Simple Water Quality Test Kits:

Pilot study review

A report prepared to meet milestones within Cotton CRC project 2.3.04

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The University of Sydney

Reference

Crossan and Kennedy 2008, Simple Water Quality Test Kits: Pilot study review. Research report (Cotton Catchment Communities CRC project 2.03.04). The University of Sydney. Sydney

Acknowledgements

We consider that this project typified successful collaborative research within the cotton industry, exemplifying the true function and purpose of cooperative research centres, and we thank all those who participated. We especially acknowledge the irrigators who tested this initiative and provided valuable feedback including those from Mollee Partnership, Kilmarnock Farming Pty Ltd, Findley Farms, and Auscott Narrabri. Our thanks especially to Alison Young, Bec Smith and Kate Lightfoot for extension and coordination of the initiative. We would also like to acknowledge the valuable practical feedback from Graham Rapp (CSIRO, Myall Vale). Finally, to the team at Usyd for helping with the development and production of the kits and collating the results, thanks to Iona, Mitch, Mick and Ed.

Executive Summary

During this pilot study 20 water quality test kits were distributed across the industry, including properties growing crops other than cotton. Key water quality parameters including turbidity, temperature, EC, pH, carbonate hardness, total hardness and nitrite, nitrate, ammonium, phosphate and chloride ion concentrations were recorded during irrigations.

Although the feedback from participants was positive, the amount of data returned was insufficient to enable the comprehensive analysis of on-farm water quality anticipated. We conclude that reduced staffing levels, as a consequence of very limited water availability, were too restrictive to allow sufficient resources to be made available for the trial.

However, analysis of the results available indicated that at least 15 to 30 % of nitrogen was lost to the tailwater systems as nitrate. This indicates that significant economic gain can be made through improving the efficiency of nutrient use by crops.

The main benefit of the water quality kits was that they provided a quantitative basis for environmental management. Site-specific water quality measurements could be collected that were directly related to local practice. Any change in practice that affects nutrient use efficiency could be assessed, thereby informing and quantifying environmental management systems such as BMP. The economic value of any improvement in practice can be readily determined from the water quality data thereby providing further impetus for improvements.

The water quality tests, which would cost approximately $120 per year per kit, provide the cotton and irrigation industry with a simple tool to seek, measure and record economic and environmental improvement.

Introduction and scope

This pilot study provided 20 irrigators with simple water quality (WQ) test kits. The purpose of the kits was to provide rapid analysis of irrigation runoff water, based upon the principle that before WQ could be managed, it must first be measured. The overall aim of the project was to assess the suitability of simple WQ testing within BMP.

Severe water limitations as a result of the enduring drought have raised the awareness of water availability, efficiency and quality. This project focused on providing tools to initiate better management of on-farm water quality that could potentially be integrated into the higher levels of BMP. There is no doubt that when climatic conditions change water availability will not be as critical. However, the focus on WQ is likely to continue with the environmental focus brought about by catchment management authorities and regulatory agencies.

Aims

The aim of this project was to test the use of simple on-farm water quality test kits. The approach was divided in two phases, firstly to develop a kit with potential for simple and practical use on an irrigation property. The second aim was to review the eagerness of the test group to adopt the technology.

Methods: Test kit and instructions (protocols)

Twenty water quality test kits were distributed via three cotton industry extension personnel. Twelve test kits were distributed within the Namoi valley catchment, five within the Border Rivers catchment, two to the Hillston area, and one to the Burdekin irrigation area.

Test Kit Contents

Each kit was uniquely numbered and contained the following equipment:

- Sampling vessel (1L plastic beaker)
- Thermometer
- Merck™ Multi test strips (pH/CH/TH/NO_2/NO_3)
- Merck™ Ammonium test strip box
- Merck™ Phosphate test strip box
- Merck™ Chloride test strips
- Salt concentration test strips (EC)
- Water bottle (for distilled water only) (1L)
- 2 x plastic pipettes (for distilled water only)
- 2 x 5 mL Syringes (Marked A and B)
- 3 x 50 mL tubes for dilutions and pH adjustment (Marked A, B and pH)
- Nitric acid in dropper bottle

- Sodium hydroxide in dropper bottle
- Merck™ Universal Indicator strips for pH adjustment.
- Small packet of paper wipes
- A plastic zip lock bag for solid wastes

Instructions and logbook

Each kit was supplied with detailed instructions and a logbook, as shown in Appendix A.

To address the second aim of the project, no reminders or follow-up by researchers to project volunteers was conducted, and enthusiasm for the technology was gauged by participation in the study and the amount of data returned.

The extension team were provided with training and support throughout the project and were encouraged to provide as much support to participants as possible.

Results and discussion

Kit distribution was undertaken by the extension team during October and November 2007.

Data was return via fax. Raw data are archived in Room 302, Ross St Building, The University of Sydney. A summary of results are tabulated below. Only a small percentage of data were obtained (25%), significantly less than anticipated. Uncertainty with respect to water availability and consequently reduced work force was cited as the main reason for not collecting data. Interestingly, only one irrigator decided not to participate after receiving the test kit, and there was no difficulty in securing a replacement volunteer. This indicates that if climatic conditions been more favourable, there would have been a greater percentage of testing undertaken and data collected.

Because of the poor data abundance only limited analysis of water quality could take place. The data in Appendix B show potential range of losses of nutrient observed on farms. There is some evidence that nutrients are circulated around property. In general, the concentration of nutrients is greater in runoff than in headwater, yet when the total mass is determined, a much greater load is carried in headwater. This is a function of the volumes of water and indicates the potential distribution of nutrients around a farm.

Nutrient transport is effected by the type and amount of fertilisers used, agronomic practices and irrigation practices such as timing of irrigations (time from nutrient application), the number of irrigations and the volume of water. Because the nutrients varieties used and the irrigation practices were different for each operation (and only 5 sets of data were available for analysis). No generalisation regarding irrigation systems or practices was possible.

The real benefit these kits is the potential to enable site-specific measurement of nutrients, which results from the site-specific practices. This would facilitate site-specific management, consistent with the principles of environmental management systems.

Acceptance

This project received great support and positive feedback from many industry participants, indicating that it is a concept worthy of further development. The main criticism of the kit format was the length of time required to take samples. A predictable and worthy note, especially as there was generally low variation between each sample. In future, a lower number of samples could be measured to provide the same information; this would also reduce the resources required.

Less than 25% of the expected data was collected during this trial. Many participants suggested they simply did not have the time to conduct all or any of the sampling and testing. The clear message was that resources have been stretched very sparsely because of the current water availability situation. It is expected that this would not be a problem with reduced time required for sampling and in good seasons where there would be more staff available. The addition of the WQ testing kits to the BMP program would also encourage participation.

Even with minimal WQ data returned, which limited data analysis and reporting, the project was considered successful. The response and feedback from industry participants showed that this approach to on-farm water quality testing was worthwhile. Further development within the cotton industry could be made through the environmental extension officer network and further a field via the catchment management authorities.

Example of the determination of the economic value of nutrient losses

To illustrate the usefulness of the WQ test kits for site-specific management the following example of cumulative nutrient loss is provided (Table 1). We had planned to include such calculation for all properties, however not all irrigation information was provided. This indicates the importance of collecting good measurement or estimates of the volumes of irrigation applied and runoff. The following example is from Property 3, which was the only property to supply sufficient data to carry out these calculations.

Table 1: Determination of nitrogen loss via nitrate ion (NO_3^-) in irrigation tailwater

Irrigation	NO_3^- Concentration ($mg\ L^{-1}$)	Runoff volume ($ML\ Ha^{-1}$)	NO_3^- Mass ($kg\ Ha^{-1}$)
1st	33.33	1.5	49.9
2nd	9.5	1	9.5
3rd	18.75	0.4	7.5
4th	8	1	8
Total Loss (NO_3^-)			74.9
[a] Equivalent NH_3^-			22.5
Applied NH_3^- ($kg\ Ha^{-1}$)			150
Indicative loss per hectare			15%

[a] Determined from mole ratio

These data shows clearly that nitrogen losses as a result of nitrate dissolved in irrigation runoff were in the order of 15% of total nitrogen applied. In economic terms, 15% of the cost of nitrogen is lost per hectare. There was some evidence that nitrogen was reapplied to fields in subsequent irrigations, however actual uptake of nitrogen by plant was not measured.

Comments and feedback

During the project comments, ideas and suggestions from collaborators and stakeholders were collected. A collection of these, showing the main themes, are presented in Table 2 below. The general message from the feedback was that the approach was good, but needed refining with respect to the time taken and the number of samples collected. Improvements of practice were observed with subsequent irrigation indicating that once users of the kit are familiar with its operation the time commitment will reduce.

Table 2: Comments and feedback from project participants

Date	Contact reference/ Source	Communication Mode	Comments
	A	email	Too complex, too hard, why not one sample at head and tail?
18/12/2007	B	phone	Raining so no sampling took place. One kit returned from a volunteer (not enough resources because of limited cropping area).
19/12/2007	C	phone	Timing for collection of set difficult, yet critical for data collection. (no EC kit as yet). Start sample collection in new year when more time available.
19/12/2007	A	phone	Protocol adapted, comments returned. Long runoff period. 8:30 to 4 pm? First sampling not great, better focus for next irrigation.
	A	phone	Added drainage probes? Misses some data, but another set added to study OK.
10/01/2008	D	phone	Good technical inclusions (impressed with simplicity). EC values too, test not sensitive enough, except for some bore applications.
	E	phone	Good kits, easy to use. Trouble getting all data because of time issues. Couldn't supply all irrigation data as requested. But could if combined with 'Irrimate' data.
29/01/2008	F	phone	Lots of rain, reduced irrigations. One kit dropped out from study, should be at Research Station. Will fax results soon. Sees good value with growers in the future, takes about an hour (but busy the whole time).

Costs of water quality analyses

Excluding costs associated with sampling and storage equipment (sturdy container and equipment used for dilution or pH adjustment) each set of analysis (nine analytes) costs approximately $4.30, or 50 c per data point (Table 3).

Extra expenses were incurred in this study by providing surplus tests (by not splitting packages) and through the provision of sampling containers and equipment, which is detailed in the "kit contents" above.

The shelf life of tests is approximately 24 months when stored well (2-8 °C). Therefore, surplus tests arising because of package sizes can be managed to reduce excess costs in future.

The total cost of the water quality test kits depends upon the number of sample to be analysed. To provide useful information for management or environmental benchmarking we estimate that at a least 4 samples should be analysed during each irrigation (7). Therefore, the variable annual costs to industry for water quality tests will be in the order of $120 (per grower).

Table 3: Costs of water quality testing

Analyte	**Tests per packet (#)**	**Cost per packet ($)**	**Cost per test ($)**	**Supplier**	**Catalogue number**
pH	50	50	1	Merck	1.17970.0001
Nitrate					
Nitrite					
Total Hardness					
Carbonate hardness					
Phosphate	100	96	0.96	Merck	1.10428.0001
Ammonium	100	101	1.01	Merck	1.10024.0001
Chloride	100	80	0.8	Merck	1.10079.0001
Salt Concentration (EC)	50	26	0.52	EnviroQuip	482028
Total		**353**	**$4.29**		

Improvements

- Based upon the comments and the spread of data analysed, fewer samples would need to be analysed. Although this potential increases the uncertainty of the approach, benefits with respect to ease of use are likely to be significantly increased. If the results of the WQ analyses are needed for indicative purposes only, then fewer samplings would be a feasible improvement to the protocol. Further, we would reschedule testing to take no more than 1 hour per irrigation, including all preparation and data recording.

- Ideally, the data from these kits would be integrated with water use efficiency (WUE) data. Increasing the accuracy of irrigation water data will also increase the accuracy of nutrient characterisation. Subsequently, changes in water use practice could be monitored with respect to the effects on nutrient application and removal.
- Simple test for insecticides or herbicides of most environmental concern would ideally be included in the kits. However the technology for simple "dip stick" tests does not yet exist. Cotton CRC project 2.03.09 aims to address this deficiency.

Conclusion

The project was successful in developing an "entry level" analytical kit and protocol to provide semi-quantitative data for irrigation water quality measurement. The results provided an indicative level of nutrient removal and potential loss or redistribution.

From the total of 20 water quality test kits distributed only five were effectively used and returned meaningful data. Although those that used the kit effectively indicated they were a positive addition to natural resource management tools, there are still technical improvements needed and motivation or incentives to be addressed before the kits could be adopted into regular practice. Insufficient time and resources (personnel and water allocation) were cited as the main reason that the kits were not used. Future improvements would include reducing the number of samples analysed, which would also make the kits more cost effective.

It was difficult to characterise nutrients in tail waters with respect to fertiliser and irrigation practice because of the limited data returned. More data would provide a greater insight into the effectiveness of the kits to aid on-farm management. The accuracy of the kits is considered to provide indicative characterisation of nutrient levels and water quality, sufficient for integration into natural resource management. This is especially the case, given that the results are obtained immediately.

These kits or a format of similar design would be well suited to integration into BMP when site-specific water characterisation is required. The data could be used to add value to water use data, indicating the value of nutrients lost and improvements from more efficient practices. The data could also identify when special controls need to be implemented to reduce the risk of potential eutrophication and improve general on-farm water quality.

Appendix A

On-Farm Water Quality Monitoring Program

Protocol and log book

The University of Sydney
Cotton CRC Research Project 2.03.04

The University of Sydney

On-Farm Water Quality Monitoring Program: Protocol and log book

Table of Contents

This document has been prepared to fulfill milestones in Cotton CRC project 2.03.04.

Reference: Crossan, A. N (2007) On-Farm Water Quality Monitoring Program: Protocol and log book. The University of Sydney and Cotton Catchment Communities Cooperative Research Centre. Sydney.

Contact: Dr A Crossan on (02) 9351 2112 or a.crossan@usyd.edu.au

Cover image: Brolga Boogie on Couch by MT Rose (reproduced with permission)

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Introduction

Thank you for participating in this research project, your commitment, feedback and time are sincerely appreciated.

This water quality program is part of the Cotton CRC's catchment research program which is sponsored by the CRDC. The data collected are to be used for research project 2.03.04 which focuses on farm water quality and remediation.

The overall aims of this program are two fold. Firstly, to assess the use of straight-forward water quality testing kits on irrigation properties. Secondly, to measure the quality of irrigation runoff. There are 20 participants in this program and we expect this will produce a unique and valuable data set. The data collected will be used to report on current management practices. In future, these kinds of data could be used to measure success in improved water management practice, economic benefits of more efficient nutrient use, or even potential reductions in greenhouse gas emissions. With sufficient data quality in this program, we hope to report runoff water quality and determine the economic benefit of best practices that reduce nutrient losses. To this end we depend on the quality of your results, detailed feedback and comments.

If you have any problems we will be happy to help out, either to assist in clarification of protocols or to help with some sampling if required at critical times. From time-to-time your extension facilitator will make contact and provide updates or extra materials.

If you have any questions during the program or afterwards, feel free to contact your extension facilitator, the Cotton CRC (Paula Jones **6799-2440**) or The University of Sydney (Angus Crossan **02 9351-2112**).

Program Outline

The following table outlines the stages of the water quality monitoring program:

Stage	Description	Timing
I	Familiarisation with the sampling kit and protocols; personal protection and safety, storage conditions, rinsing and cleaning.	Oct 07
II	Choose a test site (one irrigation set); your extension contact will assist.	↓
III	Recording general field characteristics; including slope, soil type, cotton variety (or crop variety).	
IV	Keep a record of field treatments and irrigations in your log book; including treatments made 12 months prior to planting.	
V	Monitor every irrigation event of the test field that the samples allow (at least 6). Record data and fax results as collected.	
VI	Return tests kits and completed log books.	
VII	Receive a report of your results.	June 08

Sampling Kit Contents

Each kit is uniquely numbered and contains the following:

- Sampling vessel (1L plastic beaker)
- Thermometer
- Merck™ Multi test strips (pH/CH/TH/NO_2/NO_3)
- Merck™ Ammonium test strip box
- Merck™ Phosphate test strip box
- Merck™ Chloride test strips
- Salt concentration test strips (EC)
- Water bottle (for distilled water only) (1L)
- 2 x plastic pipettes (for distilled water only)
- 2 x 5 mL Syringes (Marked A and B)
- 3 x 50 mL tubes for dilutions and pH adjustment (Marked A, B and pH)
- Nitric acid in dropper bottle
- Sodium hydroxide in dropper bottle
- Merck™ Universal Indicator strips for pH adjustment.
- Small packet of paper wipes
- A plastic zip lock bag for solid wastes

You will also need:

- A stopwatch or a wrist watch with a seconds hand
- A clip board and pen
- Personal protection equipment as required. See instructions in each test kit for warnings and information.

Notes:

Check that the contents of the kit are complete.
Seal all containers when not in use.
Your extension contact can supply additional supplies if required.
Keep kits out of direct sunlight. The test strips are stable up to the date stated on the pack when stored in the closed tube at +2 to +8 °C.

Choosing a test site

For the purpose of this program you will need to select a test site that will be used throughout the season. The ideal site would be a large section of an irrigated field that is representative of the entire property. Choose a site that will be convenient to sample, both with respect to location and timing of irrigations.

Samples will be collected and analysed from the head ditch and the tail drain (runoff) during the irrigation. You might need to access the sampling zone during wet weather or during poor light. Each sample will consist of filling a 1 L plastic beaker; consider using the drop box if suitable. See the diagram below for an example.

Field characteristics

Once a test site is identified, please fill out the following table of general information. Please draw a rough diagram (or include a field map) showing the test site with sampling zone locations.

General information regarding the test site						
A	Total field size (ha)		Length of field (m)		Width of field (m)	
B	Test site size (ha)		Length of test site (m)		Width of test site (m)	
C	Slope of field		Soil type		Cotton variety planted	
D	Any other					

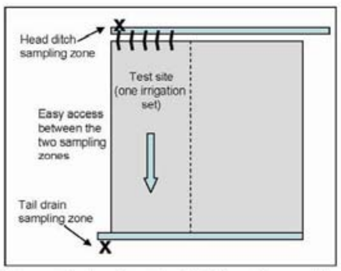


Diagram showing theoretical field layout for sampling

Please draw a rough diagram of your experimental site here or on the back of this page:

Record of field treatments

Please record all field treatments applied to the testing site (Start the record 12 months prior to the current planting and continue for the duration of the program)

Date	Field treatment and details (amount of fertilizer/type of ground preparation)	Comments/Notes

Outline of monitoring events

This section outlines the process involved when conducting a monitoring event, which is to occur every time the test site is irrigated until the test strips run out (6 irrigations or as many times as the test site is irrigated).

This analytical plan is designed to adapt to your irrigation, not dictate it. The following table outlines the general process. The specific timing of irrigation is to be determined by the irrigator. Exact timing of tasks can vary, depending upon actual events, yet the general process should be similar for each event.

Order	Process	Description
A	Plan and schedule sampling	The estimated time required is 1.5 hrs for each event including analysis, sampling, reporting and clean-up. Prepare for sampling when preparing to irrigate.
B	Conduct irrigation as usual	The analytical program should fit around your irrigation schedule. Record the timing of the start and finish of the irrigation and estimate the volume of water applied to the test set.
C	Start irrigation	Record time (and flow if possible).
D	Runoff starts	Record time and start sampling.
E	Sampling and analysis	Runoff 1, Runoff 2, Runoff 3, Head 1, Head 2, Runoff 4, Runoff 5, Runoff 6. NB: Head 1 sample can be taken prior to runoff starting, record time of analysis.
	(Conduct sampling over the duration of the irrigation runoff)	Space out analysis of samples in even intervals depending upon the duration of runoff. For example; if runoff usually lasts 40 min, then take samples every 5 mins.
	Conduct analysis	Follow **Sampling protocol (page 7)** and conduct analysis on each sample.
F	Irrigation stopped	Record the time.
G	Runoff stops	Complete all analyses.
H	Record irrigation parameters for each experimental set	Ensure all data are record and best estimates of irrigation and runoff volumes.
I	Fax completed results sheet	Fax results to (02) 9351-5108 as soon as possible. Keep the results sheet with your log book.
J	Ensure test kit is clean and stocked for next irrigation event	Request more distilled water if necessary. Contact your extension facilitator for any queries or supplies.

Sampling protocol

Order	Process	Description
1	Collect water sample	Use 1L plastic beaker to collect the head or tail water sample. Rinse three times in water to be sampled.
2	Measure turbidity	Using the turbidity circle and the chart to compare and record turbidity (page 11).
3	Measure temperature	Measure and record the temperature of the sample.
4	Conduct analytical tests	Following the instructions in each kit, or the quick reference sheet (following page), to conduct the analytical tests: Multi (pH/CH/TH/NO_2/NO_3) → NH_4 → PO_4 → Check pH → Cl^- → EC
4a	Check pH prior to Chloride test	Ensure that the pH from the Multi test shows a result for the Chloride test (5-8 pH).
4b	Adjust pH if necessary for Chloride test	See pH adjustment protocol and conduct Chloride test (page 12).
4c	Dilute samples if values too high	Identify high analytical values (above the maximum measurement zone) and refer to the dilution procedure (page 11). Repeat analysis of exceeded values only.
5	Rinse syringes and dilution/sub-sample vessels	Empty sample container and rinse out all containers and syringes in distilled water.
6	Repeat process for all samples	Complete data sheet and fax to 02 9351 5108 as soon as possible.

Turbidity protocol

Collect the sample in the 1L plastic beaker and place on the circle pattern (printed underside of test kit lid). After 10 seconds, observe the level of turbidity against the chart below. Record the score in the data sheet.

0	1	2	3	4	5
LESS					MORE

Temperature protocol

1. Carefully remove the thermometer from the case. This is most easily achieved by using both thumbs and forefinger just above the silver clip.
2. Immerse the thermometer into the samples and gently agitate (5 secs). Allow the temperature to stabilise.
3. Do not allow the thermometer to come in contact with the walls of the beaker during temperature stabilisation or reading.
4. When a stable temperature is obtained, record the temperature of the sample. Wipe the thermometer after use.

Analytical Procedures

Quick Reference Table. Refer to the individual kits for detailed instructions

Measurement		Quick Reference Instructions
pH	Acidity/Alkalinity	 Dip for 2 sec; Tap off excess; Wait 1 min; Read and record
CH	Carbonate hardness	
TH	Total Hardness	
NO_2^-	Nitrite	
NO_3^-	Nitrate	
NH_4^+	Ammonium	 Sub sample 5 mL; Add 10 drops of NH_4-1; Dip for 3 sec; Tap off excess; Wait 10 sec; Read and record
PO_4^{3-}	Phosphate	 Dip for 1 sec; Tap off excess; Add PO_4-1; Wait 15 sec; Tap off excess; Wait 1 min; Read and record
Cl^-	Chloride (check pH)	 Dip for 1 sec; Shake off excess; Wait 1 min; Read and record
EC	Salt Concentration	See package for details and instructions

Images reproduced from Merck™ test strip instruction documents.

Example of water quality results sheet (see notes on the next page)

Water Use Information						
A	Sampling Date		Kit Number		Irrigation Type	
B	Irrigation start time		Irrigation finish time		Irrigation number	
C	Volume of water applied		Runoff start time		Runoff volume	
D	Estimation uncertainty		Runoff finish time		Runoff volume uncertainty	
E	Please record the time required to complete sampling event (include planning, cleaning and administration)					
F	Any other comments/thoughts?					

Analytical Results

Sample	Time	T	Temp	pH	CH	TH	NO_2^-	NO_3^-	NH_4^+	PO_4^{3-}	Cl^-	EC	Sample description/Comments
	At sample collection	Turbidity	(°C)	Acidity/ Alkalinity	Carbonate hardness	Total hardness	Nitrite	Nitrate	Ammonium	Phosphate	Chloride	Salt conc.	Please record a brief description of sample e.g. Comment on pH, colour and/or clarity. Or anything different about the sample?
Runoff 1 (R1)													
Runoff 2 (R2)													
Runoff 3 (R3)													
Headwater 1 (H1)													
Headwater 2 (H2)													
Runoff 4 (R4)													
Runoff 5 (R5)													
Runoff 6 (R6)													
Sample ( ) Dilution [ ]													
Sample ( ) Dilution [ ]													
Sample ( ) Dilution [ ]													

Notes for completing Water Quality Results Sheet

The data collected for this project will be used for research. Please record data as accurately as possible and make comments describing estimates or explanations if necessary. The more accurate the data (and explanations) the better the results and inference we can make with regard to nutrient transport and farming practices. High quality data will be more useful for feedback into the research program and give us more confidence in reporting these results to you.

The following notes add some detail and explanation to the sample recording sheet:

A: Record the date of sampling, kit number for identification and irrigation type (e.g. flood or lateral) to allow comparisons between similar operations.

B: The irrigation start and end times will allow the duration of irrigation to be determined. Record the number of the irrigation after fertilizer application, e.g. first, second, third and so on. This information is used to better understand nutrient transport in subsequent irrigations.

C + D: This is probably the most important aspect of nutrient transport, if you have any queries, please ask your extension contact.

- Record the volume of water applied and make a note of the method used to determine the volume in your log book. Indicate if the volume is per hectare or total for the experimental set including the units (i.e. "Megs"=Megalitres or Litres or Megalitres per hectare). Runoff from the field is a critical aspect for this project. Please monitor this closely for the selected experimental zone.
- Indicate the uncertainty of your determination as a percentage or as a range in the measurement units:
  - Example 1: If you can apply 0.1 ML per hour (per hectare) and the water was turned off somewhere between 4.30 pm-4.45 pm, then the uncertainty range in this example is 0.025 ML (one quarter of the hourly figure).
  - Example 2: If you apply somewhere between 1.0 and 1.2 ML per Hectare, then 0.2 ML/ha (or 20%) is the uncertainty estimation.
  - Example 3: Both of the above situations may occur, in which case the uncertainties are combined. i.e. 0.2 plus 0.025 ML (both per hectare), which gives 0.225 ML/ha or (Record original details in notes/logbook if too complex and time consuming).
- Try to be as precise as possible in your measurements of time and volume to reduce the uncertainty.

E: We'd like to know how long each sampling task took (include preparation and review of protocols). This information will be used to further develop the sampling kits and protocols.

F: Please record any comments or thoughts you have during the project. Indicate if there are any significant differences from the previous sampling events. Feel free to use this to communicate any opinions or ideas you have regarding the program.

Dilution protocol

If any of the analytical results are **above** the maximum reading then follow these instructions:

I. Using Syringe A to take 5 mL of sample and place into Dilution Vessel A, fill the dilution vessel to the 50 mL mark with distilled water and shake well.

II. Repeat the test only for the high measurements using the new solution in Vessel A.

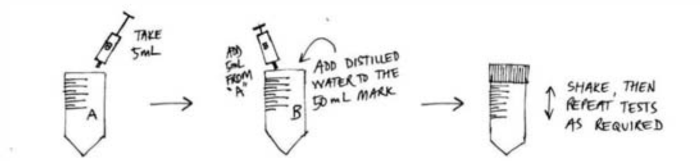
III. Record results indicating the Sample *e.g sample number* (***R6***) and Dilution [***A***] at the bottom of the results sheet in the space provided.

IV. If the results are still higher than maximum reading, use syringe B and take 5 mL from Dilution A and place into Dilution Vessel B. Fill dilution vessel B to the 50 mL mark and shake well.

V. Repeat measurements as required from the new solution in Vessel B. Record results and indicate the Sample number ( ) and Dilution [***B***].

Dilution A

Dilution B



pH adjustment protocol

For the chloride test it is important that the pH is in the correct range (between 5 and 8 pH units). Otherwise incorrect results will be given because of interference and cross reaction.

1. Before conducting the Chloride (Cl^-) test, check the pH result from the earlier Multi test.
2. If the sample shows a pH less than 5 or greater then 8, transfer about 50 mL of the sample to the pH vessel. Record the pH using the Universal Indicator pH strips.

3a. **High pH (above 8):**

- If the pH is above 8, add a drop of diluted Nitric Acid (0.02 N) from the dropper bottle to the sub-sample.
- After adding a drop of Nitric Acid to the sub-sample, shake the mixture and test the pH with the Universal Indicator. [Submerse the strip into the sub-sample until there is no further colour change. Read the colour whilst still moist against the chart in the container].
- Repeat the procedure and measure pH with a new indicator strip for each measurement until the pH value is between 5-8.

3b. **Low pH (below 5):**

- If the pH is below 5. Repeat the above protocol using Sodium Hydroxide (0.02 N) instead of Nitric Acid until the pH is in the 5 to 8 pH range.

4. Once the pH is in the desired range, record the new value in the comments space, and follow the instructions for conducting the Chloride test on the sub-sample.
5. Record the results for the Chloride test in the results sheet.

Universal indicator instructions and colour chart; used to correct the pH of a sample if the pH is not in the required range for the test strips. An important consideration for the chloride test

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Notes and comments

Appendix B: Tables of results form each property

Property 1	Irrigation 1				Irrigation 2				Irrigation 3			
	Headwater		Tailwater		Headwater		Tailwater		Headwater		Tailwater	
	Average	Mass (kg Ha^{-1})	Average	Mass (kg Ha^{-1})	Average	Mass (kg Ha^{-1})	Average	Mass (kg Ha^{-1})	Average	Mass (kg Ha^{-1})	Average	Mass (kg Ha^{-1})
Turbidity	1		4		4		4		4		4	
Temp (^{o}C)	18		28.		26.5		29.5		30.5		30.5	
pH	8.0		7.0		7.0		6.83		7.5		7.17	
Carbonate hardness	16.0		16.0		16.0		14.0		12.0		14.7	
Total hardness	4.0		5.5		15.0		10.0		5.0		10.0	
NO_2^- (mg L^{-1})	5.0	6.5	5.0	0.65	1.25	1.63	0.42	0.05	0.5	0.65	1.08	0.14
NO_3^-(mg L^{-1})	10.0	13.0	75.0	9.75	5.0	6.5	39.17	5.09	0.0	0.00	8.33	1.08
NH_4^+	0.0	0.0	0.0	0.00	0.0	0.0	0.0	0.00	0.0	0.00	0.00	0.00
PO_4^{3-}(mg L^{-1})	25.0	32.5	5.0	0.65	17.5	22.75	12.50	1.63	17.5	22.75	22.50	2.93
Cl^-(mg L^{-1})	0.0	0.0	0.0	0.00	0.0	0.0	0.0	0.00	0.0	0.00	0.00	0.00
EC	ND		ND		ND		ND		ND		ND	

Property 2	Irrigation 1				Irrigation 2				Irrigation 3			
	Headwater		Tailwater		Headwater		Tailwater		Headwater		Tailwater	
	Average	Mass (kg Ha^{-1})	Average	Mass (kg Ha^{-1})	Average	Mass (kg Ha^{-1})	Average	Mass (kg Ha^{-1})	Average	Mass (kg Ha^{-1})	Average	Mass (kg Ha^{-1})
Turbidity					2		4		2		2.833333	
Temp (^{o}C)					21		21.2		23		27.5	
pH					7		7		7		7	
Carbonate hardness					8		8		8		8	
Total hardness					5		5		5		5	
NO_2^- (mg L^{-1})	No Data				1	42.8	1	3.9	1	36.9	1	1.3
NO_3^-(mg L^{-1})					25	1070	25	98	25	922.6	25	33.6
NH_4^+					0	0	0	0	0	0	0	0
PO_4^{3-}(mg L^{-1})					25	1070	25	98	25	922.6	25	33.6
Cl^-(mg L^{-1})					0	0	0	0	0	0	0	0
EC					<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2

Property 2	Irrigation 4				Irrigation 5			
	Headwater		Tailwater		Headwater		Tailwater	
	Average	Mass (kg Ha^{-1})	Average	Mass (kg Ha^{-1})	Average	Mass (kg Ha^{-1})	Average	Mass (kg Ha^{-1})
Turbidity	4		4		3		3	
Temp (^oC)	24		27.2		23.5		24.6	
pH	7		7.3		7		7	
Carbonate hardness	8		10		8		8	
Total hardness	5		5		5		5	
NO_2^- (mg L^{-1})	1	33.6	1	1.8	1	38	1	3.5
NO_3^-(mg L^{-1})	25	839.8	25	45.1	25	950	25	86.3
NH_4^+	0	0	0	0	0	0	0	0
PO_4^{3-}(mg L^{-1})	25	839.8	83.3	150.2	25	950	45.8	158.2
Cl^-(mg L^{-1})	0	0	0	0	0	0	0	0
EC	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2

Property 3	Irrigation 1				Irrigation 2				Irrigation 3				Irrigation 4			
	Headwater		Headwater		Headwater		Headwater		Headwater		Tailwater		Headwater		Tailwater	
	Ave.	Mass (kg Ha^{-1})	Ave.	Mass (kg Ha^{-1})	Ave.	Mass (kg Ha^{-1})	Ave.	Mass (kg Ha^{-1})	Ave.	Mass (kg Ha^{-1})	Ave.	Mass (kg Ha^{-1})	Ave.	Mass (kg Ha^{-1})	Ave.	Mass (kg Ha^{-1})
Turbidity	3.3		2.8		1.5		1.0		1.5		3.8		3.5		3.6	
Temp (^oC)	19.8		21.3		23.0		22.0		20.5		21.5		22.0		22.4	
pH	7.3		7.5		7.5		7.3		7.0		7.0		7.0		7.3	
Carbonate hardness	16.0		15.2		16.0		15.5		16.0		14.0		15.0		15.2	
Total hardness	17.5		19.2		20.0		18.8		20.0		20.0		15.0		20.0	
NO_2^- (mg L^{-1})	0.6	4.2	0.7	1.1	0.5	3.3	0.5	0.5	0.5	2.0	0.4	0.2	0.3	1.7	0.3	0.3
NO_3^-(mg L^{-1})	17.5	122.5	33.3	50.0	6.0	39.0	9.5	9.5	5.0	20.0	18.8	7.5	5.0	27.5	8.0	8.0
NH_4^+	1.0	7.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
PO_4^{3-}(mg L^{-1})	3.5	24.5	1.7	2.5	10.0	65.0	5.5	5.5	2.5	10.0	3.8	1.5	2.5	13.8	0.0	0.0
Cl^-(mg L^{-1})	100.0	700.0	100.0	150.0	100.0	650.0	50.0	50.0	100.0	400.0	37.5	15.0	0.0	0.0	0.0	0.0
EC	ND		ND		0.7	0.7	0.8	0.8	0.7	0.7	0.5	0.5	ND		ND	

Property 4	Irrigation 1				Irrigation 2				Irrigation 3				Irrigation 4			
	Headwater		Headwater		Headwater		Headwater		Headwater		Tailwater		Headwater		Tailwater	
	Ave.	Mass (kg Ha^{-1})	Ave.	Mass (kg Ha^{-1})	Ave.	Mass (kg Ha^{-1})	Ave.	Mass (kg Ha^{-1})	Ave.	Mass (kg Ha^{-1})	Ave.	Mass (kg Ha^{-1})	Ave.	Mass (kg Ha^{-1})	Ave.	Mass (kg Ha^{-1})
Turbidity	1		4		4		4		4		4		4		4	
Temp (^oC)	30.5		32.2		17.0		15.5		19.0		22.0		23.0		24.0	
pH	7.0		7.0		7.0		7.0		7.0		8.0		8.0		8.0	
Carbonate hardness	14.5		10.7		12.0		12.0		16.0		16.0		16.0		16.0	
Total hardness	2.5		2.5		2.5		2.5		4.0		2.5		5.0		5.0	
NO_2^- (mg L^{-1})	1.0	5.0	1.0	0.5	1.0	6.7	1.0	0.7	1.0	5.9	2.0	1.2	2.0	11.8	1.0	0.6
NO_3^-(mg L^{-1})	10.0	50.3	10.0	5.0	10.0	67.0	10.0	6.7	10.0	59.1	25.0	14.8	50.0	295.5	50.0	29.6
NH_4^+	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
PO_4^{3-}(mg L^{-1})	250.0	1256.3	250.0	125.6	250.0	1675.0	250.0	167.5	100.0	591.0	25.0	14.8	250.0	1477.5	100.0	59.1
Cl^-(mg L^{-1})	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
EC	ND		ND		ND		ND		7.7	7.7	8.0	8.0	ND		ND	

Property 5	Irrigation 1				Irrigation 2				Irrigation 3				Irrigation 4			
	Headwater		Headwater		Headwater		Headwater		Headwater		Tailwater		Headwater		Tailwater	
	Ave.	Mass (kg Ha^{-1})	Ave.	Mass (kg Ha^{-1})	Ave.	Mass (kg Ha^{-1})	Ave.	Mass (kg Ha^{-1})	Ave.	Mass (kg Ha^{-1})	Ave.	Mass (kg Ha^{-1})	Ave.	Mass (kg Ha^{-1})	Ave.	Mass (kg Ha^{-1})
Turbidity	4		4		4		4		4		4		4		4	
Temp (^oC)	21.0		21.0		18.0		18.0		25.0		29.7		23.0		23.0	
pH	8.0		8.0		8.0		8.0		8.0		8.0		7.5		8.0	
Carbonate hardness	16.0		16.0		16.0		16.0		16.0		16.0		16.0		16.0	
Total hardness	5.0		8.3		5.0		5.0		5.0		5.0		5.0		5.0	
NO_2^- (mg L^{-1})	0.5	0.5	1.0	0.1	0.5	0.5	0.5	0.0	0.8	0.6	0.8	0.1	5.0	4.0	1.5	0.1
NO_3^-(mg L^{-1})	17.5	15.8	100.0	9.0	25.0	22.5	41.7	3.8	10.0	8.0	25.0	2.0	75.0	60.0	5.0	0.4
NH_4^+	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
PO_4^{3-}(mg L^{-1})	37.5	33.8	33.3	3.0	50.0	45.0	41.7	3.8	50.0	40.0	50.0	4.0	25.0	20.0	75.0	6.0
Cl^-(mg L^{-1})	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
EC	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2