FINAL REPORT FOR SUSTAINABLE FARMING FUND

GRANT NUMBER 00/294

Name of Applicants: **Marlborough Irrigation Scheduling Clients**

Project Title: **Predictive Water Use Model For Quality Wine Production**

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July 2003

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OBJECTIVES

The main objective of this project was:

> To deliver a predictive model for the irrigation requirements of grape vines to enable sound management of the water resource available while enhancing wine quality.

Water is an important, and rapidly becoming, a scarce resource in Marlborough. Huge increases in vineyard planting (from 2,000 hectares to an estimated 5,000 hectares in the five years since 1996) is putting pressure on this resource. In some areas, such as the southern valleys, development is being restricted by water availability. The purpose of this project is to establish a model to better match the plant water requirements with seasonal weather patterns and plant growth stage to maximise the use of underground aquifers. The predictive model will also be used to better match vine water requirements to enhance the quality of the wine produced.

INTRODUCTION

Agriculture New Zealand has been conducting irrigation scheduling services in Marlborough for the last sixteen years. During this time a large amount of data and knowledge has been obtained. The objective of this project was to find a computer model, or develop one if it could not be found, to enable valid irrigation management decisions. This model would be validated using the consultants experience and the huge database of information to ensure that recommendations being made regarding when to start, how much and when to stop irrigating were realistic in Marlborough.

Shortly into the project it became obvious there was no one model or piece of software that was going to do what was required. The closest was a software programme called Probe for Windows developed by an Australian software developer. We approached this developer to see if we could work with him to redefine this programme, rewrite some important areas so as this software would be more applicable to a range of growers and a robust service in Marlborough. This software with appropriate inputs was able to tell us on a weekly basis, how much water grapevines would require for the coming week to meet a specific plan.

The other missing piece of the puzzle was being able to make predictions long term on how much water grapevines would require for the next month or whole season. It was obvious that there were some gaps in the research data that made this prediction very difficult. The Marlborough District Council had previously allocated water at a rate of 12 litres of water per vine per day but this figure was suggested to be the maximum amount the vines will use. We were much more interested in finding the actual use during the season where less water was used at the start of the season and at the end and incorporating known data as to maximum vine water use. This would then allow predictions of grape vine water requirements out to the end of the season. This is important as severe restrictions are being placed on some aquifers limiting the total water take of the growers. If a grower was allocated 77mm of water for the whole year, they get to January and they have used all the 77mm then obvious effects will be crop loss and poor wine quality. Growers needed to be able to make decisions as early in the season as possible regarding the best way to manage a limited water supply.

We worked with HortResearch both to develop a model using their existing data and added practical aspects to a new trial at Montana’s Squire Estate. The aim was to fill in some of the gaps in the information that we had to develop the long term predictive water model. This model was named WinIR.

As the two models were being developed they were simultaneously tested in the field on the properties of all growers in the research group. As weekly soil moisture readings were taken this information was fed into the computer models and results assessed to ensure predictions being made were realistic. This field validation was done for two growing seasons using Probe for Windows and for one season using our new long term predictive software WinIR.

Working in with the research at Montana’s Squire Estate was not part of the original proposal 00/294. It shows however that in a small growing region co-operation between research projects and involving research, consultants, growers and regional authorities can hugely increase the outputs from all research sources. It also ensures that research relates practically to the growers and that it is put into use in the field promptly.

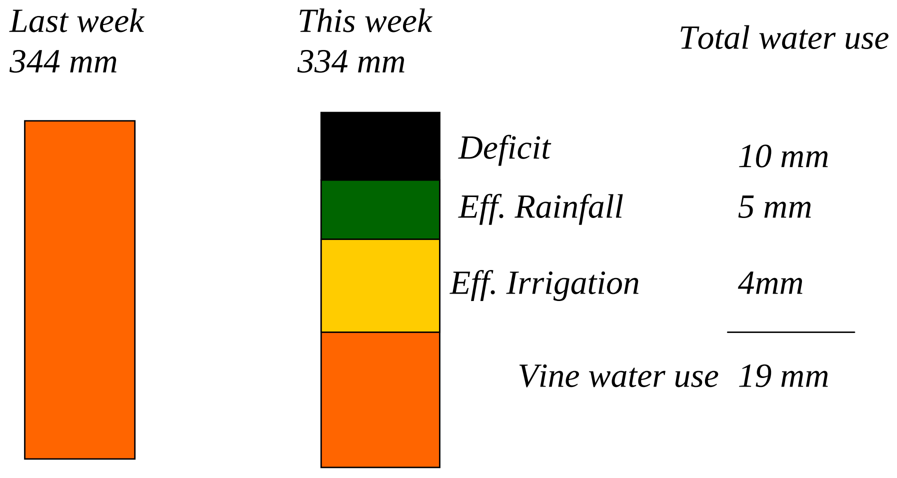
RESULTS AND DISCUSSION

PROBE FOR WINDOWS

The question that needed to be answered using this software was how much irrigation does a grower need to apply next week. Growers needed to know where soil moisture levels should be at the end of the next week and how much water the grapevines will use in that week.

The concept we developed was based on a plan for where soil moisture levels should be at any point in time during the season, was required at the start of the season. The second piece of information was how much water the grapevines are likely to use in the next week. A water balance equation based on accurate soil moisture readings was developed to determine crop water use for the past seven days. Figure one shows the simple water balance equation.

Figure One ***Simple Water Balance***



This example water balance shows last weeks soil moisture level of 344 mm this week soil moisture was 334 mm, in other words the soil moisture level had dropped. During the week there was some rainfall and irrigation was applied. However, not all of that rainfall or irrigation was available to the plant (effective). Some was lost due to interception by the crop canopy, evaporation from the soil surface and drainage. We worked with HortResearch to help determine what was effective rainfall and effective irrigation. In the example the effective rainfall was 5mm and effective irrigation was 4mm. Given these figures and a deficit of 10 mm then total vine water use for the week was 19 mm.

Based on what vine water use was last week it is possible to make some predictions on water use for the coming week. In the above example, given the same or similar weather conditions for the next week the crop use forecast is 19 mm. Using this crop use forecast the software would predict how much moisture was required in the coming week so that planned soil moisture levels at the end of the week were met. The consultant, technician or grower can then use their knowledge of soil, where down the soil profile the vines are drawing the water and visual plant symptoms to determine how best to apply this water during the week.

The water requirement could be met either by irrigation or rainfall. It was therefore important to provide recommendations in both hours and millimetres. This allowed growers to make adjustments if some of the weekly requirement was met by rainfall.

Figure Two *Probe for Windows report*

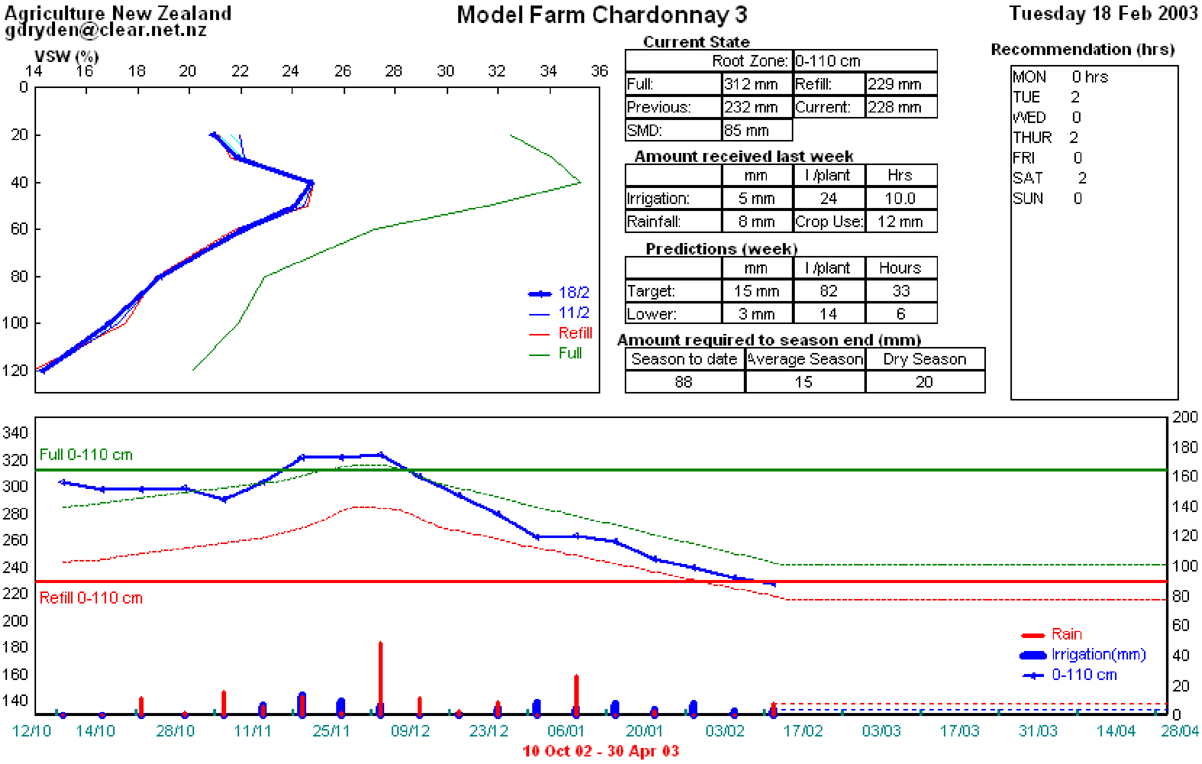


Figure two shows how all this information was incorporated and presented as a report from Probe for Windows. This is the grower report that is used on a weekly basis for recommending irrigation applications. This report is broken down into a number of sections. The bottom graph (Time Graph) shows the soil moisture level in the root zone for the season to date. The time graph also shows the plan as to where the grower wants soil moisture to be at any point during the season. This plan is shown with the two parallel dotted lines. The bottom of this graph shows irrigation and rainfall events.

The graph in the top left portion of figure two is a depth graph and shows the soil moisture measurement down the soil profile. The lines to the extreme to right and left show full and refill point respectively. Full point is the maximum amount of moisture that the soil can hold and refill point is soil moisture level at which the vines would be under mild stress. Between these two lines are this week and last week's soil moisture reading with the change shown as a shaded area.

The figures in the middle of the page show information regarding soil moisture status, irrigation, rainfall, crop use and predictions for the coming week. The output from WinIR (discussed later in this report) is also shown and includes the predicted amount of irrigation required to the end of the season.

The current state table shows the current soil moisture measurement over the stated rootzone. This can be compared to the full point, refill point and the previous weeks measurements.

The SMD (Soil Moisture Deficit) is the difference between the current reading and the full point.

The amount received last week table shows measured irrigations and rainfalls. An in-line water meter as shown in figure three measures irrigation and rainfall is measured using a rain gauge on each property. The crop use is determined by the soil budget as shown earlier. The predictions table is really important part of this report. This is effectively showing the amount of irrigation or rainfall needed to either maintain the soil moisture halfway between the two target lines (target) or, in this example, to hit the lower line (lower). This information is shown in both millimetres, litres per plant or hours of irrigation. This has been calibrated to each irrigation system for each site.

The recommendations box in the top right hand corner gives the irrigation recommendation from the predictions divided up during the week. This is entered manually by the irrigation technician and is the human input into the system. The technician makes the final recommendation based on the predictions, the depth graph, visual vine status and other vineyard management related factors (e.g. system capability). It is very important that any irrigation scheduling is not based solely on measurement but on the vineyard as a whole.

Figure Three *Water meter*

WinIR

As described earlier, WinIR is used to determine long-term irrigation requirements. The options are for a seven day period, a twenty eight day period, or to the end of the growing season. The last two are the more practical and the PRWIN report commonly incorporated the prediction to the end of the growing season.

To predict long-term irrigation requirements it was necessary to correlate crop use measurements from a soil based water balance with predicted crop water use. Predicted crop water use could then be tied with long-term weather records to determine likely irrigation requirements. A commonly used formula for calculating plant water use involves the use of Penman ET (or evapotranspiration, or Reference ET, ET_o). This is then multiplied by a crop factor in order to determine likely plant water use (ET_c). This is based on fully irrigated grass and this is assigned a crop factor of 1. It was important for us to determine a crop factor for grapes in Marlborough. Working with HortResearch at Montana's Squire Estate instrumentation was set up to determine crop water use and derive this crop factor. Some of this instrumentation included light sensors to determine crop interception of net radiation, as shown in figure four. Soil moisture probes such as TDR (Time Domain Reflectometry Probes) are shown in figure five and heat pulse sensors to measure actual vine water use as shown in figure six.

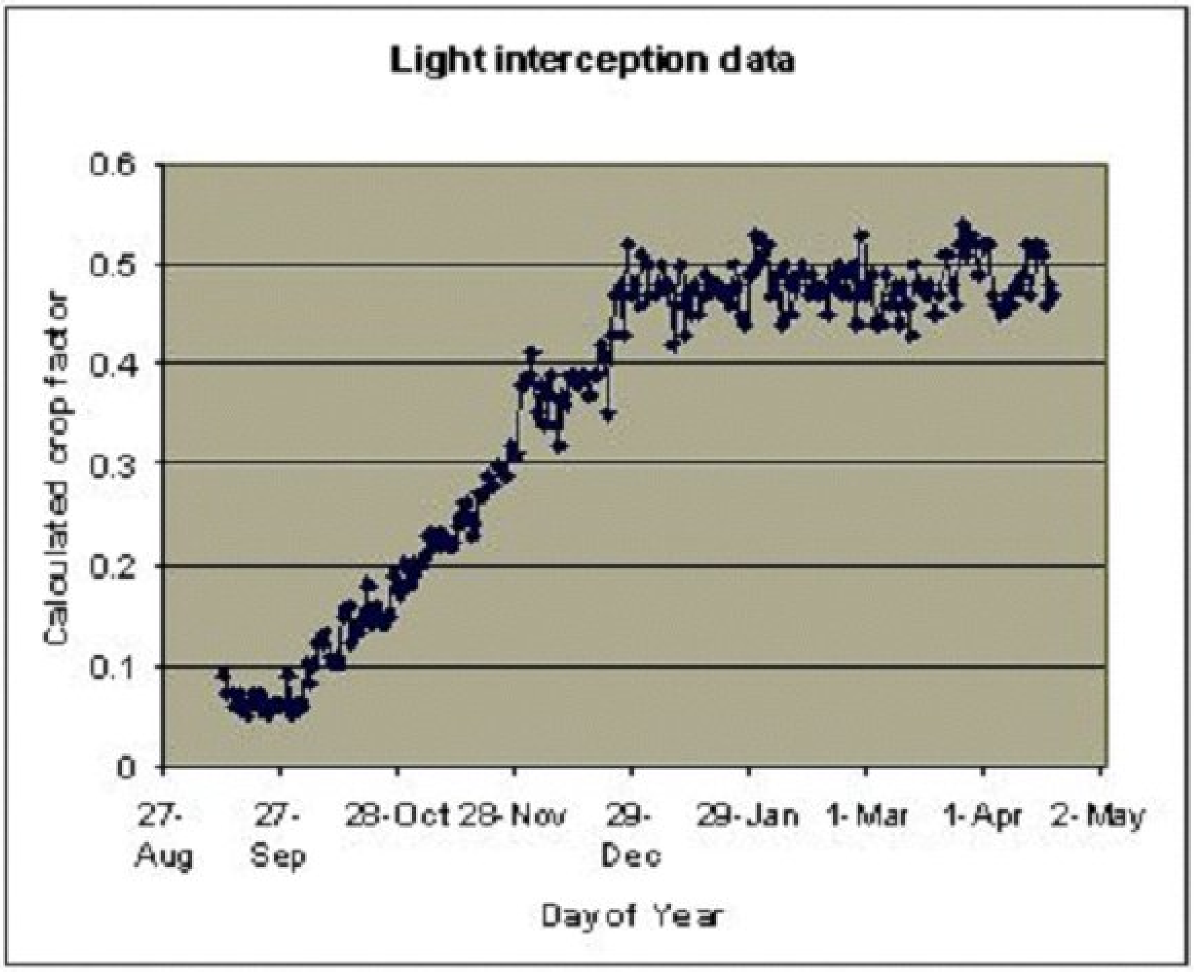
Figure Four *Light sensors for measuring light interception.*

Figure Five *TDR rods*

Figure Six *Heat pulse measuring equipment*

From the data collected by the light sensors a graph of light interception was used to develop a crop factor for grapes in Marlborough. This is shown below in figure seven. This effectively shows a maximum crop co-efficient of just under 0.5. In effect this says wine grapes in Marlborough at full canopy are using just under one half the amount of water a fully irrigated grass paddock would be at the same time. It was also shown that crop factors were directly related to canopy size. A vine with a smaller canopy had a smaller crop factor than a vine with a larger canopy.

Figure Seven *Light interception data showing correlation with crop factor*

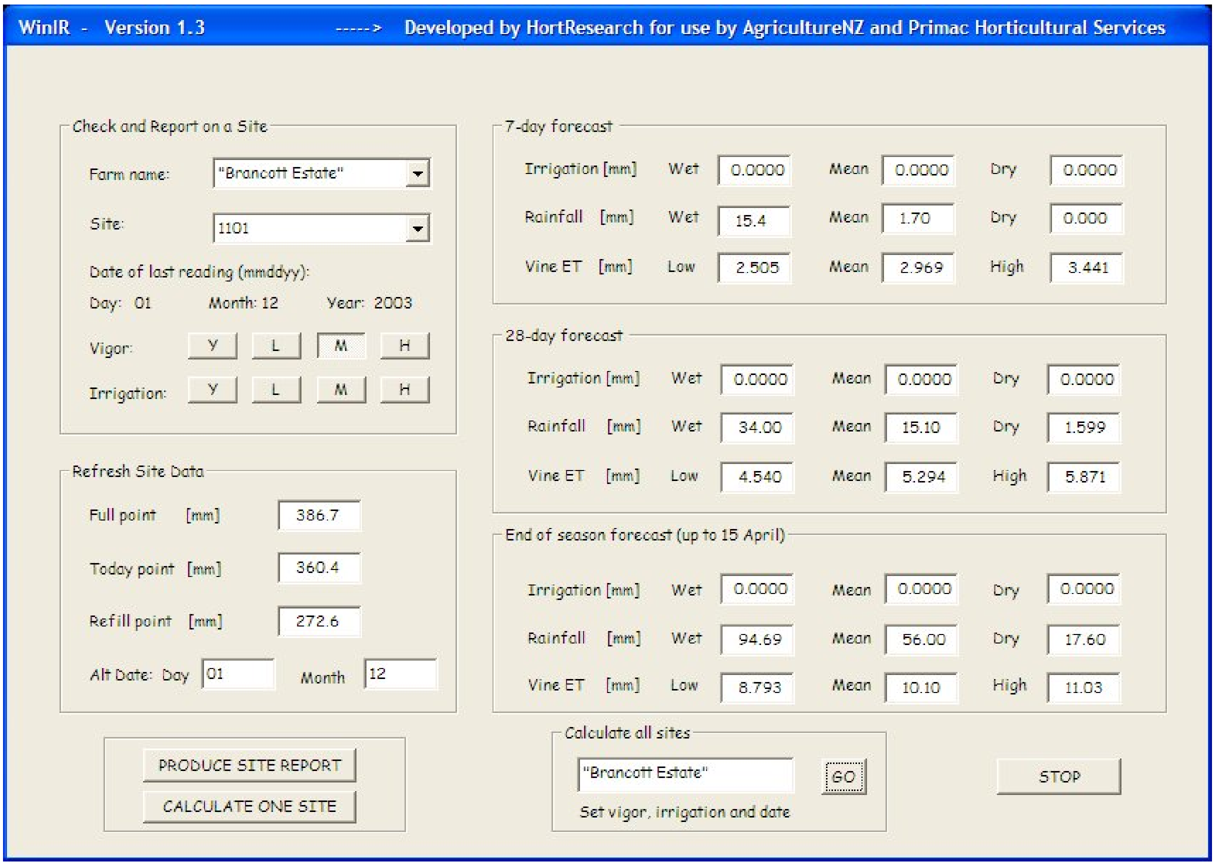


The crop use calculated by the soil based model and the modelled crop use (ET_c) was correlated with the sap flow measurements. All three methods, while not always perfect, gave similar estimates of crop use.

Crop factors were adjusted for every monitor site based on an estimate of their relative vigour. WinIR would then use these crop factors and long-term (since 1972) ET records to predict crop use. This would be combined with the current soil moisture status, the grower's soil moisture plan (as previously described) and long-term rainfall records to determine likely irrigation requirements. WinIR outputs the likely amount of irrigation, rainfall and vine ET for the next seven days, twenty-eight days or till the end of the season (nominally considered the 15^{th} April). In order to account more realistically for seasonal rain variation, such as La Nina and El Nino years, this information is presented for a wet, dry or normal season.

WinIR could then be used to test different irrigation or vine management strategies to alter the predicted amount of irrigation required. This will be particularly useful where the predicted requirement exceeds the actual amount of water available. The output from WinIR is shown as figure eight.

Figure Eight *WinIR output*



WHAT DOES IT ALL MEAN?

These modelling tools have led to a greater understanding of vine water use and provide a framework for understanding irrigation effects on grape ripening and wine quality. While having modelling tools is a huge advantage it is important to ensure that you are using them to gain an overall benefit to the water resource and to the product. There is no doubt that managing irrigation effectively can allow you to control vine vigour and influence grape ripening and ultimately wine quality. Figures nine and ten show what is possible through different irrigation regimes. Figure nine shows vines that have a much more open canopy compared to those in figure ten. This was achieved through managed soil moisture deficits and vine water stress.

Figure Nine *Good vigour control on Sauvignon Blanc*

Figure Ten *Vigorous Sauvignon Blanc requiring excessive trimming and plucking*

Reduction in vigour will result in a number of important managerial and environmental advantages. This includes less trimming and less spraying for pests and diseases both reducing fuel consumption and soil compaction. Irrigation will also be reduced as the smaller canopy uses less water and the vines use a greater amount of the soil available water.

While using the formula described before Et_o x Kc = Et_C or crop water use we can determine the irrigation requirements for fully irrigated grape vines in Marlborough. In the 2002-2003 season this was calculated at 198mm of irrigation per year (an average to dry season). The calculations below show the average irrigation applies by the applicant group compared to Etc and the standard Marlborough District Council maximum allowable water use in water permits.

Savings based on Etc calculation

	Total Water	Effective Rainfall	Irrigation
Calculated Water Requirements	325mm	127mm	198mm
Average Water Applied	236mm	127mm	109mm
Savings			**45%**

Savings based on District Council calculation

Irrigation allowed	220mm
Average Irrigation applied	109mm
Savings	**50.5%**

Volume of water saved

Est area of participant group	3000ha
Average water saving	89mm
Average water saving	890 m3/ha
Total average water saving	2.67 million m3

If we were to look at this over the whole Marlborough province, with say 6000 hectares of grapes, a saving of just 1mm per year is a saving of 60000 m3 or thirty 50 meter swimming pools 2 meters deep and 20 meters wide.

INTERNATIONAL GRAPE GROWING

During the term of this project we have been fortunate to have been able to travel to Australia and to the Napa Valley in California to assess irrigation management strategies in these two major vine growing areas. It soon became obvious in both areas that the technology and quality of information being used by Marlborough growers far surpassed their colleagues in both Australia and the US. While monitoring systems in Australia were very sophisticated the quality of interpretation of the data was less impressive. This was evident by the amount of work to upgrade the Probe for Windows software to enable it to become useful in our situation. In California the system used for determining when to start irrigation is based on a totally different system to us and uses leaf water potential. This effectively measures a stress level in the plant. While this is very useful for establishing a point of when to start irrigating it serves little use in determining how much irrigation to apply, how best to apply that irrigation and when to stop irrigating. The solution for most Californian growers seemed to be a weekly irrigation or perhaps once every two weeks and effectively applying the amount of water that they applied last year during that time. Some growers were using an ET_c based system with a number of ‘fudge factors’ to determine the amount to apply. During our time in the US we gave seminars to sixty leading wine companies and irrigation consultants from around the Napa and Sonoma Valleys. These were extremely well received and invitations to return have already been received by us.

WHERE TO FROM HERE

While we are leading the world in our irrigation management technology so far we have yet to push the boundaries. We have effectively been irrigating the plants to what they want as opposed to what they need. There are also huge efficiencies to be potentially gained from changing management strategies and the use of deficit irrigation at different times of the season. There is potential to move grape growing into much more water short areas should we be able to significantly reduce the amount of irrigation input by careful management. Research has shown that the potential may be to reduce the inputs to 25% of our ET x KC or 25% of 200mm (50mm per year). This could have a huge impact in water short areas and in districts like Marlborough where they are becoming dominated by vast plantings of vineyards. New Zealand is a young country geologically and as a consequence we are still learning about how our aquifers work. In order to protect our water for future generations and for other users we must do all we can to ensure our water resource is used to its maximum efficiency.