CASE STUDY

Winery water use and wastewater treatment at Cape Mentelle Vineyards and Stormflower Vineyard.

Margaret River Wine

During wine production water is used extensively to assist with processes and sanitation, and as a result of this the generation of wastewater can be significant. Reducing the amount of wastewater produced per tonne of crushed grapes requires an integrated approach, understanding the impacts of winery operations on the amount and quality of wastewater that requires treatment, and how to dispose of or recycle the reclaimed water to minimise its impact on the environment and improve overall water-use efficiencies.

A survey summary from 2007 (Kumar et al. 2009) reported average water use per tonne of crushed grapes in Australia as 2.4 kL/tonne crushed with a range of 0.4 to 8.0 kL/tonne crushed in wineries processing less than 1000 tonnes. For wineries processing 1000–2500 tonnes and 2500 to 10000 tonnes it was 3.7 and 2.4 kL/tonne crushed respectively.

Operational guidelines developed by the Grape and Wine Research and Development Corporation (Day et al. 2011) provide excellent strategies for wineries in relation to planning, reviewing, improving treatment and recycling of wastewater.

CAPE MENTELLE
MARGARET RIVER

STORMFLOWER
VINEYARD

This case study focuses on two Margaret River wineries varying in size, Cape Mentelle Vineyards and Stormflower Vineyard, describing the wastewater treatment processes used at each site to ensure they minimise their environmental impact, and practices implemented to work towards minimising the amount of water used to produce wine at each facility.

CAPE MENTELLE
MARGARET RIVER

Winery Profile

Established in 1970 Cape Mentelle Vineyards is one of the founding wineries in Margaret River, with over 130 Ha of vines located across four vineyards. Throughout Cape Mentelle Vineyards' 50 year history they have continually pushed the boundaries with innovation and exploration being instrumental in pioneering a number of the region's wine styles. A member of Sustainable Winegrowing Australia, Cape Mentelle Vineyards was the first winery in Margaret River to obtain the Entwine accreditation in 2010 and has successfully achieved ISO 14001:2015 Environmental Management System certification validating their strong commitment to sustainability and the environment. A signatory to the Australian Packaging Covenant Organisation (APCO) Cape Mentelle Vineyards has developed an action plan to continually improve waste minimisation, optimising recycling opportunities and is currently working towards organic certification across their vineyards.

STORMFLOWER
VINEYARD

Winery Profile

Stormflower Vineyard was planted in the mid 1990's and purchased by David Martin in 2007. Implementing an holistic approach to wine grape growing the health of the vines and soil was improved through increased use of organic composts, natural soil biology stimulants and vineyard management to reduce the reliance on chemicals. Production of wine from the estate commenced in 2009 with a winery being completed in time for the 2020 harvest at the estate. In 2016 the vineyard (and subsequently the winery) achieved organic certification with Southern Cross Certified Organics. In 2020 Stormflower Vineyard became a Sustainable Winegrowing Australia member. Operating off-grid, Stormflower Vineyard ensures their viticulture and winemaking practices have minimal impact on the environment, regenerating and working within their natural ecosystem to produce unique, hand-crafted wines off the 9.2 Ha of estate grown vines.

Margaret River Wine Producers

In 2021 there were 200 wine producers in the Margaret River region, with approximately 75 winery facilities processing 31,542 tonnes with 73% of producers crushing less than 99 tonnes (MRWA 2022), whilst the largest winery facility has the capacity to process 12,000 tonnes. Extrapolating average wastewater produced per tonnes processed figures from Kumar et al. (2009) this could equate to approximately 75,700 kL of wastewater produced in 2021 alone.

In Western Australia wineries producing 350 kL of wine per year (approximately 500 tonnes) are a prescribed premise under the *Environmental Protection Act Regulations* 1987 (WA), s 1, and required to be licenced with a works approval (*Environmental Protection Act* 1986 (WA), Part 5), reporting annually to the Department of Water and Environmental Regulation.

This potentially captures less than 50% of wastewater produced in the Margaret River region. Whilst there is no regulation over those winery facilities producing less than 350 kL wine per annum there is a duty of care to our environment to ensure we manage wastewater treatment and disposal responsibly and sustainably.

Water Use and Peak Generation of Wastewater

Water use and wastewater generation in wineries needs to be differentiated between those who bottle on site and those who do not, as bottling can contribute up to 0.9 kL/tonne crushed more wastewater and adds on average one extra step to winemaking processes (Kumar et al. 2009). Where bottling is not onsite vintage produces up to 80% of annual wastewater (Chapman et al. 2001) in small wineries (<1000 tonnes). Both Cape Mentelle Vineyards and Stormflower Vineyard bottle on site, although Stormflower Vineyard uses a contract mobile bottling facility.

Key winemaking processes that contribute to wastewater are cleaning (washing equipment, tanks, and transfer lines), barrel washing and cleaning bottles during bottling. Stormwater, if not diverted, also contributes significantly to wastewater. The capacity to reduce the number of winemaking processing steps, from grape receival to bottling, onsite contributes significantly to reducing the amount of water used per tonne and therefore wastewater generated, this includes being able to reduce the number of batch processes.

Cape Mentelle Vineyards monitors water use monthly with flowmeters located on raw and potable water entering the winery. Raw water usage can be differentiated between the crush pad area (fruit processing) and winery facility, while potable water can be differentiated between cold and hot water use. Measurement of wastewater with flowmeters is taken at two locations: the winery pump shed, which is the first collection point, and then again at the treatment ponds (Figure 1.). During vintage stormwater is diverted to wastewater at the winery ensuring all wine production waste and water is captured and treated, preventing it from entering the natural watercourse. Once fruit processing finishes stormwater is diverted back to discharge into the natural watercourse at Cape Mentelle Vineyards. With this capacity to monitor water use vintage (January to April) has been identified as the most significant period of water use with 3.07 kL water used/tonne crushed and 3.28 kL water used/tonne crushed in 2021 and 2022 respectively. The 6.8% increase in water use from 2021 to 2022 may be directly related to the 21% decrease in grapes crushed from 551 tonnes (79% white grapes) in 2021 to 435 tonnes (57% white grapes) crushed in 2022, without a decrease in the number of batches processed. Individual blocks and vineyards continued to be processed separately in 2022, requiring the a similar number of processes as 2021 regardless of yield off those blocks.

Stormflower Vineyard captures rainwater for use within the winery in a 250 kL tank, which is more than required to meet winery processing needs throughout the year. Wastewater generation is monitored on a monthly basis using a flowmeter located prior to the effluent treatment tank, and captures all water used, including stormwater. With an annual crush of between 45-55 tonnes Stormflower Vineyard uses between 1.75 to 1.95 L water per litre of wine produced, which at an average extraction rate of 700 L/tonne would be 3.6 to 4.0 kL/tonne crushed.

Both wineries have water use per tonnes of grapes crushed above the average for wineries processing less than 1000 tonnes according to the survey completed by Kumar *et al.* (2009).

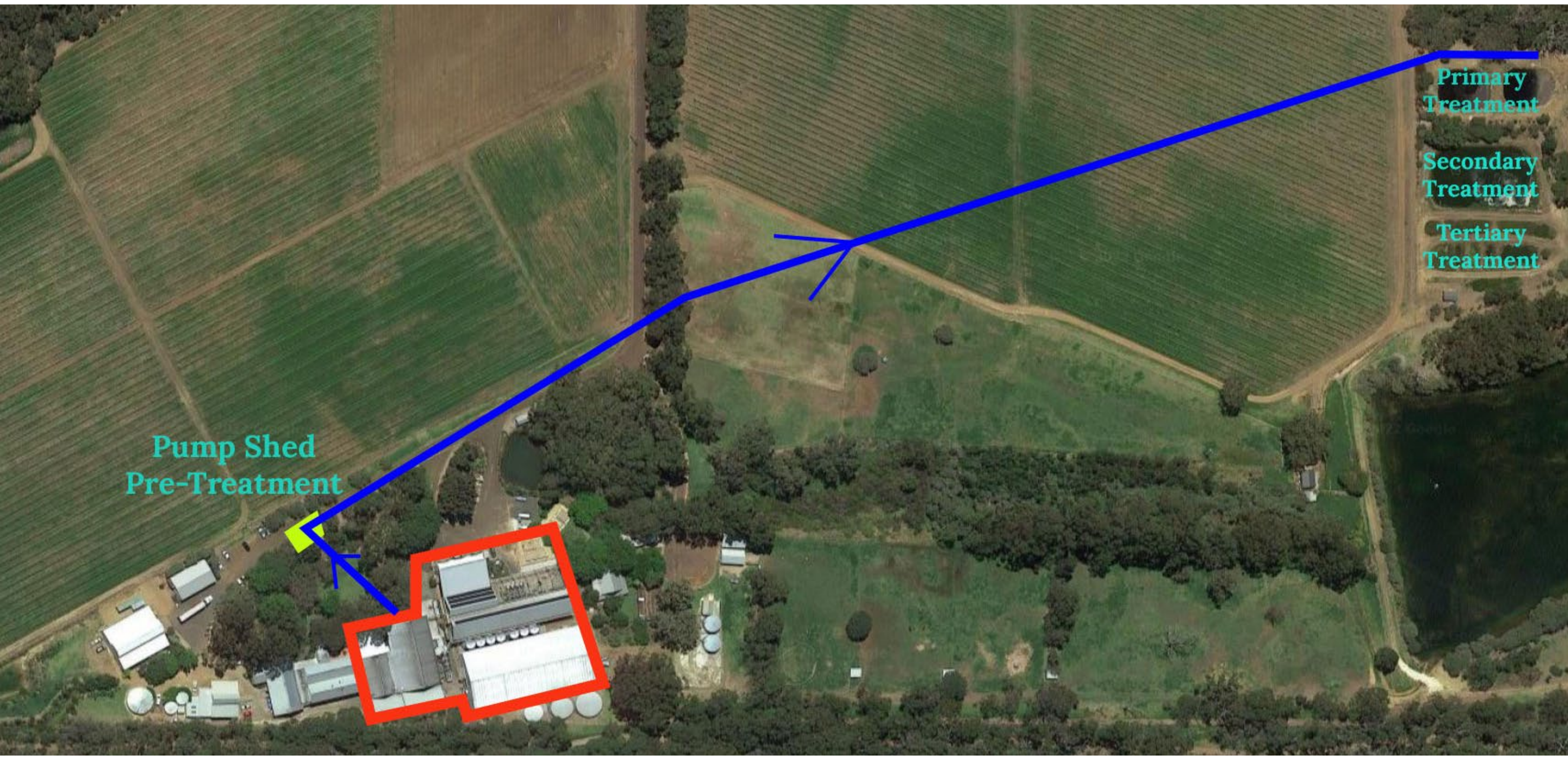

Figure 1. *Overview of Cape Mentelle Vineyards' winery facility, highlighted in red indicates wastewater catchment area at the winery. Collection of wastewater occurs at the pump shed (green). It is then pumped uphill to treatment ponds and reed beds (blue line).*

Figure 2. *Cape Mentelle Vineyards' series of treatment ponds utilising gravity flow between ponds, which can be facilitated by pumps if required. Primary treatment implements sedimentation and anaerobic digestion (1) which after 30 days feeds into the secondary aeration treatment pond (2). Aeration is supplied by two pumps suspended on floating pontoons to reduce BOD. Wastewater then passes through five papyrus reed beds (3) and is finally irrigated onto an established woodlot of eastern sheoaks (4).*

Wastewater Processes

Treatment of wastewater varies significantly between wineries, particularly those that are not regulated. There are four stages to treatment of wastewater detailed below in Table 1. Kumar et al. (2009) reported that 27% of wineries surveyed utilised pre-treatment or primary treatment only, while the remainder carried out secondary (62%) and tertiary treatment (11%) processes.

Both Cape Mentelle Vineyards and Stormflower Vineyard use tertiary treatment of their wastewater, with similar processes engaged, obviously on different scales. Wastewater is collected, allowing solid separation through sedimentation processes; the liquid is pH adjusted and decanted off solids; aeration treatment follows to reduce biological oxygen demand (BOD) after which the wastewater is passed through a series of reed beds before being irrigated onto pasture or woodlot.

Table 1. *Wastewater treatment methods (Kumar et al. 2009)*

Treatment Class	Treatment method	Objective
Pre-treatment	Screening	Coarse solids removal
	Holding tank	Flow and loading equalisation
	pH adjustment	Increase pH to levels suitable for aerobic / anaerobic digestion
	Flocculation addition	Improve fine solids removal
Primary treatment	Sedimentation	Physical treatment for fine solids removal
	Flotation	
Secondary treatment	Aerobic facultative lagoon	Biological treatment for biochemical oxygen demand (BOD) removal
	Anaerobic lagoon	
	Activated sludge process	
	Bioreactor	
Tertiary / Advanced treatment	Final filtration[1]	Additional nutrient, organics, and suspended solids removal
	Reed bed system	
	Ozone	

1 Final filtration is generally not considered a tertiary treatment

Cape Mentelle Vineyards

An issue faced by many wineries established prior to 1987, when regulation of wineries producing more than 350 kL wine began, is inadequately sized wastewater treatment systems with increased production. Cape Mentelle Vineyards' production capacity grew significantly throughout the 1990's resulting in a need to review how they treated their wastewater.

Consultation with a wastewater treatment and recycling specialist resulted in Cape Mentelle Vineyards implementing their current wastewater treatment system in 2002 with the construction of a series of catchment tanks and ponds that allows pH adjustment, sedimentation and anaerobic treatment ponds, an aerobic pond, and reed bed system prior to irrigation of treated wastewater to a woodlot (Figure 1).

Wastewater captured at the winery was initially treated with magnesium hydroxide ($Mg(OH)_2$) in holding tanks to adjust pH to 7.0, however $Mg(OH)_2$ is difficult to use and expensive. Frequent monitoring of pH identified that winery hygiene (caustic) and sanitation (ozone) processes adjusted wastewater pH sufficiently (pH 7) to exclude this step. The winery is located at the bottom of the hill requiring wastewater to be pumped, using two submersible pumps, approximately one kilometre uphill with a 13m head of water to the treatment ponds. This is considered a limiting step and a second flowmeter has been installed prior to the anaerobic treatment pond to cross check with volumes recorded at the winery. Any differences between the two flowmeters alerts to potential wastewater leaks during transfer uphill. The treatment ponds are located on a gradually sloping hill utilising gravity flow to move water through them to the reed beds.

Each treatment stage (Figure 2) has the capacity to retain wastewater for 30 days during peak season (1 Mega Litre). Trials of covering the primary anaerobic treatment ponds were made, however they proved ineffective and costly. The depth of the ponds was considered sufficient to create an anaerobic environment efficiently digesting organic matter removing the need for a cover to eliminate oxygen. Installing two primary treatment ponds allows alternating between each to ensure there is sufficient time for anaerobic processes to occur.

The location of the treatment ponds is bounded by remnant bush and vineyards resulting in minimal impact of off odours that may occur during this process on neighbours or other businesses. Responsibility for air quality is a key element of Sustainable Winegrowing's standards, Freshcare Australian Wine Industry Standards for Sustainable Practice (AWISSP), and forms part of Air Quality Management Program.

Aeration of wastewater in the secondary treatment pond occurs automatically with two pumps located on floating pontoons running in cycles of four hours duration with a two hour break throughout a 24 hour period. The water then gravity feeds through five reed beds, planted with papyrus (*Cyperus papyrus*). The fifth reed bed is clear of reeds to enable sampling for water quality monitoring and ensuring the suction on the irrigation pump does not block. Papyrus is used in the reed beds due to their hardiness, with annual slashing required to control growth. Treated water is irrigated onto a mature stand of eastern river sheoaks (*Casuarina cunninghamiana*), selected for their slow growth. An additional stand of sapling sheoaks has been planted to enable the harvesting of timber when sufficiently mature for furniture production (Figure 3).

Under the *Environmental Protection Act Regulations* 1987 prescribed premises are required to monitor wastewater quality five times per year. Cape Mentelle Vineyards monitors wastewater monthly (Table 2), which ensures they can respond to any changes within the system quickly to prevent environmental harm. At each stage of treatment there is the capacity to circulate wastewater back through the system if measurements do not fall within acceptable limits. Cape Mentelle Vineyards currently do not recycle treated wastewater into their dam as the dam overflows to an existing natural watercourse and while the treated water meets requirements for irrigation use on a woodlot it does not meet minimum levels for return to a watercourse (Table 2).

Table 2. *Cape Mentelle Vineyards' wastewater analysis averaged over three vintages (2020, 2021, 2022), samples taken during peak vintage period from final reed bed prior to irrigation on woodlot.*

Test	Irrigation water guideline limits*	January	February	March	April
Biochemical Oxygen Demand (mg/L)	1500 (kg/Ha/yr)	9.3	10.7	11.0	14.7
Electrical Conductivity (mS/m)	110-330	190.2	177.4	170.2	190.4
Total Dissolved Solids (mg/L)	704-2112	1200.0	1156.7	1016.7	1133.3
Total Kjeldahl Nitrogen (mg/L)	<5	6.2	7.4	6.9	3.7
Total Phosphorous (mg/L)	<0.05	1.0	1.1	0.6	0.7
Total Suspended Solids (mg/L)	Gross solids removed	44.3	143.0	175.3	31.7

* Sourced from Day et al. (2011), these are generic guidelines for long-term averages to avoid environmental harm.

While the concentration of wastewater pollutants is important to know, Day *et al.* (2011) advise it is also the load that is critical to understand due to its impact on the efficacy of processes within the system to be able to digest and absorb them. The frequency of monitoring has allowed Cape Mentelle Vineyards to understand when peak loads occur so that operational performance of treatment ponds is maintained by ensuring a suitable environment for desirable microbes that require time to build up populations to cope with heavy loads. Typically, this occurs during vintage (Table 2, January to February) through to the end of red racking off gross lees (June) when there is a very high amount of suspended solids and organic carbon content in wastewater increasing the BOD to above 60 mg/L. When irrigating the woodlot during this time the sprinkler outlets are moved regularly to ensure that the wastewater is dispersed over a larger area reducing the impact on plants and soil.

The system has been operating for 20 years. Maintenance during this time includes replacement of submersible pumps located at the winery pump shed every two to three years, desludging of the anaerobic ponds in 2016, including batters being repaired and covered with geocloth and roc to prevent erosion, replacement of pH probes in the anaerobic pond and reed beds in 2017, and in 2022 the plastic liner of the aerobic pond, preventing seepage into the ground, was replaced due to damage cause by submersible pumps that had previously been used, which have since been located on floating pontoons. The computer system that automates and monitors the wastewater treatment plant has also been upgraded.

Figure 3. *Ground level view of the two treatment ponds (top left two anaerobic ponds, top right aeration pond), papyrus reed beds (bottom left) and irrigation woodlot (bottom right). The woodlot shows mature eastern river sheoaks (22 years old) and recently planted saplings. Irrigation lines can be moved throughout the woodlot.*

Stormflower Vineyard

The winery at Stormflower Vineyard was completed in November 2019 and is entirely off-grid, generating its own electricity (solar and diesel generator for three phase power) and supplying all potable water with the capacity to collect 250 kL of rainwater from the winery roof, which exceeds demand. The design and construction included consideration for wastewater management, providing an opportunity to optimise gravity as a means of moving wastewater between treatment systems by locating the winery at the highest point on the estate (Figure 4). With a desire to keep the treatment system simple a key limitation was space. Stormflower Vineyard overcame this by using a series of catchment and treatment tanks located close to the winery followed by compact reed bed pods located downhill from the winery.

Critical aspects to the success of Stormflower Vineyard's wastewater treatment are the capacity to exclude coarse organic matter from entering the system, using stainless steel screens in all drains located in the winery. The winery's drains gravity feed to two 2.5 kL baffled tanks (primary treatment), in line, where heavy solids accumulate in the first, which overflows to the second. These are pumped annually by a waste contractor prior to winter rains removing accumulated solids. A submersible pump located in the second baffle tank transfers clearer wastewater into the secondary treatment tank (4 kL) via a flowmeter, which is read monthly. The treatment tank is used for further settling, pH adjustment to pH > 8.0 and aeration of the wastewater. Caustic is used for pH adjustment and a simple air compressor to inject air while circulating the tank, for a minimum of eight hours, to improve aeration and assist decreasing BOD levels. With peak usage during vintage through to bottling in July, an auxiliary storage tank (22 kL) was installed in 2021 to provide greater flexibility in relation to continued aerative treatment and storage of wastewater prior to sending it through the reed pods (Figure 5). Monitoring of pH at the secondary treatment tank using simple pH strips with colour indicators are used daily during peak periods to ensure wastewater remains within the desired range. Aeration continues until the wastewater loses off-odours. At each stage wastewater can be recycled through the system if required to extend treatment periods (Figure 6).

Figure 4. *Stormflower Vineyard showing the winery located central to the property at the top of the hill.*

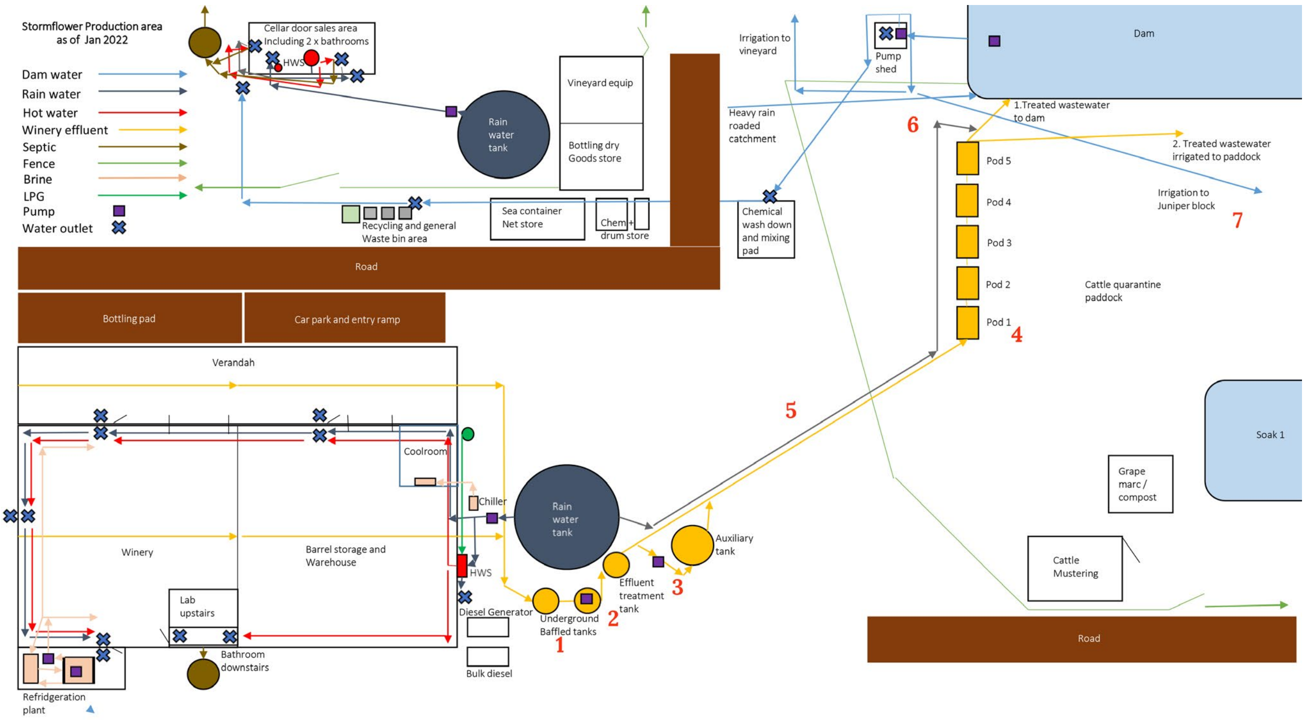

Figure 5. *Stormflower Vineyard winery wastewater (yellow highlights), including stormwater, gravity drains to baffle tanks (1) for coarse solids separation; it is transferred to a 4 kL treatment tank (2) where it is pH adjusted and aerated for 8 hours to reduce BOD. The flowmeter is located prior to the 22 kL auxiliary tank (3) where wastewater can be stored before slow gravity release to a series of five reed pods (4) for tertiary treatment removing nutrients, organic matter and BOD. Rainwater overflow can bypass wastewater treatment (5) or be recycled back through the system to assist with reducing pollutant loads. Treated wastewater is either returned to the dam, during periods of low volume (6), or irrigated onto pasture (7) during peak volumes.*

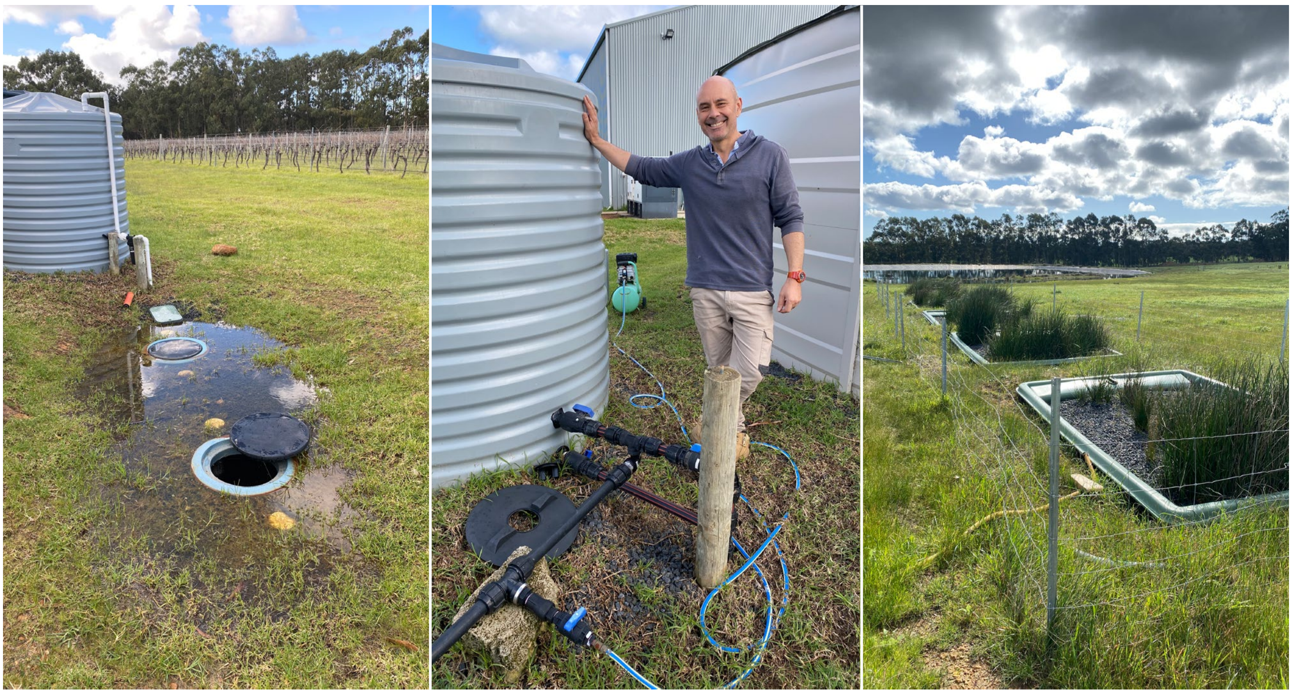

Figure 6. *Baffle tanks are in the foreground (left), with wastewater pumped to the treatment tank that can be circulated for aeration and pH adjustment (centre) before being stored in the 22 kL tank (not pictured) and sent to the five reed bed pods located downhill, halfway between the winery and dam (right). Images were taken in August 2022 following significant rain, water visible around the baffle tanks is ground water.*

Figure 7. *Reed bed pods used at Stormflower Vineyard, which are lined with a self-supporting slotted trench liner to facilitate even dispersion of wastewater to maximise interaction with reeds' root systems.*

There are five reed pods in sequence, each pod has a self-supporting arched slotted trench liner 230 mm high inside to allow fluid to disperse evenly within the pod, and has a peak daily flow of 1600 L, with two wastewater injection zones and inspection ports near the centre of each pod (Figure 7). The trench liner is covered by gravel media (blue metal) for reed plants to attach to. Native reed species, Baumia juncea, B. preisii and Bolboschoenus caldwellii, supplied by a local nursery specialising in southwest native plants, were trialled, with B. juncea and B. caldwellii thriving the best, a process that took three years to establish. The efficacy of the reeds in each pod is indicative of the plant growth and density (Figure 8), with the initial pod having weakest growth, correlating with the highest levels of BOD, solids and nutrients as wastewater enters the system. Aeration at the treatment tank decreases BOD by approximately 200 mg/L, to 1800 mg/L and pH 8.0, which is within the tolerance of the native reeds. Monitoring of pH and BOD across the five reed pods was carried out during initial stages to ensure the reeds in the pods were working efficiently. By the final reed bed there is little impact on the native reeds' health with the entire pod dense with plant growth and clear, odourless water being irrigated onto the adjacent paddock via a mobile outlet during peak volume periods (vintage to July).

Figure 8. *Looking uphill across the reed bed pod system showing the health and density of native reeds in the final pod.*

During quieter periods, when there is little to no wastewater generation (August to January), stormwater passes through the system untreated maintaining the health of the reed pods, allowing a period of regeneration, exiting into the dam, which is contained onsite with no overflow. During summer excess rainwater or dam water can be circulated through the reed pods, ensuring they do not overheat and continue to grow prior to vintage commencing. At each step of wastewater treatment Stormflower Vineyard can control flow, with the capacity to bypass or recirculate as needed depending on the quality and volume of wastewater generated, with the 22 kL auxiliary storage tank increasing flexibility to manage wastewater accordingly.

While there are obvious differences of scale, complexity, and regulatory requirements for reporting between Cape Mentelle Vineyards' and Stormflower Vineyard's wastewater treatment systems, the principles, and care taken to prevent environmental harm, are the same. Both have the capacity to recirculate wastewater back through the system if further treatment is required before irrigating to woodlot or paddock.

Improving Water Use Efficiency

Water use is affected by the number and complexity of processes used during wine production due to cleaning methods applied for each, with white winemaking on average being more complex than red winemaking, and on-site bottling being additional to this, although it does not explain all variances of water use per tonne crushed (Kumar et al. 2009). Stormwater, when not diverted, also adds extra load to wastewater systems and the capacity to control this should be a key consideration for all wineries when being constructed.

Both Cape Mentelle Vineyards and Stormflower Vineyard actively encourage and train staff to use dry cleaning techniques, particularly during vintage, at each step to minimise water use. These include dry brooming of grape skins and coarse solids, squeegees and high pressure, low volume water nozzles to clean and wash down processing areas and equipment, particularly for barrels. Screens located in all drains at both facilities capture organic material preventing it entering the wastewater, with regular clearing to prevent poor drainage. Practical measures such as increasing the number of press loads that do not require wet cleaning between batches, instead clearing press drainage screens with brushes, and recycling of hot water cleaning solutions through multiple tanks are implemented at both wineries.

Cape Mentelle Vineyards use steam for cleaning barrels and sterilising bottling fillers and ozone sanitation for empty barrels on a four week program, reducing the need for souse in barrels, all of which contribute to less water being used. Purchase of a crossflow filter in 2017 has resulted in less water use during filtration at Cape Mentelle Vineyards. Crossflow filtration is reported to have the lowest water use and pollutant concentration of any filtration process used during winemaking (Day *et al.* 2011).

Stormflower Vineyard has fewer staff (one permanent and up to two extras during vintage), which enables better control of practices in the winery than larger facilities, and they have removed destemming/crushing and must chilling from its winemaking process, as all white fruit is handpicked and directly loaded to their press via a hopper. Red fruit is harvested using a Pellenc Selectiv' harvester with an onboard hulling and sorting table that directly tips into open fermenters at the winery for red fermentation. Wineries less than 10 years old generally have less steps, due to design, than older wineries (Kumar et al. 2009). Cape Mentelle Vineyards gravity load red fermentation vessels with grapes using a Cuvons® harvest transfer tank which removes the need to push through with water from the crusher and will be simplifying their whole-bunch press loading using a hopper located above the press instead of a conveyor, which should significantly decrease water use for cleaning during this process.

Water use minimisation strategies are; eliminate steps within winemaking processes where possible, utilise pigging or inert gas at push-through instead of water, dry sweeping, high pressure cleaning equipment, automatic hose nozzles, divert stormwater and do not bottle onsite, although this could be viewed as transferring the problem (Kumar *et al.* 2009, Winewatch 2009b).

To quote Joel Page, Stormflower Vineyard's winemaker, "*I don't actually see benefits of wastewater, it's just something we have to deal with.*" Each winery, regardless of size, will have different issues with regard to capacity to change practices to reduce water use and therefore wastewater generation but all have a responsibility to be proactive about how wastewater is treated and disposed.

Resources

There are considerable resources available regarding wastewater management, including the insightful *Winewatch: Fact Sheets* series produced in 2009 by the Wine Industry Association of Western Australia, now Wines of Western Australia (WoWA) and Wine Australia's *Winery wastewater management: Online resource kit* (Wine Australia 2021) which provides best practice in sustainable management of winery wastewater treatment and recycling.

Bibliography and References

Day P, Cribb J, Boland A, Shanahan M, Oemcke D, Kumar A, Cowey G, Forsythe K and Burgi A (2011) Winery Wastewater Management and Recycling – Operational guidelines. Grape and Wine Research and Development Corporation, Adelaide, SA. (ISBN:978-0-9871444-2-3)

Chapman J, Baker p, and Wills S (2001) Winery Wastewater Handbook. Winetitles, Adelaide, SA.

Environmental Protection Act 1986 (WA). Government of Western Australia.

Environmental Protection Act Regulations 1987 (WA). Government of Western Australia.

Kumar A, Frost P, Correll R, Oemcke D (2009) Winery wastewater generation, treatment, and disposal: A survey of Australian practice. CSIRO. Adelaide SA

MRWA (2022) Margaret River Region – Media Kit. Margaret River Wine Association (https://margaretriver.wine/wp-content/uploads/2022/05/Margaret-River-Wine-Media-Kit-2022-LR.pdf)

National Water Quality Management Strategy (1998). *Effluent Management Guidelines for Australian Wineries and Distilleries*. Agriculture and Resource Management Council of Australia and New Zealand and Australian and New Zealand Environment and Conservation Council.

Wine Australia (2021) Winery wastewater management: Online resource kit. (https://www.wineaustralia.com/growing-making/winery-wastewater-online-resource-kit)

Winewatch (2009a) *Fact Sheet 1. Winery wastewater composition and potential environmental impacts of wastewater disposal from small wineries.* Wine Industry Association of Western Australia.

Winewatch (2009b) *Fact Sheet 2. Reducing winery wastewater volumes and pollution loads from small wineries.* Wine Industry Association of Western Australia.

Winewatch (2009c) *Fact Sheet 3. Winery wastewater disposal to land from small wineries.* Wine Industry Association of Western Australia.

Winewatch (2009d) *Fact Sheet 4. Subsurface disposal of winery wastewater for small wineries.* Wine Industry Association of Western Australia.

Winewatch (2009e) *Fact Sheet 5. Ponds for percolation/evaporation and storage of wastewater from small wineries.* Wine Industry Association of Western Australia.

Winewatch (2009f) *Fact Sheet 6. Case study: Disposing of winery wastewater from a small winery using irrigation.* Wine Industry Association of Western Australia.

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