

“Adopting best management irrigation practice for winery wastewater re-use onto a woodlot.”

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Introduction

The reuse of industrial wastewater onto land has become increasingly popular in Australia in recent years. In the wine industry, there has been a rapid growth in production in the past decade, which has placed greater pressure on wineries to implement more sustainable ways of managing the resultant increasing volumes of wastewater produced. One form of water reuse is the irrigation of tree crops to be used for firewood (woodlots).

A draft “Best Management Practice template for sustainable winery wastewater irrigated plantations” was developed by Sentek Pty Ltd in October 2000. The aim of this template was to compile all mandatory regulatory requirements in relation to irrigation of woodlots (Environmental Protection Agency, 1999, Thomas, 1983). Recommendations made by leading authorities such as the Commonwealth Scientific and Industrial Research Organisation (CSIRO) and other leading researchers (Honeysett *et al* 1996, Myers *et al* 1999) were also incorporated. In addition, many years of commercial practical experience in irrigation scheduling and management (Buss, 1994) was included to compile an irrigator’s action list as part of the Best Management Practice (BMP) template.

This paper outlines the approach taken by the wine company BRL Hardy Limited at their Berri Estates Winery in adjusting management practices to the methodology outlined in the BMP template in order to enhance the long-term viability of their wastewater disposal woodlot. The aim was to minimize the environmental impact and move beyond the more traditional approach of simply complying with mandatory regulations.

Background

The Berri Winery is located at Glossop near the Berri township in the Riverland region of South Australia. It is one of the largest wineries in the southern hemisphere, crushing 120,000 tonnes of grapes in the 2001 vintage. Approximately 280 Megalitres of wastewater is generated each year, which is disposed onto a 40 hectare woodlot planted to predominantly *Eucalyptus camaldulensis* (river red gum) trees. *E. camaldulensis* are particularly suited to this application due to their ability to coppice, and to withstand periods of waterlogging and drought (Stewart *et al*, 1986). The woodlot contains approximately 20 hectares of mature trees (15 years old), approximately 15 hectares of semi-mature trees (3 years old) and approximately 5 hectares of trees less than two years old. The climate in this region is semi-arid, with an average annual rainfall of 262 mm and a seasonal mean daily maximum temperature ranging from 31 degrees Celcius in the summer months to 15 degrees Celcius in the winter months. Most of the rain falls during the winter period.

The wastewater varies in quality at different stages of wine production throughout the year. The mean pH for the period of April 2001 to March 2002 was 4.5, mean electrical conductivity was 2370 μScm^{-1} and the average sodium adsorption ratio (SAR) was 11. Minimum pH has since risen with ion exchange corrections being made

at the source with magnesium hydroxide. Mean chloride levels were 457 mgL⁻¹ and mean biochemical oxygen demand (BOD) levels were 4170 mgL⁻¹, while Total Nitrogen averaged 54 mgL⁻¹ and Total Phosphorus averaged 8 mgL⁻¹. The wastewater undergoes preliminary treatment where coarse solids are settled in wedges. It is then pumped 5 kilometres from the winery to the woodlot disposal site, where it is flood-irrigated onto 12 rows of trees at a time during an irrigation shift.

Implementing Best Management Irrigation Practice – Overview & Methodology

There were three stages to the process of implementing Best Management Irrigation Practices on the woodlot. The first step involved undertaking a preliminary analysis of the spatial variability of the site. The second step entailed performance of a detailed water balance study to determine the disposal potential of the woodlot. The third step involved the implementation of rigorous and site-specific monitoring programs.

Analysis of Spatial Variability

The soil, plant and hydrological properties can vary substantially across a 40 hectare area of land. Understanding that spatial variability enables management to be tailored accordingly. A soil survey on a 75 x 75 metre grid spacing was undertaken to assess the fundamental soil properties that influence the capacity of the soils to sustain long-term disposal of winery wastewater. The soils were then mapped according to areas that were similar in respect to their capacity to receive and store wastewater.

An audit of the existing irrigation system was undertaken to assess the distribution uniformity along the length of representative flood bays. Three real-time, multiple depth soil water monitoring EnviroSCAN[®] probes were installed along the length of a flood bay at three separate locations within the woodlot, with one probe situated close to the outlet, one near the middle of the flood bay and one at the furthest end from the outlet.

The planting and irrigation plan was then overlaid on top of the soil plan. Soil units were matched to irrigation valve units and varying tree ages were taken into account to define irrigation scheduling and management units. They were drawn up on a woodlot management plan and a list was made of each valve number that was contained within each scheduling unit. Irrigation batches were set up accordingly and programmed into the irrigation controller.

Water Balance Study

A water balance study was undertaken at the woodlot to determine whether it was being over-utilized or under-utilized in terms of its capacity to store and remove wastewater. A dual approach was taken, whereby a simplified water balance was calculated for every valve unit, and a detailed water balance was performed at five representative locations within the woodlot.

In the simplified approach, the deficit or excess was calculated for the 12 month period of April 2001 to March 2002. The inputs considered were: effective rainfall (measured by a rain gauge situated under the canopy) and applied wastewater (assuming an application efficiency of 85%). The only output taken into account was potential evapotranspiration (ET_o) and no consideration was given to drainage or soil storage. The ET_o figures were derived from pan evaporation and pan coefficient values published for eucalyptus trees in the nearby Mildura region (Myers *et al*, 1999). The following equation was used:

$$\text{Deficit/Excess} = \text{Effective Rainfall} + (\text{Wastewater volume} \times 85\%) - \text{Potential Evapotranspiration}$$

In the more detailed study, the water mass conservation at the woodlot between two consecutive time steps (t and $t + 1$) was determined using the following equation:

$$\text{Storage}_{(t+1)} = \text{Storage}_{(t)} + \text{Effective Rainfall} + \text{Wastewater Volume} - \text{Drainage} - \text{Evapotranspiration}$$

It was assumed that there was no runoff out of the flood bays. Drainage was determined using the zero flux plane method. The zero flux plane is a horizontal plane defined by reversal in the direction of the unsaturated hydraulic gradient. Above this plane, the water content decrease is due to evapotranspiration. Below the zero flux plane, the hydraulic gradient is vertically downward and decreases in soil water content are assumed to reflect a net movement of water vertically downward out of the monitored soil profile (Shimada et al, 1999).

Monitoring Plan

Ongoing monitoring of key environmental factors was seen to be critical to the success and long-term viability of the woodlot. The purpose of monitoring in relation to implementing Best Management Practice was to enable continuing adjustment and improvement to management strategies and to provide early warning against any possible detrimental effects to the environment. The monitoring of the Berri woodlot was split into 6 key areas, namely wastewater, soil, vegetation, irrigation, groundwater and weather.

Samples of wastewater were collected on a regular basis and analysed for a range of quality factors including pH, salinity, BOD and nutrient loading. This data was then used to assess the nutrient, salt and organic loading of the water being applied to the woodlot. Logging of the wastewater pH enabled the water to be lime adjusted directly where needed. Magnesium hydroxide adjustment of other streams enabled better pH control of the wastewater before the storage lagoon. The volume of wastewater being pumped onto the woodlot was recorded by a flow meter and logged at 10 minute intervals in the winery's central Citect data management system. This information was then transferred into a spreadsheet that logged the amount of daily flow to each valve unit.

Soil samples were taken twice a year (before and after the main periods of wastewater application) from multiple depths and from within each of the main soil groups. These were analysed for Electrical Conductivity (EC), pH and dispersibility. Soil samples were also analysed for key nutrient and organic content to monitor any increases over time as a result of wastewater disposal.

Tree health and woodlot condition was monitored by regular inspection by the woodlot manager. In addition, annual leaf samples were taken for tissue analysis to detect any build-up of nutrients or salts within the trees. The data trends over time were compared with recommended upper threshold levels for each element monitored.

The soil water content was recorded using multiple depth, real-time soil water monitoring probes installed in each of the 11 irrigation scheduling units and connected by cable to 2 EnviroSCAN[®] data loggers. A GSM phone modem was connected to each logger to enable remote download of the data into the winery computer system. Soil water data was displayed in the EnviroSCAN[®] software to enable soil water dynamics to be interpreted.

Water table heights were measured weekly during the peak irrigation season at piezometers located both within and outside the woodlot. The height of a nearby lagoon that stores drainage water from local salt interception schemes was also recorded. This information was plotted over time to detect any impact of the wastewater

irrigation on the groundwater. Annual samples of the groundwater were collected and analysed for nutrient and total organic contents.

A Campbell Scientific weather station was installed at the woodlot to record: effective rainfall (with a rain gauge positioned under the canopy and a second rain gauge positioned outside the canopy), temperature, solar radiation, relative humidity and pan evaporation.

Results

Analysis of Spatial Variability

The analysis of spatial variability revealed that there were three major soil groups across the woodlot area. These were defined as: river flat clays with Monoman Sands underlying at 1.0 – 1.3 metres depth below the surface; river flat clays with no Monoman Sands within 1.8 metres from the surface, and profiles with shallow topsoils overlying a slow draining carbonate layer and clay. The active rootzone of the trees was predominantly located within clay of field saturated hydraulic conductivity values as measured with a Guelph Permeameter varying between $1.00 \times 10^{-4} \text{ cms}^{-1}$ and $5.2 \times 10^{-5} \text{ cms}^{-1}$. The areas with underlying sands of higher permeability were differentiated as being areas with a higher risk of impact of wastewater irrigation on the underlying groundwater. The three major soil groups were mapped and subdivided into 11 key areas to account for variations in tree size, irrigation flexibility and variation in soil salinity levels.

Water Balance Study

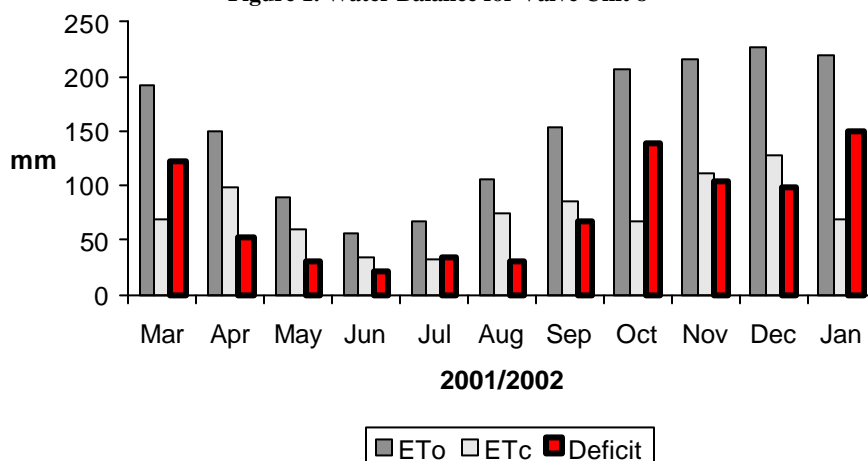
During the 11 month study period of May 2001 to March 2002 there was 206 mm of rainfall (equivalent to 156 mm net rainfall). The rainfall interception totalled 50 mm, which represented 24% of the total rainfall for this period. The total amount of wastewater applied during this period was 214.5 ML.

A monthly deficit/excess analysis of the woodlot taking into account ET_o , wastewater and net rainfall, and assuming no soil water storage potential or drainage, revealed that the woodlot was in deficit for most of the year. In other words, the amount of water that was applied to the woodlot in the form of rainfall or irrigation usually did not match the ET_o of the woodlot. For the winter months of June and July (disregarding the large potential sink of soil storage) the woodlot was in excess by 9 mm and 8 mm respectively, whereby more water was applied than was lost through potential evapotranspiration.

The estimated total water storage capacity of the soil however, is 40 % and approximately 67% of the plant available soil water had been used by the plants at the start of the study period at the end of summer. Allowing for this soil storage potential over an active root zone depth of 1 metre, the excess water applied during June and July can be seen to be readily stored in the soil profile.

This was further verified by the detailed water balance study that took into account soil water content and drainage as well as actual evapotranspiration (ET_c) and ET_o , which revealed that for the 5 areas examined, the woodlot was in deficit for all months of the year. In June, the woodlot was used at close to its full potential, but was still in substantial deficit of the ET_o (22.2 mm to 36.5 deficit). Figure 1 shows the difference between ET_c and ET_o as a deficit in millimeters for Valve Unit 8. There was some variation between the 5 sites, with annual deficits ranging from 870 mm to 1290 mm. Valve Unit 8 represents the area that was used at closest to its full potential of any of the areas studied. Other valve unit results are not shown.

Figure 1. Water Balance for Valve Unit 8



Monitoring Program

Table 1 lists the wastewater volumes applied over the period of April 2001 to March 2002. The peak volumes of wastewater production occurred in the months of March, April and May.

Table 1. Monthly wastewater volumes produced at the Berri Winery

Month	Apr 2001	May 2001	Jun 2001	Jul 2001	Aug 2001	Sept 2001	Oct 2001	Nov 2001	Dec 2001	Jan 2002	Feb 2002	Mar 2002
Wastewater produced (megalitres)	44.32	27.69	18.96	16.27	18.24	16.41	14.74	13.47	9.24	9.58	17.95	51.98

The relatively high total organic loading in the wastewater was observed to lead to a build-up of organic matter in the flood bays. A minimum time of 7 days during the winter months between irrigations was necessary to break down the organic surface layer. More frequent irrigation would lead to surface crusting which substantially reduced the water infiltration rate. This was addressed through irrigation scheduling and the allowance of sufficient drying times, and by cultivation.

Figure 2 shows soil water content data from sensors at 10 cm, 30 cm, 50 cm, 70 cm, 100 cm, 130 cm, 160 cm and 200 cm below the surface from Valve unit 8 stacked on a graph and plotted against time. From this it was possible to visualise: the active depth of rootzone^(a) as seen by diurnal variation in the rate of soil water use; the depth of effective irrigations^(b) and hence the area of likely salt build-up^(c) and the relatively static moisture content within the deeper profile^(d) indicating no deep drainage.

Figure 3 shows a sum of the data collected from each of the sensors within the active root zone in Valve unit 8 plotted over time. Upper and lower management thresholds were set within which the soil water content was maintained. Different lower thresholds, or refill points, were set at different times of the year to account for the varying evapotranspiration rates.

Water table heights varied throughout the year from 2.8 m to 6.0 m below the soil surface across the woodlot. The flux in groundwater height under the woodlot appeared to be directly related to the height of water in the nearby regional storage lagoon. Further piezometers were installed on the southern edge of the woodlot to show any impact on the water table heights in that area as a result of irrigation on neighbouring vineyards. Results from these piezometers are not yet available.

Figure 2. Stacked graph of soil moisture with time

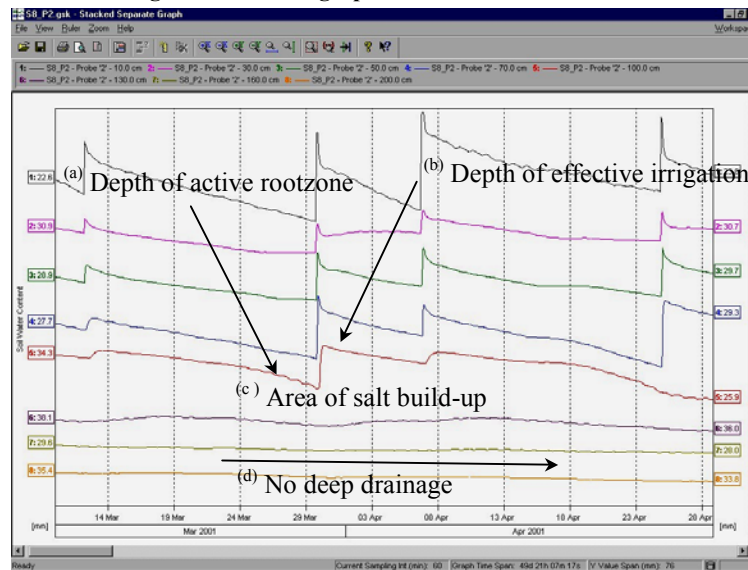
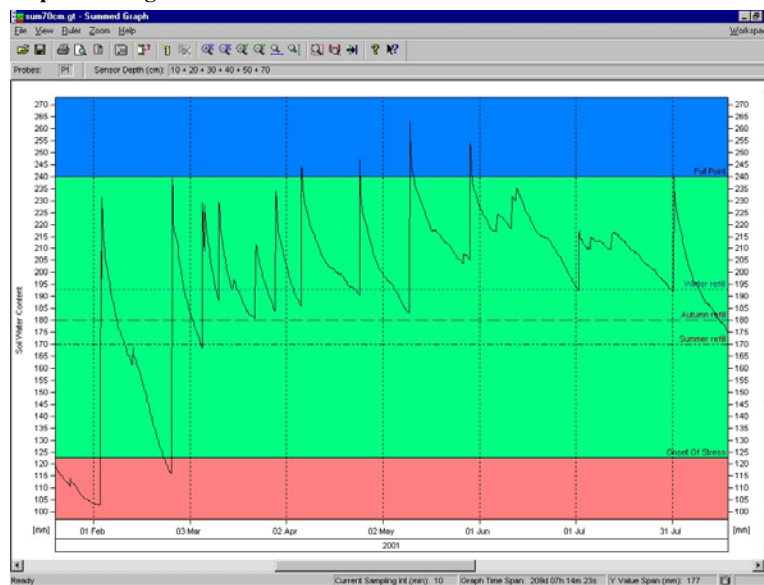


Figure 3. Graph showing sum of data from soil water sensors within the active rootzone over time



The information from the weather station was combined with the flow data and the soil water data to make informed irrigation scheduling decisions. The aim of irrigation scheduling was to ensure that:

- the full depth of active rootzone was receiving water
- sufficient leaching was applied to prevent the build-up of salts within the rootzone
- deep drainage of wastewater that would impact on the underlying groundwater was avoided
- tree stress due to a lack of water was avoided
- water logging was avoided.

The ultimate aim was to maximise plant water uptake by keeping the soil water content at an optimum level for good tree health.

Discussion

Although a monitoring program had been in place for some time at the Berri Woodlot, the aim in the past 12 months was to make the monitoring program a more substantial and proactive part of the woodlot management. An integral part of this was the appointment of a “woodlot champion”, to take on total responsibility for the monitoring and management of the woodlot.

Subdividing the woodlot into distinct management units enabled the “woodlot champion” to manage the woodlot as 11 separate irrigation batch units, rather than trying to cope with the logistical challenge of scheduling 66 individual valve units. In that respect it helped to simplify the irrigation scheduling process. Soil water data was used in conjunction with weather and flow data as well as a calendar of cultural activities (e.g. cultivation, gypsum application) to produce of a priority-based irrigation schedule for each irrigation batch unit.

In addition, it ensured that each area was being managed according to its true potential to store and utilize wastewater. This prevented problems of over-irrigation in some areas of the woodlot and under-irrigation in others. Volumes of wastewater applied in each irrigation event could be readily altered for different areas by changing the batch run times.

This water balance study was conducted when implementation of the comprehensive monitoring program had only just begun. At this time, irrigation scheduling decisions were largely based on a visual assessment of the woodlot, with irrigation events cycling through each valve unit one at a time. This accounts for the variation in how much potential had been used between sites within the woodlot. Irrigation scheduling decisions that take spatial variability into account should ensure a much more consistent utilisation of the woodlot potential, and reduce the hazards of over use in particular areas within the woodlot and potential environmental harm.

In the past, the sole determining factor for irrigation scheduling in many woodlots has been the rate of effluent production, without any consideration of the plant’s ability to transpire the water (Myers, 1992). Real-time monitoring at the Berri Woodlot enabled more accurate irrigation scheduling decisions to be made within each of the separate management units, leading to better control of the impact of wastewater irrigation on the surrounding environment. Real-time soil water data showed a slow-down in daily plant water use due to saturated and waterlogged conditions, which meant that these conditions could be readily avoided. Multiple depth sensing detected the wetting fronts of irrigation and rainfall events moving through the soil profile. Deep drainage was avoided while applying leaching irrigations in a controlled manner. Regular groundwater monitoring was seen to reinforce these data. The need for provision of water from an alternative source during the summer months when there is no wastewater generated was also identified.

Implementation of Best Management Irrigation Practice on the Berri woodlot is an ongoing process. Detailed monitoring continues to highlight new sets of problems to be addressed. For example, measuring the irrigation distribution uniformity down a row demonstrated the need for the irrigation bays to be re-laser levelled. In addition, as technology advances, new innovations need to be incorporated into the woodlot management system.

Adjustments made to the wine production process will also impact on the woodlot as a result of changes in the wastewater quality. The winery has made significant reduction to water use in terms of litres used per tonne of grape processed. While this reduces the hydrological pressures on the woodlot, the changing water quality and resultant nutrient, organic and salinity loading will need to be taken into account. The winery has a number of

environment improvement programmes in place, which focus on cleaner production. These should result in improvements in wastewater quality, which will help to enhance the long-term viability of the woodlot.

Conclusions

The key to the ongoing sustainable management of winery wastewater re-use onto the woodlot lies in the treatment of the woodlot as a living entity that must be maintained at optimum health to maximise its potential. The Best Management Practice template described here is a plan to achieve this objective. In addition, implementing this plan has brought significant cost-savings to BRL Hardy Limited through better use of existing resources.

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