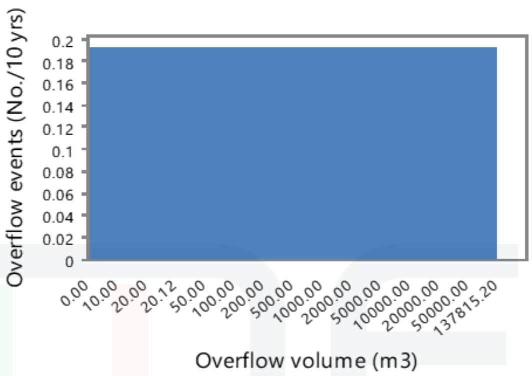


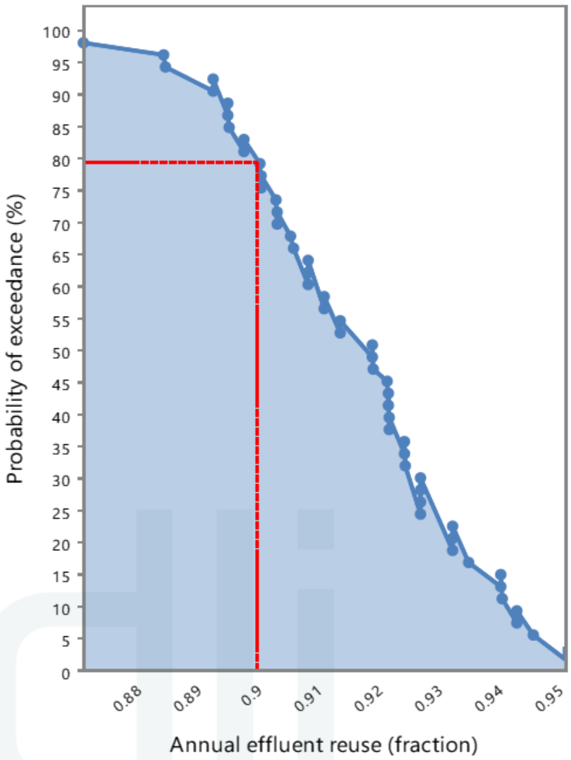

| Name | Value |
|---|---|
| Rain | 0.00 |
| Inflow | 31557.60 |
| Recycling | 0.00 |
| Evaporation | 0.00 |
| Overflow | 2650.29 |
| Irrigation | 28908.92 |
| Seepage | 0.00 |
| Removed in sludge | 0.00 |
| Delta storage | -1.62 |

## Overflow and reuse diagnostics

| Metric | Value |
|---|---|
| Total volume of overflow (m3/10 years) | 26502.92 |
| Total number of overflow events (events/10 years) | 0.19 |
| Total number of pond overflow days (days/10 years) | 3652.50 |
| Probability of at least 90% effluent reuse (%) | 79.46 |
| Effluent reuse (Proportion of inflow + net gain in rain that is irrigated) (fraction) | 0.92 |



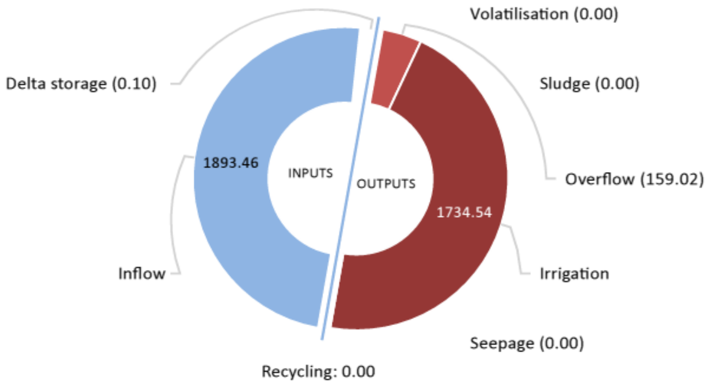



Performance

## Pond system information

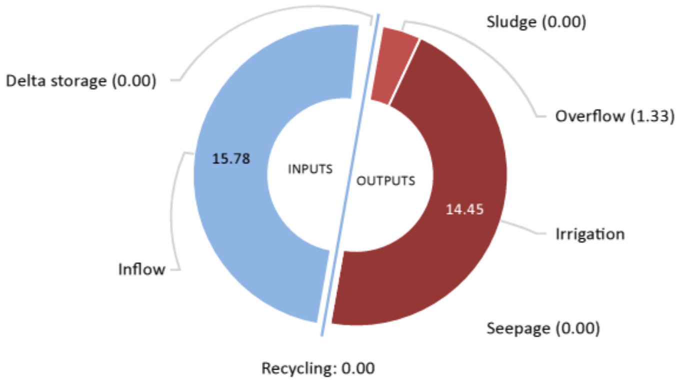
Pond System Configuration: 1 closed (sludge-free) storage tank

## Pond system nitrogen balance (kg/year)



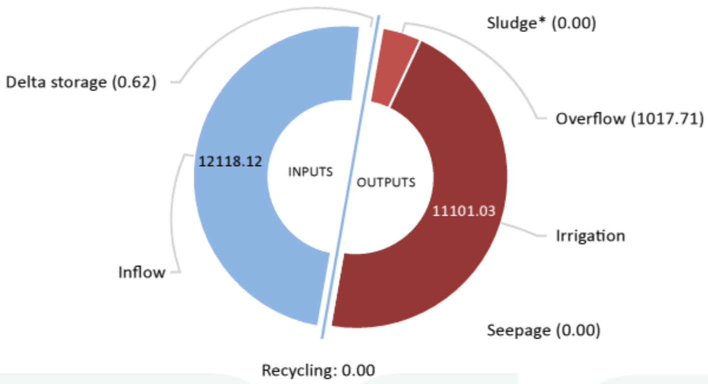

| Name | Value |
|---|---|
| Inflow | 1893.46 |
| Recycling | 0.00 |
| Volatilisation | 0.00 |
| Sludge | 0.00 |
| Overflow | 159.02 |
| Irrigation | 1734.54 |
| Seepage | 0.00 |
| Delta storage | -0.10 |

## Pond system phosphorus balance (kg/year)




| Name | Value |
|---|---|
| Inflow | 15.78 |
| Recycling | 0.00 |
| Sludge | 0.00 |
| Overflow | 1.33 |
| Irrigation | 14.45 |
| Seepage | 0.00 |
| Delta storage | 0.00 |

## Pond system salt balance (kg/year)




| Name | Value |
|---|---|
| Inflow | 12118.12 |
| Recycling | 0.00 |
| Sludge* | 0.00 |
| Overflow | 1017.71 |
| Irrigation | 11101.03 |
| Seepage | 0.00 |
| Delta storage | -0.62 |

* Salt removal in sludge is not calculated from the pond salt balance. However if salt could be assumed to be present in the sludge at the same concentration as in the pond supernatant (up to a maximum of salt added in inflow) - then salt accumulation in the sludge could be 0.00 kg/year

## Pond system sludge accumulation: 0.00 kg dwt/year

Performance

## Pond system information

Pond System Configuration: 1 closed (sludge-free) storage tank

## Pond nutrient concentrations and salinity

| Average across simulation period | Pond 1 |
|---|---|
| Average nitrogen concentration of pond liquid (mg/L) | 60.00 |
| Average phosphorus concentration of pond liquid (mg/L) | 0.50 |
| Average salinity of pond liquid (dS/m) | 0.60 |

| Value on final day of simulation period | Pond 1 |
|---|---|
| Final nitrogen concentration of pond liquid (mg/L) | 60.00 |
| Final phosphorus concentration of pond liquid (mg/L) | 0.50 |
| Final salinity of pond liquid (dS/m) | 0.60 |

Performance

## Water use (assumes 100% irrigation efficiency)

| Metric | Value |
|---|---|
| Pond water irrigated (m3/year) | 28908.92 |
| Average shandy water irrigation (m3/year) (minimum - maximum) | 0.00 (0.00 - 0.00) |
| Total water irrigated (m3/year) | 28908.92 |
| Proportion of irrigation events requiring shandying (fraction of events) | 0.00 |
| Proportion of years shandying water allocation of 0 m3/year is exceeded (fraction of years) | 0.00 |
| Average exceedance as a proportion of annual shandy water allocation (fraction of allocation) (minimum - maximum) | 0.00 (0.00 - 0.00) |

## Irrigation quality

| Metric | Value |
|---|---|
| Average nitrogen concentration of irrigation water - before ammonia loss during irrigation (mg/L) | 60.00 |
| Average nitrogen concentration of irrigation water - after ammonia loss during irrigation (mg/L) | 58.80 |
| Average phosphorus concentration of irrigation water (mg/L) | 0.50 |
| Average salinity of irrigation water (dS/m) | 0.60 |

## Irrigation diagnostics

| Metric | Value |
|---|---|
| No. periods/year without any irrigable effluent in the wet weather storage pond (periods/year) | 0.00 |
| Average length of such periods (days) | 0.00 |

## Irrigation triggering and application

No. Days without Irrigation Applied per Year: 21.10 (with rain exceeding specified rainfall threshold)
No. Days without Irrigation Applied per Year: 21.10 (with not triggered)
No. Days with Irrigation Applied per Year: 344.15 (with full application)
No. Days with Irrigation Triggered per Year: 344.15

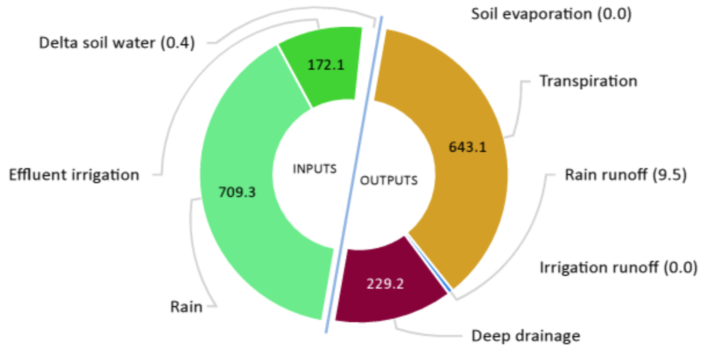
Performance

## Paddock information

Paddock: New paddock, 16.8 ha

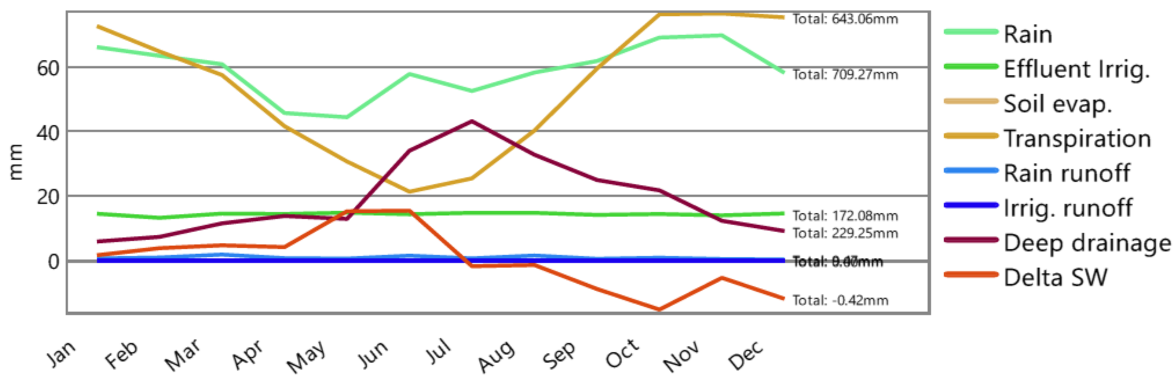
Soil Type: Red ferrosol, 53.30 mm PAWC at maximum root depth

## Soil water balance (mm/year)

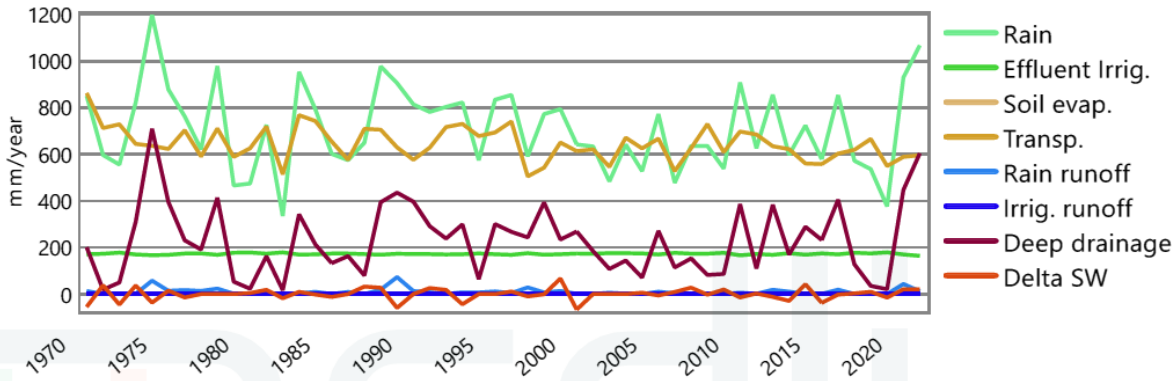



| Name | Value |
|---|---|
| Rain | 709.3 |
| Effluent irrigation | 172.1 |
| Soil evaporation | 0.0 |
| Transpiration | 643.1 |
| Rain runoff | 9.5 |
| Irrigation runoff | 0.0 |
| Deep drainage | 229.2 |
| Delta soil water | -0.4 |

## Average monthly totals (mm)




## Average annual totals (mm/year)



Performance

## Paddock information

Paddock: New paddock, 16.8 ha
Soil Type: Red ferrosol
Irrigation Ammonia-N Volatilisation Losses (kg/ha/year): 2.06
Proportion of Total Nitrogen in Irrigated Effluent as Ammonium-N (fraction): 0.10
Nitrogen Added by Irrigation: 101.18
Phosphorus Added by Irrigation: 0.86
Planting Regime: Monthly Green Covers - New cover species

## Plant salinity tolerance

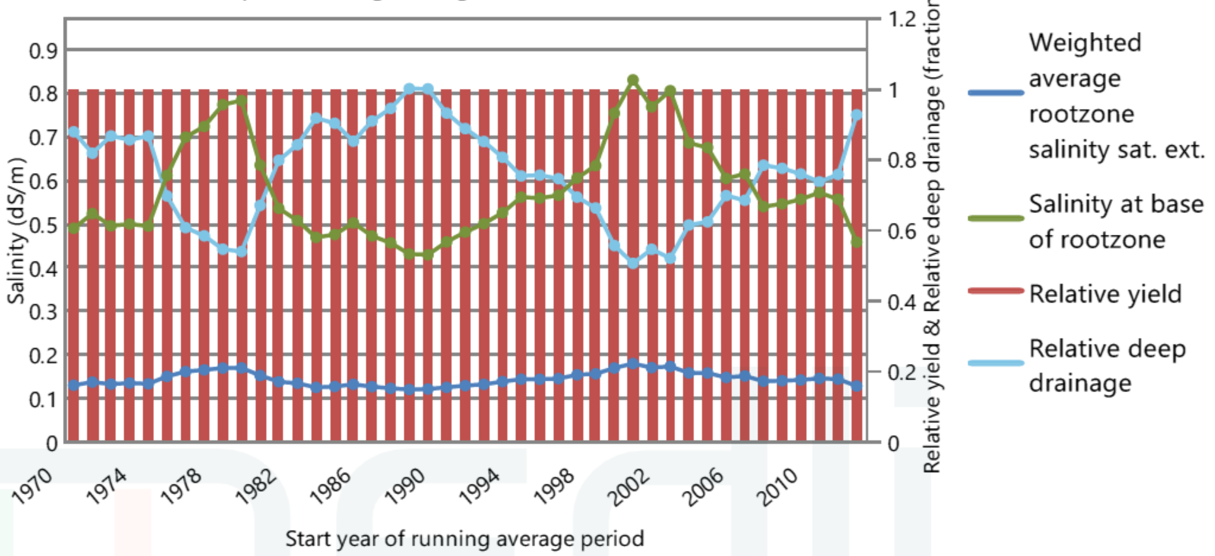
| Metric | Value |
|---|---|
| Salt tolerance | Tolerant |
| Salinity threshold (dS/m soil saturation extract) | 3.00 |
| Proportion of yield decrease per dS/m increase (fraction/dS/m) | 0.00 |
| No. years assumed for leaching to reach steady-state (years) | 10.00 |

## Soil salinity

| Metric | Value |
|---|---|
| Salinity of infiltrated water (Average salinity of rainwater = 0.03 dS/m) (dS/m) | 0.14 |
| Salt added by rainfall (kg/ha/year) | 134.36 |
| Average annual salt added & leached at steady state (kg/ha/year) | 795.14 |
| Average leaching fraction based on 10 -year running averages (fraction) | 0.46 |
| Average water-uptake-weighted rootzone salinity sat. ext. (dS/m) | 0.14 |
| Salinity of the soil solution (at drained upper limit) at base of rootzone (dS/m) | 0.58 |
| Relative crop yield expected due to salinity (fraction) | 1.00 |
| Proportion of years that crop yields would be expected to fall below 90% of potential due to salinity (fraction) | 0.00 |

## Average annual rootzone salinity and relative yield

*All values based on 10 -year running averages.*

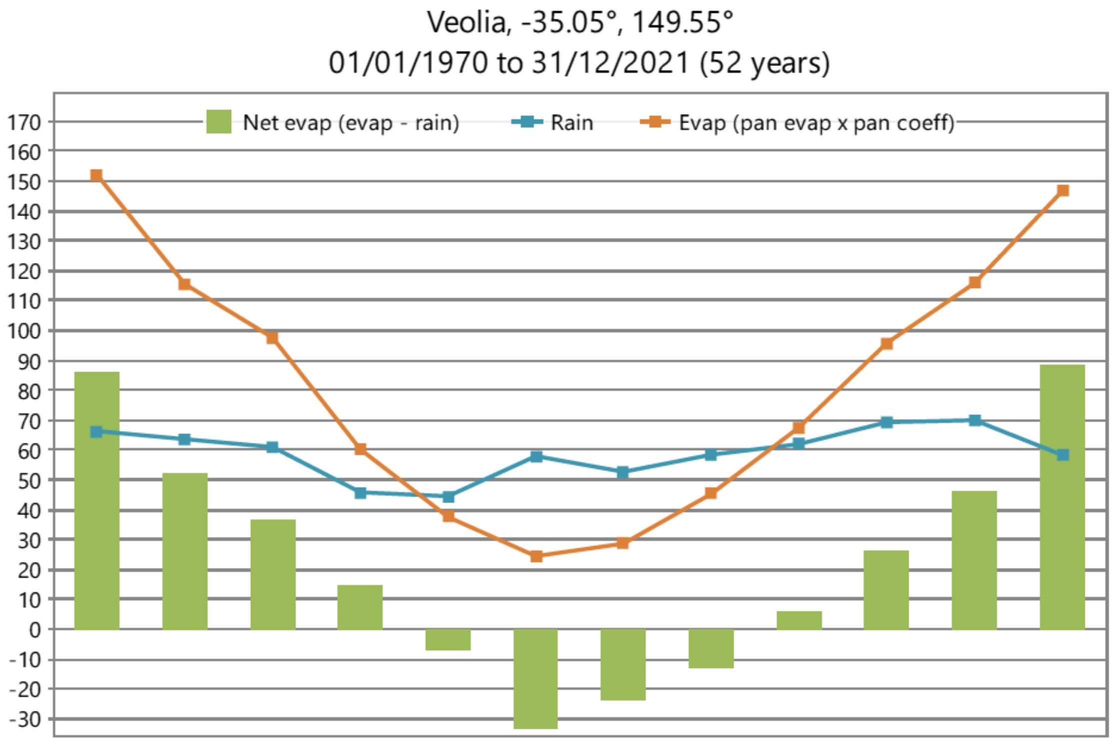


Diagnostics

## Scenario information

Enterprise: 25.04.2025 Woodlawn double RO 0.6dS.m

## Climate long-term monthly averages (mm)




| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Year |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Rain | 66.3 | 63.6 | 60.9 | 45.8 | 44.5 | 57.9 | 52.6 | 58.4 | 61.9 | 69.2 | 69.9 | 58.3 | 709.3 |
| Evap | 152.0 | 115.5 | 97.5 | 60.2 | 37.5 | 24.4 | 28.6 | 45.2 | 67.5 | 95.7 | 115.8 | 146.6 | 986.6 |
| Net evap | 85.7 | 51.9 | 36.6 | 14.4 | -7.0 | -33.5 | -24.0 | -13.1 | 5.6 | 26.5 | 45.9 | 88.3 | 277.3 |
| Net evap/day | 2.8 | 1.8 | 1.2 | 0.5 | -0.2 | -1.1 | -0.8 | -0.4 | 0.2 | 0.9 | 1.5 | 2.8 | 0.8 |

Diagnostics

## Pond system information

Pond System Configuration: 1 closed (sludge-free) storage tank
Effluent Type: - 31557.60 m3/year or 86.40 m3/day generated on average

## Effluent entering pond system after any pretreatment and recycling

*Average (Minimum-Maximum) influent quality calculated for 365.25 non-zero flow days/year.*

| Constituent | Concentration (mg/L) | Load (kg/year) |
|---|---|---|
| Total nitrogen | 60.00 (60.00 - 60.00) | 1893.46 (1892.16 - 1897.34) |
| Total phosphorus | 0.50 (0.50 - 0.50) | 15.78 (15.77 - 15.81) |
| Total dissolved salts | 384.00 (384.00 - 384.00) | 12118.12 (12109.82 - 12143.00) |
| Volatile solids | 0.00 (0.00 - 0.00) | 0.00 (0.00 - 0.00) |
| Total solids | 0.00 (0.00 - 0.00) | 0.00 (0.00 - 0.00) |

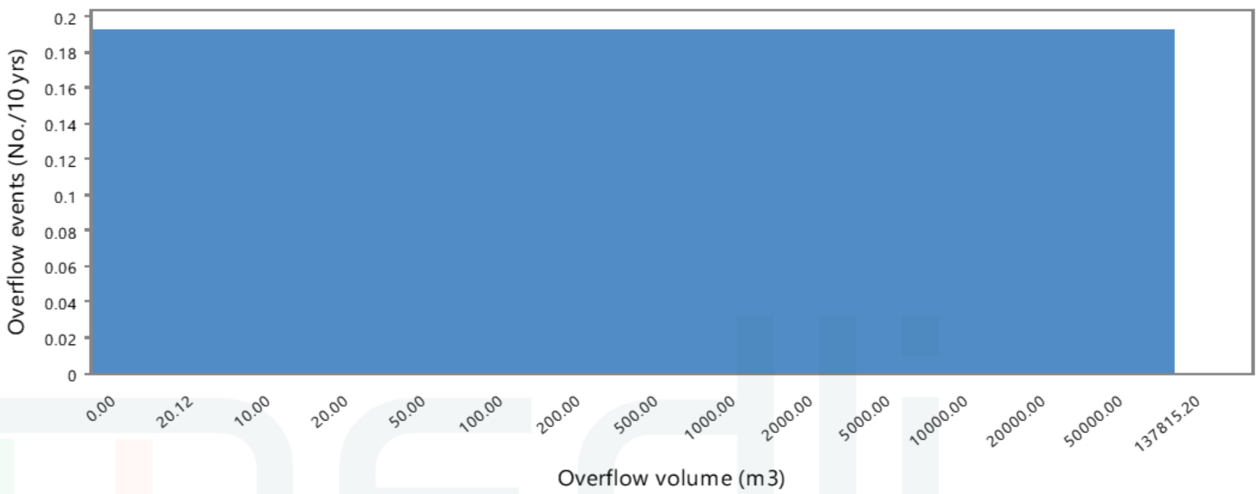
## Ammonia-N loss from pond system water surface area: 0.00 kg/m2/year

## Last pond (wet weather store): 100000.00 m3

| Metric | Value |
|---|---|
| Theoretical hydraulic retention time (days) | 1157.41 |
| Volume of overflow (m3/year) Average (minimum-maximum) | 2650.29 (1548.00 - 4068.00) |
| Volume of overflow per day (m3/day) Average (minimum-maximum) | 7.26 (2.40 - 86.40) |
| No overflow days - Average per year (Total in run period) | 365.25 (18993) |
| No. overflow events per 10 years exceeding threshold of 20.116 m3* (events/10 years) | 0.19 |
| Average overflow event recurrence interval (years) | 52.00 |
| Average duration of overflow (days) | 18993.00 |
| Probability of at least 90% effluent reuse (%) | 79.46 |
| Effluent reuse (proportion of inflow + net rain gain that is irrigated) (fraction) | 0.92 |
| Average salinity (dS/m) | 0.60 |
| Salinity on final day of simulation (dS/m) | 0.60 |

* The threshold is the volume equivalent of the top 1 mm depth of water of a full pond

## Volume distribution of the overflow events



Diagnostics

## Scenario information

Area irrigated: 16.8 ha total area

## Loading to whole irrigation area: (assuming 100% irrigation efficiency)

| | Quantity/year | Quantity/ha/year |
|---|---|---|
| Total irrigation applied (m3) | 28908.92 | 1720.77 |
| Total nitrogen applied (kg) | 1699.84 | 101.18 |
| Total phosphorus applied (kg) | 14.45 | 0.86 |
| Total salts applied (kg) | 11101.03 | 660.78 |

## Shandying

| Metric | Value |
|---|---|
| Annual allocation of fresh water for shandying (m3/year) | 0.00 |
| Average shandy water irrigation (m3/year) (minimum - maximum) | 0.00 (0.00 - 0.00) |
| Average exceedance as a proportion of annual shandy water allocation (% of allocation) (minimum - maximum) | 0.00 (0.00 - 0.00) |
| Minimum shandy water is used | No |

## Irrigation issues

| Metric | Value |
|---|---|
| Number of days without irrigation (days/year) | 21.10 |

Diagnostics

## Paddock information

Paddock: New paddock, 16.8 ha

## Irrigation: Fixed sprinkler with 0.2% ammonium loss during irrigation

| |
|---|
| Irrigation triggered every 1 days and when rainfall is less than or equal to 10.00 mm |
| Irrigate a fixed amount of 0.50 mm |
| Irrigation window from 1/1 to 31/12 including the days specified<br>A minimum of 0 days must be skipped between irrigation events |

## Soil water balance (mm): Red ferrosol, 53.30 mm PAWC at maximum root depth

| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Year |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Rain | 66.3 | 63.6 | 60.9 | 45.8 | 44.5 | 57.9 | 52.6 | 58.4 | 61.9 | 69.2 | 69.9 | 58.3 | 709.3 |
| Efflt. irrg. | 14.5 | 13.2 | 14.5 | 14.4 | 14.8 | 14.3 | 14.8 | 14.7 | 14.1 | 14.4 | 14.0 | 14.5 | 172.1 |
| Soil evap | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Transpn. | 72.8 | 64.9 | 57.6 | 41.7 | 30.7 | 21.3 | 25.5 | 40.3 | 59.6 | 76.5 | 76.7 | 75.5 | 643.1 |
| Rain runoff | 0.5 | 0.8 | 1.8 | 0.6 | 0.5 | 1.4 | 0.6 | 1.5 | 0.4 | 0.8 | 0.4 | 0.2 | 9.5 |
| Irr. runoff | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Drainage | 5.8 | 7.3 | 11.5 | 13.8 | 12.8 | 34.1 | 43.2 | 32.8 | 25.0 | 21.7 | 12.3 | 9.1 | 229.2 |
| Delta SW | 1.6 | 3.7 | 4.6 | 4.1 | 15.2 | 15.4 | -1.9 | -1.5 | -8.9 | -15.3 | -5.5 | -12.0 | -0.4 |

## Planting regime: Monthly Green Covers - New cover species

| | |
|---|---|
| Average monthly cover (fraction) (minimum - maximum)<br>Average monthly crop factor (fraction) (minimum - maximum) | 1.00 (1.00 - 1.00)<br>0.72 (0.72 - 0.72) |
| Dead cover (if Mthly Covers) or Tot. cover left after harvest (fraction)<br>Average rooting depth in defined soil profile (mm) | 0.00<br>500.00 |

## Soil salinity - plant salinity tolerance: Tolerant

*Assumes 1.0 dS/m Electrical Conductivity = 640 mg/L Total Dissolved Salts*

*All values based on 10 -year running averages.*

| Metric | Value |
|---|---|
| Salinity of infiltrated water (Average salinity of rainwater = 0.03 dS/m) (dS/m) | 0.14 |
| Salt added by rainfall (kg/ha/year) | 134.36 |
| Average annual salt added & leached at steady state (kg/ha/year)<br>Average leaching fraction based on 10 -year running averages (fraction) | 795.14<br>0.46 |
| Average water-uptake-weighted rootzone salinity sat. ext. (dS/m) | 0.14 |
| Salinity of the soil solution (at drained upper limit) at base of rootzone (dS/m) | 0.58 |
| Relative crop yield expected due to salinity (fraction) | 1.00 |
| Proportion of years that crop yields would be expected to fall below 90% of potential due to salinity (fraction) | 0.00 |

Diagnostics

## Run information

| Messages generated when the scenario was run |
|---|
| *************************************** WASTESTREAM RESULTS *************************************** |
| TABLE OF QUANTITY AND QUALITY OF EACH RAINFALL-INDEPENDENT WASTESTREAM<br>(AFTER PRETREATMENT AND BEFORE ENTERING ANY SEDIMENTATION BASIN) |
| ________________________________________________________________________________________________ |
| Source Volume_m3/yr N conc_mg/L P conc_mg/L TDS conc_mg/L N load_kg/yr P load_kg/yr TDS load_kg/yr |
| New generic system 31557.6 60.0 0.5 384.0 1893.5 15.8 12118.1<br>________________________________________________________________________________________________ |
| |
| *************************************** END WASTESTREAM RESULTS *************************************** |
| Monthly Green Covers plant option does not model soil nitrogen and soil phosphorus.<br>NOTE: Groundwater nitrate module cannot be run when Monthly Green Covers plant option is chosen |
| UNCONDITIONAL FINISH |

# Impact of double reverse osmosis on permeate quality

Prepared for
Veolia Environmental Services (Australia) Pty Ltd

Under direction of
**Raymond Choy, Paul McParland and Jordan Gavel**

Prepared by

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Principal Natural Resource Scientist
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NSW

# Document Registration

| | |
|---|---|
| **Consultancy request** | Veolia Environmental Services (Australia) Pty Ltd<br>Under direction of<br>Raymond Choy, Paul McParland and Jordan Gavel |
| **Prepared By** | Woodlots & Wetlands Pty Ltd<br>220 Purchase Road<br>Cherrybrook NSW 2126<br>Mobile: 0427905440<br>E mail:<br>woodlots3@bigpond.com |
| **Date Issued** | 28 April 2025 |
| **Document File name** | **Impact of double reverse osmosis on permeate quality V8 28.04.2025** |
| **Document Title** | **Impact of double reverse osmosis on permeate quality** |
| **Document Registered By** | Peter Bacon<br>Principal Consultant |

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The assistance of Paul McParland, Raymond Choy and Jordan Gavel is gratefully appreciated.

# Contents

# 1. BACKGROUND

The Veolia Woodlawn Operations Site at Tarago, NSW processes over 40% of Sydney's 'red' bin waste. The treatment process results in excess water that leaches out of the processed product.

The untreated leachate water contains elevated concentrations of sodium, chloride, nutrients and potentially toxic elements and compounds. It requires major reductions in salinity, the concentrations of nutrients and potentially toxic elements compounds before the water can be safely returned to the environment.

It is proposed to use a double Reverse Osmosis (RO) to remove a proportion of the contaminants[1] that is incorporated after the existing leachate treatment plant. The Reverse Osmosis system will include a preliminary filtration stage to safeguard the membrane when processing the stored treated leachate. After the RO process, the purified water will undergo additional treatment through activated carbon filters for polishing and an ion exchange process specifically designed to remove Boron. With reverse osmosis the feed water is pressurised and is forced through a semi permeable membrane. This process will produce water (hereafter referred to as permeate) that is suitable for irrigation. The retentate that does not cross the semi permeable barrier consists of retained water with an increased contaminant load.

Veolia wish to irrigate the permeate onto paddocks to the west of their effluent ponds. A critical issue is the management of potential for any contaminants, e.g. herbicides, pesticides and other chemicals to damage the vegetation and the soil in the irrigated area. It is also necessary to consider the risk to the local waters from any runoff or deep percolation of the permeate.

Figure 1 shows the proposed irrigation land. The headwaters of a local stream are over 100m from the nearest point of the irrigation area.

## Report author

Dr Bacon, CPSS, CEnvP, CPESC has over 45 years' experience in soil and water chemistry. He was Senior Research Scientist in NSW Agriculture and later, in NSW State Forests. He undertook major projects on the impact of potentially contaminated biosolids application to soils. In the past decade he has investigated contamination at over 50 sites in NSW.

[1] This is the same process used at Kurnell to produce potable water for Sydney from seawater.


**Figure 1. The proposed initial irrigation area is 16.8 ha in area. There is a buffer over 100m wide between the SW corner of the irrigation area and the headwaters of the nearest streamline.**

The approach to minimising environmental risk to local watercourses include:
1. Double Reverse Osmosis (the same process used to produce drinking water at Sydney desalination plant in Kurnell).
2. Irrigation at extremely low rates (0.5mm/irrigation) to minimise the possibility of runoff.
3. Not irrigating on days when 10mm or more rainfall is predicted.
4. Each morning undertake a visual inspection of area 2 boundaries to determine if runoff is occurring. Do not irrigate if there is evidence of saturation (which would likely result in runoff).
5. Maintain a minimum of 100m between the edge of the irrigation area and any drainage line.

The table below sets out the recommended separation distances between the outer edge of the irrigation areas and the nearest water bodies.

A separation distance of 50m is recommended between effluent irrigation systems and natural waterbodies.

**Recommended buffer distances to water resources and public areas (copy of DEC, 2004, table 4.9).**

| Sensitive area | Separation distance (low strength effluent) | Separation distance (medium to high strength) | Impact of concern/comments |
|---|---|---|---|
| Natural waterbodies (e.g. rivers, lakes) | 50 m | 50 m | Protection of water quality and aquatic ecosystems. Supplementary requirements may be included for human sourced effluent to protect public health in recreation areas. |
| Other waters (e.g. artificial waters with beneficial uses, small streams, intermittent streams, water distribution and drainage channels, farm dams) | Site-specific | Site-specific | Protection of water quality for most sensitive water uses of the potentially affected waterbody. |
| Domestic well used for household water supply | Site-specific | 250 m | Groundwater quality for domestic human uses protected. |
| Town water supply bores | Site-specific | 1000 m | Water and groundwater quality for drinking water supply protected. Town bores generally pump at high rates and draw water from a large area. |

**Notes:** 1. Recommended in ARMCANZ, ANZECC and NHMRC (2000) for the spray application of reclaimed water from sewerage systems.

# 2. PREDICTED RESULTS OF DOUBLE REVERSE OSMOSIS

The predicted values of the estimates were assessed against the ANZECC (2000[2] and 2018[3]) guidelines. The Irrigation water quality guidelines were released in draft form in January, 2024[4]. They are cited as ANZG (2023). The logic for including the irrigation guidelines is that the permeate will be irrigated onto pasture at an indicative rate of 0.5 mm/day. The nearest water body is the head water of a first order stream over 100m away, which is twice the distance recommended buffer distance described in the DEC 2004 guidelines.

The threshold values for permeate discharged to the local stream was set at 95$^{th}$ percentile protection level for local freshwater species. That is, 95% of NSW Freshwater species could tolerate the assessed value of the attributes[5].

There were 774 attributes measured. 614 of these did not have guideline values. Another 129 attributes had double RO permeate values LESS than the 95%ile threshold value. There were 5 attributes that exceeded the threshold value. In some cases, this excess was a value that exceeded the ANZECC Guideline. For example, the ANZECC Guideline range for upland rivers is 6.5 to 8. The double RO permeate value is 8.5.

Table 1 shows the default toxicity thresholds for 95% of freshwater species in NSW[6].

Table 2 shows the attributes that exceeded the ANZECC (2000 and 2018) guidelines. The implications of these results are also shown.

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[2] Australian and New Zealand Environment and Conservation Council/Agriculture and Resource Management Council of Australia and New Zealand (ANZECC/ARMCANZ) 2000. Australian and New Zealand guidelines for fresh and marine water quality. National Water Quality Management Strategy Paper No 4. Australian and New Zealand Environment and Conservation Council and Agriculture and Resource Management Council of Australia and New Zealand. Canberra, ACT.

[3] ANZG 2018. Australian and New Zealand Guidelines for Fresh and Marine Water Quality. Australian and New Zealand Governments and Australian state and territory governments, Canberra, ACT, Australia. https://www.waterquality.gov.au/anz-guidelines.

[4] ANZG (2023). DRAFT *Water Quality for Irrigation and General Water Uses: Guidelines*. Australian and New Zealand Guidelines for Fresh and Marine Water Quality. Australian and New Zealand governments and Australian state and territory governments, Canberra.

[5] The term 'value' is used because some attributes, e.g. pH and SAR, are not measured in standard units i.e. ug/L and mg/L.

[6] NOTE the threshold concentration in freshwater. The aim of the Sustainable Irrigation Plan is to apply a very low daily application rate of 0.5 mm of permeate. Irrigation to occur only on days when runoff is not anticipated. Additional irrigation of up to 1.5mm/day can occur on dry summer days. The target annualised irrigation rate is 177 mm/year.

**Table 1. Toxicants and their default values for freshwater streams in NSW. The 95%ile value refers to the threshold values for toxicity impact for 95% of species in NSW freshwaters. The Tox LOSP unknown has estimated toxicity threshold values in the ANZECC table. Where applicable, these have been used to assess toxicity issues with the double RO permeate. NOTE not all chemical constituents listed in the table have toxicity thresholds listed in ANZECC. Data source: Copied from the ANZECC web site. Accessed Nov. 2024.**

| Toxicant name | Toxicant Class | Tox Reliability | Publish date | Tox LOSP 95 | Tox LOSP unknown | Tox LOSP Unit |
|---|---|---|---|---|---|---|
| 1,1,1-Trichloroethane | Chloroethanes | Unknown | 2000 | 270 | | µg/L |
| 1,1,2,2-Tetrachloroethane | Chloroethanes | Unknown | 2000 | 400 | | µg/L |
| 1,1,2,2-Tetrachloroethylene | Chlorinated Alkenes | Unknown | 2000 | 70 | | µg/L |
| 1,1,2-Trichloroethane | Chloroethanes | Moderate | 2000 | 6500 | | µg/L |
| 1,1,2-Trichloroethylene | Chlorinated Alkenes | Unknown | 2000 | 330 | | µg/L |
| 1,1-Dichloroethylene | Chlorinated Alkenes | Unknown | 2000 | 700 | | µg/L |
| 1,1-Dichloropropane | Chloropopanes | Unknown | 2000 | 500 | | µg/L |
| 1,2,3,4-Tetrachlorobenzene | Chlorobenzenes and Chloronaphthalenes | Unknown | 2000 | 4 | | µg/L |
| 1,2,3,5-Tetrachlorobenzene | Chlorobenzenes and Chloronaphthalenes | Unknown | 2000 | 5 | | µg/L |
| 1,2,3-Trichlorobenzene | Chlorobenzenes and Chloronaphthalenes | Low | 2000 | 10 | | µg/L |
| 1,2,4,5-Tetrachloro-3-nitrobenzene | Nitrobenzenes | Unknown | 2000 | | 0.3 | µg/L |
| 1,2,4,5-Tetrachlorobenzene | Chlorobenzenes and Chloronaphthalenes | Unknown | 2000 | 7 | | µg/L |
| 1,2,4-Trichlorobenzene | Chlorobenzenes and Chloronaphthalenes | Low | 2000 | 170 | | µg/L |
| 1,2-Dichlorobenzene | Chlorobenzenes and Chloronaphthalenes | Low | 2000 | 160 | | µg/L |
| 1,2-Dichloroethane | Chloroethanes | Unknown | 2000 | 1900 | | µg/L |
| 1,2-Dichloropropane | Chloropopanes | Unknown | 2000 | 900 | | µg/L |
| 1,3,5-Trichlorobenzene | Chlorobenzenes and Chloronaphthalenes | Unknown | 2000 | 13 | | µg/L |
| 1,3,5-Trinitrobenzene | Nitrobenzenes | Unknown | 2000 | | 4 | µg/L |
| 1,3-Dichlorobenzene | Chlorobenzenes and Chloronaphthalenes | Low | 2000 | 260 | | µg/L |
| 1,3-Dichloropropane | Chloropopanes | Unknown | 2000 | 1100 | | µg/L |
| 1,3-Dinitrobenzene | Nitrobenzenes | Unknown | 2000 | | 13 | µg/L |

| Toxicant name | Toxicant Class | Tox Reliability | Publish date | Tox LOSP 95 | Tox LOSP unknown | Tox LOSP Unit |
|---|---|---|---|---|---|---|
| 1,4-Dichlorobenzene | Chlorobenzenes and Chloronaphthalenes | Moderate | 2000 | 60 | | µg/L |
| 1,4-Dinitrobenzene | Nitrobenzenes | Unknown | 2000 | | 0.6 | µg/L |
| 1-Chloro-3-nitrobenzene | Nitrobenzenes | Unknown | 2000 | | 12 | µg/L |
| 1-Methoxy-2-nitrobenzene | Nitrobenzenes | Unknown | 2000 | | 130 | µg/L |
| 2,3,4,6-Tetrachlorophenol | Phenols and Xylenols | Low | 2000 | 20 | | µg/L |
| 2,3,5,6-Tetrachlorophenol | Phenols and Xylenols | Unknown | 2000 | | 0.2 | µg/L |
| 2,3-Dichlorophenol | Phenols and Xylenols | Unknown | 2000 | | 31 | µg/L |
| 2,4,5-T | Phenoxyacetic Acid Herbicides | Moderate | 2000 | 36 | | µg/L |
| 2,4,6-Trichlorophenol | Phenols and Xylenols | Moderate | 2000 | 20 | | µg/L |
| 2,4,6-Trinitrophenol | Nitrophenols | Unknown | 2000 | | 250 | µg/L |
| 2,4,6-Trinitrotoluene | Nitrotoluenes | Moderate | 2000 | 140 | | µg/L |
| 2,4-D | Phenoxyacetic Acid Herbicides | Moderate | 2000 | 280 | | µg/L |
| 2,4-Dichloroaniline | Anilines | Low | 2000 | 7 | | µg/L |
| 2,4-Dichlorophenol | Phenols and Xylenols | Low | 2000 | 160 | | µg/L |
| 2,4-Dimethylphenol | Phenols and Xylenols | Unknown | 2000 | | 2 | µg/L |
| 2,4-Dinitrophenol | Nitrophenols | Moderate | 2000 | 45 | | µg/L |
| 2,4-Dinitrotoluene | Nitrotoluenes | Moderate | 2000 | 65 | | µg/L |
| 2,6-Dichlorophenol | Phenols and Xylenols | Unknown | 2000 | | 34 | µg/L |
| 2-Chlorophenol | Phenols and Xylenols | Moderate | 2000 | 490 | | µg/L |
| 2-Nitrotoluene | Nitrotoluenes | Unknown | 2000 | | 110 | µg/L |
| 3,4-Dichloroaniline | Anilines | Moderate | 2000 | 3 | | µg/L |
| 3-Chloropropene | Chlorinated Alkenes | Unknown | 2000 | | 3 | µg/L |
| 3-Nitrotoluene | Nitrotoluenes | Unknown | 2000 | | 75 | µg/L |
| 4-Chlorophenol | Phenols and Xylenols | Moderate | 2000 | 220 | | µg/L |
| 4-Nitrophenol | Nitrophenols | Unknown | 2000 | | 58 | µg/L |
| 4-Nitrotoluene | Nitrotoluenes | Unknown | 2000 | | 120 | µg/L |
| Acrolein | Miscellaneous Herbicides | Unknown | 2000 | | 0.01 | µg/L |
| Alcohol ethoxylated sulfate (AES) | Surfactants | Low | 2000 | 650 | | µg/L |

| Toxicant name | Toxicant Class | Tox Reliability | Publish date | Tox LOSP 95 | Tox LOSP unknown | Tox LOSP Unit |
|---|---|---|---|---|---|---|
| Alcohol ethoxylated surfactants (AE) | Surfactants | Moderate | 2000 | 140 | | µg/L |
| Aldrin | Organochlorine Pesticides | Unknown | 2000 | | 0.001 | µg/L |
| Alpha-cypermethrin | Pyrethroids | Moderate | 2023 | 0.006 | | µg/L |
| Aluminium (pH <6.5) | Metals and Metalloids | Unknown | 2000 | | 0.8 | µg/L |
| Aluminium (pH >6.5) | Metals and Metalloids | Low | 2000 | 55 | | µg/L |
| Ammonia | Non-metallic Inorganics | Very High | 2000 | 900 | | µg/L |
| Aniline | Anilines | Moderate | 2000 | 250 | | µg/L |
| Anthracene | Polycyclic Aromatic Hydrocarbons | Unknown | 2000 | 0.4 | | µg/L |
| Antimony | Metals and Metalloids | Unknown | 2000 | | 9 | µg/L |
| Aroclor 1242 | Polychlorinated Biphenyls (PCBs) & Dioxins | Low | 2000 | 0.6 | | µg/L |
| Aroclor 1254 | Polychlorinated Biphenyls (PCBs) & Dioxins | Moderate | 2000 | 0.03 | | µg/L |
| Arsenic (AsIII) | Metals and Metalloids | Moderate | 2000 | 24 | | µg/L |
| Arsenic (AsV) | Metals and Metalloids | Moderate | 2000 | 13 | | µg/L |
| Atrazine | Triazine Herbicides | Moderate | 2000 | 13 | | µg/L |
| Azinphos methyl | Organophosphorus Pesticides | Moderate | 2000 | 0.02 | | µg/L |
| Benzene | Aromatic Hydrocarbons | Moderate | 2000 | 950 | | µg/L |
| Benzo(alpha)pyrene | Polycyclic Aromatic Hydrocarbons | Unknown | 2000 | 0.2 | | µg/L |
| Bis(diethylthiocarbamyl)disulfide | Organic Sulfur Compounds | Unknown | 2000 | | 1 | µg/L |
| Bis(dimethylthiocarbamyl)sulfide | Organic Sulfur Compounds | Unknown | 2000 | | 10 | µg/L |
| Bishphenol A | Miscellaneous industrial organic chemicals | Very High | 2023 | 6.8 | | µg/L |
| Boron | Metals and Metalloids | Very High | 2021 | 940 | | µg/L |
| BP 1100X | Oil Spill Dispersants | Unknown | 2000 | | | µg/L |
| Cadmium | Metals and Metalloids | Very High | 2000 | 0.2 | | µg/L |
| Carbofuran | Carbamate & other Pesticides | Moderate | 2000 | 1.2 | | µg/L |
| Carbon disulfide | Organic Sulfur Compounds | Unknown | 2000 | | 20 | µg/L |
| Carbon tetrachloride | Chloromethanes | Unknown | 2000 | 240 | | µg/L |
| Chlordane | Organochlorine Pesticides | Moderate | 2000 | 0.08 | | µg/L |

| Toxicant name | Toxicant Class | Tox Reliability | Publish date | Tox LOSP 95 | Tox LOSP unknown | Tox LOSP Unit |
|---|---|---|---|---|---|---|
| Chlorine | Non-metallic Inorganics | Moderate | 2000 | 3 | | µg/L |
| Chloroethylene | Chlorinated Alkenes | Unknown | 2000 | 100 | | µg/L |
| Chloroform | Chloromethanes | Unknown | 2000 | 770 | | µg/L |
| Chlorpyrifos | Organophosphorus Pesticides | Moderate | 2000 | 0.01 | | µg/L |
| Chromium (CrIII) | Metals and Metalloids | Unknown | 2000 | | 3.3 | µg/L |
| Chromium (CrVI) | Metals and Metalloids | Very High | 2000 | 1 | | µg/L |
| Cobalt | Metals and Metalloids | Unknown | 2000 | | 1.4 | µg/L |
| Copper | Metals and Metalloids | Very High | 2000 | 1.4 | | µg/L |
| Corexit 9527 | Oil Spill Dispersants | Unknown | 2000 | | | µg/L |
| Corexit 9550 | Oil Spill Dispersants | Unknown | 2000 | | 140 | µg/L |
| Cumene (isopropylbenzene) | Aromatic Hydrocarbons | Unknown | 2000 | 30 | | µg/L |
| Cyanide | Non-metallic Inorganics | Moderate | 2000 | 7 | | µg/L |
| DDT | Organochlorine Pesticides | Moderate | 2000 | 0.01 | | µg/L |
| Deltamethrin | Pyrethroids | Unknown | 2000 | | 0.0001 | µg/L |
| Di(2-ethylhexyl)phthalate | Phthalates | Unknown | 2000 | | 1 | µg/L |
| Diazinon | Organophosphorus Pesticides | Moderate | 2000 | 0.01 | | µg/L |
| Dibutylphthalate | Phthalates | Low | 2000 | 26 | | µg/L |
| Dichloromethane | Chloromethanes | Unknown | 2000 | 4000 | | µg/L |
| Dicofol | Organochlorine Pesticides | Unknown | 2000 | | 0.5 | µg/L |
| Dieldrin | Organochlorine Pesticides | Unknown | 2000 | | 0.01 | µg/L |
| Diethylphthalate | Phthalates | Very Low | 2000 | 1000 | | µg/L |
| Dimethoate | Organophosphorus Pesticides | Low | 2000 | 0.15 | | µg/L |
| Dimethylformamide | Miscellaneous Industrial Chemicals | Unknown | 2000 | | 1000 | µg/L |
| Dimethylphthalate | Phthalates | Low | 2000 | 3700 | | µg/L |
| Dioxins | Polychlorinated biphenyls (PCBs) & Dioxins | Moderate | 2023 | 0.005 | | ng/L |
| Diquat | Bypyridilium Herbicides | Low | 2000 | 1.4 | | µg/L |
| Diuron | Urea Herbicides | Unknown | 2000 | | 0.2 | µg/L |
| Endosulfan | Organochlorine Pesticides | Moderate | 2000 | 0.2 | | µg/L |

| Toxicant name | Toxicant Class | Tox Reliability | Publish date | Tox LOSP 95 | Tox LOSP unknown | Tox LOSP Unit |
|---|---|---|---|---|---|---|
| Endrin | Organochlorine Pesticides | Moderate | 2000 | 0.02 | | µg/L |
| Esfenvalerate | Pyrethroids | High | 2000 | | 0.001 | µg/L |
| Ethanol | Organic Alcohols | Low | 2000 | 1400 | | µg/L |
| Ethylbenzene | Aromatic Hydrocarbons | Unknown | 2000 | 80 | | µg/L |
| Ethylene glycol | Organic Alcohols | Unknown | 2000 | | 330 | µg/L |
| Fenitrothion | Organophosphorus Pesticides | Moderate | 2000 | 0.2 | | µg/L |
| Fipronil | Pyrazole insecticides | Moderate | 2023 | 0.018 | | µg/L |
| Fluoranthene | Polycyclic Aromatic Hydrocarbons | Unknown | 2000 | 1.4 | | µg/L |
| Fluoride | Non-metallic Inorganics | Moderate | 2024 | 1.7 | | mg/L |
| Glyphosate | Miscellaneous Herbicides | Very High | 2021 | 320 | | µg/L |
| Heptachlor | Organochlorine Pesticides | Moderate | 2000 | 0.09 | | µg/L |
| Hexachlorobenzene | Chlorobenzenes and Chloronaphthalenes | Unknown | 2000 | 0.1 | | µg/L |
| Hexachloroethane | Chloroethanes | Low | 2000 | 360 | | µg/L |
| Hydrogen sulfide | Non-metallic Inorganics | Moderate | 2000 | 1 | | µg/L |
| Isophorone | Miscellaneous Industrial Chemicals | Unknown | 2000 | | | µg/L |
| Isopropyl alcohol | Organic Alcohols | Unknown | 2000 | | 4200 | µg/L |
| Lead | Metals and Metalloids | Moderate | 2000 | 3.4 | | µg/L |
| Lindane | Organochlorine Pesticides | Moderate | 2000 | 0.2 | | µg/L |
| Linear alkylbenzene sulfonates (LAS) | Surfactants | Low | 2000 | 280 | | µg/L |
| Malathion | Organophosphorus Pesticides | Moderate | 2000 | 0.05 | | µg/L |
| Mancozeb | Thiocarbamate Herbicides | Moderate | 2023 | 1.2 | | µg/L |
| Manganese | Metals and Metalloids | Moderate | 2000 | 1900 | | µg/L |
| MCPA | Phenoxyacetic Acid Herbicides | Moderate | 2024 | 7.7 | | µg/L |
| Mercury (inorganic) | Metals and Metalloids | Moderate | 2000 | 0.6 | | µg/L |
| Methomyl | Carbamate & other Pesticides | Low | 2000 | 3.5 | | µg/L |
| Methoxychlor | Organochlorine Pesticides | Unknown | 2000 | | 0.005 | µg/L |
| Metolachlor | Miscellaneous Herbicides | Very High | 2020 | 0.46 | | µg/L |
| Metsulfuron-methyl | Sulfonylurea herbicides | Moderate | 2021 | 0.018 | | µg/L |

| Toxicant name | Toxicant Class | Tox Reliability | Publish date | Tox LOSP 95 | Tox LOSP unknown | Tox LOSP Unit |
|---|---|---|---|---|---|---|
| Mirex | Organochlorine Pesticides | Unknown | 2000 | | 0.04 | µg/L |
| Molinate | Thiocarbamate Herbicides | Low | 2000 | 3.4 | | µg/L |
| Molybdenum | Metals and Metalloids | Unknown | 2000 | | 34 | µg/L |
| Monochlorobenzene | Chlorobenzenes and Chloronaphthalenes | Unknown | 2000 | 55 | | µg/L |
| m-Xylene | Aromatic Hydrocarbons | Unknown | 2000 | 75 | | µg/L |
| Naphthalene | Polycyclic Aromatic Hydrocarbons | Low | 2000 | 16 | | µg/L |
| Nickel | Metals and Metalloids | Low | 2000 | 11 | | µg/L |
| Nitrate | Non-metallic Inorganics | NA | 2000 | 15 ug/L $NO_x$ for slightly disturbed ecosystem (ANZECC, 2000) | | |
| Nitrobenzene | Nitrobenzenes | Low | 2000 | 550 | | µg/L |
| o-Xylene | Aromatic Hydrocarbons | Low | 2000 | 350 | | µg/L |
| Paraquat | Bypyridilium Herbicides | Moderate | 2024 | 1.2 | | µg/L |
| Parathion | Organophosphorus Pesticides | Moderate | 2000 | 0.004 | | µg/L |
| Pentachlorobenzene | Chlorobenzenes and Chloronaphthalenes | Unknown | 2000 | 2 | | µg/L |
| Pentachloroethane | Chloroethanes | Unknown | 2000 | 80 | | µg/L |
| Pentachlorophenol | Phenols and Xylenols | Moderate | 2000 | 10 | | µg/L |
| Phenanthrene | Polycyclic Aromatic Hydrocarbons | Unknown | 2000 | 2 | | µg/L |
| Phenol | Phenols and Xylenols | Moderate | 2000 | 320 | | µg/L |
| Picloram | Herbicides | Low | 2023 | 87 | | µg/L |
| Poly(acrylonitrile-co-butadiene-co-styrene) | Miscellaneous Industrial Chemicals | Low | 2000 | 530 | | µg/L |
| Profenofos | Organophosphorus Pesticides | Unknown | 2000 | | 0.02 | µg/L |
| p-Xylene | Aromatic Hydrocarbons | Low | 2000 | 200 | | µg/L |
| Selenium (total) | Metals and Metalloids | Moderate | 2000 | 11 | | µg/L |
| Silver | Metals and Metalloids | Low | 2000 | 0.05 | | µg/L |
| Simazine | Triazine Herbicides | Very High | 2024 | 12 | | µg/L |
| S-Methoprene | Carbamate & other Pesticides | Unknown | 2000 | | 0.2 | µg/L |
| Sulfometuron-methyl | Sulfonylurea Herbicides | Unknown | 2024 | | 0.02 | µg/L |
| Tebuthiuron | Urea Herbicides | Low | 2000 | 2.2 | | µg/L |

| Toxicant name | Toxicant Class | Tox Reliability | Publish date | Tox LOSP 95 | Tox LOSP unknown | Tox LOSP Unit |
|---|---|---|---|---|---|---|
| Temephos | Organophosphorus Pesticides | Unknown | 2000 | | 0.05 | µg/L |
| Thallium | Metals and Metalloids | Unknown | 2000 | | 0.03 | µg/L |
| Thiobencarb | Thiocarbamate Herbicides | Moderate | 2000 | 2.8 | | µg/L |
| Thiram | Thiocarbamate Herbicides | Moderate | 2000 | 0.2 | | µg/L |
| Toluene | Aromatic Hydrocarbons | Unknown | 2000 | 180 | | µg/L |
| Toxaphene | Organochlorine Pesticides | Moderate | 2000 | 0.2 | | µg/L |
| Trifluralin | Miscellaneous Herbicides | Moderate | 2000 | 4.4 | | µg/L |
| Uranium | Metals and Metalloids | Unknown | 2000 | | 0.5 | µg/L |
| Vanadium | Metals and Metalloids | Unknown | 2000 | | 6 | µg/L |
| Zinc | Metals and Metalloids | Very High | 2000 | 8 | | µg/L |

The thresholds in table 1 were used to assess the potential toxicity of the ‘permeate’ derived from the raw water sample taken in October 2024.

In table 2, below, compliant concentrations are shown in GREEN, substances where a threshold is not known are shown in YELLOW. Non-compliant contaminant concentrations in the permeate are shown in RED.

**Table 2. Listing of all attributes measured on a sample taken in October 2024. The estimated impact of single and double RO treatment is shown. The concentrations in the double RO permeate is compared with the Toxicity 95% threshold where the permeate is non-toxic for 95% of NSW freshwater species. The advisory toxicity thresholds for short and long term irrigation are also shown. Source: ANZG 2018 for species freshwater toxicity. The toxicity thresholds for short and long term irrigation are from Draft revised Chapter 4.2 Water Quality for Irrigation and General Water Uses: Guidelines Report [Draft] January 2024**

| Attribute | Units | Practical quantification limit (PQL) | Raw Water Analysis 01.10.24 | Pass 1 permeate (estimated) | Pass 2 permeate (estimated) | Tox LOSP 95: threshold where permeate is non-toxic for an estimated 95% of NSW freshwater fauna<br>GREEN is compliant.<br>YELLOW is used where a threshold o Issue or value is not available<br>RED is for non-compliant attributes | Short term irrigation (20 years) | Long term irrigation (100 years) | Comment |
|---|---|---|---|---|---|---|---|---|---|
| pH | pH Units | 0.02 | 8.6 | >6.5 | >6.5 | 6.5 TO 7.5 IS UPLAND DEFAULT TRIGGER VALUE RANGE. Key impacts include lower solubility of many metals . The proportion of ammoniacal-N as NH3 becomes greater as the pH rises above 8.5. | | within range of 5 to 9 | The 5 to 9 pH range helps prevent corrosion and fouling of irrigation equipment |
| Escherichia coli | CFU/ 100mL | 1 | ~20 | 0.2 | 0.002 | 150 cfu/100 mL For PRIMARY CONTACT | | | Not an issue as no human contact is proposed. |
| Thermotolerant Coliforms | CFU/100 mL | 1 | ~20 | 0.2 | 0.002 | <10cfu/100 mL FOR FOOD CROPS EATEN RAW E.G SALAD VEGETABLES | | | Not an issue as no human contact is proposed. |
| Electrical Conductivity (EC) | µS/cm | 1 | 23000 | 1300 | 600 | 350 FOR upland rivers (ANZECC, 2000) | Low and not an issue | Low and not an issue | OK for irrigation (0.6 dS/m or 384 mg/L of total dissolved solids ('salt') |
| Phosphorus - Total | mg/L | 0.05 | 35 | 3.5 | 0.35 | 0.02 The issue is algal growth but algal growth stimulation it is not an issue if the permeate is irrigated soon after production | Up to 12 | 0.05 | To minimise clogging of irrigation equipment only. 0.5mg/L in 1.83 ML of permeate irrigation /ha/y is 0.9 kg/ha/y. A typical 12 T/year Perennial pasture will accumulate 36 kg P/ha/y NSW Agriculture 1997). So, the permeate will |

| Attribute | Units | Practical quantification limit (PQL) | Raw Water Analysis 01.10.24 | Pass 1 permeate (estimated) | Pass 2 permeate (estimated) | Tox LOSP 95: threshold where permeate is non-toxic for an estimated 95% of NSW freshwater fauna<br>GREEN is compliant.<br>YELLOW is used where a threshold d<br>Issue or value is not available<br>RED is for non-compliant attributes | Short term irrigation (20 years) | Long term irrigation (100 years) | Comment |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | supply <3% of the anticipated demand. |
| Total Nitrogen in water | mg/L | 0.1 | 2200 | 880 | 60 | 0.25 mg/L in the threshold in IN UPLAND RIVERS. So, ensure there is no excessive irrigation OR permeate runoff. | <125 | <5 | A perennial ryegrass pasture will accumulate an indicative 420 kg/ha/y of Nitrogen.(NSW Agriculture (1997). Applying 183 mm/year containing 60 mg/L N will supply 110 kg/ha/y of N. This is 26% of the pasture N demand. |
| Ammonia as N in water (operational max based on repeated sampling) | mg/L | 0.005 | 10 | 1 | 0.10 | 0.9 mg/L as AMMONIACAL-N | | | Ensure there is no permeate runoff to streams. See above comment in relation to total N being 26% of pasture demand. |
| Nitrate as N in water (operational max based on repeated sampling) | mg/L | 0.005 | 1500 | 255 | 50 | 15 ug/L as NOx-N | | | Ensure there is no permeate runoff to streams. See above comment in relation to total N being 26% of pasture demand. |
| Nitrite as N in water (operational max based on repeated sampling) | mg/L | 0.005 | <0.50 | 0.075 | 11.25 ug/L | 15 ug/L as NOx-N | | | OK |
| Sodium Adsorption Ratio | - | 0.01 | 28 | ? | ? | A significant issue. However, it can be readily adjusted by adding dissolved calcium to the permeate. | Water with an SAR>6 AND | Add dissolved Calcium to | Check soil. Exchangeable Na % every 3 years. Add |

| Attribute | Units | Practical quantification limit (PQL) | Raw Water Analysis 01.10.24 | Pass 1 permeate (estimated) | Pass 2 permeate (estimated) | Tox LOSP 95: threshold where permeate is non-toxic for an estimated 95% of NSW freshwater fauna<br>GREEN is compliant.<br>YELLOW is used where a threshold c Issue or value is not available<br>RED is for non-compliant attributes | Short term irrigation (20 years) | Long term irrigation (100 years) | Comment |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | salinity <350 uS/cm can create structurally unstable soil following irrigation. | the permeate | 5T/ha of gypsum to the soil if Exch Na%>5%. |
| Arsenic-Dissolved | µg/L | 1 | 320 | 32 | 3.2 | As (111) 24 ug/L, As(V) 13 ug/L | 20000 | 5000 | OK |
| Aluminium-Dissolved | µg/L | 10 | 2000 | 200 | 20 | if pH>6.5 55ug/L. if pH<6.5 ox LOSP unknown 0.8 ug/L is listed | 20000 | 5000 | OK for irrigation. Ensure that there is no permeate runoff. |
| Aluminium-Total | µg/L | 10 | 4800 | 336 | 24 | NA | 20000 | 5000 | OK for irrigation |
| Antimony-Dissolved | µg/L | 1 | 18 | 1.8 | 0.8 | ox LOSP unknown 9 ug/L is listed | | | OK for irrigation |
| Boron-Dissolved | µg/L | 20 | 4600 | 3220 | 340 | 940 | 750 to 1500 | 500 | OK for short term irrigation. Raising the soil pH to>7 will increase Fe and Al sorption of B (Strawn, et al, 2015). |
| Cadmium-Dissolved | µg/L | 0.1 | 3.4 | 0.4 | <0.1 | 0.2 | 50 | 10 | OK for irrigation |
| Calcium - Dissolved | mg/L | 0.5 | 52 | 5.2 | 0.52 | NA | | | |
| Calcium - Total | mg/L | 0.5 | 120 | 12 | 1.2 | NA | | | |
| Chromium-Total | µg/L | 1 | 790 | 79 | 7.9 | NA | | | |
| Cobalt Total | ug/L | 1 | 110 | 11 | 1.1 | | | | |
| Cobalt -Dissolved | µg/L | 1 | 94 | 9.4 | 0.94 | Tox LOSP unknown 1.4 ug/L shown | | | |
| Copper -Total | µg/L | 1 | 170 | 17 | 1.7 | 1.4 | 5000 | 200 | |

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|---|---|---|---|---|---|---|---|---|---|
| Copper -Dissolved | µg/L | 1 | 12 | 1.2 | <1 | 1.4 | 5000 | 200 | |
| Fluoride, F | mg/L | 0.1 | 1.4 | 0.14 | 0.014 | 1.7 | 2 | 1 | OK for irrigation |
| Lead-Dissolved | µg/L | 1 | 24 | 2.4 | 0.24 | 3.4 | | | |
| Lead-Total | µg/L | 1 | 120 | 12 | 1.2 | 3.4 | 5000 | 2000 | OK for irrigation |
| Manganese-Dissolved | µg/L | 5 | 250 | 25 | 2.5 | 1900 | | | |
| Manganese-Total | µg/L | 5 | 1600 | 160 | 16 | 1900 | 1000 | 200 | OK for irrigation |
| Mercury-Dissolved | µg/L | 0.05 | <0.5 | 0.05 | 0.005 | 0.6 | | | |
| Mercury-Total | µg/L | 0.05 | <0.50 | 0.05 | 0.005 | 0.6 | 2 | 2 | OK for irrigation |
| Molybdenum-Dissolved | µg/L | 1 | <10 | 1 | 0.1 | 34 | | | |
| Molybdenum-Total | µg/L | 1 | 13 | 1.3 | 0.13 | 34 | 50 | 10 | OK for irrigation |
| Nickel-Dissolved | ug/L | 1 | 290 | 29 | 3 | 11 | | | |
| Nickel-Total | µg/L | 1 | 330 | 30 | 3 | 11 | 2000 | 200 | OK for irrigation |
| Selenium-Total | µg/L | 1 | <10 | 1 | 0.1 | 11 | 50 | 20 | Total |
| Sodium - Dissolved | mg/L | 0.5 | 1800 | 180 | 18 | <224 mg/L FOR upland rivers (<350 uS/cm) | | | OK |
| Sodium - Total | mg/L | 0.5 | 2500 | 250 | 25 | <224 mg/L FOR upland rivers (<350 uS/cm) | | | OK |
| Vanadium-Dissolved | µg/L | 1 | 110 | 10 | <4 | 4 ug/L Tox LOSP unknown | | | |
| Vanadium-Total | µg/L | 1 | 110 | 10 | 1 | 4 ug/L Tox LOSP unknown | 500 | 100 | OK for irrigation |
| Zinc-Total | µg/L | 1 | 12000 | 1200 | 120 | NA | 5000 | 2000 | OK for irrigation |
| Zinc-Dissolved | µg/L | 1 | 2100 | 210 | 21 | 8 ug/L (Zn solubility falls with increased pH | | | No runoff of permeate to local streamlines. |
| Free Chlorine | mg/L | 0.1 | <10 | 0 | 0 | total Chlorine threshold<3 ug/L (0.003 mg/L) | | | Chlorine reacts with organic matter and is inactivated. The combination of pasture |

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|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | biomass and organic matter in soils will rapidly inactivate the chlorine so that it is not an issue. |
| Total Chlorine | mg/L | 0.1 | <10 | 1 | 0.1 | 3 | | | Not an issue |
| Methoxychlor | µg/L | 0.2 | <2.0 | 0.1 | 0.005 | 0.005 | | | |
| Chlorpyriphos | µg/L | 0.2 | <2.0 | 0.1 | 0.005 | 0.01 (OK if lower initial concentration) | | | |
| Diazinon | µg/L | 0.2 | <2.0 | 0.1 | 0.005 | 0.01 | | | |
| pp-DDT | µg/L | 0.2 | <2.0 | 0.1 | 0.005 | 0.01 | | | |
| Endrin | µg/L | 0.2 | <2.0 | 0.1 | 0.005 | 0.02 (OK if lower initial concentration) | | | |
| Malathion | µg/L | 0.2 | <2.0 | 0.1 | 0.005 | 0.05 | | | |
| alpha-Chlordane | µg/L | 0.2 | <2.0 | 0.1 | 0.005 | 0.08 | | | |
| Hexachlorobenzene | µg/L | 2 | <20 | 1 | 0.05 | 0.1 | | | |
| 2,3,5,6-Tetrachlorophenol | µg/L | 2 | <20 | 1.6 | 0.128 | 0.2 | | | |
| Anthracene | µg/L | 0.1 | <1.0 | 0.2 | 0.04 | 0.2 | | | |
| Benzo(a)pyrene | µg/L | 0.1 | <1.0 | 0.1 | 0.01 | 0.2 | | | |
| Benzo(a)pyrene TEQ | µg/L | 0.5 | <5 | 0.5 | 0.05 | 0.2 | | | |
| gamma-BHC (Lindane) | µg/L | 2 | <20 | 2 | 0.2 | 0.2 | | | |
| Anthracene | µg/L | 2 | <20 | 1.6 | 0.128 | 0.4 | | | |
| Metolachlor | µg/L | 2 | <20 | 2 | 0.2 | 0.46 | | | |
| Aroclor 1242 | µg/L | 2 | <20 | 1 | 0.05 | 0.6 | | | |
| Carbofuran | µg/L | 0.5 | <5.0 | 0.5 | 0.05 | 1.2 | | | |
| Fluoranthene | µg/L | 2 | <20 | 1 | 0.05 | 1.4 | | | |
| Fluoranthene | µg/L | 0.1 | <1.0 | 0.2 | 0.04 | 1.4 | | | |

| Attribute | Units | Practical quantification limit (PQL) | Raw Water Analysis 01.10.24 | Pass 1 permeate (estimated) | Pass 2 permeate (estimated) | Tox LOSP 95: threshold where permeate is non-toxic for an estimated 95% of NSW freshwater fauna<br>GREEN is compliant.<br>YELLOW is used where a threshold c<br>Issue or value is not available<br>RED is for non-compliant attributes | Short term irrigation (20 years) | Long term irrigation (100 years) | Comment |
|---|---|---|---|---|---|---|---|---|---|
| Pentachlorobenzene | µg/L | 2 | <20 | 2 | 0.2 | 2 | | | |
| Phenanthrene | µg/L | 2 | <20 | 1.6 | 0.128 | 2 | | | |
| Phenanthrene | µg/L | 0.1 | <1.0 | 0.2 | 0.04 | 2 | | | |
| Molinate | µg/L | 0.5 | <5.0 | 0.75 | 0.1125 | 3.4 | | | |
| 1,2,3,4-Tetrachlorobenzene | µg/L | 2 | <20 | 2 | 0.2 | 4 | | | |
| Trifluralin | µg/L | 2 | <20 | 2 | 0.2 | 4.4 | | | |
| 1,2,3,5 & 1,2,4,5-Tetrachlorobenzene | µg/L | 4 | <40 | 4 | 0.4 | 5 | | | |
| Bisphenol A (BPA) | µg/L | 20 | 220 | 2 | 0.2 | 6.8 | | | |
| Total Cyanide | mg/L | 0.004 | 0.051 | 0.0077 | 0.0011 | 7 | | | |
| MCPA | µg/L | 0.50 | <5.0 | 1 | 0.2 | 7.7 | | | |
| 1,2,3-trichlorobenzene | µg/L | 1 | <10 | 1.5 | 0.225 | 10 | | | |
| 1,2,3-Trichlorobenzene | µg/L | 2 | <20 | 3 | 0.45 | 10 | | | |
| Pentachlorophenol | µg/L | 10 | <100 | 5 | 0.25 | 10 | | | |
| Simazine | µg/L | 2 | <20 | 3 | 0.45 | 12 | | 0.5 | OK |
| 1,3,5-Trichlorobenzene | µg/L | 2 | <20 | 3 | 0.45 | 13 | | | |
| Atrazine | µg/L | 2 | <20 | 2 | 0.2 | 13 | | 10 | OK |
| Naphthalene | µg/L | 2 | <20 | 3 | 0.45 | 16 | | | |
| Naphthalene | µg/L | 1 | <10 | 10 | 10 | 16 | | | |
| Naphthalene | µg/L | 0.1 | <1 | 1 | 1 | 16 | | | |
| 2,3,4,5 & 2,3,4,6-Tetrachlorophenol | µg/L | 4 | <40 | 3.2 | 0.256 | 20 | | | |
| 2,4,6-Trichlorophenol | µg/L | 2 | <20 | 2 | 0.2 | 20 | | | |
| Isopropylbenzene | µg/L | 1 | <10 | 2 | 0.4 | 30 | | | |
| 2,6-Dinitrotoluene | µg/L | 5 | <50 | 7.5 | 1.125 | 36 | | | |

| Attribute | Units | Practical quantification limit (PQL) | Raw Water Analysis 01.10.24 | Pass 1 permeate (estimated) | Pass 2 permeate (estimated) | Tox LOSP 95: threshold where permeate is non-toxic for an estimated 95% of NSW freshwater fauna<br>GREEN is compliant.<br>YELLOW is used where a threshold o<br>Issue or value is not available<br>RED is for non-compliant attributes | Short term irrigation (20 years) | Long term irrigation (100 years) | Comment |
|---|---|---|---|---|---|---|---|---|---|
| 2,6-Dinitrotoluene | µg/L | 1 | <10 | 1.5 | 10 | 36 | | | |
| 1,2-Dichlorobenzene | µg/L | 2 | <20 | 4 | 0.8 | 60 | | | |
| 1,4-dichlorobenzene | µg/L | 1 | <10 | 1.5 | 0.225 | 60 | | | |
| 1,4-Dichlorobenzene | µg/L | 2 | <20 | 4 | 0.8 | 60 | | | |
| 2,4-Dinitrotoluene | µg/L | 5 | <50 | 7.5 | 1.125 | 65 | | | |
| 2,4-Dinitrotoluene | µg/L | 1 | <10 | 10 | 10 | 65 | | | |
| Ethylbenzene | µg/L | 1 | <10 | 2 | 0.4 | 80 | | | |
| Ethylbenzene | µg/L | 1 | <10 | 3 | 0.9 | 80 | | | |
| Pentachloroethane | µg/L | 2 | <20 | 2 | 0.2 | 80 | | | |
| Picloram | µg/L | 1.0 | <10 | 2 | 0.4 | 87 | | | |
| 2,4,6-Trinitrotoluene | µg/L | 1 | <10 | 10 | 10 | 140 | | | |
| 2,4-Dichlorophenol | µg/L | 2 | <20 | 3 | 0.45 | 160 | | | |
| 1,2,4-trichlorobenzene | µg/L | 1 | <10 | 1.5 | 0.225 | 174 | | | |
| 1,2,4-Trichlorobenzene | µg/L | 2 | <20 | 3 | 0.45 | 174 | | | |
| Toluene | µg/L | 1 | <10 | 2 | 0.4 | 180 | | | |
| Toluene | µg/L | 1 | <10 | 4 | 1.6 | 180 | | | |
| Carbon tetrachloride | µg/L | 1 | <10 | 1.5 | 0.225 | 240 | | | |
| 1,3-dichlorobenzene | µg/L | 1 | <10 | 1.5 | 0.225 | 260 | | | |
| 1,3-Dichlorobenzene | µg/L | 2 | <20 | 4 | 0.8 | 260 | | | |
| 1,1,1-trichloroethane | µg/L | 1 | <10 | 2 | 0.4 | 270 | | | |
| 2,4-D | µg/L | 0.50 | <5.0 | 1 | 0.2 | 280 | | | |
| Phenol | µg/L | 2 | 35 | 2 | 0.8 | 320 | | | |
| Total Phenolics (as Phenol) | mg/L | 0.05 | <0.5 | 0.075 | 0.01125 | 320 | | | |
| o-xylene | µg/L | 1 | <10 | 2 | 0.4 | 350 | | | |

| Attribute | Units | Practical quantification limit (PQL) | Raw Water Analysis 01.10.24 | Pass 1 permeate (estimated) | Pass 2 permeate (estimated) | Tox LOSP 95: threshold where permeate is non-toxic for an estimated 95% of NSW freshwater fauna<br>GREEN is compliant.<br>YELLOW is used where a threshold c<br>Issue or value is not available<br>RED is for non-compliant attributes | Short term irrigation (20 years) | Long term irrigation (100 years) | Comment |
|---|---|---|---|---|---|---|---|---|---|
| o-xylene | µg/L | 1 | <10 | 3 | 0.9 | 350 | | | |
| Hexachloroethane | µg/L | 2 | <20 | 2 | 0.2 | 360 | | | |
| 1,1,2,2-tetrachloroethane | µg/L | 1 | <10 | 1.5 | 0.225 | 400 | | | |
| 2-Chlorophenol | µg/L | 2 | <20 | 5 | 1.25 | 490 | | | |
| Nitrobenzene | µg/L | 5 | <50 | 10 | 2 | 550 | | | |
| Nitrobenzene | µg/L | 1 | <10 | 10 | 10 | 550 | | | |
| Chloroform | µg/L | 1 | <10 | 2 | 0.4 | 770 | | | |
| 1,2-dichloropropane | µg/L | 1 | <10 | 2.5 | 0.625 | 900 | | | |
| Benzene | µg/L | 1 | <10 | 2 | 0.4 | 950 | | | |
| Diethyl phthalate | µg/L | 10 | <100 | 10 | 1 | 1000 | | | |
| 1,3-dichloropropane | µg/L | 1 | <10 | 2.5 | 0.625 | 1100 | | | |
| Ethanol | µg/L | 50 | <500 | 350 | 245 | 1400 | | | |
| 1,1,2-trichloroethane | µg/L | 1 | <10 | 2 | 0.4 | 1900 | | | |
| 1,2-dichloroethane | µg/L | 1 | <10 | 3 | 0.9 | 1900 | | | |
| Dimethyl phthalate | µg/L | 10 | <100 | 10 | 1 | 3700 | | | |
| alpha-Chlordane (cis-Chlordane) | µg/L | 2 | <20 | 1 | 0.05 | 0.08 (FOR 'Chlordane'). | | | |
| gamma-Chlordane | µg/L | 0.2 | <2.0 | 0.1 | 0.005 | 0.08 (FOR 'Chlordane'). | | | |
| gamma-Chlordane (trans-Chlordane) | µg/L | 2 | <20 | 1 | 0.05 | 0.08 (FOR 'Chlordane'). | | | |
| Heptachlor | µg/L | 2 | <20 | 2 | 0.2 | 0.09 (0.25 FOR 90%ILE) | | | |
| Heptachlor | µg/L | 0.2 | <2.0 | 0.1 | 0.005 | 0.09 (0.25 FOR 90%ILE) | | | |
| Endosulfan I | µg/L | 2 | <20 | 1 | 0.05 | 0.2 (FOR ENDOSULFAN) | | | |
| Endosulfan I | µg/L | 0.2 | <2.0 | 0.1 | 0.005 | 0.2 (FOR ENDOSULFAN) | | | |
| Endosulfan II | µg/L | 2 | <20 | 1 | 0.05 | 0.2 (FOR ENDOSULFAN) | | | |

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|---|---|---|---|---|---|---|---|---|---|
| Endosulfan II | µg/L | 0.2 | <2.0 | 0.1 | 0.005 | 0.2 (FOR ENDOSULFAN) | | | |
| Endosulfan Sulphate | µg/L | 2 | <20 | 1 | 0.05 | 0.2 (FOR ENDOSULFAN) | | | |
| Endosulfan Sulphate | µg/L | 0.2 | <2.0 | 0.1 | 0.005 | 0.2 (FOR ENDOSULFAN) | | | |
| 1,3-Dinitrobenzene | µg/L | 5 | <50 | 7.5 | 1.125 | 13(TOX LOSP UNKNOWN) | | | |
| 1,3-Dinitrobenzene | µg/L | 1 | <10 | 10 | 10 | 13(TOX LOSP UNKNOWN) | | | |
| 2-Nitrotoluene & 4-Nitrotoluene | µg/L | 5 | <50 | 50 | 50 | 140 (NITROTOLUENE) | | | |
| m+p-xylene | µg/L | 2 | <20 | 4 | 0.8 | 200 (p-xylene) | | | |
| Di-n-butyl phthalate | µg/L | 50 | <500 | 25 | 1.25 | 26 (DIBUTYL PHTHALATE) | | | |
| Di-n-octyl phthalate | µg/L | 50 | <500 | 25 | 1.25 | 26 (DIBUTYL PHTHALATE) | | | |
| 2,6-D | µg/L | 0.50 | <5.0 | 1 | 0.2 | 34 Tox LOSP unknown | | | |
| 2,6-Dichlorophenol | µg/L | 2 | <20 | 3 | 0.45 | 34 Tox LOSP unknown | | | |
| 4-Nitrophenol | µg/L | 20 | <200 | 40 | 8 | 58 Tox LOSP unknown | | | |
| Tributyltin | µg/L | 0.0020 | | | | BELOW DETECTION | | | |
| 3-Nitrotoluene | µg/L | 1 | <10 | 10 | 10 | Tox LOSP unknown 75 | | | |
| Isopropyl Alcohol | µg/L | 50 | <500 | 350 | 245 | Tox unknown 4200 | | | |
| Extracted ISTD13C2 6:2FTS | % | | 91 | | | NA | | | |
| 1,1,1,2-tetrachloroethane | µg/L | 1 | <10 | 1.5 | 0.225 | NA | | | |
| 1,1-dichloroethane | µg/L | 1 | <10 | 3 | 0.9 | NA | | | |
| 1,1-Dichloroethene | µg/L | 1 | <10 | 2.5 | 0.625 | NA | | | |
| 1,1-dichloropropene | µg/L | 1 | <10 | 2.5 | 0.625 | NA | | | |
| 1,2,3,4,6,7,8-HpCDD | pg/L | 20 | 780 | 4 | 0.2 | NA | | | |
| 1,2,3,4,6,7,8-HpCDD I-TEQ1 | pg/L | | 7.8 | 0.04 | 0.002 | NA | | | |

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|---|---|---|---|---|---|---|---|---|---|
| 1,2,3,4,6,7,8-HpCDD I-TEQ2 | pg/L | | 7.8 | 0.04 | 0.002 | NA | | | |
| 1,2,3,4,6,7,8-HpCDD I-TEQ3 | pg/L | | 7.8 | 0.04 | 0.002 | NA | | | |
| 1,2,3,4,6,7,8-HpCDD WHO-TEQ1 | pg/L | | 7.8 | 0.04 | 0.002 | NA | | | |
| 1,2,3,4,6,7,8-HpCDD WHO-TEQ2 | pg/L | | 7.8 | 0.04 | 0.002 | NA | | | |
| 1,2,3,4,6,7,8-HpCDD WHO-TEQ3 | pg/L | | 7.8 | 0.04 | 0.002 | NA | | | |
| 1,2,3,4,6,7,8-HpCDF | pg/L | 20 | <200 | 10 | 0.5 | NA | | | |
| 1,2,3,4,6,7,8-HpCDF I-TEQ1 | pg/L | | 0.0 | 0 | 0 | NA | | | |
| 1,2,3,4,6,7,8-HpCDF I-TEQ2 | pg/L | | 1.0 | 0 | 0 | NA | | | |
| 1,2,3,4,6,7,8-HpCDF I-TEQ3 | pg/L | | 2.0 | 0 | 0 | NA | | | |
| 1,2,3,4,6,7,8-HpCDF WHO-TEQ1 | pg/L | | 0.0 | 0 | 0 | NA | | | |
| 1,2,3,4,6,7,8-HpCDF WHO-TEQ2 | pg/L | | 1.0 | 0 | 0 | NA | | | |
| 1,2,3,4,6,7,8-HpCDF WHO-TEQ3 | pg/L | | 2.0 | 0 | 0 | NA | | | |
| 1,2,3,4,7,8,9-HpCDF | pg/L | 20 | <200 | 10 | 0.5 | NA | | | |
| 1,2,3,4,7,8,9-HpCDF I-TEQ1 | pg/L | | 0.0 | 0 | 0 | NA | | | |
| 1,2,3,4,7,8,9-HpCDF I-TEQ2 | pg/L | | 1.0 | 0 | 0 | NA | | | |
| 1,2,3,4,7,8,9-HpCDF I-TEQ3 | pg/L | | 2.0 | 0 | 0 | NA | | | |

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|---|---|---|---|---|---|---|---|---|---|
| 1,2,3,4,7,8,9-HpCDF WHO-TEQ1 | pg/L | | 0.0 | 0 | 0 | NA | | | |
| 1,2,3,4,7,8,9-HpCDF WHO-TEQ2 | pg/L | | 1.0 | 0 | 0 | NA | | | |
| 1,2,3,4,7,8,9-HpCDF WHO-TEQ3 | pg/L | | 2.0 | 0 | 0 | NA | | | |
| 1,2,3,4,7,8-HxCDD | pg/L | 20 | <200 | 10 | 0.5 | NA | | | |
| 1,2,3,4,7,8-HxCDD I-TEQ1 | pg/L | | 0.0 | 0 | 0 | NA | | | |
| 1,2,3,4,7,8-HxCDD I-TEQ2 | pg/L | | 10 | 0 | 0 | NA | | | |
| 1,2,3,4,7,8-HxCDD I-TEQ3 | pg/L | | 20 | 0 | 0 | NA | | | |
| 1,2,3,4,7,8-HxCDD WHO-TEQ1 | pg/L | | 0.0 | 0 | 0 | NA | | | |
| 1,2,3,4,7,8-HxCDD WHO-TEQ2 | pg/L | | 10 | 0 | 0 | NA | | | |
| 1,2,3,4,7,8-HxCDD WHO-TEQ3 | pg/L | | 20 | 0 | 0 | NA | | | |
| 1,2,3,4,7,8-HxCDF | pg/L | 20 | <200 | 10 | 0.5 | NA | | | |
| 1,2,3,4,7,8-HxCDF I-TEQ1 | pg/L | | 0.0 | 0 | 0 | NA | | | |
| 1,2,3,4,7,8-HxCDF I-TEQ2 | pg/L | | 10 | 0 | 0 | NA | | | |
| 1,2,3,4,7,8-HxCDF I-TEQ3 | pg/L | | 20 | 0 | 0 | NA | | | |
| 1,2,3,4,7,8-HxCDF WHO-TEQ1 | pg/L | | 0.0 | 0 | 0 | NA | | | |
| 1,2,3,4,7,8-HxCDF WHO-TEQ2 | pg/L | | 10 | 0 | 0 | NA | | | |

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|---|---|---|---|---|---|---|---|---|---|
| 1,2,3,4,7,8-HxCDF WHO-TEQ3 | pg/L | | 20 | 0 | 0 | NA | | | |
| 1,2,3,6,7,8-HxCDD | pg/L | 20 | <200 | 10 | 0.5 | NA | | | |
| 1,2,3,6,7,8-HxCDD I-TEQ1 | pg/L | | 0.0 | 0 | 0 | NA | | | |
| 1,2,3,6,7,8-HxCDD I-TEQ2 | pg/L | | 10 | 0 | 0 | NA | | | |
| 1,2,3,6,7,8-HxCDD I-TEQ3 | pg/L | | 20 | 0 | 0 | NA | | | |
| 1,2,3,6,7,8-HxCDD WHO-TEQ1 | pg/L | | 0.0 | 0 | 0 | NA | | | |
| 1,2,3,6,7,8-HxCDD WHO-TEQ2 | pg/L | | 10 | 0 | 0 | NA | | | |
| 1,2,3,6,7,8-HxCDD WHO-TEQ3 | pg/L | | 20 | 0 | 0 | NA | | | |
| 1,2,3,6,7,8-HxCDF | pg/L | 20 | <200 | 10 | 0.5 | NA | | | |
| 1,2,3,6,7,8-HxCDF I-TEQ1 | pg/L | | 0.0 | 0 | 0 | NA | | | |
| 1,2,3,6,7,8-HxCDF I-TEQ2 | pg/L | | 10 | 0 | 0 | NA | | | |
| 1,2,3,6,7,8-HxCDF I-TEQ3 | pg/L | | 20 | 0 | 0 | NA | | | |
| 1,2,3,6,7,8-HxCDF WHO-TEQ1 | pg/L | | 0.0 | 0 | 0 | NA | | | |
| 1,2,3,6,7,8-HxCDF WHO-TEQ2 | pg/L | | 10 | 0 | 0 | NA | | | |
| 1,2,3,6,7,8-HxCDF WHO-TEQ3 | pg/L | | 20 | 0 | 0 | NA | | | |
| 1,2,3,7,8,9-HxCDD | pg/L | 20 | <200 | 10 | 0.5 | NA | | | |

| Attribute | Units | Practical quantification limit (PQL) | Raw Water Analysis 01.10.24 | Pass 1 permeate (estimated) | Pass 2 permeate (estimated) | Tox LOSP 95: threshold where permeate is non-toxic for an estimated 95% of NSW freshwater fauna<br>GREEN is compliant.<br>YELLOW is used where a threshold c<br>Issue or value is not available<br>RED is for non-compliant attributes | Short term irrigation (20 years) | Long term irrigation (100 years) | Comment |
|---|---|---|---|---|---|---|---|---|---|
| 1,2,3,7,8,9-HxCDD I-TEQ1 | pg/L | | 0.0 | 0 | 0 | NA | | | |
| 1,2,3,7,8,9-HxCDD I-TEQ2 | pg/L | | 10 | 0 | 0 | NA | | | |
| 1,2,3,7,8,9-HxCDD I-TEQ3 | pg/L | | 20 | 0 | 0 | NA | | | |
| 1,2,3,7,8,9-HxCDD WHO-TEQ1 | pg/L | | 0.0 | 0 | 0 | NA | | | |
| 1,2,3,7,8,9-HxCDD WHO-TEQ2 | pg/L | | 10 | 0 | 0 | NA | | | |
| 1,2,3,7,8,9-HxCDD WHO-TEQ3 | pg/L | | 20 | 0 | 0 | NA | | | |
| 1,2,3,7,8,9-HxCDF | pg/L | 20 | <200 | 10 | 0.5 | NA | | | |
| 1,2,3,7,8,9-HxCDF I-TEQ1 | pg/L | | 0.0 | 0 | 0 | NA | | | |
| 1,2,3,7,8,9-HxCDF I-TEQ2 | pg/L | | 10 | 0 | 0 | NA | | | |
| 1,2,3,7,8,9-HxCDF I-TEQ3 | pg/L | | 20 | 0 | 0 | NA | | | |
| 1,2,3,7,8,9-HxCDF WHO-TEQ1 | pg/L | | 0.0 | 0 | 0 | NA | | | |
| 1,2,3,7,8,9-HxCDF WHO-TEQ2 | pg/L | | 10 | 0 | 0 | NA | | | |
| 1,2,3,7,8,9-HxCDF WHO-TEQ3 | pg/L | | 20 | 0 | 0 | NA | | | |
| 1,2,3,7,8-PeCDD | pg/L | 20 | <200 | 10 | 0.5 | NA | | | |
| 1,2,3,7,8-PeCDD I-TEQ1 | pg/L | | 0.0 | 0 | 0 | NA | | | |
| 1,2,3,7,8-PeCDD I-TEQ2 | pg/L | | 50 | 0 | 0 | NA | | | |

| Attribute | Units | Practical quantification limit (PQL) | Raw Water Analysis 01.10.24 | Pass 1 permeate (estimated) | Pass 2 permeate (estimated) | Tox LOSP 95: threshold where permeate is non-toxic for an estimated 95% of NSW freshwater fauna<br>GREEN is compliant.<br>YELLOW is used where a threshold c<br>Issue or value is not available<br>RED is for non-compliant attributes | Short term irrigation (20 years) | Long term irrigation (100 years) | Comment |
|---|---|---|---|---|---|---|---|---|---|
| 1,2,3,7,8-PeCDD I-TEQ3 | pg/L | | 100 | 0 | 0 | NA | | | |
| 1,2,3,7,8-PeCDD WHO-TEQ1 | pg/L | | 0.0 | 0 | 0 | NA | | | |
| 1,2,3,7,8-PeCDD WHO-TEQ2 | pg/L | | 100 | 0 | 0 | NA | | | |
| 1,2,3,7,8-PeCDD WHO-TEQ3 | pg/L | | 200 | 0 | 0 | NA | | | |
| 1,2,3,7,8-PeCDF | pg/L | 20 | <200 | 10 | 0.5 | NA | | | |
| 1,2,3,7,8-PeCDF I-TEQ1 | pg/L | | 0.0 | 0 | 0 | NA | | | |
| 1,2,3,7,8-PeCDF I-TEQ2 | pg/L | | 5.0 | 0 | 0 | NA | | | |
| 1,2,3,7,8-PeCDF I-TEQ3 | pg/L | | 10 | 0 | 0 | NA | | | |
| 1,2,3,7,8-PeCDF WHO-TEQ1 | pg/L | | 0.0 | 0 | 0 | NA | | | |
| 1,2,3,7,8-PeCDF WHO-TEQ2 | pg/L | | 3.0 | 0 | 0 | NA | | | |
| 1,2,3,7,8-PeCDF WHO-TEQ3 | pg/L | | 6.0 | 0 | 0 | NA | | | |
| 1,2,3-trichloropropane | µg/L | 1 | <10 | 2 | 0.4 | NA | | | |
| 1,2,4-trimethyl benzene | µg/L | 1 | <10 | 2 | 0.4 | NA | | | |
| 1,2-dibromo-3-chloropropane | µg/L | 1 | <10 | 1 | 0.1 | NA | | | |
| 1,2-dibromoethane | µg/L | 1 | <10 | 1.5 | 0.225 | NA | | | |
| 1,2-dichlorobenzene | µg/L | 1 | <10 | 1.5 | 0.225 | NA | | | |
| 1,3,5-trimethyl benzene | µg/L | 1 | <10 | 2 | 0.4 | NA | | | |
| 1,3,5-Trinitrobenzene | µg/L | 1 | <10 | 10 | 10 | NA | | | |

| Attribute | Units | Practical quantification limit (PQL) | Raw Water Analysis 01.10.24 | Pass 1 permeate (estimated) | Pass 2 permeate (estimated) | Tox LOSP 95: threshold where permeate is non-toxic for an estimated 95% of NSW freshwater fauna<br>GREEN is compliant.<br>YELLOW is used where a threshold c<br>Issue or value is not available<br>RED is for non-compliant attributes | Short term irrigation (20 years) | Long term irrigation (100 years) | Comment |
|---|---|---|---|---|---|---|---|---|---|
| 10:2 FTS | µg/L | 0.002 | 0.021 | 0.0021 | 0.00021 | NA | | | |
| 13C-1,2,3,4,6,7,8-HpCDD | % | | 61.8 | | | NA | | | |
| 13C-1,2,3,4,6,7,8-HpCDF | % | | 59.6 | | | NA | | | |
| 13C-1,2,3,4,7,8,9-HpCDF | % | | 60.1 | | | NA | | | |
| 13C-1,2,3,4,7,8-HxCDD | % | | 64.3 | | | NA | | | |
| 13C-1,2,3,4,7,8-HxCDF | % | | 75.4 | | | NA | | | |
| 13C-1,2,3,6,7,8-HxCDD | % | | 66.4 | | | NA | | | |
| 13C-1,2,3,6,7,8-HxCDF | % | | 72.6 | | | NA | | | |
| 13C-1,2,3,7,8,9-HxCDF | % | | 76.8 | | | NA | | | |
| 13C-1,2,3,7,8-PeCDD | % | | 81.7 | | | NA | | | |
| 13C-1,2,3,7,8-PeCDF | % | | 74.1 | | | NA | | | |
| 13C-2,3,4,6,7,8-HxCDF | % | | 74.3 | | | NA | | | |
| 13C-2,3,4,7,8-PeCDF | % | | 76.7 | | | NA | | | |
| 13C-2,3,7,8-TCDD | % | | 71.6 | | | NA | | | |
| 13C-2,3,7,8-TCDF | % | | 74.5 | | | NA | | | |
| 13C-OCDD | % | | 49.5 | | | NA | | | |
| 17a-Estradiol | ng/L | 10 | <500 | 25 | 1.25 | NA | | | |
| 17a-ethinyl estradiol | ng/L | 5.0 | <500 | 25 | 1.25 | NA | | | |
| 17b-Estradiol | ng/L | 10 | 3200 | 10 | 0.5 | NA | | | |
| 19-Norethindrone | ng/L | 20 | <1000 | 50 | 2.5 | NA | | | |
| 1-Chloronaphthalene | µg/L | 2 | <20 | 2 | 0.2 | NA | | | |
| 1-Methylnaphthalene | µg/L | 2 | <20 | 2.4 | 0.288 | NA | | | |

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|---|---|---|---|---|---|---|---|---|---|
| 1-Naphthylamine | µg/L | 5 | <50 | 10 | 2 | NA | | | |
| 1-Octanol | % | | 111 | | | NA | | | |
| 2,2-dichloropropane | µg/L | 1 | <10 | 2.5 | 0.625 | NA | | | |
| 2,3,4,6,7,8-HxCDF | pg/L | 20 | <200 | 10 | 0.5 | NA | | | |
| 2,3,4,6,7,8-HxCDF I-TEQ1 | pg/L | | 0.0 | 0 | 0 | NA | | | |
| 2,3,4,6,7,8-HxCDF I-TEQ2 | pg/L | | 10 | 0 | 0 | NA | | | |
| 2,3,4,6,7,8-HxCDF I-TEQ3 | pg/L | | 20 | 0 | 0 | NA | | | |
| 2,3,4,6,7,8-HxCDF WHO-TEQ1 | pg/L | | 0.0 | 0 | 0 | NA | | | |
| 2,3,4,6,7,8-HxCDF WHO-TEQ2 | pg/L | | 10 | 0 | 0 | NA | | | |
| 2,3,4,6,7,8-HxCDF WHO-TEQ3 | pg/L | | 20 | 0 | 0 | NA | | | |
| 2,3,4,7,8-PeCDF | pg/L | 20 | <200 | 10 | 0.5 | NA | | | |
| 2,3,4,7,8-PeCDF I-TEQ1 | pg/L | | 0.0 | 0 | 0 | NA | | | |
| 2,3,4,7,8-PeCDF I-TEQ2 | pg/L | | 50 | 0 | 0 | NA | | | |
| 2,3,4,7,8-PeCDF I-TEQ3 | pg/L | | 100 | 0 | 0 | NA | | | |
| 2,3,4,7,8-PeCDF WHO-TEQ1 | pg/L | | 0.0 | 0 | 0 | NA | | | |
| 2,3,4,7,8-PeCDF WHO-TEQ2 | pg/L | | 30 | 0 | 0 | NA | | | |
| 2,3,4,7,8-PeCDF WHO-TEQ3 | pg/L | | 60 | 0 | 0 | NA | | | |

| Attribute | Units | Practical quantification limit (PQL) | Raw Water Analysis 01.10.24 | Pass 1 permeate (estimated) | Pass 2 permeate (estimated) | Tox LOSP 95: threshold where permeate is non-toxic for an estimated 95% of NSW freshwater fauna<br>GREEN is compliant.<br>YELLOW is used where a threshold c<br>Issue or value is not available<br>RED is for non-compliant attributes | Short term irrigation (20 years) | Long term irrigation (100 years) | Comment |
|---|---|---|---|---|---|---|---|---|---|
| 2,3,7,8-TCDD | pg/L | 5.0 | <50 | 2.5 | 0.125 | NA | | | |
| 2,3,7,8-TCDD I-TEQ1 | pg/L | | 0 | 0 | 0 | NA | | | |
| 2,3,7,8-TCDD I-TEQ2 | pg/L | | 25 | 0.25 | 0.0125 | NA | | | |
| 2,3,7,8-TCDD I-TEQ3 | pg/L | | 50 | 0 | 0 | NA | | | |
| 2,3,7,8-TCDD WHO-TEQ1 | pg/L | | 0.0 | 0 | 0 | NA | | | |
| 2,3,7,8-TCDD WHO-TEQ2 | pg/L | | 25 | 0.25 | 0.0125 | NA | | | |
| 2,3,7,8-TCDD WHO-TEQ3 | pg/L | | 50 | 0 | 0 | NA | | | |
| 2,3,7,8-TCDF | pg/L | 5.0 | <50 | | | NA | | | |
| 2,3,7,8-TCDF I-TEQ1 | pg/L | | 0.0 | 0 | 0 | NA | | | |
| 2,3,7,8-TCDF I-TEQ2 | pg/L | | 2.5 | 0.025 | 0.00125 | NA | | | |
| 2,3,7,8-TCDF I-TEQ3 | pg/L | | 5.0 | 0 | 0 | NA | | | |
| 2,3,7,8-TCDF WHO-TEQ1 | pg/L | | 0.0 | 0 | 0 | NA | | | |
| 2,3,7,8-TCDF WHO-TEQ2 | pg/L | | 2.5 | 0.025 | 0.00125 | NA | | | |
| 2,3,7,8-TCDF WHO-TEQ3 | pg/L | | 5.0 | 0 | 0 | NA | | | |
| 2,4,5-T | µg/L | 0.50 | <5.0 | 1 | 0.2 | NA | | | |
| 2,4,5-TP | µg/L | 0.50 | <5.0 | 1 | 0.2 | NA | | | |
| 2,4,5-Trichlorophenol | µg/L | 2 | <20 | 2 | 0.2 | NA | | | |
| 2,4,6-T | µg/L | 0.50 | <5.0 | 1 | 0.2 | NA | | | |
| 2,4-DB | µg/L | 0.50 | <5.0 | 1 | 0.2 | NA | | | |
| 2,4-DCPA | % | | 90.8 | | | NA | | | |
| 2,4'-DDD (op-DDD) | µg/L | 2 | <20 | 1 | 0.05 | NA | | | |

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|---|---|---|---|---|---|---|---|---|---|
| 2,4'-DDE (op-DDE) | µg/L | 2 | <20 | 1 | 0.05 | NA | | | |
| 2,4'-DDT (op-DDT) | µg/L | 2 | <20 | 1 | 0.05 | NA | | | |
| 2,4-Dimethylphenol | µg/L | 2 | <20 | 5 | 1.25 | NA | | | |
| 2,4-Dintrophenol | µg/L | 20 | <200 | 24 | 2.88 | NA | | | |
| 2-Acetylaminofluorene | µg/L | 2 | <20 | 1 | 0.05 | NA | | | |
| 2-Chloronaphthalene | µg/L | 2 | <20 | 2 | 0.2 | NA | | | |
| 2-Chlorophenoxy acetic acid | µg/L | 0.50 | <5.0 | 1 | 0.2 | NA | | | |
| 2-chlorotoluene | µg/L | 1 | <10 | 2 | 0.4 | NA | | | |
| 2-Fluorobiphenyl | % | | 120 | | | NA | | | |
| 2-Fluorobiphenyl | % | | 120 | | | NA | | | |
| 2-Fluorobiphenyl | % | | 120 | | | NA | | | |
| 2-Methylnaphthalene | µg/L | 2 | <20 | 3 | 0.45 | NA | | | |
| 2-Methylphenol (o-Cresol) | µg/L | 2 | <20 | 6 | 1.8 | NA | | | |
| 2-Naphthylamine | µg/L | 5 | <50 | 10 | 2 | NA | | | |
| 2-Nitroaniline | µg/L | 5 | <50 | 10 | 2 | NA | | | |
| 2-Nitrophenol | µg/L | 2 | <20 | 4 | 0.8 | NA | | | |
| 2-Picoline | µg/L | 2 | <20 | 6 | 1.8 | NA | | | |
| 3,5-Dichlorobenzoic acid | µg/L | 0.50 | <5.0 | 1 | 0.2 | NA | | | |
| 3,5-Dinitroaniline | µg/L | 1 | <10 | 10 | 10 | NA | | | |
| 3/4-Methylphenol (m/p-Cresol) | µg/L | 4 | 7.3 | 0.09 | 0.027 | NA | | | |
| 3-Methylcholanthrene | µg/L | 2 | <20 | 1 | 0.05 | NA | | | |
| 3-Nitroaniline | µg/L | 5 | <50 | 10 | 2 | NA | | | |

| Attribute | Units | Practical quantification limit (PQL) | Raw Water Analysis 01.10.24 | Pass 1 permeate (estimated) | Pass 2 permeate (estimated) | Tox LOSP 95: threshold where permeate is non-toxic for an estimated 95% of NSW freshwater fauna GREEN is compliant. YELLOW is used where a threshold o Issue or value is not available RED is for non-compliant attributes | Short term irrigation (20 years) | Long term irrigation (100 years) | Comment |
|---|---|---|---|---|---|---|---|---|---|
| 4-&2-AM-DNT(Isomeric Mixture) | µg/L | 2 | <20 | 20 | 20 | NA | | | |
| 4,4'-DDD (pp-DDD) | µg/L | 2 | <20 | 1 | 0.05 | NA | | | |
| 4,4'-DDE (pp-DDE) | µg/L | 2 | <20 | 1 | 0.05 | NA | | | |
| 4,4'-DDT (pp-DDT) | µg/L | 2 | <20 | 1 | 0.05 | NA | | | |
| 4,6-Dinitro-2-methylphenol | µg/L | 20 | <200 | 20 | 2 | NA | | | |
| 4:2 FTS | µg/L | 0.001 | <0.01 | 0.001 | 0.0001 | NA | | | |
| 4-Aminobiphenyl | µg/L | 5 | <50 | 7.5 | 1.125 | NA | | | |
| 4-Bromophenyl phenyl ether | µg/L | 5 | <50 | 7.5 | 1.125 | NA | | | |
| 4-Chloro-3-methylphenol | µg/L | 5 | <50 | 10 | 2 | NA | | | |
| 4-Chloroaniline | µg/L | 5 | <50 | 12.5 | 3.125 | NA | | | |
| 4-Chlorophenoxy acetic acid | µg/L | 0.50 | <5.0 | 1 | 0.2 | NA | | | |
| 4-Chlorophenyl phenyl ether | µg/L | 5 | <50 | 7.5 | 1.125 | NA | | | |
| 4-chlorotoluene | µg/L | 1 | <10 | 2 | 0.4 | NA | | | |
| 4-isopropyl toluene | µg/L | 1 | <10 | 2 | 0.4 | NA | | | |
| 4-Nitroaniline | µg/L | 5 | <50 | 10 | 2 | NA | | | |
| 4-n-nonyl phenol | ng/L | 20 | <500 | 75 | 11.25 | NA | | | |
| 4-n-octyl phenol | ng/L | 20 | <500 | 75 | 11.25 | NA | | | |
| 4-t-octyl phenol | ng/L | 20 | 1500 | 75 | 11.25 | NA | | | |
| 5-Nitro-o-toluidine | µg/L | 5 | <50 | 7.5 | 1.125 | NA | | | |
| 6:2 FTS | µg/L | 0.0004 | 0.07 | 0.007 | 0.0007 | NA | | | |

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|---|---|---|---|---|---|---|---|---|---|
| 7,12-Dimethylbenz(a)anthracene | µg/L | 2 | <20 | 1 | 0.05 | NA | | | |
| 8:2 FTS | µg/L | 0.0004 | <0.02 | 0.002 | 0.0002 | NA | | | |
| Acenaphthene | µg/L | 2 | <20 | 2 | 0.2 | NA | | | |
| Acenaphthene | µg/L | 0.1 | <1.0 | 0.2 | 0.04 | NA | | | |
| Acenaphthylene | µg/L | 2 | <20 | 2 | 0.2 | NA | | | |
| Acenaphthylene | µg/L | 0.1 | <1.0 | 0.2 | 0.04 | NA | | | |
| Acesulfame K | ng/L | 1000 | <50000 | 7500 | 1125 | NA | | | |
| Acetophenone | µg/L | 5 | <50 | 10 | 2 | NA | | | |
| Acifluorfen | µg/L | 2.0 | <20 | 4 | 0.8 | NA | | | |
| Acrylonitrile Butadiene Styrene Copolymer (ABS) | µg/L | 4 | <4 | 0.04 | 0.0004 | NA | | | |
| Alachlor | µg/L | 2 | <20 | 2 | 0.2 | NA | | | |
| alpha-BHC | µg/L | 2 | <20 | 2 | 0.2 | NA | | | |
| alpha-BHC | µg/L | 0.2 | <2.0 | 0.2 | 0.02 | NA | | | |
| Alpha-Trenbolone | % | | 96.6 | | | NA | | | |
| Alpha-Trenbolone | % | | 84.0 | | | NA | | | |
| Aluminium-Total | µg/L | 10 | 4800 | 40 | 2 | NA | | | |
| Ametryn | µg/L | 2 | <20 | 2 | 0.2 | NA | | | |
| Amitriptyline | ng/L | 500 | <25000 | 1250 | 62.5 | NA | | | |
| Androstanolone | ng/L | 200 | <10000 | 500 | 25 | NA | | | |
| Androstenedione | ng/L | 10 | <500 | 25 | 1.25 | NA | | | |
| Androsterone | ng/L | 100 | <5000 | 250 | 12.5 | NA | | | |
| Aniline | µg/L | 5 | 30 | 0 | 0 | NA | | | |

| Attribute | Units | Practical quantification limit (PQL) | Raw Water Analysis 01.10.24 | Pass 1 permeate (estimated) | Pass 2 permeate (estimated) | Tox LOSP 95: threshold where permeate is non-toxic for an estimated 95% of NSW freshwater fauna<br>GREEN is compliant.<br>YELLOW is used where a threshold c<br>Issue or value is not available<br>RED is for non-compliant attributes | Short term irrigation (20 years) | Long term irrigation (100 years) | Comment |
|---|---|---|---|---|---|---|---|---|---|
| Antimony-Total | µg/L | 1 | 26 | 0.3 | 0.015 | NA | | | |
| Aroclor 1016 | µg/L | 2 | <20 | 1 | 0.05 | NA | | | |
| Aroclor 1221 | µg/L | 2 | <20 | 2 | 0.2 | NA | | | |
| Aroclor 1232 | µg/L | 2 | <20 | 2 | 0.2 | NA | | | |
| Aroclor 1248 | µg/L | 2 | <20 | 1 | 0.05 | NA | | | |
| Aroclor 1254 | µg/L | 2 | <20 | 1 | 0.05 | NA | | | |
| Aroclor 1260 | µg/L | 2 | <20 | 1 | 0.05 | NA | | | |
| Arsenic-Total | µg/L | 1 | 430 | 43 | 4.3 | NA | | | |
| Atenolol | ng/L | 1000 | <50000 | 7500 | 1125 | NA | | | |
| Azinphos-methyl (Guthion) | µg/L | 2 | <20 | 2 | 0.2 | NA | | | |
| Azinphos-methyl (Guthion) | µg/L | 0.2 | <2.0 | 0.1 | 0.005 | NA | | | |
| Azobenzene | µg/L | 5 | <50 | 7.5 | 1.125 | NA | | | |
| Bacillus cereus | CFU/100 mL | 1 | <10000 | 100 | 1 | NA | | | |
| Barium-Dissolved | µg/L | 1 | 150 | 15 | 1.5 | NA | | | |
| Barium-Total | µg/L | 1 | 350 | 2.5 | 0.125 | NA | | | |
| Bentazon | µg/L | 1.0 | <10 | 2 | 0.4 | NA | | | |
| Benzene | µg/L | 1 | <10 | 4 | 1.6 | NA | | | |
| Benzo(a)anthracene | µg/L | 2 | <20 | 1 | 0.05 | NA | | | |
| Benzo(a)anthracene | µg/L | 0.1 | <1.0 | 0.15 | 0.0225 | NA | | | |
| Benzo(a)pyrene | µg/L | 2 | <20 | 1 | 0.05 | NA | | | |
| Benzo(b,j,k)fluoranthene | µg/L | 4 | <40 | 2 | 0.1 | NA | | | |
| Benzo(b,j+k)fluoranthene | µg/L | 0.2 | <2.0 | 0.3 | 0.045 | NA | | | |

| Attribute | Units | Practical quantification limit (PQL) | Raw Water Analysis 01.10.24 | Pass 1 permeate (estimated) | Pass 2 permeate (estimated) | Tox LOSP 95: threshold where permeate is non-toxic for an estimated 95% of NSW freshwater fauna<br>GREEN is compliant.<br>YELLOW is used where a threshold c<br>Issue or value is not available<br>RED is for non-compliant attributes | Short term irrigation (20 years) | Long term irrigation (100 years) | Comment |
|---|---|---|---|---|---|---|---|---|---|
| Benzo(e)pyrene | µg/L | 2 | <20 | 1 | 0.05 | NA | | | |
| Benzo(g,h,i)perylene | µg/L | 2 | <20 | 1 | 0.05 | NA | | | |
| Benzo(g,h,i)perylene | µg/L | 0.1 | <1.0 | 0.1 | 0.01 | NA | | | |
| Benzyl Alcohol | µg/L | 5 | <50 | 15 | 4.5 | NA | | | |
| Beryllium-Dissolved | µg/L | 0.5 | <5 | 5 | 5 | NA | | | |
| Beryllium-Total | µg/L | 0.5 | <5 | 0.25 | 0.0125 | NA | 500 | 100 | Total |
| beta-BHC | µg/L | 2 | <20 | 2 | 0.2 | NA | | | |
| beta-BHC | µg/L | 0.2 | <2.0 | 0.2 | 0.02 | NA | | | |
| Bicarbonate Alkalinity as CaCO3 | mg/L | 5 | 8700 | 35 | 1.75 | NA | | | |
| Bifenthrin | µg/L | 0.5 | <5.0 | 0.25 | 0.0125 | NA | | | |
| Bis(2-Chloroethoxy) methane | µg/L | 5 | <50 | 7.5 | 1.125 | NA | | | |
| Bis(2-chloroethyl) ether | µg/L | 5 | <50 | 7.5 | 1.125 | NA | | | |
| Bis(2-Chloroisopropyl) ether | µg/L | 5 | <50 | 7.5 | 1.125 | NA | | | |
| Bis(2-ethylhexyl)phthalate (DEHP) | µg/L | 50 | <500 | 25 | 1.25 | NA | | | |
| BOD | mg/L | 5 | 880 | 8 | 0.8 | NA | | | |
| Boron-Total | µg/L | 20 | 5600 | 3640 | 360 | NA | | | |
| Bromobenzene | µg/L | 1 | <10 | 1.5 | 0.225 | NA | | | |
| Bromochloromethane | µg/L | 1 | <10 | 2.5 | 0.625 | NA | | | |
| Bromodichloromethane | µg/L | 1 | <10 | 2 | 0.4 | NA | | | |
| Bromoform | µg/L | 1 | <10 | 1 | 0.1 | NA | | | |
| Bromomethane | µg/L | 10 | <100 | 30 | 9 | NA | | | |
| Bromophos ethyl | µg/L | 0.2 | <2.0 | 0.1 | 0.005 | NA | | | |

| Attribute | Units | Practical quantification limit (PQL) | Raw Water Analysis 01.10.24 | Pass 1 permeate (estimated) | Pass 2 permeate (estimated) | Tox LOSP 95: threshold where permeate is non-toxic for an estimated 95% of NSW freshwater fauna<br>GREEN is compliant.<br>YELLOW is used where a threshold c<br>Issue or value is not available<br>RED is for non-compliant attributes | Short term irrigation (20 years) | Long term irrigation (100 years) | Comment |
|---|---|---|---|---|---|---|---|---|---|
| Bromophos-ethyl | µg/L | 2 | <20 | 2 | 0.2 | NA | | | |
| Bromoxynil | µg/L | 0.50 | <5.0 | 1 | 0.2 | NA | | | |
| Bupropion | ng/L | 50 | <2500 | 375 | 56.25 | NA | | | |
| Butanol | µg/L | 50 | <500 | 350 | 245 | NA | | | |
| Butyl benzyl phthalate | µg/L | 10 | <100 | 5 | 0.25 | NA | | | |
| Cadmium-Total | µg/L | 0.1 | 20 | 2 | 0.2 | NA | | | |
| Caffeine | ng/L | 100 | 28000 | 1600 | 320 | NA | | | |
| Campylobacter sp | | | Not Detected | | | NA | | | |
| Carbamazepine | ng/L | 10 | 840 | 6 | 0.9 | NA | | | |
| Carbaryl | µg/L | 0.5 | <5.0 | 0.75 | 0.1125 | NA | | | |
| Carbazole | µg/L | 5 | <50 | 7.5 | 1.125 | NA | | | |
| Carbonate Alkalinity as CaCO3 | mg/L | 5 | 2300 | 15 | 0.75 | NA | | | |
| Carbophenothion | µg/L | 2 | <20 | 2 | 0.2 | NA | | | |
| Chloramben | µg/L | 1.0 | <10 | 2 | 0.4 | NA | | | |
| Chloramine* | mg/L | 0.1 | <10 | 0 | 0 | NA | | | |
| Chloride, Cl | mg/L | 1 | 2600 | 30 | 1.5 | NA | | | |
| Chlorobenzene | µg/L | 1 | <10 | 2 | 0.4 | NA | | | |
| Chloroethane | µg/L | 10 | <100 | 35 | 12.25 | NA | | | |
| Chloromethane | µg/L | 10 | <100 | 40 | 16 | NA | | | |
| Chloromethyliso thiazolinone (MCI or CMIT) | ng/L | 1000 | <50000 | 20000 | 8000 | NA | | | |
| Chlorpyrifos-methyl | µg/L | 2 | <20 | 2 | 0.2 | NA | | | |
| Chlorpyriphos-methyl | µg/L | 0.2 | <2.0 | 0.1 | 0.005 | NA | | | |

| Attribute | Units | Practical quantification limit (PQL) | Raw Water Analysis 01.10.24 | Pass 1 permeate (estimated) | Pass 2 permeate (estimated) | Tox LOSP 95: threshold where permeate is non-toxic for an estimated 95% of NSW freshwater fauna GREEN is compliant. YELLOW is used where a threshold c Issue or value is not available RED is for non-compliant attributes | Short term irrigation (20 years) | Long term irrigation (100 years) | Comment |
|---|---|---|---|---|---|---|---|---|---|
| Chrysene | µg/L | 2 | <20 | 1 | 0.05 | NA | | | |
| Chrysene | µg/L | 0.1 | <1.0 | 0.15 | 0.0225 | NA | | | |
| Cis-1,2-dichloroethene | µg/L | 1 | <10 | 2.5 | 0.625 | NA | | | |
| cis-1,3-dichloropropene | µg/L | 1 | <10 | 2.5 | 0.625 | NA | | | |
| cis-Chlorfenvinphos | µg/L | 2 | <20 | 2 | 0.2 | NA | | | |
| cis-Permethrin | µg/L | 0.5 | <5.0 | 0.25 | 0.0125 | NA | | | |
| Clopyralid | µg/L | 0.50 | <10 | 2 | 0.4 | NA | | | |
| Clostridium perfringens | Spores/100mL | 1 | 24000 | 40 | 0.4 | NA | | | |
| Coronene | µg/L | 2 | <20 | 1 | 0.05 | NA | | | |
| Coumaphos | µg/L | 2 | <20 | 2 | 0.2 | NA | | | |
| Coumaphos | µg/L | 0.2 | <2.0 | 0.1 | 0.005 | NA | | | |
| Cyanazine | µg/L | 2 | <20 | 2 | 0.2 | NA | | | |
| Cyclohexane | µg/L | 1 | <10 | 3 | 0.9 | NA | | | |
| Cyclohexanone | µg/l | 2 | <20 | 5 | 1.25 | NA | | | |
| Cyfluthrin | µg/L | 2 | <20 | 1 | 0.05 | NA | | | |
| Cypermethrin | µg/L | 2 | <20 | 1 | 0.05 | NA | | | |
| Cyproconazole 1&2 | ng/L | 50 | <5000 | 250 | 12.5 | NA | | | |
| DecaBDE (Br10) | µg/L | 1 | <1 | 1 | 1 | NA | | | |
| delta-BHC | µg/L | 2 | <20 | 2 | 0.2 | NA | | | |
| delta-BHC | µg/L | 0.2 | <2.0 | 0.2 | 0.02 | NA | | | |
| Demeton-S-methyl | µg/L | 2 | <20 | 2 | 0.2 | NA | | | |
| Desipramine | ng/L | 500 | <25000 | 1250 | 62.5 | NA | | | |
| Di(2-ethylhexyl)adipate (DEHA) | µg/L | 50 | <500 | 25 | 1.25 | NA | | | |
| DiBDE (Br2) | µg/L | 0.1 | <0.1 | 0.1 | 0.1 | NA | | | |

| Attribute | Units | Practical quantification limit (PQL) | Raw Water Analysis 01.10.24 | Pass 1 permeate (estimated) | Pass 2 permeate (estimated) | Tox LOSP 95: threshold where permeate is non-toxic for an estimated 95% of NSW freshwater fauna<br>GREEN is compliant.<br>YELLOW is used where a threshold o<br>Issue or value is not available<br>RED is for non-compliant attributes | Short term irrigation (20 years) | Long term irrigation (100 years) | Comment |
|---|---|---|---|---|---|---|---|---|---|
| Dibenzo(a,h)anthracene | µg/L | 2 | <20 | 1 | 0.05 | NA | | | |
| Dibenzo(a,h)anthracene | µg/L | 0.1 | <1.0 | 0.1 | 0.01 | NA | | | |
| Dibenzofuran | µg/L | 5 | <50 | 10 | 2 | NA | | | |
| Dibromochloromethane | µg/L | 1 | <10 | 1.5 | 0.225 | NA | | | |
| Dibromomethane | µg/L | 1 | <10 | 2 | 0.4 | NA | | | |
| Dibutyltin | µg/L | 0.010 | Not detectable | | | NA | | | |
| Dicamba | µg/L | 0.50 | <10 | 2 | 0.4 | NA | 0.006 | | Well below PQL limit |
| Dichlorodifluoromethane | µg/L | 10 | <100 | 30 | 9 | NA | | | |
| Dichloromethylisothiazolinone (DCMIT) | ng/L | 500 | <25000 | 5000 | 1000 | NA | | | |
| Dichlorprop | µg/L | 0.50 | <5.0 | 1 | 0.2 | NA | | | |
| Dichlorvos | µg/L | 2 | <20 | 3 | 0.45 | NA | | | |
| Dichlorvos | µg/L | 0.2 | <2.0 | 0.1 | 0.005 | NA | | | |
| Diclofenac | ng/L | 50 | 7800 | 40 | 2 | NA | | | |
| Dieldrin | µg/L | 2 | <20 | 1 | 0.05 | NA | | | |
| Dieldrin | µg/L | 0.2 | <2.0 | 0.1 | 0.005 | NA | | | |
| Diethylstilbestrol (synthetic) | ng/L | 10 | <500 | 25 | 1.25 | NA | | | |
| Difenoconazole | ng/L | 200 | <20000 | 1000 | 50 | NA | | | |
| Dimethoate | µg/L | 0.2 | <2.0 | 0.1 | 0.005 | NA | | | |
| Dinoseb | µg/L | 20 | <200 | 20 | 2 | NA | | | |
| Dinoseb | µg/L | 1.0 | <10 | 2 | 0.4 | NA | | | |

| Attribute | Units | Practical quantification limit (PQL) | Raw Water Analysis 01.10.24 | Pass 1 permeate (estimated) | Pass 2 permeate (estimated) | Tox LOSP 95: threshold where permeate is non-toxic for an estimated 95% of NSW freshwater fauna<br>GREEN is compliant.<br>YELLOW is used where a threshold of Issue or value is not available<br>RED is for non-compliant attributes | Short term irrigation (20 years) | Long term irrigation (100 years) | Comment |
|---|---|---|---|---|---|---|---|---|---|
| Diphenylamine | µg/L | 5 | <50 | 7.5 | 1.125 | NA | | | |
| Disulfoton | µg/L | 2 | <20 | 2 | 0.2 | NA | | | |
| Disulfoton | µg/L | 0.2 | <2.0 | 0.1 | 0.005 | NA | | | |
| Duloxetine | ng/L | 1000 | <50000 | 2500 | 125 | NA | | | |
| e-Caprolactam | µg/L | 5 | <50 | 15 | 4.5 | NA | | | |
| Endrin Aldehyde | µg/L | 2 | <20 | 1 | 0.05 | NA | | | |
| Endrin Aldehyde | µg/L | 0.2 | <2.0 | 0.1 | 0.005 | NA | | | |
| Endrin Ketone | µg/L | 2 | <20 | 1 | 0.05 | NA | | | |
| EPN | µg/L | 2 | <20 | 2 | 0.2 | NA | | | |
| Epoxiconazole | ng/L | 50 | <5000 | 250 | 12.5 | NA | | | |
| Equilenin | ng/L | 10 | <500 | 25 | 1.25 | NA | | | |
| Equilin | ng/L | 10 | <500 | 25 | 1.25 | NA | | | |
| Escitalopram Oxalate | ng/L | 50 | <2500 | 2500 | 2500 | NA | | | |
| Esfenvalerate I | µg/L | 0.5 | <5.0 | 0.25 | 0.0125 | NA | | | |
| Estriol | ng/L | 5.0 | <6500 | 325 | 16.25 | NA | | | |
| Estrone | ng/L | 5.0 | <250 | 12.5 | 0.625 | NA | | | |
| Ethion | µg/L | 2 | <20 | 2 | 0.2 | NA | | | |
| Ethion | µg/L | 0.2 | <2.0 | 0.1 | 0.005 | NA | | | |
| Ethoprophos | µg/L | 2 | <20 | 2 | 0.2 | NA | | | |
| Ethyl Methanesulfonate | µg/L | 5 | <50 | 12.5 | 3.125 | NA | | | |
| Etiocholanolone | ng/L | 50 | <15000 | 750 | 37.5 | NA | | | |
| EtPerfluorooctanesulf-amid oacetic acid | µg/L | 0.002 | <0.02 | 0.002 | 0.0002 | NA | | | |
| Extracted ISTD 13C2 4:2FTS | % | | 65 | | | NA | | | |

| Attribute | Units | Practical quantification limit (PQL) | Raw Water Analysis 01.10.24 | Pass 1 permeate (estimated) | Pass 2 permeate (estimated) | Tox LOSP 95: threshold where permeate is non-toxic for an estimated 95% of NSW freshwater fauna<br>GREEN is compliant.<br>YELLOW is used where a threshold c<br>Issue or value is not available<br>RED is for non-compliant attributes | Short term irrigation (20 years) | Long term irrigation (100 years) | Comment |
|---|---|---|---|---|---|---|---|---|---|
| Extracted ISTD 13C2 8:2FTS | % | | 104 | | | NA | | | |
| Extracted ISTD 13C2 PFDA | % | | 62 | | | NA | | | |
| Extracted ISTD 13C2 PFDoDA | % | | 65 | | | NA | | | |
| Extracted ISTD 13C2 PFHxA | % | | 38 | | | NA | | | |
| Extracted ISTD 13C2 PFTeDA | % | | 53 | | | NA | | | |
| Extracted ISTD 13C2 PFUnDA | % | | 63 | | | NA | | | |
| Extracted ISTD 13C3 PFBS | % | | 60 | | | NA | | | |
| Extracted ISTD 13C3 PFPeA | % | | 79 | | | NA | | | |
| Extracted ISTD 13C4 PFBA | % | | 41 | | | NA | | | |
| Extracted ISTD 13C4 PFHpA | % | | 43 | | | NA | | | |
| Extracted ISTD 13C4 PFOA | % | | 54 | | | NA | | | |
| Extracted ISTD 13C4 PFOS | % | | 73 | | | NA | | | |
| Extracted ISTD 13C5 PFNA | % | | 55 | | | NA | | | |
| Extracted ISTD 13C8 FOSA | % | | 61 | | | NA | | | |
| Extracted ISTD 18O2 PFHxS | % | | 69 | | | NA | | | |

| Attribute | Units | Practical quantification limit (PQL) | Raw Water Analysis 01.10.24 | Pass 1 permeate (estimated) | Pass 2 permeate (estimated) | Tox LOSP 95: threshold where permeate is non-toxic for an estimated 95% of NSW freshwater fauna GREEN is compliant. YELLOW is used where a threshold or Issue or value is not available RED is for non-compliant attributes | Short term irrigation (20 years) | Long term irrigation (100 years) | Comment |
|---|---|---|---|---|---|---|---|---|---|
| Extracted ISTD d3 N MeFOSA | % | | 61 | | | NA | | | |
| Extracted ISTD d3 N MeFOSAA | % | | 70 | | | NA | | | |
| Extracted ISTD d5 N EtFOSA | % | | 55 | | | NA | | | |
| Extracted ISTD d5 N EtFOSAA | % | | 85 | | | NA | | | |
| Extracted ISTD d7 N MeFOSE | % | | 56 | | | NA | | | |
| Extracted ISTD d9 N EtFOSE | % | | 68 | | | NA | | | |
| Fenamiphos | µg/L | 2 | <20 | 2 | 0.2 | NA | | | |
| Fenamiphos | µg/L | 0.2 | <2.0 | 0.1 | 0.005 | NA | | | |
| Fenbuconazole | ng/L | 50 | <5000 | 250 | 12.5 | NA | | | |
| Fenitrothion | µg/L | 2 | <20 | 2 | 0.2 | NA | | | |
| Fenitrothion | µg/L | 0.2 | <2.0 | 0.1 | 0.005 | NA | | | |
| Fensulfothion | µg/L | 2 | <20 | 2 | 0.2 | NA | | | |
| Fenthion | µg/L | 2 | <20 | 2 | 0.2 | NA | | | |
| Fenthion | µg/L | 0.2 | <2.0 | 0.1 | 0.005 | NA | | | |
| Fluorene | µg/L | 2 | <20 | 2 | 0.2 | NA | | | |
| Fluorene | µg/L | 0.1 | <1.0 | 0.2 | 0.04 | NA | | | |
| Fluoxetine | ng/L | 50 | <2500 | 125 | 6.25 | NA | | | |
| Fluquinconazole | ng/L | 500 | <50000 | 2500 | 125 | NA | | | |
| Fluroxypyr | µg/L | 1.0 | <10 | 2 | 0.4 | NA | | | |
| Flusilazole | ng/L | 50 | <5000 | 250 | 12.5 | NA | | | |

| Attribute | Units | Practical quantification limit (PQL) | Raw Water Analysis 01.10.24 | Pass 1 permeate (estimated) | Pass 2 permeate (estimated) | Tox LOSP 95: threshold where permeate is non-toxic for an estimated 95% of NSW freshwater fauna<br>GREEN is compliant.<br>YELLOW is used where a threshold c<br>Issue or value is not available<br>RED is for non-compliant attributes | Short term irrigation (20 years) | Long term irrigation (100 years) | Comment |
|---|---|---|---|---|---|---|---|---|---|
| Formaldehyde in waters | µg/L | 10 | 420 | 16 | 12.8 | NA | | | |
| Gabapentin | ng/L | 500 | <25000 | 5000 | 1000 | NA | | | |
| Galaxolide | ng/L | 100 | 1200 | 10 | 0.5 | NA | | | |
| gamma-BHC | µg/L | 0.2 | <2.0 | 0.2 | 0.02 | NA | | | |
| Gemfibrozil | ng/L | 20 | 800 | 0 | 0 | NA | | | |
| Hardness - Total (calc) equiv CaCO3 | mg/L | 3 | 1100 | 5 | 0.25 | NA | <60 mg/L CaCO3 | | increased risk of corrosion |
| Hardness (calc) equivalent CaCO3 | mg/L | 3 | 760 | 36 | 21.6 | NA | | | |
| HCB | µg/L | 0.2 | <2.0 | 0.2 | 0.02 | NA | | | |
| HeptaBDE (Br7) | µg/L | 0.2 | <0.2 | 0.2 | 0.2 | NA | | | |
| Heptachlor Epoxide | µg/L | 2 | <20 | 1 | 0.05 | NA | | | |
| Heptachlor Epoxide | µg/L | 0.2 | <2.0 | 0.1 | 0.005 | NA | | | |
| HexaBDE (Br6) | µg/L | 0.2 | <0.2 | 0.2 | 0.2 | NA | | | |
| Hexachlorobutadiene | µg/L | 1 | <10 | 1 | 0.1 | NA | | | |
| Hexachlorobutadiene | µg/L | 2 | <20 | 1 | 0.05 | NA | | | |
| Hexachlorocyclopentadiene | µg/L | 5 | <50 | 2.5 | 0.125 | NA | | | |
| Hexachloropropene | µg/L | 2 | <20 | 2 | 0.2 | NA | | | |
| Hexazinone | µg/L | 2 | <20 | 2 | 0.2 | NA | | | |
| HMX | µg/L | 1 | <10 | 10 | 10 | NA | | | |
| Hydroxide Alkalinity (OH-) as CaCO3 | mg/L | 5 | <5 | 0.25 | 0.0125 | NA | | | |
| Ibuprofen | ng/L | 20 | 3600 | 90 | 13.5 | NA | | | |
| Imipramine | ng/L | 1000 | <50000 | 2500 | 125 | NA | | | |

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|---|---|---|---|---|---|---|---|---|---|
| Indeno(1,2,3-c,d)pyrene | µg/L | 2 | <20 | 1 | 0.05 | NA | | | |
| Indeno(1,2,3-c,d)pyrene | µg/L | 0.1 | <1.0 | 0.1 | 0.01 | NA | | | |
| Ioxynil | µg/L | 1.0 | <10 | 2 | 0.4 | NA | | | |
| Irgarol (Cybutryn) | µg/L | 2 | <20 | 2 | 0.2 | NA | | | |
| Iron-Dissolved | µg/L | 10 | 15000 | 1500 | 150 | NA | | | |
| Iron-Total | µg/L | 10 | 25000 | 2500 | 250 | NA | 10000 | 2000 | Total |
| Isobutyl Alcohol | µg/L | 50 | <500 | 350 | 245 | NA | | | |
| Isodrin | µg/L | 2 | <20 | 2 | 0.2 | NA | | | |
| Isophorone | µg/L | 5 | <50 | 10 | 2 | NA | | | |
| Isosafrole (cis+trans) | µg/L | 10 | <10 | 2 | 0.4 | NA | | | |
| lamda-Cyhalothrin | µg/L | 0.5 | <5.0 | 0.25 | 0.0125 | NA | | | |
| Levonorgestrel (isomer of Norgestrel) | ng/L | 10 | <500 | 25 | 1.25 | NA | | | |
| Lithium-Dissolved | µg/L | 1 | 230 | 23 | 2.3 | NA | | | |
| Lithium-Total | µg/L | 1 | 280 | 28 | 2.8 | NA | 75 to 2500 | 75 (citrus only) | OK for irrigation |
| m+p-xylene | µg/L | 2 | <20 | 6 | 1.8 | NA | | | |
| Magnesium - Dissolved | mg/L | 0.5 | 150 | 2.5 | 0.125 | NA | | | |
| Magnesium - Total | mg/L | 0.5 | 190 | 4.5 | 0.225 | NA | | | |
| MCPB | µg/L | 0.50 | <5.0 | 1 | 0.2 | NA | | | |
| Mecoprop | µg/L | 0.50 | 8.7 | 0.14 | 0.028 | NA | | | |
| MePerfluorooctanesulf-amid oacetic acid | µg/L | 0.002 | 0.031 | 0.0031 | 0.00031 | NA | | | |
| Mestranol | ng/L | 10 | <2500 | 125 | 6.25 | NA | | | |
| Methanol | µg/L | 200 | <2000 | 1400 | 980 | NA | | | |

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|---|---|---|---|---|---|---|---|---|---|
| Methapyrilene | µg/L | 10 | <100 | 10 | 1 | NA | | | |
| Methidathion | µg/L | 2 | <20 | 2 | 0.2 | NA | | | |
| Methidathion | µg/L | 0.2 | <2.0 | 0.1 | 0.005 | NA | | | |
| Methyl Methanesulfonate | µg/L | 2 | <20 | 5 | 1.25 | NA | | | |
| Methylisothiazolinone (MIT) | ng/L | 1000 | <50000 | 20000 | 8000 | NA | | | |
| Metribuzin | µg/L | 2 | <20 | 2 | 0.2 | NA | | | |
| Mevinphos | µg/L | 2 | <20 | 3 | 0.45 | NA | | | |
| Mevinphos | µg/L | 0.2 | <2.0 | 0.1 | 0.005 | NA | | | |
| Mirtazapine | ng/L | 1000 | <50000 | 2500 | 125 | NA | | | |
| MonoBDE (Br1) | µg/L | 0.1 | <0.1 | 0.1 | 0.1 | NA | | | |
| Monobutyltin | µg/L | 0.020 | Not detected | | | NA | | | |
| Monobutyltin as Sn | µg/L | 0.020 | <0.20 | 0.02 | 0.002 | NA | | | |
| Monocrotophos | µg/L | 2 | <20 | 2 | 0.2 | NA | | | |
| Mould | CFU/100 mL | 1 | <100 | 1 | 0.01 | NA | | | |
| Naproxen | ng/L | 20 | <500 | 75 | 11.25 | NA | | | |
| n-butyl benzene | µg/L | 1 | <10 | 2 | 0.4 | NA | | | |
| N-Et perfluorooctanesulfonamid oethanol | µg/L | 0.5 | <0.5 | 0.05 | 0.005 | NA | | | |
| N-Ethyl perfluorooctanesulfonamide | µg/L | 0.1 | <0.1 | 0.01 | 0.001 | NA | | | |

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|---|---|---|---|---|---|---|---|---|---|
| Nitroglycerine | µg/L | 1 | <10 | 1 | 0.1 | NA | | | |
| N-Me perfluoro Ctanesulfonamid oethanol | µg/L | 0.05 | 0.1 | 0.01 | 0.001 | NA | | | |
| N-Methyl Perfluorooctane sulfonamide | µg/L | 0.05 | <0.05 | 0.005 | 0.0005 | NA | NA | | |
| N-Nitrosodiethylamine (NDEA) | µg/L | 5 | <50 | 20 | 8 | NA | | | |
| N-Nitrosodi-n-propylamine (NDPA) | µg/L | 5 | <50 | 20 | 8 | NA | | | |
| N-Nitrosomethylethylamine (NMEA) | µg/L | 5 | <50 | 20 | 8 | NA | | | |
| N-Nitrosomorpholine (NMOR) | µg/L | 5 | <50 | 20 | 8 | NA | | | |
| N-Nitroso-n-butylamine (NDBA) | µg/L | 5 | <50 | 20 | 8 | NA | | | |
| N-Nitrosopiperidine (NPIP) | µg/L | 5 | <50 | 20 | 8 | NA | | | |
| N-Nitrosopyrolidine (NPYR) | µg/L | 5 | <50 | 20 | 8 | NA | | | |
| NonaBDE (Br9) | µg/L | 0.5 | <0.5 | 0.5 | 0.5 | NA | | | |
| Nortriptyline | ng/L | 20 | <1000 | 50 | 2.5 | NA | | | |
| n-propyl benzene | µg/L | 1 | <10 | 2 | 0.4 | NA | | | |
| Nylon-6 (N-6) | µg/L | 2 | <2 | 0.02 | 0.0002 | NA | | | |
| Nylon-6,6 (N-66) | µg/L | 6 | <6 | 0.06 | 0.0006 | NA | | | |

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|---|---|---|---|---|---|---|---|---|---|
| OCDD | pg/L | 50 | 4900 | 45 | 2.25 | NA | | | |
| OCDD I-TEQ1 | pg/L | | 4.9 | 0.045 | 0.00225 | NA | | | |
| OCDD I-TEQ2 | pg/L | | 4.9 | 0.045 | 0.00225 | NA | | | |
| OCDD I-TEQ3 | pg/L | | 4.9 | 0.045 | 0.00225 | NA | | | |
| OCDD WHO-TEQ1 | pg/L | | 1.5 | 0.025 | 0.00125 | NA | | | |
| OCDD WHO-TEQ2 | pg/L | | 1.5 | 0.025 | 0.00125 | NA | | | |
| OCDD WHO-TEQ3 | pg/L | | 1.5 | 0.025 | 0.00125 | NA | | | |
| OCDF | pg/L | 50 | <500 | 25 | 1.25 | NA | | | |
| OCDF I-TEQ1 | pg/L | | 0.0 | 0 | 0 | NA | | | |
| OCDF I-TEQ2 | pg/L | | 0.25 | 0.0125 | 0.000625 | NA | | | |
| OCDF I-TEQ3 | pg/L | | 0.50 | 0.025 | 0.00125 | NA | | | |
| OCDF WHO-TEQ1 | pg/L | | 0.0 | 0 | 0 | NA | | | |
| OCDF WHO-TEQ2 | pg/L | | 0.075 | 0.00375 | 0.0001875 | NA | | | |
| OCDF WHO-TEQ3 | pg/L | | 0.15 | 0.0075 | 0.000375 | NA | | | |
| OctaBDE (Br8) | µg/L | 0.2 | <0.2 | 0.2 | 0.2 | NA | | | |
| Octinoxate | ng/L | 50 | <500 | 25 | 1.25 | NA | | | |
| Octocrylene | ng/L | 100 | 9600 | 30 | 1.5 | NA | | | |
| o-desmethylvenlafaxine | ng/L | 20 | 6500 | 25 | 1.25 | NA | | | |
| Oil & Grease (LLE) | mg/L | 5 | <10 | 0.5 | 0.025 | NA | | | |
| Oxybenzone | ng/L | 50 | <500 | 75 | 11.25 | NA | | | |
| Paracetamol (Acetaminophen) | ng/L | 200 | <10000 | 2000 | 400 | NA | | | |
| Parathion-methyl | µg/L | 2 | <20 | 2 | 0.2 | NA | | | |
| Parathion-Methyl | µg/L | 0.2 | <2.0 | 0.1 | 0.005 | NA | | | |
| Paroxetine | ng/L | 5000 | <250000 | 12500 | 625 | NA | | | |

| Attribute | Units | Practical quantification limit (PQL) | Raw Water Analysis 01.10.24 | Pass 1 permeate (estimated) | Pass 2 permeate (estimated) | Tox LOSP 95: threshold where permeate is non-toxic for an estimated 95% of NSW freshwater fauna<br>GREEN is compliant.<br>YELLOW is used where a threshold c Issue or value is not available<br>RED is for non-compliant attributes | Short term irrigation (20 years) | Long term irrigation (100 years) | Comment |
|---|---|---|---|---|---|---|---|---|---|
| PCB C101 | µg/L | 0.5 | <5.0 | 0.25 | 0.0125 | NA | | | |
| PCB C118 | µg/L | 0.5 | <5.0 | 0.25 | 0.0125 | NA | | | |
| PCB C138 | µg/L | 0.5 | <5.0 | 0.25 | 0.0125 | NA | | | |
| PCB C153 | µg/L | 0.5 | <5.0 | 0.25 | 0.0125 | NA | | | |
| PCB C180 | µg/L | 0.5 | <5.0 | 0.25 | 0.0125 | NA | | | |
| PCB C28 | µg/L | 1 | <10 | 1 | 0.1 | NA | | | |
| PCB C52 | µg/L | 1 | <10 | 0.5 | 0.025 | NA | | | |
| p-cumylphenol | ng/L | 20 | 1700 | 105 | 15.75 | NA | | | |
| p-Dimethylaminoazobenzene | µg/L | 5 | <50 | 7.5 | 1.125 | NA | | | |
| Penconazole | ng/L | 50 | <5000 | 750 | 112.5 | NA | | | |
| PentaBDE (Br5) | µg/L | 0.2 | <0.2 | 0.2 | 0.2 | NA | | | |
| Pentachloronitrobenzene | µg/L | 5 | <50 | 7.5 | 1.125 | NA | | | |
| Perfluorobutanesulfonic acid | µg/L | 0.0004 | 22 | 0.2 | 0.02 | NA | | | |
| Perfluorobutanoic acid | µg/L | 0.002 | 0.51 | 0.051 | 0.0051 | NA | | | |
| Perfluorodecanesulfonic acid | µg/L | 0.002 | <0.02 | 0.002 | 0.0002 | NA | | | |
| Perfluorodecanoic acid | µg/L | 0.002 | 0.046 | 0.0046 | 0.00046 | NA | | | |
| Perfluorododecanoic acid | µg/L | 0.005 | <0.05 | 0.005 | 0.0005 | NA | | | |
| Perfluoroheptanesulfonic acid | µg/L | 0.001 | <0.01 | 0.001 | 0.0001 | NA | | | |
| Perfluoroheptanoic acid | µg/L | 0.0004 | <0.01 | 0.001 | 0.0001 | NA | | | |
| Perfluorohexanesulfonic acid - PFHxS | µg/L | 0.0002 | 0.078 | 0.0078 | 0.00078 | NA | | | |

| Attribute | Units | Practical quantification limit (PQL) | Raw Water Analysis 01.10.24 | Pass 1 permeate (estimated) | Pass 2 permeate (estimated) | Tox LOSP 95: threshold where permeate is non-toxic for an estimated 95% of NSW freshwater fauna<br>GREEN is compliant.<br>YELLOW is used where a threshold c<br>Issue or value is not available<br>RED is for non-compliant attributes | Short term irrigation (20 years) | Long term irrigation (100 years) | Comment |
|---|---|---|---|---|---|---|---|---|---|
| Perfluorohexanoic acid | µg/L | 0.0004 | 2.8 | 0.08 | 0.008 | NA | | | |
| Perfluorononanoic acid | µg/L | 0.001 | 0.012 | 0.0012 | 0.00012 | NA | | | |
| Perfluorooctane sulfonamide | µg/L | 0.01 | <0.1 | 0.01 | 0.001 | NA | | | |
| Perfluorooctanesulfonic acid PFOS | µg/L | 0.0002 | 0.17 | 0.017 | 0.0017 | NA | | | |
| Perfluorooctanoic acid PFOA | µg/L | 0.0002 | 0.068 | 0.0068 | 0.00068 | NA | | | |
| Perfluoropentanesulfonic acid | µg/L | 0.001 | <0.01 | 0.001 | 0.0001 | NA | | | |
| Perfluoropentanoic acid | µg/L | 0.002 | 0.7 | 0.07 | 0.007 | NA | | | |
| Perfluorotetradecanoic acid | µg/L | 0.05 | <0.5 | 0.05 | 0.005 | NA | | | |
| Perfluorotridecanoic acid | µg/L | 0.01 | <0.1 | 0.01 | 0.001 | NA | | | |
| Perfluoroundecanoic acid | µg/L | 0.002 | <0.02 | 0.002 | 0.0002 | NA | | | |
| Perylene | µg/L | 2 | <20 | 1 | 0.05 | NA | | | |
| PETN | µg/L | 1 | <10 | 10 | 10 | NA | | | |
| Phenacetin | µg/L | 5 | <50 | 7.5 | 1.125 | NA | | | |
| Phorate | µg/L | 2 | <20 | 2 | 0.2 | NA | | | |
| Phorate | µg/L | 0.2 | <2.0 | 0.1 | 0.005 | NA | | | |
| Phosalone | µg/L | 2 | <20 | 2 | 0.2 | NA | | | |
| Phosalone | µg/L | 0.2 | <2.0 | 0.1 | 0.005 | NA | | | |
| Phosmet | µg/L | 2 | <20 | 2 | 0.2 | NA | | | |
| Pirimiphos-ethyl | µg/L | 2 | <20 | 2 | 0.2 | NA | | | |
| Pirimiphos-methyl | µg/L | 2 | <20 | 2 | 0.2 | NA | | | |

| Attribute | Units | Practical quantification limit (PQL) | Raw Water Analysis 01.10.24 | Pass 1 permeate (estimated) | Pass 2 permeate (estimated) | Tox LOSP 95: threshold where permeate is non-toxic for an estimated 95% of NSW freshwater fauna<br>GREEN is compliant.<br>YELLOW is used where a threshold c Issue or value is not available<br>RED is for non-compliant attributes | Short term irrigation (20 years) | Long term irrigation (100 years) | Comment |
|---|---|---|---|---|---|---|---|---|---|
| Polycarbonate (PC) | µg/L | 3 | <3 | 0.03 | 0.0003 | NA | | | |
| Polyethylene (PE) | µg/L | 18 | <18 | 0.18 | 0.0018 | NA | | | |
| Polyethylene Terephthalate (PET) | µg/L | 6 | <6 | 0.06 | 0.0006 | NA | | | |
| Polymethyl Methacrylate (PMMA) | µg/L | 3 | <3 | 0.03 | 0.0003 | NA | | | |
| Polypropylene (PP) | µg/L | 8 | <8 | 0.08 | 0.0008 | NA | | | |
| Polystyrene (PS) | µg/L | 2 | <2 | 0.02 | 0.0002 | NA | | | |
| Polyurethane (PU) | µg/L | 1 | <1 | 0.01 | 0.0001 | NA | | | |
| Polyvinyl Chloride (PVC) | µg/L | 10 | <10 | 0.1 | 0.001 | NA | | | |
| Potassium - Dissolved | mg/L | 0.5 | 1100 | 6 | 0.36 | NA | | | |
| Potassium - Total | mg/L | 0.5 | 1000 | 0 | 0 | NA | | | |
| pp-DDD | µg/L | 0.2 | <2.0 | 0.1 | 0.005 | NA | | | |
| pp-DDE | µg/L | 0.2 | <2.0 | 0.2 | 0.02 | NA | | | |
| Progesterone | ng/L | 5.0 | <250 | 12.5 | 0.625 | NA | | | |
| Prometryn | µg/L | 2 | <20 | 2 | 0.2 | NA | | | |
| Propazine | µg/L | 2 | <20 | 2 | 0.2 | NA | | | |
| Propiconazole A | µg/L | 2 | <20 | 1 | 0.05 | NA | | | |
| Propiconazole B | µg/L | 2 | <20 | 1 | 0.05 | NA | | | |
| Propranolol | ng/L | 1000 | <50000 | 7500 | 1125 | NA | | | |
| Propyl Alcohol | µg/L | 50 | <500 | 350 | 245 | NA | | | |
| Prothiophos | µg/L | 2 | <20 | 2 | 0.2 | NA | | | |
| Pyrene | µg/L | 2 | <20 | 1 | 0.05 | NA | | | |
| Pyrene | µg/L | 0.1 | <1.0 | 0.15 | 0.0225 | NA | | | |
| Ranitidine | ng/L | 10 | <500 | 75 | 11.25 | NA | | | |

| Attribute | Units | Practical quantification limit (PQL) | Raw Water Analysis 01.10.24 | Pass 1 permeate (estimated) | Pass 2 permeate (estimated) | Tox LOSP 95: threshold where permeate is non-toxic for an estimated 95% of NSW freshwater fauna<br>GREEN is compliant.<br>YELLOW is used where a threshold c<br>Issue or value is not available<br>RED is for non-compliant attributes | Short term irrigation (20 years) | Long term irrigation (100 years) | Comment |
|---|---|---|---|---|---|---|---|---|---|
| RDX | µg/L | 1 | <10 | 10 | 10 | NA | | | |
| Ronnel | µg/L | 2 | <20 | 2 | 0.2 | NA | | | |
| Ronnel | µg/L | 0.2 | <2.0 | 0.1 | 0.005 | NA | | | |
| Safrole | µg/L | 5 | <50 | 10 | 2 | NA | | | |
| Salmonella sp | | 1 | Not detected | | | NA | | | |
| Sec-butyl benzene | µg/L | 1 | <10 | 2 | 0.4 | NA | | | |
| Selenium-Dissolved | µg/L | 1 | <10 | 10 | 10 | NA | | | |
| Sertraline | ng/L | 1000 | <50000 | 2500 | 125 | NA | | | |
| Styrene | µg/L | 1 | <10 | 2 | 0.4 | NA | | | |
| Styrene Butadiene Rubber (SBR) | µg/L | 4 | <4 | 0.04 | 0.0004 | NA | | | |
| Sulfamethoxazole | ng/L | 20 | <1000 | 150 | 22.5 | NA | | | |
| Sulfur -Total | mg/L | 0.5 | 250 | 50 | 50 | NA | | | |
| Sulprofos (Bolstar) | µg/L | 2 | <20 | 2 | 0.2 | NA | | | |
| Tebuconazole | µg/L | 2 | <20 | 1 | 0.05 | NA | | | |
| Terbuthylazine | µg/L | 2 | <20 | 2 | 0.2 | NA | | | |
| Terbuthylazine-d5 | % | | 94.5 | | | NA | | | |
| Terbutryn | µg/L | 2 | <20 | 2 | 0.2 | NA | | | |
| Tert-butyl benzene | µg/L | 1 | <10 | 2 | 0.4 | NA | | | |
| Testosterone | ng/L | 5.0 | <250 | 12.5 | 0.625 | NA | | | |
| TetraBDE (Br4) | µg/L | 0.1 | <0.1 | 0.1 | 0.1 | NA | | | |
| Tetrachloroethene | µg/L | 1 | <10 | 1.5 | 0.225 | NA | | | |
| Tetrachlorvinphos | µg/L | 2 | <20 | 2 | 0.2 | NA | | | |
| Tetraconazole | ng/L | 50 | <5000 | 500 | 50 | NA | | | |
| Tetryl | µg/L | 1 | <10 | 10 | 10 | NA | | | |

| Attribute | Units | Practical quantification limit (PQL) | Raw Water Analysis 01.10.24 | Pass 1 permeate (estimated) | Pass 2 permeate (estimated) | Tox LOSP 95: threshold where permeate is non-toxic for an estimated 95% of NSW freshwater fauna GREEN is compliant. YELLOW is used where a threshold c Issue or value is not available RED is for non-compliant attributes | Short term irrigation (20 years) | Long term irrigation (100 years) | Comment |
|---|---|---|---|---|---|---|---|---|---|
| Thiabendazole | ng/L | 50 | <5000 | 1000 | 200 | NA | | | |
| Tin-Dissolved | µg/L | 1 | 54 | 5.4 | 0.54 | NA | | | |
| Tin-Total | µg/L | 1 | 130 | 13 | 1.3 | NA | | | |
| Tonalide | ng/L | 100 | <1000 | 50 | 2.5 | NA | | | |
| Total +ve TRH (>C10-C40) | µg/L | 50 | 7400 | 400 | 400 | NA | | | |
| Total +ve TRH (C10-C36) | µg/L | 50 | 7500 | 500 | 500 | NA | | | |
| Total +ve PAH's | µg/L | 0.1 | <1 | 0.1 | 0.01 | NA | | | |
| Total Alkalinity as CaCO3 | mg/L | 5 | 11000 | 50 | 2.5 | NA | | | |
| Total Organic Carbon | mg/L | 1 | 1900 | 90 | 9 | NA | | | |
| Total Positive PBDE Br1-Br10 | µg/L | 0.1 | <0.1 | 0.1 | 0.1 | NA | | | |
| Total Positive PBDE Br1-Br9 | µg/L | 0.1 | <0.1 | 0.1 | 0.1 | NA | | | |
| Total Positive PFAS | µg/L | 0.0002 | 26 | 0.6 | 0.06 | NA | | | |
| Total Positive PFHxS & PFOS | µg/L | 0.0002 | 0.25 | 0.025 | 0.0025 | NA | | | |
| Total Positive PFOS & PFOA | µg/L | 0.0002 | 0.24 | 0.024 | 0.0024 | NA | | | |
| Tramadol | ng/L | 5.0 | 1300 | 15 | 0.75 | NA | | | |
| Trans-1,2-dichloroethene | µg/L | 1 | <10 | 2.5 | 0.625 | NA | | | |
| trans-1,3-dichloropropene | µg/L | 1 | <10 | 2.5 | 0.625 | NA | | | |
| trans-Chlorfenvinphos | µg/L | 2 | <20 | 2 | 0.2 | NA | | | |

| Attribute | Units | Practical quantification limit (PQL) | Raw Water Analysis 01.10.24 | Pass 1 permeate (estimated) | Pass 2 permeate (estimated) | Tox LOSP 95: threshold where permeate is non-toxic for an estimated 95% of NSW freshwater fauna<br>GREEN is compliant.<br>YELLOW is used where a threshold c<br>Issue or value is not available<br>RED is for non-compliant attributes | Short term irrigation (20 years) | Long term irrigation (100 years) | Comment |
|---|---|---|---|---|---|---|---|---|---|
| trans-Nonachlor | µg/L | 2 | <20 | 1 | 0.05 | NA | | | |
| Trazodone | ng/L | 10 | <500 | 25 | 1.25 | NA | | | |
| TRH >C10 - C16 | µg/L | 50 | 2700 | 700 | 700 | NA | | | |
| TRH >C10 - C16 less Naphthalene (F2) | µg/L | 50 | 2700 | 700 | 700 | NA | | | |
| TRH >C16 - C34 | µg/L | 100 | 4500 | 500 | 500 | NA | | | |
| TRH >C34 - C40 | µg/L | 100 | 180 | 80 | 80 | NA | | | |
| TRH C10 - C14 | µg/L | 50 | 2200 | 200 | 200 | NA | | | |
| TRH C15 - C28 | µg/L | 100 | 4600 | 600 | 600 | NA | | | |
| TRH C29 - C36 | µg/L | 100 | 710 | 10 | 10 | NA | | | |
| TRH C6 - C10 | µg/L | 10 | 100 | 0 | 0 | NA | | | |
| TRH C6 - C10 less BTEX (F1) | µg/L | 10 | 100 | 0 | 0 | NA | | | |
| TRH C6 - C9 | µg/L | 10 | 100 | 0 | 0 | NA | | | |
| TriBDE (Br3) | µg/L | 0.1 | <0.1 | 0.1 | 0.1 | NA | | | |
| Tributyltin as Sn | µg/L | 0.0020 | <0.020 | 0.002 | 0.0002 | NA | | | |
| Trichloroethene | µg/L | 1 | <10 | 1.5 | 0.225 | NA | | | |
| Trichlorofluoromethane | µg/L | 10 | <100 | 20 | 4 | NA | | | |
| Triclopyr | µg/L | 0.50 | <10 | 2 | 0.4 | NA | | | |
| Triclosan | ng/L | 20 | <500 | 75 | 11.25 | NA | | | |
| Triphenyltin | % | | 95.6 | | | NA | | | |
| Venlafaxine | ng/L | 10 | <500 | 25 | 1.25 | NA | | | |
| Vinyl Chloride | µg/L | 10 | <100 | 30 | 9 | NA | | | |
| Vitamin E Acetate | ng/L | 100 | 5800 | 40 | 2 | NA | | | |
| Yeast | CFU/100 mL | 1 | 100 | 0 | 0 | NA | | | |

| Attribute | Units | Practical quantification limit (PQL) | Raw Water Analysis 01.10.24 | Pass 1 permeate (estimated) | Pass 2 permeate (estimated) | Tox LOSP 95: threshold where permeate is non-toxic for an estimated 95% of NSW freshwater fauna GREEN is compliant. YELLOW is used where a threshold c Issue or value is not available RED is for non-compliant attributes | Short term irrigation (20 years) | Long term irrigation (100 years) | Comment |
|---|---|---|---|---|---|---|---|---|---|
| Dibutyltin as Sn | µg/L | 0.010 | <0.10 | 0.01 | 0.001 | NA (Sn not listed) | | | |
| Parathion | µg/L | 2 | <20 | <2 | <0.2 | 0.004 (<PQL) | | | |
| Parathion | µg/L | 0.2 | <2.0 | <0.1 | <0.005 | 0.004 (<PQL) | | | |
| Chlorpyrifos | µg/L | 2 | <20 | <2 | <0.2 | 0.01 (<PQL) | | | |
| Diazinon | µg/L | 2 | <20 | <2 | <0.2 | 0.01 (<PQL) | | | |
| Endrin | µg/L | 2 | <20 | <1 | <0.05 | 0.02 (<PQL) | | | |
| Malathion | µg/L | 2 | <20 | <2 | <0.2 | 0.05 (<PQL) | | | |
| Dimethoate | µg/L | 2 | <20 | <2 | <0.2 | 0.15 (<PQL) | | | |
| trans-Permethrin | µg/L | 0.5 | <5.0 | <0.25 | <0.0125 | (Alpha-cypermethrin 0.006 ) (<PQL) | | | |
| Methoxychlor | µg/L | 2 | <20 | <1 | <0.05 | 0.005 (default value) (<PQL) | | | |
| Mirex | ug/L | 2 | <20 | <1 | <0.05 | 0.04 (default value) (<PQL) | | | |
| Mirex | ug/L | 0.2 | <2.0 | <0.1 | <0.005 | 0.04 (default value) (<PQL) | | | |
| Aldrin | µg/L | 2 | <20 | <2 | <0.2 | Tox LOSP unknown (0.001 ug/L IS LISTED) | | | |
| Aldrin | µg/L | 0.2 | <2.0 | <0.1 | <0.005 | Tox LOSP unknown (0.001 ug/L IS LISTED) | | | |
| Deltamethrin | µg/L | 0.5 | <5.0 | <0.25 | <0.0125 | Tox LOSP unknown (0.0001 is | | | |

There are 21 Non-compliant attributes for upland rivers in SE Australia.
These included Electrical conductivity, total Nitrogen, Nitrate-N, total Phosphorus and Dissolved Chromium. However, the concentrations of these attributes comply with the ANZECC (2000) guideline threshold for irrigation. It is obviously essential that there be no runoff of permeate to local stream lines. See discussion in Woodlots and Wetlands (2025a,b). Obvious in table 3, is that the Tox LOSP 95 threshold is set below the Practical Quantification Limit for routine analyses of many anolytes. That is non-specialised, but NATA registered, laboratories cannot quantify some analyte concentrations that occur at or below Tox LOSP 95 threshold. Note that there is expected to be a similar log reduction of any contaminants from the feed to the permeate, presented above.

Table 3 provides comment on the non-compliant attributes.

**Table 3. The attributes that exceeded the threshold values in the ANZECC (2000 - 2024) guidelines. The units are shown in column 2. The comments are designed to interpret the result. For many attributes the estimated concentration following double reverse osmosis is less than the practical quantification limit (PQL). The TOX LOSP 95 threshold is also below the PQL. This can occur because of interference within liquids containing multiple contaminants. This apparent incongruity creates an issue in interpreting the data.**

| Attribute | Units | Practical quantification limit (PQL) | Raw Water Analysis 01.10.24 | RO Pass 1 permeate (estimated) see column 2 for units | RO Pass 2 permeate (estimated) see column 2 for units | Tox LOSP 95 (threshold where water is non-toxic for an estimated 95% of NSW freshwater fauna) | Comments |
|---|---|---|---|---|---|---|---|
| Parathion | µg/L | 2 | <20 | 2 | 0.2 | 0.004 | Threshold <practical quantification limit (PQL) |
| Parathion | µg/L | 0.2 | <2.0 | 0.1 | 0.005 | 0.004 | Threshold <practical quantification limit (PQL) |
| Chlorpyrifos | µg/L | 2 | <20 | 2 | 0.2 | 0.01 | Threshold <practical quantification limit (PQL) |
| Diazinon | µg/L | 2 | <20 | 2 | 0.2 | 0.01 | Threshold <practical quantification limit (PQL) |
| Endrin | µg/L | 2 | <20 | 1 | 0.05 | 0.02 | Threshold <practical quantification limit (PQL) |
| Malathion | µg/L | 2 | <20 | 2 | 0.2 | 0.05 | Threshold <practical quantification limit (PQL) |
| Dimethoate | µg/L | 2 | <20 | 2 | 0.2 | 0.15 | Threshold <practical quantification limit (PQL) |
| | | | | | | | |
| trans-Permethrin | µg/L | 0.5 | <5.0 | 0.25 | 0.0125 | (Alpha-cypermethrin 0.006 ) | Threshold <practical quantification limit (PQL) |
| Methoxychlor | µg/L | 2 | <20 | 1 | 0.05 | 0.005 (default value) | Threshold <practical quantification limit (PQL) |
| Mirex | ug/L | 2 | <20 | 1 | 0.0.05 | 0.04 (default value) | Threshold <practical quantification limit (PQL) |
| Mirex | ug/L | 0.2 | <2.0 | 0.1 | 0.005 | 0.04 (default value) | Threshold <practical quantification limit (PQL). However, the estimated concentration in double RO permeate is <the default concentration. So, OK. |
| Aldrin | µg/L | 2 | <20 | 2 | 0.2 | Tox LOSP unknown (0.001 ug/L IS LISTED) | aldrin is rapidly converted to dieldrin in the environment. Toxicity of dieldrin is 'unknown' 9ANZECC, 2018). |
| Aldrin | µg/L | 0.2 | <2.0 | 0.1 | 0.005 | Tox LOSP unknown (0.001 ug/L IS LISTED) | See above |
| Deltamethrin | µg/L | 0.5 | <5.0 | 0.25 | 0.0125 | Tox LOSP unknown 0.0001 ug/L shown | Toxicity is unknown (ANZECC, 2018). |

# Comments of the attribute concentrations

728 attributes were measured. 564 attributes had no relevant threshold Tox LOSP 95. Some 147 of the attributes were found to be less than the threshold Tox LOSP 95. That is the threshold where water is non-toxic for an estimated 95% of NSW freshwater fauna. A further 21 attributes exceeded the threshold where water is non-toxic for an estimated 95% of NSW freshwater fauna. Importantly, the attributes met the ANZECC (2000) criteria for irrigation suitability (the proposed use). This includes the thresholds for irrigation in 20 or 100 years duration showed that the elements tested were compliant for iridaiton.

A number of the attributes were not concentrations. For example, pH and SAR.

Comments on pH were taken from ANZECC, 2000, tables 2.3.2 and 2.3.3.

The SAR (Sodium Absorption Ratio) is a measure of the ratio of Na/(Ca+Mg). The higher the number the more the risk of irrigated soil structural instability. Adding dissolved Ca to the permeate will reduce the SAR while increasing the ionic strength. Adding lime if the soil is acidic or adding gypsum if the soil is near neutral pH will also reduce the SAR value.

Other attributes, especially dissolved metals, are very pH dependent. Typically, the solubility of the potentially toxic metals fall rapidly with pH increase. The practical response to this is to raise the soil pH to an indicative 6.5 to 7.

The ammoniacal-N form is also very pH dependent. At a pH<8 almost all the ammoniacal-N is in a monovalent cation form: i.e. $NH_4$ N. The $NH_4$ N becomes a dissolved gas ($NH_3$-N) as the pH rises above a pH of around 8.4 to 8.5. This can result in loss of ammonia from surface soil, vegetation and water via gas to the atmosphere. It is important to contextualise that for the proposed purpose of irrigation without runoff, total Nitrogen concentration in the double RO permeate is estimated as being 60 mg/L. This is over an order of magnitude higher than the 0.25 mg/L guideline threshold for slightly disturbed upland rivers (ANZECC, 2000).

The nitrogen application rate should be less than the nitrogen uptake rate by the pasture. According to NSW Agriculture (1997), a typical 12 T/ha perennial ryegrass pasture will accumulate some 420 kg/ha/y of nitrogen. The proposed application rate of around 37 kg N/ha/year via the permeate (60mg/L*1.83 (ML/ha/y) =110 kg/ha/y) is less than 27% of the nitrogen demand for a typical perennial ryegrass pasture (NSW Agriculture 1997).

The predicted phosphorus concentration in the permeate is 0.5mg/L. The proposed irrigation rate is 1.83 ML/ha/year. Therefore, the phosphorus application via the permeate is 0.9 kg/ha/y. A typical 12 T/year Perennial ryegrass pasture will accumulate 36 kg P/ha/y NSW Agriculture (1997). That is, the permeate will supply 2.5% of the anticipated phosphorus demand.

# Use irrigation, do not discharge permeate to watercourses

A critical issue is that the permeate is used for IRRIGATION without direct discharges to watercourses.

The irrigation area is more than 100m from any watercourse. Additionally, the design irrigation rate is 0.5mm/day. This is extremely low and much of the water will be evaporated directly from leaves wetted with the permeate. The remainder will infiltrate the clay loam soil and interact via sorption processes, eventually being degraded or sorbed in the soil.

Daily pre-irrigation site assessment is required to ensure there is no runoff from the irrigation area. Irrigation MUST not occur if there is field saturation (which would likely result in runoff.

Table 3, above, shows that the concentrations of many attributes in the double permeate are below the practical quantification limit.

# Potential impact of double RO permeate on suitability for long term irrigation.

Table 4 shows typical double RO chemical constituent concentrations against the ANZECC (2000) guideline thresholds for long term irrigation (Table 4.2.10 in ANZECC, 2000).

The concentrations of dissolved substances in the double RO permeate are well below the thresholds for long term irrigation ss per ANZG (2023).

**Table 4. The typical attributes of the double RO permeate and their compliance compared with ANZG (2023a) long term irrigation threshold values.**

| Component | Units (ug/L) unless noted. | Indicative post double RO (ug/L) Dissolved concentrations | Compliance with ANZG (2023a) long term irrigation and general use guidelines. (ug/L unless noted) | Comments regarding post double RO water |
|---|---|---|---|---|
| Al | ug/L | 12 | 5000 | Ok |
| As | ug/L | 20 | 100 | OK |
| B | ug/L | 340 | 500 | The background concentration in soils is 1000 ug/kg. Note that Boron losses to fodder are typical. |
| Ca | ug/L | | NA | Ca is a valuable element; it increases soil stability as well as improve plant growth |
| Cd | ug/L | 0.4 | 10 | OK |
| Co | ug/L | 1 | 50 | OK |
| Cr (111) | ug/L | 3 | 100 | OK |
| Cu | ug/L | 0.12 | 200 | OK |
| Mg | ug/L | 475 | | Not listed. However, Mg is useful in 'moderate' concentrations to plant development. |
| Mn | ug/L | 50 | 200 | OK |
| Na | ug/L | 4.5 | <115,000 to avoid foliar injury in sensitive plants. | The lower the better. |
| Ni | ug/L | 3 | 200 | OK |
| K | ug/L | | | OK. An important plant nutrient. |
| Ba | ug/L | | | Not listed |
| Se | ug/L | 1 | 20 | OK |
| NH4-N | ug/L | 900 | 5000 | OK |
| Fe | ug/L | 150 | 200 | Ok |
| Pb | ug/L | 1 | 2000 | OK |
| Zn | ug/L | 21 | 2000 | OK |
| NO3 | ug/L | | | Nitrate-N concentration is elevated but is below the toxicity threshold for babies <3 months old. |
| F | ug/L | | 1 | OK |
| Br | ug/L | 600 | 500 | OK for <20 years' irrigation. Raising the soil pH will increase Fe and Al sorption of Br. |

| Component | Units (ug/L) unless noted. | Indicative post double RO (ug/L) Dissolved concentrations | Compliance with ANZG (2023a) long term irrigation and general use guidelines. (ug/L unless noted) | Comments regarding post double RO water |
|---|---|---|---|---|
| B (Boron) | ug/L | 340 | 500 | OK |
| $PO_4$ | ug/L | 350 | 50 | P leaching is highly unlikely as the application rate in 1.8 ML/ha/y is 9 kg/ha/y. A typical 12 T/ha/y perennial ryegrass crop accumulates some 36 kg P. This is 4 times the application rate via the irrigation system. |
| TDS | mg/l | | Yes | Very low, so non-saline water |
| Electrical conductivity at 25$^{o}$C/ 37$^{o}$C | uS/cm | 600 | Yes | Very low and non-saline, so OK |
| 'Salt concentration | mg/L | 840 | Yes | Assumes 1000 uS/cm is equivalent to 640 mg/L |
| pH | pH | pH will be adjusted to be in the 6.5 to 8 range. | Yes | 6.5 to 8 is the 'normal range. So OK |
| PFOA | µg/L | 0.4 | | .Irrigation water so OK *(EPA. 2020)* |
| PFOS | µg/L | 0.3 | | Irrigation water so OK *(EPA. 2020)* |
| PFHxS | µg/L | 0.09 | | |
| perfluorooctane sulfonate (PFOS) and perfluorohexane sulfonate (PFHxS) | µg/L | NA | | 0.07 ug/L drinking water. And 2 ug/L for recreational water. |

Based on the results in table 4, it is reasonable to conclude that based on the chemicals tested, the double RO permeate is suitable for pasture irrigation.

## Importance of the low irrigation rate per day and the distance to water courses.

It is important to note that the permeate will be applied at 0.5 mm/day (except when the predicted rainfall will create runoff). No irrigation will occur if the predicted rainfall is 100mm or greater. The 0.5mm irrigation will largely be retained within the leaves. The net effect is that irrigated permeate will be retained in the topsoil.

Additionally, the proposed irrigation area is over 100m from the headwaters of the nearest local streamline. So, even if there was some off site migration of the permeate, it is extremely unlikely that the permeate would reach local surface waters.

The water is 'non-saline' so the risk of salinisation of the site, the groundwater or local streams is negligible.

## The proposed irrigation area

The proposed irrigation areas are on low hills. The geology is largely volcanic, with some surface rocks being metamorphosed siliceous bedrock (see Espade v2.2).

The initial development will be concentrated on a relatively flat area within the NW portion of the Veolia Property. See figure 1.

## The recommended irrigation strategy based on permeate chemistry

A series of wastewater irrigation models were examined to address the impacts. These were then assessed to determine the most suitable strategy.

The recommended irrigation strategy is to apply a small quantity of irrigation (0.5 mm) each day when the predicted rainfall is <10mm. The 10mm irrigation cutoff threshold for predicated rainfall is less than the rainfall runoff threshold of 17mm/day (from USDA model).

The irrigation is to be applied via fixed or mobile sprinklers. A total of 16.8 ha of irrigation is expected to be installed. 0.5mm over 16.8 ha is 84 cubic m/day. This is a permeate flow of 1 L/sec. If this rate is applied 365 days/y, the annual volume is 31.5 ML/y (1*60*60*24*365/1000000).

The recommended model (as discussed in the Sustainable Irrigation Management Plan, Woodlots and Wetlands 2025b), has 12 days/year when irrigation will not occur. Note that in summer, the irrigation rate can be doubled to 1mm/day on 12 dry warm days to 'make up' for the 12 days/ average year with zero irrigation. The annualised irrigation rate would be 183 mm/year. With maintenance downtime, the indicative application rate is 177 mm/year. Any temporary cessation of irrigation can be recovered by applying a higher daily application rate once the weather becomes warm and dry. However, the annual rate of 183 mm/year is assumed for modelling purposes.

Note it is critically important to raise the soil pH to at least 6.5.

The proposed irrigation protocol had minimal increase in surface runoff as table 5 shows (2 mm/year). However deep percolation was increased from 153 mm/year without irrigation, to 232 mm/year for a scenario of 0.5 mm/day of permeate unless there was at least 10mm of rainfall predicted.

**Table 5. The water balance components with and without permeate irrigation. For details see the Sustainable Irrigation Plan (Woodlots and Wetlands, 2025b).**

| Water balance component (all mm/y) | Zero irrigation | 0.5mm every day if <10 mm of rain predicted | Change (mm/y) |
|---|---|---|---|
| Rainfall (1980 to 2021) | 709 | 709 | 0 |
| Permeate irrigation | 0 | 177 | +177 |
| Soil evaporation | 0 | 0 | 0 |
| Transpiration | 549 | 644 | +95 |
| Rainfall runoff | 8 | 10 | +2 |
| Irrigation runoff | 0 | 0 | 0 |
| Deep drainage | 153 | 232 | +79 |

7Note that the SW corner of the irrigation area should be inspected each morning. The SW corner is the portion of area 2 closest to the drainage line. Do NOT irrigate if there is runoff from the site.

The key result of the permeate irrigation is an increase in transpiration and in deep percolation. The MEDLI modelling shows there is no accumulation of 'salt' anywhere in the profile. The reasons for this are that the

- soils are currently non – saline,
- there is a minimal quantity of salt in the permeate
- the irrigation rate of 183 mm/year is very low.

# 3. CONCLUSIONS

The double RO permeate has greatly reduced contaminant concentrations. However, there are some chemicals whose post double RO attributes exceed the 95% of NSW aquatic species toxicity threshold. This issue is addressed via irrigation rather than discharge of the double RO permeate. The anticipated quality attributes are compliant with the ANZECC 2000 guidelines for irrigation.

The irrigation is based on application of 0.5mm/day every day when the forecast rainfall is less than 10mm. (runoff threshold is 17mm/day).

There is more than 100 m of unirrigated buffer lands between the irrigation area and the headwaters of a first order watercourse. It is therefore extremely unlikely that the constituents in the double RO permeate will reach the watercourse. Management of this will be verified as per the control described, including daily inspections to verify the fields are unsaturated as well as the plant control measures described in the Sustainable Irrigation Management Plan.

# 4. REFERENCES

ANZG 2023a. Water Quality for Irrigation and General Water Uses: Guidelines. Australian and New Zealand Guidelines for Fresh and Marine Water Quality. Australian and New Zealand governments and Australian state and territory governments, Canberra.  See 2024 revised draft.

NSW Agriculture 1997. The New South Wales Feedlot Manual. Inter- Departmental Committee on Intensive Animal Industries (Feedlot Section), NSW Agriculture, Orange, NSW

Woodlots and Wetlands. 2025. Sustainable Irrigation Management Plan

# Suitability of four potential irrigation areas at the Veolia Woodlawn Operations Site to sustainably receive treated process leachates

Prepared for
Veolia Environmental Services (Australia) Pty Ltd

Under direction of
**Raymond Choy and Jordan Gavel**

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# Document Registration

| | |
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| **Document Registered By** | Peter Bacon<br>Principal Consultant |

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The assistance of Raymond Choy and Jordan Gavel is gratefully appreciated.

# 1. Executive summary

The Veolia Woodlawn Operations Site processes over 40% of Sydney's 'red' bin waste. The treatment process results in excess water that leaches out of the processed product.

The untreated leachate water contains elevated concentrations of sodium, chloride, nutrients and potentially toxic elements. It may also contain chemicals of concern such as PFAS / PFOS and endocrine disruptors. The untreated leachate will require major reductions in salinity as well as in the concentrations of nutrients and potentially toxic elements before the water can be safely returned to the environment via irrigation.

It is proposed to use a double Reverse Osmosis (RO) to remove a proportion of the contaminants. In the RO process, the leachate is pressurised and is forced through a semi permeable membrane. This process will produce water ( hereafter referred to as permeate) that is suitable for irrigation. The retentate that does not cross the semi permeable barrier consists of water with an increased contaminant concentration load.

A critical issue in the current report is to establish the quantity of permeate that can be safely used on lands to the west of the current storage ponds on the Veolia site. A total of 77 ha was assessed (figure 5.1, below). This document focusses on suitability of the 77 ha for irrigation with the double RO permeate.
The document titled: ***Impact of double reverse osmosis on permeate quality***
And
The document titled: ***Sustainable Irrigation Management Plan***
Provide details on the anticipated quality of the permeate and on the methodology for achieving a sustainable irrigation system.

The key guidance document for the current document is
DEC (2004).Use of Effluent by Irrigation.

The table below shows the anticipated chemical characteristics of the permeate following double RO.

**Table 1. The anticipated attributes of the double RO permeate compared with the short and long term ANZECC (2000) guidelines for irrigation water.**

| Attribute | Units | Pass 2 permeate (estimated) | Short term irrigation (20 years) | Long term irrigation (100 years) | Comment |
|---|---|---|---|---|---|
| pH | pH Units | >6.5 | | within range of 5 to 9 | The 5 to 9 pH range helps prevent corrosion and fouling of irrigation equipment |
| Escherichia coli | CFU/ 100mL | 0.002 | | | Not an issue as no human contact is proposed. |
| Thermotolerant Coliforms | CFU/100 mL | 0.002 | | | Not an issue as no human contact is proposed. |
| Electrical Conductivity | µS/cm | 600 | Low and not an issue | Low and not an issue | OK for irrigation (0.6 dS/m or 384 mg/L of total dissolved solids ('salt') |
| Total dissolved solids | mg/kg | 384 | | | See above |

| Attribute | Units | Pass 2 permeate (estimated) | Short term irrigation (20 years) | Long term irrigation (100 years) | Comment |
|---|---|---|---|---|---|
| Phosphorus - Total | mg/L | 0.35 | Up to 12 | 0.05 | To minimise clogging of irrigation equipment only. 0.5mg/L in 1.83 ML of permeate irrigation /ha/y is 0.9 kg/ha/y. A typical 12 T/year Perennial pasture will accumulate 36 kg P/ha/y NSW Agriculture 1997). So, the permeate will supply <3% of the anticipated demand. |
| Total Nitrogen in water | mg/L | 60 | <125 | <5 | A perennial ryegrass pasture will accumulate an indicative 420 kg/ha/y of Nitrogen.(NSW Agriculture (1997). Applying 183 mm/year containing 60 mg/L N will supply 110 kg/ha/y of N. This is 26% of the pasture N demand. |
| Ammonia as N in water (operational max based on repeated sampling) | mg/L | 0.10 | | | Ensure there is no permeate runoff to streams. See above comment in relation to total N being 26% of pasture demand. |
| Nitrate as N in water (operational max based on repeated sampling) | mg/L | 50 | | | Ensure there is no permeate runoff to streams. See above comment in relation to total N being 26% of pasture demand. |
| Nitrite as N in water (operational max based on repeated sampling) | mg/L | 11.25 ug/L | | | OK |
| Sodium Adsorption Ratio | - | ? | Water with an SAR>6 AND salinity <600 uS/cm can create structurally | Add dissolved Calcium to the permeate | Check soil Exchangeable Na % every 3 years. Add 5T/ha of gypsum to the soil if Exch Na%>5%. |

| Attribute | Units | Pass 2 permeate (estimated) | Short term irrigation (20 years) | Long term irrigation (100 years) | Comment |
|---|---|---|---|---|---|
| | | | unstable soil following irrigation. | | |
| Arsenic-Dissolved | µg/L | 3.2 | 20000 | 100 | OK |
| Aluminium-Dissolved | µg/L | 20 | 20000 | 5000 | OK for irrigation. Ensure that there is no permeate runoff. |
| Aluminium-Total | µg/L | 24 | 20000 | 5000 | OK for irrigation |
| Antimony-Dissolved | µg/L | 0.8 | | | OK for irrigation |
| Boron-Dissolved | µg/L | 340 | 750 to 1500 | 500 | OK for short term irrigation. Raising the soil pH to>7 will increase Fe and Al sorption of B (Strawn, et al, 2015). |
| Cadmium-Dissolved | µg/L | <0.1 | 50 | 10 | OK for irrigation |
| Calcium - Dissolved | mg/L | 0.52 | | | |
| Calcium - Total | mg/L | 1.2 | | | |
| Cobalt-Dissolved | µg/L | 0.94 | 100 | 50 | OK for irrigation |
| Copper-Total | µg/L | 1.7 | 5000 | 200 | OK for irrigation |
| Copper-Dissolved | µg/L | <1 | 5000 | 200 | See above |
| Fluoride, F | mg/L | 0.014 | 2 | 1 | OK for irrigation |
| Lead-Dissolved | µg/L | 0.24 | | | |
| Lead-Total | µg/L | 1.2 | 5000 | 2000 | OK for irrigation |
| Manganese-Dissolved | µg/L | 2.5 | | | |
| Manganese-Total | µg/L | 16 | 10000 | 200 | OK for irrigation |
| Mercury-Dissolved | µg/L | 0.005 | | | |
| Mercury-Total | µg/L | 0.005 | 2 | 2 | OK for irrigation |
| Molybdenum-Dissolved | µg/L | 0.1 | | | |
| Molybdenum-Total | µg/L | 0.13 | 50 | 10 | OK for irrigation |
| Nickel-Dissolved | ug/L | 3 | | | |
| Nickel-Total | µg/L | 3 | 2000 | 200 | OK for irrigation |
| Selenium-Total | µg/L | 0.1 | 50 | 20 | OK for irrigation |
| Sodium - Dissolved | mg/L | 18 | | | OK for irrigation |
| Sodium - Total | mg/L | 25 | | | OK for irrigation |
| Vanadium-Dissolved | µg/L | <4 | | | |
| Vanadium-Total | µg/L | 1 | 500 | 100 | OK for irrigation |
| Zinc-Total | µg/L | 120 | 5000 | 2000 | OK for irrigation |
| Zinc-Dissolved | µg/L | 21 | | | No runoff of permeate to local streamlines. |
| Free Chlorine | mg/L | 0 | | | Chlorine reacts with organic matter and is |

| Attribute | Units | Pass 2 permeate (estimated) | Short term irrigation (20 years) | Long term irrigation (100 years) | Comment |
|---|---|---|---|---|---|
| | | | | | inactivated. The combination of pasture biomass and organic matter in soils will rapidly inactivate the chlorine so that it is not an issue. |
| Total Chlorine | mg/L | 0.1 | | | Not an issue |

Essentially the post double RO permeate is suitable for irrigation provided the Calcium concentration, either in the permeate or as gypsum applied at 5T/ha to the soil surface.

The entire proposed irrigation area drains to Lake George. Lake George is a closed basin.

The proposed irrigation areas are on rolling low hills. The geology is largely volcanic along Collector Road, areas 1 and 2, and some surface rocks being metamorphosed siliceous bedrock in areas 3 and 4 (see Espade v2.2 ). Areas 3 and 4 were steeper than areas 1 and 2.

The soil characteristics that made the sites suitable for irrigation were:

- Soil depth at least 0.8m and preferable >1m deep
- Surface soil loams to pedal clay loams (facilitating rapid infiltration of water)
- Structurally stable clay subsoils (Facilitating moderate infiltration and large ability to retain nutrients, contaminants and water).
- sprinkler irrigation can be used at least to 15% grade.

These attributes largely applied to areas 1 and 2.

The key limitations in areas 3 and 4 were:

- Shallow soils
- Rocky sub soils
- Water logging and poor physical conditions in the subsoil as indicated by a bleached $A_2$ horizon. These soils have low wet strength and this can result in ‘bogging’ of vehicles and the travelling irrigators.
- Some slopes too steep for sprinkler irrigation.
- The current pastures are not designed to maximise response to irrigation. Pasture species/cultivars designed to respond to irrigation need to be planted.
- Weed control is essential
- The pH is too low. Lime is required. Liming will also increase the percentage of exchangeable Ca. This, in turn will increase soil structural stability.
- Available P concentration is very low. Apply 20 kg P/ha/y.
- Potassium and boron fertilisation will be needed in future.

A range of model parameters were used.

The water holding capacity of the soil was set at 90mm. This is the quantity of water (mm) in the surface 500mm of soil can store water before free drainage occurs.

# Conclusions And Recommendations

- There were 4 irrigation areas.
- Areas 1 and 2 are the most favourable for irrigation on the Veolia Site. Their soils are relatively deep. They have good nutrient retention ability and are non-saline.
- Areas 3 and 4 have less favourable conditions. Typically, shallower soil, steeper slopes and in some cases convergence runon from upslope areas.
- All areas are deficient in nutrients.
- Some areas require liming and /or gypsum to correct soil acidity/ structural instability.

# Recommendations

1. Fixed sprinkler systems are RECOMMENDED
2. All areas require establishment of improved pastures. Legumes are recommended in the pasture mix.

The proposed irrigation areas will need a topographical survey.

Area 2 was selected for the first phase of this irrigation project.

It is proposed to apply 0.5mm/day every day when there is ZERO runoff and when there less than 10 mm of rainfall is predicted.

# Contents

# 1. BACKGROUND

## The project

Veolia Environmental Services (Australia) Pty Ltd, hereafter Veolia, receives some 40% of Sydney's putrescible wastes at its Woodlawn Site. The waste treatment process generates excess leachate. Currently this leachate is retained in effluent storage dams. However, leachate volumes requiring storage have exceeded modelled values. This has resulted in the need to safely dispose of excess volume.

Irrigation onto lands within the Woodlawn site was explored as an option. Appendix 1 contains the detailed modelling. Appendix 2 contains soil / landform information.

The treated leachate chemistry is a major constraint to reuse. The treated leachate was extremely saline. Its sodium concentration is extremely high. Application of treated leachate to land would kill off most vegetation as well as lead to loss of soil structural stability. See table 2.2 for details.

A reverse osmosis (hereafter RO) plant is proposed as a way of removing contaminants that make the treated leachate unsuitable for irrigation. It is proposed to irrigate nearby pastures with the permeate. Management of the retentate is under investigation.

The proposed irrigation area is currently used for sheep grazing. Major pasture plants on site include fescue and phalaris. However, weeds currently dominate the pastures.

Fescue and phalaris can tolerate irrigation water with 3 to 4 dS/m of salinity (ANZECC, 2000, Table 4.2.5). A 2 pass RO system can reduce salinity from 13 - 17 dS/m to 0.2 to 0.3 dS/m (table 2.2). That is, the permeate is suitable for pasture irrigation. The treated leachate would also be suitable for some clovers.

The current project assesses the proposed irrigation areas for various types of irrigation. It also considers the suitability of the soil for irrigation.

## Location of the irrigation areas

The proposed irrigation areas cover some 72 ha on the western edge of the Veolia Site (see figure 1.1).

This area of the Veolia site drains to Lake George. Lake George is a 'closed' catchment that is separate from the Sydney Water hydrological catchment . ***Lake George is 25 kilometres long, 10 kilometres wide, and very shallow. The lake has no surface outflow but water is lost through evaporation and underground*** *seepage*. ***This natural drainage basin is fed by 10 major tributaries that drain from the surrounding hilly country. These tributaries originally drained to the Yass River before they were cut off by the uplift of the Lake George Range*** (see NSW Water website).

Figure 1.1 and 1.2 show the flow direction.

This drainage patter is important because it means that the proposed irrigation areas are NOT part of the Sydney Hydrological Catchment.

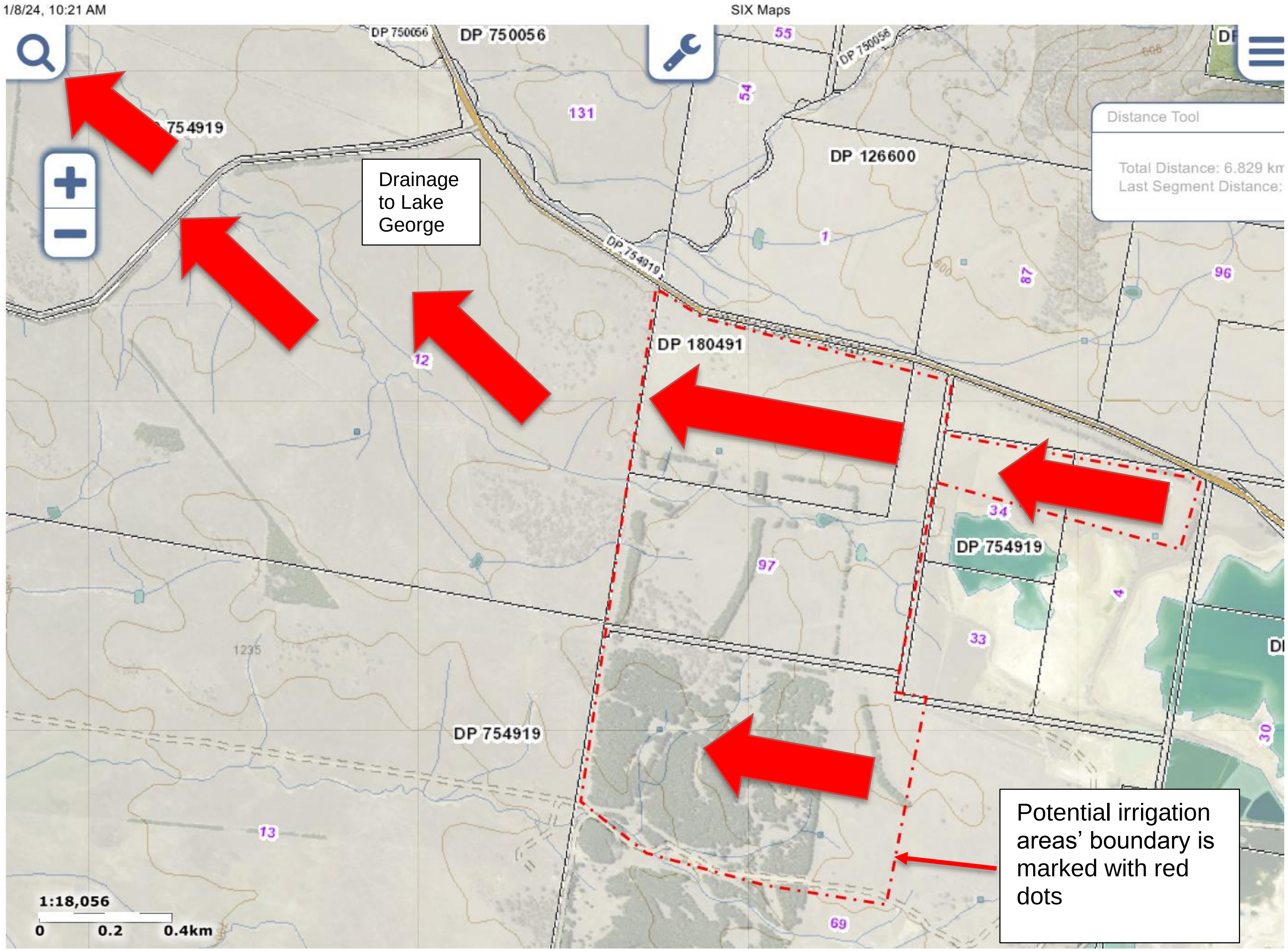
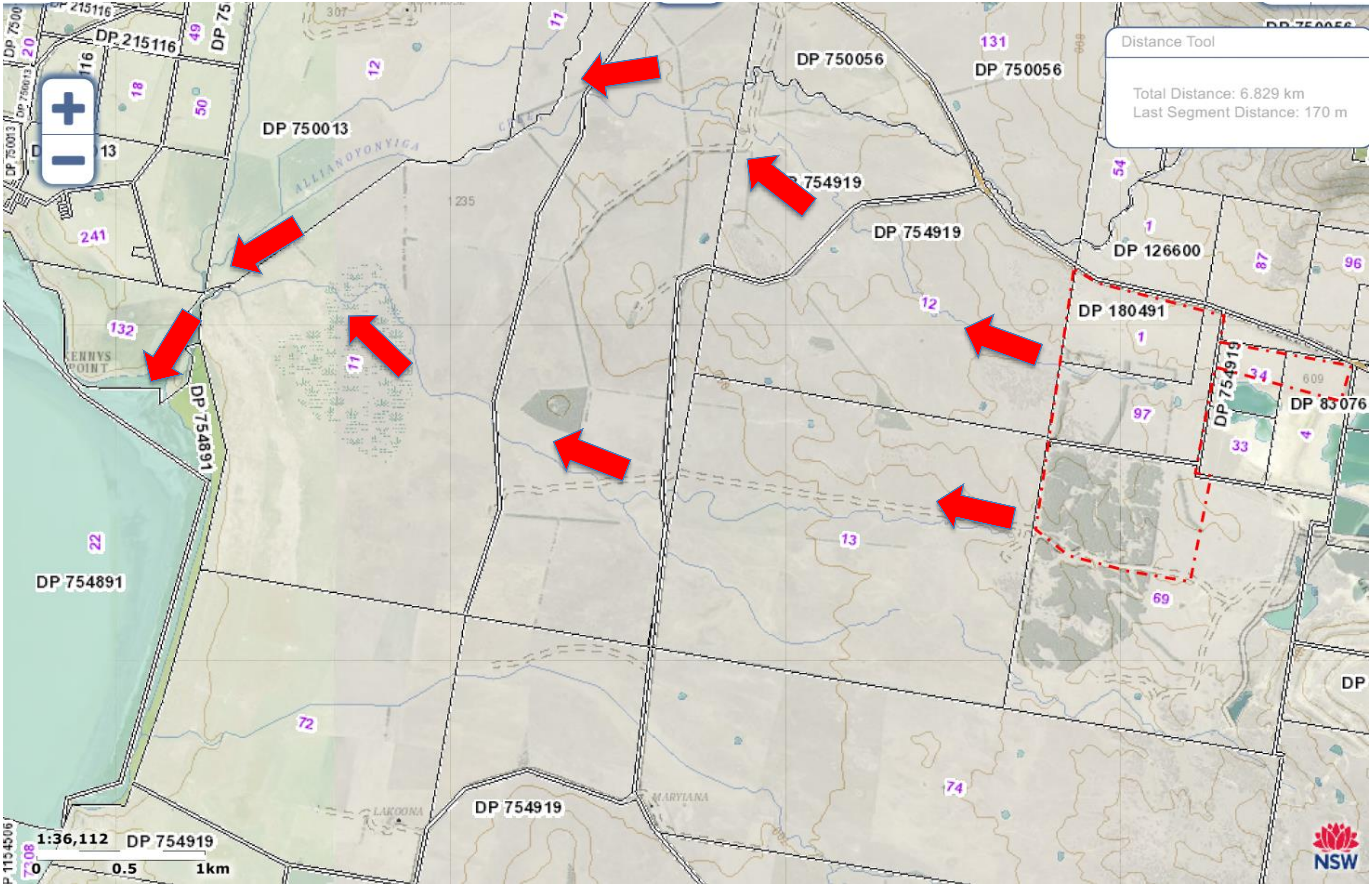



**Figure 1.1. The proposed irrigation areas all drain towards Lake George (image source: NSW Gov). See figure 1.2 below. Note that the irrigation is onto pastures. The treed areas are excluded.**



Distance Tool
Total Distance: 6.829 km
Last Segment Distance: 170 m
DP 215116
DP 750013
DP 750056
DP 754919
DP 126600
DP 180491
DP 83076
DP 754891
ALLIANOYONYIGA
KENNYS POINT
LAKOONA
MARYIANA
1:36,112
0
0.5
1km
NSW

# Report author

Peter Bacon has over 35 years' experience in investigating nutrient and water dynamics. In this time, he has published over 300 articles, ranging from expert systems to international reviews of major ecological processes.

During the 1980s he lectured to irrigation science students at Yanco Agricultural College.

In 1992 he was awarded a Churchill Fellowship to study effluent management and the environment in South Africa, Israel, Portugal and the USA. Specific aspects included modelling effluent quality changes to soil and water, the effects of land management on aquatic ecosystems, biosolids reuse in forests and the environmental effects of effluent reuse. In 1994 he founded Woodlots & Wetlands, an environmental consultancy, specialising in stormwater and wastewater management and eco engineering.

Since 2007 he has been a Fellow of UTS and guest lectured to postgraduate Environmental Engineers in environmental risk and on wetland design to manage waste waters.

He has undertaken over 200 effluent and waste management projects including ones for food processing facilities, tanneries, abattoirs, chicken sheds, piggeries, dairies, wineries, industrial sites, aboriginal settlements, towns, cities and individual resort and institutional developments. He has also undertaken compliance investigations for waste food processing and for processing of treated grease trap wastes from commercial premises and industrial plants.

Since 2005 he has provided expert witness in several Land and Environment Court cases involving waste management and effluent reuse.

# 2. THE PROPOSED PERMEATE PRODUCTION RATES

## Reverse osmosis process

RO (reverse osmosis), operates by forcing pressurised water through a semi permeable membrane, leaving the retentate, with the dissolved contaminants, behind.

The water with the reduced concentration of contaminants is referred to as the permeate. The remaining water and contaminants are referred to as the retentate.

## RO production rates and irrigation area needs.

Veolia expects to produce between 2 and a maximum of 8 L/sec of permeate from a proposed RO plant. Table 2.1 shows the consequent volumes of permeate water available for irrigation The area of irrigation land required is discussed later in this report.

**Table 2.1. The volumes of permeate water over different time periods based on production of 1 to 8 L/sec. The initial estimate of the minimum irrigation area for different production rates are also shown. Note the areas are rounded up to the next ha.**

| L/sec | L/day | Cubic m/day | ML/y | Minimum Ha required assuming an annualised irrigation rate of 1.8 ML/ha/y (0.5 mm/day | Minimum Ha required assuming an annualised irrigation rate of 3 ML/ha/y (0.8 mm/day) | Minimum Ha required assuming an annualised irrigation rate of 4 ML/ha/y (1.1 mm/day) | Minimum Ha required assuming annualised irrigation rate of 5 ML/ha/y (1.4 mm/day) | Minimum Ha required assuming annualised irrigation rate of 6 ML/ha/y (1.7 mm/day) |
|---|---|---|---|---|---|---|---|---|
| 1 | 86,400 | 86.4 | 31 | 17 | 11 | 8 | 7 | 6 |
| 2 | 172,800 | 173 | 62 | 35 | 21 | 16 | 12 | 10 |
| 4 | 345,600 | 346 | 124 | 69 | 41 | 31 | 25 | 21 |
| 6 | 518,400 | 518 | 187 | 104 | 62 | 47 | 37 | 31 |
| 8 | 691,200 | 691 | 249 | 139 | 83 | 62 | 50 | 42 |

Table 2.1 shows that, depending on the permeate production rate and the irrigation rate , between 6 and 138 ha of irrigation will be required.

The quantity of buffer / wet weather storage will depend on the permeate production rate. This will depend on the configuration of the RO system and the actual rate of permeate irrigation.

The reason for this is that if there is no irrigation demand, the RO plant output will be set to ‘idle’ phase, sufficient to maintain the membranes.

## Permeate quality

The RO plant is designed to have a two pass system, with the permeate being subject to double RO. Permeate quality is discussed in detail in the document:

**Woodlots and Wetlands (2024a). Impact of double reverse osmosis on permeate quality**

The predicted permeate quality is compliant with both ANZECC and Australian Drinking Water Guidelines.

The soils are acidic, so they must receive lime as part of the site preparation for irrigation.

The critical issue is how many ML/ha/year can be sustainably applied to soils.  The next section examines site suitability for irrigation.

# 3. SITE SUITABILITY FOR IRRIGATION

Site suitability for irrigation is based on a combination of physical, chemical and biological attributes.

**Table 3.1. Site attributes and their impact on their suitability for irrigation.**

| Attribute | Issue | Comment and potential responses |
|---|---|---|
| Site infrastructure | Nearness to roads and power lines | Areas 1 and 2 are adjacent to Collector Road. The separation distance requirement depends on the quality of the water (Especially potential pathogen load). The load is essentially zero following Double RO.<br>The existing power line through areas 1 and 2 limit the full potential of centre pivot systems. Fixed sprinklers are an option.<br><br>Taking the power lines and the Collector Road into account means there is a total of 18.7 ha in area 1 and 16.8 ha in area 2. |
| Climate | Heavy rainfall can cause water logging of the soil. This increases runoff risk | Irrigate frequently (daily) subject to predicted rainfall on that day |
| Slope | Increased slope can increase runoff risk. In turn this can result in convergence zones which can be saturated for long periods.<br><br>Travelling irrigators and centre pivot irrigation is limited to relatively low slopes.<br>Fixed sprinklers can operate at up to 15% slope | Avoid irrigating obvious wet areas.<br><br>Runoff convergence areas can have little or no ability to utilise run-on water.<br><br>Areas 1 and 2 are largely ‘flat’.<br>Areas 3 and, especially 4, have some steep slopes. This will reduce the proportion of areas 3 and 4 that can be irrigated. |
| Soil depth | Shallow soils overlying rock can become waterlogged under heavy rainfall or irrigation | Soil parts of areas 3 and 4 have shallow soil. . |
| Soil chemical instability | Unstable surface soil can develop a crust that inhibits water penetration.<br><br>An unstable B horizon can act as a choke inhibiting water movement through the soil. | A light grey $A_2$ horizon typically indicates an internal drainage issue.<br><br>This can be related to unstable subsoil Portion of areas 3 and 4 have evidence of poor internal drainage. |
| Low nutrient status | | Areas 1 and 2 soils are based on volcanic rock. These soils are typically fertile.<br>Areas 3 and 4 are largely based on metamorphosed rock(with some influence of the nearby volcanic rock. These soil normally have lower inherent soil fertility. |

# 4. SOIL LANDSCAPE TYPES

Irrigation areas 1 and 2 are largely on the Duckfield Hut Variant ‘B’ soil landscape as figure 4.1 shows. These are reasonably fertile soils with slopes less than 10% and low local relief, being in the 5 to 30m range.

Irrigation areas 3 and 4 as shown in figure 4.1 are on the main type of Duckfield Hut Soil Landscape. This soil landscape has steeper slopes with some areas over 10% gradient.

Travelling irrigators operate at up to 8% slope and 3% cross slope. Fixed sprinklers can operate on slopes of 15%, provided they are well designed.

Slope is a key landform limitation.

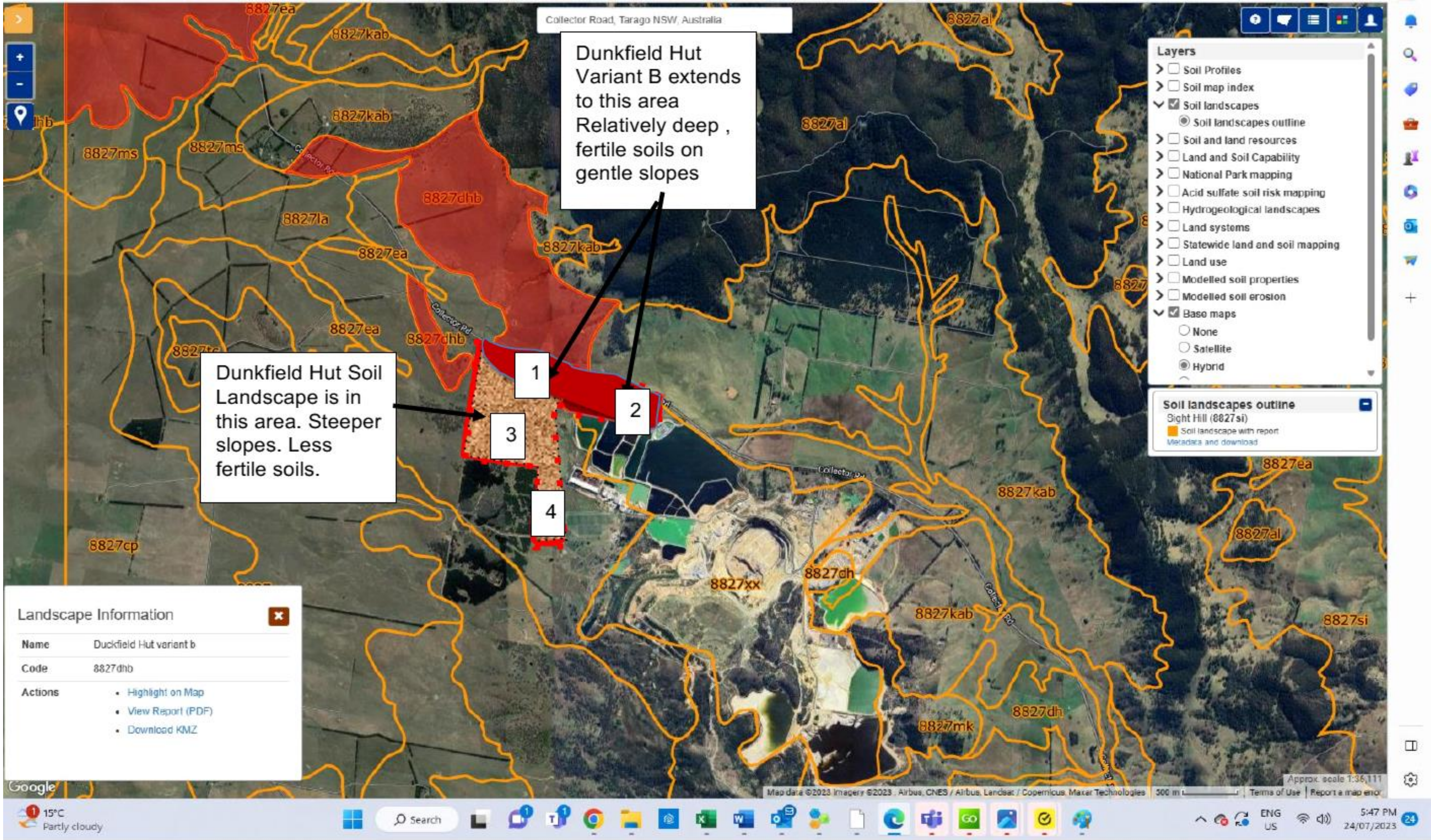



**Figure 4.1. The areas surveyed along Collector Road were part of the Duckfield Soil Landscape Variant b. These were irrigation areas 1 and 2. Irrigation areas 3 and 4 to the south were part of the Duckfield Soil Landscape. The soil landscape report is shown as appendix 1 below.**

# 5. LANDFORM CONDITIONS IN THE IRRIGATION AREAS

The Australian Soil and Land survey Field Handbook (NCST, 2009) was used as a template to describe site conditions.

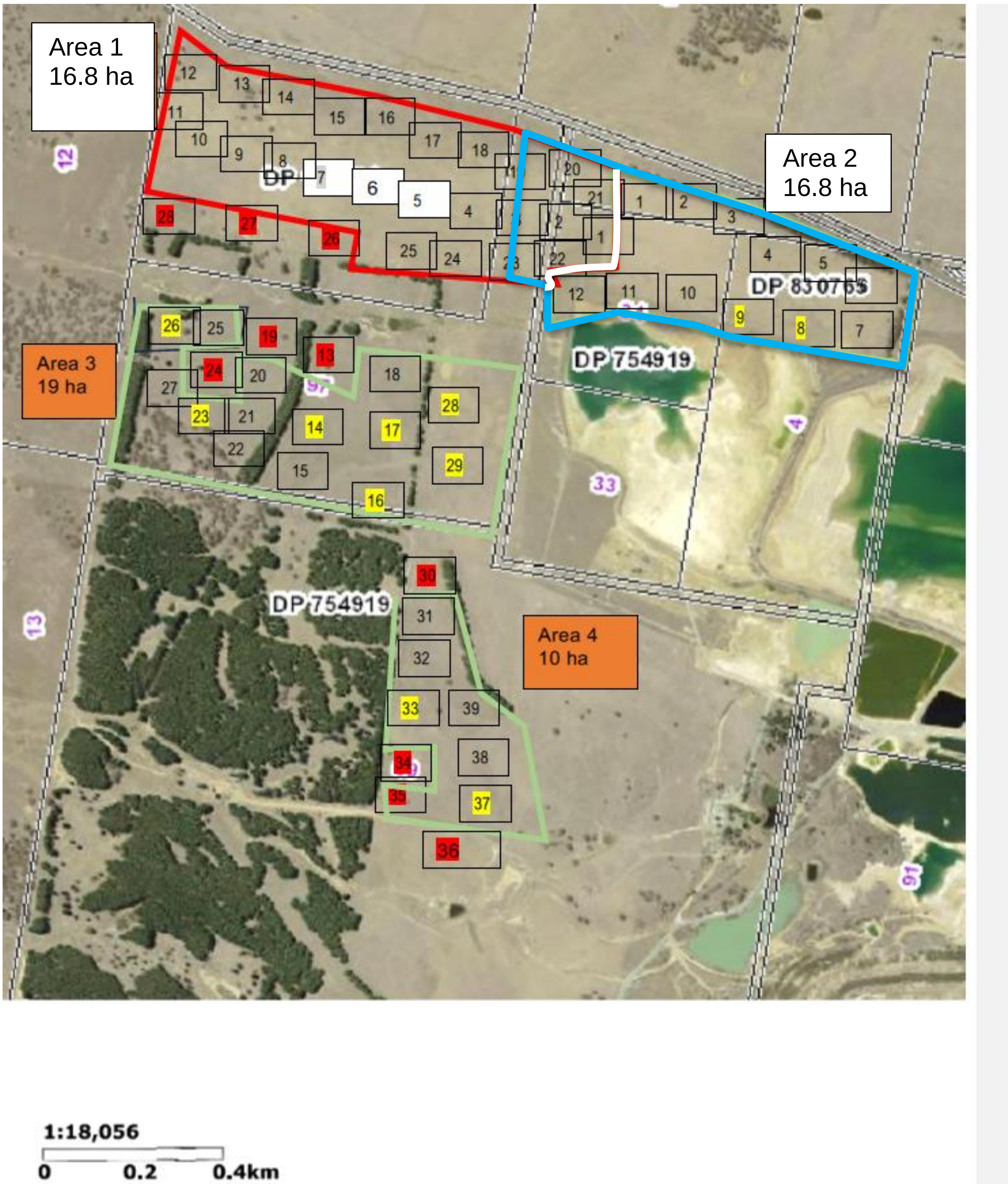



**Figure 5.1. The soil sampling and landform assessment points within each of the four areas (image source: NSW Gov). NOTE that the areas shown are the maximum extent of each area. Areas 1 and 2 both have 16.8 ha. See below.**


**Figure 5.2. A back hoe was used to excavate observation pits, to determine soil depth and to facilitate soil sampling. Note the thick pasture cover.**

Landforms and irrigation suitability within each area is described below.

The landform conditions in area 1 are summarised in table 5.1 to 5.4.

# Landform attributes and irrigation suitability conditions in Area 1

**Table 5.1. Landform attributes in the first 9 sampling pits in Area 1.**

| Site Number | VW - 1 | VW12 - 2 | VW12 - 3 | VW 1 - 4 | VW 1 - 5 | VW 1 - 6 | VW1 2 - 7 | VW 1 - 8 | VW1 -9 |
|---|---|---|---|---|---|---|---|---|---|
| **Critical limitation** | | | | | | | | | |
| **Slope** | 2% | 0 | 2% | 0 | 1% | 0 | 0 | 0 | 0 |
| **Slope length (m)** | 0 | 0 | 30 | 0 | 00 | 0 | 0 | 0 | 0 |
| **Aspect** | NW | Flat | North | Flat | Flat | Flat | Flat | Flat | Flat |
| **Landscape position** | Minor ridge line | | | | | | | | |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Land form pattern** | Level | Very gently inclined | level | Very gently inclined | Very gently inclined | level | level | level | level |
| **Landform element** | Low | | | | | | | | |
| **Drainage line distance (m)** | >100 | | | | | | | | |
| **Run-on/ runoff** | Low | | | | | | | | |
| **Surface water bodies- streams, dams, springs** | Effluent storage dam to south / south east | | | | | | | | |
| **Storm water** | Minimal to low run-on | | | | | | | | |
| **Salt** | No evidence | | | | | | | | |
| **Current erosion potential** | Extremely low | | | | | | | | |
| **Rock out crops %** | <2% | | | | | | | | |
| **Soil parent material** | Volcanic | | | | | | | | |
| **Depth to hard rock (cm)** | See soil profile data  Most areas have soils >1m deep. | | | | | | | | |
| **Water table, depth** | >1m | | | | | | | | |
| **Soil moisture** | Moist | | | | | | | | |
| **Flood risk** | Zero | | | | | | | | |
| **Land use** | Semi improved but weedy pasture | | | | | | | | |
| **Land use history DISTURBANCE EVIDENCE** | Long term pasture.  Minimal disturbance. | | | | | | | | |
| **Distance to public roads houses, etc** | >100m | | | | | | | | |
| **Fire hazard** | Low to moderate | | | | | | | | |

The conditions in the first 9 sampling pits were very similar.

Table 5.2 contains a summary of each sampling point in Area 1 as shown in figure 5.1.
Table 5.3 contains an indicative soil profile from Area 1.
Table 5.4 provides commentary of the soil conditions in Area 1.
Tables 5.5 to 5.7 show conditions in areas 2, 3 and 4.

# The pasture mix requirements

There is a need to include Phalaris (*Phalaris aquatica*), Tall Fescue (*Festuca arundinacea*) and Perennial Ryegrass (*Lolium perenne*) in the pasture mix.

Subterraneam clover (*Trifolium subterraneum*), especially Yannminicum types are best for wet soils.

White clover (*Trifolium repens*) is useful in cool wet soils. The grazing pressure needs to be managed to give regeneration of annual pasture species a chance to occur. Heavy harvesting is required in late summer to remove the excess phalaris, fescue and ryegrass vegetation.

Area 1 was selected for the first assessment because the preliminary assessment showed that it had low slopes, appeared to be well drained and had thick grass cover.

Area 2 was adjacent to Area 1 ,but was closer to the likely RO plant location. It also had a treed buffer zone between it and Collector Road. The soils in these two areas were very similar.

**Table 5.2. Summary of the landform conditions in area 1. Figure 5.1 shows the sampling sites. Areas surrounding sample points 1.26 and 1.28 are not suitable for irrigation. All other sampling areas are suitable.**

| Pit | GPS | Landform element | Aspect | Slope % | Up slope length | Distance to drainage line (m) | Vegetation | Evidence of erosion | Neighbours, roads, etc, distance (m) | Critical Constraints |
|---|---|---|---|---|---|---|---|---|---|---|
| VW 1 - 1 | 1098 | Ridge top | Flat | 0 | 75 | >100 | Semi improved pasture Lots of weeds | Nil | >100 | Nil |
| VW1 - 2 | 1099 | Ridge top | Flat | 0 | 50 | >100 | | | >100 | Nil |
| VW1 - 3 | 1100 | Ridge top | SW | 2% | 50 | >100 | | | >100 | Nil |
| VW1 - 4 | 1101 | Ridge top | S | 3% | 75 | >100 | | | >100 | Nil |
| VW1 - 5 | 1102 | Ridge top | Flat | 0% | 0 | >100 | | | >100 | Nil |
| VW 1 - 6 | 1103 | Ridge top | Flat | 0% | 0 | >100 | | | >100 | Nil |
| VW 1 - 7 | 1104 | Ridge top | W | 7% | 65 | >100 | | | >100 | Nil |
| VW1 - 8 | 1105 | Ridge top | W | 10% | 105 | >100 | | | >100 | Nil |
| VW 1 - 9 | 1106 | Upper slope | W | 3% | 300 | >100 | | | >100 | Nil |
| VW 1 - 10 | 1107 | Mid slope | W | 5% | 250 | >100 | | | >100 | Nil |
| VW1 - 11 | 1108 | Upper slope | S | 4% | 220 | >100 | | | >100 | Nil |
| VW 1 - 12 | 1109 | Upper slope | N | 4% | 200 | >100 | | | >100 | Nil |
| VW 1 - 13 | 1110 | Upper slope | W | 4% | 110 | 100 | | | 80 | Nil |
| VW 1 - 14 | 1111 | Mid slope | N | 5% | 110 | 90 | | | 90 | Nil |
| VW 1 - 15 | 1112 | Mid slope | N | 8% | 120 | >130 | | | 80 | Nil |
| VW 1 - 16 | 1113 | Mid slope | NW | 3% | 160 | 130 | | | 50 | Nil |
| VW1 - 17 | 1114 | Not evaluated | NW | 3% | 120 | 100 | | | 50 | Nil |
| VW 1 - 18 | 1115 | Mid slope | NW | 7% | 100 | 80 | | | 50 | Nil |
| VW 1 - 19 | 1116 | Lower slope | N | 8% | 100 | >100 | | | >300 | Nil |
| VW 1 - 20 | 1117/1118 | Lower slope | S | 7% | 80 | >100 | | | >300 | Nil |
| VW 1 - 21 | 1119 | Upper slope | S | 8% | 110 | >100 | | | >300 | Nil |
| VW 1 - 22 | 1120 | Upper slope | S | 7% | 140 | >100 | | | >300 | Nil |
| VW 1 - 23 | 1121 | Upper slope | S | 9% | 90 | >100 | | | >300 | Nil |
| VW 1 - 24 | 1122 | Upper slope | S | 10% | 100 | <100 | | | >300 | Nil |
| VW 1 - 25 | 1123 | Mid slope | SSW | 7% | 120 | >100 | | | >300 | Nil |
| VW 1 - 26 | 1124 | Mid slope | SW | 5% | 270 | >100 | | | >300 | Rocky Shallow soil |
| VW 1 - 27 | 1125 | Lower slope | SSW | 7% | 200 | 60 | | | >300 | |
| VW 1 - 28 | 1127 | Lower slope | SSW | 8% | 250 | 60 | | | >300m | Wet, Steep |

**Table 5.3. Indicative soil profile in area 1.**

| Site name | Depth (cm) | Field texture | Consistency | Pedality | Fabric | Colour | Boundaries | Mottles % | Nodules % | Hard pan | Bleached A2 | Root number | Biological activity | Texture change | Hard setting | Rock % |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| VW1-4 | 0-22 | Clay loam | Firm | Moderate | Earthy | Brown | Diffuse | No | No | No | No | Abundant | No | Gradual | No | 0% |
| | 22-56 | Light clay | Firm | Moderate | Earthy | Brown | Diffuse | No | Common Dark grey | | | Rare | No | Gradual | | 30% |
| | 56--80 | Medium clay | Firm | Massive | Earthy | Very light brown | Diffuse | 10% red | No | | | None | No | Gradual | | 50% |
| | 80-110 | Light clay | Firm | Massive | Earthy | Light brown | Diffuse | No | No | | | None | No | Gradual | | 50% |
| | 110-140 | | | | | | | | | | | | | | | 80% rock |

The key soil features are shown below.

**Table 5.4 Areas 1 and 2, soil profile features and comments.**

| Features | Comment |
|---|---|
| 10 to 20 cm of loam to clay loam topsoil | Loam to clay loam topsoils is preferred as they are reasonably permeable, so runoff is reduced. An irrigation strategy involving almost daily watering with 0.9 to 1.5 mm of permeate will minimise runoff risk. |
| Not hard setting | Good as moderate soil permeability is ideal for irrigation |
| Light to medium clay below the topsoil | Good as the clay dominant subsoil means that the nutrients are retained within the soil profile. |
| No evidence of a structurally unstable $A_2$ horizon | Good as there is less likelihood of a perched water table during prolonged wet weather. |
| Friable, weakly pedal topsoil overlying a firm to very firm subsoil. | The friability will assist root penetration. The weak structure means the soil is likely to become rutted when saturated. The irrigator will need wide tyres. |
| Brown to dark brown topsoil, graduating into a light brown to grey subsoil | Grey subsoil typically indicates poor deep drainage. |
| Subsoil commonly has 10% orange mottles (indicating occasional saturation and anaerobic conditions at depth). | Orange mottles indicate that the subsoil is a mosaic of saturated , anaerobic zones and areas where at least some oxygen is present. |
| Abundant roots and occasional earthworms in the topsoil | Abundant roots in the topsoil indicates good growing conditions.<br>Earthworms are less abundant in very acidic soils. Their presence is an indication of reasonable soil health. |
| Increasing rock percentage with increasing depth | The increasing rock at depth means there is less oxygen and less ability to retain nutrients with increasing depth. The increased rock reduces the volume of soil able to retain water and nutrients.<br><br>Relatively frequent, light irrigations are preferred. |

## Landform attributes and limitations in Area 2

**Table 5.5. Landform attributes in area 2. Figure 5.1 shows the sampling positions.**
**Area 2 sites with moderate limitations are highlighted in YELLOW. Sites with severe limitations are highlighted in RED.**

| Site Number | VW 2 - 1 | VW 2 - 2 | VW 2 - 3 | VW 2 - 4 | VW 2 - 5 | VW 2 - 6 | VW 2 - 7 | VW 2 - 8 | VW 2 - 9 | VW 2 - 10 | VW 2 - 11 | VW 2 - 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Area** | **2** | **2** | **2** | **2** | **2** | **2** | **2** | **2** | **2** | **2** | **2** | **2** |
| **Limitation** | | | | | | | | Bleached A2 | Wet area nearby Bleached A2 | | | |
| **Slope** | 2% | 0 | 2% | 0 | 1% | 0 | 0 | 0 | 0 | 3% | 2% | 3% |
| **Slope length (m)** | 60 | 0 | 40 | 0 | 60 | 0 | 0 | 0 | 0 | 70 | 60 | 60 |
| **Aspect** | NW | Flat | North | Flat | Flat | Flat | Flat | Flat | Flat | SW | SW | SW |
| **Land scape position** | Minor ridge line | | | | | | | | | | | |
| **Land form pattern** | Level | Very gently inclined | level | Very gently inclined | Very gently inclined | level | level | level | level | Very gently inclined | Very gently inclined | Very gently inclined |
| **Landform element** | Low | | | | | | | | | | | |
| **Drainage line distance (m)** | >100 | | | | | | | | | | | |
| **Run-on/ runoff** | Low | | | | | | | | | | | |

| Site Number | VW 2 - 1 | VW 2 - 2 | VW 2 - 3 | VW 2 - 4 | VW 2 - 5 | VW 2 - 6 | VW 2 - 7 | VW 2 - 8 | VW 2 - 9 | VW 2 - 10 | VW 2 - 11 | VW 2 - 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Area** | **2** | **2** | **2** | **2** | **2** | **2** | **2** | **2** | **2** | **2** | **2** | **2** |
| **Surface water bodies-streams, dams, springs** | Effluent storage dam to south | | | | | | | | | | | |
| **Storm water** | Minimal to low runon | | | | | | | | | | | |
| **Salt** | No evidence | | | | | | | | | | | |
| **Erosion potential based on current landuse** | Extremely low | | | | | | | | | | | |
| **Rock out crops %** | None | | | | | | | | | | | |
| **Soil parent material** | Volcanic | | | | | | | | | | | |
| **Depth to hard rock (cm)** | See soil profiles | | | | | | | | | | | |
| **Water table, depth** | >1m | | | | | | | | | | | |
| **Soil moisture** | Moist | | | | | | | | | | | |
| **Flood risk** | Zero | | | | | | | | | | | |
| **Land use** | Semi improved but weedy pasture | | | | | | | | | | | |
| **Land use history DISTURBANCE EVIDENCE** | Long term pasture | | | | | | | | | | | |

| Site Number | VW 2 - 1 | VW 2 - 2 | VW 2 - 3 | VW 2 - 4 | VW 2 - 5 | VW 2 - 6 | VW 2 - 7 | VW 2 - 8 | VW 2 - 9 | VW 2 - 10 | VW 2 - 11 | VW 2 - 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Area** | **2** | **2** | **2** | **2** | **2** | **2** | **2** | **2** | **2** | **2** | **2** | **2** |
| **Distance to public roads houses, etc** | >100m | | | | | | | | | | | |
| **Fire hazard** | Low to moderate (NOTE irrigation will keep the site moist reducing fire risk.) | | | | | | | | | | | |

## Landform attributes and limitations in Area 3

**Table 5.6. Landform attributes in area 3. Figure 5.1 shows the sampling positions. Area 3 sites with Moderate limitations are highlighted in YELLOW. Sites with critical limitations are also noted and highlighted in RED.**

| Site Number | VW 2 - 13 | VW 2 - 14 | VW 2 - 15 | VW 2 - 16 | VW 2 - 17 | VW 2 - 18 | VW 2 - 19 | VW 2 - 20 | VW 2 - 21 | VW 2 - 22 | VW 2 - 23 | VW 2 - 24 | VW 2 - 25 | VW 2 - 26 | VW 2 - 27 | VW 2 - 28 | VW 2 - 29 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Area | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 |
| Limitation | Shallow soil | | | Bleached A2 | Bleached A2 | | Wet area Avoid | | | | Bleached A2 | Wet. Bleached A2 Convergence zone | Wet Bleached A2 | Minor erosion | Bleached A2 | Bleached A2 | Bleached A2 |
| Slope | 12% | 8% | 3% | 8% | 6% | 4% | 7% | 4% | 4% | 5% | 5% | 4% | 5% | 6% | 5% | 5% | 7% |
| Slope length (m) | 120 | 120 | 120 | 90 | 70 | 150 | 70 | 90 | 120 | 50 | 70 | 250 | 30 | 100 | 200 | 200 | 150 |
| Aspect | W | NW | NW | W | SW | SW | W | W | NW | NW | NE | NE | NW | NE | N | NE | NW |
| Land scape position | lower slope | lower slope | Mid slope | Upper slope | Mid slope | Mid slope | lower slope | Mid slope | Mid slope | Upper slope | Mid slope | Lower slope | Lower slope | Lower slope | Mid slope | Upper slope | Upper slope |
| Land form pattern | Rolling low hills | Undulating low hills | Very gently inclined | Undulating low hills | Undulating low hills | Undulating low hills | Undulating low hills | Undulating low hills | Undulating low hills | Undulating low hills | Undulating low hills | Undulating low hills | Undulating low hills | Undulating low hills | Undulating low hills | Undulating low hills | Undulating low hills |
| Landform element | Low | | | | | | | | | | | | | | | | |
| Drainage line distance (m) | >100 | >100 | >100 | >100 | >100 | >100 | 70 | >100 | >100 | >100 | >100 | >100 | >100 | >100 | >100 | >100 | >100 |

| Site Number | VW 2 - 13 | VW 2 - 14 | VW 2 - 15 | VW 2 - 16 | VW 2 - 17 | VW 2 - 18 | VW 2 - 19 | VW 2 - 20 | VW 2 - 21 | VW 2 - 22 | VW 2 - 23 | VW 2 - 24 | VW 2 - 25 | VW 2 - 26 | VW 2 - 27 | VW 2 - 28 | VW 2 - 29 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Area** | **3** | **3** | **3** | **3** | **3** | **3** | **3** | **3** | **3** | **3** | **3** | **3** | **3** | **3** | **3** | **3** | **3** |
| **Run-on/ runoff** | Low to moderate | Low | Low | Low | Low | Low to moderate | Moderate | Low to moderate | Low | Low | Low | Low to moderate | Moderate | Low to moderate | Low to moderate | Low to moderate | Low to moderate |
| **Surface water bodies-streams, dams, springs** | Headwaters of unnamed creek >100m away | Headwaters of unnamed creek >100m away | Headwaters of unnamed creek >100m away | Headwaters of unnamed creek >100m away | Headwaters of unnamed creek >100m away | Headwaters of unnamed creek >100m away | 70m | Headwaters of unnamed creek >100m away | Headwaters of unnamed creek >100m away | Headwaters of unnamed creek >100m away | Headwaters of unnamed creek >100m away | Headwaters of unnamed creek >100m away | Headwaters of unnamed creek >100m away | Headwaters of unnamed creek >100m away | Headwaters of unnamed creek >100m away | Headwaters of unnamed creek >100m away | Headwaters of unnamed creek >100m away |
| **Storm water** | Minor runon | Minor runon | Minimal to low runon | Minimal to low runon | Minimal to low runon | Minimal to low runon | Minimal to low runon | Minimal to low runon | Minimal to low runon | Minimal to low runon | Minimal to low runon | Moderate | Minimal to low runon | Minimal to low runon | Minimal to low runon | Minimal to low runon | Minimal to low runon |
| **Salt** | No evidence | | | | | | | | | | | | | | | | |
| **Erosion potential based on current landuse** | Extremely low | | | | | | | | | | | | | | | | |
| **Rock out crops %** | 10% | 0 | %% | 0 | 0 | 0 | None | 10% | 5% | None | None | None | None | None | None | 1% | 5% |
| **Soil parent material** | Volcanic | Volcanic | Volcanic | Volcanic | Volcanic | Volcanic | Metamorphosed sandstone | Not evident | Not evident | Metamorphosed sandstone | Not evident | Not evident | Metamorphosed sandstone | Metamorphosed sandstone | Metamorphosed sandstone | Volcanic | Metamorphosed sandstone |

| Site Number | VW 2 - 13 | VW 2 - 14 | VW 2 - 15 | VW 2 - 16 | VW 2 - 17 | VW 2 - 18 | VW 2 - 19 | VW 2 - 20 | VW 2 - 21 | VW 2 - 22 | VW 2 - 23 | VW 2 - 24 | VW 2 - 25 | VW 2 - 26 | VW 2 - 27 | VW 2 - 28 | VW 2 - 29 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Area** | **3** | **3** | **3** | **3** | **3** | **3** | **3** | **3** | **3** | **3** | **3** | **3** | **3** | **3** | **3** | **3** | **3** |
| **Depth to hard rock (cm)** | 80 | | | | | | 48 | | | 85 | | | | | | | |
| **Water table, depth** | >1m | | | | | | | | | | | | | | | | |
| **Soil moisture** | Moist | Moist | Moist | Moist | Moist | Moist | Wet | Moist | Wet | Moist | Moist | Wet. | Wet | Moist | Moist | Moist | Moist |
| **Flood risk** | Zero | | | | | | | | | | | | | | | | |
| **Land use** | Semi improved but weedy pasture | | | | | | | | | | | | | | | | |
| **Land use history DISTURBANCE EVIDENCE** | Long term pasture | | | | | | | | | | | | | | | | |
| **Distance to public roads houses, etc** | >100m | | | | | | | | | | | | | | | | |
| **Fire hazard** | Low to moderate | | | | | | | | | | | | | | | | |

# Landform attributes and limitations in Area 4

**Table 5.7. Landform attributes in area 4. Figure 5.1 shows the sampling positions. Area 4 sites with Moderate limitations are highlighted in YELLOW. Sites with critical limitations are also noted and highlighted in RED.**

| Site Number | VW 2 - 30 | VW 2 - 31 | VW 2 - 32 | VW 2 - 33 | VW 2 - 34 | VW 2 - 35 | VW 2 - 36 | VW 2 - 37 | VW 2 - 38 | VW 2 - 39 |
|---|---|---|---|---|---|---|---|---|---|---|
| **Area** | **4** | **4** | **4** | **4** | **4** | **4** | **4** | **4** | **4** | **4** |
| **Limitation** | Bleached A2. Steep for travelling irrigator | | Bleached A2. Steep for travelling irrigator | Wet soil Bleached A2. Steep for travelling irrigator | Drainage line approximately 40m away. Avoid the area | Steep for travelling irrigator | Steep for travelling irrigator | Shallow soil | Shallow soil | Bleached A2. Slope |
| **Slope** | 10% | 7% | 11% | 15% | 9% | 11% | 20% | 5% | 8% | 8% |
| **Slope length (m)** | 120 | 90 | 120 | 160 | 70 | 80 | 40 | 10 | 40 | 60 |
| **Aspect** | N | W | SW | W | W | NW | SW | Crest | W | SW |
| **Land scape position** | Upper slope | Upper slope | Upper slope | Mid slope | Mid slope | Mid slope | Mid slope | Upper slope | Upper slope | Upper slope |
| **Land form pattern** | Rolling low hills | Undulating low hills | Rolling low hills | Rolling low hills | Undulating low hills | Rolling low hills | Rolling low hills | Rolling low hills | Rolling low hills | Rolling low hills |
| **Landform element** | Low | | | | | | | | | |
| **Drainage line distance (m)** | 45 m | >100 | >100 | >100 | >100 | >100 | >100 | >100 | >100 | >100 |
| **Run-on/ runoff** | Low to moderate | Low to moderate | Low to moderate | Low to moderate | Low to moderate | Low to moderate | Low to moderate | Very low | Very low | Very low |

| Site Number | VW 2 - 30 | VW 2 - 31 | VW 2 - 32 | VW 2 - 33 | VW 2 - 34 | VW 2 - 35 | VW 2 - 36 | VW 2 - 37 | VW 2 - 38 | VW 2 - 39 |
|---|---|---|---|---|---|---|---|---|---|---|
| **Area** | **4** | **4** | **4** | **4** | **4** | **4** | **4** | **4** | **4** | **4** |
| **Surface water bodies-streams, dams, springs** | Headwaters of unnamed creek >100m away | Headwaters of unnamed creek >100m away | Headwaters of unnamed creek >100m away | Headwaters of unnamed creek >100m away | Headwaters of unnamed creek >40m away | Headwaters of unnamed creek >100m away | Headwaters of unnamed creek >100m away | Headwaters of unnamed creek >100m away | Headwaters of unnamed creek >100m away | Headwaters of unnamed creek >100m away |
| **Storm water** | Minimal to low runon | | | | | | | | | |
| **Salt** | No evidence | | | | | | | | | |
| **Erosion potential based on current landuse** | Extremely low | | | | | | | | | |
| **Rock out crops %** | 5% | 10% | 5% | 1% | 2% | 1% | 5% | 4% | 5% | 1% |
| **Soil parent material** | Volcanic | Meta morphosed sandstone | Meta morphosed sandstone | Not evident | Volcanic | Meta morphosed sandstone | Not evident | Meta morphosed sandstone | Meta morphosed sandstone | Meta morphosed sandstone |
| **Depth to hard rock (cm)** | >1m | >1m | >1m | >1m | >1m | >1m | >1m | 45cm | 65 cm | >1m |
| **Water table, depth** | >1m | | | | | | | | | |
| **Soil moisture** | Moist | Moist | Moist | Wet | Moist | Moist | Moist | Moist | Moist | Moist |
| **Flood risk** | Zero | | | | | | | | | |
| **Land use** | Semi improved but weedy pasture | | | | | | | | | |
| **Land use history DISTURBANCE EVIDENCE** | Long term pasture | | | | | | | | | |

| Site Number | VW 2 - 30 | VW 2 - 31 | VW 2 - 32 | VW 2 - 33 | VW 2 - 34 | VW 2 - 35 | VW 2 - 36 | VW 2 - 37 | VW 2 - 38 | VW 2 - 39 |
|---|---|---|---|---|---|---|---|---|---|---|
| Area | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 |
| Distance to public roads houses, etc | >100m | | | | | | | | | |
| Fire hazard | Low to moderate | | | | | | | | | |

# Key landform limitations

## Area 1:

Sites 26 and 28 have significant limitations and should be avoided if possible

## Area 2:

Sites 8 and 9 have moderate limitations and should be avoided if possible. Machinery bogging may be an issue with the centre pivot. Fixed sprinklers are the preferred irrigation method. Use large quantities of gypsum to coagulate the soil and improve internal drainage on Area 2, sites 8 and 9.

## Area 3 :

Most sites in area 3 have moderate limitations. Avoid Area 3, sites 19 and 20. Both are ‘wet’.

## Area 4:

Sites 37 and 38 have shallow soil. Site 34 is within 50m of a drainage line. This area should NOT be irrigated.

Most sites in area 4 have ‘moderate’ limitations.

# Conclusions regarding the 4 areas

Area 1 has the fewest soil / landform limitations.

Area 2 is broadly similar to area 1. There is a poorly drained area (sites 8 and 9). Adding an initial topdressing of 4 T/ha of gypsum will assist in improving drainage in this area.

Much of Area 3 has moderate limitations. The irrigation application rate needs to adjusted downwards to minimise risk of water logging. Applying less than a mm/irrigation day is advised.

Most of Area 4 has moderate to severe limitations. Applying a very low irrigation rate, e.g., less than a mm/day, will assist in overcoming moderate limitations. Irrigation should not occur in the SW portion (sites 34, 35 and 36).

# 6. SOIL CHEMICAL DATA FOR AREA 1`

Soil samples were taken from 66 topsoil sites within areas 1 to 4. Figure 5.1 shows the sampling positions. The reason for emphasis on topsoil chemistry this is that the topsoil is a key determinant of successful irrigation.

- It controls the water infiltration rate
- It contains the bulk of the plant root systems
- It contains a high proportion of plant nutrients
- Under good soil conditions it contains a large and diverse biota that can increase nutrient availability as well as assist in accumulating resilient soil organic carbon.

Area 1 was sampled and analysed first. The reason for this is that preliminary assessment indicated that it probably contained the most suitable soils and landforms for irrigation. Area 1 therefore set the 'standard' for the other 3 areas.

The 'raw' data for the topsoils at 27 pits in area 1 is shown in table 6.1. Note the sampling point 1.28 was not sampled as it was wet and unsuitable for irrigation.

Table 6.2 presents the statistical analyses for area 1 topsoils.

**Table 6.1. The 'raw' data for the 27 topsoil samples taken from Area 1. Figure 5.1 shows the sampling positions.**

| *Parameter* | **VW 1 0-15** | **VW 2 0-20** | **VW 3-0-19** | **VW 4 0-22** | **VW 5 0-17** | **VW 6 0-22** | **VW 7 0-14** | **VW 8 0-15** | **VW 9 0-15** | **VW 10 0-10** | **VW 11 0-15** | **VW 12 0-20** | **VW 13 0-16** | **VW 14 0-10** | **VW 15 0-15** | **VW 16 0-7** | **VW 17 0-12** | **VW 18 0-13** | **VW 19 0-15** | **VW 20 0-15** | **VW 21 0-16** | **VW 22 0-9** | **VW 23 0-15** | **VW 24 0-15** | **VW 25 0-15** | **VW 26 0-13** | **VW 27 0-10** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Soluble Ca (mg/kg) | 772 | 851 | 744 | 524 | 636 | 610 | 622 | 370 | 324 | 310 | 593 | 671 | 289 | 986 | 1129 | 840 | 815 | 842 | 1058 | 715 | 901 | 749 | 946 | 732 | 803 | 247 | 202 |
| Soluble Mg (mg/kg) | 170 | 383 | 210 | 141 | 129 | 149 | 150 | 104 | 100 | 123 | 170 | 217 | 100 | 316 | 283 | 234 | 226 | 290 | 302 | 223 | 212 | 184 | 264 | 187 | 212 | 63 | 65 |
| Soluble K (mg/kg) | 100 | 56 | 132 | 63 | 53 | 120 | 116 | 63 | 49 | 114 | 43 | <25 | 52 | <25 | 34 | 49 | 54 | 28 | <25 | 68 | 134 | <25 | <25 | <25 | <25 | 53 | 48 |
| Soluble P (mg/kg) | 4.7 | 2.4 | 1.3 | 1.7 | 2.0 | 2.3 | 1.7 | 1.9 | 1.4 | <1 | 2.4 | 1.1 | <1 | <1 | 2.1 | 4.2 | 2.9 | 1.7 | 1.8 | 1.7 | 7.4 | 1.6 | <1 | 1.8 | <1 | 1.5 | <1 |
| Available P (Bray 1 mg/kg) | 14 | 4.1 | 4.3 | 3.9 | 9.6 | 6.8 | 4.9 | 5.1 | 5.6 | 4.4 | 4.1 | 1.2 | 8.8 | 1.1 | 4.5 | 7.5 | 2.6 | 3.2 | 2.0 | 3.9 | 31.2 | 3.6 | 1.6 | 1.5 | 2.1 | 9.4 | 4.0 |
| Available P (Bray 2 mg/kg) | 63 | 7.3 | 7.6 | 8.0 | 18 | 12 | 10 | 7.3 | 11 | 8.7 | 6.1 | 2.0 | 12 | 2.5 | 7.8 | 10.2 | 5.6 | 5.0 | 4.2 | 6.4 | 54 | 7.5 | 3.2 | 2.8 | 6.1 | 13 | 7.5 |
| Nitrate-N (mg/kg) | 7.2 | 4.5 | 12.2 | 16.7 | 10.9 | 8.6 | 9.3 | 4.7 | 8.0 | 6.7 | 11.6 | 5.0 | 2.7 | 1.8 | 8.1 | 20.6 | 10.1 | 12.6 | 6.2 | 7.2 | 22.2 | 10.9 | 5.4 | 8.2 | 7.3 | 12.9 | 11 |
| Ammonium -N (mg/kg) | 4.2 | 6.0 | 6.5 | 7.0 | 12.5 | 5.7 | 4.4 | 6.4 | 5.4 | 13.6 | 16.0 | 4.4 | 3.2 | 4.6 | 8.7 | 13.8 | 4.9 | 12.8 | 3.7 | 4.0 | 9.4 | 5.1 | 6.7 | 5.9 | 6.9 | 11.3 | 7.6 |
| Sulfur (mg/kg S) | 13 | 13.6 | 7.4 | 10.7 | 9.3 | 11.7 | 10.0 | 5.7 | 14.6 | 4.4 | 7.2 | 7.0 | 10.7 | 9.3 | 10.2 | 11.9 | 10.9 | 11.1 | 9.9 | 11.9 | 15.3 | 14.9 | 5.5 | 11.3 | 12.5 | 10.5 | 3.3 |
| pH (5:1 Water: Soil) | 5.49 | 5.38 | 5.50 | 5.01 | 5.07 | 5.11 | 5.34 | 5.29 | 5.16 | 5.62 | 5.11 | 5.80 | 5.68 | 6.12 | 5.55 | 5.21 | 5.52 | 5.42 | 5.95 | 5.63 | 5.58 | 5.04 | 5.66 | 5.55 | 5.74 | 5.11 | 5.12 |
| pH ( dS/m 5:1 Water: Soil) | 0.072 | 0.050 | 0.066 | 0.094 | 0.063 | 0.071 | 0.061 | 0.040 | 0.058 | 0.054 | 0.067 | 0.033 | 0.053 | 0.034 | 0.054 | 0.095 | 0.057 | 0.065 | 0.043 | 0.059 | 0.115 | 0.059 | 0.032 | 0.048 | 0.041 | 0.054 | 0.043 |
| Exch Ca *cmol+/kg) | 7.0 | 8.77 | 7.03 | 4.75 | 5.60 | 5.66 | 5.88 | 2.97 | 2.61 | 2.60 | 5.09 | 6.04 | 2.25 | 9.12 | 10.97 | 8.05 | 7.37 | 8.45 | 10.40 | 6.27 | 8.04 | 7.51 | 9.56 | 6.70 | 7.50 | 2.00 | 1.7 |
| Exch Mg *cmol+/kg) | 2.4 | 5.31 | 2.55 | 1.61 | 1.42 | 1.75 | 1.72 | 1.05 | 1.04 | 1.25 | 1.83 | 2.52 | 0.94 | 3.50 | 3.35 | 2.74 | 2.48 | 3.57 | 3.52 | 2.44 | 2.37 | 2.25 | 3.22 | 2.11 | 2.47 | 0.66 | 0.66 |
| Exch K *cmol+/kg) | 0.39 | 0.31 | 0.61 | 0.26 | 0.21 | 0.58 | 0.57 | 0.24 | 0.19 | 0.40 | 0.18 | <0.12 | 0.15 | <0.12 | 0.19 | 0.21 | 0.26 | 0.17 | 0.14 | 0.29 | 0.65 | 0.15 | <0.12 | <0.12 | <0.12 | 0.25 | 0.20 |
| Exch K *cmol+/kg) | 0.23 | 0.15 | 0.08 | 0.10 | <0.065 | <0.065 | 0.07 | <0.065 | 0.11 | 0.11 | 0.07 | 0.08 | 0.13 | 0.10 | 0.10 | 0.13 | 0.08 | 0.08 | 0.11 | 0.12 | 0.11 | 0.07 | 0.10 | 0.09 | 0.09 | <0.065 | 0.12 |

| | | | | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Exch K *cmol+/kg) | 0.09 | 0.41 | 0.18 | 0.66 | 0.56 | 0.58 | 0.25 | 0.34 | 0.66 | 0.15 | 0.59 | 0.09 | 0.15 | 0.05 | 0.13 | 0.29 | 0.12 | 0.35 | 0.06 | 0.05 | 0.07 | 1.22 | 0.16 | 0.15 | 0.10 | 0.51 | 0.84 |
| Exch K *cmol+/kg) | 0.25 | 0.22 | 0.13 | 0.29 | 0.27 | 0.27 | 0.20 | 0.21 | 0.26 | 0.14 | 0.28 | 0.17 | 0.18 | 0.19 | 0.13 | 0.23 | 0.14 | 0.23 | 0.20 | 0.28 | 0.22 | 0.53 | 0.18 | 0.19 | 0.17 | 0.31 | 0.33 |
| Effective Cation Exchange Capacity (ECEC) ($cmol_+/kg$) | 10 | 15.16 | 10.58 | 7.67 | 8.12 | 8.92 | 8.69 | 4.86 | 4.87 | 4.65 | 8.03 | 9.00 | 3.80 | 13.04 | 14.86 | 11.65 | 10.46 | 12.84 | 14.44 | 9.46 | 11.46 | 11.72 | 13.27 | 9.37 | 10.42 | 3.78 | 3.8 |
| Ca as % of effective CEC | 67 | 57.8 | 66.4 | 61.9 | 69.0 | 63.5 | 67.6 | 61.1 | 53.6 | 55.9 | 63.3 | 67.1 | 59.1 | 69.9 | 73.8 | 69.1 | 70.5 | 65.8 | 72.0 | 66.3 | 70.2 | 64.1 | 72.0 | 71.5 | 72.0 | 52.9 | 44 |
| Mg as % of effective CEC | 23 | 35.0 | 24.1 | 21.0 | 17.5 | 19.6 | 19.8 | 21.7 | 21.4 | 27.0 | 22.8 | 28.0 | 24.8 | 26.8 | 22.5 | 23.5 | 23.7 | 27.8 | 24.4 | 25.8 | 20.7 | 19.2 | 24.2 | 22.5 | 23.7 | 17.4 | 17 |
| K as % of effective CEC | 3.7 | 2.0 | 5.8 | 3.4 | 2.6 | 6.5 | 6.6 | 4.9 | 3.9 | 8.7 | 2.2 | 1.2 | 4.0 | 0.6 | 1.3 | 1.8 | 2.5 | 1.3 | 1.0 | 3.1 | 5.7 | 1.3 | 0.4 | 1.3 | 0.8 | 6.6 | 5.3 |
| Na as % of effective CEC | 2.2 | 1.0 | 0.8 | 1.3 | 0.8 | 0.7 | 0.9 | 1.0 | 2.2 | 2.3 | 0.8 | 0.9 | 3.5 | 0.8 | 0.6 | 1.1 | 0.8 | 0.6 | 0.8 | 1.3 | 0.9 | 0.6 | 0.7 | 1.0 | 0.9 | 1.2 | 3.2 |
| Al as % of effective CEC | 0.89 | 2.7 | 1.7 | 8.6 | 6.9 | 6.6 | 2.9 | 7.0 | 13.7 | 3.2 | 7.4 | 1.0 | 3.8 | 0.4 | 0.9 | 2.5 | 1.1 | 2.7 | 0.4 | 0.5 | 0.6 | 10.4 | 1.2 | 1.6 | 0.9 | 13.6 | 22 |
| H as % of effective CEC | 2.4 | 1.4 | 1.3 | 3.8 | 3.3 | 3.1 | 2.3 | 4.3 | 5.4 | 3.1 | 3.5 | 1.9 | 4.7 | 1.5 | 0.9 | 2.0 | 1.4 | 1.8 | 1.4 | 2.9 | 1.9 | 4.5 | 1.4 | 2.1 | 1.7 | 8.3 | 8.5 |
| Ca : Mg ratio | 2.9 | 1.7 | 2.8 | 2.9 | 3.9 | 3.2 | 3.4 | 2.8 | 2.5 | 2.1 | 2.8 | 2.4 | 2.4 | 2.6 | 3.3 | 2.9 | 3.0 | 2.4 | 3.0 | 2.6 | 3.4 | 3.3 | 3.0 | 3.2 | 3.0 | 3.0 | 2.5 |
| Zinc (mg/kg) | 6.8 | 3.9 | 6.4 | 5.4 | 8.4 | 7.6 | 6.9 | 2.6 | 3.9 | 5.3 | 4.8 | 1.5 | 2.7 | 1.1 | 3.8 | 4.7 | 4.7 | 4.1 | 2.0 | 3.4 | 6.7 | 6.0 | 4.0 | 5.4 | 4.4 | 3.9 | 3.6 |
| Manganese (mg/kg) | 34 | 46 | 73 | 73 | 37 | 92 | 79 | 30 | 23 | 12 | 72 | 24 | 7 | 28 | 52 | 77 | 56 | 74 | 42 | 42 | 63 | 88 | 51 | 74 | 58 | 51 | 9.2 |
| Iron (mg/kg) | 328 | 167 | 377 | 435 | 316 | 556 | 388 | 308 | 391 | 421 | 512 | 193 | 160 | 97 | 181 | 300 | 262 | 329 | 105 | 360 | 363 | 477 | 308 | 303 | 423 | 262 | 376 |
| Copper (mg/kg) | 1.2 | 1.4 | 1.9 | 1.3 | 1.5 | 1.8 | 1.5 | 0.9 | 0.9 | 0.5 | 1.6 | 0.9 | 0.2 | 1.4 | 1.6 | 1.9 | 1.9 | 1.8 | 1.6 | 1.4 | 1.7 | 2.1 | 1.5 | 2.1 | 2.0 | 0.7 | 0.43 |

| | | | | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Boron (mg/kg) | 0.45 | 0.61 | 0.54 | 0.34 | 0.34 | 0.41 | 0.36 | 0.20 | 0.14 | 0.20 | 0.22 | 0.29 | 0.20 | 0.23 | 0.37 | 0.37 | 0.35 | 0.38 | 0.45 | 0.39 | 0.56 | 0.41 | 0.64 | 0.54 | 0.54 | 0.25 | 0.40 |
| Silicon (mg/kg) | 50 | 60 | 56 | 55 | 63 | 69 | 50 | 34 | 25 | 28 | 47 | 29 | 18 | 37 | 44 | 49 | 49 | 50 | 45 | 53 | 65 | 56 | 43 | 38 | 50 | 21 | 21 |
| Texture | Clay Loam | Clay Loam | Clay Loam | Clay Loam | Clay Loam | Clay Loam | Clay Loam | Clay Loam | Clay Loam | Clay Loam | Clay Loam | Clay Loam | Clay Loam | Clay Loam | Clay Loam | Clay Loam | Clay Loam | Clay Loam | Clay Loam | Clay Loam | Clay Loam | Clay Loam | Clay Loam | Clay Loam | Clay Loam | Clay Loam | Clay Loam |
| Chloride (mg/kg) | 46 | 32 | 42 | 60 | 40 | 45 | 39 | 26 | 37 | 35 | 43 | 21 | 34 | 22 | 35 | 61 | 36 | 42 | 28 | 38 | 74 | 38 | 20 | 31 | 26 | 35 | 28 |
| Phosphorus sorption (mg/kg) | 136 | 319 | 242 | 286 | 227 | 290 | 246 | 191 | 266 | 211 | 301 | 249 | 136 | 244 | 308 | 299 | 264 | 345 | 286 | 246 | 205 | 387 | 196 | 299 | 376 | 167 | 268 |
| Horizon thickness (cm) | 15 | 20 | 19 | 22 | 17 | 22 | 14 | 15 | 15 | 10 | 15 | 20 | 16 | 10 | 15 | 7 | 12 | 13 | 15 | 15 | 16 | 9 | 15 | 15 | 15 | 13 | 10 |
| Assumed bulk density | 1.50 | 1.50 | 1.50 | 1.50 | 1.50 | 1.50 | 1.50 | 1.50 | 1.50 | 1.50 | 1.50 | 1.50 | 1.50 | 1.50 | 1.50 | 1.50 | 1.50 | 1.50 | 1.50 | 1.50 | 1.50 | 1.50 | 1.50 | 1.50 | 1.50 | 1.50 | 1.50 |
| P sorption (kg/ha) | 307 | 957 | 690 | 944 | 433 | 862 | 517 | 409 | 599 | 317 | 678 | 746 | 285 | 366 | 693 | 283 | 475 | 674 | 579 | 554 | 491 | 497 | 441 | 673 | 846 | 293 | 403 |

**Table 6.2. The statistical analyses of the 27 topsoil samples from Area 1.**

| *Parameter* | Indicative guideline values for clay loam | Indicative guideline values for loam | Min | Max | Count | Average | Stdev | Confidence interval | lower 95%ile CI | Upper 95%ile CI | Comment |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Soluble Ca (mg/kg) | *750* | *375* | 202 | 1129 | 27 | 677 | 248 | 94 | 583 | 771 | Within desirable range for loam to clay loam soils |
| Soluble Mg (mg/kg) | *105* | *60* | 63.3 | 383 | 27 | 193 | 78 | 30 | 163 | 222 | A bit high. Add lime to balance the Ca : Mg ratio |
| Soluble K (mg/kg) | *75* | *60* | 28.4 | 134 | 20 | 71.5 | 33.1 | 14.5 | 57.0 | 86.0 | Within desirable range for loam to clay loam soils |
| Soluble P (mg/kg) | *12* | *10* | 1.09 | 7.38 | 21 | 2.36 | 1.42 | 0.61 | 1.75 | 2.96 | Very low Add P fertiliser |
| Available P (Bray 1 mg/kg) | *30* | *24* | 1.13 | 31.2 | 27 | 5.75 | 5.80 | 2.19 | 3.56 | 7.93 | Very low Add P fertiliser |
| Available P (Bray 2 mg/kg) | *60* | *48* | 2.02 | 63.2 | 27 | 11.4 | 13.8 | 5.22 | 6.20 | 16.6 | Very low Add P fertiliser |
| Nitrate-N (mg/kg) | *13* | *10* | 1.84 | 22.2 | 27 | 9.34 | 4.73 | 1.78 | 7.55 | 11.1 | A bit low. Encourage Sub clover. |
| Ammonium-N (mg/kg) | *18* | *15* | 3.19 | 16.0 | 27 | 7.43 | 3.50 | 1.32 | 6.11 | 8.75 | A bit low. Encourage Sub clover. |
| Sulfur (mg/kg S) | *8.0* | *8.0* | 3.30 | 15.3 | 27 | 10.1 | 3.08 | 1.16 | 8.99 | 11.3 | Within desirable range for loam to clay loam soils |
| pH (5:1 Water: Soil) | *6.5* | *6.3* | 5.01 | 6.12 | 27 | 5.44 | 0.29 | 0.11 | 5.33 | 5.54 | A bit low add lime. Check % Exch Al to determine application rate. |
| pH ( dS/m 5:1 Water: Soil) | *0.150* | *0.120* | 0.03 | 0.12 | 27 | 0.06 | 0.02 | 0.01 | 0.05 | 0.07 | Low salinity and therefore OK |
| Exch Ca *cmol+/kg | *10.8* | *5.0* | 1.67 | 11.0 | 27 | 6.29 | 2.57 | 0.97 | 5.32 | 7.26 | Within desirable range for loam. Slightly low for clay loam soils |
| Exch Mg *cmol+/kg | *1.7* | *1.2* | 0.66 | 5.31 | 27 | 2.25 | 1.04 | 0.39 | 1.86 | 2.64 | A bit high. Add lime to increase the Ca: Mg ratio |
| Exch K *cmol+/kg | *0.50* | *0.40* | 0.14 | 0.65 | 22 | 0.30 | 0.16 | 0.07 | 0.23 | 0.37 | A bit low. Add K containing fertilizer |
| Exch Na *cmol+/kg | *0.26* | *0.22* | 0.07 | 0.23 | 23 | 0.11 | 0.03 | 0.01 | 0.09 | 0.12 | Low and OK. Check SAR |
| Exch Al *cmol+/kg | *0.5* | *0.4* | 0.05 | 1.22 | 27 | 0.33 | 0.29 | 0.11 | 0.22 | 0.43 | Low and OK. Check % Exchangeable Al |
| Exch $H^+$ *cmol+/kg | *0.5* | *0.4* | 0.13 | 0.53 | 27 | 0.23 | 0.08 | 0.03 | 0.20 | 0.26 | Low and OK. |
| Effective Cation Exchange Capacity (ECEC) ($cmol_+$/kg) | *14.3* | *7.8* | 3.78 | 15.2 | 27 | 9.46 | 3.40 | 1.28 | 8.17 | 10.74 | Within desirable range for loams. A bit low for clay loam soils |
| Ca as % of effective CEC | *75.7* | *65.6* | 44 | 74 | 27 | 65 | 7 | 3 | 62 | 67 | A bit low. Add lime. |

| *Parameter* | Indicative guideline values for clay loam | Indicative guideline values for loam | Min | Max | Count | Average | Stdev | Confidence interval | lower 95%ile CI | Upper 95%ile CI | Comment |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Mg as % of effective CEC | *11.9* | *15.7* | 17 | 35 | 27 | 23 | 4 | 1 | 22 | 25 | A bit high. Add lime. NO dolomite required. |
| K as % of effective CEC | *3.5* | *5.2* | 0 | 9 | 27 | 3 | 2 | 1 | 2 | 4 | A bit low. Add K containing fertilizer |
| Na as % of effective CEC | *1.8* | *2.9* | 1 | 4 | 27 | 1 | 1 | 0 | 1 | 2 | Low and OK |
| Al as % of effective CEC | *7.1* | *10.5* | 0 | 22 | 27 | 5 | 5 | 2 | 3 | 7 | Zero is preferable. Add lime. |
| H as % of effective CEC | | | 1 | 9 | 27 | 3 | 2 | 1 | 2 | 4 | Zero is preferable. Add lime. |
| Ca : Mg ratio | *6.4* | *4.2* | 1.65 | 3.95 | 27 | 2.85 | 0.46 | 0.17 | 2.68 | 3.02 | Low. Add lime. |
| Zinc (mg/kg) | *5.0* | *4.0* | 1.06 | 8.44 | 27 | 4.60 | 1.80 | 0.68 | 3.92 | 5.28 | OK |
| Manganese (mg/kg) | *22* | *18* | 7.46 | 92.4 | 27 | 50.6 | 24.0 | 9.06 | 41.6 | 59.7 | A bit high, but low toxicity. Liming will reduce availability |
| Iron (mg/kg) | *22* | *18* | 97 | 556 | 27 | 322 | 115 | 44 | 279 | 366 | A bit high, but low toxicity. Liming will reduce availability |
| Copper (mg/kg) | *2.0* | *1.6* | 0.22 | 2.15 | 27 | 1.40 | 0.51 | 0.19 | 1.20 | 1.59 | Within desirable range for loam to clay loam soils |
| Boron (mg/kg) | *1.7* | *1.4* | 0.14 | 0.64 | 27 | 0.38 | 0.13 | 0.05 | 0.33 | 0.43 | A bit low. Consider adding boron |
| Silicon (mg/kg) | *45* | *40* | 18.3 | 68.8 | 27 | 44.7 | 13.7 | 5.2 | 39.5 | 49.8 | Within desirable range for loam to clay loam soils |
| Chloride (mg/kg) | | .. | 20.5 | 73.6 | 27 | 37.5 | 12.1 | 4.6 | 32.9 | 42.0 | Low and indicating good soil drainage |
| Phosphorus sorption (mg/kg) | | | 136 | 387 | 27 | 259 | 63 | 14 | 245 | 274 | |

**Table 6.3. Phosphorus sorption capacity down to rock at 5 sites in Area 1 (VW 2, VW 8, VW 15, VW 22 And VW 27). Figure 5.1 shows the sampling positions. Soil depths are in cm.**

| P Sorption components | VW 2 0-20 cm | VW 2 20-50 | VW 2 50-95 | VW8 0-15 | VW 8 15-55 | VW8 55-80 | VW8 80-105 | VW 15 0-15 | VW15 14-45 | VW15 45-75 | VW15 75-97 | VW 22 0-9 | VW22 9-55 | VW22 55-72 | VW 27 0-10 | VW 27 10-60 | VW 27 61-100 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Phosphorus sorption (mg/kg) | 319 | 699 | 372 | 191 | 616 | 559 | 240 | 308 | 411 | 572 | 409 | 387 | 624 | 251 | 268 | 655 | 260 |
| Horizon thickness (cm) | 20 | 30 | 45 | 15 | 40 | 35 | 25 | 15 | 30 | 30 | 22 | 9 | 46 | 17 | 10 | 50 | 39 |
| Assumed bulk density | 1.50 | 1.60 | 1.60 | 1.50 | 1.60 | 1.60 | 1.60 | 1.50 | 1.60 | 1.60 | 1.60 | 1.50 | 1.60 | 1.60 | 1.50 | 1.60 | 1.60 |
| Rock as a proportion of total volume | 0.00 | 0.10 | 0.30 | 0.05 | 0.05 | 0.20 | 0.70 | 0.00 | 0.40 | 0.50 | 0.60 | 0.05 | 0.40 | 0.85 | 0.00 | 0.00 | 0.80 |
| P sorption (kg/ha) | 957 | 3018 | 1874 | 409 | 3744 | 2503 | 288 | 693 | 1185 | 1373 | 576 | 497 | 2756 | 102 | 403 | 5240 | 324 |
| Total profile P sorption in kg/ha | | | 5848 | | | | 6944 | | | | 3827 | | | 3355 | | | 5966 |

**Table 6.4 statistical analyses of P sorption capacity data for 5 profiles in Area 1.**

| Mean | Stdev | Count | Confidence Interval (CI) | Lower 95%ile CI | Upper 95%ile CI |
|---|---|---|---|---|---|
| 5188 | 1528 | 5 | 1339 | 3849 | 6527 |

# Discussion of topsoil chemistry in Area 1

## Soluble cations

The top soils are Ca dominant. This is desirable as Ca is a major determinant of soil structure. Good structure is essential for irrigation as soil structure is a major determinant of soil infiltration rate.
The combination of permanent pasture and high calcium content is highly desirable for this project

The Mg content is high. This is an issue as too much Mg, compared with Ca reduces soil stability. Add lime to correct.

K content is within the desirable range.
Some K rich fertiliser may be required in the long term.

## P availability

Soluble P is very low. These soils are severely P deficient. This deficit needs to be rectified because the key to maximising evapotranspiration and therefore irrigation demand is to have lots of healthy pasture biomass.

Available P (expressed as Bray available P), is extremely low. For example, the 'desirable' range for loams to clay loams is 24 to 30 mg/kg. The 95% upper Confidence limit for Bray 1 P is 7.9 mg/kg. The addition of at least 20 kg/ha of P as superphosphate every year for at least 5 years is considered essential to the viability of the irrigation scheme.

## Nitrogen

Nitrate-N concentration is 'moderate'. Adding more subclover to the pasture mix will increase nitrogen addition.

Ammonium-N concentration is low. Increasing phosphorus availability will increase sub clover growth (note pH will also need to be increased as acid conditions prevent clover rhizobia from establishing).

## Sulfur

Sulfur concentration is adequate. Addition of superphosphate will further increase S availability.

## Acidity

The pH range is relatively low. The 95%ile upper and lower confidence interval is 5.33 to 5.44. This is low and the addition of agricultural lime is considered essential. The target pH is 6 to 7 (Hazelton and Murphy, 2016).

## Salinity

Salinity is very low. This indicates a well-drained soil. Maintaining good soil drainage is important as it will assist in maximising plant vigour and evapotranspiration.

## Exchangeable cations

Exchangeable Ca concentration is slightly low. Add lime ($CaCO_3$) to maximise soil fertility and utilisation of the irrigation water.

The Ca as a % of ECE is important as a Ca dominant soil is more structurally stable. The proposed liming will increase Ca percentage.

Exchangeable Mg concentration is high. This can be adjusted by adding agricultural lime. It is important because excess Mg can increase the risk of structural degradation.

The Mg as a % of the CEC is high. Too high a percentage will encourage loss of soil structure. Adding lime will reduce this percentage.

Exchangeable K concentration is low. Some potassium fertilizer is recommended. The 95% upper and lower limits are 2% to 4%. The desirable percentage is 4% to 5%. Adding K based fertiliser will assist in maximising pasture growth and therefore water utilisation.

Exchangeable Na concentration is low. This is good as excess Na increases soil structural instability. The Na as a percentage of the ECEC should be <3%. The 95% lower and upper confidence interval is 1 to 2%. This result is good.

Exchangeable Al concentration is higher than desirable in soil of the soils. Adding lime will address this issue. The Al as a percentage of the ECEC should be <11 (for loams). The maximum is 22%. This is very high and will stunt root growth of some pasture plants, especially clovers. Adding lime will reduce this percentage. Liming is considered essential.

Exchangeable $H^+$ concentrations are within the ‘desirable’ range. The lower the better, as a very low number indicates maximisation of the CEC that is occupied by ‘desirable’ cations such as Ca and K. There is no issue at present with the Exchangeable $H^+$ as a percentage of the ECEC.

Effective Cation Exchange Capacity ($Ca+Mg+Na+K+Al+H^+$), is a measure of the soil’s ability to retain cations. The 95%ile lower and upper concentrations are 8 to 11 $cmol_+$/kg. The ‘desirable’ range for loams to clay loams is 8 to 14. This suggests that some of the soils have relatively low ECEC. Increasing the pH via liming, plus the irrigation will increase pasture growth. In turn the improved growth will increase Soil Organic Carbon. Increased SOC concentrations will increase CEC values.

The Ca : Mg ratio is low. This can lead to structural instability. Liming will increase the ratio.

Adding lime is essential.
The quantity of lime required/ha is discussed below.

## Micro nutrient sufficiency

The 95%ile CI (Confidence interval) available Zn range is 3.9 to 5.3 mg/kg. This is close to the desirable range of 4 to 5 mg/kg. Zinc is not an issue.

The 95% CI range for available Manganese range is 42 to 60 mg/kg. This is substantially higher than the desirable range of 18 to 22. Adding lime will increase the soil pH, and this will reduce Mn availability.

The 95% available CI for iron in soils is 279 to 366 mg/kg. This is substantially higher than the desirable range of 18 to 22. Adding lime will increase the soil pH, and this will reduce Fe availability.

The 95%ile CI for available Copper range is1.2 to 1.6 mg/kg. This is slightly lower than the desirable range of 1.6 to 2.0. This is not considered an issue at present.

The 95%ile CI for available Boron range is 0.33 to 0.43 mg/kg. This is much lower than the desirable range of 1.4 to 1.7. Boron deficiency has been reported in soils with less than 0.15 mg/kg. This is not considered an issue at present, but needs to be monitored, especially as boron is a very mobile nutrient in soil. More than 5 mg/kg is considered very high (Bruse and Rayment, 1982). 15 mg/ka is toxic to some cereals

The irrigation is likely to increase leaching of this nutrient. Boron will be required in future.

## Phosphorus sorption capacity

P sorption capacity is a measure of the soil's ability to retain phosphorus as well as other elements such as Arsenic.

P sorption capacity is important in reducing P loss from irrigated soil. Irrigation can result in soluble P being leached through the profile.

There is an over 3 fold range in P sorption in the topsoils, from 283 to 957 kg/ha. A 'heavy' fertilizer application will supply around 20 kg/ha. Good pasture can accumulate more than 30 kg/ha/y (see table 9.3). So, provided the pasture growth is vigorous, it is likely that the P sorption capacity of the pasture lands will not fall over time. The main 'export' of the phosphorus will be via sheep wool and meat.

## How much lime is needed?

Lime requirement is expressed as:
1 $cmol_+$/kg of $CaCO_3$ requirement for every $cmol_+$/kg of aluminium.
Assuming a bulk density of 1.5 T per cubic m, 15 cm depth, a 1.5 correction coefficient and the 95%ile upper Exch Al concentration is 0.43 $cmol_+$/kg, the mass of lime required is 500 * 1.5*15*1.5*0.43= 725 kg/ha.

Typically, this can be rounded up to 1 T/ha.

Application of 1 T/ha of agricultural lime is RECOMMENDED.

Insist on a documented Neutralisation Value (NV) of at least 90%.

# Phosphorus sorption capacity in the soil profiles in area 1.

Table 6.3 shows the phosphorus sorption capacity down 5 profiles. The P sorption capacity is based on The thickness of the soil horizon, the P sorption capacity in mg/kg down the profiles, an assumed bulk density of 1.5 T/cubic m and the percentage of rock in each horizon.

The average P sorption over the 5 profiles is 5188 kg/ha as table 6.4 shows. This suggests that these soils have significant ability to retain nutrients and contaminants. Leaching of phosphorus to the local stream lines is highly unlikely. The rationale behind this statement is:

P concentration in the permeate is very low (see table 2.2), and there is a significant P sorption capacity in the profiles as table 6.4 shows. Therefore, excess P leading to leaching is unlikely to occur under the proposed irrigation regime.

# Conclusions regarding the soils in area 1.

The Area 1 soils have moderate fertility and are currently supporting a vigorous, but weedy pasture. There are several significant nutrient and acidity limitations, but these can be overcome. It is critical that pasture growth be vigorous. Low phosphorus availability will limit plant vigour and therefore plant transpiration over the entire life cycle.

Apply a minimum of 20 kg/ha/y of elemental P.
For example,
if using Single Superphosphate (9% P) apply 220 to 250 kg/ha.
Double superphosphate (17.5%P) will need to be applied at 115 to 120 kg/ha in order to add 20 kg/ha of P.
MAP (21%P), apply 95 kg/ha is required.
DAP (20%P), apply 100 kg/ha is required.

Boron will become an issue. Borax and Solubor are two products that can be applied. See Dear and Weir, (2004).Boron deficiency in pastures and field crops Agfact P1.AC.1, 2nd edition 2004

The soils have comparatively high P sorption capacity.  The combination of low P concentration in the RO permeate and the relatively high profile P sorption capacity mean that leaching of P to groundwater or local streams lines is highly unlikely.

## Overall suitability of Area 1 soils.

The chemical limitations of the soils in area 1 can be addressed by a combination of agricultural lime, superphosphate and some potassium fertiliser.  Boron deficiency is likely in the future.

Addressing these chemical limitations is important as chemical fertility is a major determinant of pasture growth. In turn pasture growth is a key determinant of evapotranspiration.

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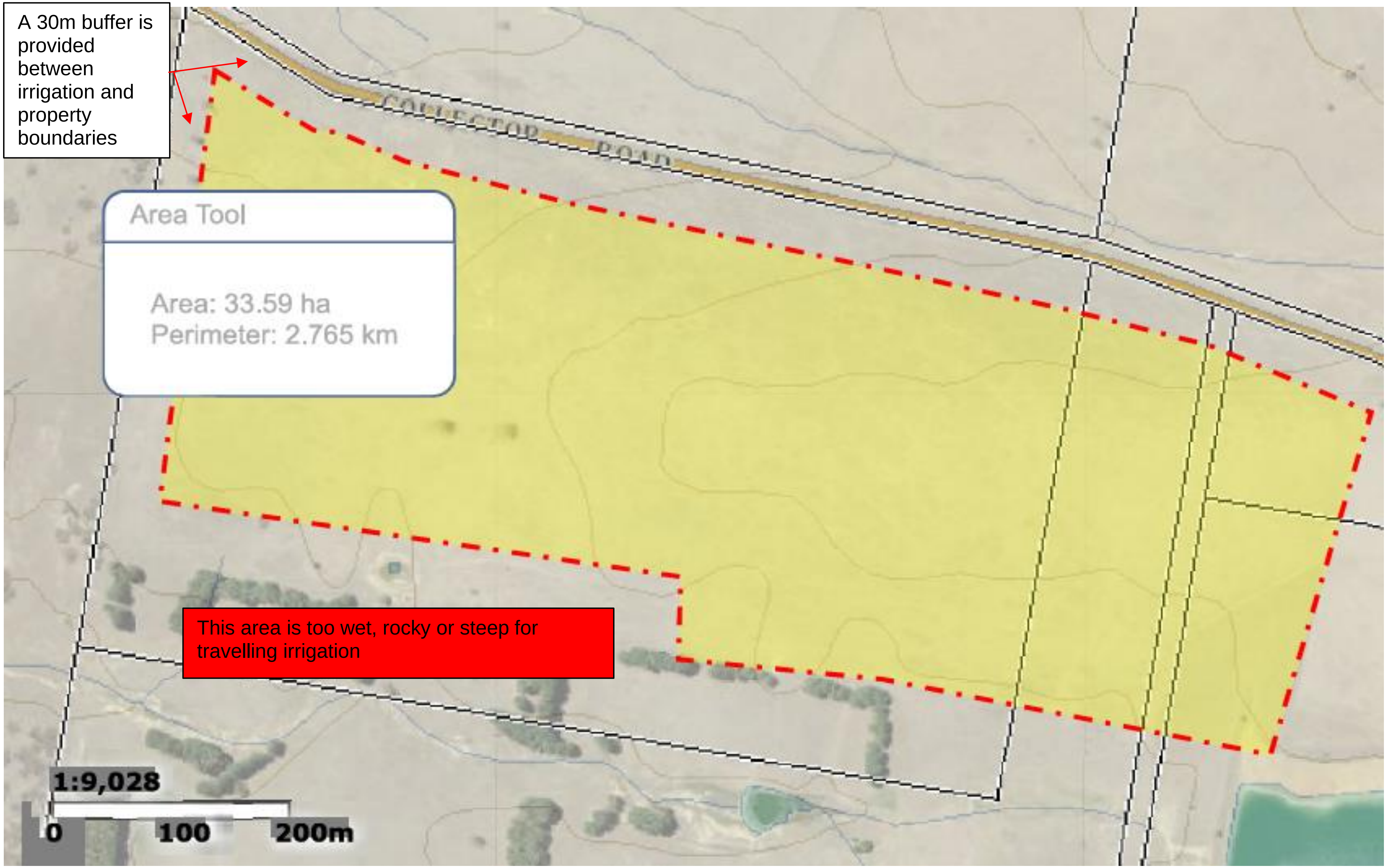


**Figure 6.1. The area determined to be suitable for irrigation in Area 1 (Image source: NSW Gov).**

# 7. SOIL CHEMISTRY ASSESSMENT IN AREAS 2, 3 AND 4

Areas 2, 3 and 4 cover at least 42 ha. Surface soils from 39 locations within areas 2, 3 and 4 were analysed for the same anolytes as used for the first set. Figure 5.1 shows the sampling locations.

The results are shown in table 7.1 below.

The key issues are similar to the first set of soils:

- Low P availability
- Acidic
- Low in Exch Ca
- Low in nitrogen
- Low cation exchange capacity (CEC)
- Low in K
- Some areas low in Zn
- Low in Mn.
- Low in Boron.

All of these issues can be addressed via P fertilisation, liming and future addition of Potassium and Boron to maximise plant growth and transpiration.

**Table 7.1. The statistical analyses of the 27 surface soil samples from area 1. NOTE this is the same as table 6.2. It is included here for ease of comparison with the other 3 areas.**

| *Parameter* | Indicative guideline values for clay loam | Indicative guideline values for loam | Min | Max | Count | Average | Stdev | Confidence interval | lower 95%ile CI | Upper 95%ile CI | Comment |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Soluble Ca (mg/kg) | *750* | *375* | 202 | 1129 | 27 | 677 | 248 | 94 | 583 | 771 | Within desirable range for loam to clay loam soils |
| Soluble Mg (mg/kg) | *105* | *60* | 63.3 | 383 | 27 | 193 | 78 | 30 | 163 | 222 | A bit high. Add lime to balance the Ca : Mg ratio |
| Soluble K (mg/kg) | *75* | *60* | 28.4 | 134 | 20 | 71.5 | 33.1 | 14.5 | 57.0 | 86.0 | Within desirable range for loam to clay loam soils |
| Soluble P (mg/kg) | *12* | *10* | 1.09 | 7.38 | 21 | 2.36 | 1.42 | 0.61 | 1.75 | 2.96 | Very low Add P fertiliser |
| Available P (Bray 1 mg/kg) | *30* | *24* | 1.13 | 31.2 | 27 | 5.75 | 5.80 | 2.19 | 3.56 | 7.93 | Very low Add P fertiliser |
| Available P (Bray 2 mg/kg) | *60* | *48* | 2.02 | 63.2 | 27 | 11.4 | 13.8 | 5.22 | 6.20 | 16.6 | Very low Add P fertiliser |
| Nitrate-N (mg/kg) | *13* | *10* | 1.84 | 22.2 | 27 | 9.34 | 4.73 | 1.78 | 7.55 | 11.1 | A bit low. Encourage Sub clover. |
| Ammonium-N (mg/kg) | *18* | *15* | 3.19 | 16.0 | 27 | 7.43 | 3.50 | 1.32 | 6.11 | 8.75 | A bit low. Encourage Sub clover. |
| Sulfur (mg/kg S) | *8.0* | *8.0* | 3.30 | 15.3 | 27 | 10.1 | 3.08 | 1.16 | 8.99 | 11.3 | Within desirable range for loam to clay loam soils |
| pH (5:1 Water: Soil) | *6.5* | *6.3* | 5.01 | 6.12 | 27 | 5.44 | 0.29 | 0.11 | 5.33 | 5.54 | A bit low add lime. Check % Exch Al to determine application rate. |
| pH ( dS/m 5:1 Water: Soil) | *0.150* | *0.120* | 0.03 | 0.12 | 27 | 0.06 | 0.02 | 0.01 | 0.05 | 0.07 | Low salinity and therefore OK |
| Exch Ca *cmol+/kg | *10.8* | *5.0* | 1.67 | 11.0 | 27 | 6.29 | 2.57 | 0.97 | 5.32 | 7.26 | Within desirable range for loam. Slightly low for clay loam soils |
| Exch Mg *cmol+/kg | *1.7* | *1.2* | 0.66 | 5.31 | 27 | 2.25 | 1.04 | 0.39 | 1.86 | 2.64 | A bit high. Add lime to increase the Ca: Mg ratio |
| Exch K *cmol+/kg | *0.50* | *0.40* | 0.14 | 0.65 | 22 | 0.30 | 0.16 | 0.07 | 0.23 | 0.37 | A bit low. Add K containing fertilizer |
| Exch Na *cmol+/kg | *0.26* | *0.22* | 0.07 | 0.23 | 23 | 0.11 | 0.03 | 0.01 | 0.09 | 0.12 | Low and OK. Check SAR |
| Exch Al *cmol+/kg | *0.5* | *0.4* | 0.05 | 1.22 | 27 | 0.33 | 0.29 | 0.11 | 0.22 | 0.43 | Low and OK. Check % Exchangeable Al |
| Exch $H^+$ *cmol+/kg | *0.5* | *0.4* | 0.13 | 0.53 | 27 | 0.23 | 0.08 | 0.03 | 0.20 | 0.26 | Low and OK. |
| Effective Cation Exchange Capacity (ECEC) ($cmol_+$/kg) | *14.3* | *7.8* | 3.78 | 15.2 | 27 | 9.46 | 3.40 | 1.28 | 8.17 | 10.74 | Within desirable range for loams. A bit low for clay loam soils |
| Ca as % of effective CEC | *75.7* | *65.6* | 44 | 74 | 27 | 65 | 7 | 3 | 62 | 67 | A bit low. Add lime. |

| *Parameter* | Indicative guideline values for clay loam | Indicative guideline values for loam | Min | Max | Count | Average | Stdev | Confidence interval | lower 95%ile CI | Upper 95%ile CI | Comment |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Mg as % of effective CEC | *11.9* | *15.7* | 17 | 35 | 27 | 23 | 4 | 1 | 22 | 25 | A bit high. Add lime. NO dolomite required. |
| K as % of effective CEC | *3.5* | *5.2* | 0 | 9 | 27 | 3 | 2 | 1 | 2 | 4 | A bit low. Add K containing fertilizer |
| Na as % of effective CEC | *1.8* | *2.9* | 1 | 4 | 27 | 1 | 1 | 0 | 1 | 2 | Low and OK |
| Al as % of effective CEC | *7.1* | *10.5* | 0 | 22 | 27 | 5 | 5 | 2 | 3 | 7 | Zero is preferable. Add lime. |
| H as % of effective CEC | | | 1 | 9 | 27 | 3 | 2 | 1 | 2 | 4 | Zero is preferable. Add lime. |
| Ca : Mg ratio | *6.4* | *4.2* | 1.65 | 3.95 | 27 | 2.85 | 0.46 | 0.17 | 2.68 | 3.02 | Low. Add lime. |
| Zinc (mg/kg) | *5.0* | *4.0* | 1.06 | 8.44 | 27 | 4.60 | 1.80 | 0.68 | 3.92 | 5.28 | OK |
| Manganese (mg/kg) | *22* | *18* | 7.46 | 92.4 | 27 | 50.6 | 24.0 | 9.06 | 41.6 | 59.7 | A bit high, but low toxicity. Liming will reduce availability |
| Iron (mg/kg) | *22* | *18* | 97 | 556 | 27 | 322 | 115 | 44 | 279 | 366 | A bit high, but low toxicity. Liming will reduce availability |
| Copper (mg/kg) | *2.0* | *1.6* | 0.22 | 2.15 | 27 | 1.40 | 0.51 | 0.19 | 1.20 | 1.59 | Within desirable range for loam to clay loam soils |
| Boron (mg/kg) | *1.7* | *1.4* | 0.14 | 0.64 | 27 | 0.38 | 0.13 | 0.05 | 0.33 | 0.43 | A bit low. Consider adding boron |
| Silicon (mg/kg) | *45* | *40* | 18.3 | 68.8 | 27 | 44.7 | 13.7 | 5.2 | 39.5 | 49.8 | Within desirable range for loam to clay loam soils |
| Chloride (mg/kg) | .. | .. | 20.5 | 73.6 | 27 | 37.5 | 12.1 | 4.6 | 32.9 | 42.0 | Low and indicating good soil drainage |
| Phosphorus sorption (mg/kg) | | | 136 | 387 | 27 | 259 | 63 | 24 | 235 | 283 | |

**Table 7.2. Chemistry of the surface soil samples from Area 2. Figure 5.1 shows the sampling positions.**

| Anolyte | VW 2 1 0-10 | VW 2 2 0-9 | VW 2 3 0-9 | VW 2 4 0-12 | VW 2 5 0-16 | VW 2 6 0-12 | VW 2 7 0-9 | VW 2 8 0-15 | VW 2 9 0-11 | VW 2 10 0-9 | VW 2 11 0-16 | VW 2 12 0-13 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Soluble Calcium (mg/kg) | 374 | 947 | 621 | 287 | 197 | 359 | 478 | 313 | 603 | 367 | 706 | 482 |
| Soluble Magnesium (mg/kg) | 130 | 298 | 374 | 79 | 43 | 97 | 285 | 75 | 125 | 85 | 195 | 149 |
| Soluble Potassium (mg/kg) | 34 | 29 | 48 | <25 | <25 | <25 | <25 | 36 | <25 | <25 | <25 | 39 |
| Soluble Phosphorus (mg/kg) | 1.5 | 2.1 | 1.9 | <1 | <1 | <1 | 1.3 | 1.5 | 1.1 | <1 | <1 | 1.6 |
| Phosphorus- Bray 1 (mg/kg P) | 4.9 | 4.0 | 2.4 | 2.7 | 4.4 | 2.3 | 2.8 | 8.3 | 1.8 | 2.1 | 1.2 | 7.4 |
| Phosphorus- Bray 2 (mg/kg P) | 6.6 | 6.5 | 5.3 | 3.8 | 4.3 | 3.2 | 4.6 | 11 | 4.4 | 3.9 | 2.1 | 11.8 |
| Nitrate Nitrogen (mg/kg N) | 26 | 20 | 16 | 6.4 | 5.0 | 11 | 7.4 | 4.2 | 9.3 | 5.0 | 5.8 | 13.5 |
| Ammonium Nitrogen (mg/kg N) | 4.9 | 3.8 | 5.0 | 2.1 | 1.9 | 2.2 | 4.7 | 32 | 16.0 | 9.5 | 4.2 | 9.2 |
| Sulfur (mg/kg S) | 11 | 11 | 10 | 6.5 | 6.2 | 6.9 | 8.0 | 12 | 7.0 | 7.6 | 4.2 | 12.7 |
| pH (1:5) Water:soil | 5.01 | 5.66 | 5.81 | 5.33 | 5.40 | 5.63 | 5.65 | 5.72 | 5.89 | 5.46 | 5.85 | 5.22 |
| Electrical Conductivity (dS/m) (1:5 Water:soil) | 0.089 | 0.078 | 0.081 | 0.047 | 0.053 | 0.052 | 0.056 | 0.061 | 0.066 | 0.045 | 0.047 | 0.050 |
| Exchangeable Calcium ($cmol_+$/kg) | 3.1 | 9.5 | 5.8 | 2.2 | 1.3 | 3.0 | 4.4 | 2.4 | 5.2 | 2.57 | 6.21 | 4.49 |
| Exchangeable Magnesium ($cmol_+$/kg) | 1.3 | 3.4 | 4.5 | 0.82 | 0.40 | 1.0 | 3.3 | 0.70 | 1.3 | 0.80 | 2.08 | 1.71 |
| Exchangeable Potassium ($cmol_+$/kg) | 0.15 | 0.16 | 0.24 | <0.12 | <0.12 | <0.12 | 0.15 | 0.12 | <0.12 | <0.12 | <0.12 | 0.23 |
| Exchangeable Sodium ($cmol_+$/kg) | 0.15 | 0.16 | 0.29 | 0.07 | <0.065 | 0.13 | 0.27 | 0.11 | 0.18 | 0.10 | 0.11 | 0.15 |
| Exchangeable Aluminium ($cmol_+$/kg) | 0.60 | 0.14 | 0.13 | 0.28 | 0.31 | 0.19 | 0.32 | 0.23 | 0.05 | 0.43 | 0.08 | 0.72 |
| Exchangeable Hydrogen ($cmol_+$/kg) | 0.40 | 0.18 | 0.05 | 0.18 | 0.32 | 0.05 | 0.26 | 0.15 | 0.22 | 0.34 | 0.24 | 0.49 |

| Anolyte | VW 2 1 0-10 | VW 2 2 0-9 | VW 2 3 0-9 | VW 2 4 0-12 | VW 2 5 0-16 | VW 2 6 0-12 | VW 2 7 0-9 | VW 2 8 0-15 | VW 2 9 0-11 | VW 2 10 0-9 | VW 2 11 0-16 | VW 2 12 0-13 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Effective Cation Exchange Capacity (ECEC) ($cmol_+/kg$)** | 5.7 | 14 | 11 | 3.6 | 2.5 | 4.5 | 8.6 | 3.7 | 7.07 | 4.35 | 8.80 | 7.80 |
| **Calcium (%)** | 54 | 70 | 53 | 61 | 54 | 67 | 51 | 65 | 73 | 59.0 | 70.6 | 57.6 |
| **Magnesium (%)** | 23 | 25 | 41 | 23 | 16 | 24 | 38 | 19 | 19 | 18.4 | 23.6 | 22.0 |
| **Potassium (%)** | 2.7 | 1.2 | 2.2 | 1.9 | 2.0 | 1.00 | 1.8 | 3.3 | 1.6 | 2.2 | 0.9 | 3.0 |
| **Sodium - ESP (%)** | 2.6 | 1.2 | 2.6 | 1.9 | 2.6 | 2.9 | 3.2 | 2.9 | 2.6 | 2.4 | 1.3 | 1.9 |
| **Aluminium (%)** | 11 | 1.0 | 1.2 | 7.8 | 12 | 4.3 | 3.7 | 6.2 | 0.66 | 10.0 | 0.9 | 9.2 |
| **Hydrogen (%)** | 6.9 | 1.4 | 0.47 | 5.0 | 13 | 1.0 | 3.0 | 3.9 | 3.2 | 7.9 | 2.7 | 6.3 |
| **Calcium/Magnesium Ratio** | 2.3 | 2.8 | 1.3 | 2.7 | 3.4 | 2.9 | 1.3 | 3.5 | 3.9 | 3.2 | 3.0 | 2.6 |
| **Zinc (mg/kg)** | 4.3 | 4.7 | 4.2 | 3.1 | 3.1 | 3.2 | 7.4 | 6.8 | 7.6 | 4.0 | 4.0 | 6.4 |
| **Manganese (mg/kg)** | 25 | 52 | 15 | 8.3 | 21 | 18 | 7.9 | 9.5 | 37 | 17 | 14 | 44 |
| **Iron (mg/kg)** | 427 | 196 | 419 | 281 | 269 | 291 | 425 | 496 | 334 | 408 | 253 | 478 |
| **Copper (mg/kg)** | 1.4 | 2.1 | 1.6 | 0.80 | 1.0 | 1.0 | 1.6 | 1.2 | 2.3 | 1.8 | 1.2 | 1.9 |
| **Boron (mg/kg)** | 0.24 | 0.31 | 0.89 | 0.14 | 0.10 | 0.13 | 0.34 | 0.20 | 0.33 | 0.33 | 0.57 | 0.46 |
| **Silicon (mg/kg Si)** | 47 | 59 | 66 | 26 | 27 | 32 | 40 | 40 | 28 | 35 | 46 | 36 |
| **Basic Texture** | Clay Loam | Clay Loam | Clay Loam | Clay Loam | Clay Loam | Clay Loam | Clay Loam | Clay Loam | Loam | Loam | Loam | Loam |
| **Phosphorus Sorption (mg P/kg)** | 319 | 320 | 468 | 160 | 153 | 207 | 382 | 254 | 384 | 376 | 339 | 465 |

**Table 7.3. Statistical analyses of Area 2 soils.**

| Parameter | Medium texture soil desirable value | Light texture soil desirable value | Min | Max | Count | Average | Stdev | Confidence interval | lower 95%ileCI | Upper 95%ileCI | Comment |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Soluble Calcium (mg/kg)** | 750 | 375 | 196.54 | 946.6 | 12 | 477.8 | 201.61 | 114.07 | 363 | 591 | *A bit low for clay loam soils* |
| **Soluble Magnesium (mg/kg)** | 105 | 60 | 43.32 | 373.7 | 12 | 161.3 | 100.32 | 56.76 | 104 | 216 | *High. Add lime* |
| **Soluble Potassium (mg/kg)** | 75 | 60 | 28.81 | 47.7 | 5 | 37.1 | 6.31 | 5.53 | 31.6 | 42.7 | *Low add K fertilizer* |
| **Soluble Phosphorus (mg/kg)** | 12 | 10 | 1.14 | 2.1 | 7 | 1.6 | 0.31 | 0.23 | 1.35 | 1.81 | *Very low Add P fertiliser* |
| **Phosphorus- Bray 1 (mg/kg P)** | 30 | 24 | 1.22 | 8.3 | 12 | 3.7 | 2.12 | 1.20 | 2.50 | 4.90 | *Very low Add P fertiliser* |
| **Phosphorus- Bray 2 (mg/kg P)** | 60 | 48 | 2.08 | 11.8 | 12 | 5.6 | 2.81 | 1.59 | 4.00 | 7.18 | *Very low Add P fertiliser* |
| **Nitrate Nitrogen (mg/kg N)** | 13 | 10 | 4.16 | 26.3 | 12 | 10.8 | 6.64 | 3.76 | 7.04 | 14.56 | *OK* |
| **Ammonium Nitrogen (mg/kg N)** | 18 | 15 | 1.90 | 31.9 | 12 | 7.9 | 8.20 | 4.64 | 3.31 | 12.58 | *A bit low. Encourage Sub clover.* |
| **Sulfur (mg/kg S)** | 8.0 | 8.0 | 4.16 | 12.7 | 12 | 8.6 | 2.54 | 1.44 | 7.16 | 10.04 | *Within desirable range for loam to clay loam soils* |
| **pH (1:5) Water:soil** | 6.5 | 6.3 | 5.01 | 5.9 | 12 | 5.6 | 0.26 | 0.15 | 5.41 | 5.70 | *low add lime. Check % Exch Al* |
| **Electrical Conductivity (dS/m) (1:5 Water:soil)** | 0.150 | 0.120 | 0.05 | 0.1 | 12 | 0.1 | 0.01 | 0.01 | 0.05 | 0.07 | *Low salinity and therefore OK* |
| **Exchangeable Calcium ($cmol_+$/kg)** | 10.8 | 5.0 | 1.35 | 9.5 | 12 | 4.2 | 2.17 | 1.23 | 2.95 | 5.40 | *Low add lime* |
| **Exchangeable Magnesium ($cmol_+$/kg)** | 1.7 | 1.2 | 0.40 | 4.5 | 12 | 1.8 | 1.23 | 0.70 | 1.09 | 2.48 | *OK* |
| **Exchangeable Potassium ($cmol_+$/kg)** | 0.50 | 0.40 | 0.12 | 0.2 | 6 | 0.2 | 0.04 | 0.04 | 0.14 | 0.21 | *Low add K fertiliser* |
| **Exchangeable Sodium ($cmol_+$/kg)** | 0.26 | 0.22 | 0.07 | 0.3 | 11 | 0.2 | 0.07 | 0.04 | 0.12 | 0.20 | *Low and so OK* |
| **Exchangeable Aluminium ($cmol_+$/kg)** | 0.5 | 0.4 | 0.05 | 0.7 | 12 | 0.3 | 0.20 | 0.11 | 0.18 | 0.40 | *Within desirable range, but the % of ECEC that is Exch Al is more important* |

| Parameter | Medium texture soil desirable value | Light texture soil desirable value | Min | Max | Count | Average | Stdev | Confidence interval | lower 95%ileCI | Upper 95%ileCI | Comment |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Exchangeable Hydrogen ($cmol_+$/kg)** | 0.5 | 0.4 | 0.05 | 0.5 | 12 | 0.2 | 0.13 | 0.07 | 0.17 | 0.31 | *Within desirable range, but the % of ECEC that is Exch Al is more important* |
| **Effective Cation Exchange Capacity (ECEC) ($cmol_+$/kg)** | 14.3 | 7.8 | 2.48 | 13.6 | 12 | 6.8 | 3.20 | 1.81 | 4.95 | 8.57 | *A bit low. Increasing pH and increasing pasture growth will address this.* |
| **Calcium (%)** | 75.7 | 65.6 | 50.67 | 73.3 | 12 | 61.2 | 7.46 | 4.22 | 57.02 | 65.47 | *Low Add lime* |
| **Magnesium (%)** | 11.9 | 15.7 | 15.97 | 40.9 | 12 | 24.3 | 7.25 | 4.10 | 20.16 | 28.37 | *High. Add lime. Do not add dolomite.* |
| **Potassium (%)** | 3.5 | 5.2 | 0.86 | 3.3 | 12 | 2.0 | 0.73 | 0.41 | 1.56 | 2.38 | *Ok. But some potassium fertiliser is required* |
| **Sodium - ESP (%)** | 1.8 | 2.9 | 1.19 | 3.2 | 12 | 2.3 | 0.61 | 0.34 | 1.99 | 2.67 | *Low and OK. Non sodic at present. Increasing soil organic carbon will help maintain stability.* |
| **Aluminium (%)** | 7.1 | 10.5 | 0.66 | 12.3 | 12 | 5.7 | 4.07 | 2.30 | 3.35 | 7.96 | *% ECEC as AL is highly variable. Add lime* |
| **Hydrogen (%)** | | | 0.47 | 12.8 | 12 | 4.5 | 3.35 | 1.90 | 2.64 | 6.44 | *Ok. But some potassium fertiliser is required* |
| **Calcium/Magnesium Ratio** | 6.4 | 4.2 | 1.29 | 3.9 | 12 | 2.7 | 0.76 | 0.43 | 2.30 | 3.16 | *A bit low add lime.* |
| **Zinc (mg/kg)** | 5.0 | 4.0 | 3.06 | 7.6 | 12 | 4.9 | 1.61 | 0.91 | 3.97 | 5.80 | *Good* |
| **Manganese (mg/kg)** | 22 | 18 | 7.93 | 51.6 | 12 | 22.4 | 13.79 | 7.80 | 14.59 | 30.19 | *Slightly low. So do not overdose on lime.* |
| **Iron (mg/kg)** | 22 | 18 | 195.63 | 495.9 | 12 | 356.4 | 93.58 | 52.95 | 303 | 409 | *High, but not an issue* |
| **Copper (mg/kg)** | 2.0 | 1.6 | 0.80 | 2.3 | 12 | 1.5 | 0.45 | 0.26 | 1.23 | 1.74 | *OK* |
| **Boron (mg/kg)** | 1.7 | 1.4 | 0.10 | 0.9 | 12 | 0.3 | 0.21 | 0.12 | 0.22 | 0.46 | *Low. Add B fertiliser.* |
| **Silicon (mg/kg Si)** | 45 | 40 | 26.24 | 66.4 | 12 | 40.2 | 12.12 | 6.86 | 33.36 | 47.07 | *I bit low, but OK* |
| **Chloride Estimate (equiv. mg/kg)** | | | 28.80 | 57.0 | 12 | 38.7 | 9.11 | 5.16 | 33 | 44 | Low and OK |

| Parameter | Medium texture soil desirable value | Light texture soil desirable value | Min | Max | Count | Average | Stdev | Confidence interval | lower 95%ileCI | Upper 95%ileCI | Comment |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Phosphorus Sorption (mg P/kg)** | | | 153.00 | 468.0 | 12 | 318.9 | 102.01 | 57.72 | 261 | 377 | Good nutrient retention ability. |

Table 7.4. Chemistry of the surface soil samples from Area 3. Figure 5.1 shows the sampling positions.

| Parameter | VW 2 13 0-10 | VW 2 14 0-7 | VW 2 15 0-7 | VW 2 16 0-5 | VW 2 17 0-7 | VW 2 18 0-9 | VW 2 19 0-15 | VW 2 20 0-11 | VW 2 21 0-11 | VW 2 22 0-9 | VW 2 23 0-8 | VW 2 24 0-9 | VW 2 25 0-12 | VW 2 26 0-9 | VW 2 27 0-10 | VW 2 28 0-10 | VW 2 29 0-8 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Soluble Calcium (mg/kg) | 378 | 439 | 949 | 586 | 561 | 635 | 235 | 827 | 560 | 566 | 693 | 979 | 211 | 171 | 816 | 309 | 221 |
| Soluble Magnesium (mg/kg) | 186 | 89 | 108 | 120 | 81 | 46 | 25 | 56 | 128 | 127 | 78 | 63 | 72 | 67 | 112 | 166 | 86 |
| Soluble Potassium (mg/kg) | 121 | 60 | 64 | 55 | 29 | <25 | <25 | <25 | 28 | <25 | 117 | <25 | 79 | 53 | <25 | 30 | 109 |
| Soluble Phosphorus (mg/kg) | 1.8 | 5.2 | 14.1 | 5.1 | 2.8 | 1.4 | <1 | 4.6 | 2.5 | 2.2 | 11.5 | 6.6 | <1 | <1 | 3.1 | <1 | 1.2 |
| Phosphorus-Bray 1 (mg/kg P) | 2.6 | 70.7 | 66.3 | 23.7 | 18.3 | 3.8 | 2.1 | 19.3 | 22.7 | 19.1 | 100.4 | 27.5 | 2.3 | 2.5 | 13.4 | 2.6 | 6.0 |
| Phosphorus-Bray 2 (mg/kg P) | 4.0 | 192 | 195 | 62.6 | 45 | 5.2 | 2.7 | 40.7 | 56 | 48.9 | 281.0 | 69.2 | 4.5 | 5.3 | 41.7 | 5.0 | 15 |
| Nitrate Nitrogen (mg/kg N) | 23.0 | 9.2 | 11.6 | 20.1 | 7.6 | 1.9 | 8.4 | 7.0 | 2.8 | 3.6 | 13.2 | 7.5 | 2.5 | 1.1 | 10.0 | 1.7 | 5.3 |
| Ammonium Nitrogen (mg/kg N) | 27.1 | 8.0 | 6.9 | 8.5 | 6.1 | 4.6 | 7.7 | 4.2 | 9.1 | 6.3 | 6.5 | 7.3 | 19.1 | 6.5 | 7.0 | 12.8 | 20.3 |
| Sulfur (mg/kg S) | 8.0 | 5.8 | 9.3 | 13.7 | 13.7 | 9.4 | 6.6 | 15.0 | 8.8 | 6.7 | 6.7 | 3.9 | 6.3 | 4.5 | 9.8 | 8.4 | 6.1 |
| pH (1:5) Water:soil | 5.47 | 6.11 | 6.67 | 6.04 | 6.33 | 6.77 | 5.67 | 7.01 | 6.29 | 6.29 | 6.32 | 7.22 | 5.73 | 5.51 | 6.74 | 5.51 | 5.51 |
| Electrical Conductivity (dS/m) (1:5 Water:soil) | 0.093 | 0.068 | 0.083 | 0.097 | 0.074 | 0.058 | 0.033 | 0.104 | 0.058 | 0.056 | 0.078 | 0.073 | 0.043 | 0.031 | 0.070 | 0.052 | 0.061 |

| Parameter | VW 2 13 0-10 | VW 2 14 0-7 | VW 2 15 0-7 | VW 2 16 0-5 | VW 2 17 0-7 | VW 2 18 0-9 | VW 2 19 0-15 | VW 2 20 0-11 | VW 2 21 0-11 | VW 2 22 0-9 | VW 2 23 0-8 | VW 2 24 0-9 | VW 2 25 0-12 | VW 2 26 0-9 | VW 2 27 0-10 | VW 2 28 0-10 | VW 2 29 0-8 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Exchangeable Calcium ($cmol_+/kg$)** | 3.31 | 3.91 | 7.85 | 5.08 | 4.37 | 4.87 | 1.60 | 6.42 | 4.51 | 4.14 | 5.02 | 6.30 | 1.44 | 1.30 | 6.98 | 2.55 | 1.82 |
| **Exchangeable Magnesium ($cmol_+/kg$)** | 1.95 | 1.00 | 1.06 | 1.27 | 0.80 | 0.48 | 0.23 | 0.55 | 1.34 | 1.21 | 0.71 | 0.53 | 0.67 | 0.69 | 1.23 | 1.92 | 0.88 |
| **Exchangeable Potassium ($cmol_+/kg$)** | 0.57 | 0.23 | 0.27 | 0.25 | 0.13 | <0.12 | <0.12 | <0.12 | 0.15 | <0.12 | 0.43 | <0.12 | 0.31 | 0.22 | <0.12 | 0.17 | 0.46 |
| **Exchangeable Sodium ($cmol_+/kg$)** | 0.09 | 0.24 | 0.16 | 0.18 | 0.24 | 0.14 | <0.065 | 0.13 | 0.24 | 0.22 | <0.065 | 0.08 | 0.08 | <0.065 | 0.20 | 0.23 | 0.09 |
| **Exchangeable Aluminium ($cmol_+/kg$)** | 0.19 | 0.02 | <0.01 | 0.01 | 0.01 | 0.02 | 0.10 | 0.04 | 0.01 | <0.01 | 0.01 | <0.01 | 0.26 | 0.41 | 0.01 | 0.55 | 0.35 |
| **Exchangeable Hydrogen ($cmol_+/kg$)** | 0.29 | 0.12 | <0.01 | 0.12 | 0.07 | <0.01 | 0.14 | <0.01 | 0.09 | 0.06 | 0.07 | <0.01 | 0.23 | 0.28 | <0.01 | 0.37 | 0.31 |
| **Effective Cation Exchange Capacity (ECEC) ($cmol_+/kg$)** | 6.40 | 5.51 | 9.35 | 6.92 | 5.63 | 5.60 | 2.17 | 7.26 | 6.33 | 5.75 | 6.30 | 6.99 | 2.99 | 2.97 | 8.53 | 5.79 | 3.91 |
| **Calcium (%)** | 51.6 | 71.0 | 83.9 | 73.5 | 77.7 | 87.0 | 73.4 | 88.4 | 71.2 | 72.0 | 79.6 | 90.1 | 48.0 | 43.8 | 81.8 | 44.0 | 46.5 |
| **Magnesium (%)** | 30.4 | 18.1 | 11.4 | 18.3 | 14.2 | 8.7 | 10.4 | 7.6 | 21.1 | 21.0 | 11.3 | 7.6 | 22.6 | 23.3 | 14.5 | 33.2 | 22.4 |
| **Potassium (%)** | 8.9 | 4.1 | 2.8 | 3.7 | 2.4 | 1.6 | 3.5 | 1.6 | 2.4 | 1.9 | 6.9 | 1.1 | 10.3 | 7.5 | 1.2 | 2.9 | 11.8 |
| **Sodium - ESP (%)** | 1.4 | 4.3 | 1.7 | 2.5 | 4.2 | 2.6 | 1.8 | 1.8 | 3.8 | 3.8 | 0.8 | 1.1 | 2.8 | 1.9 | 2.4 | 4.0 | 2.2 |
| **Aluminium (%)** | 3.0 | 0.4 | 0.1 | 0.2 | 0.2 | 0.3 | 4.7 | 0.6 | 0.2 | 0.2 | 0.2 | 0.1 | 8.7 | 13.9 | 0.2 | 9.5 | 9.1 |
| **Hydrogen (%)** | 4.6 | 2.1 | 0.0 | 1.8 | 1.3 | 0.0 | 6.2 | 0.0 | 1.4 | 1.1 | 1.2 | 0.0 | 7.6 | 9.5 | 0.0 | 6.4 | 8.1 |

| Parameter | VW 2 13 0-10 | VW 2 14 0-7 | VW 2 15 0-7 | VW 2 16 0-5 | VW 2 17 0-7 | VW 2 18 0-9 | VW 2 19 0-15 | VW 2 20 0-11 | VW 2 21 0-11 | VW 2 22 0-9 | VW 2 23 0-8 | VW 2 24 0-9 | VW 2 25 0-12 | VW 2 26 0-9 | VW 2 27 0-10 | VW 2 28 0-10 | VW 2 29 0-8 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Calcium/ Magnesium Ratio** | 1.7 | 3.9 | 7.4 | 4.0 | 5.5 | 10.0 | 7.1 | 11.6 | 3.4 | 3.4 | 7.0 | 11.8 | 2.1 | 1.9 | 5.7 | 1.3 | 2.1 |
| **Zinc (mg/kg)** | 13.2 | 9.5 | 10.5 | 12.3 | 6.4 | 1.3 | 1.3 | 12.9 | 5.8 | 5.1 | 14.5 | 14.6 | 4.5 | 2.4 | 18.2 | 7.2 | 9.3 |
| **Manganese (mg/kg)** | 22 | 5.6 | 4.1 | 11 | 10 | 3.1 | 4.6 | 2.6 | 3.5 | 3.7 | 4.3 | 8.3 | 7.7 | 14 | 5.0 | 9.3 | 3.7 |
| **Iron (mg/kg)** | 318 | 443 | 262 | 367 | 289 | 209 | 130 | 160 | 408 | 402 | 358 | 68 | 341 | 343 | 211 | 796 | 592 |
| **Copper (mg/kg)** | 2.0 | 3.7 | 3.9 | 4.8 | 2.9 | 1.2 | 0.4 | 9.2 | 2.6 | 2.5 | 6.7 | 10.4 | 1.3 | 0.9 | 12.9 | 1.7 | 1.2 |
| **Boron (mg/kg)** | 0.44 | 0.45 | 0.39 | 0.37 | 0.16 | 0.13 | 0.32 | 0.33 | 0.39 | 0.42 | 0.29 | 0.21 | 0.18 | 0.30 | 0.27 | 0.31 | 0.33 |
| **Silicon (mg/kg Si)** | 24 | 35 | 39 | 35 | 35 | 21 | 37 | 27 | 32 | 38 | 44 | 22 | 32 | 34 | 28 | 30 | 30 |
| **Basic Texture** | Loam | Loam | Loam | Loam | Loam | Loam | Loam | Loam | Loam | Loam | Loam | Loam | Loam | Loam | Loam | Loam | Loam |
| **Chloride Estimate (equiv. mg/kg)** | 60 | 44 | 53 | 62 | 47 | 37 | 21 | 67 | 37 | 36 | 50 | 47 | 28 | 20 | 45 | 33 | 39 |
| **Phosphorus Sorption (mg P/kg)** | 319 | 293 | 197 | 278 | 305 | 211 | 214 | 190 | 340 | 341 | 266 | 206 | 351 | 339 | 262 | 404 | 458 |

**Table 7.5. Statistical analyses of Area 3 soils.**

| Parameter | Medium texture soil | Light texture soil | Min | Max | Count | Average | Stdev | Confidence interval | lower 95%ileCI | Upper 95%ileCI | Comment |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Soluble Calcium (mg/kg)** | 750 | 375 | 171 | 979 | 17 | 540 | 246 | 117 | 423 | 657 | A bit low for clay loam soils |
| **Soluble Magnesium (mg/kg)** | 105 | 60 | 25 | 186 | 17 | 93 | 40 | 19 | 75 | 112 | OK |
| **Soluble Potassium (mg/kg)** | 75 | 60 | 28 | 121 | 11 | 68 | 31 | 18 | 50 | 86 | OK |
| **Soluble Phosphorus (mg/kg)** | 12.0 | 10.0 | 1.2 | 14.1 | 13.0 | 5.6 | 4.1 | 2.2 | 3.4 | 7.8 | Low Add P fertiliser |
| **Phosphorus- Bray 1 (mg/kg P)** | 30.0 | 24.0 | 2 | 100 | 17 | 24 | 28 | 13.2 | 10.5 | 36.9 | OK at present will require maintenance application |
| **Phosphorus- Bray 2 (mg/kg P)** | 60 | 48 | 3 | 281 | 17 | 63 | 79 | 38 | 26 | 101 | OK at present will require maintenance application |
| **Nitrate Nitrogen (mg/kg N)** | 12.5 | 10.0 | 1 | 23 | 17 | 8 | 6 | 2.8 | 5.6 | 11.2 | Low N is required. |
| **Ammonium Nitrogen (mg/kg N)** | 18.0 | 15.0 | 4 | 27 | 17 | 11 | 6 | 2.9 | 7.7 | 13.5 | Low. Encourage Sub clover. |
| **Sulfur (mg/kg S)** | 8.0 | 8.0 | 4 | 15 | 17 | 8 | 3 | 1.4 | 7.0 | 9.8 | Within desirable range for loam to clay loam soils |
| **pH (1:5) Water:soil** | 6.50 | 6.30 | 5 | 7 | 17 | 6 | 1 | 0.25 | 5.96 | 6.46 | Apply maintenance application of lime if/when required |
| **Electrical Conductivity (dS/m) (1:5 Water:soil)** | 0.150 | 0.120 | 0 | 0 | 17 | 0 | 0 | 0.014 | 0.060 | 0.088 | Low salinity and therefore OK |
| **Exchangeable Calcium ($cmol_+$/kg)** | 10.80 | 5.00 | 1 | 8 | 17 | 5 | 2 | 1.12 | 3.47 | 5.71 | OK |
| **Exchangeable Magnesium ($cmol_+$/kg)** | 1.70 | 1.20 | 0 | 2 | 17 | 1 | 0 | 0.22 | 0.80 | 1.25 | OK |
| **Exchangeable Potassium ($cmol_+$/kg)** | 0.50 | 0.40 | 0 | 1 | 11 | 0 | 0 | 0.08 | 0.23 | 0.40 | Low add K fertiliser |
| **Exchangeable Sodium ($cmol_+$/kg)** | 0.26 | 0.22 | 0 | 0 | 14 | 0 | 0 | 0.03 | 0.14 | 0.21 | Low and so OK |
| **Exchangeable Aluminium ($cmol_+$/kg)** | 0.50 | 0.40 | 0 | 1 | 14 | 0 | 0 | 0.10 | 0.08 | 0.28 | Within desirable range, but the % of ECEC that is Exch Al is more important |

| Parameter | Medium texture soil | Light texture soil | Min | Max | Count | Average | Stdev | Confidence interval | lower 95%ileCI | Upper 95%ileCI | Comment |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Exchangeable Hydrogen ($cmol_+/kg$)** | 0.50 | 0.40 | 0 | 0 | 12 | 0 | 0 | 0.08 | 0.14 | 0.30 | Within desirable range, but the % of ECEC that is Exch Al is more important |
| **Effective Cation Exchange Capacity (ECEC) ($cmol_+/kg$)** | 14.30 | 7.80 | 2 | 9 | 17 | 6 | 3 | 1.24 | 5.10 | 7.58 | A bit low. Increasing pH and increasing pasture growth will address this. |
| **Calcium (%)** | 75.7 | 65.6 | 44 | 90 | 17 | 70 | 15 | 7.2 | 62.6 | 76.9 | OK |
| **Magnesium (%)** | 11.9 | 15.7 | 8 | 33 | 17 | 17 | 7 | 3.4 | 13.6 | 20.4 | Ok. Do not add dolomite. |
| **Potassium (%)** | 3.5 | 5.2 | 1 | 12 | 17 | 4 | 3 | 1.5 | 2.9 | 5.9 | OK |
| **Sodium - ESP (%)** | 1.8 | 2.9 | 1 | 4 | 17 | 3 | 1 | 0.5 | 2.0 | 3.0 | Low and OK. Non sodic at present. Increasing soil organic carbon will help maintain stability. |
| **Aluminium (%)** | 7.1 | 10.5 | 0 | 14 | 17 | 4 | 4 | 2.1 | 1.5 | 5.8 | OK at present |
| **Hydrogen (%)** | | | 0 | 10 | 17 | 3 | 3 | 1.5 | 1.5 | 4.5 | Low and OK |
| **Calcium/Magnesium Ratio** | 6.4 | 4.2 | 1 | 12 | 17 | 5 | 3 | 1.5 | 3.8 | 6.8 | OK |
| **Zinc (mg/kg)** | 5.0 | 4.0 | 1 | 18 | 17 | 8 | 5 | 2.3 | 6.0 | 10.6 | OK |
| **Manganese (mg/kg)** | 22.0 | 18.0 | 3 | 22 | 17 | 9 | 6 | 2.9 | 5.6 | 11.4 | OK Do not lime |
| **Iron (mg/kg)** | 22 | 18 | 68 | 796 | 17 | 302 | 187 | 89 | 213 | 391 | High, but not an issue |
| **Copper (mg/kg)** | 2.0 | 1.6 | 0 | 13 | 17 | 4 | 3 | 1.6 | 2.1 | 5.4 | OK |
| **Boron (mg/kg)** | 1.70 | 1.40 | 0.13 | 0.45 | 17.00 | 0.44 | 0.39 | 0.19 | 0.25 | 0.63 | Low. Add B fertiliser. |
| **Silicon (mg/kg Si)** | 45 | 40 | 21 | 44 | 17 | 33 | 7 | 3 | 30 | 36 | A bit low, but OK |
| **Chloride Estimate (equiv. mg/kg)** | | | 20 | 67 | 17 | 43 | 13 | 6 | 36 | 49 | Low and OK |
| **Phosphorus Sorption (mg P/kg)** | | | 190 | 458 | 17 | 293 | 74 | 35 | 257 | 328 | Good nutrient retention ability. |

Table 7.6. Chemistry of the surface soil samples from Area 4. Figure 5.1 shows the sampling positions.

| Parameter | | VW 2 30 0-10 | VW 2 31 0-12 | VW 2 32 0-10 | VW 2 33 0-7 | VW 2 34 0-12 | VW 2 35 0-5 | VW 2 36 0-10 | VW 2 37 0-9 | VW 2 38 0-7 | VW 2 39 0-9 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Soluble Calcium (mg/kg) | | 348 | 290 | 182 | 332 | 283 | 140 | 426 | 164 | 231 | 344 |
| Soluble Magnesium (mg/kg) | | 86 | 105 | 57 | 51 | 144 | 41 | 121 | 43 | 102 | 127 |
| Soluble Potassium (mg/kg) | | 104 | 39 | 45 | 38 | 110 | 59 | 47 | 86 | 40 | 64 |
| Soluble Phosphorus (mg/kg) | | 2.5 | 1.3 | <1 | 1.7 | 3.6 | 1.0 | 2.8 | 1.3 | 1.4 | 2.2 |
| Phosphorus- Bray 1 (mg/kg P) | | 14.8 | 5.1 | 5.4 | 13.2 | 10.1 | 5.1 | 4.3 | 4.8 | 4.4 | 4.3 |
| Phosphorus- Bray 2 (mg/kg P) | | 40.3 | 10.7 | 10.5 | 26.9 | 15 | 7.0 | 8.7 | 7.6 | 7.2 | 11 |
| Nitrate Nitrogen (mg/kg N) | | 21.1 | 1.6 | 3.9 | 0.3 | 34.1 | 10 | 8.8 | 11.4 | 4.0 | 23.8 |
| Ammonium Nitrogen (mg/kg N) | | 47.9 | 6.0 | 11.1 | 10.3 | 32.7 | 8.5 | 18.9 | 26.7 | 12.6 | 13.2 |
| Sulfur (mg/kg S) | | 22.1 | 11.2 | 6.1 | 9.7 | 13.2 | 6.8 | 24.1 | 8.2 | 8.9 | 9.6 |
| pH (1:5) Water:soil | | 5.23 | 5.23 | 5.55 | 5.66 | 5.71 | 5.05 | 5.43 | 4.96 | 5.51 | 5.27 |
| Electrical Conductivity (dS/m) (1:5 Water:soil) | | 0.073 | 0.065 | 0.041 | 0.060 | 0.156 | 0.047 | 0.075 | 0.069 | 0.058 | 0.110 |
| Exchangeable Calcium | (cmol$_+$/kg) | 3.47 | 2.71 | 1.25 | 2.63 | 2.98 | 1.2 | 3.72 | 1.41 | 1.99 | 3.37 |
| Exchangeable Magnesium | (cmol$_+$/kg) | 0.98 | 1.16 | 0.51 | 0.49 | 1.75 | 0.45 | 1.30 | 0.45 | 1.09 | 1.38 |
| Exchangeable Potassium | (cmol$_+$/kg) | 0.47 | 0.19 | 0.18 | 0.17 | 0.50 | 0.30 | 0.24 | 0.44 | 0.19 | 0.29 |
| Exchangeable Sodium | (cmol$_+$/kg) | 0.09 | 0.23 | 0.12 | 0.23 | 0.39 | 0.07 | 0.11 | 0.12 | 0.27 | 0.34 |
| Exchangeable Aluminium | (cmol$_+$/kg) | 0.96 | 0.62 | 0.49 | 0.28 | 0.04 | 1.09 | 0.36 | 1.25 | 0.48 | 0.41 |
| Exchangeable Hydrogen | (cmol$_+$/kg) | 0.63 | 0.40 | 0.36 | 0.26 | 0.22 | 0.53 | 0.46 | 0.59 | 0.33 | 0.35 |
| Effective Cation Exchange Capacity (ECEC) (cmol$_+$/kg) | | 6.60 | 5.31 | 2.90 | 4.07 | 5.88 | 3.6 | 6.19 | 4.26 | 4.35 | 6.13 |
| Calcium (%) | | 52.6 | 51.0 | 43.0 | 64.7 | 50.6 | 33 | 60.1 | 33.1 | 45.8 | 54.9 |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Magnesium (%)** | 14.9 | 21.8 | 17.6 | 12.2 | 29.7 | 12 | 21.1 | 10.6 | 25.1 | 22.4 |
| **Potassium (%)** | 7.1 | 3.7 | 6.1 | 4.2 | 8.5 | 8.2 | 3.8 | 10.3 | 4.4 | 4.7 |
| **Sodium - ESP (%)** | 1.4 | 4.3 | 4.1 | 5.6 | 6.7 | 2.0 | 1.7 | 2.9 | 6.1 | 5.6 |
| **Aluminium (%)** | 14.6 | 11.7 | 16.8 | 6.8 | 0.8 | 30 | 5.7 | 29.3 | 11.0 | 6.7 |
| **Hydrogen (%)** | 9.5 | 7.6 | 12.3 | 6.5 | 3.7 | 14.5 | 7.5 | 13.8 | 7.6 | 5.7 |
| **Calcium/Magnesium Ratio** | 3.5 | 2.3 | 2.4 | 5.3 | 1.7 | 2.6 | 2.9 | 3.1 | 1.8 | 2.4 |
| **Zinc (mg/kg)** | 17.8 | 10.3 | 4.2 | 10.3 | 13.4 | 5.3 | 116.3 | 12.3 | 9.3 | 21.2 |
| **Manganese (mg/kg)** | 6.8 | 6.7 | 3.8 | 2.2 | 26 | 16.8 | 41 | 21 | 6.5 | 5.0 |
| **Iron (mg/kg)** | 521 | 493 | 387 | 409 | 182 | 276 | 235 | 306 | 340 | 562 |
| **Copper (mg/kg)** | 1.8 | 1.1 | 0.8 | 0.9 | 0.8 | 1.24 | 2.3 | 2.1 | 1.2 | 1.4 |
| **Boron (mg/kg)** | 0.30 | 0.22 | 0.18 | 0.28 | 0.38 | 0.46 | 0.32 | 0.38 | 0.29 | 0.45 |
| **Silicon (mg/kg Si)** | 35 | 31 | 23 | 23 | 45 | 28 | 22 | 27 | 22 | 36 |
| **Basic Texture** | Loam | Loam | Loam | Loam | Loam | Loam | Loam | Loam | Loam | Loam |
| **Chloride Estimate (equiv. mg/kg)** | 47 | 42 | 26 | 38 | 100 | 30 | 48 | 44 | 37 | 70 |
| **Phosphorus Sorption (mg P/kg)** | 419 | 415 | 370 | 374 | 170 | 354 | 391 | 375 | 358 | 437 |

**Table 7.7. Statistical analyses of area 4 soils.**

| Parameter | Indicative guideline clay loams | Indicative guideline loams | Min | Max | Count | Average | Stdev | Confidence interval | lower 95%ileCI | Upper 95%ileCI | Comment |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Soluble Calcium (mg/kg)** | *750* | *375* | 140 | 426 | 10 | 274 | 88.3 | 55 | 219 | 329 | **A bit low for clay loam soils. Add lime** |
| **Soluble Magnesium (mg/kg)** | *105* | *60* | 41 | 144 | 10 | 88 | 35.7 | 22 | 66 | 110 | **A bit high Add lime** |
| **Soluble Potassium (mg/kg)** | *75* | *60* | 38 | 110 | 10 | 63 | 26.0 | 16.1 | 47.2 | 79.4 | **Within desirable range for loam to clay loam soils** |
| **Soluble Phosphorus (mg/kg)** | *12* | *10* | 1.0 | 3.56 | 9 | 2.0 | 0.8 | 0.52 | 1.45 | 2.49 | **Very low Add P fertiliser** |
| **Phosphorus- Bray 1 (mg/kg P)** | *30*[5] | *24* | 4.3 | 15 | 10 | 7.1 | 3.8 | 2.4 | 4.8 | 9.5 | **Very low Add P fertiliser** |
| **Phosphorus- Bray 2 (mg/kg P)** | *60*[5] | *48* | 7.0 | 40 | 10 | 14.5 | 10.2 | 6.4 | 8.1 | 20.8 | **Very low Add P fertiliser** |
| **Nitrate Nitrogen (mg/kg N)** | *13* | *10* | 0.3 | 34 | 10 | 11.9 | 10.5 | 6.50 | 5.43 | 18.42 | **A bit low. Encourage Sub clover.** |
| **Ammonium Nitrogen (mg/kg N)** | *18* | *15* | 6.0 | 48 | 10 | 18.8 | 12.5 | 7.78 | 11.02 | 26.57 | **A bit low. Encourage Sub clover.** |
| **Sulfur (mg/kg S)** | *8.0* | *8.0* | 6.1 | 24 | 10 | 12.0 | 5.9 | 3.65 | 8.34 | 15.65 | **OK** |
| **pH (1:5) Water:soil** | *6.5* | *6.3* | 5.0 | 5.71 | 10 | 5.4 | 0.2 | 0.148 | 5.21 | 5.51 | **low add lime. Check % Exch Al** |
| **Electrical Conductivity (dS/m) (1:5 Water:soil)** | *0.150* | *0.120* | 0.04 | 0.16 | 10 | 0.1 | 0.0 | 0.020 | 0.055 | 0.095 | **Low salinity and therefore OK** |
| **Exchangeable Calcium (cmol$_+$/kg)** | *10.8* | *5.0* | 1.2 | 3.72 | 10 | 2.5 | 0.9 | 0.562 | 1.91 | 3.03 | **Low add lime** |
| **Exchangeable Magnesium (cmol$_+$/kg)** | *1.7* | *1.2* | 0.5 | 1.75 | 10 | 1.0 | 0.4 | 0.270 | 0.686 | 1.23 | **Low. Check future sampling to check if dolomite is needed** |
| **Exchangeable Potassium (cmol$_+$/kg)** | *0.50* | *0.40* | 0.2 | 0.50 | 10 | 0.3 | 0.1 | 0.075 | 0.221 | 0.371 | **Low add K fertiliser** |
| **Exchangeable Sodium (cmol$_+$/kg)** | *0.26* | *0.22* | 0.1 | 0.39 | 10 | 0.2 | 0.1 | 0.066 | 0.131 | 0.263 | **Low and so OK** |
| **Exchangeable Aluminium (cmol$_+$/kg)** | *0.5* | *0.4* | 0.0 | 1.25 | 10 | 0.6 | 0.4 | 0.226 | 0.371 | 0.823 | **Within desirable range, but the % of ECEC that is Exch Al is more important** |

| Parameter | Indicative guideline clay loams | Indicative guideline loams | Min | Max | Count | Average | Stdev | Confidence interval | lower 95%ileCI | Upper 95%ileCI | Comment |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Exchangeable Hydrogen ($cmol_+/kg$)** | *0.5* | *0.4* | 0.2 | 0.63 | 10 | 0.4 | 0.1 | 0.080 | 0.333 | 0.493 | **Within desirable range, but the % of ECEC that is Exch Al is more important** |
| **Effective Cation Exchange Capacity (ECEC) ($cmol_+/kg$)** | *14.3* | *7.8* | 2.9 | 6.60 | 10 | 4.9 | 1.2 | 0.7 | 4 | 6 | **A bit low. Increasing pH and increasing pasture growth will address this.** |
| **Calcium (%)** | *75.7* | *65.6* | 33 | 64.74 | 10 | 48.9 | 10.0 | 6.2 | 43 | 55 | **Low Add lime** |
| **Magnesium (%)** | *11.9* | *15.7* | 11 | 29.68 | 10 | 18.8 | 5.9 | 3.7 | 15 | 22 | **High. Add lime. Do not add dolomite.** |
| **Potassium (%)** | *3.5* | *5.2* | 4 | 10.30 | 10 | 6.1 | 2.2 | 1.4 | 5 | 7 | **Ok. But some potassium fertiliser is required** |
| **Sodium - ESP (%)** | *1.8* | *2.9* | 1 | 6.69 | 10 | 4.0 | 1.8 | 1.1 | 3 | 5 | **Low and OK. Non sodic at present. Increasing soil organic carbon will help maintain stability.** |
| **Aluminium (%)** | *7.1* | *10.5* | 1 | 30.12 | 10 | 13.4 | 9.3 | 5.8 | 8 | 19 | **% ECEC as AL is highly variable. Add lime** |
| **Hydrogen (%)** | | | 4 | 14.52 | 10 | 8.9 | 3.4 | 2.1 | 7 | 11 | **Ok. But some potassium fertiliser is required** |
| **Calcium/Magnesium Ratio** | *6.4* | *4.2* | 2 | 5.32 | 10 | 2.8 | 1.0 | 0.6 | 2.2 | 3.4 | **A bit low add lime.** |
| **Zinc (mg/kg)** | *5.0* | *4.0* | 4 | 116 | 10 | 22.0 | 31.8 | 19.7 | 2.3 | 41.7 | **Good** |
| **Manganese (mg/kg)** | *22* | *18* | 2 | 41 | 10 | 13.6 | 11.8 | 7.3 | 6.3 | 20.9 | **Slightly low. So do not overdose on lime.** |
| **Iron (mg/kg)** | *22* | *18* | 182 | 562 | 10 | 371 | 120 | 74.4 | 297 | 446 | **High, but not an issue** |
| **Copper (mg/kg)** | *2.0* | *1.6* | 0.8 | 2.30 | 10 | 1.4 | 0.5 | 0.3 | 1.04 | 1.67 | **OK** |
| **Boron (mg/kg)** | *1.7* | *1.4* | 0 | 0.46 | 10 | 0.3 | 0.1 | 0.1 | 0.273 | 0.4 | **Low. Add B fertiliser.** |
| **Silicon (mg/kg Si)** | *45* | *40* | 22 | 45 | 10 | 29.4 | 7.1 | 4.4 | 24.9 | 34 | **A bit low, but OK** |
| **Chloride Estimate (equiv. mg/kg)** | .. | .. | 26 | 100 | 10 | 48 | 20.6 | 12.8 | 35.5 | 61 | **Low and OK** |
| **Phosphorus Sorption (mg P/kg)** | | | **170** | **437** | **10** | **366** | **70.3** | **43.6** | **323** | **410** | **Good nutrient retention ability.** |

**Table 7.8. Statistical analyses of area 1, 2, 3 and 4 surface soils.**

| *Parameter* | *Desirable for Clay Loam* | *Desirable for Loam* | *Area1 lower limit* | *Area 1 upper limit* | *Area 2 lower limit* | *Area 2 upper limit* | *Area 3 lower limit* | *Area 3 upper limit* | *Area 4 lower limit* | *Area 4 upper limit* | *Comment: That are the 95%ile values in each of the 4 areas similar?* |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Soluble Calcium (mg/kg)** | 750 | 375 | 370 | 535 | 363 | 591 | 423 | 657 | 219 | 329 | Area 4 is lower than areas 1, 2 and 3 |
| **Soluble Magnesium (mg/kg)** | 105 | 60 | 83 | 113 | 104 | 216 | 75 | 112 | 66 | 110 | All overlap |
| **Soluble Potassium (mg/kg)** | 75 | 60 | 52 | 77 | 32 | 43 | 50 | 86 | 47 | 79 | Area 2 is lower than areas 1, 3 and 4 |
| **Soluble Phosphorus (mg/kg)** | 12 | 10 | 2.16 | 4.71 | 1.35 | 1.81 | 3.4 | 7.8 | 1.45 | 2.49 | Area 2 is lower than areas 1 and 3. |
| **Bray 1 Available P (mg/kg)** | 30 | 24 | 7.79 | 23.6 | 2.50 | 4.90 | 10.5 | 36.9 | 4.8 | 9.5 | Area 2 is lower than area 3. |
| **Bray 2 Available P (mg/kg)** | 60[5] | 48[5] | 17.4 | 62.6 | 4.00 | 7.18 | 26 | 101 | 8.1 | 20.8 | Area 2 is lower than areas 1 and 3. |
| **Nitrate Nitrogen (mg/kg N)** | 13 | 10 | 6.60 | 12.1 | 7.04 | 14.56 | 5.6 | 11.2 | 5.43 | 18.42 | All similar with overlap. |
| **Ammonium Nitrogen (mg/kg N)** | 18 | 15 | 9.38 | 16.1 | 3.31 | 12.58 | 7.7 | 13.5 | 11.02 | 26.57 | All similar with overlap. |
| **Sulfur (mg/kg S)** | 8.0 | 8.0 | 7.88 | 11.1 | 7.16 | 10.04 | 7.0 | 9.8 | 8.34 | 15.65 | All similar with overlap. |
| **pH** | 6.5 | 6.3 | 5.64 | 6.05 | 5.41 | 5.70 | 5.96 | 6.46 | 5.21 | 5.51 | Area 4 is more acidic than areas 1 and 3. |
| **Electrical Conductivity (dS/m)** | 0.15 | 0.120 | 0.059 | 0.076 | 0.05 | 0.07 | 0.060 | 0.088 | 0.055 | 0.095 | All very low and nonsaline. All similar with overlap. |
| **Exch Ca (cmol+/kg)** | 10.8 | 5.0 | 3.06 | 4.34 | 2.95 | 5.40 | 3.47 | 5.71 | 1.91 | 3.03 | Area 4 is lower than area 1 and area 3. |
| **Exch Mg (cmol+/kg)** | 1.7 | 1.2 | 0.86 | 1.20 | 1.09 | 2.48 | 0.80 | 1.25 | 0.67 | 1.23 | All similar with overlap. |
| **Exch K (cmol+/kg)** | 0.5 | 0.4 | 0.24 | 0.34 | 0.14 | 0.21 | 0.23 | 0.40 | 0.22 | 0.37 | Exch K is lower in areas 2 and 3 than in area 1. |
| **Exch Na (cmol+/kg)** | 0.26 | 0.22 | 0.143 | 0.20 | 0.12 | 0.20 | 0.14 | 0.21 | 0.13 | 0.26 | All similar, with overlap. |
| **Exch Al (cmol+/kg)** | 0.5 | 0.4 | 0.21 | 0.46 | 0.18 | 0.40 | 0.08 | 0.28 | 0.37 | 0.82 | Area 3 has lower Exch Al than area 4 |
| **Exch H+ (cmol+/kg)** | 0.5 | 0.4 | 0.23 | 0.35 | 0.17 | 0.31 | 0.14 | 0.30 | 0.33 | 0.49 | Areas 2 and 3 have lower Exch H than area 4 |
| **Effective Cation Exchange Capacity (ECEC) ($cmol_+$/kg)** | 14.3 | 7.8 | 5.1 | 6.3 | 5.0 | 8.7 | 5.1 | 7.7 | 4.2 | 5.7 | All similar with overlap. |
| **Calcium (%)** | 76 | 66 | 57 | 68 | 57. | 65 | 63 | 77 | 43 | 55 | Area 4 is lower than areas 1, 2 and 3, |

| *Parameter* | *Desirable for Clay Loam* | *Desirable for Loam* | *Area1 lower limit* | *Area 1 upper limit* | *Area 2 lower limit* | *Area 2 upper limit* | *Area 3 lower limit* | *Area 3 upper limit* | *Area 4 lower limit* | *Area 4 upper limit* | *Comment: That are the 95%ile values in each of the 4 areas similar?* |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Magnesium (%)** | 12 | 15.7 | 16.0 | 20.6 | 20.2 | 28.4 | 13.6 | 20.4 | 15 | 22 | All similar with overlap. |
| **Potassium (%)** | 3.5 | 5.2 | 4 | 6 | 2 | 3 | 3 | 6 | 5 | 7 | Area 2 is lower than areas 1 and 4. |
| **Sodium - ESP (%)** | 1.8 | 2.9 | 2 | 3 | 2 | 3 | 2 | 3 | 3 | 5 | All similar with overlap. |
| **Aluminium (%)** | 2 | 11 | 4 | 9 | 3 | 8 | 2 | 6 | 8 | 19 | Area 4 is higher than area 3. |
| **Hydrogen (%)** | 2.1 | | 4 | 7 | 3 | 6 | 2 | 5 | 7 | 11 | Area 4 is higher than area 2 or area 3. |
| **Calcium/Magnesium Ratio** | 6.4 | 4.2 | 3.24 | 5.20 | 2.30 | 3.16 | 3.8 | 6.8 | 2.2 | 3.4 | All similar with overlap. |
| **Zinc (mg/kg)** | 5.0 | 4.0 | 5.74 | 19.5 | 3.97 | 5.80 | 6.0 | 10.6 | 2.3 | 41.7 | Area 2 is lower than area 3. |
| **Manganese (mg/kg)** | 22 | 18 | 7.98 | 15.9 | 14.59 | 30.19 | 5.6 | 11.4 | 6.3 | 20.9 | All similar with overlap. |
| **Iron (mg/kg)** | 22 | 18 | 299 | 403 | 303 | 409 | 213 | 391 | 297 | 446 | All similar with overlap. |
| **Copper (mg/kg)** | 2.0 | 1.6 | 1.83 | 3.91 | 1.23 | 1.74 | 2.1 | 5.4 | 1.04 | 1.67 | Areas 2 and 4 are lower than area 1 |
| **Boron (mg/kg)** | 1.7 | 1.4 | 0.30 | 0.37 | 0.22 | 0.46 | 0.25 | 0.63 | 0.27 | 0.4 | All similar with overlap. |
| **Silicon (mg/kg Si)** | 45 | 40 | 29 | 34 | 33 | 47 | 30 | 36 | 24 | 34 | All similar with overlap. |
| **Chloride (mg/kg)** | | | 33 | 42 | 33 | 44 | 36 | 49 | 35.5 | 61 | All similar with overlap. |
| **Phosphorus sorption capacity (mg/kg)** | | | 245 | 274 | 261 | 377 | 257 | 328 | 323 | 410 | Area 4 has higher concentration than area 1. |

## Conclusions regarding soil chemistry in the 4 areas

The table below highlights statistically significant difference in soil among the 4 areas. It also contains comments and proposed responses.

**Table 7.9. Comments on the differences among the 4 areas.**

| Attributes with statistically significant differences | Response |
|---|---|
| • Area 2 has lower soluble Ca and P than area 1. | • Addition of a minimum of 20 kg of P/ha/y[1] to area 2 is required.<br>• Area 1 requires a minimum of 15 kg/ha of P/ha/y. Adjust according to plant and soil monitoring results. |
| • Area 2 has lower concentration of available P than area 1. | • See above |
| • Area 4 is more acidic than area 1. | • This can reduce clover growth. Apply lime to Area 4.<br>• Each cmol+/kg of exchangeable Al requires 750 kg/ha of high quality agricultural lime (100% Ca $CO_3$) Area 4 averages 0.65 cmol/kg of exch Al, so 450 kg/ha of lime is required. Add 1 t/ha to area 4. |
| • Area 4 has lower Exch Ca than area 1 or 2. | • Add 2T/ha of gypsum to area 4. Note the agricultural lime will also assist in increasing exch Ca concentration. |
| • Area 3 has lower Exch Al than area 4 | • See above. |
| • Exch K is lower in area 2 than in area 1 and area 4 | • Apply 100 kg/ha of Potassium/ha to area 2. Include potassium content in pasture and soil monitoring. |
| • Areas 2 and 4 have lower Cu concentrations than area 1 | • Copper concentrations can be higher in soil 'near' Copper ore bodies. However, the difference is minor. The ecological investigation concentration for Cu is 100 mg/kg. This is more than 7 the maximum Cu concentration of 13 mg/kg found in an area 3 soil. |
| • Area 4 has higher P sorption capacity than area 1. | • The 95%ile lower limit is 323 mg/kg. in a topsoil in area 4. This is 'high compared with most Australian soils and the permeate P concentration is below 1 mg/L, so deep penetration of the soil profile is highly unlikely. There is absolutely minimal risk that the phosphorus in the permeate would reach the groundwater. |

It is CONCLUDED that the 4 proposed irrigation areas have soil chemistry that will not impact on their suitability for irrigation with the permeate with its predicted chemistry.

[1] The P requirement is in kg P/ha/y. The mass of fertiliser added each year depends on the nutrient content of the fertilizer. If single superphosphate is used and the P concentration is 8.9%, then 225 kg/ha of single superphosphate is required to apply 20 kg/ha/y. .

If Diammonium phosphate is used and the P requirement is 20 kg P/ha then 77 kg of DASP/ha is required. This would also provide 14 kg/ha of Nitrogen.

# P sorption capacity in areas 2, 3 and 4

The soil sampling techniques in areas 2. 3 and 4 were the same as for areas 1.

That is: Approximately one sample pit per 1 to 2 ha of potential irrigated area. The pits were visually assessed. Three sample depts were typically taken:

1. The surface (A) horizon : typically, 10 cm
2. The depth of main root zone : typically, 10 to 40 cm
3. The clay dominant layer, with increasing percentage of rocks: typically, 40 to 100 cm.

Some soils had a distinctly bleached $A_2$ horizon. The bleached $A_2$ horizon is found immediately below the A horizon. It is indicative of water logging. Typically, this horizon has low nutrient holding capacity and can act as a barrier to root development.

**Table 7.10. The P sorption capacity statistics for the surface 100 cm of 39 soils.in areas 2, 3 and 4.**

| Sample ID and depth increment | Min | Max | Count | Mean | Stdev | Confidence interval | lower 95%ileCI | Upper 95%ileCI |
|---|---|---|---|---|---|---|---|---|
| P sorption (mg/kg) | 65 | 819 | 96 | 474 | 185 | 37 | 437 | 511 |
| Profile P sorption capacity (kg/ha) top 100 cm. | 1108 | 11198 | 31 | 7073 | 2574 | 906 | 6167 | 7979 |

The minimum P sorption capacity was 65 mg/kg. This was found in the bleached $A_2$ horizon of pit 24. The pit was located in an overland flow convergence zone. At this site, the soil below the $A_2$ horizon extended a minimum of 79 cm and contained 5405 kg/ha of P sorption capacity, so the total profile p sorption capacity was over 6,000 kg/ha. That is, the $A_2$ horizon is not an issue for P sorption capacity provided there is sufficient capacity within the remainder of the profile.

The lowest Profile P sorption capacity was 1108 kg/ha. This was pit 34 which had only 40 cm of soil. Table 5.6 shows that this area has been excluded from being irrigated.

The average capacity per profile for the 39 sites in areas 2, 3 and 4 was 7073 kg/ha. Typically, phosphorus application rates on irrigated pastures are around 20 kg P/ha/y. Uptake by vigorous pasture is 20 to 30 kg P/ha/y. So, the uptake potential typically exceeds the application rate. Even if the pasture were to receive an excess supply of 30 kg P/ha/y, it would take over 200 years to 'saturate' the surface metre of soil P sorption capacity. This is extremely unlikely to occur using RO permeate for irrigation. Virtually all the phosphorus has been excluded from the permeate, as the data in
**Woodlots and Wetlands (2024a). Impact of double reverse osmosis on permeate quality** demonstrates.

## Conclusions regarding P sorption capacity

Soil profile P sorption capacity had 95%ile confidence range of 6167 to 7979 kg/ha. This is high compared with many Australian soils.

P sorption is indicative of the ability of the soil to retain nutrients (and contaminants) from leaching. So, the relatively high storage capacity of the proposed irrigation area soils mean that the proposed irrigation areas have a low risk of ground water contamination with phosphorus.

This is important, as it is intended to operate the irrigation system so that the soils are close to field capacity for the entire year.  Increased water availability will increase deep drainage.  However, this will not result in significant leaching of phosphorus as the P sorption values are very large compared with the available P concentrations in the soils and in the permeate.

# 8. IRRIGATION MANAGEMENT AND WATER BALANCE

## Irrigation management

The proposed irrigation regime is based on an understanding of soil water dynamics and daily check of evapotranspiration data and rainfall prediction.

The aim of a typical irrigation system is to remove, or at least minimise, plant moisture stress as a limitation on plant growth.

In the current situation, maximising plant growth and leaf production will increase plant water demand.  In turn, the maximised plant water demand will facilitate maximum utilisation of the RO permeate.

The proposed system increases total water application to meet, and even exceed meeting the plant potential water demand.

The rainfall is 703 mm/year.  The potential evapotranspiration is 1056 mm/year. Therefore, the moisture deficit is some 353 mm/yr (note that this will vary among years).

The plant growth response to irrigation is typically 20 to 30 kg/ha/ mm of additional water. Therefore, assuming say 25 kg/ha of dry matter increment /mm of rainfall/year, the additional 353 mm of water will increase pasture production by a modelled 8825 kgs/year.

A daily time step water balance was used to determine the volume of water that can be sustainably irrigated onto the site. The water balance model is based on a 5km*5km gridded data set derived from the SILO website (www.longpaddock.qld.gov.au).

The time duration of the modelling is 43 years, from January 1, 1980 to 13 June 2023. The most recent 43 year period was selected to reflect recent changes in rainfall and potential evapotranspiration that are likely to reflect climate change[2].

The model inputs/ assumptions are:

- Rainfall data is for a 5km*5 km grid centred on the Veolia site ( see figure 3.1).
- The daily rainfall is based on a 2 dimensional simulation using nearby meteorological stations.
- The potential evapotranspiration (PET) is based on the FAO 56 model see figure 3.1).
- The landuse is assumed to be pasture with moderate grazing pressure
- The soil is assumed to be clay loam topsoil, with a low permeability clay subsoil.
- Runoff commences when the daily rainfall exceeds 17.8 mm (USDA, 1984).
- Available water holding capacity in the root zone is 90mm.
- Once the combination of available soil water content + infiltration exceeds 90mm, the excess water percolated below the root zone.  NOTE that this drainage is assumed to happen over the following 24 hrs.  In practice, the clay subsoil is likely to take a minimum of 2 days. This creates opportunity for increased evapotranspiration.  That is, the model is ‘conservative’,

[2] Climate change in SE Australia is expected to increase potential evapotranspiration and to reduce rainfall.  These changes will both increase irrigation demand.

- Plant water use ((evapotranspiration rate, or Et) is 100 % of PET until 50% of WHC (45 mm of available water), then a linear fall in Et as the available soil water content falls to zero.
- The irrigation strategy is to apply a small quantity of irrigation i.e., 0.5 mm, each day when the predicted rainfall was well below the rainfall runoff threshold of 18mm.

# Irrigation strategy

The irrigation strategy is:

- Ensure the permeate has very low salinity, so that there is minimal risk of salinisation of the soil and water.
- Maximise the volume of permeate that is used on the pastures within the subject property.
- Do NOT irrigate if the paddock is saturated and runoff is occurring.
- Apply the permeate via a low application rate/day to minimise the risk of runoff: Apply irrigation at 0.5 mm/irrigation day
- Only irrigate on days when rainfall is less than the likely runoff threshold of 18mm. The threshold for no irrigation was set at 10 mm of rain.
- Use warm dry summer days to increase the application rate to 1mm/day on an average of 21 days per year. This will compensate for the zero irrigation on the average of 21 days per year.
- That is the annual rate is 365.25*0.5 mm/day = 183mnm/year.
- The assumed irrigation area was 16.8 ha

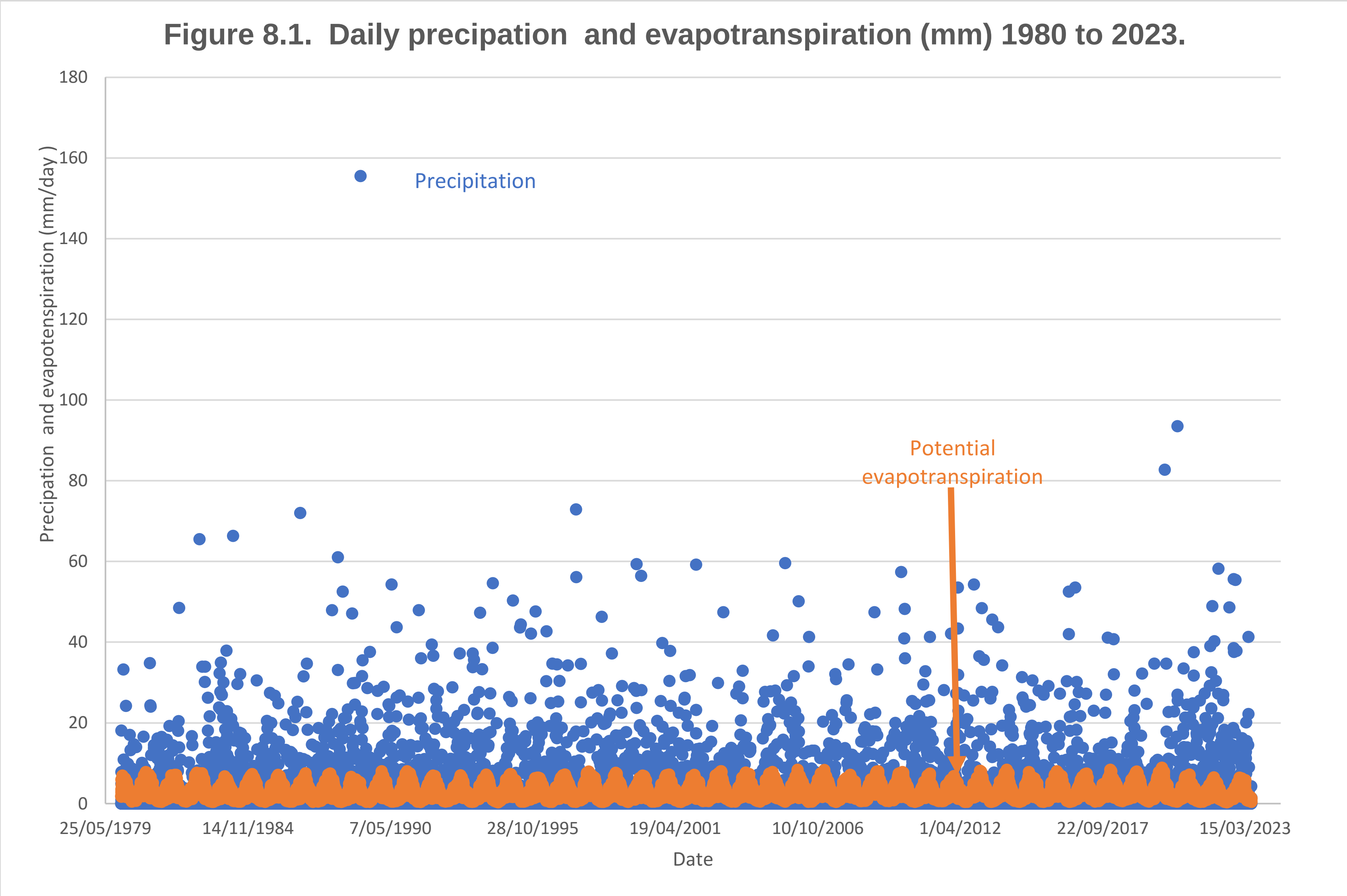
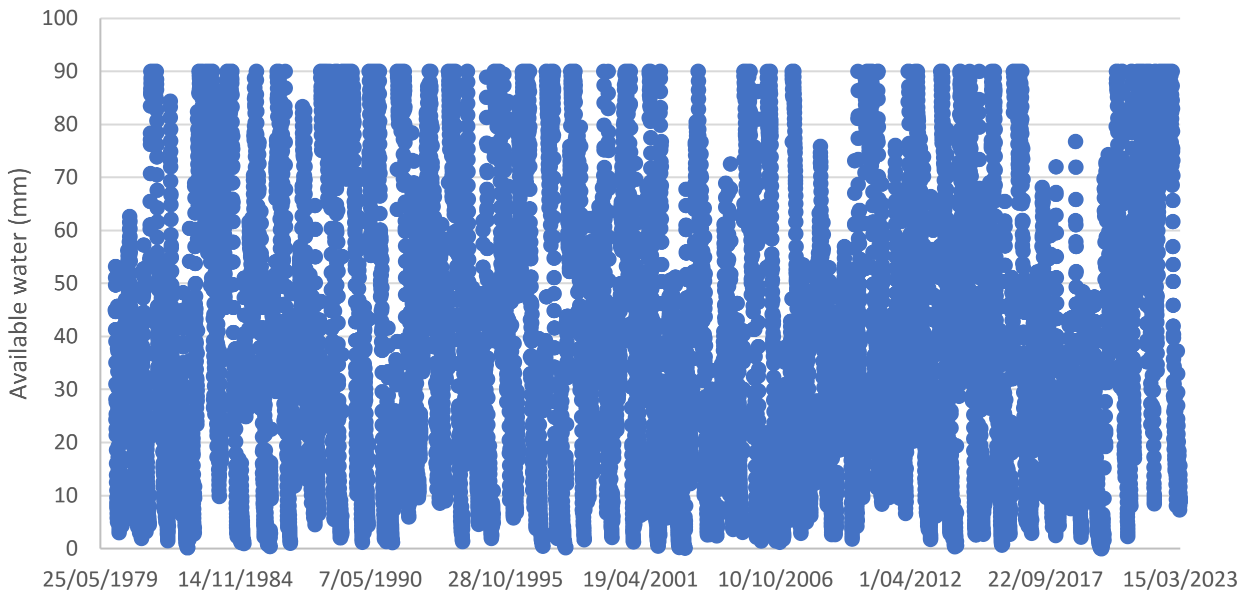


Figure 8.1. Daily precipation and evapotranspiration (mm) 1980 to 2023.
Precipation and evapotenspiration (mm/day)
180
160
140
120
100
80
60
40
20
0
Precipitation
Potential
evapotranspiration
25/05/1979
14/11/1984
7/05/1990
28/10/1995
19/04/2001
10/10/2006
1/04/2012
22/09/2017
15/03/2023
Date

# Available soil water quantity without irrigation

A daily available soil water content model was used to identify the soil water content.  The available soil water content (ASWC) is the water content, in mm, between field capacity and permanent wilting point in the surface metre of soil.  Based on a clay loam topsoil and a medium clay subsoil, the WHC in the bulk of the root zone was assumed to be 90mm (Geeves, et al, 2007).

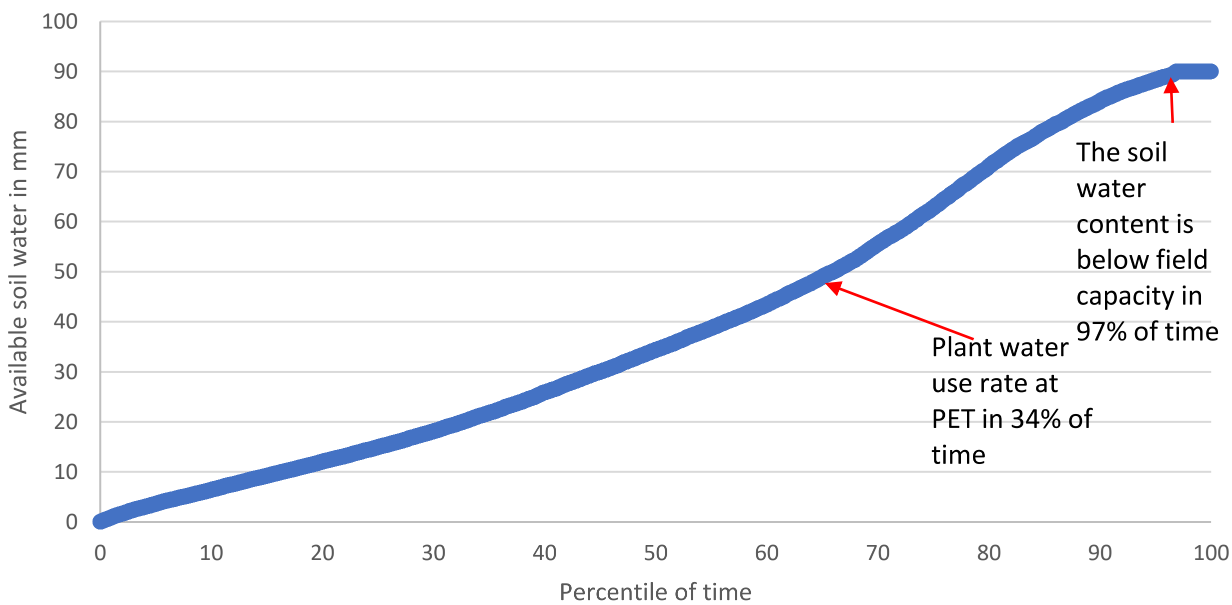
Figure 8.2.  Available soil water (mm) between January 1980 and June 2023.  Maximum is 90mm.




It is obvious from figure 8.2 that there are numerous periods when available water content approaches zero.

The model used assumes 100% of potential evapotranspiration (PET) down to 50% of field capacity (45 mm).  Figure 8.5 shows the available water then falls to less than 10% of the maximum Water Holding

Figure 8.3. Available soil water (mm) as a percentile of time based on daily available water content 1980 to 2023.



Capacity in 16% of time.  In 97% of time the profile is not ‘full’.  That is in some 97% of days it is possible to irrigate a small quantity of permeate. without exceeding the soil water holding capacity.

Note that in periods when the antecedent day had heavy rainfall, the soil water content could still be above 90mm as the water drained into the subsoil.

The strategy is therefore to apply an extremely low irrigation rate, and only when the model suggests that there is a moisture storage capacity available in the soil.

# Irrigation strategy

The irrigation strategy is:

- Ensure the permeate has very low salinity, so that there is minimal risk of salinisation of the soil and water.
- Maximise the volume of permeate that is used on the pastures within the subject property.
- Apply the permeate at a low application rate/day (0.5mm), to minimise the risk of runoff.
- Only irrigate on days when rainfall is not more than 10mm
- Apply the strategy to the 16.8 ha of area 2.

The irrigation management modelling and results are detailed in the
***Sustainable Irrigation Management (Woodlots and Wetlands 2024b).***

# 9. CALCULATION OF SOIL SALINISATION AND NUTRIENT ACCUMULATION

## SALINISATION

ANZECC (2000), chapter 4, gives methodology to predict soil salinity based on the salinity of the irrigation water and the leaching fraction[3]

The predicted salinity of the irrigation water is less than 0.3 dS/m.  See Woodlots and Wetlands (2025a)..
.
The leaching fraction is calculated as the proportion of irrigation water that percolated below the root zone.

Table 9.1 shows the leaching fraction.   Note the MEDLI model estimates that the leaching fraction of the 1.5mm/day irrigation is 0.54 (Woodlots and Wetlands 2025b).  The daily time step model assumes 183 mm of permeate irrigation with a salinity of 0.6 dS/m.   The irrigation increases the deep drainage from 91 mm/year without irrigation to 186 mm/year with 183 mm/year irrigation.  That is a 95mm/year increase in deep drainage.  The leaching fraction is 95/183.  That is a leaching fraction of 0.5.

The anticipated soil salinity, expressed as a saturated paste extract was calculated as:

Root zone salinity (SAT PASTE) (dS/m) = EC of irrigation water (permeate salinity 0.6 )
-                                                     (2.2* Leaching fraction (table 9.1, ABOVE).

Or 0.55 dS/m.

This salinity is very low and there will not be an issue with salt accumulation in these soils.  For example, table 4.2.4 in ANZECC (2000) shows soils with less than 0.95 dS/m average root zone salinity can support 'salt sensitive' plants.  The average salinity predicted is 0.55 dS/m or less than 60% of this value.

## Nutrient demand

The table below is from DEC (2004).  It was derived from  NSW Agriculture (1997).
.
**Table 9.3.  Dry matter production and nutrient uptake from southern highlands pastures  (derived from DEC, 2004 and NSW Agriculture 1997).**

| Pasture | Growth season | Average yield (tonnes/ ha dry matter) | N % in harvested tissue | P % in harvested tissue | K % in harvested tissue | N Uptake (kg/ha) | P Uptake (kg/ha) | K Uptake (kg/ha) |
|---|---|---|---|---|---|---|---|---|
| Phalaris | Mar–Nov | 12 | 1.1 | 0.3 | 2.8 | 132 | 36 | 336 |
| Perennial ryegrass | Mar–Dec | 12 | 3.5 | 0.3 | 2 | 420 | 36 | 240 |
| Fescue | All year | 14 | 2.4 | 0.4 | 2.1 | 336 | 56 | 294 |
| Lucerne | All year | 20 | 3.5 | 0.4 | 2.5 | 700 | 80 | 500 |
| White clover | Sept–Feb | 20 | 3.7 | 0.4 | 2.6 | 740 | 80 | 520 |

Key points:

- A mix of species is more likely to produce year round pasture production

[3] The proportion of the applied water that is leached below the root zone

- Non legume species will typically produce 12 to 14 T/ha/yr of dry matter
- Legume species produce up to 20 T/ha/y.
- Note that the dry matter production under irrigation is expected to be greater than under dryland conditions.
- The legume containing pasture will produce more dry matter than the non-legume pastures. This suggests that the pasture mix should include white clover
- A mix of perennial ryegrass, fescue and white clover will result in 'high' demand for NPK.
- The N, P and K mass/ha/year from the permeate application is estimated as 12 kg N/ha, 0.3 kg P/ha and 2 kg K/ha respectively. That is, the proposed 5 to 5.6 ML/ha/y of permeate will only supply a few percent of the plant demand for N, P and K.
- Soil and plant tissue monitoring followed by required fertilisation is essential to maintain plant productivity and therefore maximise evapotranspiration.
- As a minimum the fertilisation rates should be similar to anticipated plant demand.
- In order to minimise leaching of nutrients, the fertiliser application should meet the seasonal demand. That is, apply fertiliser to meet seasonal demand by plants. Heavier applications in spring, with low or zero application in winter.
- Regular sapling the pasture tissue and the soil is essential. At least annual sampling of pasture plants and biennial sampling of the soil.

The volume of RO water that can be accommodated per ha of irrigated land is discussed in detail in the ***Woodlots and Wetlands (2024b) Sustainable Irrigation Plan.***

# Management of buffer areas

It is expected that the buffer areas between the permeate irrigation areas and any drainage lines or property will be planted and maintained with the same species as used in the irrigation areas.

These areas already have a thick but very weedy pasture cover. Weed management will improve the utility of the buffer vegetation . The buffer areas can then be forage harvested whenever there is sufficient fodder. The cutting height should be adjusted to reflect the slower growth in the non-irrigated area. Note that strategic harvesting of the fodder can encourage tillering and nutrient demand. In turn this will increase the ability of the buffer areas to slow rainfall induced runoff from the permeate treatment areas.

# Potential for changes in permeate quality

Changes could occur via the following mechanisms:

- The high temperature compositing process may change via improvements that remove more of the contaminants.
    - In turn this would further reduce the contamination in the raw water.
    - The process water has been stored in the large lagoons for several decades now. Long term storage with associated fluctuations in pH and Eh can cause contaminant precipitation so that there is a long term reduction in contaminants in the final pondage water.
    - The current proposal is for the long term storage to continue, but that there will be a 'bleed' point from the final pond to the RO plant. Assuming a dynamic equilibrium is established, there will still be over 12 months residence time. This is sufficient to allow significant precipitation of heavy metal cations to occur.
    - The Double RO system plus the irrigation area should be designed to process the net accumulation of excess water from the high temperature composting process.
    - Ideally a residence time of 12 months should be implemented.
- The membranes in the RO plant may leak. The unexpected increase in salinity of the permeate is an obvious trigger. Change in salinity can be monitored in real time, and attached to visible, audible and electronic alarm systems. If it occurs then the RO plant must shut down and the issue addressed.
- Power outage may occasionally occur (note the adjacent wind farm). The RO plant will shut down and will need restarting.

# Site monitoring

The site modelling requirements are detailed in the
***Sustainable Irrigation Management (Woodlots and Wetlands 2024b).***

Key components are set out below.

## The water flow and quality monitoring program involves

- Permeate volumes and chemistry.
  Record weekly cumulative flow:
- permeate chemistry 3 monthly at the RO outlet  PLUS sampling following significant maintenance / repairs of the RO system. Follow DEC (2004), table 5.1 schedule for pH, EC, SAR, Total N, Total P, Metals
- Water courses downslope of the irrigation area sample annually for pH, EC, SAR, Total N, Total P.  Measure annually in spring time .
- Several small farm dams on site annually in spring time record pH, EC, SAR, Total N, Total P. Measure

## The pasture monitoring program involves

- Undertake plant sampling each year in late spring.  The sample harvest to be at ground level and just before forage harvesting.  A minimum of 1 sample/4ha (14 samples) to be taken.  The sample points to be geolocated and NOT resampled.
- Recording the number and type (s) of bales harvest at each cut for each of the 4 areas.
- Do an annual dry mass estimate based on typical samples.
- Annually sample the fodder and obtain chemical analyses to identify nutrient export.
- Assess the pasture species and indicative dominant / major species at the flowering stage.
- Note need if any, for weed management

## The soil management program involves

- Sampling a minimum of 1 sample points 5/ ha.
  - Area 2,  4 sample points.

**Every 3rd  year:** Sample a composite soil sample of 40 soil cores per 5 ha (4 locations in total), taken at a depth of 0- 10 cm.  For pH, EC, Available P, total P, total N, Organic carbon, Exch Cations, pesticides, heavy metals, PFAS.

**Every 10th year:** Composite soil samples of 5 cores at four depth intervals to 1 metre, within a 5 metre diameter plot. The four depths should fall within 0–20, 20–40, 40–70 and 70–100 cm depth increments, and positioned within major soil horizons or layers.

- Sampling to 1m of to rock
- Note topsoil depth (cm), the presence of a bleached A2 horizon and the depth to rock.
- Sample all four depths for pH, EC, P sorption capacity, major cations,

- ADDITIONALLY, Sample a composite soil sample of 40 soil cores per 5 ha (4 locations in total), taken at a depth of 0- 10 cm.  For pH, EC, Available P, total P, total N, Organic carbon, Exch Cations, pesticides, heavy metals, PFAS

# Required responses

## Permeate quality and quantity

Establish a log book.  Record

- Daily flows
- Include daily weather conditions, especially rainfall. (Use SILO for weather for past 24 hrs).
- Certify that the maintenance schedule is being followed.
- Note any deficiencies.
- Record water quality results at least quarterly.

## Surface and subsurface water

Undertake the sampling as outlined above.

# 10. CONCLUSIONS and RECOMMENDATIONS

- There are 4 irrigation areas.
- Areas 1 and 2 are the most favourable for irrigation on the Veolia Site. The areas are relatively low slope. Their soils are relatively deep. They have good nutrient retention ability and are non-saline.
- Areas 3 and 4 have less favourable conditions. Typically, shallower soil, steeper slopes and in some cases convergence run on from upslope areas.
- It is RECOMMENDED that 16.8 ha in area 2 be developed for fixed sprinkler irrigation in phase 1 of the project.
- All areas are deficient in nutrients.
- Some areas require liming and /or gypsum to correct soil acidity/ structural instability.
- The predicted chemistry of the double reverse osmosis permeate is similar to that of very good quality irrigation water (table 2.2).

# Recommendations

1. Fixed or travelling sprinklers are RECOMMENDED.

Area 2 will receive 0.5 mm of irrigation whenever the predicted precipitation on the irrigation day is not>10mm. SEE: ***Sustainable Irrigation Management (Woodlots and Wetlands 2024b).***

2. All irrigated areas require establishment of improved pastures. Legumes are recommended in the pasture mix.
3. As per DEC (2004) the low strength permeate requires all irrigation areas to have a minimum buffer of 50m to any sensitive areas/receptors, drainage lines, creeks and permanent watercourse(s).
4. MONITORING
    a. There must be flow meters on the irrigation area.
    b. Cumulative volumes to be recorded each week
    c. A site rainfall gauge is to be installed and precipitation to be recorded daily (may already be on site, if so, check suitability and location).
    d. The predicted rainfall each day is to be accessed for Bungendore from the www / BOM website, and recorded PRIOR to irrigation commencement. NO irrigation IF the predicted rainfall is >8mm[4].
    e. The pasture will need to be machine harvested and the fodder removed. This WILL require the irrigation to be turned off to allow the fodder to dry out prior to baling. This is easier in hot dry weather. It may not be practical in winter. ALTERNATIVELY, it can be wet harvested and used to make silage.
    f. Moderate pasture cutting height to be used, e.g 100 to 120 mm above ground to leave a residual pasture mass, e.g 5 T/ha, to recover rapidly from harvest.
    g. Undertake plant sampling each year in late spring. The sample harvest to be at ground level and just before forage harvesting. A minimum of 1 sample/4ha (14 samples) to be taken. The sample points to be geolocated and NOT resampled. Harvest dry weight/msq sample to be recorded and samples for N, P, K and micro nutrients to be recorded.
    h. Undertake soil sampling to 1m soil depth (or rock) every second year. Sampling the same geo position as the pasture sample. Report top soil and subsoil chemistry as required by the EPA (base on DEC, 2004).
5. The actual harvest process needs to be established prior to irrigation commencement. The critical issue is maximising pasture DM production. This will require a severe harvest in late summer/ autumn to allow the clover component to establish before winter. A cutting height of some 50 mm to leave a residual pasture mass of 3 T/ha. This severe cut is required to allow the clover component to re-establish after summer growth conditions.

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[4] NOTE that the daily rainfall should bd checked against the predicted rain at the site. After a few years it will be possible to ‘adjust’ the predicted rainfall to the likely actual rainfall.

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Woodlots and Wetlands 2024a. Impact of double reverse osmosis on permeate quality

Woodlots and Wetlands 2024b Sustainable Irrigation Management.

# APPENDIX 1. SOIL ATTRIBUTES OF THE 39 PROFILES IN AREAS 2, 3 and 4.

| Site name | Depth (cm) | Field texture | Consistency | Pedality | Colour | Boundaries | Mottles % | Nodules % | Hardpan | Bleached A2 | Root number | Biological activity | Texture change | Hardsetting | Rock % |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| VW 2 -1 | 0-10 | Loam | Weak, friable | Moderate | Dark brown | Diffuse | No | No | No | No | Abundant | Earth worms | Gradual | No | 10% |
| | 10-40 | Clay loam | firm | Weak | Reddish brown | Diffuse | No | No | | | Common | No | Gradual | | <5% |
| | 40-68 | Light clay | Firm | Weak | Brown | Diffuse | 40% orange | No | | | None | No | | | 65% |
| | | | | | | | | | | | | | | | |
| VW 2-2 | 0-9 | Loam | Weak, friable | Moderate | Reddish brown | Diffuse | No | No | No | No | Abundant | No | Gradual | No | <5% |
| | 9-40 | Medium clay | Firm | Weak | Grey | Diffuse | 25% orange | No | | | Occasional; | No | Gradual | | <5% |
| | 40-100 | Medium clay | Firm | Apedal | Grey | Diffuse | 25% orange | No | | | Rare | No | | | 10% |
| | | | | | | | | | | | | | | | |
| VW 2-3 | 0-9 | Clay loam | Soft friable | Moderate | Reddish brown | Diffuse | No | No | No | No | Abundant | Earth worms | Gradual | No | <5% |
| | 9-44 | Light clay | Firm | Moderate | Light yellow | Diffuse | 10% orange | No | No | | Occasional | No | Gradual | | <5% |
| | 44-10 | Light clay | Firm | weak | Grey green | Diffuse | 20% orange | No | No | | Occasional | No | | | 10% |
| | | | | | | | | | | | | | | | |

| Site name | Depth (cm) | Field texture | Consistency | Pedality | Colour | Boundaries | Mottles % | Nodules % | Hardpan | Bleached A2 | Root number | Biological activity | Texture change | Hardsetting | Rock % |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| VW 2- 4 | 0-12 | Clay loam | Friable | Moderate | Dark yellowish brown | Diffuse | No | No | No | No | Abundant | Earth worms | Gradual | No | 20% |
| | 12-44 | Clay loam | Firm | Moderate | Yellowish red | Diffuse | No | No | No | No | Common | No | Gradual | | 10% |
| | 44-100 | Medium clay | Firm | Massive | Light yellow | Diffuse | 40% red | No | | | Occasional | No | Gradual | | 10% |
| | | | | | | | | | | | | | | | |
| VW 2- 5 | 0-16 | Silty loam | Soft friable | weak | Light brown | Diffuse | No | No | No | No | Abundant | Earthworms | Gradual | No | <5% |
| | 16-50 | medium clay | Firm | Moderate | Brownish yellow | Diffuse | 15% orange | Common Dark grey | | | Occasional | No | Gradual | | <5% |
| | 50-100 | Medium clay | Firm | Massive | Pale brown | Diffuse | 5% red | No | | | Rare | No | Gradual | | 20% |
| | | | | | | | | | | | | | | | |
| VW 2-6 | 0-12 | Silty loam | Soft friable | Weak | Dark reddish grey | Diffuse | No | No | No | No | Common | No | Gradual | No | <5% |
| | 12-40 | Medium clay | Firm | Weak | Brown | Diffuse | 40% orange | No | No | No | Occasional | No | Gradual | | <10% |
| | 52-100 | Medium clay | Firm | Weak | Brownish yellow | Diffuse | 4-% light orange | No | No | No | Occasional | Some burnt roots | | | <10% |
| | | | | | | | | | | | | | | | |
| VW 2 7 | 0-9 | Silt Loam | Soft friable | Moderate | Dark brown | Diffuse | No | No | No | No | Abundant | Earthworms | Gradual | No | <10% |
| | 9-40 | Medium clay | Firm | Weak | Brownish yellow | Diffuse | 10% orange | No | No | No | Occasional | No | Gradual | | <10% |

| Site name | Depth (cm) | Field texture | Consistency | Pedality | Colour | Boundaries | Mottles % | Nodules % | Hardpan | Bleached A2 | Root number | Biological activity | Texture change | Hardsetting | Rock % |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 40-100 | Medium clay | Firm | Weak | Brownish yellow | Diffuse | 40% Orange | No | No | No | Rare | No | | | <10% |
| | | | | | | | | | | | | | | | |
| VW 2 8 | 0-15 | Silt loam | Soft friable | Moderate | Brown | Diffuse | No | No | No | No | Abundant | No | Gradual | No | 0% |
| | 15-45 | Silt loam | Friable | Moderate | Light grey | Diffuse | 20% orange | No | No | Thin bleached A2 horizon. | Rare | No | Gradual | | 50% pebbles |
| | 45-100 | Medium clay | Firm | Weak | Light orange | | 40% grey, 10% red | No | No | | Rare | No | | | 10% |
| | | | | | | | | | | | | | | | |
| VW 2 9 | 0-11 | Clay loam | Firm | Moderate | Dark yellowish brown | Diffuse | No | No | No | No | Common | No | Gradual | No | 0% |
| | 11-53 | Medium clay | Firm | Weak | Light yellow | Gradual | 20% orange | No | No | Grey bleaching | Occasional | No | Gradual | No | 10% |
| | 53-100 | Medium clay | Firm | Weak | Orange | Gradual | 40% bleached | | | | Rare | No | Gradual | | 40% |
| | | | | | | | | | | | | | | | |
| VW 2 10 | 0-9 | Loam | Soft friable | Moderate | Brown | Gradual | No | No | No | No | Abundant | Earth worms | Gradual | No | 0% |
| | 9 -40 | Light clay | Firm | Weak | Brown | Gradual | 25% orange | No | No | No | Occasional | No | Gradual | | 5% |
| | 40-100 | Light clay | firm | Weak | Light brownish yellow | Gradual | 30% orange | No | No | No | Occasional | No | Gradual | | 20% |

| Site name | Depth (cm) | Field texture | Consistency | Pedality | Colour | Boundaries | Mottles % | Nodules % | Hardpan | Bleached A2 | Root number | Biological activity | Texture change | Hardsetting | Rock % |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | | | | | |
| VW 2 11 | 0-16 | Silty clay loam | Soft friable | Moderate | Light brown | Gradual | No | No | No | No | Abundant | No | Gradual | No | 0% |
| | 11-40 | Light clay | Firm | Weak | Light yellowish brown | Gradual v | No | No | No | No | Common | No | Gradual | | 40% |
| | 40-100 | Med clay | Firm | Weak | Grey | Gradual | 30% orange | No | No | No | Occasional | No | | | 80% |
| | | | | | | | | | | | | | | | |
| VW 2 12 | 0-13 | Loam | Soft friable | Moderate | Dark brown | Gradual | No | No | No | No | Abundant | No | Gradual | No | 30% |
| | 13-40 | Light clay | Firm | Weak | Light brown | Gradual | 40% orange | No | No | | Common | No | Gradual | | 35% |
| | 40--100 | Medium clay | firm | Weak | Light brown | Gradual | 20% orange | No | No | | Rare | No | | | 45% |
| | | | | | | | | | | | | | | | |
| VW 2 13 | 0-10 | Loam | Soft friable | Moderate | Dark brown | Clear | No | No | No | No | Abundant | Earthworms | Gradual | No | 10% |
| | 10-45 | Light clay | Firm | Moderate | Yellowish brown | Gradual | No | No | No | No | Common | No | Gradual | | 30% |
| | 48-84 | Medium clay | Firm | Massive | Yellowish brown | | 10% orange | Fe and Mn nodules 5% | No | No | Rare | No | | | 40% |
| | | | | | | | | | | | | | | | 100% below 84 cm |
| | | | | | | | | | | | | | | | |

| Site name | Depth (cm) | Field texture | Consistency | Pedality | Colour | Boundaries | Mottles % | Nodules % | Hardpan | Bleached A2 | Root number | Biological activity | Texture change | Hardsetting | Rock % |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| VW 2 14 | 0 - 7 | Loam | Friable | Moderate | Dark brown | Clear | No | No | No | | Abundant | No | Gradual | No | <5% |
| | 7-21 | Silt loam | Massive | Weak | Light brown | Gradual | No | No | No | Yes | Common | No | Duplex | | 15% |
| | 21-40 | Medium clay | Friable | Weak | Light orange | Gradual | No | No | No | | Abundant | No | Gradual | | 20% |
| | 40-100 | Medium clay | Firm | Weak | Yellow | | 30% orange | No | No | | Rare | No | | | 60% |
| | | | | | | | | | | | | | | | |
| VW 2 15 | 0-7 | Clay loam | Firm | Moderate | Dark brown | Clear | No | No | No | Yes | Abundant | Earthworms | Gradual | No | 10% |
| | 7-44 | Light clay | Firm | Moderate | Orange | Diffuse | 40% red | No | No | | Occasional | No | Gradual | | 30% |
| | 44-100 | Light clay | Firm | Moderate | Pale yellow | | 5% red | No | No | | Rare | No | Gradual | | 30% |
| | | | | | | | | | | | | | | | |
| VW 2 16 | 0-5 | Loam | Friable | Strong | Greyish brown | Clear | No | No | No | Yes | Abundant | Earthworms | Gradual | No | 0% |
| | 5 -20 | Silty clay loam | Weak | Weak | Light grey | Clear | No | No | No | Yes | Occasional | No | Gradual | No | No |
| | 20-45 | Light clay | Firm | Weak | Bronze | Diffuse | 40% orange | No | No | Yes | Rare | No | Gradual | No | 20% |
| | 45-82 | Med clay | Firm | Massive | Grey | | 40% orange | No | No | Yes | Rare | No | Gradual | No | 80% Metamorphosed |
| | >88 | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | |
| VW 2 17 | 0-7 | Silt loam | Friable | Weak | Brown | Clear | No | No | No | | Abundant | No | Gradual | No | 0% |

| Site name | Depth (cm) | Field texture | Consistency | Pedality | Colour | Boundaries | Mottles % | Nodules % | Hardpan | Bleached A2 | Root number | Biological activity | Texture change | Hardsetting | Rock % |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 7--40 | Silty clay loam | Firm (Wet) | Apedal | Light grey | Diffuse | No | No | No | Yes | Rare | No | Gradual | No | 25% |
| | 40-82 | Light clay | Firm | Weak | Light yellow | Diffuse | 40% orange | No | | | Rare | No | | No | 100% @ 82 cm |
| | | | | | | | | | | | | | | | |
| VW 2 18 | 0-9 | Silt loam | Friable | Moderate | Light brown | Diffuse | No | No | No | No | Abundant | No | Gradual | No | 10% |
| | 9-50 | Medium clay | Firm | Moderate | Red | Diffuse | No | No | No | No | Rare | No | | No | 10% |
| | 50-100 | Medium clay | Firm | Moderate | Light grey | | 10% orange | No | No | No | Rare | No | | No | 20% |
| | | | | | | | | | | | | | | | 20% |
| | | | | | | | | | | | | | | | |
| VW 2 19 | 0-15 | Silt loam | Friable | Moderate | Grey | Diffuse | No | iron nodules | No | No | Occasional | No | Gradual | No | 50% (iron nodules) |
| | 15-48 | Light clay | firm | Moderate | Grey | Clear | 30% orange | No | No | No | Rare | No | Abrupt | No | 40% |
| | Metamorphosed rock below 48 cm | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | |
| VW 2 20 | 0-11 | Loam | Friable | Moderate | Dark yellowish brown | Diffuse | No | No | No | No | Abundant | Earthworms | Gradual | No | 0% |
| | 11-50 | Clay | Firm | Weak | Red | Diffuse | 40% orange | No | No | No | Common | No | Gradual | No | 20% |
| | 50-100 | Medium clay | Firm | Weak | Orange | | 25% red | No | No | No | Occasional | No | | No | 30% |
| | | | | | | | | | | | | | | | |

| Site name | Depth (cm) | Field texture | Consistency | Pedality | Colour | Boundaries | Mottles % | Nodules % | Hardpan | Bleached A2 | Root number | Biological activity | Texture change | Hardsetting | Rock % |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| VW 2 21 | 0-11 | Loam | Friable | Moderate | Brown | Diffuse | No | No | No | No | Abundant | No | Gradual | No | None |
| | 11 -43 | Medium clay | Firm | Weak | Light brown | Diffuse | 40% red | No | No | No | Common | No | Gradual | No | None |
| | 43-108 | Medium clay | Firm | Weak | Yellowish brown | | | White nodules | No | No | Rare | No | Gradual | No | None |
| | | | | | | | | | | | | | | | |
| VW 2 22 | 0-8 | Loam | Friable | Moderate | Brown | Diffuse | No | No | No | No | Common | Earthworms | Gradual | No | None |
| Irrigation may be difficult | 9 - -44 | Medium clay | Firm | Weak | Orange | Diffuse | 30% red | No | No | No | Occasional | No | Gradual | No | None |
| | 44- 84 | Medium clay | Firm | Weak | Orange | Diffuse | 10% white | No | No | No | Rare | No | Gradual | No | None |
| | 83 | | | | | | | | | | | | | | Quartzite like rock |
| | | | | | | | | | | | | | | | |
| VW 2 23 | 0 - 8 | Clay loam | Friable | Moderate | Dark brown | Clear | No | No | No | No | Common | No | Gradual | No | 5% |
| | 8 -15 | Medium clay | Firm | Weak | Grey | Clear | 20% orange | No | No | Yes | Rare | No | No | No | 10% |
| | 15 - 45 | Medium clay | Firm | Weak | Pale brownish yellow | Diffuse | 25% orange | No | No | | Rare | No | No | | 20% |
| | 45-105 | Medium clay | Firm | Weak | Grey | Diffuse | 25% orange | No | No | | Rare | No | No | | 60% sandstone/ quartzite type rock |
| | | 100% rock at 105 cm | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | |

| Site name | Depth (cm) | Field texture | Consistency | Pedality | Colour | Boundaries | Mottles % | Nodules % | Hardpan | Bleached A2 | Root number | Biological activity | Texture change | Hardsetting | Rock % |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| VW2 24 | 0 - 9 | Loam | Friable | Weak | Brown | Clear | No | No | No | Yes | Common | No | Gradual | No | 0% |
| Convergence zone . Wet | 9 - 29 | Gravelly loam | Friable | Apedal | Light brownish grey | Clear | No | No | No | | Rare | No | | | 15% |
| | 29 - 41 | Medium clay | Firm | Apedal | Grey | Diffuse | 50% orange in layers | white nodules common | No | | Rare | No | | | 40% |
| | 41 – 105 | Medium clay | Firm | Apedal | Olive yellow | Diffuse | 50% orange | White nodules | No | | Rare | No | Gradual | | 60% |
| | | | | | | | | | | | | | | | |
| VW 2 25 | 0 - 12 | Clay loam | Friable | Moderate | Dark yellowish brown | Diffuse | No | No | No | No | Abundant | No | Gradual | No | None |
| | | | | | | | Narrow bleached A2 band between 10 and 12 cm | | | | | | | | |
| | 12 - 50 | Light clay | Firm | Weak | Light brown | Diffuse | 10% red | | No | | Common | No | Gradual; | | None |
| | 50 - 100 | Medium clay | Very firm | Weak | Brown | Diffuse | 10% red | | No | | Rare | Old root channels | | | None |
| | | | | | | | | | | | | | | | |
| VW 2 26 | 0 - 9 | Silty loam | Friable | Weak | Yellowish brown | Clear | No | No | No | No | Abundant | Earthworms | Gradual | No | 20% |
| Eroded area | 9 -45 | Clay | Firm | Moderate | Red | diffuse | No | 5% black nodules | No | No | Occasional | No | Gradual | No | 20% |
| | 45-105 | Medium clay | Firm | | | | | | | | | | | | 30% |
| | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | |

| Site name | Depth (cm) | Field texture | Consistency | Pedality | Colour | Boundaries | Mottles % | Nodules % | Hardpan | Bleached A2 | Root number | Biological activity | Texture change | Hardsetting | Rock % |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| VW 2 27 | 0 - 10 | Clay loam | Friable | Moderate | Dark brownish grey | Clear | No | No | No | Yes | Abundant | Earthworms | Gradual | No | 0% |
| | 10-15 | | | | | | Narrow bleached A2 band between 10 and 15 cm | | | | | | | | 0% |
| | 15 - 45 | Medium clay | Firm | Weak | Brownish yellow | diffuse | 10% orange | No | No | No | Occasional | No | Gradual | | 0% |
| | 45 - 100 | Medium clay | Very firm | Very weak | Brownish yellow | | 5% orange 5% white | No | No | | Root channels | No | no | | 60% |
| | | 60% rotted rock fragments at 100 cm | | | | | | | | | | | | | 60% |
| | | | | | | | | | | | | | | | |
| VW2 28 | 0 - 10 | Clay loam | Friable | Moderate | brown | Clear | No | No | No | Yes | Common | No | Gradual | No | 0% |
| | 10-12 | | | | | | Minor A2 bleaching | | | | | | | | 0% |
| | 12 - 43 | Medium clay | Firm (wet) | Weak | Orange brown | diffuse | 40% orange | No | No | Yes | Occasional | No | Gradual | | 0% |
| | 43 - 100 | Medium clay | Very firm | Very weak | Yellowish brown | | 50% orange | No | No | | Rare | No | Bo | | 80% |
| | | 80% rotted rock fragments at 100 cm | | | | | | | | | | | | | 60% |
| | | | | | | | | | | | | | | | |
| VW2 29 | 0 - 8 | Clay loam | Friable | Weak | Brown | Clear | No | No | No | No | Common | | Gradual | No | 0% |
| | 8 - 10 | | | | | | Minor A2 bleaching | | | | | | | | 0% |
| | 10 - 44 | Medium clay | Very firm | Weak | Brownish yellow | diffuse | 10% orange | No | No | No | Occasional | No | Gradual | | 0% |

| Site name | Depth (cm) | Field texture | Consistency | Pedality | Colour | Boundaries | Mottles % | Nodules % | Hardpan | Bleached A2 | Root number | Biological activity | Texture change | Hardsetting | Rock % |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 44 - 85 | Medium clay | Very firm | Very weak | Brownish yellow | | 5% red 5% white | No | Bo | | Rare | No | | | 20% |
| | | rotted rock fragments at 85 cm | | | | | | | | | | | | | 60% |
| | | | | | | | | | | | | | | | |
| VW 2 - 30 | 0 - 10 | Clay loam | Friable | Moderate | Dark brown | Clear | No | No | No | No | Abundant | Earthworms | Gradual | No | 0% |
| | 10-13 | | | | | | Narrow bleached A2 band between 10 and 13 cm | | | | | | | | 0% |
| | 13 - 41 | Medium clay | Firm | Weak | Red | Clear | 25% orange/ yellow | No | No | No | Occasional | No | Gradual | | 0% |
| | 41 - 108 | Medium clay | Very firm | Very weak | Grey | Diffuse | 30% orange | No | Bo | | No | No | Bo | | 0% |
| | | 60% rotted rock fragments at 100 cm | | | | | | | | | | | | | 60% |
| VW 2 - 31 | 0 - 12 | Clay loam | Friable | Moderate | Dark brown | Clear | No | No | No | No | Abundant | Earthworms | Gradual | No | 0% |
| | 12 - 45 | Medium clay | Firm | Moderate | Orange red | diffuse | 25% bronze | No | No | No | Rare | No | Gradual | | 40% rock |
| | 45 - 70 | Medium clay | Very firm | Moderate | Reddish orange | Clear | 25% bronze | No | No | No | Rare | No | No | | Red 'volcanic'? 30% |
| | 70 - 105 | Medium clay | Very firm | Moderate | Pale yellow | | 5% orange | No | No | No | Rare | No | No | | 40% sandstone |
| | | | | | | | | | | | | | | | |
| VW 2 - 32 | 0 - 10 | Clay loam | Weak | Moderate | Brown | Clear | No | No | No | No | Abundant | Earthworms | Gradual | No | 10% |
| | 10-12 | | | | | | Narrow slightly bleached A2 band between 10 and 20 cm | | | | | | | | 0% |

| Site name | Depth (cm) | Field texture | Consistency | Pedality | Colour | Boundaries | Mottles % | Nodules % | Hardpan | Bleached A2 | Root number | Biological activity | Texture change | Hardsetting | Rock % |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 20 - 46 | Gravelly clay | Friable | Weak | Light orange yellow | Clear | No | No | No | No | Common | No | Gradual | | 30% |
| | 46 - 100 | Light clay | Weak | Very weak | Light orange | clear | 30% orange | No | Bo | | None | No | | | 40% |
| | | 60% rotted rock fragments at 100 cm | | | | | | | | | | | | | 60% |
| | | | | | | | | | | | | | | | |
| VW 2 33 | 0 -70 | Clay loam | Firm | Moderate | Light brown | Clear | No | No | No | Yes | Abundant | No | Gradual | No | 0% |
| | 7 - 15 | Clay | | Weak | Very pale yellow | | Narrow bleached A2 band between 10 and 15 cm | | | | Occasional | No | | | 0% |
| | 15 - 41 | Light clay | Firm | Weak | Brownish yellow | diffuse | 10% orange | No | No | No | Occasional | No | | | 10% |
| | 41 - 76 | Light clay | Very firm | Apedal | Light grey | Diffuse | 10% red | No | | | Occasional | No | | | 60% metamorphosed shale |
| | | | | | | | | | | | | | | | |
| VW 2 - 34 | 0 - 12 | Clay loam | Friable | Moderate | Dark brown | Clear | No | No | No | No | Abundant | Earthworms | Gradual | No | 0% |
| Shallow soil | 12 - 40 | Gravelly clay | Friable | Weak | Light yellowish brown | Clear | No | No | No | No | Occasional | No | Gradual | | 0% |
| | 40-100 | 55% metamorphosed rock fragments at >40 cm | | | Light brown | | | | | | Rare | No | | | 55% |
| | | | | | | | | | | | | | | | |
| VW 2 35 | 0 -5 | Very rocky, metamorphosed sandstone. High runoff risk Avoid | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | |

| Site name | Depth (cm) | Field texture | Consistency | Pedality | Colour | Boundaries | Mottles % | Nodules % | Hardpan | Bleached A2 | Root number | Biological activity | Texture change | Hardsetting | Rock % |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| VW 2 36 | 0-10 | Clay loam | Friable | Moderate | Dark brown | Clear | No | No | No | No | Abundant | No | Gradual | No | 20% |
| | 10- 45 | Medium clay | Friable | Moderate pedality | Light brown | Diffuse | No | No | No | No | Rare | No | Gradual | No | 70% |
| | 45- 85 | Steep shallow rocky site. avoid | | | | | | | | | | | | | 90% |
| | | | | | | | | | | | | | | | |
| VW 2 - 37 | 0 - 9 | Clay loam | Friable | Moderate | Dark brown | Gradual | No | No | No | No | Abundant | No | Gradual | No | 20% |
| Shallow site | 12 - 34 | Clay loam | Friable | Moderate | Brown | Gradual | No | No | No | No | Occasional | No | Gradual | | 80% rock |
| | 34 - 60 | Medium clay | Very firm | Moderate | Light brown | Gradual | 25% bronze | No | No | No | Rare | No | No | | 95% |
| | | | | | | | | | | | | | | | |
| VW 2 - 38 | 0 - 7 | Gravelly clay loam | Friable | Weak | Yellowish brown | Clear | 40% red | No | No | No | Abundant | No | Gradual | No | 20% |
| | 7 - 40 | Medium clay | Firm | Weak | Light brown | Diffuse | 5% red | No | No | No | Rare | No | Gradual | | 40% rock |
| | 40 - 60 | Medium clay | Firm | Moderate | Light brown | | No | No | No | No | No | No | No | | 80% |
| | | | | | | | | | | | | | | | |
| VW 2 - 39 | 0 - 9 | Clay loam | Friable | Moderate | Dark brown | Clear | No | No | No | Yes. | Abundant | No | Gradual | No | 10% |
| | 9 to 31 | Medium clay (saturated) | Firm | Moderate | Very pale brown | diffuse | No | No | No | 22 cm A2 horizon | Occasional | No | Gradual | | 20% rock |
| | 31 to 40 | Medium clay | Very firm | Moderate | Brown | Clear | 25% bronze | No | No | No | Rare | No | No | | 60% rock lenses |

| Site name | Depth (cm) | Field texture | Consistency | Pedality | Colour | Boundaries | Mottles % | Nodules % | Hardpan | Bleached A2 | Root number | Biological activity | Texture change | Hardsetting | Rock % |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 40 - 100 | Medium clay | firm | weak | Whitish yellow | | 30% red | No | No | No | Rare | No | No | | 40% rock |