

WHY WASTE WATER? – HARVESTING FOR IRRIGATION

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ABSTRACT

The Pines II WWTP near Rolleston was designed for an ultimate population of 60,000. This stage was completed in 2013 for a population of 30,000. It currently consists of inlet works, bioreactors, clarifiers, UV disinfection and irrigation to pasture.

An evaluation of the relative merits of different irrigation methods found the centre pivot irrigators to be the most cost effective and efficient irrigation system for the site.

Most pasture species have a high nutrient uptake rate and a high nutrient export value when the end use is cut and carry. For the soil type at the Pines II WWTP a hydraulic loading rate of up to 8 mm/d is being used. The use of treated wastewater to irrigate pastures also helps to conserve groundwater.

The arrangement with the local contractor to cut and carry the pasture negates any costs to the Selwyn District Council (SDC) for cutting of the grass whilst also adding value to the local economy in the form of animal fodder which would otherwise be a waste product., Overall the cut and carry operation is likely to be carbon negative due to the removal of the grass..

Since the treated effluent has been applied to the land there have been no measured negative effect(s) on groundwater quality and soil characteristics.

KEYWORDS

“Irrigation, Treated Wastewater, Cut and Carry, Ground Water Monitoring”

1 INTRODUCTION

Pines I treated wastewater irrigation scheme was developed in 2004, to serve the predicted growth in Rolleston.

The Pines I irrigation system involved staged development of a total 80ha on the south side of Burham School Road.

The 80ha irrigation site was originally surrounded by the pine plantation of the Selwyn Plantation Board Ltd (SPBL), however in 2006/07 this land was converted to pasture.

Rapid growth has continued in Rolleston, with similar pressure on other communities in the Eastern Selwyn area; with significant growth in the communities of Prebbleton, Lincoln and Rolleston (as well as other Council areas).

Treatment and disposal of sewage for some of these communities has been either a problem or a growth restriction. The Selwyn District Council considered future sewerage options for these communities concluding the preferable option was to integrate sewage disposal in the Eastern Selwyn area and expand the previous Pines concept with treatment and disposal of high quality effluent at the Pines site and potentially on or around the recently converted pasture land owned by SPBL. The expanding irrigation concept is called Pines II, with the collection system serving Prebbleton, Lincoln and Rolleston called the Eastern Selwyn Sewerage Scheme (ESSS).

In 2007 it became apparent that the continued growth in the Rolleston and East Selwyn area would soon exceed the capacity of the Pines I plant and that a new, larger plan would be required. The result of this was the Pines II

WWTP, which was designed for an ultimate connected population of 60,000. The first stage of the ultimate capacity was constructed for a connected population of 30,000 and was completed at the beginning of 2013. The current Pines II WWTP consists of inlet works, secondary treatment in two bioreactors for advanced nitrogen removal, secondary clarifiers, UV disinfection and irrigation of treated wastewater to dedicated land for growing pastures. An additional two bioreactors and clarifiers are required to bring the WWTP to its ultimate design capacity. A new centre pivot irrigator is currently being procured that is capable of accepting the full flow from the WWTP.

This paper will present the irrigation strategy, crop selection and management, treated wastewater quality, borehole and soil monitoring results and operational experience.

2 DISPOSAL OPTIONS

2.1 HIGH LEVEL

A fundamental criterion for the scheme was the ability to dispose of the wastewater. There was no spare capacity under the existing discharge agreements with Christchurch City Council (CCC) to meet the growth predictions for either Prebbleton or Lincoln. Options to increase the allocation were formally discussed with CCC staff throughout the options development stage and through to completion of the consenting of the irrigation block at the Pines WWTP. Limitations within the downstream network and the timing of future upgrades meant the discharge volumes could not be increased and therefore SDC needed to provide an alternative solution.

Discharge of treated wastewater via waterways was not considered viable due the water quality requirements and the cultural sensitivity of the ultimate receiving environment (Lake Ellesmere / Te Waihora). Therefore, two viable solutions were considered, Land Disposal and Ocean Outfall Disposal.

Each of these viable solutions were evaluated against the four well beings and tested against their compatibility with the District and development visions statements. In comparing the Land Disposal and Ocean Outfall options, each had a similar weighting in terms of scores against the Environmental and Social well beings, however Land based disposal was clearly favoured over Ocean Outfall disposal with higher scores against Economic and Cultural well beings. The Ocean Outfall option was estimated as being ~30% (\$33M) more expensive than the Land based disposal option. The Land based disposal option had a smaller risk profile and a higher certainty of outcome than that of the Ocean Outfall option given the existing consent (circa 2004) established for treatment and land disposal at the Pines WWTP site.

For Land Disposal, localised treatment and land irrigation was considered. The land in the vicinity of the communities of Lincoln and Prebbleton is not suitable for land based discharge due to the soil types and high groundwater table. A centralised option at the existing Pines WWTP site was considered the most viable solution for Land Disposal due to:

- Availability and suitability of adjacent land for irrigation disposal.
- Ability to consent for the proposed activity (existing consent on the adjacent land).
- Reuse of existing infrastructure.
- Upgrades would be required of the wastewater treatment infrastructure at Pines WWTP for Rolleston in the immediate future to meet the continuing growth. This would allow integration of treatment solutions.

A further benefit from the irrigation was the ability to contribute to groundwater recharge.

An evaluation of the relative merits of different irrigation methods found the centre pivot irrigators to be the most cost effective and efficient for the Pines II WWTP. The irrigators allow the application depth to be varied by adjusting the rotational speed so distribution is very uniform in even windy conditions due to relatively large droplets which minimise spray drift.



Photograph 1: Irrigator 5

2.2 LAND USE OPTIONS

Various land use options are available for use in conjunction with centre pivot irrigation. These are outlined below.

2.2.1 CUT AND CARRY

Cut and carry systems require little operational input and cost. Every few months during spring, summer and autumn (less frequently if at all during winter), the pasture is cut and taken off site as silage or baleage. This is carried out by a specialist contractor and minimises the involvement of the plant operator in routine day to day farm or agricultural management. Removing the herbage exports nutrients stored within the harvested material. Nutrient export, particularly nitrogen, allows a higher nitrogen loading rate. This is typically in the order of 500-600 kg N/ha/yr with winter uptake and leaching rates determining the overall loading rates. While the current irrigation and cut and carry operation could be considered carbon neutral, because ultimately the baleage is fed to beef cattle, the overall process may be carbon negative.



Photograph 2: harvesting in operation

2.2.2 STOCK GRAZING

Routine or regular stock grazing is not a suitable use for the pasture grown at wastewater irrigation sites and Pines II WWTP is no exception. There are a number of disadvantages:

- Full time involvement in stock procurement and management **or** dependence on a farmer to supply stock.
- Need to irrigate areas where stock are grazing (need to be immediately moved elsewhere).
- Stand down period before stock can graze irrigated land, requiring regular rotation of stock between paddocks and hence intensive stock and pasture management.
- A lower nitrogen loading rate of between 150-200 kg N/ha/yr because of nitrogen recycling to the soil from stock urine and dung.
- Compaction of the soil from stock reducing infiltration capacity.
- Damage to solid set irrigation systems if this system is used.

2.2.3 CASH CROPS

Arable and horticulture crops such as cereals (wheat, barley, oats and maize), vegetables and fruit crops could be irrigated with waste water. These crops have high nitrogen uptake rates and have a harvested value. However, in the operation of the Pines WWTP or any wastewater irrigation plant, effluent must be irrigated year round. Arable crops typically require the land to be fallowed and a “dry” harvest period of 4-8 weeks. Fruiting trees have a long dormant period and are mostly susceptible to “wet feet”. Bare land or dormant trees would have to be irrigated in winter resulting in greater leaching or the need for significantly lower application rates (and therefore storage), soil degradation and surface runoff. In addition, there is the issue of sale and consumption of edible crops grown with sewage wastewater.

Commercial crops such as these were considered and dismissed as viable land use options.

2.3 GRASS TYPE

The consented nitrogen loading rate is 204.4kg/ha¹ annually after rebate from cut and carry. The pasture species selected is primarily Italian ryegrass with added white clover. Tall fescue, chicory and plantain have also been sown in the irrigation areas of pivots 1 and 2. The latest areas to be developed for irrigation have not replaced the grass already present in the paddocks, which have been harvested for biallage and used for feeding beef cattle.

2.4 CONSIDERATION OF IRRIGATION AREAS

The Pines II irrigation expands the original irrigation into the adjacent paddocks, previously owned by SPBL. This land has now been purchased by SDC and where not currently required for irrigation, has been leased to local farmers for grazing. When developed for irrigation, stock will be fenced out of the paddocks. The figure below shows the areas currently irrigated, with new areas to be irrigated shown in pink. The areas available to be used for irrigation are based on the following parameters.

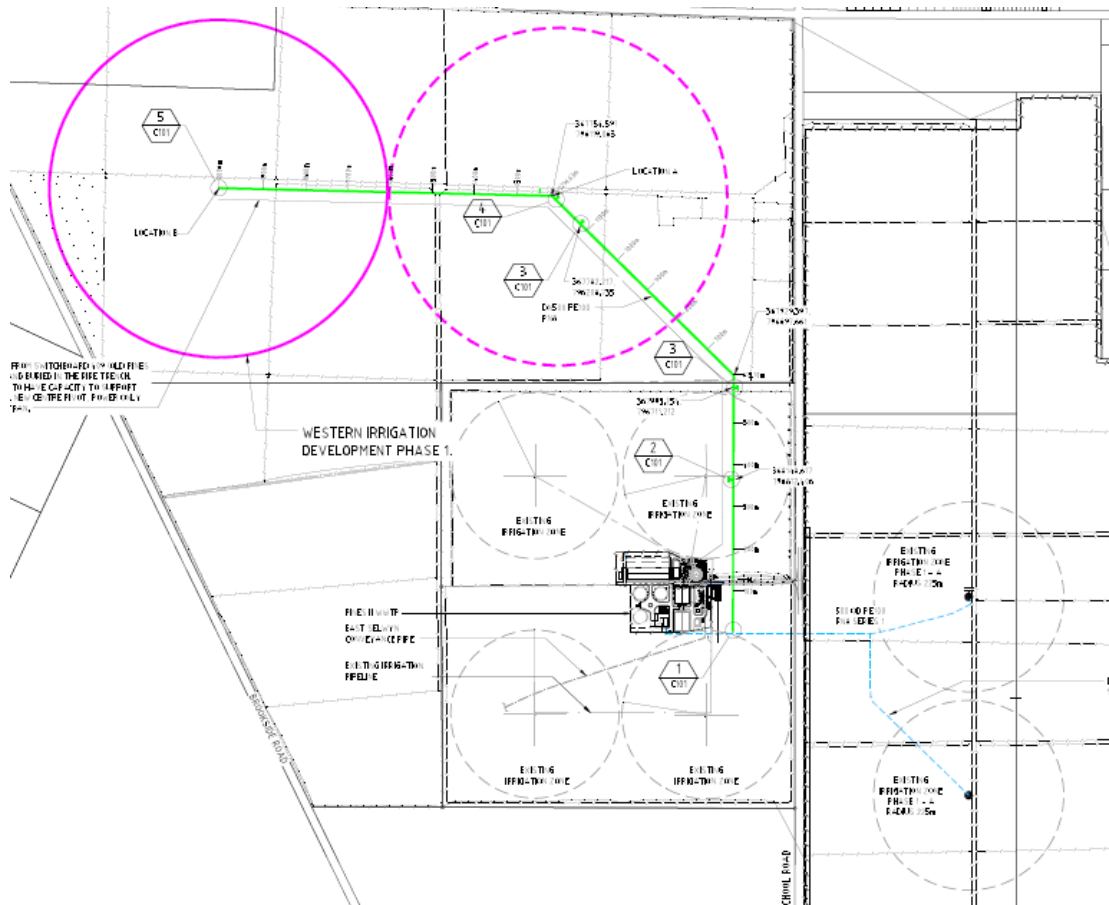


Figure 1: Location of Irrigators

Minimum buffer zone separation:

- Road Boundaries - 20m (to allow for shelter belt).
- Road Boundary with adjacent private owners (with downstream groundwater abstraction possibilities).

¹ Consent number CRC101109.1

3 DISCUSSION ON ENVIROMENTAL EFFECTS

3.1 IRRIGATION QUALITY

The stakeholders clearly identified the expectation of a high quality of treated effluent with minimal environmental impacts. Such requirements are the basis for fulfilling the RMA obligations and gaining a consent.

The Pines II discharge is based on high quality treated effluent of a standard above most typical treatment systems in New Zealand and close to the best. The treatment process is an aerobic “mechanical” system (termed activated sludge) with additional process screening, grit removal and biological nitrogen removal (BNR) in a four stage activated sludge process and UV disinfection to reduce pathogens to a level that could be expected in average quality surface waters. To reduce the risks of nitrates getting into groundwater, the nitrogen content of the final treated wastewater is reduced by the BNR process. This also allows the hydraulic loading rate and the nitrogen loading rate to be better balanced, allowing optimum use of land area.

The original Pines I treatment plant operated to expectations hence the same treatment process was used as a basis for the design of the Pines II treatment plant. Similarly, environmental monitoring of the Pines I irrigation system shows minimal impacts and that predictions provided in the current process were being met.



Photograph 3: Irrigator operating

The treated wastewater quality after UV disinfection and prior to irrigation is presented in Table 1 and compared to the resource consent conditions. As can be seen from the results the treated wastewater quality complies with all the standards of the resource consent.

Table 1: Treated Wastewater Quality for the period 1 August 2013 to 31 May 2015

Parameter	Unit	Median	95 % ile
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		8/13 - 5/15	RC	8/13 - 5/15	RC
BOD	mg/L	4	15	11.1	60
SS	mg/L	5	20	27	90
TN	mg/L	5.8	7	9	35
FC	cfu/100ml	60	500	545	1,000

The average daily flow was 4,893 m³/day and the peak flow was 9,405 m³/day for the period 1 August 2013 to 31 May 2015.

The total flow irrigated during the period was 3,273,344 m³ and at a median TN concentration of 5.8 mg/L the mass of nitrogen applied to the land was 18,985 kg. The area irrigated during this period was 0.80 ha which equates to an annual application rate of about 130 kgN/ha which is considerable lower than the allowable application rate with or without export of harvested material.

3.2 NITROGEN REMOVAL

The grass is harvested on average three times a year by a contractor and the grass is analysed for nitrogen content. The total matter harvested was 2,170 tonnes of bailage with a total nitrogen content of 46,635 kg for the period 1 August 2013 to May 2015.

As can be seen from the nitrogen balance the nitrogen incorporated in the grass exceeds the nitrogen load applied by the treated wastewater. It seems that there is additional nitrogen uptake from the soil as well.

The grass sampling procedure is provided in Appendix C.

3.3 SOIL

The site is flat and located next to a pine plantation that has been converted to pasture land. The soil type is Lismore Stony Silt which is free draining and has physical characteristics that are favourable for pasture root growth and contain fine grained particles for absorption of nutrients and organic contaminants.

The soil monitoring has found that the nitrogen content seems to fluctuate up and down but remains within a low concentration. Soil samples are analysed twice annually from the land beneath each pivot that has received treated wastewater.

The soil samples are analysed for arsenic, cadmium, calcium, chromium, copper, lead, magnesium, sodium, zinc, cation exchange capacity (CEC), nitrogen organics and pH. The trace element concentrations comply with the standards of the resource consent.

The nitrogen concentration in the soils is as follows is shown in table 2:

Table 2 : Nitrogen concentration in soil:

Pivots	Date	Nitrogen g/100g dry solids	
		Average	Range
CP 1	Jan 13 to Jan 15	0.30	0.28 to 0.31
CP 2	Jan 13 to Jan 15	0.30	0.28 to 0.33
CP 3	Jul 13 to Jan 15	0.27	0.22 to 0.33
CP 4	Jul 13 to Jan 15	0.28	0.23 to 0.36
CP 5	Jul 13 to Jan 15	0.25	0.22 to 0.34
CP 6	Jul 13 to Jan 15	0.27	0.32 to 0.22

3.4 GROUNDWATER IMPACTS

There are a number of bores in the area that are used to monitor the groundwater quality, these are highlighted below in green dots. The bores circled in red are graphically shown in the Appendix A and present the nitrate concentrations and E Coliform numbers for the period 1 January 2013 to 31 May 2015. As can be seen from the trend line for borehole BX23/0204 there has been an increase in nitrate concentrations but this cannot be attributed to irrigation as the land is adjacent to a golf course and upstream of the current irrigation system. The other bores (M36/7461, M36/20416 and M36/7464) are more directly affected by irrigation and there is no noticeable increase in nitrate concentration and the E Coli numbers are < 1/ 100 ml.

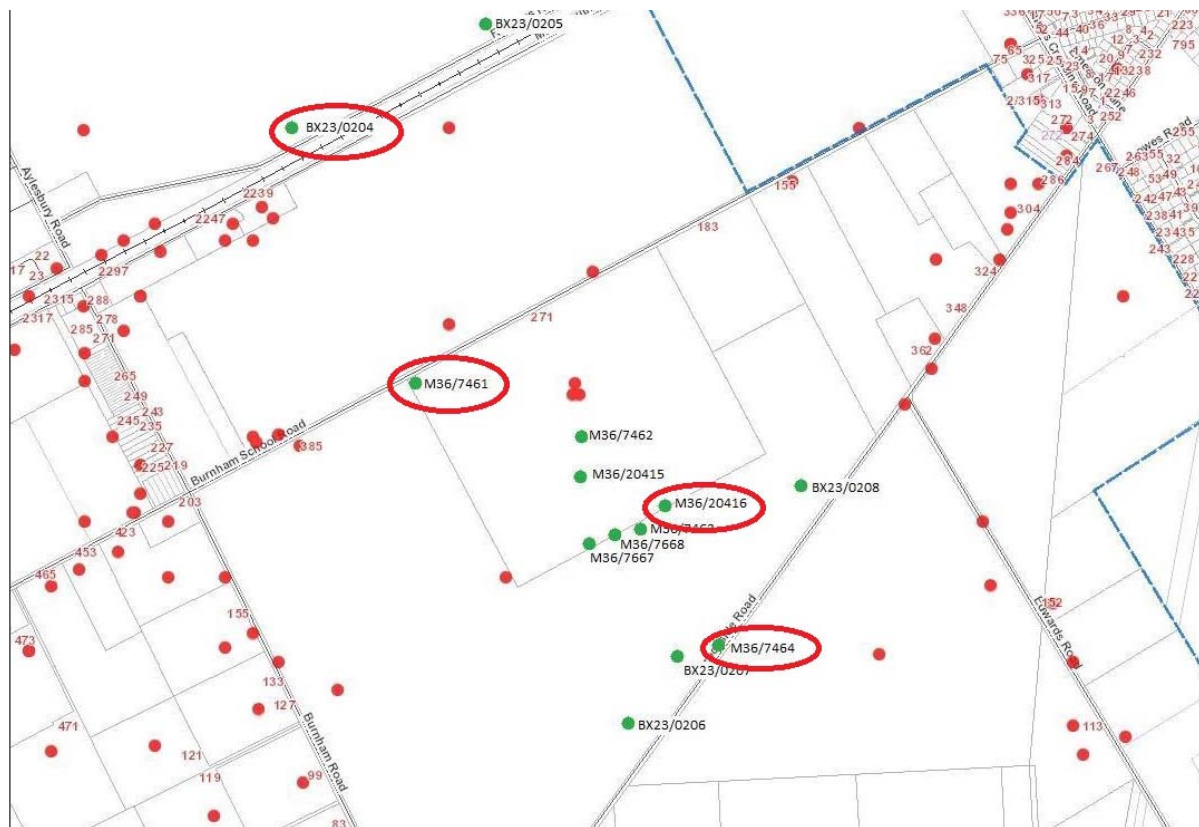


Figure 2: Bore Locations

Linked to the desire for irrigation of a high quality treated wastewater, stakeholders wanted little or no groundwater impacts. Clearly with any surface activities, there is the potential for groundwater impacts and a likely key issue is the extent of any groundwater impacts and effect on others. The results of the borehole monitoring shows no signs of contamination at this stage. It seems that most of the contaminants are trapped in the grass.

The original Pines I site was well isolated from adjacent owners and groundwater users by the extensive surrounding land. This land provided a separation distance of at least 300 meters. With the expanding Pines II irrigation area, this buffer area has been reduced with reduced distances to other land owners and greater risk or effects to users of groundwater. In the worst case, groundwater could be adversely effected, and as this would be an unacceptable situation, either the Pines II scheme would need to provide an alternative water source or not adversely affect groundwater.

To overcome this perception, an extensive monitoring program has been carried out.

Given the extensive development in the Rolleston area, there is likely to be further development in the surrounding area. In addition to providing consent compliance, the testing regime also ensures that any bores located within the effected groundwater area have confidence that there will be no contamination.

As general groundwater contamination would not be expected, general groundwater abstraction and uses for irrigation and the like could continue. It could be expected in some farm situations that irrigation supplies would also provide stockwater and domestic drinking water. While the Council potable supply would be provided to replace this domestic supply, it would not be practical or economic to separate out the stockwater and irrigation system. It may therefore eventuate that a farm stockwater system may remain extracting from the immediate groundwater system. If this is so, then notwithstanding the provision of alternative domestic supply, it may be necessary to minimise potential groundwater contaminate to ensure stockwater protection.

3.5 GROUNDWATER PROTECTION REQUIREMENTS

The following are statutory guidelines for water quality for either potable or stockwater use.

Indicator Bacteria

Potable (drinking water) <1.0 E.Coli/100ml (NZDWS and ECan)

Stockwater 1,000 faecal coliforms/100ml (ECan)

Nitrogen

Potable (drinking water) 11.3g/m³ Nitrate Nitrogen (NZDWS)

Stockwater 30mg/l Nitrate Nitrogen (ECan)

The results of the monitoring show that the quality of the borehole water is within the statutory standards for potable use. Refer to Appendix B for details.

4 OPERATIONAL EXPERIENCE

4.1 IRRIGATOR OPERATION

One pivot is set-up as the primary duty irrigator, with the others set up as primary assist and secondary assist, etc. the number of pivots required is controlled by the level in the wet well, with initially just the duty pivot called. As the level in the wet well rises, the primary assist, secondary assist pivots are called, followed by all available pivots.

The pivot duty changes after the duty pivot has made a full revolution.

The average flow-rates applied via each irrigator and the area the irrigator covers is presented in Table 3 below:

Table 3: Irrigator flow rates

Pivot 1	Pivot 2	Pivot 3	Pivot 4	Pivot 5	Pivot 6
8.6 l/s	9.1 l/s	9.4 l/s	9.6 l/s	12.8 l/s	13.5 l/s
12.2 ha	12.2 ha	12.6 ha	12.6 ha	15.6 ha	15.6 ha

The set-points in the irrigation wet well are outlined in Table 4 below:

Table 4: Irrigation wet well set-points

Irrigator	Start Wet Well Level (%)	Stop Wet Well Level (%)
Duty	38	24
Primary Assist	44	27
Secondary Assist	50	30
Thirst Assist	54	34
All Pivots	56	27

4.2 OPERATOR FEEDBACK

It has been found that the irrigators have performed very well in the application of treated wastewater to the paddocks. There were some issues with blockages of the sprinkler nozzles in the first 6 months of operation after the commissioning of the Pines II plant. This appeared to be due to small plastic particles from construction making their way through the plant and being pumped to the irrigators. Since this time, there have been no issues with blockages.

Minimal maintenance of the system is required, the main irrigator boom is flushed quarterly with the gearboxes and motors services annually.

Due to rutting, the wheel tracks require occasional “topping up”, but this has only been required twice in the last eight years.

The arrangement with the local contractor to cut and carry negates any costs to the Selwyn District Council as there is no need to engage/pay for maintenance/ cutting of the grass whilst also adding value to the local economy in the form of animal fodder which would otherwise be a waste product. This arrangement allows for SDC and their maintenance contractors to focus upon their core activities, and not have to purchase specialised harvesting equipment that would have minimal operating time during the year. The contractor pay a fee to SDC based upon the weight of the baleage that they produce.



Photograph 4: harvesting in operation

The system works in a robust fashion with minimal input required from the operators.

5 STAGING OF WORKS

A key element in the design of the Pines II was the ability to stage elements of the construction of the plant. The initial stage of development was for a treatment process to treat 30,000 person equivalents (PE). The equipment and civil structures have then been designed in approximately 15,000 PE modules to be staged for future growth. This takes the potential capacity of the WWTP out beyond the 2041 design horizon and out to the life of the civil structures without investing in the ultimate solution now.

This design philosophy also extended to the installation of the irrigators. When the stage 2 development was complete, there were 6 irrigators installed, providing a total irrigated area of 80 ha. This provided for a total peak application rate of up to 160 l/s.

At present there is no spare capacity in the irrigators, i.e. no irrigators can be taken out of service when peak flows are anticipated. Whilst the irrigators are reliable and rarely out of service, but if on a rare occasion one irrigator out of service, then a breach of the consent limit could occur.

The latest Valley irrigator to be installed at the plant has a peak application rate of 116 l/s and will bring the total peak application rate to 276 l/s. The 5 day consented application limit is 64 mm and no single application shall exceed 20 mm.

6 CONCLUSIONS

The irrigators at the Pines WWTP have been installed in stages since 2005 and a treated wastewater has been applied to the land for close to 10 years on the areas under pivots 1 to 4 and during this period ongoing monitoring was conducted of the treated wastewater, soil characteristics, ground water and grass dry matter as part of the consent requirements.. During this time it has been found that there has been no notable increase in the baseline levels of either E-Coli, nitrogen or phosphorus, or any other contaminants in either the groundwater or soil characteristics.

Given the location of Rolleston and its distance from the sea or a suitable watercourse, the most suitable options for final effluent disposal was to land. A significant level of background research, stakeholder consultation, along with monitoring was carried out to ensure that this option had negligible impact upon the local environment or community.

The use of pivot irrigators to apply treated wastewater on pasture for cut and carry operation has worked well with minimal operator input a net benefit to the local economy with the silage created and a probable net negative carbon effect. The application of the treated wastewater has helped to maintain the soil condition without the need for any fertilization of the ground with the return of trace elements, nutrients and organic compounds to the soil. The use of treated wastewater to irrigate pastures also helps to conserve groundwater.

ACKNOWLEDGEMENTS

The assistance and support of the Selwyn District Council in providing data and plant information is gratefully acknowledged, in particular Christopher Salkeld from Sicon Ferguson, has been helpful in providing valuable data and feedback on the operation of the facility.

REFERENCES

MWH (2008) 'Concept for Pines II Irrigation. Report prepared for the Selwyn District Council'

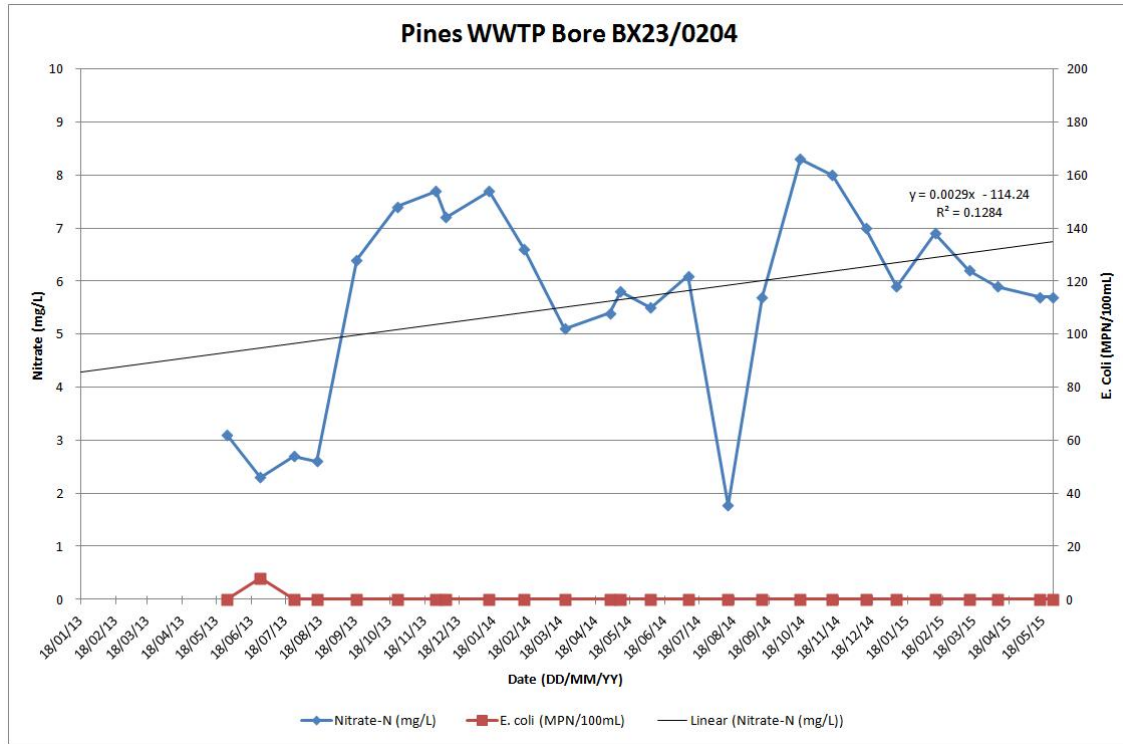
Dr Anthony Davoren (2008) 'Pines Stage 2, Waste Water Disposal Options'

Bishop, S. and Ure, T. (2013) 'Eastern Selwyn Sewerage Scheme-Planning for Growth, but Planning it wisely'
Water New Zealand's Annual Conference & Expo, Hamilton 16 to 18 October 2013

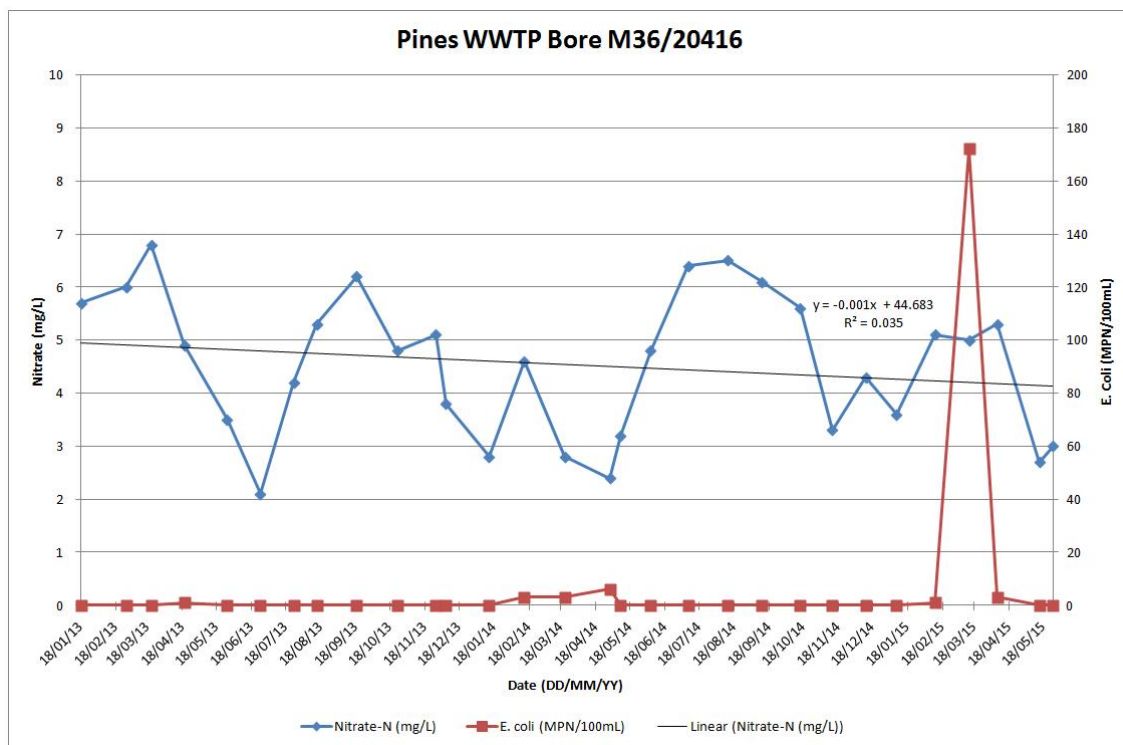
Wang, H. and Tomer, M. (2000) "Guidelines for utilisation of sewage effluent onto land, New Zealand Land Treatment Collective"

Appendix A – Nitrate and E Coli Graphs

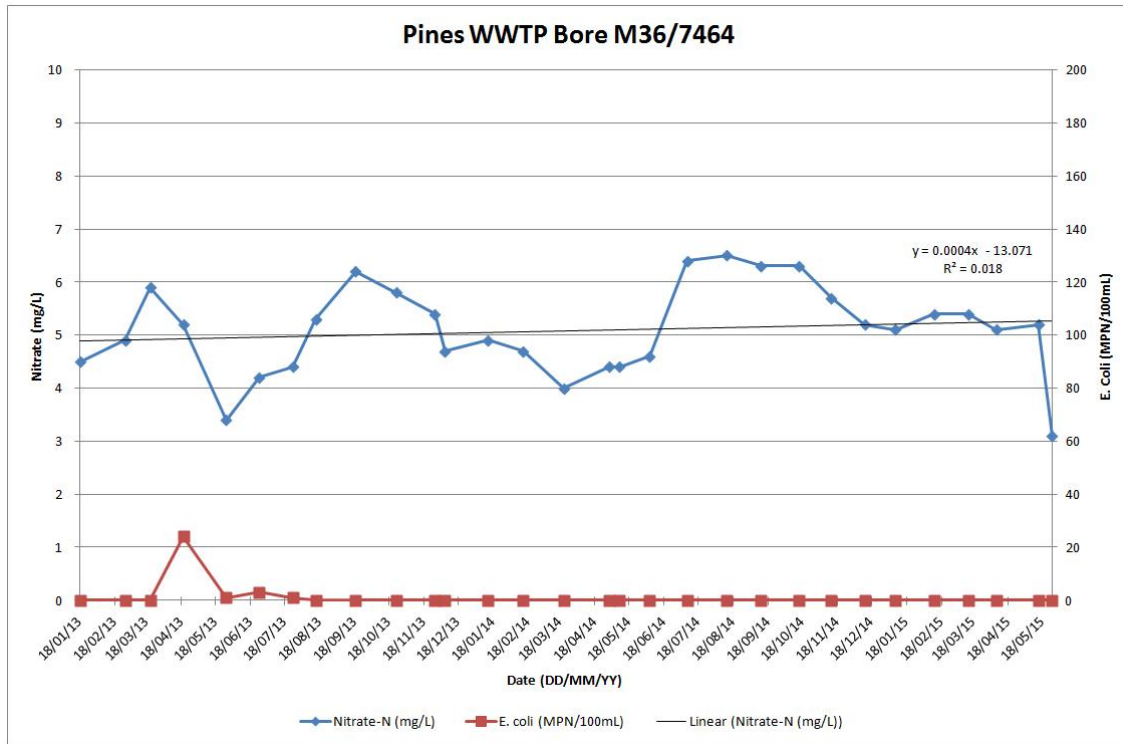
Bore BX23/0204



Bore M36/20416



Bore M36/7464



Appendix B - Results of Borehole Monitoring

Boreholes	pH		Chloride mg/L		Total Nitrogen mg/L as N		Nitrate mg/L as N		Total P mg/L	
	Median	95 % ile	Median	95 % ile	Median	95 % ile	Median	95 % ile	Median	95 % ile
M36/7461	6.8	7.6	33	36	4.9	8.6	4.8	8.4	0.029	0.09
M36/7462	6.9	7.2	27	32	5.1	6.8	4.4	6.3	0.143	1.56
M36/7463	6.9	7.4	27	34	2.7	5.8	2.4	5.8	0.034	0.85
M36/7464	6.8	7.7	30	51	5.5	6.4	5.3	6.5	0.001	1.03
M36/7667	6.9	7.4	31	39	2.9	5.5	2.7	5.9	0.008	0.41
M36/7668	6.7	7.5	32	42	2.9	9.7	2.5	6.0	0.009	0.34
M36/20415	6.8	7.5	28	39	6.0	8.8	6.0	9.1	0.109	0.76
M36/20416	6.9	7.7	30	45	6.0	9.0	5.5	8.7	0.032	0.78
M36/0204	7.2	7.5	29	41	7.1	8.3	5.9	7.9	0.007	0.01
BX23/0205	7.2	7.5	21	22	6.5	8.9	5.6	9.3	0.007	0.02
BX23/0206	7.5	7.8	17	18	7.5	8.1	7.4	9.5	0.007	0.01
BX23/0207	7.4	7.6	16	20	2.9	3.4	2.6	3.8	0.007	0.01
BX23/0208	7.3	7.6	27	35	6.3	6.8	5.6	6.4	0.005	0.01

Appendix C – Pasture Sampling Procedure

Rolleston Pines - Pasture Sampling Procedure

The pasture sampling procedure used at the Rolleston Pines site is as follows:

- A total area of 2 m² of pasture is sampled per centre-pivot.
- A 0.25 m² circular steel quadrat is used to accurately measure the sampling area.
- The centre-pivot area is split into 4 quarters and 2 samples are taken within each quarter (8 in total). The locations of the sampling points are taken at approximately 2/3rd of the pivot length (from the centre). The quadrat is thrown to avoid selection bias.
- Care must be taken to ensure that only grass within the quadrat area is sampled.
- The grass is sampled using hand cutters and all grass is placed into a plastic sample bag.
- The grass is cut down to grazing height (approximately 5-6 cm).
- The collected grass samples are taken to Hill Laboratories on the same day as they are sampled where the samples are weighed for total fresh weight, and analysed dry matter content and total nitrogen content.