Supporting education of youth in sustainable water management

Draft report to Riverland West Landcare Group on the Young Irrigator Trial 2011/12

1 Introduction

As part of the project - Supporting education of youth in sustainable water management the Riverland West Landcare Group in conjunction with staff of Natural Resources SA continued to work with the Young Irrigator Group throughout the 2011/12 period.

This report chronicles progress against the following targets detailed in the original application:

Project Objective	Activity undertaken
1. Develop an improved understanding amongst young irrigators of the risks of de-nitrification and nitrous oxide emissions from the use of nitrogenous fertilizers	2 workshops held, one developed basic understanding of macro and micro nutrient usage, the second delved into the chemistry of fertilizer usage
2. Expand the use of on farm equipment installed under the previous round from soil solute analysis for soil salinity control to integrate field analysis of soil nitrate presence before, during and after the fertigation season	Soil monitoring for nitrate was undertaken at all 17 sampling sites between Cadell and Woolpunda. Of these the results of 2 of the sites have been utilized in developing the basic guidelines
3. Investigate the depth of irrigation calculations and the risks of nitrate leaching at a per trial site basis	A combination of examining capacitance probe graphs (as representations of drainage events), soils data and soil solute nitrate test strip data has been evaluated
4. Provide training to the young irrigators in relation to the use of nitrogenous fertilizers, particularly with respect to the risks associated with de-nitrification and the potential for nitrous oxide emissions; and write this up in a series of brief guidelines at the end of the season.	2 x workshops held as per point 1 and trial data communicated to YIG's together with interpretation of results throughout the 11/12 growing season – guidelines as per this report
5. Build on the introduction to the pressurized irrigation code of practice guidelines undertaken in 2010/11 through on farm review of property scale consistency with the guidelines at all of the previously established sites	Riverland West Landcare Group
6. Build capacity of young irrigators to provide leadership within their industry into the future and build strong relationships with Government departments	Riverland West Landcare Group

Table 1: Objectives of grant and record of key contributing activities

2 Achievements against objectives

Objective 1

Develop an improved understanding amongst young irrigators of the risks of de-nitrification and nitrous oxide emissions from the use of nitrogenous fertilizers

The project undertook two dedicated training sessions for the young irrigator group. The sessions were split into a preliminary one day workshop on the fundamentals of macro and micro nutrients. This course was run by Brian McLeod of Australian Perry Agricultural Laboratories. Brian has previously assisted the Young Irrigator Group with interpreting many of the soil tests undertaken at trial properties involved in the project. The timing

of the first course was designed to coincide with some of the latter fertigations that growers would be undertaking in the early part of the season. Most of the YIG's are tree and vine crop growers.

Course content was presented electronically to a group of 10 of the YIG group at Banrock Station on 21/11/11. The course content was an examination of all of the macro and micro nutrients relevant for crop and livestock growth and examinations of how local soil pH can be limiting the uptake and availability of key nutrients. Many questions were answered with respect to which fertilizers and application techniques worked best in the Riverland region.

Figure 1: YIG's undertaken training with Brian McLeod on 21/11/11

All attendees received a comprehensive course manual which would form a valuable component of any on farm fertilizer usage decision making process into the future.

Key outcomes: 10 Young irrigators successfully undertake advanced training in the application and usage of macro and micro nutrients for irrigated cropping situations.

A secondary course was run on 22/6/12 to improve understanding around the molecular composition of nitrogenous fertilizers, de-nitrification risks and the potential for a carbon constrained future in agriculture. This course was run by Greg Butler of the South Australian No-Till Farmers Association. Greg has extensive industry experience in both broad acre and horticulture and his intimate knowledge of soil, soil water and fertilizer chemistry provided a revealing insight into what happens when you apply fertilizers to soil with water.

The course started examining the molecular compositions of water, soils and a range of common agricultural fertilizers such as mono-ammonium phosphate and di-ammonium phosphate and urea ammonium nitrate. Greg used a number of power point based animations to show how the nitrogen cycle works with the varying form of nitrogen, including the processes of ammonification, de-ammonification and de-nitrification. In all cases the material was presented in a very progressive and easy to understand format.

The final part of the training session focused on de-nitrification risks in practical situations and the potential for identifying and reducing risks on farm, particularly with regards to nitrous oxide generation. This worked well with the results of field monitoring undertaken as part of the overall project which found some mild occurrences of de-nitrification at monitored soil solute monitoring sites. Greg also covered the risks associated with methane emissions and the preliminaries of the carbon farming initiative.

Greg's powerpoint is attached as a reference to this activity.

Key outcomes: 9 young irrigators successfully undertake advanced training in understanding the nitrogen cycle and the implications of using nitrogenous fertilizers on farm. Irrigators also develop improved knowledge of the carbon farming initiative and the opportunities and relevance of this initiative to their own production systems.

Objectives 2 & 3

Expand the use of on farm equipment installed under the previous round from soil solute analysis for soil salinity control to integrate field analysis of soil nitrate presence before, during and after the fertigation season; & Investigate the depth of irrigation calculations and the risks of nitrate leaching at a per trial site basis

The soil solute extractor network used in both 09/10 and 10/11 was re-utilized for the 2011/12 period to examine the occurrence of both nitrate (NO_3), nitrite (NO_2) and electrical conductivity (EC) of irrigated water after application and percolation into the soil. Of particular emphasis in the 11/12 project period was the investigation of whether the soil solute system could provide meaningful indications of nitrate/nitrite presence based on the use of field test strips. This approach has had little uptake and use by irrigators but potentially

represents a much more practical and ‘ready’ approach to interpreting the effectiveness of fertigation activities. In particular the utilization of the method enables the irrigator to assess the concentration of applied NO_3 by irrigated depth (in line with the depths of solute extractors – generally 30cm, 60cm and 90cm).

Sampling was undertaken at all of the 17 soil solute sampling sites. A table chronicling the location and crops at each of the sampling sites is detailed below in table 2.

Name	Location/Crop	Sampler ID	Monitored
Justin Loffler	Waikerie/Stone fruit	J Loffler Plums	EC, NO_3, NO_2
	Waikerie/Stone fruit	J Loffler Persimmons	EC, NO_3, NO_2
Dave Arnold	Waikerie/Citrus	D. Arnold Home Block	EC, NO_3, NO_2
	Ramco/Citrus	D. Arnold Schiller’s	EC, NO_3, NO_2
Paul Wurst	Waikerie/Pistachio	P. Wurst (North)	EC, NO_3, NO_2
	Waikerie/Pistachio	P. Wurst (South)	EC, NO_3, NO_2
Craig Miller	Qualco/Winegrapes	C. Miller (Rise)	EC, NO_3, NO_2
	Qualco/Winegrapes	C. Miller (Swale)	EC, NO_3, NO_2
Steve Liebich	Cadell/Winegrapes	S. Liebich (West Row 36)	EC, NO_3, NO_2
	Cadell/Winegrapes	S. Liebich (West Row 16)	EC, NO_3, NO_2
	Cadell/Winegrapes	S. Liebich (East Row 36)	EC, NO_3, NO_2
Angus Reid	Morgan/Citrus	A Reid (Young Washy’s)	EC, NO_3, NO_2
	Morgan/Citrus	A Reid (Old Citrus)	EC, NO_3, NO_2
Dave Liebich	Taylorville/Winegrapes	D. Liebich (Colombard West)	EC, NO_3, NO_2
	Taylorville/Winegrapes	D. Liebich (Colombard East)	EC, NO_3, NO_2
Jim Thomson	Woolpunda/Winegrapes	J. Thomson (Rise 98)	EC, NO_3, NO_2
	Woolpunda/Winegrapes	J. Thomson (Swale 34)	EC, NO_3, NO_2

Table 2: Location of soil solute monitoring sites which operated under the project in 2011/12

Courtesy: Sentek

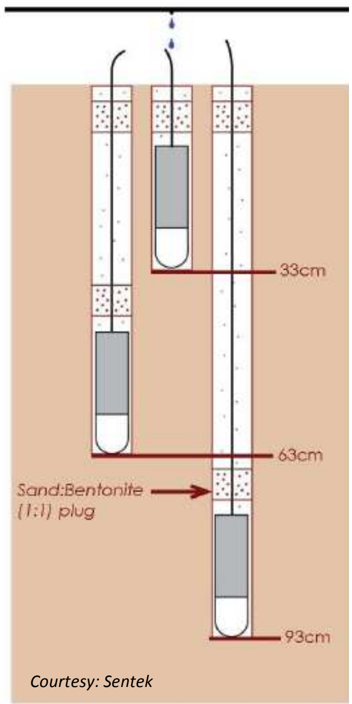


Figure 2: Clockwise from left - An uninstalled solu sampler showing porous cup vacuum tube and isolation tap; view of a standard established 3 sampler site in a vineyard showing syringe extraction technique; diagram of preferred extractor installation configuration at 30, 60 and 90 cm below ground surface; use of test strip to identify nitrate/nitrite presence in field

Commencing in November 2011 sampling of all three parameters began. It was quickly found that all sites produced zero NO_3/NO_2 results unless synthetic forms of nitrogenous fertilizer were applied as part of a general

fertigation regime. A number of sites which employed broadcast of ‘flicked’ applications of granular fertilizers did not produce any real tangible results via the solu sampler system.

This would tend to imply that either the fertilizer reacted with the atmosphere quickly and potentially ‘volatilized’ rendering any nitrate benefit to the crop as minimal, or the crop utilized the nitrogen content of this fertilizer rapidly and/or irrigated depth was not sufficient to push the nitrate down to the shallowest (30cm) extractor. The latter is likely to be the case although the general finding suggests that either broadcasting of nitrogenous fertilizers in partial cover sprinkler fed orchard situations is risky (which it can be) or that the benefits must be being solely delivered to the upper extremity of the crop’s nutritional rootzone. Developing understanding of this issue requires further investigation.

Aqueous fertilizer applications through fertigation however provided immediate signature traces of nitrate presence under most of the sites monitored. The black and white nature of nitrate presence in all of the Riverland sampling sites meant that it was possible to identify the approximate timing of fertigation activities through weekly monitoring activities. The strategy within the project was to identify fertigation activities and then highlight to irrigators when their irrigated depth was pushing nitrate beyond the reach of the crop’s rootzone. The drivers for this were of course, a) to reduce toxicity of and rates of deep drainage on groundwater systems, and b) to improve production efficiencies and economic outcomes.

A third major objective was to reduce the risks of de-nitrification as a precursor to mitigating potential for nitrous oxide emissions. Throughout the trial a handful of instances of de-nitrification were found however their incidence was generally short lived, based on identifying presence through weekly solute analysis by test strip use.

Overall the findings confirmed a definite link between irrigation and fertigation activities and de-nitrification and suggests that a more rigorous investigation of soil composition and general irrigation practice is required. In general the highest incidences were found where sites were underlain by impervious layers such as clay or calcrete which mitigated drainage and obviously were promoting anaerobic conditions. This is interesting as it suggests that future risk classifications for irrigation areas based around nitrous oxide emissions propensity in the Riverland irrigation areas could be well served by a straightforward analysis of Blanchetown Clay distribution and soil depth to Blanchetown Clay/Calcrete in irrigation areas.

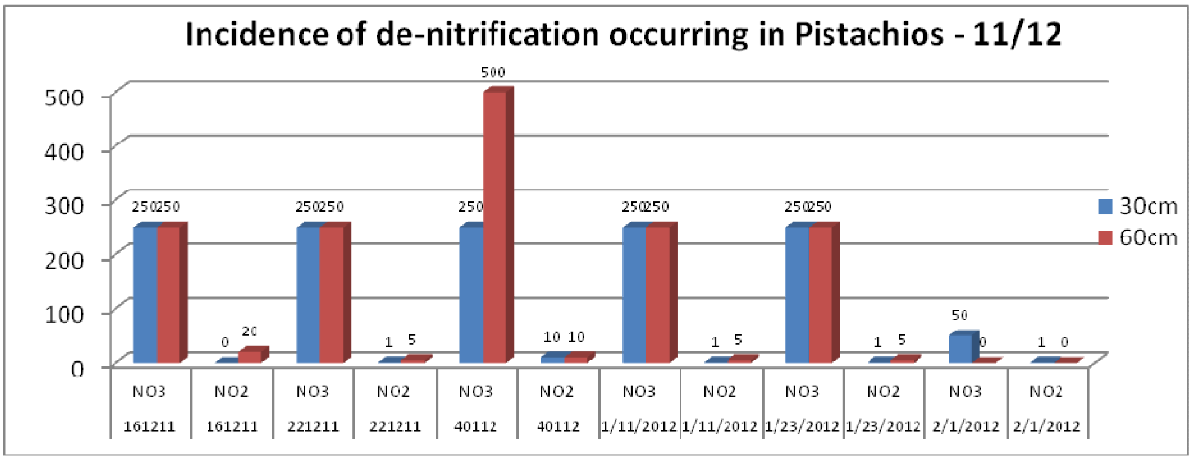


Figure 3: Incidence and pattern of nitrate increases in soil solute to nitrite results

In figure 3 the results from one of the monitoring sites (Pistachio crop) shows a run of identified nitrite presence. It can be seen that on 16/12/11 nitrite levels had risen to a modest 20 mg/L at 60 cm and that nitrate levels remained high at 30/60 cm. Nitrite concentrations continued to rise through November and into January before available nitrate became depleted, presumably through crop use/drainage . The property from which these results were taken has sheet limestone below 60 cm (hence no 90 cm sampling point) and observably due to a lack of natural drainage nitrogen rich soil water was retained for some time in the top soils. Unfortunately in practice it was found that the presence of nitrite greatly depreciated the accuracy of nitrate concentration estimations derived by test strip. When no nitrite was present the strip estimations of nitrate were found to be reasonably accurate compared to laboratory results. However even small amount of nitrite concentrations

were found to radically skew the color indication of nitrate and no pattern of correlation was identified to permit possible correction based on a nitrite concentration. There is potentially a relationship but ultimately it is unlikely that irrigators would try to employ and 'offset' correction in-field so the dynamics of this with respect to the test strip method were not investigated further.

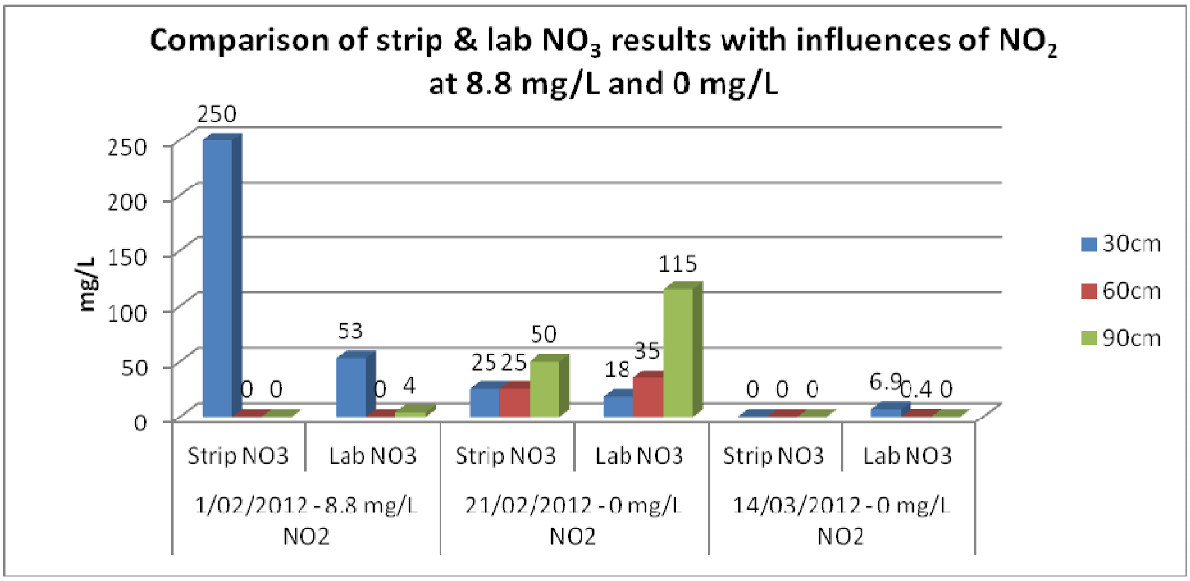


Figure 4: Sample of errors found between laboratory sample analyses and field strip estimations of nitrate and nitrite

With respect to laboratory correlation of nitrate:nitrite concentrations and accuracies in figure 4 it can be seen that at 8.8 mg/L of laboratory interpreted nitrite concentration that on 1/2/12 a test strip nitrate estimation of 250 mg/L was actually only a 53 mg/L concentration. On 21/2/12 a clear and stronger correlation between field results and lab testing was achieved at all three depths from the same sampling point and then again on 14/3/12 when both laboratory and field nitrite was at 0 mg/L. This throws into question the validity of the nitrate results in figure 3 but does prove that de-nitrification is a risk even in the lighter textured soils of the Riverland, especially when irrigated soils are underlain by heavy sediments.

2.1 Interpretation of Nitrate monitoring for irrigators

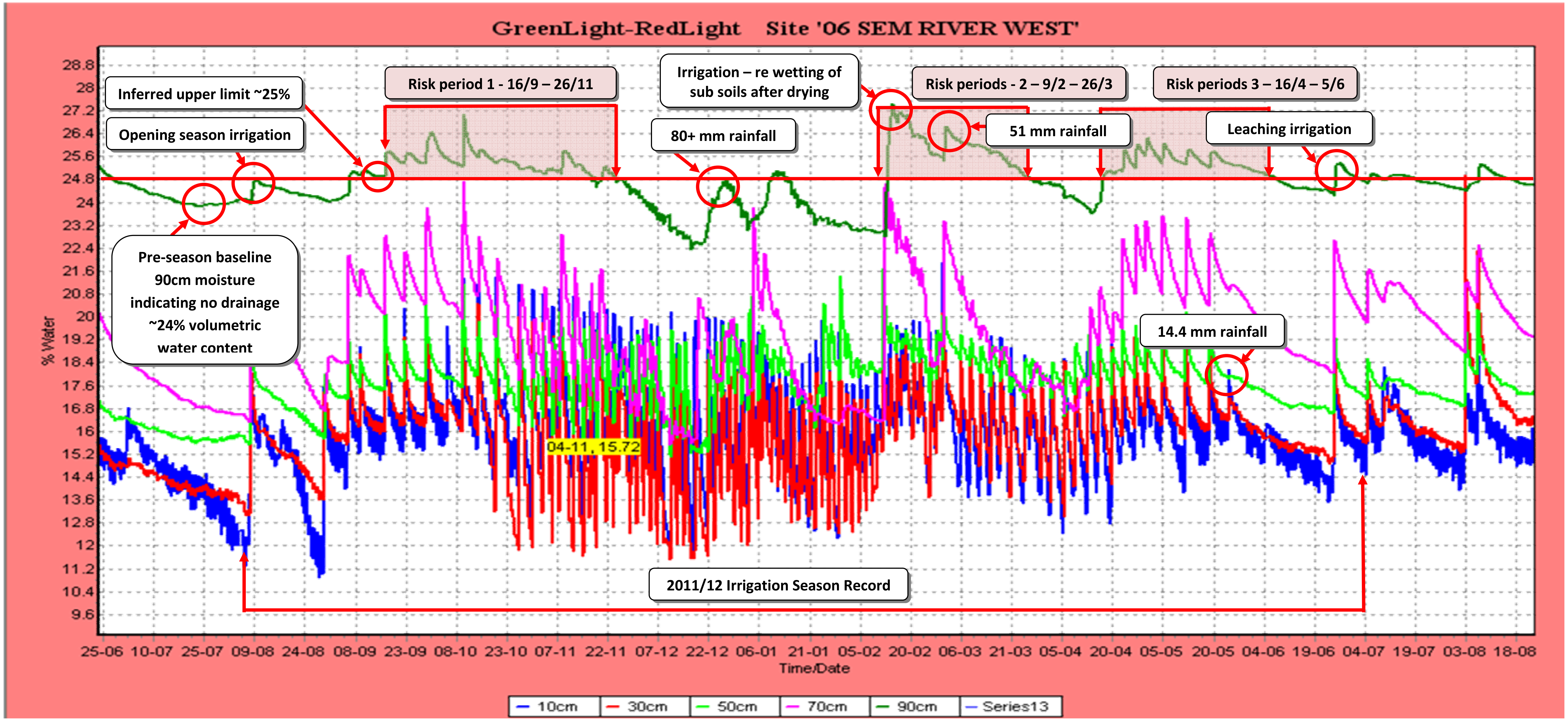
After initial clarification of the method of test strip usage at the beginning of the project a casual field sampler was employed to monitor test sites on a weekly basis. This was undertaken between mid November 2011 and April 2012.

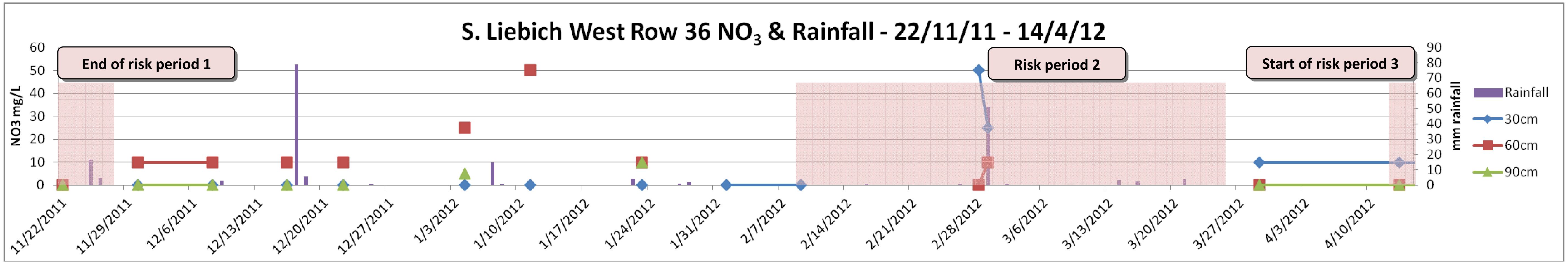
Ultimately field results were analyzed and graphed and then published back to the young irrigator group with open evaluations of developing trends and highlights of potential risks. Due to the close working nature of the group no problem was identified in publishing an all property excel workbook containing named property graphs of field monitoring results by email. Phone calls to various growers were undertaken during the season and a number of irrigators sought further more specialized fertilizer usage advice as a result of the program

A big consideration in promoting fertilizer use efficiency to the group was depth of irrigation and defining whether in practice excessive irrigation depth would cause nitrogenous fluxes below the crop rootzone. The objectives cited in the overall trial are noted in the previous discussions.

All sites were graphed for nitrate/nitrite and salinity trends. Of the 17 sites utilized in the trial two were specifically selected for more rigorous scrutiny. Of these two sites one irrigator chose not to forward irrigation records for evaluation. The original intention with the two selected sites was to provide a detailed examination of irrigation efficiency, irrigated depth and overlay nitrate monitoring findings to highlight potential positives/negatives of conventional approaches to fertigation. As one irrigator chose not to participate this kind of analysis (which is in addition to the communications of results during the growing season) is presented in figure 5.

Figure 5: Results of field sampling for NO_3/NO_2 – Sample site – Steve Liebich West Row 36 – Capacitance Probe trace (top) and graphed nitrate/rainfall (bottom)





In figure 5 over a year's worth of irrigation capacitance probe information has been presented together with results of nitrate monitoring. The visual analysis shown in figure 5 revolves around 3 key risk periods when the inferred upper limit of the soil at 90 cm (25% volumetric content) was exceeded either by irrigation or rainfall or both.

The three derived risk periods have then been compared to the results of nitrate/nitrite monitoring in the lower graph. Although this graph appears devoid of information many of the blank spots represent periods where it was not possible to extract soil moisture under vacuum, thus indicating dry soil conditions and reduced propensity for drainage, let alone leaching.

To enable the evaluation of efficiency of irrigation relative to nitrate/nitrite results monitoring the irrigator provided the following information:

- *Monthly metered consumption at the block;*
- *Cropped area data, block size, irrigation system type, output rate, emitter and row spacing;*
- *Timing of fertigation activities and an annual fertilizer program (rates, fert brand, actual N content and target rates per hectare). These details were supplied by a district agronomist and reflected industry rates of suggested N replenishment for the target crop);*

An abridged irrigation efficiency calculation to that used in the Water Allocation Plan for the River Murray was utilized to determine irrigation efficiency for the irrigation year. This calculation was as follows:

ETo (tall crop per month) x monthly crop coefficient = ETc (Evapo-transpiration crop)

The sum of monthly crop evapo-transpiration totals was then divided by the actual metered applications summed with effective rainfall (60% of total annual rainfall received) to produce the efficiency rating which expresses efficiency at a per hectare rate. The results of the efficiency assessment for the site analyzed produced a very high efficiency of 136%.

The result means that the irrigator was able to maintain irrigation to a very precise block based requirement which was heavily influenced by the availability of the on-site capacitance probe information as a decision making tool. Overall this result correlates both a high standard of irrigation management and supports the following findings of the nitrate monitoring study -

- *Of the three key risk periods, risk period one was not fully accounted for by the timing of the nitrate monitoring trial. However, drainage events in this period were not significant or long lived and as it is presumed that nitrate levels were also low at this time that risk was minimal;*
- *During risk period two some deep drainage occurred as the irrigator re-wet the sub-surface soils (early post harvest period) after they dried back significantly in hot conditions under the maturing crop. A secondary rise in soil moisture was attributable to ~51 mm of rain and this, it can be seen in the nitrate graph led to NO3 levels at 30 cm leaching back from 50 mg/L to 25 mg/L. Conversely NO3 at 60 cm went from 0 mg/L to 10 mg/L between the period 28 – 29/2/12. This was a post harvest fertigation of urea;*
- *The short duration within which this leaching event occurred shows the rapid nature of NO3 movement in response to irrigation/rainfall in the lighter textured sandy soils of the Mallee. This also highlights that monitoring for nitrate must be consistently undertaken after events to capture the potentially rapid and transient nature of the nitrate anion;*
- *Overall the highest ever concentration of nitrate found at 90 cm of 10 mg/L occurred on 23/1/12 and this was actually one of the few samples ever drawn from this level – correlating further both the evidence of the capacitance probe (minimal drainage) and the findings of the separate irrigation efficiency assessment;*
- *An irrigation efficiency assessment of the site found that the application rate overall by month and for the year produced a 136% efficiency against the calculated theoretical crop water requirement. Capacitance probe data as per figure 5 previous also records minimal drainage and this tends to support the minimal ability to extract soil solute samples at 90 cm beyond a few occasions.*

Ultimately the project referenced the growing season risks to nitrate leaching and de-nitrification at the 18 soil solute extractor sites. As per the example just highlighted in detail this monitoring data was compared to capacitance probe data and the results published to the irrigators during the growing season.

The major finding in undertaking this assessment was that both to the focus sites displayed an excellent ability to irrigate to soil depth and fertigations were generally not accompanied by excessive over irrigation (or post wash). The main risks for de nitrification out of all 17 sites appeared to be mostly confined to where

soils were extensively underlain by heavier sediments that reduce free draining at shallow depth. These conditions were not present at either of the focus sites.

This creates opportune conditions for nitrate to reduce, presumably under the influence of resident soil microbial activity. This is a significant finding for the project as it suggests that (as previously mentioned) that future risk mapping for de-nitrification risk can be linked to the presence of sub-surface soil constraints such as calcrete, marl or clay. Such impediments are extensive in many Riverland irrigation areas and have been mapped in detail for other related issues such as perched groundwater risk in the past.

Key outcomes: **8** young irrigators successfully participate in the use of soil solute monitoring for nitrate/nitrite management with a total area of influence of **344 hectares** (irrigated)

21 irrigators improve knowledge of in season risks associated with the application of nitrogenous fertilizers through the publication of monitoring information and through monitoring activities and property visits. Total estimated area of influence of **1,310 hectares** (irrigated).

Provide training to the young irrigators in relation to the use of nitrogenous fertilizers, particularly with respect to the risks associated with de-nitrification and the potential for nitrous oxide emissions; and write this up in a series of brief guidelines at the end of the season.

Training provided to the YIG group was discussed previously in section 2, objective 1. Essentially all young irrigators have been trained in the use of the soil solute system. This training goes back to 2010 with the initial training in soil salinity management through field analysis of soil solute. This training has been progressed through this project to utilize the same extraction and set-up methods but differing tools, (i.e. test strips) in addition to a hand held EC meter used for conductivity assessments.

This project has provided irrigators with an improved means to build on managing annual soil salinity trends through the additional ability to reliably detect the presence and concentration of the nitrate anion as an indication of fertilizer movement and behavior in the crop's root zone.

Additionally this work has also extended to opening up a basic method of identifying the occurrence and approximate duration of de-nitrification events. In practice it is suggested that the approaches developed through this project have a high reliance on a supplementary capacitance probe installation per monitoring site to enable cross validation of soil moisture conditions (this has been the case in all of the installations undertaken in the 3 year history of the YIG group).

In reality in today's Riverland an ever increasing percentage of irrigators have one or more capacitance probe sites so the application of the soil solute technology more widely for the purposes sought through this project is not seen as unrealistic. In a future likely to comprise a higher carbon accounting liability per landholder/production system the results of this project can only be viewed as beneficial.

This is particularly evident when considering the new generation of Federal Government programs aimed at encouraging the rural sector to reduce green house gas emissions and to sequester carbon. It is currently accepted that nitrous oxide emissions are some 298 more damaging to the earth's atmosphere than carbon dioxide emissions.[1] The results of this project which exposed episodes of de-nitrification suggest that nitrous oxide generation is occurring and this is a particular focus of the Federal Government's current Carbon Farming Initiative which nominates the proven reduction of nitrous oxide generation at a local level as a credit generating activity.[2]

The relevance of this matter to this objective and the overall discussion is that the guidelines provided for measuring nitrate/nitrite in this report should form the basis for further exploratory work by the irrigation community and research partners. If the field based method utilized in this project could be reliably spliced to reliable estimates of nitrous oxide generation/ha the way would be paved forward for landholder's to develop N_2O reduction methodologies for the Federal Government to consider.

Ultimately such activities could conceivably result in the generation of income streams for irrigators into the future based on their ability to uphold a consistent standard of irrigation practice. The guidelines presented in the following section should provide a good starting base from which such projects could start. Certainly in conclusion the validity and applicability of the overall approach has been demonstrated successfully within this project setting.

[1]http://www.worldpreservationfoundation.org/blog/climate/un-ipcc-states-that-nitrous-oxide-n2o-is-298-times-more-powerful-than-carbon-dioxide-as-a-greenhouse-gas/ [2] http://www.climatechange.gov.au/cfi

3 Guidelines for nitrate/nitrite management in irrigated vineyard/orchard situations in the South Australian Murray-Darling Basin NRM area

The establishment of potential monitoring sites need to be assessed firstly against the relative performance of the irrigation distribution system and the fertigation system. Where broadcast fertilizer is applied testing can still be undertaken however little evidence of nitrate presence was found when broadcast fertilizers were utilized, suggesting that the solu sampler method may not be adequate to identify both passage and/or de-nitrification or volatilization risks in this instance.

Step 1 – Assess irrigation delivery system performance

Before looking for site locations to install solu sampler equipment or to implement the monitoring method it is necessary firstly to undertake an assessment of irrigation system performance and soil moisture holding capacity. Main and delivery system pressures should be recorded with emitter pressures being recorded at various points through the irrigated valve patch to determine what the percentage fluctuation is across the valve. To undertake this test it is recommended that a 0 – 250 kpa pressure gauge is used together with a suitable screw on adapter that will enable both sampling from pressure monitoring points or directly from emitter orifices. Main system operating pressures are generally visible through the installation of permanent gauging around the point of main delivery.

Both pressures at the emitter and emitter flow rates should be recorded within each irrigated valve by monitoring at the beginning/mid and at the end of crop rows at a staggered frequency across the valve to provide sufficient information to identify what the upper and lower ranges of pressures and emitter outputs are.

This is particularly important where systems are not pressure compensated, eg. Under canopy sprinklers or where changes in system elevation/depression occur. Record emitter output rates and determine an average application rate in mm/hr by performing the following calculation after having converted 1 minute volumes to hourly equivalents, i.e. (1 minute result in ml x 60 = output rate in ml/hr which can then be converted to L/hr):

$$\text{Application rate (mm/hr)} = \frac{\text{L/hour recorded at emitter}}{\text{Emitter spacing (m) x row width (m)}}$$

Refer also the method in the referenced fact sheet.[1]

Step 2 – Assess the performance of the fertigation delivery system

Mix marker dye with water to be injected at a suggested rate of 5L dye : 1000 L of injected water. Operators should be cautious not to mix too strongly allowing time for an addition of dye to a fertigation tank to fully mix out before any supplementary additions. Using two persons in the field position one person at one of the closest emitters to the mainline delivery and one at the farthest emitter from the delivery system. Both persons will need a small measuring jug, a stop watch and a means of communicating. After starting up the irrigation of the valve in question commence the test of the fertigation system when irrigation system pressures are normal. Both persons in field need to start recording time from when the fertigation system is activated until dye is collected at a consistent visual clarity in their respective measuring jugs at their monitoring points. The time taken to reach the farthest point essentially becomes the minimum wash out time period required to be sure that fertilizer has been adequately purged from the system after fertigation.

At an example property the duration taken from the time of the commencement of injection to the time to reach the nearest point was 13 minutes. Time taken to reach the farthest emitter was 25 minutes. This therefore means that a post fertigation 'wash out' should be greater than 25 minutes to adequately clean out the irrigation system.

[1]http://www.samdbnrm.sa.gov.au/Portals/9/Publications%20and%20Resources/Fact%20Sheets/Water/Irrig%20fact%203.pdf

Step 3 – Determine the mean readily available water content

If a target property has no readily available water (RAW) mapping or no investigations have ever been undertaken it will be necessary to undertake soil coring in a similar configuration to that undertaken during the emitter auditing.

Challenges arise in all irrigation areas where greatly varying RAW contents reside within one irrigated valve. This is where the operator must experiment with irrigation hours relative to a median RAW between all identified sites to find irrigation shift lengths that provide enough for soils of greater depth (and presumably crops of greater vigour) but which do not cause excessive drainage at neighbouring sites which have limited moisture holding capacity. An irrigation valve that straddles a sandhill and a clay flat is a classic example of where this can occur. Guidelines for undertaking a RAW assessment are detailed in the attached fact sheet.[1] An example of a 30 mm RAW is used in the calculations in step 4.

Step 4 – Determine crop water requirement, irrigation shift length and irrigation interval

Having determined the RAW content of your soils at a per hectare level it is essential to visualize this total RAW as a function of the wetted area delivered by your irrigation system. As a general rule drip irrigation is considered to generate a wetted area that is only one third of the total cropped area 33% of the total cropped area. With under canopy systems that extend spray patterns into the inter row this may extend to what is termed a half coverage system 50% of the total cropped area. Where doubts exist mark out the extent of the wetter areas of your system and measure them as a percentage of total row space (from trellis to trellis or mound centre to mound centre).

Full coverage systems in orchard/vineyard systems are far less common in today's irrigated industry but some overhead sprinkler systems that function well could be rated as full coverage systems or (1.0) - 100% coverage. Surface irrigation methods such as flood/furrow irrigation require broadcasting of fertilizers and are not covered by these guidelines.

Assuming that the soil profile is at the point of requiring a full recharge of soil moisture the following example shows how to integrate the emitter rate calculations done at step 1 with the RAW values derived at step 3 with the use of climatic data and averages to work out a basic irrigation schedule. The targeted fertigation is then derived as a component of this irrigation shift to show how irrigated depth and timing need to be accounted for to deploy nitrate to the target depth of 30 cm below the soil surface.

Example – Drip irrigated vineyard in Riverland

A) Determine Crop Water Requirement
Either access recent daily reference crop evapo-transpiration rates from your nearest weather station[2] or use the average ETo figures in the online consumption tracking tool.[3]. Multiply this figure of daily reference crop water use by a monthly crop coefficient
Reference Crop Evapo-transpiration (tall crop) x monthly crop coefficient
4.1 mm/day for October x co-efficient value of .63
= 2.6 mm/day theoretical crop water use for November

B) Calculate Irrigation Interval
Divide rootzone RAW by Daily Crop Water Use (CWU)
Rootzone RAW (example: drip system ~33% coverage)
= 30 mm RAW x .33 = 9.9 mm RAW for a drip system
9.9 mm divided by 2.6 mm/day
= 3.8 days between each full depth irrigation

[1] http://www.samdbnrm.sa.gov.au/Portals/9/Publications%20and%20Resources/Fact%20Sheets/Water/Irrig%20fact%202.pdf
[2] http://www.aws-samdbnrm.sa.gov.au/ [3] www.ruralsolutions.sa.gov.au/__.../Water_Budget_Tool_v12c.xls

C) Irrigation hours
Divide rootzone RAW by system application rate
If the drip system has an output of 1.10 mm/hr this would then
= 9.9 mm RAW/1.10 mm/hour
= 9 hour irrigation

Step 5 – Determine fertigation shift length/timing

In step 4 the fundamentals of irrigation shift timing and interval were determined. It is now necessary to overlay the requirement of the fertigation. As there are so many variations between fertigation system types, output rates as well as delivery concentrations it is only possible to provide a decision making framework in these guidelines. The recommendations of agronomists and fertilizer manufacturers need to be considered when considering fertilizer mixing (from granular form) into tanking as high concentrations of fertilizer may not dilute if the water mix solution becomes saturated with high rates of dissolved fertilizer. Additionally extreme caution needs to be exercised in using tanking used for other chemical purposes for fertigation as some fertilizers can react violently with some commonly used chemical residues, such as chlorine exuding noxious fumes and creating other potential hazards.

A fertigation is essentially an add on component of an existing irrigation shift designed to additionally deliver fertilizer. Where shifts are exclusively run to deliver fertilizer questions need to be asked about irrigated depth and to what depth the fertilizer is being pushed by further irrigation. A fertigation comprises of three distinct sections, the pre – wet, which essentially creates an infiltration pathway for the aqueous fertilizer to move into the soil matrix, the fertigation period itself which is the period that system injection occurs and the post wash. The post wash is essentially the period between when the fertigation ceases being injected and when the irrigation system is shut down. The post wash needs to be long enough to ensure a high percentage of fertilizer residues are removed from the irrigation system.

This is highly important when using drip or other micro irrigation techniques where emitter orifices are small and potentially where lateral pressures in above ground delivery systems may be low, i.e. at the farthest point of the irrigation delivery system.

Using the example vineyard a target of 30 L/ha of liquid Urea Ammonium Nitrate (UAN – 42% N) has been recommended by an agronomist as a supplement with other nitrogenous fertilizers for the whole season. Of this 15 L/ha has been recommended for September and another 15 L/ha for October.

The target application rate of liquid UAN is 15L/ha, but the question that needs to be clarified is: Is this figure 15 L/irrigated hectare of 15 L/whole hectare? Most agronomists/manufacturers and irrigators generally work on target rates per planted hectare which is the total planted block size, not making compensation for variations in wetted area.

As such for the example drip irrigated vineyard the requirement for 15L/ha of UAN is calculated as follows:

15 L UAN x 8 hectares = 120 L required

The fertigation system which is a spray cart injects directly into the mainline and delivers the liquid at a rate of 100 L/7 minutes. The spray tank is 1000 L in total capacity, therefore we will require 880 L water and 120 L UAN. After checking tank compatability firstly place in the liquid fertilizer and then add the injection water to automatically mix the liquid.

For granular fertilizer mixing refer manufacturer's or dealer's instructions. Take care to adequately mix granular fertilizers to ensure best use of the quantity mixed. Agitators and mixers are recommended with the use of such fertilizers to maintain agitation and prevent settling during the fertigation period.

The time determined at step 2 for a liquid based substance (injected at this rate) to reach the farthest point of the irrigation system is 25 minutes. This therefore means that at a minimum our wash out will need to be 25 minutes in length.

Now we need to consider the irrigated depth required to move the fertilizer to the depth we are seeking relative to the total shift length and the duration of irrigation. Our shift length of 9 hours calculated at step 4 is derived from a 1.10 mm/hr infiltration rate with respect to a 9.9 mm RAW content. The 9.9 mm RAW is derived from a one metre soil depth. (RAW depths can be restricted in calculation if soils are shallow, see also the fact sheet)[1]. If our target fertilizer 'depth' is 30 cm this is effectively a third of the irrigated depth and consequently one third of the irrigation shift. Therefore the last third of the irrigation shift can be reserved for fertigation.

Based on our calculations if we divide the 9 hour shift into three we can leave the first two thirds to run as irrigation and commence fertigation 6 hours into the irrigation shift. We will then need to fertigate (at 100 L injected per 7 minutes) for 70 minutes. This will then leave the remainder of the shift for both infiltration and for system wash out. Due to the irrigation shift being a function of emitter rate (mm/hr) and RAW content we can be certain that the fertigation will only be irrigated to the desired 30 cm depth and that additionally, total irrigated depth will not greatly exceed the RAW value of the soil, leading to either drainage or fertilizer loss.

A more exacting approach would conclude the fertigation precisely at the beginning of the last 3 hours of irrigation to utilize the last component of the irrigation entirely for infiltration to the desired 30 cm depth (or one third of the RAW - 9.9 divided by 3 = 3.3 mm).

Where possible cross validate irrigation decisions with the results of capacitance probe monitoring.

4 Guidelines for using the solu sampler system to reference nitrate/nitrite in field

The solu sampler system provides a relatively inexpensive and easy to use method to both assess the conductivity of irrigated soil water as well as other water borne constituents such as nitrate and nitrite. The relevancy of undertaking monitoring for nitrate/nitrite presence has been discussed previously in the report for outcomes against objectives 1, 2 and 3.

Guidelines for site establishment of the solu sampler system is best referenced in the manufacturer's installation guidelines.[2] Sites are recommended to be installed at 30, 60 and 90 cm where possible. Sites should be located well within the central irrigation area to be representative and should if possible, be located adjacent capacitance probes.

The previous discussion detailed some of the fundamental considerations involved in developing fertigation decisions. The use of the solu sampler system provides in field validation of the outcomes of fertigations where nitrogenous fertilizers are in use. Chiefly this comprises an ability to identify the depth and concentration of the nitrate anion under the crop's rootzone after fertigation through the use of nitrate/nitrite indicator strips in extracted solutes at varying depths. The benefits of the use of this system is that it allows a far more accurate appreciation of where the transient nitrate molecule is in relation to:

Nitrate concentration by location – After fertigation is nitrate predominantly at 30 cm, 60 cm or 90 cm and if so, at what concentrations?

Supplementary irrigation – is irrigation after the fertigation moving nitrate deeper in the soil?

Rainfall – is rainfall moving nitrate around, or is it largely ineffective?

Crop use of nitrate – is the concentration of nitrate at varying levels increasing/decreasing and is this related to irrigation, rainfall, more fertigation or crop uptake or a combination of the four?

[1] http://www.samdbnrm.sa.gov.au/Portals/9/Publications%20and%20Resources/Fact%20Sheets/Water/Irrig%20fact%202.pdf
[2] http://www.irrigationfutures.org.au/imagesDB/news/SentekSoluSAMPLERInstructionManual-Version20.pdf

Essentially the use of the solu sampler system itself is relatively straightforward. This is well detailed in the referenced user guide.

4.1 General guidelines for solu sampler operation

Figure 6: Sampling soil solute from an extractor – good coordination is required to turn off the tap whilst maintaining the plunger in position under vacuum

1. Sites need to be primed by syringe suction at least 24 hours prior to irrigation activities;
2. Where possible sites should be installed close to any soil moisture monitoring equipment such as a capacitance probe or tension based monitors;
3. Allow several hours after irrigation has ceased before attempting to sample, it is essential to let soils stabilize after irrigation to get an accurate perspective of what is occurring in the soil;
4. When sampling from the solu sampler system take particular care when extracting to not attempt to over extract from the sampling point, watch out for buckling or warping of the syringe as this could lead to a vacuum loss and the loss of a sample. Change sampling syringes regularly to avoid this occurring;
5. Always close off the sampler tap between releasing the syringe and disconnect the syringe to retract to plunger prior to re-engaging and attempting another suction sample after re-opening the sampler tap – pay particular attention to making sure the syringe has a good seal with the inside of the sampling tap otherwise a vacuum loss could result;
6. You will need hand strength – during sampling you will need to be able to hold the plunger in position whilst you turn off the sampler tap in between pulling up further fluid samples. Failure to do so will either lose the vacuum in the sampler or allow the sampled fluid in the syringe to retract back down the sampler tube.
7. When extracting solute place samples in sterile sampling jars and wash out syringe with distilled water before moving on to the next sampling point.

4.12 Interpreting solu sampler nitrate/nitrite test strip results

Figure 7: (left) sampling into a washed jug with test strip being inserted, (right) correlating paddle colors after testing sample, sample shown has around 1 mg/L nitrite so nitrate concentration is likely to be inaccurate – this would tend to suggest that the sub-soil is waterlogged

Ultimately the solu sampler system provides a method of identifying nitrate/nitrite concentrations at varying depths under an irrigated crop. Undertaking a sampling relies on pre-pressurization of each of the samplers. Sampling of sites needs to coincide with the point of maximum moisture retention in the cropped soils.

It is recommended that sampling results are recorded on paper in field as the sampling exercise requires consistent washing out of the syringe.

The nitrate/nitrite analysis method relies on the use of credible industry grade nitrate/nitrite test strips. The brand recommended through this trial work is the Quantofix Nitrate/Nitrite test strip (Ref 913 13 manufacturer code). Always check the use by date of the strips on the packet prior to purchase and use. Extracted samples should also be monitored for electrical conductivity as well as nitrate/nitrite. For this purpose a similarly credible industry grade hand electrical conductivity sensor should be used. Ensure the device is calibrated before use.

After extraction of a soil solute sample a nitrate/nitrite test strip should be inserted into the recovered sample which should be immediately deposited into a sterile sampling jar. If re-using jars or containers ensure that they are thoroughly washed before re-use to avoid influencing future sampling activities. It would pay to experiment with cleaning of the jars and cross comparing values gained from samples placed in sterile versus recycled jars.

The test strips should be immersed in the sample fluid for no longer than several seconds, after this withdraw the test strip and flick it so that excess moisture is removed. If a strip is dropped, discard it and re-do the test with a fresh strip. Always collect and dispose of test strips appropriately.

The test strips should be allowed to cure for approximately one minute before the coloration of either or both of the nitrate and nitrite paddles becomes apparent. Refer to the manufacturer's instructions for correct identification of which strip provides which function. In our example the left hand paddle registers nitrate and the right hand nitrite. As previously discussed in the main report the occurrence of nitrite has an extremely de-stabilizing result on nitrate concentration estimations so when nitrite (NO_2) coloration is evident the nitrate (NO_3) paddle coloration becomes more intense and generally an overestimation of nitrate occurs.

As a general rule (with regards to the type of strips used in this project) the presence of nitrite is sufficient evidence to suggest that nitrate has broken down under the influence of soil microbes and this is likely representing an oxygen deprived environment in the sub soils. This is generally related to a poorly draining situation and the result should be cross compared (by sampled depth) to soil logs, capacitance probe results and depth of irrigation records to see if future fertigation activities can avoid this eventuation through a reduction in irrigated depth with the fertigation.

If situations remain oxygen deprived eventually the nitric (NO) compound can form followed by the nitrous oxide compound (N_2O). As detailed in the report, nitrous oxide is rated at some 298 times more damaging to the earth's atmosphere as a green house gas compared to CO_2 emission.

After approximately one minute the paddle colors should be cross referenced with the color key which is usually printed on either the packet or on the strip container. Pay particular attention to grading the samples in natural light, but not in full sunlight, or with sun glasses on. It is essential to take that bit extra time to grade paddle colors to the closest match on the container or the reference chart. For this reason always keep the reference source in a packet and out of sunlight as much as possible to preserve the integrity of the color reference.

Do not try to infer half measures between paddle colors – go with what is closest to the color match indicated.

Based on the discussions within the report high concentrations of nitrate below 60 cm are really being wasted. Most tree and vine crops draw their nutrients from the top 40 cm of the soil and deeper root systems are generally mainly seeking moisture and providing plant stability. This doubtless varies but the main point is with the negatively charged nitrate anion (NO_3^-) is that it leaches readily with the passage of water in the soil matrix. This means that follow up irrigations are progressively going to move nitrate already at depth well out of the reach of the crop's rootzone, rendering it little more than a potential pollutant for groundwater systems.

Irrigators should aim to correlate crop use of nitrate in tandem with observing how concentration changes are persisting between 30, 60 and 90 cm after fertigation and around general crop water use and follow on irrigations. Irrigations on top of fertigations need to be conservative and based around a target depth of irrigation that is factoring in nitrate concentration and location. In practice it will be seen (particularly in light textured soils) that nitrate will move out of the crop rootzone very quickly if irrigated depth is to great.

It is essential to maintain sampling at a high frequency after fertigations and around irrigation activities to capture as many trends as possible, this will be the only way that the best information regarding nitrate presence in the soil can be gained and appropriate irrigation decisions made.