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REDUCING EVAPORATION AND EFFICIENT WATER HARVESTING



FINAL REPORT to

GRAPE AND WINE RESEARCH & DEVELOPMENT CORPORATION

Project Number: RT07/02-1

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Research Organisation: **Department of Agriculture and Food, Western Australia**

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Contents

Abstract **2**
Executive summary **3**
Background **5**
Project aims and performance targets **10**
Methods and Results **11**
Overall Conclusions **25**
Recommendations **27**
Appendix 1. Communication **28**
Appendix 2. Intellectual Property **33**
Appendix 3. References **34**
Appendix 4. Staff **35**
Appendix 5. Budget reconciliation **36**

Abstract

The wine industry in the Great Southern region of Western Australia relies on irrigation water harvested from artificial catchments such roaded catchments. A roaded catchment is designed to increase the amount of run-off from the catchment above a storage dam. The "roads" of a roaded catchment are generally parallel ridges of earth with batters (or side slopes) that cause run-off to be directed into troughs or channels. The surface is lined with clay and compacted to make it smooth and impervious to reduce infiltration and increase run-off.

In a drying climate it is becoming critical to consider the efficiency of water harvesting infrastructure and storage. This project focused on extension and demonstration of water savings by reducing evaporation from water storages and water harvesting by increasing the run-off efficiencies of roaded catchments.

This project highlighted:

- the water savings that can be made by using a monolayer (Aquatain®) on stored water in dams to reduce evaporation

- the water harvesting efficiency gains that could be made by improving the maintainance and design of roaded catchments

Executive summary

With a drying environment, the efficient collection, storage and use of water is paramount for industries dependant on surface water for irrigation in order to sustain productivity and profitability.

Vineyards in the Great Southern Region of Western Australia collect rainwater using roaded catchments which are designed to direct the water into a storage dam. Roaded catchments are constructed with earth moving equipment to form a series of sloping surfaces of compacted clay to promote rainfall run-off (Stanton, 2005). An effective roaded catchment harvests about 30% of the annual rainfall which is many times more than the runoff from a pasture paddock. As a rule approximately one hectare of roaded catchment is needed for every 2.5 hectares of vineyard assuming an average rainfall of 600mm per year in this region.

The effectiveness of roaded catchments in the region has been shown to be variable from property to property (Lantkze, 2005). An effective roaded catchment was shown to shed water after about 4mm of rain or less while the threshold for an ineffective roaded was up to 14mm. With an annual rainfall of 600mm, this difference in efficiency equates to approximately 2.6ML/ha of harvested water. Over an average sized roaded catchment of say 25ha, this equates to a potential loss of 65ML of harvestable water. This variation in performance was expected to be typical of the region indicating a huge potential for efficiency gains.

The Department of Agriculture and Food showed that many roaded catchments in the region can be improved markedly by rolling/compacting, and the use of a soil sealant (Lantkze, 2004). Treating the surface of roaded catchments with a spray-on polymer soil sealant dramatically improved the run-off percentage relative to an untreated "effective" roaded catchment. This technique was quickly adopted on many vineyards in the region – at a cost of $2000 per hectare of roaded catchment.

The annual evaporation for the region is about 1500mm per year which equates to a water loss of nearly 11ML/year from a 50ML dam. Therefore reducing losses from water storages by minimising seepage/leakage and evaporation is equally important as harvesting water as efficiently. Inefficient water harvesting surfaces and high evaporation losses increase the risk of depleted water supplies in years where rainfall is below average. This highlights the need to raise the awareness amongst vineyard managers of strategies to secure their water supply.

The project reported here, conducted in the Lower Great Southern Wine Region during 2007 to 2009, aimed to: (i) evaluate the effectiveness of a monolayer (Aquatain®) to reduce evaporation from water storages, and (ii) benchmark the run-off threshold of roaded catchments in the region and identify catchment conditions which contribute to inefficiencies of the water harvesting surface.

Aquatain® applied to the water surface of a dam at Crystal Brook during a 17 week period from December 2007 to the end of March 2008 reduced evaporation losses by 18%. In a 50ML dam this equates to a saving of 2ML of water.

Ten properties in the Frankland and Mount Barker regions were included in the roaded catchment benchmarking study. Before estimating the run-off threshold observations were made of the surface conditions of roads. It was apparent that the original compacted surface of many of the catchments had been severely eroded (fretted) on the crests of the

roads, depositing fine material lower (soft and loose) in the troughs of the roads. There were at least three different surface conditions on many catchments, smooth and compacted, fretted and friable, soft and loose. It was evident that the run-off threshold of the roaded catchments would only be as good as the least efficient component of the road.

Various sites were chosen on each roaded catchment to estimate the run-off threshold using a rainfall simulator. The results confirmed that there was a large variation between the water harvesting effectiveness of roaded catchments within the region. The run-off thresholds varied between 2 to 18mm and were correlated with surface condition. Surfaces which closely resembled the original compacted surface were the most efficient with run-off thresholds varying from 2 to 11.7mm. The run-off thresholds of surfaces that were eroded ranged from 4.9 to 18mm. Compaction of the surfaces did not necessarily decrease the run-off threshold and on some cases the run-off threshold increased.

These results were presented to vignerons participating in the study at a workshop with property specific reports. There were no surprises to the vineyard managers that their roaded catchments were not harvesting water efficiency. However the cost of annual maintenance was seen as the main barrier to implementing a maintenance plan. While there has been a large capital outlay in roaded catchments to secure an irrigation water source for the vineyard, planning for capital expenditure to maintain the property asset has not been considered.

This raises the issue that while water has an "intrinsic" value to the production system, the opportunity cost of not investing in the maintenance needed to optimise the water harvesting potential has not been realised. The real value of water has not been realised.

It is recommended that there is an ongoing communication plan to raise and maintain manager's awareness of water harvesting, storage and use efficiency aimed at adoption of industry best practice. To have a major impact the communication plan needs to include financial analysis which justifies ongoing maintenance of water harvesting infrastructure and strategic use of methods to reduce evaporation on major dams. The communication plan should encourage capital investment in roaded catchments in areas where the implementation of such structures will not be detrimental to environmental flows. The cost of roaded catchments needs to highlight the real cost of the initial capital outlay and the ongoing maintenance cost to preserve the roaded catchment in a good condition and maximize the capture of run off year in year out.

To realize the real value of water to the production and business environment it is further recommended that a cost/benefit analysis is undertaken. The analysis should also include the use a monolayer to reduce evaporation and the associated increase in water storage. This process will develop a methodology for quantifying the value of water to a business in terms of the vine quality, quantity and profitability. A component of this analysis will need to consider the risk of failure in below average rainfall years when the roaded catchment fails to supply sufficient irrigation water for the vineyard. This analysis would ascertain long term business viability by considering the frequency of average and above average rainfall years. An output of this analysis will be a sensitivity analysis that will identify the value of capital investment (initial plus maintenance) relative to the additional water captured based on various assumed water values.

Background

The availability of sufficient water for irrigation is the major physical limitation to the sustainable development and expansion of viticulture in the Great Southern Region of Western Australia. In 2003 and 2004, for example, grape harvests were compromised due to a lack of irrigation water as a result of below average rainfall.

Grape growers in the Great Southern Region of Western Australia harvest rainfall for irrigation by using roaded catchments (Figure 1). These are designed as a series of sloping roads made from compacted clay subsoils, and collecting drains leading to a dam (Stanton, 2005). Vineyard owners in the region build approximately one hectare of roaded catchment to harvest sufficient water to irrigate 2.5 hectares of vines. This is a major cost and takes up land that could otherwise be used for viticulture. Roaded catchments are designed as a series of sloping roads and collecting drains leading to a dam (Figure 2.)



Figure 1: Roaded catchments (yellow areas) within the Frankland area of the Lower Great Southern used for harvesting rainwater for irrigation.



Figure 2: Section of a roaded catchment showing water being harvested during a rain event.

A previous project funded by GWRDC (RD 03/20-4) "Increasing run-off from roaded catchments by chemical application", was undertaken by Neil Lantzke and Rod Short of the Department of Agriculture and Food Western Australia. These researchers tested soil sealant products and found that a polymer substance called TGC (Total Ground Cover) was the most effective and appropriate product for use on roaded catchments in wine grape vineyards. When sprayed onto the surface of a roaded catchment the product typically doubles the volume of run-off (Lantzke, 2005). The cost is around $2000/ha and the benefit lasts for at least two seasons. The viticulture industry in the Great Southern took great interest in the research and the polymer is now being used successfully by a number of large vineyards.

Given the success of the soil sealant when applied to roaded catchments the question arose as to whether the product could be used to harvest rainwater from within vineyard rows. This was investigated in the GWRDC funded project RD 04/01-1 "Increasing irrigation water and controlling vigour by collecting runoff from the mid row of vineyards". Harvesting rainwater from within the planted area would have advantages of reducing the area needed for roaded catchments and allowing more hectares of vines to be planted on the property. In addition harvesting rainwater would reduce infiltration into the groundwater thereby addressing the regional problem of rising salinity. In the work a soil sealant or a layer of black plastic was used to demonstrate harvesting of rainwater from within vineyard rows. The black plastic proved to be a practical solution for vineyards with the majority of rain before bud burst being harvested. Black plastic between vine rows could be a viable solution to minimise the area of roaded catchment needed, thereby increasing the area of vineyards. This solution needs to be well thought through in the planning stages of the vineyard and associated infrastructure. The decreased water availability to the vines with black plastic between the rows did not affect vine vigour, fruit yield and quality even though the work was conducted over a dry season. It was recommended that further communication and demonstration of the application of black plastic between vineyard rows would be critical to industry uptake of the methodology.

Another option to reduce the rising salinity issue down slope from the vineyard could be the inclusion of cover crops between the vineyard rows which increase the effectiveness of rainfall events in leaching salts.

There is strong evidence that there has been a significant ($p < 0.01$) decline in the long term average rainfall for the Great Southern Region. In particular Frankland (Figure 3) has experienced a decline of 108mm from the long term average for the period of 1942 to 1975 of 711mm to the long term average from 1976 to 2009 of 603mm. This highlights the increased priority on efficient water capture and evaporation reduction to ensure water needs are met for vineyard management, particularly where water is primarily sourced from surface runoff.

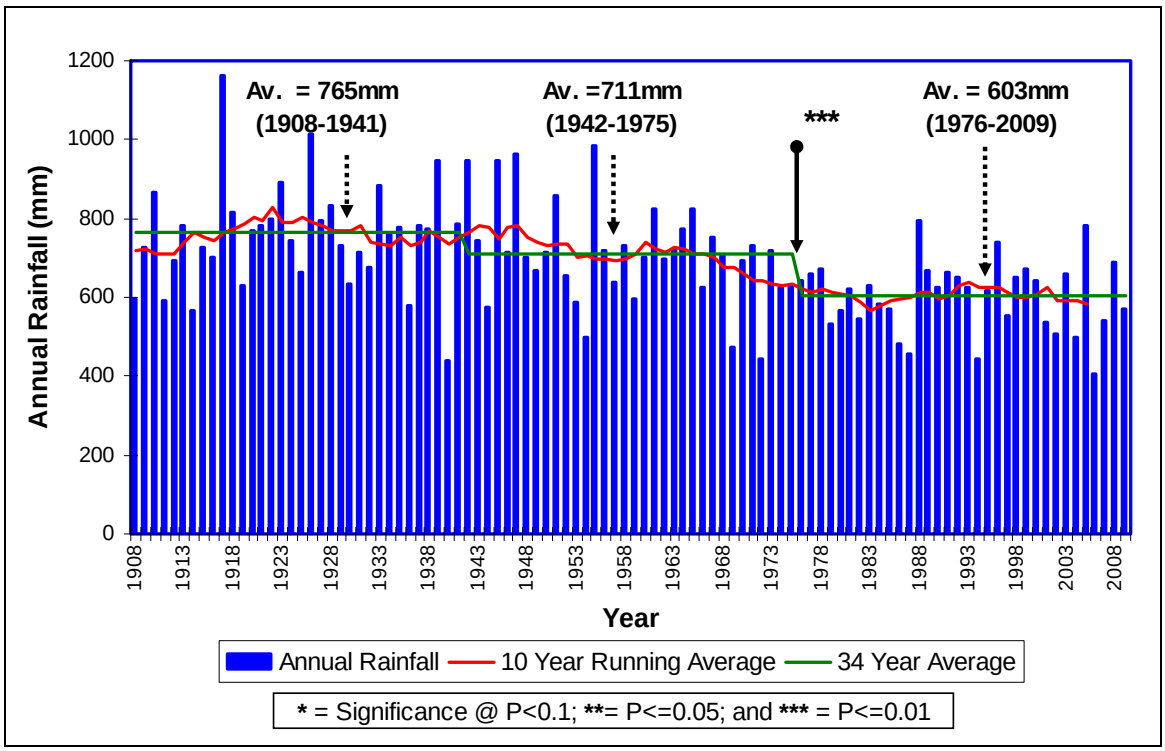


Figure 3. Long term (1908-2009) variability in annual rainfall for Frankland, Great Southern Wine area; reflecting the significant decline in long term average (LT. Av.) rainfall.

Products to reduce evaporation from dams have been researched widely for many years. One such product called 'Aquatain®' (a monolayer) is particularly easy to use. Monolayers spread over the whole the water surface in a layer of a single molecule thickness.

Stafford (2008) and Chalmers (2009) summarise the potential values of native grasses as an inter vineyard cover crop. The vertical fibrous root systems of perennial grasses can significantly reduce soil compaction and surface crusting, improve soil structure, water holding capacity and the rate of water infiltration. As a result of the soil structure improvements, surface runoff and erosion is likely to decrease.

Stafford (2008) has indicated that *Chloris truncate* as a C_4 warm season grass is compatible with vineyard management practices. *Chloris* is dormant in winter and therefore it facilitates the infiltration of water into the soil profile. It is also relatively tolerant to glyphosate, as such competing weeds of which it is vulnerable to; can be

sprayed out in spring to provide exposure of the soil for frost control. To decrease the vulnerability of the *Chloris* sward from being out competed by other weeds, Stafford , 2008) identifies the need to keep soil nutrient levels low in order to decrease weed competition.

The project reported here was initially designed to demonstrate and extend the following technologies to enhance adoption:

1) The use of soil sealants to double the rainwater harvested from roaded catchments (Neil Lantzke, 2005).
2) The use of black plastic to harvest a third of the rainwater from within vineyard rows (Colin McDonald, 2008).
3) The use of monolayer polymers (Aquatain®) to reduce dam evaporation by up to 80% (Graham Strachan, 2006).
4) Adjusting (and optimising) the competition between vine and cover crop via varying the width of cover crop (Bhat, 2009).
5) The use of native perennial cover crop such as *Danthonia* species *(Wallaby Grass*) to persist and suppress weeds (John Stafford, 2008).
6) The use of cover crop such as Lucerne to effectively minimize undesirable recharge of ground water (Michael Robertson, 2006).
7) The use of a cover crop of *Chloris truncate* (Windmill Grass) to be effectively increasing soil carbon levels (John Stafford, 2008).

Adoption of any of the above management practices could have significant economic, environmental or social benefits:

- Economic benefits including water harvesting, evaporation control, weed suppression, vine vigour control
- Environmental benefits including reduced groundwater recharge and increased soil carbon
- Social benefits including improved viability and sustainability as a result of the above).

However, following the demonstration of the use of Aquatain® to reduce dam evaporation and the use of black plastic to harvest rainfall to industry, it was considered more important to concentrate on improving the water harvesting systems used in the region. Consequently a variation to the project was sought and accepted to undertake an assessment of rainfall harvesting systems used on up to 15 vineyards in the Great Southern Region. This was to involve testing the run-off threshold of roaded catchments using a trailer mounted rainfall simulator. The run-off threshold is that quantity of rainfall required on a surface before runoff is evident. Additionally a visual assessment would be conducted of the design and maintenance issues of the catchment drains and dams. This would form the backbone of a benchmarking study, where a standardized confidential report for each property would detail the results and assessments and make recommendations for any improvements.

Lantzke (2005) showed that the efficiency of seven roaded catchments on vineyards in Frankland varied greatly. The work indicated that the most efficient catchment would achieve rainfall run-off after 4mm of rain while the least efficient would need 14mm of rain before run-off would occur. It was considered that such variation in performance would probably be typical of the region indicating a huge potential for improvement.

Lantzke and Short (2004) showed that many roaded catchments in the region can be improved markedly by rolling/compacting, and the use of a soil sealant. However, people need to be aware of how efficiently their rainfall harvesting systems are currently operating before they will decide to make any improvements.

The variation sought excluded demonstrations involving cover crops such as *Danthonia*, *Chloris* and Lucerne as a means of demonstrating overall vineyard water balance and to develop the concept of sustainable floor management and improved soil health, as it became apparent that many growers were aware of the benefits of cover crops. Additionally, while it was initially thought that Lucerne could be grown as an inter row crop to assist in decreasing ground water recharge, all lucerne varieties are summer active and as such an interrow crop of lucerne would be a direct competitor against vines for high value irrigation water during summer, which could impact on vine vigour and quality and yield. At the same time, as a summer active crop, there would be added competition for labour in its management at the same time as the labour requirement for irrigation and vine management would be at a premium. As a result it was decided to not progress a demonstration of lucerne as a cover crop.

The results of the benchmarking study were to be presented with advice on design flaws and catchment management and maintenance. Each property would be presented with their property specific assessment at the workshop. The overall findings would be presented to the whole industry through an article to be published in the Australian Viticulture magazine.

Project aims and performance targets

The initial project submission was focused on demonstrating the seven technologies outlined in the background. The three aims were:

1) To Maximize the exposure of these management techniques to the industry using:
   - A well known commercial vineyard (Fox River Wines)
   - A highly visible site being on a main highway and well signposted.
   - All the techniques to be demonstrated a the one site
   - Well advertised, repeated local articles and radio presentations
   - One or more field days.
2) To develop the concept of managing for overall vineyard water balance; and
3) To develop the concept of sustainable floor management and improved health.

Upon achievement of the first aim and the successful justification for a variation to the project which excluded needing to achieve aims two (2) and three (3), the additional aim was:

4) To benchmark the runoff efficiency of 15 roaded catchments in the Great Southern Region, to identify the scope for improving roaded catchments on at least 15 properties in the region and to extend this information to the wider industry.

Outputs	Performance Targets	Target Date
Year 1 • Demonstration activity. • Workshop with managers • Results published to broader viticulture industry	Demonstration of a technique to reduce dam evaporation by up to 80% using a polymer (Aquatain®).	2008
Year 2 • Runoff efficiency and roaded catchment condition assessments undertaken on 15 vineyards in the Great Southern Region. • Standardized report for each property manager on water harvesting efficiency of the vineyard roaded catchments. • Workshop with participants to review results. • Results published in accordance with benchmarking standards to maintain confidentiality between vineyards. (Western Australian and National)	To benchmark the runoff efficiency of 15 roaded catchments in the Great Southern Region	May, 2009

Methods and Results

Year 1: Reducing evaporation from dams: a practical demonstration.

Method

A preliminary demonstration site was installed during the summer of 2007-08 to show the reduction in evaporation from the application of Aquatain® to an open tank of 7.6m in diameter. There was no noticeable difference in evaporation in the tank demonstration.

Before studying evaporation from dams it is essential to first estimate any leakage/seepage from the dam. Many dams in the Great Southern region routinely lose water through the dam wall from leakage. The dam wall leakage was measured over a two week period.

In order to estimate leakage and later, evaporation from the dam we installed a depth board in the dam to read the water level each week As a control a large plastic forklift tub was floated out into the dam, tethered and filled with water to 150mm from the top (Figure 4). Two depth boards were installed on opposite sides inside the tub. The two depth boards in the tub were used to check any error that could result if the tub was to lean to one side during the study.

The dam used had a surface area of 0.24ha (64m x 37m). There was no water pumped or taken from the dam during the period of the trial. If the dam had been used for regular irrigation this would have complicated the study and increased the risk of error in the results. There was also no water pumped into the dam during the study and there were no drains entering the dam.

The estimate of leakage loss from the dam was done over the first 15 days (14 November to 29 November 2007). A dingy was used to paddle out to read the depth boards in the dam and in the plastic tub. The loss from the dam minus the loss from the tub was used to calculate the seepage loss from the dam.



Figure 4: Plastic tub partly filled with water floating out in the dam used for the Aquatain® study. The depth board in the dam can also be seen on the right.

After estimating dam leakage, Aquatain® was applied to the water surface according to the manufacturer's recommendations of four litres per hectare of water surface. A further two litres per hectare was then added at ten day intervals. Aquatain® was not applied to the water in the plastic tub as this was the control treatment for the study.

The difference between the water lost from the dam (taking leakage into account) and that lost from the tub gave us our estimates of the benefit of Aquatain. The study ran for approximately 17 weeks (118 days, 29 November 2007 to 27 March 2008). The tub was topped up with a measured quantity of water on four occasions during the trial.





Figures 5 and 6: Aquatain® quickly spreads over the whole water surface giving it a smooth shining appearance.

Results

A leakage loss of 5.67mm days was calculated from the first 15 days of the study and this figure was used to estimate leakage for the remaining 118 days during which the Aquatain® comparison was undertaken.

It did not rain during the period of estimating dam leakage, however 11 rainfall events occurred during the remainder of the study giving a total 116.4mm recorded at a local research station. In our calculations we assumed that the rainfall (mm) falling on the dam was the same as that falling on the control tub.

Taking both the dam leakage and the rainfall into account we calculated that the reduction in evaporation achieved by the use of Aquatain® was 18% (Fig. 7.).

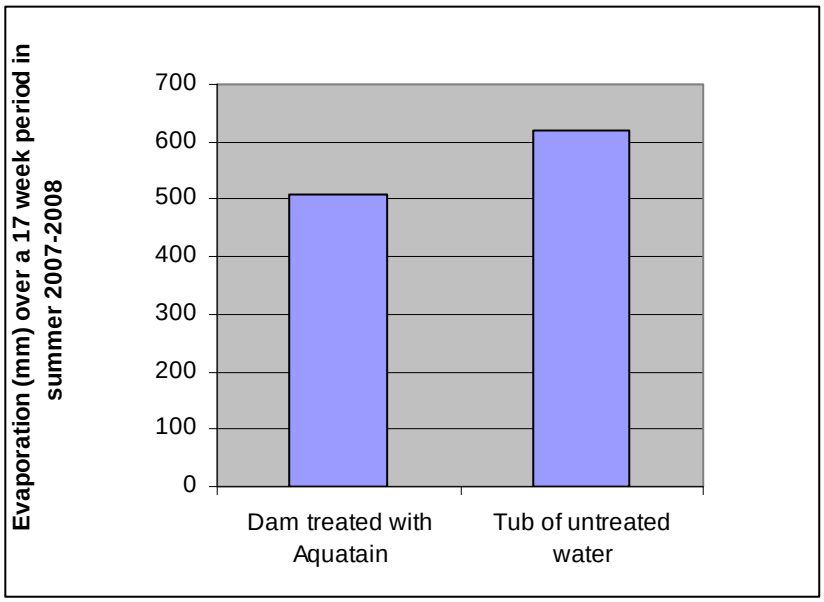


Figure 7: Comparison of evaporation from a body of water treated with Aquatain® compared to a tub of water not treated with Aquatain®.

Discussion

Many vineyards in the Great Southern Region have been faced with shortages of irrigation water over recent dry years. A benefit of an18% saving in evaporation by using Aquatain may be economically viable in these circumstances. Annual evaporation in the region is in the order of 1500mm per year. In a 50 mega litre dam this equates to a loss of nearly 11 mega litres per year. Thus if 18% of this were to be saved by using Aquatain® the benefit gained would be an extra two mega litres of water. This water could be of great benefit towards the end of the season.

Surface layers such as Aquatain® can tend to lose their effectiveness in windy conditions. Wind blowing across the water surface tends to push the monolayer to the far side of the dam leaving the nearside section open to evaporation. For this reason, we would expect variable results from Aquatain® due to differences in windiness between periods in the same dam as well as between different dams. Windbreaks (artificial or trees) have the potential to reduce the impact of wine on the water surface (Hipsey, 2002) thus significantly increasing the effectiveness of Aquatain®).

Aquatain® is said to tend to adhere to soil particles, so the lapping of water against the dam bank tends to slowly remove the product from the water surface- hence the recommendation to keep adding Aquatain® to the water at 10 day intervals. It is also possible that different soils in different dams may remove Aquatain® to different degrees. It may also be that Aquatain® is less effective in water with high turbidity (cloudiness due to suspended clay) as compared to clear water.

Our results are greatly dependant on the accuracy of the estimate of dam leakage/seepage. We have assumed a constant rate of seepage over the period of the trial. While this is the rate we measured at the start it is possible that the rate varied during the study. For example, as the dam level dropped during summer the pressure of water on the bank would have also dropped and this may have reduced the rate of leakage. Therefore this trial may have underestimated the effectiveness of Aquatain.

The effectiveness of Aquatain will vary between dams and other circumstances.

Conclusions

The demonstration showed that Aquatain® applied at the recommended rate of 4L/ha of water surface in a dam could reduce evaporation of the water stored by 18% and this reduction in evaporation would be critical in drier years.

It is necessary to re-apply the monolayer to the water surface every 10 days to minimise water loss due to evaporation.

Windy conditions minimise the effectiveness of the monolayer by moving the layer to the leeward side of the water surface where it tends to adheres to soil particles, necessitating more frequent applications in windy conditions.

Tree shelter belts could be planted to reduce the effect of wind on the water surface and therefore the frequency of application in windy conditions.

Evaporation is not the only means of water loss from a dam and as such the application of the monolayer will not prevent dam wall leakage or general seepage from the dam.

Year 2: Benchmarking the runoff efficiency of designed roaded catchments in the Great Southern wine region.

Method

An invitation to participate in the roaded catchment benchmarking study was sent to all vineyards within the Great Southern region via letter and flyer. Ten property managers nominated to be involved in the benchmarking study.

Field observations and assessments were carried out on roaded catchments of ten vineyards within the Great Southern over the summer of 2008/09. The field assessment component comprised of observations and photographs of the surface condition and of roaded catchment design flaws resulting in the break down of the surface condition. Based on the observations of the surface condition, sites were selected on the catchment for measuring the runoff threshold of the surface as an indicator of the efficiency of the surface for harvesting water.

At each site, an estimate of the run off threshold was taken using a rainfall simulator (Figure 8) according to standard operating procedures. On surfaces that were relatively intact, two measurements were taken: the first on the original surface and the second on the original surface following compaction of the dry surface using a 1 tonne roller. The results were recorded and then collated for all roaded catchments in the region.

For any other surface condition type only one estimate of the run-off threshold was taken per surface type per site on each vineyard. If there was evidence that a polymer had been applied to the catchment the runoff threshold of this area was also measured.



Figure 8: Rainfall simulator used to estimate the run-off threshold of roaded catchment surfaces.

Results

Observations of surface condition.

During the site selection process, it was observed that many crests of the roaded catchment surfaces had eroded. While the upper crests of the roaded catchment roads were often in a stable and relatively smooth condition, many roaded catchment roads had eroded mid slope of the crests (Figure 9 and 10). This erosion point resembled a miniature scarp with the fretted surface below this point being extremely rough and pebbly. In some situations, the troughs of the roads contained loose deposited material from the side slopes (Figure 11).

With three different surface conditions, smooth and compacted, fretted and friable, soft and loose it became self evident that the run-off threshold of the roaded catchments would only be as good as the least efficient component of the road.

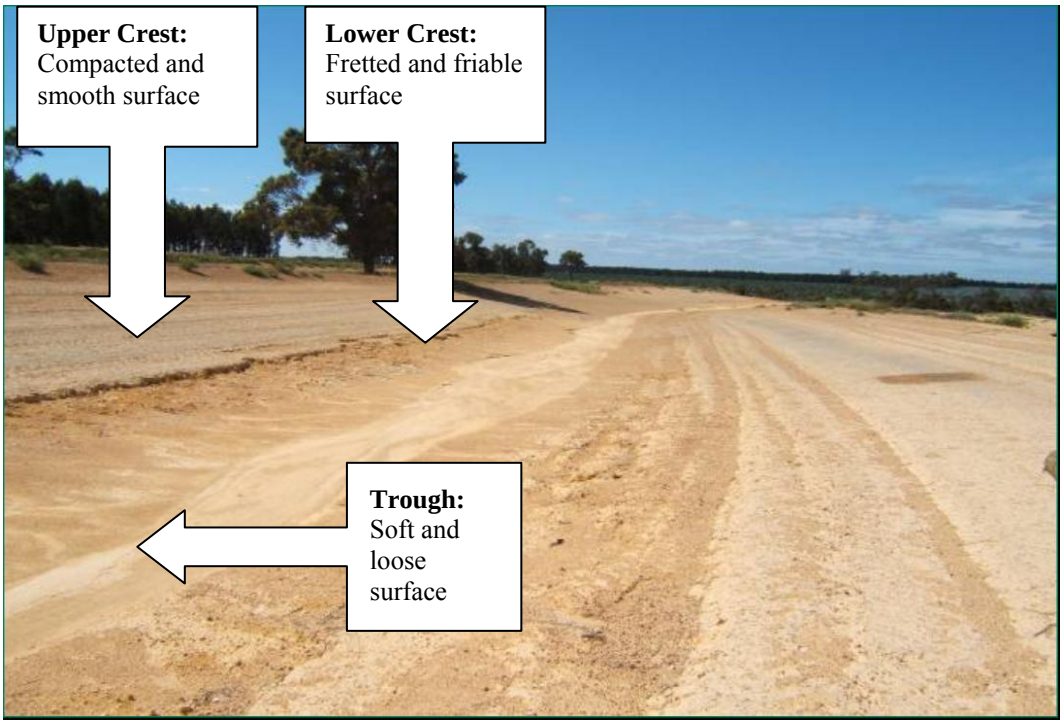


Figure 9: Typical roaded catchment structure within the Great Southern. Note the surface conditions of the upper and lower crests and the troughs.



Figure 10: Close up of the original relatively intact roaded catchment surface of the upper crest (Left) and the fretted and eroded surface of the lower crest of the roaded catchment (Right). Note the clear edge of the compacted surface with the rough gravely surface creating a miniature scarp for water to fall over and continue to cut back at the compacted surface. This surface has also been impacted upon by tractor and livestock movement over the surface contributing to the breakdown of the compacted surface.

In the most severe situations the side slopes of the crests had not only undergone sheet erosion, but more severe rill and gully erosion was evident on steeper slopes.



Figure 11: Deposition of soft and loose eroded material from the side and lower slopes of the crests in the channels of the roaded catchment. Note also the vegetation on the catchment surface and the livestock tracks in the loose material.

While there were three dominant surface conditions, as noted in Figure 11, weeds growing on the roaded catchments would also be contributing to the breakdown of the original compacted surface (Figure 12). The plant roots would be breaking down the compacted clay mantle which forms the roaded catchment surface, thereby increasing the infiltration rate of water into the profile and extracting water needed to plant growth. Weeds would therefore be reducing the run-off threshold of the area and therefore the water harvesting efficiency.

For weeds to establish on this catchment in the first place the catchment was probably not compacted sufficiently to reduce the risk of plant establishment on the roads, so weeds are a secondary issue. Once the weeds are established the breakdown of the surface condition is hastened.



Figure 12: Roaded catchment surface covered with woody perennials, summer grasses and forbs growing on the crest side slopes.

Another observation included the discovery of cracking clay soils (Figure 13). Soils which characteristically shrink and swell as a response to the drying and wetting of the soil profile would exhibit a variable run-off threshold. Cracking clay soils would have a high runoff threshold when the cracks are observable as a result of the drying out of the profile. In contrast, as the clay swells with increasing soil moisture content, the run-off efficiency is likely to increase.

Figure 13 identifies an area of cracking clay soil which may have been exposed in the catchment building process. A major gully has developed as a result of the bare landscape, high gradient and the erodibility of cracking clays. A test for the sodicity of the soil and therefore the dispersive nature of the soil was not undertaken. If the cracking clay soil was highly dispersive then this would have contributed to the intense gully erosion as well.



Figure 13: Erosion gully carving its way through the catchment on a cracking clay soil**.**

Estimated run-off threshold.

Over the ten properties involved there was a large range in the efficiency at which the roaded catchments harvested water (Figure 14). The most efficient surface ran water after a 1.8mm simulated rainfall event, while the most inefficient had not started running water after 18mm of simulated rainfall. The most effective surface water harvesting surface was a site (1C) which had previously had a polymer incorporated into the surface.

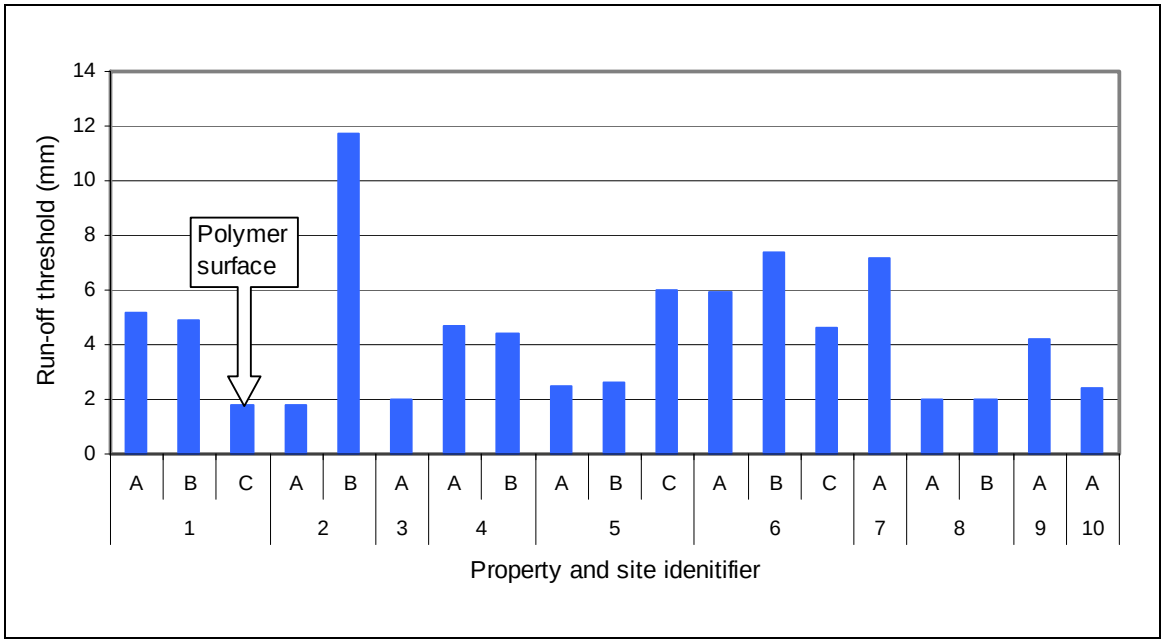


Figure 14: Range of run-off thresholds on roaded catchment surfaces appearing to be in a relatively intact condition in the Great Southern. Roaded catchment surface condition: A = original surface, B = following compaction of original surface, C = evidence that a polymer had been applied to the catchment.

Where the roaded catchment appeared to be in a relatively intact condition, the runoff efficiency ranged between 1.8 and 11.7mm with an average of 4.4mm. As a comparison a second test was conducted on these areas following compaction using a one (1) tonne roller. While the results are unclear, the site (2B in Figure 15) which had the least efficient runoff threshold (11.7mm) became more efficient at harvesting water with a runoff threshold of 5.6mm following compaction. Surfaces which were relatively effective as a water harvesting surface with a runoff threshold of less than 6mm either maintained or became less effective as water harvesting surface following compaction. Without further investigation into these areas, it is difficult to provide a conclusive statement as to why the run-off threshold increased following compaction of some sites. However, one idea is that the surface is close to being unstable and the pressure of rolling may have further broken down the structure. As such this identifies the importance of having the correct moisture content when compacting the clay surface.

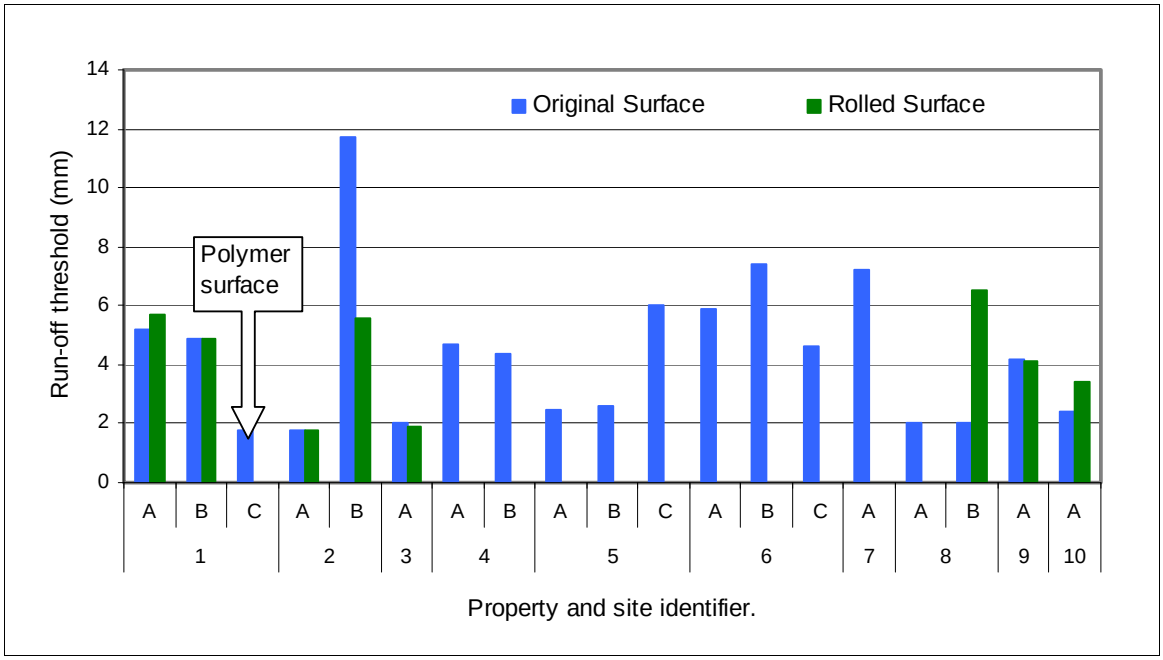


Figure 15. Run-off thresholds for roaded catchment surfaces consistent in appearance to a relatively intact condition before and after compaction in the Great Southern.

The run-off thresholds of the fretted surfaces were greater than that of the intact surfaces (Figure 16) with the run-off threshold ranging from 5mm to greater than 18mm. It should be noted that the run-off threshold at site 5C on the cracking clay surface had not started running after 18mm of simulated rainfall and therefore the run off threshold is assumed to be greater than 18mm on this site. It is evident that cracking clay soils inhibit the runoff threshold significantly when the soil surface is completely dry.

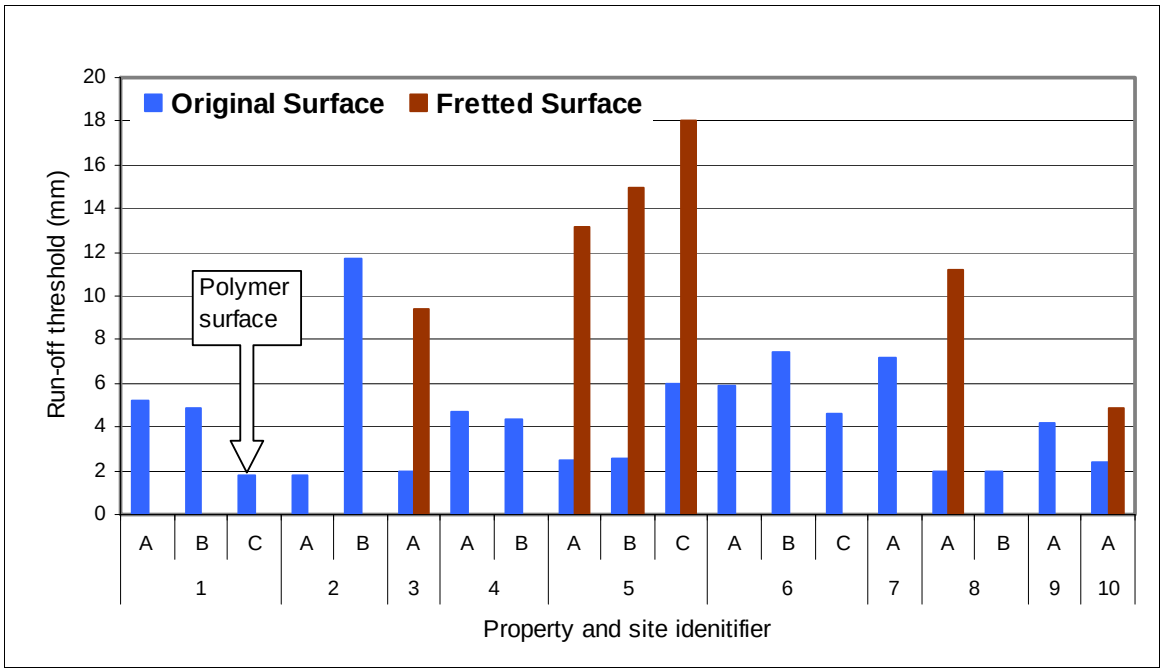


Figure 16: Run-off thresholds of roaded catchment surfaces of varying conditions in the Great Southern.

Discussion

Of the ten properties involved, there was a wide range (2mm to 18mm+) of runoff thresholds across the area with the majority of catchments exhibiting a loss in efficiency since their establishment.

The range of run off thresholds was directly related to the surface condition of the catchment. If the surface was relatively intact resembling a smooth and compacted surface then the run off threshold was low, however if the surface was rough and loose the run off threshold was higher.

There are a variety of issues that are evident on roaded catchments in the Great Southern that are contributing to decreasing the water harvesting efficiency, resulting in less water for storage and an increased risk of running out of water in years with below average rainfall. These issues which stem from design or building flaws and a lack of ongoing maintenance include: soil erosion (fretting, rilling and gullying), siltation, cracking and dispersion, inadequate compaction and plant establishment within the roaded catchment surface.

Information was presented to five vineyard managers in a workshop environment on the roaded catchment maintenance. Each manager identified that they would like to have their catchments working more efficiently, however the cost of the maintenance was seen as prohibitive towards scheduling an immediate response.

This highlighted the critical need to financially plan for and implement a regular maintenance schedule over the catchment to decrease the rate of surface condition decline. Maintenance of a whole catchment is a costly exercise and in these economic times the cost of applying major works to large catchments is prohibitive. A regular maintenance

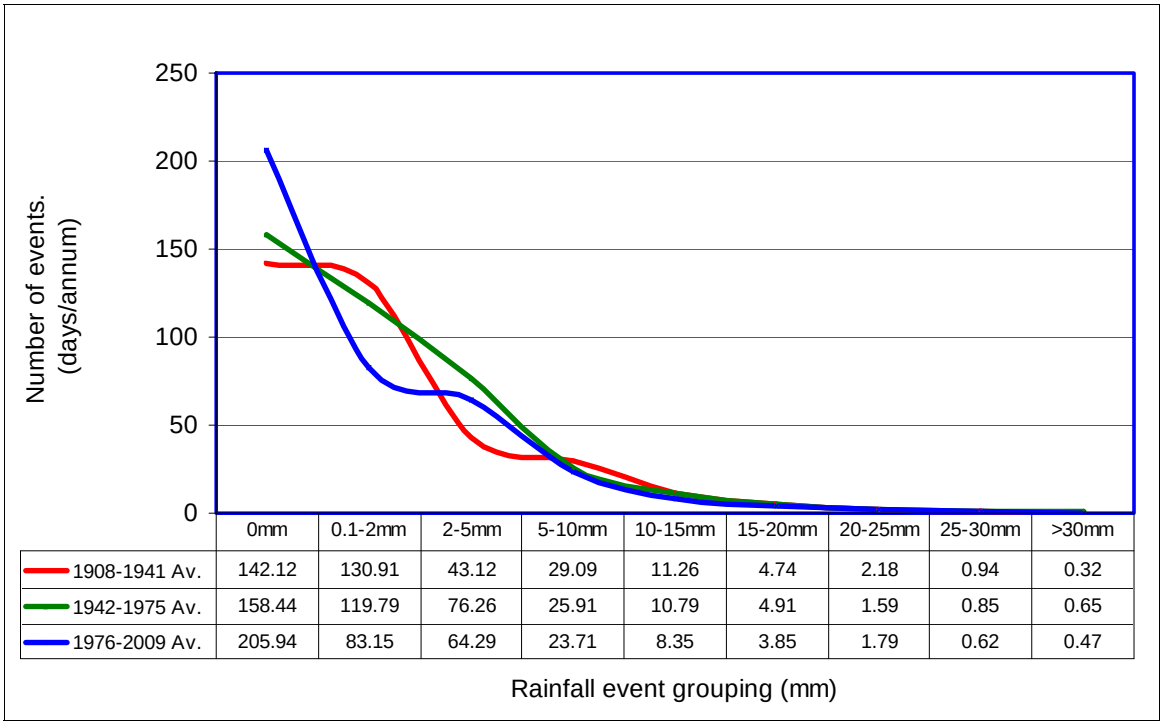
schedule with a budgeted allocation each year would negate the need for a large capital injection.

There is strong evidence that the average annual rainfall for the South West of Western Australia since the mid-1970's has gradually declined. The Lower Great Southern inclusive of areas such as Frankland and Mount Barker are no exception.

For example the current long term (1976-2009) annual average rainfall for Frankland (Figure 3) is some 106mm lower than the average for the time period 1941-1975 (711mm). This decline in average annual rainfall is statistically significant ($p<=0.01$). The current (1976-2009) average rainfall for Frankland is 603mm.

With this drying trend, it is critical to evaluate roaded catchment, storage and irrigation efficiencies to ensure that our water supplies will meet our production demands so that crop yields will not be significantly reduced due to a lack of irrigation water.

An analysis of the pattern of rainfall events (Figure 5) over time is indicating that for the period 1976-2008 there is an increase in the average number of days that are dry and in the number of daily events which receive between 20mm and 25mm of rain relative to the time period 1943-1975. However, the increased frequency in rainfall events from 20 -25mm is not significant while the increase in the number of dry days is significant. In contrast, there is a decreased frequency of all other rainfall event sizes between the two time periods.



	0mm	0.1-2mm	2-5mm	5-10mm	10-15mm	15-20mm	20-25mm	25-30mm	>30mm
1908-1941 Av.	142.12	130.91	43.12	29.09	11.26	4.74	2.18	0.94	0.32
1942-1975 Av.	158.44	119.79	76.26	25.91	10.79	4.91	1.59	0.85	0.65
1976-2009 Av.	205.94	83.15	64.29	23.71	8.35	3.85	1.79	0.62	0.47

Figure 17: Frequency of rainfall events per annum for a range of daily rainfall events for Frankland.

Using the average rainfall statistics from the period of 1976 to 2008 for Frankland, we can estimate the potential loss in water harvesting efficiency if the runoff threshold is not low (2-4mm) relative to a higher rainfall threshold of 8mm. Reading of Figure 6: a catchment which has a uniform surface with a runoff threshold of 2mm will capture approximately 90% of the years rainfall, while a catchment which has an average runoff threshold of 8mm, will capture less than 50% of the total annual rainfall. As such the runoff efficiency is critical for sustained water harvesting into the future if rainfall continues to decline.

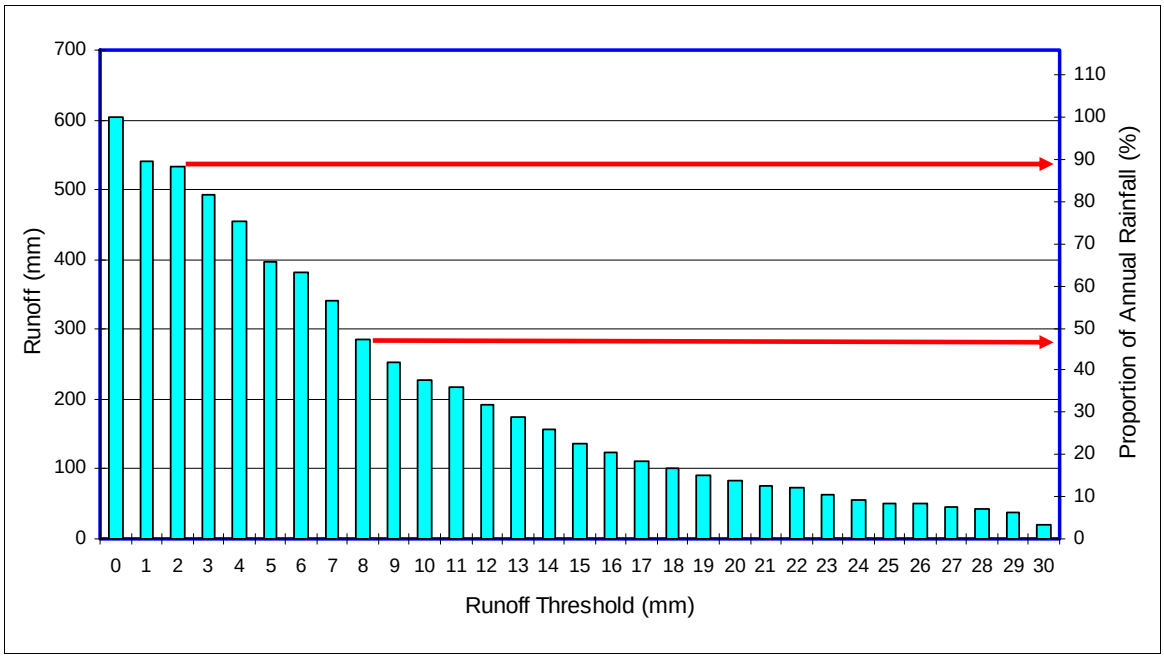


Figure 18: Correlation between proportion of run off and rainfall harvestable relative to various run-off thresholds for the Frankland area experiencing on average 600mm of rainfall per annum.

Using a similar analysis assuming that the catchment condition or runoff threshold is uniform and that the design and site conditions are ideal and a regular maintenance program is implemented, an estimate of the potential volume of water that could be harvested can be estimated (Figure 19). As such with a run off threshold of 2mm, there may be the potential to harvest 5.4ML per ha of roaded catchment. With an increase in the run off threshold to 8mm, the water harvesting capacity falls dramatically to 2.8ML/ha.

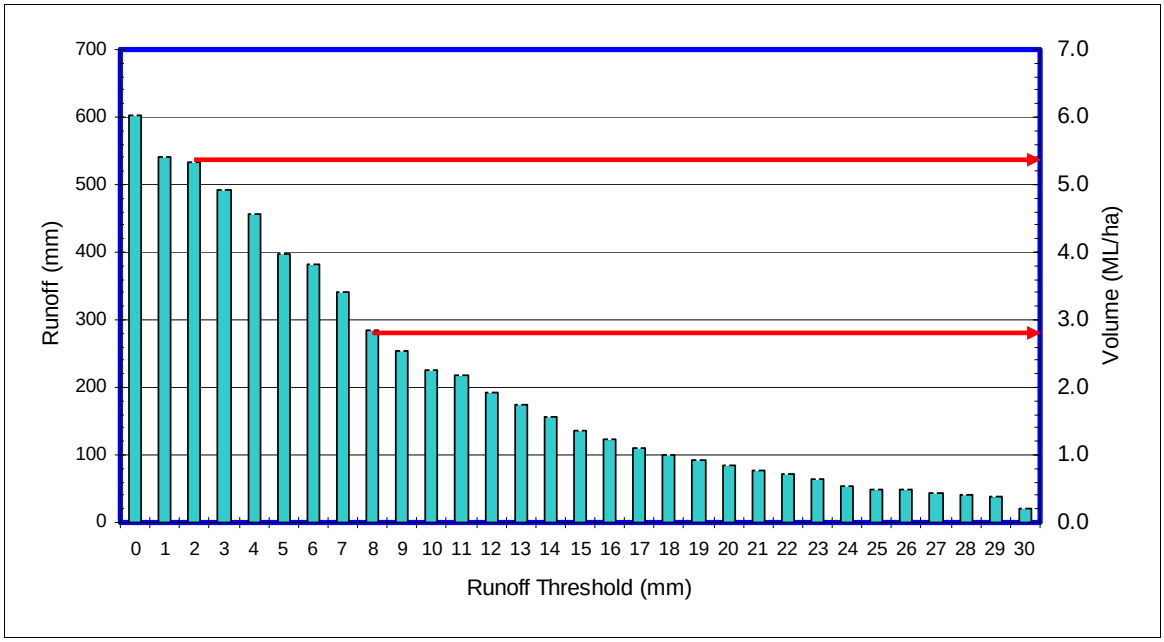


Figure 19: Comparison of the run off threshold with the quantity of runoff harvestable and therefore the volume of water stored per hectare of catchment for Frankland.

Conclusions

It is critical at the outset in planning, designing and building roaded catchment structures that many factors are considered to ensure that the large up front capital investment requires minimal ongoing maintenance and will deliver the volume of water necessary for the planned scale of operations not only for now but for the future in a drying environment.

Roaded catchments are a common water harvesting structure for the Great Southern viticulture industry to supplement the rainfall, where the ground water is either too saline or unavailable.

The roaded catchments vary widely in their efficiency to harvest water due to the surface condition breakdown over time. The surface conditions have failed mainly as a result of design and building failures.

Regular planned maintenance of roaded catchment surfaces is critical to ensure the surface condition does not deteriorate beyond a run off threshold at which point the quantity water harvested is below that necessary to ensure sufficient water in a below average rainfall year.

Overall Conclusions

With a drying climate in the Great Southern wine growing region, it is imperative that vineyards manage for more seasonal variability and a long term continued trend of less rainfall for water harvesting. With less rainfall likely in the future it is important to ensure that water harvesting structures are working to their maximum capability and that evaporation is minimised in dams. While this project has not considered the irrigation efficiency of vignerons, this is the third component for improved water management.

While the work conducted received favourable feedback from vineyard managers, it was evident that water as a resource had not been given a dollar value in the production environment. Individual business budgets have not included ongoing maintenance of water harvesting structures and as such without regular maintenance the once off long term cost of maintenance is exorbitant and prohibitive to the business undergoing any maintenance.

Recommendations

1) It is recommended that there is an ongoing communication plan to raise manager's awareness of water harvesting, storage and use efficiency aimed at adoption of industry best practice.

   This communication plan could include financial analysis which justifies ongoing maintenance of water harvesting infrastructure and strategic use of a monolayer to reduce evaporation on major dams.

2) It is recommended that capital investment in road catchments be encouraged to maintain water harvesting and storage particularly, for summer irrigation and low rainfall years. This requires recognition of the need for initial capital investment plus an additional capital requirement for ongoing maintenance to keep the road catchments in good condition and to maximise capture of run off. This can be expressed as

   $K = K_0 + \sum k_{it}$

   where K = total capital investment;

   where K_0 = initial capital investment;

   where k_{it}= capital required to maintain the condition of the road catchments, discounted over the required period.

   These costs need to be understood by industry prior to undertaking any developments.

3) It is recommended that a cost/benefit analysis is undertaken to quantify the benefits of undergoing regular maintenance on roaded catchments to ensure adequate water supply in comparison to un-maintained catchments that are failing to supply adequate water on an ongoing basis. This process will develop a methodology for quantifying the value of water to a business in terms of the vine quality, quantity and profitability.

   This could be undertaken as a series of case studies with individual vineyards or as a benchmarking study comparing a number of businesses. It is recognized that the value of water will vary for each business depending on the total capital outlay and the scale of each business.

   A component of this analysis will need to consider the risk of failure in below average rainfall years of the roaded catchment to supply sufficient irrigation water dependant on various run-off thresholds and the water demand as per the scale of the vineyard. This analysis linked to the frequency of average years and above average rainfall years would ascertain the long term business viability.

   The analysis should also include a cost/benefit analysis comparing the use of a monolayer to reduce evaporation and the associated increase in water supply.

   An output of this analysis will be a sensitivity analysis that will identify the value of capital investment (initial plus maintenance) relative to the additional water captured based on various assumed water values.

Appendix 1. Communication

Year 1: Demonstration of a technique to reduce dam evaporation by up to 80% using a polymer (Aquatain®).

- Demonstration site set up at Fox River Vinery adjacent to the Albany Highway and at Crystal Brook Vineyard.
- Workshop "*Rainwater harvesting and storage: - How good is your system?"* to present results. (8th of February, 2008 – See Agenda below)
- Results published to broader viticulture industry:
  - McDonald, C and Hetherington, R (2008) *Reducing dam evaporation by pouring "Aquatain®" onto the surface*. Australian Viticulture July/August Vol. 12 (No. 4) pages 82-84.
  - Hetherington, R and McDonald, C (2008) *Reducing dam evaporation by pouring "Aquatain®" onto the surface*. Western Australian Wine Industry Newsletter. No. 87 June. Newsletter of the Department of Agriculture and Food.
  - Lang, Miriam (2008) Historical rainfall trends for Frankland: where are we relative to the average? Wine Industry Newsletter, No. 86 March. Newsletter of the Department of Agriculture and Food.

Year 2: To benchmark the runoff efficiency of 15 roaded catchments in the Great Southern Region

- 10 individual and confidential property specific reports delivered to property managers
  - Lang, M (2009) Benchmarking study of the runoff threshold of roaded catchments of the Lower Great Southern:- Ferndale Vineyard. Department of Agriculture and Food.
  - Lang, M (2009) Benchmarking study of the runoff threshold of roaded catchments of the Lower Great Southern:- Ferngrove Vineyard. Department of Agriculture and Food.
  - Lang, M (2009) Benchmarking study of the runoff threshold of roaded catchments of the Lower Great Southern:- Fox River Vineyard. Department of Agriculture and Food.
  - Lang, M (2009) Benchmarking study of the runoff threshold of roaded catchments of the Lower Great Southern:- Frankland Vineyard. Department of Agriculture and Food.
  - Lang, M (2009) Benchmarking study of the runoff threshold of roaded catchments of the Lower Great Southern:- Hay View Vineyard. Department of Agriculture and Food.
  - Lang, M (2009) Benchmarking study of the runoff threshold of roaded catchments of the Lower Great Southern:- Landsdale Vineyard. Department of Agriculture and Food.
  - Lang, M (2009) Benchmarking study of the runoff threshold of roaded catchments of the Lower Great Southern:- Pilandri Vineyard. Department of Agriculture and Food.
  - Lang, M (2009) Benchmarking study of the runoff threshold of roaded catchments of the Lower Great Southern:- Powderbark Vineyard. Department of Agriculture and Food.

- Lang, M (2009) Benchmarking study of the runoff threshold of roaded catchments of the Lower Great Southern:- Riverdale Vineyard. Department of Agriculture and Food.
- Lang, M (2009) Benchmarking study of the runoff threshold of roaded catchments of the Lower Great Southern:- Vintage Park Vineyard. Department of Agriculture and Food.
- Lang, Miriam (2008) Water: a declining resource to be managed on the vineyard especially in Frankland. Wine Industry Newsletter, No. 86 March. Newsletter of the Department of Agriculture and Food.
- Lang (2009) Every mm of rainfall counts in water harvesting. Australian Viticulture Journal July/August 2009. Volume 13, No. 4. Pp 37-43

- Each property specific report outlined the following:
  - Climatic trends of the properties closest long term weather reporting station.
  - Trends in the frequency of daily rainfall events per annum.
  - Analysis of the impact of decreased water harvesting efficiency based on current average rainfall on the volume of water harvestable per hectare of catchment.
  - Aerial and oblique Figures of the catchment infrastructure identifying the location where the runoff threshold measurements were taken and the condition of the catchment surface. The catchment area was estimated from the aerial Figure.
  - Measured runoff thresholds for various surface conditions.
  - Indicative volume (or range) of water harvestable per hectare of roaded catchment based on the measured runoff threshold and the long term average rainfall pattern for an area.
  - Management issues of the roaded catchment

- Benchmarking results for all properties to give a regional and property specific perspective.
  - Workshop "Viticulture Roaded Catchment Benchmarking Study Workshop?" (8th of May, 2009) Workshop highlighted the necessity to improve water harvesting efficiency in a drying environment, presented the results of the field assessments, and identified roaded catchment surface conditions and design flaws that were limiting to water harvesting efficiency with a special component on weed management. To wrap up the workshop a presentation was given on emerging solutions for water harvesting and the rainfall simulator was demonstrated.

Part 1: Field Day Agenda of the 8th of February, 2008.

Rainfall harvesting and storage: How good is your system?
Viticulture Field Day at Gilberts Wines

Friday 8 February 2008 8.45am-1.30pm
Lunch Provided

(Note: Now at Gilberts, not at Fox River as previously advertised)

8.45: Arrive at Gilberts Wines, Albany Highway, Kendenup

8.55 Introduction, Glynn Ward, Manager, Premium Wine Project, Department of Agriculture and Food (DAFWA), South Perth

Session 1: Harvesting the rain that falls

9.00 Good rainfall events for water harvesting are becoming much less frequent in Mt Barker, Miriam Lang, Senior Project Officer, Water, DAFWA , Albany

9.10 Many of our roaded catchments can be improved: Research at Frankland, Colin McDonald, Senior Research Officer and Rob Hetherington, Senior Technical Officer, Viticulture, DAFWA, Albany

9.25 New research on roaded catchments at Mt Barker Research Station (surface treatments), Todd Stokes, Research Officer, University of WA, Nedlands

9.35 Harvesting rainwater from vineyard rows: Current research at Powderbark Ridge Vineyard, Rob Hetherington

9.50 Costs of harvested water?? Andrew van Burgel, Statistician, DAFWA, Albany

10.00 Morning tea/coffee

Session 2: Conserving the water that has been harvested

10.30 What makes a good dam? Jill Lisson, Catchment Technician, DAFWA, Albany

10.45 Can leaky dams be repaired? Austin Rogerson, Catchment Technician, DAFWA, Albany

11.00 Windbreaks to reduce evaporation from dams, speaker to be confirmed

11.15 "Aquatain" liquid poured onto the surface to reduce evaporation from dams', Rob Hetherington

11.30 Cover crop decisions for dry or wet years: Current research at Powderbark Ridge Vineyard, Colin McDonald

11.50 Efficient irrigation: "Waterwise" training course, Peta Richards, Development Officer, Manjimup

12.00 But some people say we're not using enough water! , Rui Ferdowsian, Hydrologist, DAFWA, Albany

12.10 Lunch at Gilberts Wines

12.40 Grape grower's priorities for research in the Great Southern (from 2004): Progress report, Colin McDonald.

1.00 Key Messages from the day and Farewell, Glynn Ward

1.15 Optional extra: View demonstrations at Fox River Vineyard
-rainfall thresholds, rainfall simulator, harvesting rain from within the vineyard, 'Aquatain' study

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Department of Agriculture and Food WA
Wine Industry Association WA
Grape and Wine Research and Development Corporation

RSVP: 5 February: Phone Belinda on: 98 928 444, Email: ballain@agric.wa.gov.au

Enquiries: Colin McDonald, Department of Agriculture and Food, Albany: 98 928 481

Part 2: Workshop Agenda

Viticulture Roaded Catchment Benchmarking Study Workshop
Draft Agenda
Tuesday 5th of May, 2009
9.45 to 1.30pm.
Gilberts Winery, Albany Highway,
(10km north of Mt Barker).

9.45 am	Morning Tea	
10.00	Welcome and Introduction	Glynn Ward
10.05	Benchmarking Results	Rob Hetherington
10:20	Water harvesting efficiency in a drying environment.	Miriam Lang
10: 40	Roaded catchment maintenance	Austin Rogerson
11.00	Weed management.	John Moore
11.15	Emerging solutions for water harvesting	David Stanton
12.00pm	Wrap up	Glynn Ward
12:15pm	Demonstration of rainfall simulator	Rob Hetherington
12:30 -1.30	Lunch	

The workshop will be presenting information to the participants of a benchmarking study. Participants of the benchmarking study will be sent a report for there property prior to the workshop and are encouraged to bring the property report to the workshop. Confidentiality will be maintained during the workshop and individual properties be able to identify themselves by a alpha character.

RSVP by the 24th of April, 2009, to Kelly Hill by either leaving a message on mobile: 0417 837 983 or email:kelly.hill@agric.wa.gov.au

Further communication

It is recommended that there is an ongoing communication plan to raise and maintain manager's awareness of water harvesting, storage and use efficiency aimed at adoption of industry best practice.

To have a major impact the communication plan needs to include financial analysis which justifies ongoing maintenance of water harvesting infrastructure and strategic use of a monolayer to reduce evaporation on major dams.

The communication plan should encourage capital investment in roaded catchments in areas where the implementation of such structures will not be detrimental to environmental flows. Communication pertaining to the cost of roaded catchments needs to highlight the real cost of the initial capital outlay and the ongoing maintenance cost to preserve the roaded catchment in a good condition and maximize the capture of run off year in year out.

Appendix 2. Intellectual Property

No intellectual property has been generated as part of this research and extension project. This research has focused on the development of knowledge for industry which is contained herein.

Appendix 3. References

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Appendix 4. Staff

Staff engaged on this project include:

- Miriam Lang, Senior Project Officer, DAFWA Albany
- Colin McDonald, Senior Research Officer, DAFWA, Albany
- Rob Hetherington, Senior Technical Officer, DAFWA, Albany

Workshop contributions:

- Glynn Ward, Senior Research Officer (Viticulture), DAFWA, South Perth.
- John Moore, Senior Weed Science Research Officer, DAFWA, Albany
- David Stanton, Senior Technical Officer, DAFWA Perth
- Austin Rogerson, Senior Technical Officer, DAFWA, Albany

Acknowledgements

The report authors wish to acknowledge the contribution of the following:

Fox River Vineyard

Crystal Brook Vineyard

Gilberts Winery

The ten vineyard participating in the roaded catchment benchmarking study

The Western Australian Wine Industry Association

Appendix 5. Budget reconciliation

Budget reconciliation is supplied by the Wine Industry Association of Western Australia (WIAWA) in a separate document.