Soil quality monitoring and management

Report 3 – Irrigation
(Activities from 1 July to 31 December 2013)

Tiedman Irrigation Program

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for AGL Upstream Investments Pty Ltd

January 2014

Table of Contents

Item	Contents	Page

Attachments

Executive Summary

This is Compliance Report 3 of a series of four (4) reports that will be undertaken during the Tiedman Irrigation Program and covers the baseline soils analysis, subsequent soil improvement and re-testing of those soils, establishment of all data collection and monitoring equipment and establishment, irrigation then harvesting of irrigated fodder crops. This report covers the period from 1st July 2013 to 31st December 2013.

This report provides further information on the effect of irrigating blended water on the natural and improved soils on AGL's Tiedman property over the period of the irrigation program. These reports are submitted in compliance with the approved Soil Quality Monitoring and Management Program.

The Tiedman Irrigation Program is being carried out across two areas within the AGL Tiedman property known as Stage 1A and Stage 1B. The Stage 1A area is generally referred to as the main trial area.

The Stage 1A area is the major focus of the approved Soil Quality Monitoring and Management Program. There has been extensive sampling and analysis of the quality of the parent and treated soils. This area is being intensively monitored for soil, water and crop performance.

The Stage 1A area is 12 hectares in size and is made up of 16 equal sized plots, 0.74 hectares (ha) in size, where two crop systems (annuals and perennials) and four soil treatment types have been installed. These are being monitored and analysed to establish an optimum design for any blended water irrigation scheme adopted for the Gloucester Gas Project (GGP).

In relation to the Stage 1A area, this report sets out:

- the trial plot layout, crop selection and planting;
- the mass balance results for the reporting period;
- the performance of soils on the Stage 1A irrigation area;
- the performance of soils on the Stage 1B irrigation area;
- the performance of the sedimentation, runoff and erosion control measures; and
- the critical control points and any necessary responses.

The Stage 1B area is approximately 40 hectares. The main irrigation area for the next 12 months is made up of 4 plots that total approximately 4 ha.

Blended water with a salinity of 1680µS/cm was applied to Stage 1A (32.45 megalitres (ML) irrigated) and Stage 1B (11.45 ML irrigated) during the reporting period. During the same period some 27.55 ML of rain occurred across the Stage 1A area and 9.44 ML on the Stage 1B area.

In total, 46 % of the water received by the Stage 1A area fell as rain, while the balance (54 %) was applied by irrigation of blended water.

For the main irrigation area (Stage 1A) none of the Critical Control Point trigger levels were reached during the reporting period.

The soil structure in Stage 1A plot areas appears to be significantly improved from the amendments and shows no indication of adverse effects (such as abnormal salinity or sodium levels, and clay particle dispersion) from the irrigation of blended water or periodic rainfall at this time.

1. Introduction

AGL Upstream Investments Pty Ltd (AGL) engaged Fodder King Ltd (FK) to provide technical advisory services (including soil investigations and the preparation of compliance reports) associated with the Tiedmans irrigation program. The irrigation program involves two main irrigation areas (Stage 1A and Stage 1B). This report is the third compliance report for the irrigation program. It covers the assessment of soils after the soil treatments, establishment of crops within the Stage 1A area and after the commencement of irrigation of blended water. The report covers the period from 1 July to 31 December 2013 and also describes the soil conditions within the Stage 1B irrigation area. The two primary irrigation areas are shown in Figure 1.

Stage 1A is the major focus of the Soil Quality Monitoring and Management Program (SQMMP). This area is undergoing intensive monitoring of soil, water and crops, and application (after blending) of most of the produced water for irrigation. The Stage 1A area is about 22 hectares (ha) in total, of which 12 ha is being irrigated. Crop types are lucerne, forage sorghum, triticale and oats. It is expected that between 100 and 180 megalitres (ML) of blended water will be irrigated across this area during the approved irrigation period.

Stage 1B is where the lower salinity water, in the produced water storage dams, was irrigated in late 2012. Some additional irrigation, using blended water, will occur for the balance of the irrigation period on a 4.1 ha portion within the Stage 1B area. Stage 1B is approximately 40 ha, of which around 10-20 ha of pasture could be irrigated. The main pasture types to be grown include a mix of annual and perennial species.

There is an additional approved irrigation area (the Stage 2 area) which is approximately 15 ha. This area was not irrigated during the reporting period and will only be used if irrigation application rates on Stage 1A and Stage 1B are less than anticipated.

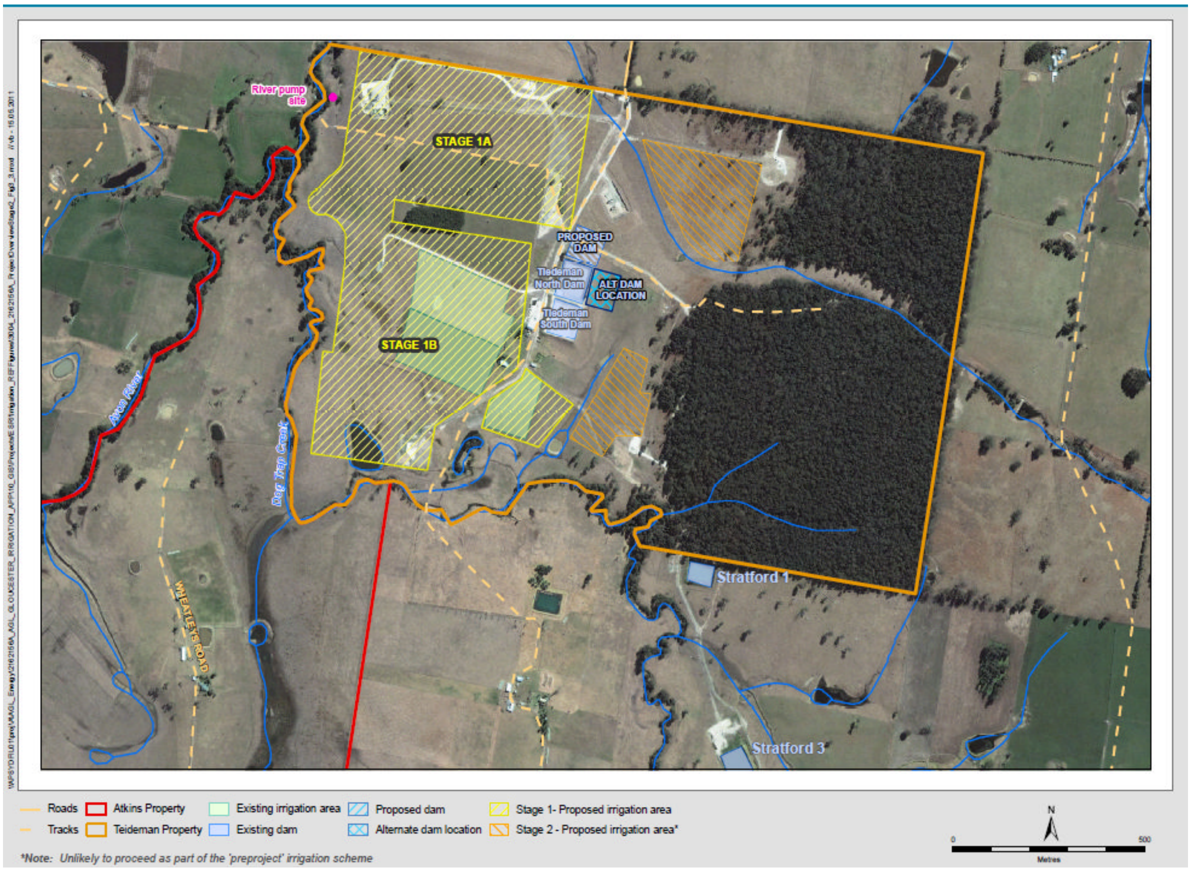


Figure 1: Gloucester Irrigation Areas for Exploration Produced Water

The Stage 1A, Stage 1B and Stage 2 irrigation areas are all located off the floodplain of the Avon River. The irrigation program was approved in July 2012 after the Tiedman Irrigation Program REF (PB, 2011) and supplementary documents were submitted to NSW Trade and Investment (Division of Resources and Energy (DRE)) during 2011/12.

1.1. Requirements under the Soil Quality Monitoring and Management Program.

The Soil Quality Monitoring and Management Program (SQMMP) was approved by DRE in October 2012 for the two irrigation areas and for the irrigation of up to 70 ML of produced water across an area of up to 40 ha.

Overall objectives

The overall objectives of the SQMMP are to:

- Develop and monitor the performance of soils on the irrigation area against baseline soil quality parameters;
- Develop, manage and monitor the water and salt balance; and
- Monitor, act and report on any adverse trends or impacts on soil structure and quality parameters.

Stage 1A objectives

The objectives of the Stage 1A Irrigation Trial are to:

- Derive information about the use of blended water on improved soils in order to optimise the beneficial use of produced water.;
- Provide information to optimise the design of a water treatment and storage system to match the beneficial re-use system; and
- In order to minimise the overall 'footprint' of the project on the surrounding landscape, the irrigation program is aiming to achieve blended water application rates in the range of 3-5 megalitres/hectare/year.

Stage 1B objectives

The objectives of the Stage 1B area are to:

- Allow for the irrigation of the lowest salinity produced water stored in the holding dams to provide improved pasture for stock grazing across the property (which is the traditional land use);
- Provide additional irrigated land area (to the intensive Stage 1A area) in the early stages of irrigation so that "air space" can be provided in the holding dams for the blending of the more brackish produced water that is in storage.

1.2. Stage 1A Irrigation Trial description

In brief, the Stage 1A Irrigation Trial involves the addition and mixing of ameliorants with the parent soils, the application of blended water (CSG water and fresh water) to those soils with the aid of an accurate irrigation system, the regular sampling and testing of the soils, the regular analysis of mass and water balances, analysis of results and reporting on the results.

The main activities are outlined as follows:

Baseline 1 soil study

A comprehensive baseline soil study to ascertain the characteristics of the parent soils across the Tiedman property but in particular the Stage 1A irrigation area. This data was collected and reported as part of the irrigation trial design during 2011 (FK, 2011).

Baseline 2 soil study

On completion of the soil amelioration, repeat the soil sampling and analysis to ascertain the baseline characteristics of the treated soil prior to irrigation.

Compliance Report 1 (FK (2013a) *Soil quality monitoring and management, Report 1- Pre irrigation (Activities to 31 March 2013),* covered the site soil investigations up to and including the Baseline 2 soil study and prior to the commencement of irrigation of the Stage 1A area.

Baseline 3 soil study

On completion of irrigation of blended water during the reporting period (1st April 2013 to 30th June 2013), repeat the soil sampling and analysis to ascertain the characteristics of the treated soil after initial irrigation and assess any trends.

Compliance Report 2, (FK (2013b) *Soil quality monitoring and management, Report 2 - Irrigation (Activities from 1 April to 30 June 2013),* covered the site soil investigation and results carried out at the end of this reporting period.

Baseline 4 soil study

On completion of irrigation of blended water during the reporting period (1st July 2013 to 31st December 2013), repeat the soil sampling and analysis to ascertain the characteristics of the treated soil after extended irrigation and assess any trends.

Compliance Report 3 (this report), covers the site soil investigation and results carried out on the 7th and 8th November 2013.

Perched water piezometers

Paired piezometers to monitor the potential for the development of perched water zones in the shallow soil profile have been installed inside and immediately outside (i.e. down gradient) the area of each of the different soil treatment types. Construction details are provided in FK (2013a) *Soil quality monitoring and management, Report 1- Pre irrigation (Activities to 31 March 2013.*

Irrigation Program

The application of blended water to the Stage 1A trial area is subject to recommendations arising from daily water balance monitoring and anticipated weather conditions.

In the period from 1st July to 31st December 2013, approximately 32.45ML of blended water was irrigated across the Stage 1A area to grow triticale, forage sorghum and Lucerne. This water was taken from the Tiedman South blended water irrigation dam and applied using an overhead linear move irrigator.

Carry out monitoring and data gathering

The requirement is to undertake all detailed monitoring and data gathering, including regular soil sampling and testing, and provide 6 monthly reports to NSW Trade and Investment (Division of Resources and Energy [DRE]) in accordance with REF approval conditions 3 and 6.

On completion of the Stage 1A trial in mid-2014, comprehensive soil sampling and testing will be undertaken (similar to the FK baseline study done in 2011) to establish the effect of irrigation on the ameliorated soil, prior to submission of a final report (Compliance Report 4) to DRE.

1.3. Soil quality monitoring and management program requirements

In order to manage the ameliorated soils during the Stage 1A irrigation trial, a number of soil quality attributes are being monitored. These include water balance, salt balance, nutrient balance, carbon balance and soil structure. Crop yield, crop persistence and crop health are also being monitored.

Water balance

The water balance provides the framework for tracking inputs to calculate salt, nutrient and carbon balances in the receiving soil and for detecting trigger points to prevent adverse impacts on soil quality. The water balance is based on the *Environmental Guidelines: Use of Effluent by Irrigation (DECC, 2004).*

The aim of irrigation management during the irrigation program is to maintain a soil moisture deficit, within the optimal soil moisture range for crop growth, which is between wilting point and field capacity. Soil moisture is continually monitored to track soil moisture patterns (surplus or deficit) due to both rainfall and irrigation. Irrigation is only applied when there is both a daily irrigation deficit and a soil moisture deficit (with respect to soil field capacity). The AGL on-site weather station data and available rainfall forecasts are used to guide the applied irrigation water and to monitor the water balance.

Salt, nutrient and carbon balances

The salt (sodium), nutrient (nitrogen and phosphorus) and soil carbon (Total C) balances are determined during the Stage 1A irrigation program. Monitoring and analysis of blended CSG water applied, soil chemistry and soil-water allow the determination of inputs and outputs, and sources and sinks, to interpret mass balance processes and the management implications for short and long-term irrigation.

Soil structure

Apart from the physical causes of soil erosion, such as loss of groundcover, key soil chemistry parameters such as soil pH, Cation Exchange Capacity (CEC) and the soil Exchangeable Sodium Percentage (ESP) indicate the potential for loss of soil structure when irrigated with waters of a given electrolyte concentration. The relationship between ESP, the Sodium Adsorption Ratio (SAR) of permeating soil water, and the potential impact on soil structure is summarised in the *Environmental Guidelines: Use of Effluent by Irrigation* (DECC, 2004), detailed in Lucas (2009) and discussed further in *Section 4. Performance of soils on Stage 1A irrigation area* of this report.

Crop growth, persistence and health

Crop growth is determined from measuring dry matter yield after harvest over successive cropping cycles. An important aspect of the trial was to establish ground cover as quickly as possible after installation to minimise the risk of erosion of bare ameliorated soil. During the reporting period the improved soil enabled rapid establishment of the annual summer crop (forage sorghum) which replaced the winter cereal.

Crop persistence is measured by plant counts and monitored at regular intervals and crop health is measured by pasture sample analysis, leaf tissue analysis, harvested fodder analysis and monitored at regular intervals by an agronomist.

1.4. Stage 1B irrigation program description

The principal use of the Stage 1B area is to:

i. Initially directly irrigate the lower salinity produced water in the Tiedman South dam so as to create capacity in the dam for blending of the larger volumes of produced water.
ii. As part of the program, establish some shallow rooted pasture species on a 4.1 ha area to evaluate irrigation application rates and irrigability of these traditional pastures in comparison with the more salt tolerant and deeper rooted crops that are established in the Stage 1A area. Blended irrigation water is to be used for this part of the program.

In the period from July to the end of December 2013, approximately 11.45 ML of blended water was irrigated across the Stage 1B area to grow improved pasture. This water was taken from the same dam (Tiedman South) as the blended water applied to Stage 1A and applied using a small travelling irrigator.

The Stage 1B improved pasture/grazing area is currently being managed by a lessee. The lessee is using rotational grazing as a method to finish EU accredited cattle prior to slaughter. There are 12-14 head of cattle on this area at any one time.

2. Irrigation program layout, crop selection and planting

2.1. Stage 1A irrigation area

2.1.1. Trial layout

The Stage 1A irrigation layout was designed to ensure minimum buffer distances from the Avon River (40 m), boundaries (10 m), power lines (15 m) and a copse of trees (10 m).

This created an irrigable area of 587 m (oriented east-west) and 322 m (oriented north-south). From within this area the final trial irrigation area was selected to satisfy the following requirements:

- Four soil treatments;
- Two crop systems (annuals and perennial);
- An individual plot size that could accommodate the typical range of agricultural operations;
- Irrigated by a low pressure overhead spray linear irrigator, creating a rectangular shaped irrigation zone with a central road for the linear cart to traverse; and
- The need to have a trial area as close as possible to final scale.

This resulted in a trial plot area measuring approximately 395 m from east to west and 313 m from north to south. See Attachment 1.

There are 16 equal-sized trial plots. Each individual trial plot is approximately 0.75 hectares in size, measuring 47.85 m by 156.62 m. This size enables most agricultural equipment to operate within the plot.

Factoring in non-productive crop areas taken up by bund walls the ‘green’ crop area is 0.73 hectares (46.85 m x 155.62 m).

Due to the selection of a centre feed linear move irrigator as the method for applying irrigation water, each treatment and crop combination was split evenly on either side of the centreline of the linear irrigator, resulting in 8 plots (Plots 1-8) under the northern leg of the irrigator and 8 plots (Plots 9-16) under the southern leg of the irrigator.

This accommodated the need for 2 crop types and 4 treatment depths on either side of the cart track.

2.1.2. Crop selection

Due to the expected year-round flow characteristics of produced water, perennials and annuals are being trialled to develop crop combinations that will maximise the utilisation of water.

The crop types being irrigated for the 18 month program are:

- Perennials (lucerne) – 8 plots x 4 treatment depths
- Annuals - 8 plots x 4 treatment depths
  - winter forage cereals (triticale), harvested and removed in September 2013
  - followed by a summer forage (forage sorghum), established in September 2013

2.1.3. Planting

The Stage 1A crops and varieties were planted as follows:

- Triticale
  - Planted - 27/03/2013
  - Variety – “Monstress”
  - Seeding rate – 120 kg/ha
  - Removed and replaced by Forage sorghum

- Forage sorghum
    - Planted – 25/09/2013
    - Variety – "BMR Octane"
    - Seeding rate – 25 kg/ha
- Lucerne
    - Planted - 12/04/2013
    - Variety – "L91"
    - Seeding rate – 20 kg/ha.

2.1.4. Crop performance since planting

Table 2.1 provides a summary of crop production for the reporting period. The Triticale, which was the selected winter annual, was harvested in July and September and then replaced with the summer annual – Forage Sorghum. Both the Triticale and the Forage Sorghum have performed satisfactorily.

Table 2.1: Crop production summary for the reporting period

Crop	Number of bales		Bale weights		Total dry matter yield (tonnes)	Total dry matter yield (tonnes/ hectare)
	Silage bales	Hay bales	Silage bales (kg)	Hay bales (kg)		
Triticale						
Harvest 1 (28/07/2013)	165	0	550	N/A	40.11	6.87
Harvest 2 (23/09/2013)	9	0	495	N/A	2.49	0.43
Forage Sorghum						
Harvest 1 (19/12/2013)	84	0	510	N/A	21.42(est)	3.67
Lucerne						
Harvest 1 (28/07/2013)	12	0	700	N/A	2.59	0.44
Harvest 2 (23/09/2013)	14	0	430	N/A	4.17	0.71
Harvest 3 (4/11/2013)	0	13	N/A	470	4.82	0.83
Harvest 4 (19/12/2013)	0	33	N/A	405	10.89	1.86
Total for the period (1/07/2013 – 31/12/2013)					**86.49**	**7.41**

During the period the production volumes were:

- Triticale – harvested in July (40.11 DM tonnes) and harvested in September (2.49 DM tonnes)
- Forage sorghum – harvested in December (21.42 DM tonnes)

The Lucerne, which is a summer-active perennial, has performed satisfactorily. During the period, the production volumes were 22.47 DM tonnes for the 4 harvests to the end of December.

The total production of 86.49 DM tonnes (see Table 2.1) is consistent with the accumulated yield expected by the end of December.

2.2. Stage 1B irrigation area

The four Stage 1B irrigation plots are located just to the south of the Stage 1A trial plots and are sized and named as follows:

- AL1 – 0.97 hectares
- AL2 – 0.89 hectares
- AL3 – 1.13 hectares
- AL4 – 1.10 hectares

The total area is 4.1 ha and the layout of this area is provided in Attachment 2.

2.2.1. Pasture selection

The pasture type chosen for this area is a pasture mix (71 % Ryegrass, 20 % Clover, and 9 % Chicory) which is the same for all 4 plots. There is no deep soil treatment across any of these four plots.

2.2.2. Planting

The pasture mix varieties were planted on 28/03/2013 at a combined rate of 35 kg/ha:

- Ryegrass
  - Planted – 28/03/2013
  - Variety – "Knight"
  - Seeding rate – 25 kg/ha
- Clover
  - Planted – 28/03/2013
  - Variety – "USA Red Clover"
  - Seeding rate – 7kg/ha
- Chicory
  - Planted – 28/03/2013
  - Variety – "Punter"
  - Seeding rate – 3 kg/ha

2.2.3. Pasture performance since planting

A satisfactory pasture density has been maintained for cattle grazing during the reporting period.

3. Mass balance results for the period

3.1. Average rainfall patterns

The irrigation site lies within a relatively high rainfall zone, with a mean rainfall of approximately 983 millimetres (mm). The rainfall pattern is slightly summer-dominant with 56 % occurring between November and March and 44 % occurring between April and October. As a result the consideration of rainfall is a significant factor in determining the timing of when irrigation will be undertaken.

3.2. Rainfall and Evapotranspiration

Figure 3.1 summarises rainfall and evapotranspiration (ETo) between the 1st July – 31st December 2013 where 230.8 mm of rain occurred during the period. The monitoring period was unusually dry especially between July and early November, and again in December. Most rainfall fell in November 2013 (163.6 mm against a total for the period of 230.8 mm). Rainfall across the total Stage 1A plot area of 11.94 ha was 27.55 ML. The equivalent volume across the Stage 1B area of 4.1 ha was 9.44 ML.

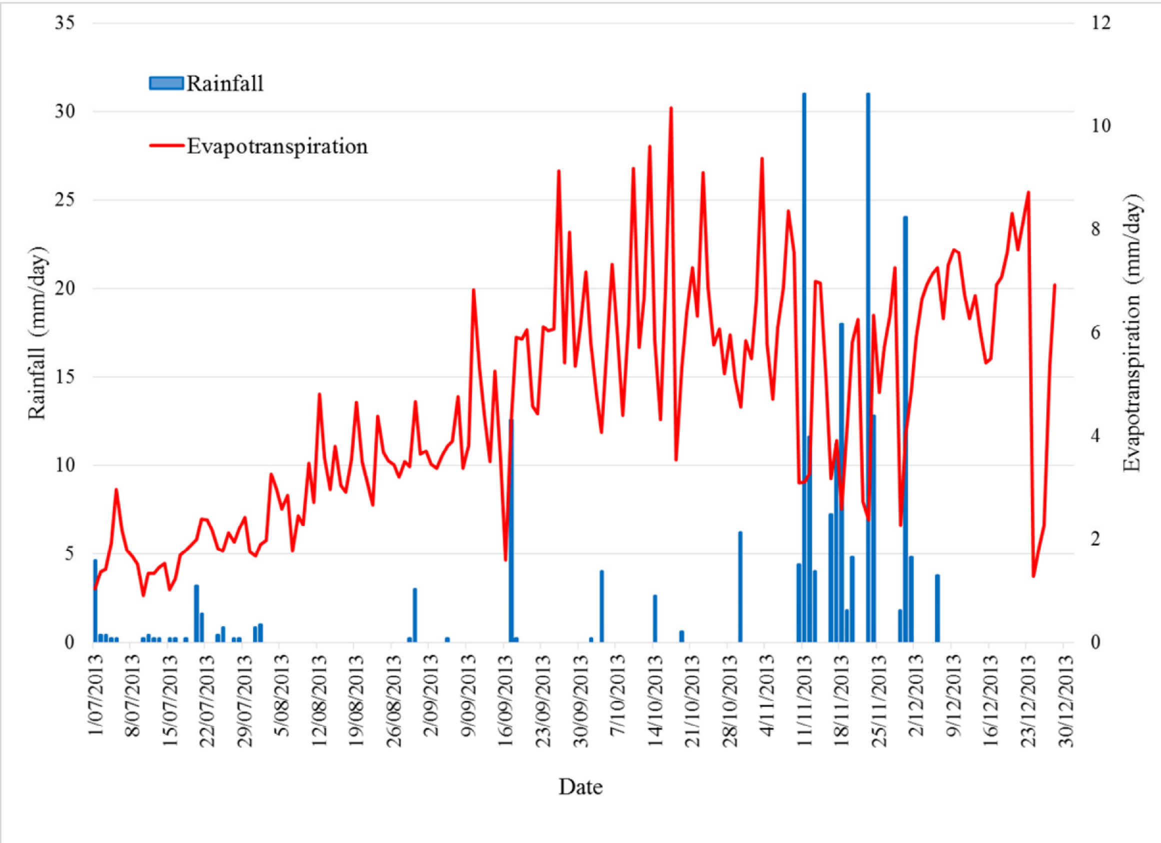


Figure 3.1: Rainfall and Evapotranspiration for the Period (1st July – 31st December 2013)

There is no evapotranspiration (see explanation in FK, 2011) data specific to the site, however ETo was interpolated from regionally available data through the *iWater* service.

During the reporting period 54 % of the total water received across the Stage 1A area came from blended water while 46 % came from rainfall (refer Table 3.1).

Table 3.1 Rainfall and irrigation for the period – Stage 1A

Units	Rainfall for the period	Irrigation for the period	Total
mm	230.8	270.4	501.2
ML	27.55	32.45	60
%	46	54	100

3.3. Irrigation scheduling and water balance

3.3.1. Stage 1A

The water balance was based on *Environmental Guidelines: Use of Effluent for Irrigation (DECC, 2004)*:

Applied CSG water (Qcsg) + Rainfall (Qr) ≤ Evapotranspiration (ET) + Percolation (P) + Runoff (R) + Interception Loss (IL), where R designed to be zero, therefore the daily water balance is:

- Qcsg ≤ ET + P + IL – Qr
- Daily Irrigation Deficit (DID) = ET + P + IL – (Qr + Qcsg)

Negative values mean irrigation should not be applied.

The cumulative DID (over 6 day periods) was used in conjunction with real-time soil moisture to determine if irrigation was possible at a given time. For example, a 25 mm rainfall event may offset 6 days (or more) of low ETo, and if the rainfall event saturates the soil, then irrigation does not occur.

Figure 3.2 summarises the Daily Irrigation Deficit (DID), cumulative DID (6-day) and applied Irrigation of blended CSG water (1st July – 31st December 2013)

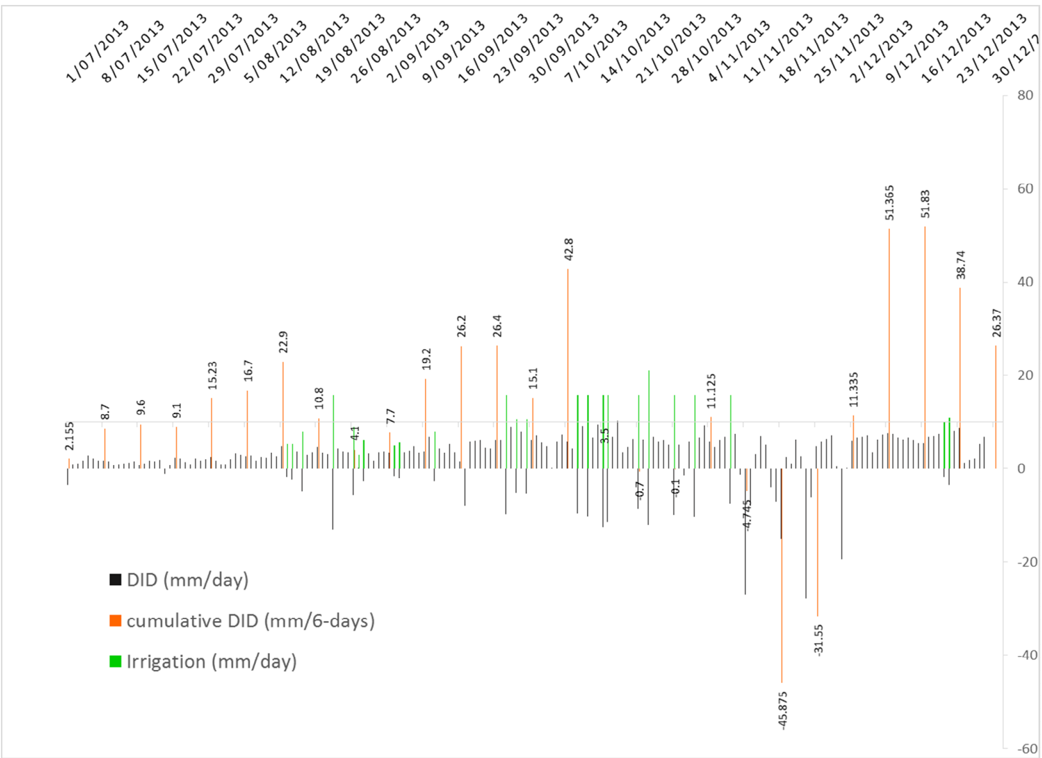


Figure 3.2: Stage 1A - Daily Irrigation Deficit (DID), 6-day cumulative DID and Irrigation applied for the Period (1st July – 31st December 2013)

In addition to the water balance, real-time soil moisture monitoring ensured that irrigation was only applied when there was available “space” in the soil profile. Figures 3.3a and 3.3b show the wetting and drying patterns of MS1 (outside the irrigation area) and MS5 (in deepest treatment zone within irrigation area).

The general similarity between irrigated and non-irrigated soils and their wetting and drying periods indicates that the structure of the receiving soil is being maintained and water is passing to the deeper parent soil. For example, comparison of Figure 3.3a to 3.3b shows that water movement through the soil has not been significantly altered by irrigation. That is, the general wetting and drying periods in MS1 (due to rainfall shown by blue columns) are generally observed in MS5 trends. Water is either moving to deeper groundwater or being used by plants to create these similar patterns. However, irrigation (black columns) was applied to MS5 and, while the irrigation “spikes” increased the presence of soil water during this period, this allowed considerable water uptake by plants in the trial area. Further discussion on soil water dynamics will be provided in *Section 4.3 Key Findings – Baseline 4(irrigated soils) vs Baseline 3(irrigated soils)*.

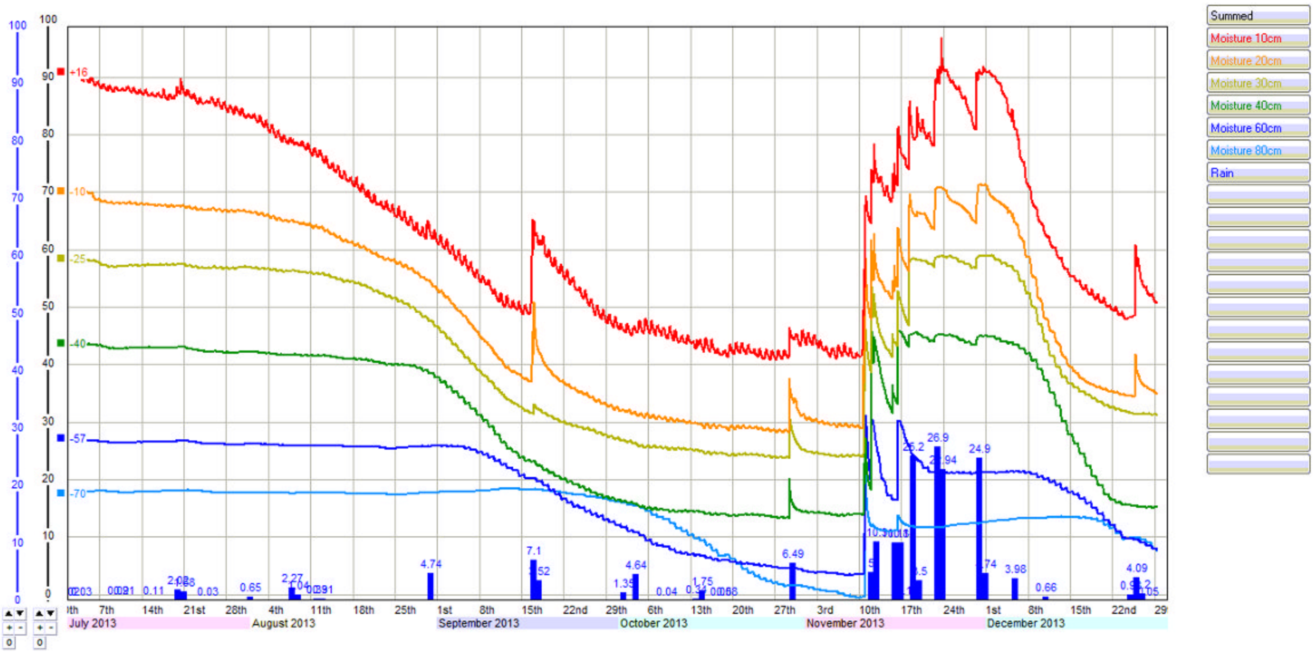


Figure 3.3a: Soil moisture monitoring showing wetting and drying periods for MS1 (control, outside irrigation area) from 1st July – 31st December 2013

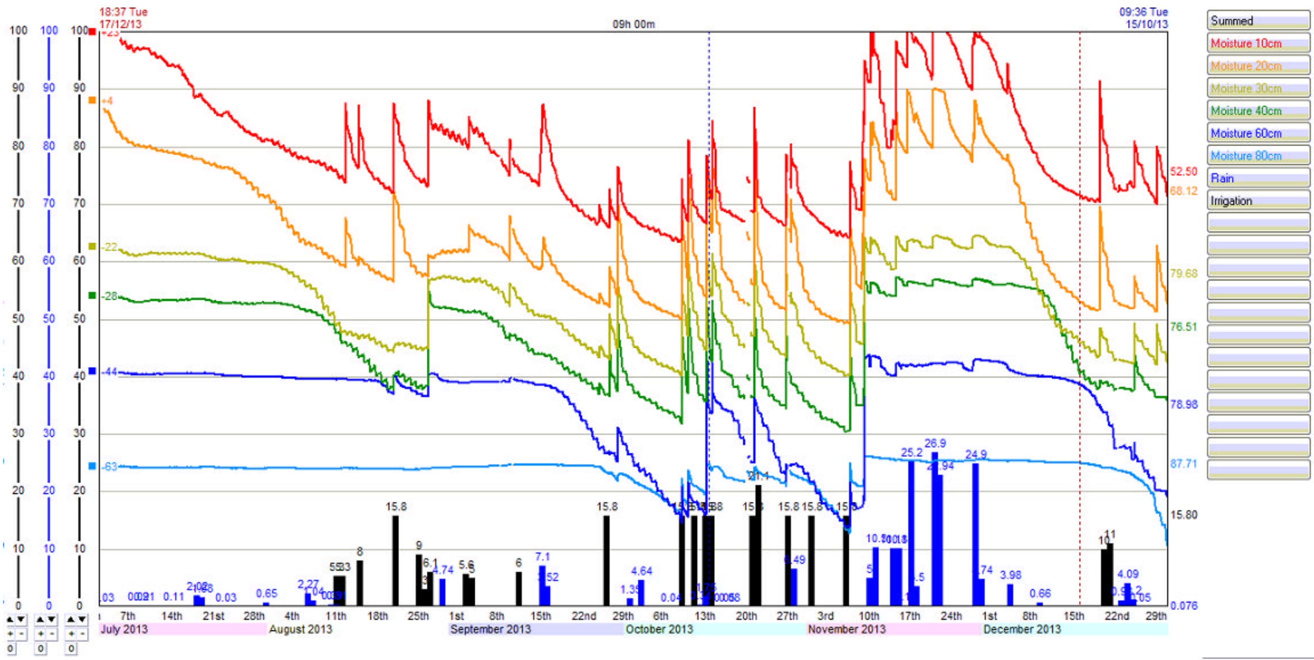


Figure 3.3b: Soil moisture monitoring showing wetting and drying periods for MS5 (inside irrigation area) from 1st July – 31st December 2013

Irrigation of blended CSG water occurred intermittently from 1st July – 31st December 2013 as indicated by the water balance previously described in the Section 3.3.1. Approximately 32.45 ML of blended CSG water was applied to the Stage 1A area during the period compared to 4.66 ML in the previous reporting period. The DID, cumulative DID and soil moisture indicated that these were optimum irrigation opportunities that would result in zero runoff while maintaining soil moisture levels suitable for crop growth.

3.3.2. Stage 1B

The water balance used for Stage 1A was also used for Stage 1B and is shown in Figure 3.4. Approximately 11.45 ML (~ 225 mm) was applied to the 4 ha in Stage 1B from 1st July – 31st December 2013.

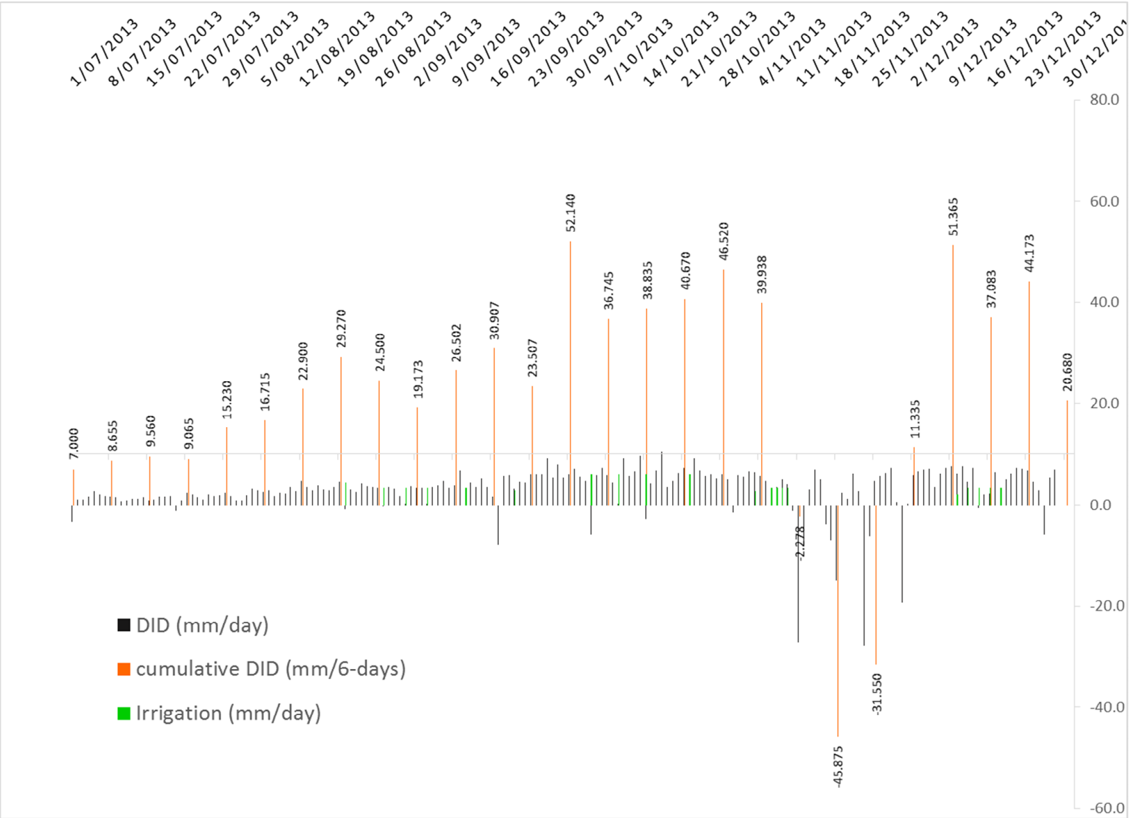


Figure 3.4: Stage 1B - Daily Irrigation Deficit (DID), 6-day cumulative DID and Irrigation applied for the Period (1st July – 31st December 2013)

3.4. Irrigation water quality

Table 3.2 summarises water quality of the blended CSG water prior to irrigation of Stages 1A and 1B from 1st July – 31st December 2013 (from Parsons Brinckerhoff, 2014). The water quality results are from the August 2013 quarterly sampling event and are from the Tiedman South dam (TSD).

The blended water (August 2013) had an EC of 1680 µS/cm which was 12 % higher than the mixing-model design objective for water quality prior to irrigation (≈ 1500 µS/cm). The elevated lab pH (9.04) is of minor concern to site soils at these EC values as the pH can be attributed to carbonate interactions in the blended water and there is substantial buffering capacity in the amended soils. The field pH of 8.39 is considered more representative. Also in the water monitoring compliance reports (Parsons Brinckerhoff, 2013 and Parsons Brinckerhoff, 2014) the ANZECC irrigation guidelines have been adopted as the most appropriate criteria to assess the suitability of blended water for irrigation. The pH criteria range is between 6 and 9.

The blended irrigation water has elevated pH and this may cause some nutrient uptake problems. The blended irrigation water was generally low in nutrients (nitrate and ortho-phosphate) however at a pH of 9.04 all phosphorus is in the bound form and is not available to plants. For example, adjustment of the pH to around 7.5 would release phosphorus for crop assimilation.

Sodium, nutrients and Total Organic Carbon (TOC) values are discussed further in section 3.5 with respect to mass balance results and potential impacts on site soils.

Table 3.2: Water quality of the blended CSG water prior to irrigation (from TSD)

Parameter	Units	Value
Electrical Conductivity (EC) (lab)	µS/m	1680
pH (lab)	no units	9.04
Chloride (Cl)	mg/L	276
Sodium (Na)	mg/L	229
Sodium Adsorption Ratio (SAR)	-	10
Total Alkalinity	mg $CaCO_3$/L	331
Bicarbonate Alkalinity (HCO_3)	mg $CaCO_3$/L	248
Carbonate Alkalinity (CO_3^-)	mg $CaCO_3$/L	83
Hardness	mg $CaCO_3$/L	50
Aluminium (Al)	mg/L	0.04
Boron (B)	mg/L	0.16
Calcium (Ca)	mg/L	10
Copper (Cu)	mg/L	0.002
Fluoride (F)	mg/L	0.2
Iron (Fe)	mg/L	<0.05
Magnesium (Mg)	mg/L	6
Manganese (Mn)	mg/L	<0.001
Nitrate nitrogen (NO_3)	mg/L	1.9
Total Kjeldahl Nitrogen (TKN)	mg/L	5.2
Total Phosphorus (P)	mg/L	0.64
Orthophosphate (PO_4^{3-})	mg/L	<0.01
Potassium (K)	mg/L	142
Sulfate (SO_4^{2-})	mg/L	69
Zinc (Zn)	mg/L	0.014
Total Dissolved Solids (TDS)	mg/L	1020
Total Organic Carbon (TOC)	mg/L	37

Note – Water quality analysis is from Parsons Brinckerhoff 2014, laboratory results from August 2013 sampling event

3.5. Sodium, nutrient and carbon balance

The aim of using mass balances was to determine how the sodium, nutrient and carbon load in the applied water was accumulating in the receiving soil over time. Mass balance results are presented as mg/kg applied during the period and are compared to soil data to determine changes over time.

3.5.1. Stage 1A

The mass of soil in Stage 1A was calculated as:

11.94 ha = 119,400 m^2 x 0.333 m (average treatment depth) x 1200 kg/m^3 (bulk density of the soil) = 47,712,240 kg of soil in Stage 1A.

Table 3.3 provides a summary of mass balances for sodium, nitrate nitrogen, total phosphorus and total organic carbon

Table 3.3: Stage 1A mass balance summary for sodium, nitrate nitrogen, total phosphorus and total organic carbon

	Dam WQ (mg/L)	Irrigation (ML)	Total Applied (mg)	Site soil mass (kg)	Total Applied (mg/kg)
Sodium (Na)	229	32.45	7,431,050,000	47,712,240	155.7
Nitrate nitrogen (NO_3^-)	1.9	32.45	61,655,000	47,712,240	1.3
Total Kjeldahl Nitrogen (TKN)	7.12	32.45	231,044,000	47,712,240	4.8
Total Phosphorus (P)	0.64	32.45	20,768,000	47,712,240	0.4
Total Organic Carbon (TOC)	37	32.45	1,200,650,000	47,712,240	25.2

For example, 155.7 mg/kg of sodium has been applied during the period. Soil analysis over this period (discussed in Section 4) indicated that sodium ranged from approximately 273 mg/kg to 456 mg/kg (to 1200 mm) with an average of 346 mg/kg. Coupled with excess rainfall in November 2013, and saturated soils, the 155.7 mg/kg applied during this period did increase soil sodium compared to Baseline 3 however it is not likely to significantly impact on soil structure or water movement through the soil. The impact of sodium on soil structure is discussed in *Section 4.3 Key Findings – Baseline 4(irrigated soils) vs Baseline 3(irrigated soils)*.

Nitrate nitrogen, total phosphorus and total organic carbon have been applied in negligible quantities through irrigation during the reporting period.

3.5.2. Stage 1B

The mass of soil in Stage 1B was calculated as:
4ha = 400,000 m^2 x 0.15 m (average treatment depth) x 1200 kg/m^3 (bulk density of the soil)
= 7,200,000 kg of soil in Stage 1B

Table 3.4 provides a summary of mass balances for sodium, nitrate nitrogen, total phosphorus and total organic carbon.

Table 3.4: Stage 1B mass balances summary for sodium, nitrate nitrogen, total phosphorous and total organic carbon

	Dam WQ (mg/L)	Irrigation (ML)	Total Applied (mg)	Site soil mass (kg)	Total Applied (mg/kg)
Sodium (Na)	229	11.45	2,622,050,000	7,200,000	364.2
Nitrate nitrogen (NO_3^-)	1.9	11.45	21,755,000	7,200,000	3.0
Total Kjeldahl Nitrogen (TKN)	7.12	11.45	81,524,000	7,200,000	11.3
Total Phosphorus (P)	0.64	11.45	7,328,000	7,200,000	1.0
Total Organic Carbon (TOC)	37	11.45	423,650,000	7,200,000	58.8

For example, 364.2 mg/kg of sodium has been applied during the period. Soil analysis over this period (discussed in Section 4) indicated that sodium ranged from ~ 165 mg/kg to ~ 345 mg/kg (0-20cm depth) over the last two sampling campaigns. The 364.2 mg/kg applied during this latest period did significantly increase sodium in the soil profile which increased soil ESP from ~ 8 to ~ 15.

Nitrate nitrogen, total phosphorus and total organic carbon have been applied in minimal quantities through irrigation at this time and pose no threat to soil or crop health.

3.6. Perched water piezometer results

Shallow piezometers installed around and within the respective irrigation areas also provided data to assist irrigation scheduling. Table 3.5 shows the dual piezometer sites and water levels during 2013. Piezometer locations are shown in Attachment 2.

Table 3.5: Piezometer sites and water level depths in 2013

Piezometer ID	Piezometer Depth below surface (mm)	Water level in Piezometer (mm) on sampling date						
		6/02/2013	7/03/2013	11/04/2013	21/05/2013	13/06/2013	1/10/2013	8/11/2013
SP1A	600	600	570	60	210	600	0	0
SP1B	1200	0	0	0	0	0	0	0
SP2A	600	530	550	0	0	510	0	90
SP2B	1200	1200	950	140	0	1000	200	0
SP3A	900	540	0	0	0	680	70	0
SP3B	1200	0	0	0	0	0	0	0
SP4A	1200	400	0	0	0	730	0	290
SP4B	1200	0	0	0	0	0	0	0
SP5A	400	0	0	0	0	270	0	10
SP5B	1200	0	420	0	0	1090	320	220
SP6A *	1200	580	0	160	0	1200	390	0
SP6B *	1200	0	0	0	0	0	0	110
SP7A	400	270	0	90	160	280	0	140
SP7B	1200	0	0	0	0	0	0	0
SP8A	400	380	0	0	100	400	0	110
SP8B	1200	0	925	0	0	210	0	0
SP9A ^	500	Not installed until May 2013				0	0	0
SP9B ^	700	Not installed until May 2013				0	0	0
SP10A ^	500	Not installed until May 2013				0	80	80
SP10B ^	700	Not installed until May 2013				0	0	0
Rainfall between periods (mm)		*82*	*101*	*28*	*34*	*98*	*54*	*9*
Irrigation between periods (mm) (Stage 1B in brackets)		*0 (0)*	*0 (0)*	*0 (0)*	*29 (0)*	*10 (75)*	*108 (88)*	*131 (59)*
Total water applied between periods (mm) (Stage 1B in brackets)		*82 (82)*	*101 (101)*	*28 (28)*	*63 (34)*	*108 (173)*	*162 (142)*	*140 (68)*

Key * - dual piezometers located upstream and downstream of catch dam 2 (CDW) outside the irrigation area;
^ - Stage 1B area

The piezometers within the trial area (those denominated by the letter "A") were installed to depths that matched the depth of treatment for each location. The paired piezometers outside of the trial area (those denominated by the letter "B") were all installed to the same depth of 1.2 metres.

The piezometers within the Stage 1A irrigation area generally contained more water than the outside piezometers. This is due to the substantially improved infiltration rate of the ameliorated soils inside the trial area, resulting in the promotion of downward movement of water into the soil (to treatment depth), rather than surface runoff which would occur in the parent soils. Also, most piezometers accumulated water during high rainfall however piezometer water level trends indicate that this water either permeated into the surrounding soil over time and/or was transpired by plants.

Paired piezometers (SP9a, SP9b, SP10a, and SP10b) were installed in the Stage 1B area (see Attachment 2) to monitor the potential for perched water to develop inside and immediately outside (i.e. down gradient) of the irrigated pasture area. The piezometers were installed to a depth of 500mm inside the area to be irrigated and 700mm outside the area to be irrigated.

In Stage 1A two of the perched water monitoring piezometers located in the parent soils (SP2B and SP5B) displayed high water levels and these are discussed below.

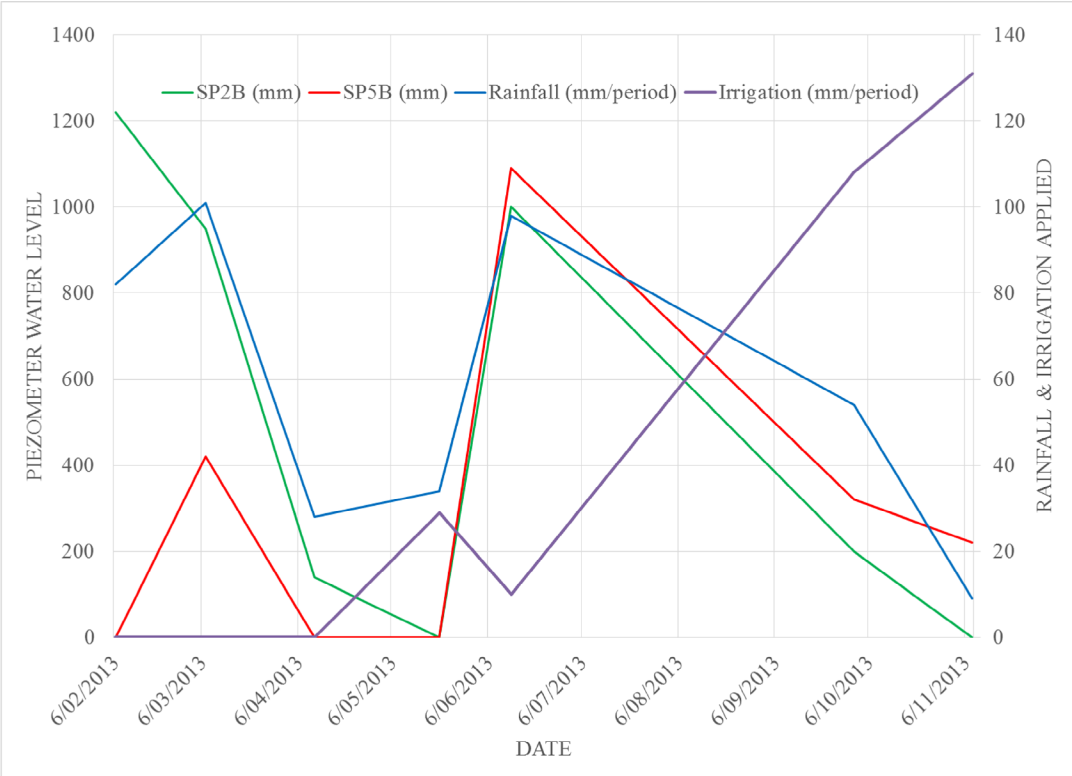
Table 3.6 Rainfall versus Irrigation correlation for SP2B and SP5B

r^2	SP2B	SP5B
Rainfall	0.91	0.58
Irrigation	-0.61	-0.05

Table 3.6 shows the correlation (r^2) of SP2B and SP5B versus rainfall and irrigation. Note there is a strong correlation between SP2B and rainfall and a weaker correlation between SP5B and rainfall; and no correlation at all between water level in the piezometers and applied irrigation.

Figure 3.5 shows the plot of rainfall and irrigation over time at the two piezometers with high water levels. See Figure 3.1 for rainfall and irrigation events.

Figure 3.5: Plot of piezometer water level versus rainfall and irrigation in SP2B and SP5B



Piezometer SP2B is located upslope in an area where shallow rock was detected in early soil investigations. The likely presence of shallow rock may be having an effect on the movement of subsoil moisture, resulting in higher readings at this piezometer.

Piezometer SP5B is located downslope of the relatively large catchment that drains towards Catch Dam 2 (CDW) from the south-east and north east of the piezometer. It is not unexpected to have perched water persisting for longer periods at low lying locations such as this.

In both cases the ongoing presence of water is a result of rainfall, as indicated by the high r^2 correlations in Table 3.6.

4. Performance of soils on the Stage 1A irrigation area

This report (Report 3) was prepared after blended irrigation water was applied to the trial area and after the collection of Baseline 4 soil samples in early November 2013.

4.1. Soil analysis parameters

The Stage 1A soil analysis program covers measurement of the parameters shown in Table 4.1

Table 4.1 – Soil analysis parameters

Parameter	Measurement Units
Chlorides	mg/kg
Electrical Conductivity - Soil:water (1:5)	dS/m
pH (1:5 water)	-
pH (1:5 $CaCl_2$)	-
Organic Carbon (OC)	%
Nitrate Nitrogen (NO_3)	mg/kg
Phosphorus (Colwell)	mg/kg
Phosphorus Buffer Index (PBI-Col)	-
Sulphur	mg/kg
Copper	mg/kg
Zinc	mg/kg
Manganese	mg/kg
Iron	mg/kg
Boron	mg/kg
Potassium	mg/kg, meq/100g
Calcium	mg/kg, meq/100g
Magnesium	mg/kg, meq/100g
Sodium	mg/kg, meq/100g
Aluminium	mg/kg, meq/100g
Potassium %	%
Calcium %	%
Magnesium %	%
Sodium %	%
Aluminium %	%
Effective Cation Exchange Capacity (ECEC)	meq/100g
Calcium/Magnesium Ratio	-
Soil texture	-
Soil colour	-
Physical analysis: (bulk density, porosity, and infiltration rate)	-

4.2. Baseline 4 – Amended soil sampling and test results

The 16 soil sampling locations (CS1-CS16) were re-sampled on the 7th and 8th November 2013 and subsequently analysed. The location of these 16 sites is shown in Attachment 1. Soil samples were taken immediately prior to the start of the large rain event in November 2013 and after a period of extended blended water irrigation. Soil samples were taken manually using a hand auger to the depths dictated by the different treatments in order to minimise disturbance. The full suite of desired samples was extracted.

The summarised soil test results are shown in Attachment 3.

4.3. Key findings – Baseline 4 (irrigated soils) vs Baseline 3 (irrigated soils)

The changes in average values between Baseline 4 and Baseline 3 are shown in Attachment 4. In addition, Baseline 4 is also compared against Baseline 1 (parent soil) values.

Salinity (as EC)

As discussed in Report 2, the salinity 'spike' resulting from the use of compost and the mixing of layer 3 of the parent soil has subsided. Baseline 4 data indicates minimal changes in EC compared to Baseline 3 results (refer Figure 4.1 and Figure 4.2).

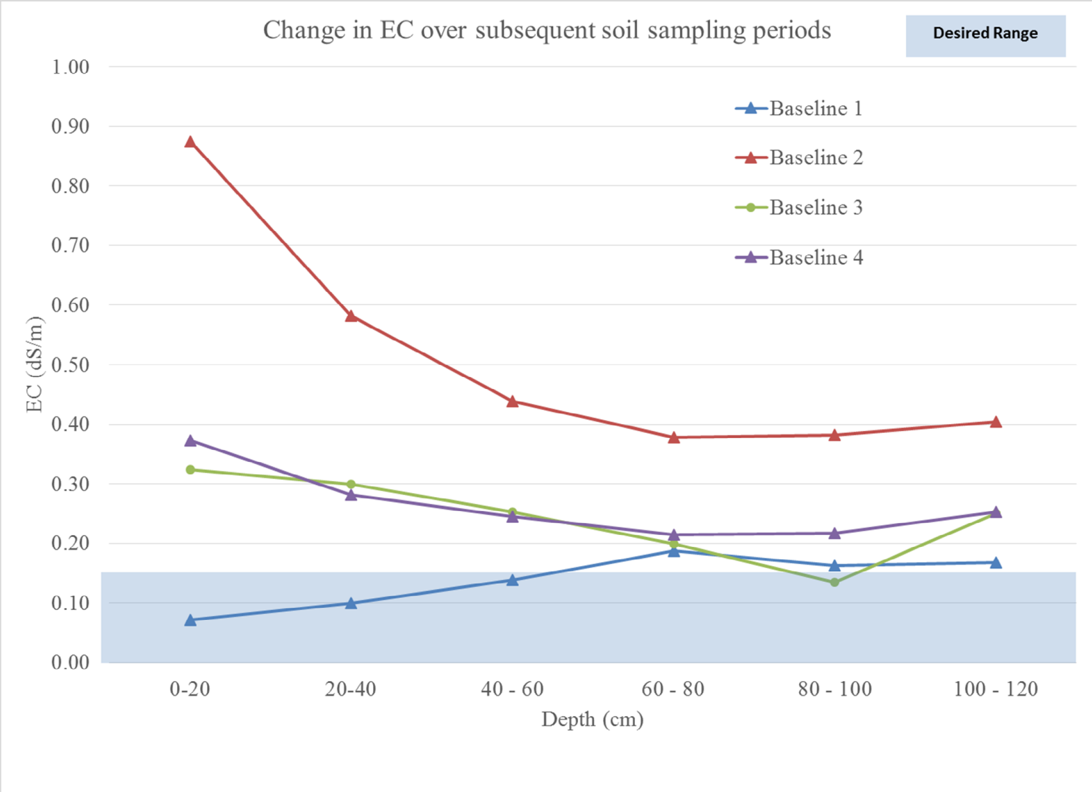


Figure 4.1: Change in (average) EC for all sites over subsequent sampling periods

Figure 4.2 shows change in EC over subsequent sampling periods for a single site (CS3 with a treatment depth of 1200 mm). Salinity has increased to depths of 60cm since the Baseline 3 sampling event in June 2013.

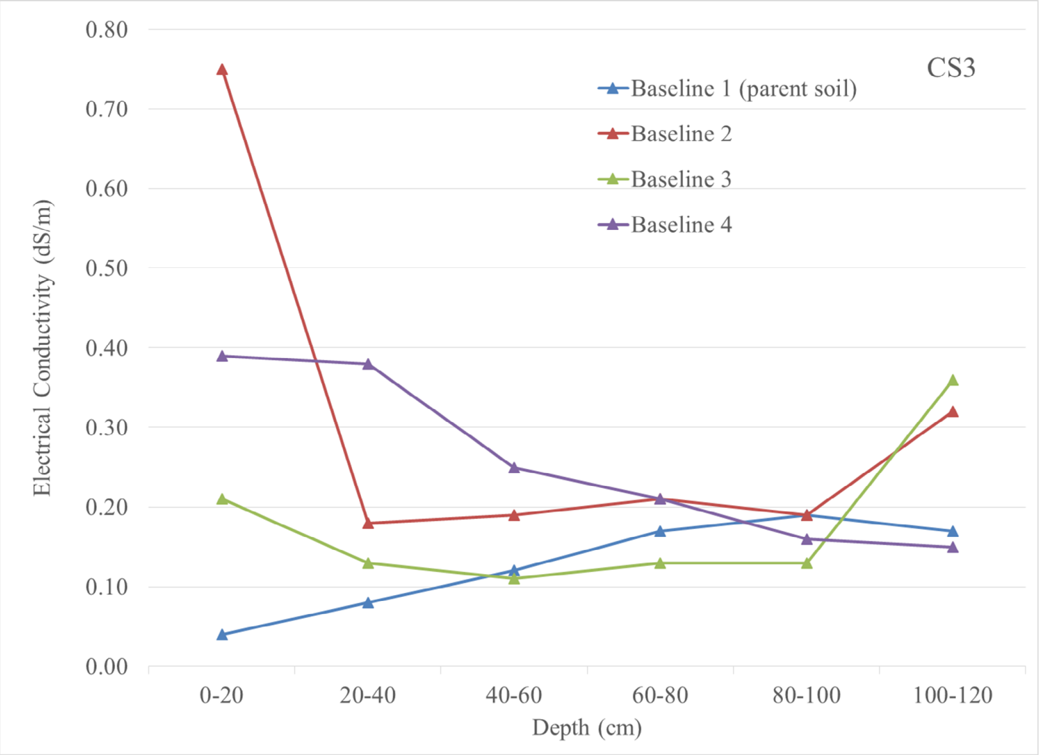


Figure 4.2: Change in EC for site CS3 (treatment depth = 1200 mm) over subsequent sampling periods

Sodium and Exchangeable Sodium Percentage (ESP)

The sodium values have slightly increased at all depths (as expected with a dominance of irrigation over rainfall). As a result the exchangeable sodium percentages have also increased and were marginally above desirable level of < 6 % to 80 cm depth (refer to the composite changes shown in Figure 4.3). The percentage increase from Baseline 3 results was greatest in the shallowest soil samples to 40 cm depth (again as expected given there was no deep leaching occurring prior to the large November rainfall event).

Large rainfall events (e.g. 100 mm over 5 days) are a common feature of the Gloucester climate during the October to April period. Subsequent to the soil sampling on the 7th and 8th November there was a large rainfall event. Commencing on the 10th November through to the 24th November, 137.8 mm of rainfall occurred. This event may have caused a reduction in sodium and ESP by downward 'flushing' of the relatively mobile sodium through the ameliorated soil. Additional soil monitoring during the course of this irrigation program are required after a series of large rainfall events to confirm the effectiveness of deep leaching due to rainfall.

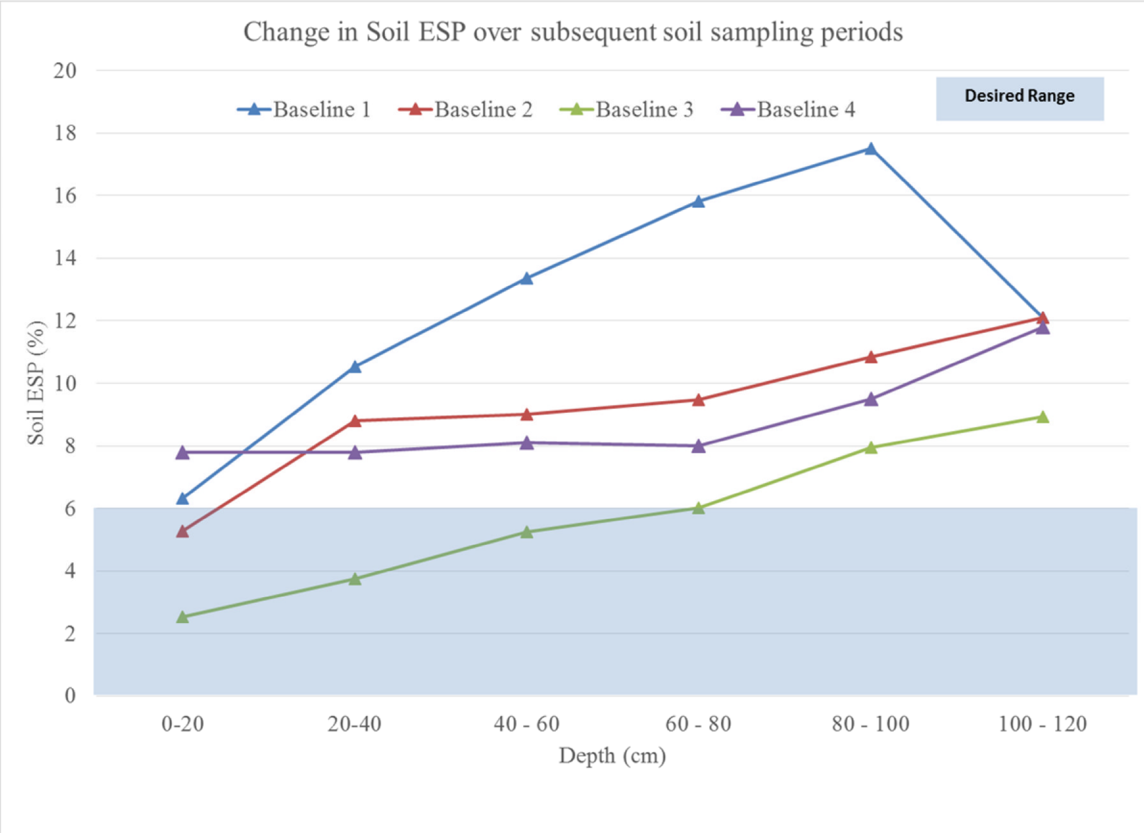


Figure 4.3. Change in Exchangeable Sodium Percentage (ESP)

Nitrate

Nitrate levels at all sites are very low due to crop uptake.

Calcium

Calcium levels remained stable and have contributed to minimising soil ESP increases.

Calcium/Magnesium Ratio

A Calcium/Magnesium ratio of around 2 is considered to represent an optimum balance for plant growth. The calcium/magnesium ratio has increased to the optimum at depth.

Effective Cation Exchange Capacity (ECEC)

The cation exchange capacities have stabilised near the surface at all sites due to the addition of lime after Baseline 2 (refer Figure 4.4). This favours healthy plant growth.

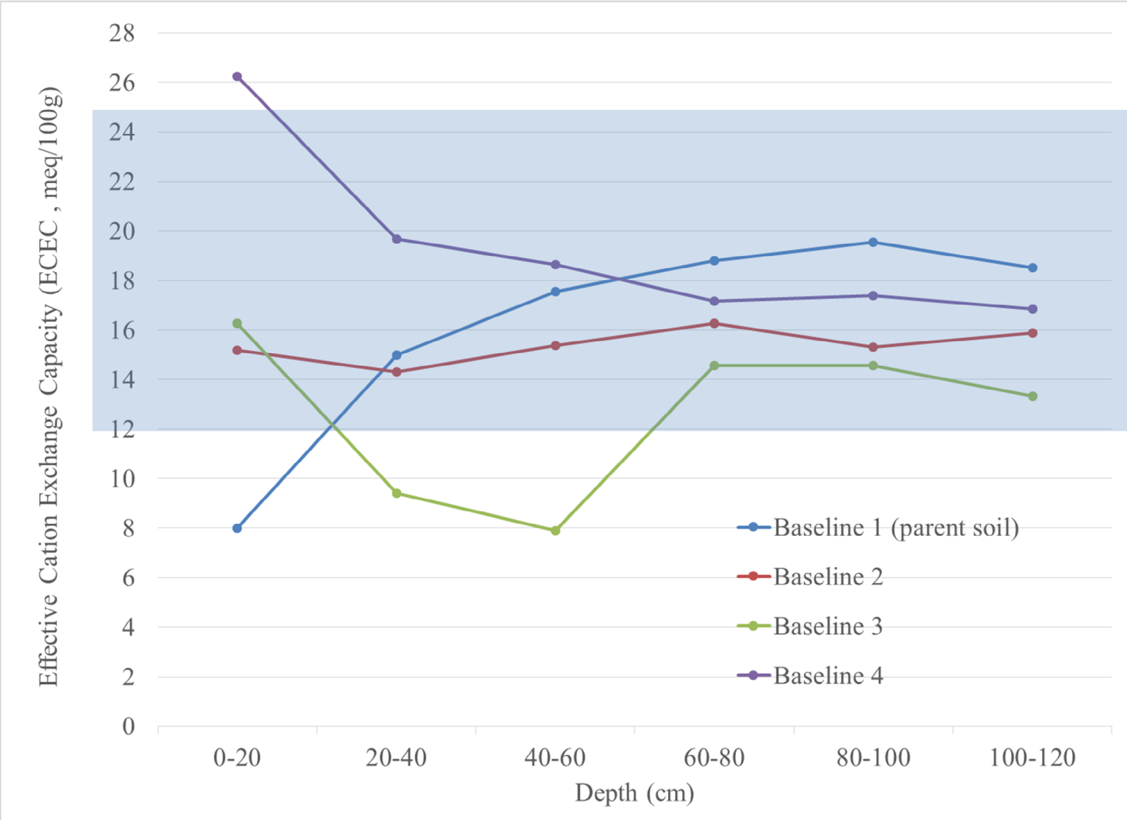


Figure 4.4: Change in (average) ECEC for all sites over subsequent sampling periods

Soil structure

Soil amendments and application of blended CSG water has the potential to impact on soil structure. Close scrutiny has been applied to the Tiedman irrigation program with respect to maintaining soil structure and monitoring changes in soil chemistry and the water quality of applied waters (irrigation and rainfall).

Maintaining soil structure can be interpreted from the leaching dynamics between Baseline soil sampling campaigns. For example, the first 4 coloured columns in Table 4.2 show average results for Baseline 1 (B1), Baseline 2 (B2), Baseline 3 (B3) and Baseline 4 (B4). The 4 middle columns show the relative difference between each Baseline. The last 4 columns show the relative difference between each Baseline compared to Baseline 1.

Table 4.2 – Leaching dynamics between Baseline soil surveys

	B1	B2	B3	B4	B2-B1	B3-B2	B4-B3	B2-B1	B3-B1	B4-B1
Na (mg/kg)										
(cm)										
0-20	135	239	128	342	104	-111	213	104	-7	207
20-40	381	356	153	273	-25	-203	121	-25	-228	-108
40 - 60	527	361	181	306	-166	-180	125	-166	-346	-221
60 - 80	606	383	220	331	-223	-163	112	-223	-387	-275
80 - 100	643	426	298	367	-217	-129	69	-217	-345	-276
100 - 120	624	501	308	456	-123	-193	148	-123	-316	-168
ESP (%)										
(cm)	**B1**	**B2**	**B3**	**B4**	**B2-B1**	**B3-B2**	**B4-B3**	**B2-B1**	**B3-B1**	**B4-B1**
0-20	6.2	5.3	2.5	7.8	-0.9	-2.8	5.2	-0.9	-3.7	1.6
20-40	10.5	8.6	3.8	7.8	-1.9	-4.8	4.0	-1.9	-6.7	-2.7
40 - 60	13.5	8.9	5.2	8.1	-4.6	-3.7	2.9	-4.6	-8.3	-5.4
60 - 80	15.7	9.6	6.0	8.0	-6.1	-3.5	2.0	-6.1	-9.7	-7.7
80 - 100	17.4	11.1	7.9	9.5	-6.4	-3.1	1.6	-6.4	-9.5	-7.9
100 - 120	13.9	12.0	8.9	11.8	-1.9	-3.1	2.9	-1.9	-5.0	-2.2
Ca (mg/kg)										
(cm)	**B1**	**B2**	**B3**	**B4**	**B2-B1**	**B3-B2**	**B4-B3**	**B2-B1**	**B3-B1**	**B4-B1**
0-20	570	2364	2981	2351	1794	617	-630	1794	2411	1781
20-40	360	1456	2094	1586	1096	638	-508	1096	1734	1226
40 - 60	259	1243	1385	1361	984	142	-25	984	1126	1102
60 - 80	292	1088	1075	1219	796	-14	144	796	783	927
80 - 100	165	943	443	1106	779	-500	663	779	278	941
100 - 120	147	903	370	897	756	-533	527	756	223	750
Mg (mg/kg)										
(cm)	**B1**	**B2**	**B3**	**B4**	**B2-B1**	**B3-B2**	**B4-B3**	**B2-B1**	**B3-B1**	**B4-B1**
0-20	625	1135	688	655	510	-447	-33	1135	687	655
20-40	1360	1337	801	797	-23	-536	-4	1337	801	797
40 - 60	1520	1507	884	982	-12	-623	98	1507	884	982
60 - 80	1449	1519	1033	1087	71	-487	54	1519	1032	1087
80 - 100	1420	1446	1279	1089	26	-168	-190	1446	1279	1089
100 - 120	1360	1434	1183	1195	74	-252	13	1434	1183	1195
Ca/Mg ratio										
(cm)	**B1**	**B2**	**B3**	**B4**	**B2-B1**	**B3-B2**	**B4-B3**	**B2-B1**	**B3-B1**	**B4-B1**
0-20	0.7	2.1	2.8	2.3	1.5	0.7	-0.6	1.5	2.2	1.6
20-40	0.2	0.9	1.8	1.4	0.8	0.9	-0.4	0.8	1.6	1.3
40 - 60	0.1	0.8	1.0	0.9	0.7	0.2	-0.1	0.7	0.9	0.8
60 - 80	0.1	0.7	0.7	0.8	0.6	0.0	0.1	0.6	0.6	0.7
80 - 100	0.1	0.6	0.2	0.8	0.5	-0.4	0.6	0.5	0.2	0.7
100 - 120	0.1	0.4	0.2	0.5	0.4	-0.2	0.3	0.4	0.1	0.4

Key:B1 = Baseline 1 soil sampling, B2 = Baseline 2 soil sampling, B3 = Baseline 3 soil sampling, B4 = Baseline 4 soil sampling

Table 4.2 indicates that, when compared to B1, sodium (Na^+) generally decreased for B2 and B3 then increased in B4. Similar trends can be observed in the soil ESP results which are a result of the balance between Na^+ and Calcium (Ca^{2+}) and Magnesium (Mg^{2+}). Both Ca^{2+} and Mg^{2+} remained relatively stable throughout the profile and their presence maintains soil ESP. Even though soil Na^+ increased from B3 to B4 the B4 results still remain considerably less than B1 results (parent soil) at this time. Also, the Ca/Mg ratio has generally increased due to the previous addition of ameliorants and both cations have minimised Na^+ accumulation by preferentially occupying exchange sites in the soil.

Another key to maintaining soil structure is the sodium adsorption ratio (SAR) of applied waters (irrigation and rainfall) and the subsequent impact on clay dispersion/flocculation. Clay dispersion is one end of diffuse double layer (DDL) theory where clay particles separate into single platelets; clay particle flocculation is where many platelets align together to form clusters. Both depend on the electrolyte concentration of the applied waters and the antecedent ESP of the receiving soil (refer Chapter 2 in Lucas, 2009).

The degree of clay dispersion that may occur has a direct effect on permeability and downward soil water movement. Therefore maintaining clay (micro-aggregate) stability will promote suitable infiltration rates. Lucas (2009) describes the soil ESP/effluent SAR continuum for micro-aggregate/soil pore stability which predicts clay particle behaviour in a soil of known ESP and irrigated with a water of known SAR.

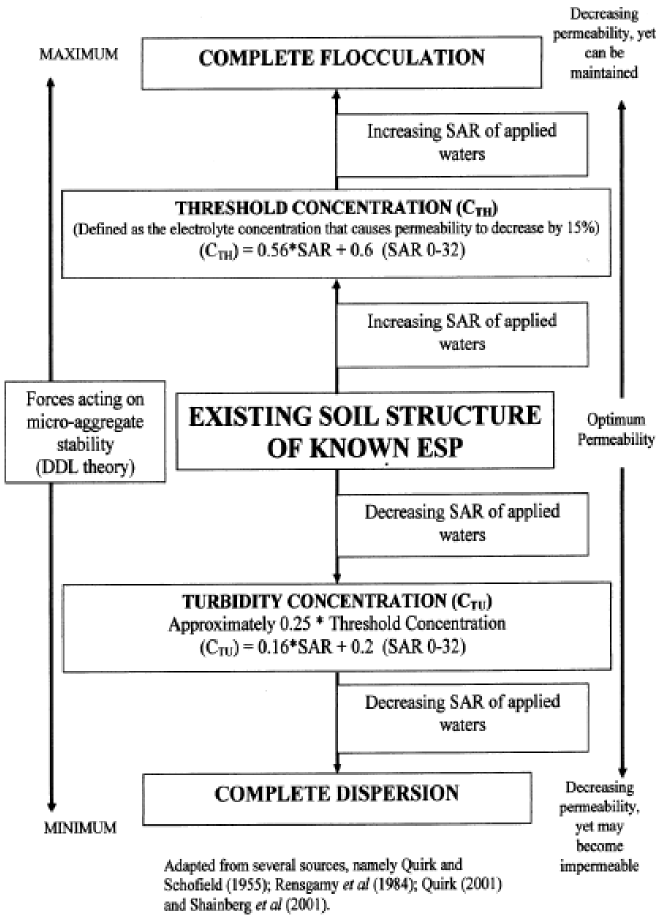


Figure 4.2 Soil ESP/effluent SAR continuum for micro-aggregate/soil pore stability (from Lucas, 2009)

Different electrolyte concentrations from blended irrigation water and from rainfall will initiate changes in clay particle behaviour (flocculation to dispersion) in the receiving soil over time. For example, the average soil ESP in the upper 40 cm of the soil profile was 7.8 in Baseline 4. The SAR of irrigation waters was approximately 10 during the same period. Based on the equation in Figure 4.2, the threshold concentration (C_{TH}) that maintains micro-aggregate stability would be 6.2. The applied blended CSG water with a SAR of 10 exceeds the C_{TH} indicating that while permeability would be maintained there would be a small (expected) decrease in infiltration rate.

Furthermore, rainfall near the coast typically contains a relatively higher concentration of Na^+ compared to Ca^{2+} and Mg^{2+}, so while having a lower electrolyte concentration compared to blended irrigation water, rainfall SAR is usually around 3. Based on the equation in Figure 4.2, the turbidity concentration (C_{TU}) that causes complete dispersion of micro-aggregates would be 1.8. Rainfall with a SAR of 3 exceeds the C_{TU} indicating that permeability would decrease.

Problems may occur if Na^+ is allowed to accumulate over time as the soil ESP would gradually rise and micro-aggregate/soil pore stability would be reflected in the changing C_{TH} and C_{TU}. For example, if soil ESP increased to 20 % in the upper 40 cm of the soil profile then the corresponding C_{TH} and C_{TU} would be 12.6 and 4.2. This means that rainfall would cause complete dispersion of surface micro-aggregates that would block soil pore spaces and severely reduce infiltration in the upper 10 cm of the soil profile.

It is important to note that as ESP increases, the electrolyte concentration of the applied solution must also increase to maintain optimum permeability. For example, Davidson and Quirk (1961) demonstrate the impact of changing the electrolyte concentration of irrigation waters, using Riverina clay (60% clay, pH=7.4, ESP=23) near Deniliquin, NSW. The soil was irrigated with waters that had an electrolyte concentration slightly higher than the C_{TH} (point A in Figure 4.3) and with Murrumbidgee River water, which was approximately half the C_{TU} (point B in Figure 4.3). In the first case, the 7.5 cm of water applied was observed to have permeated completely into the soil after 16 hours (Quirk, 2001). In contrast, large volumes of the Murrumbidgee water remained pooled on the surface after a similar time period.

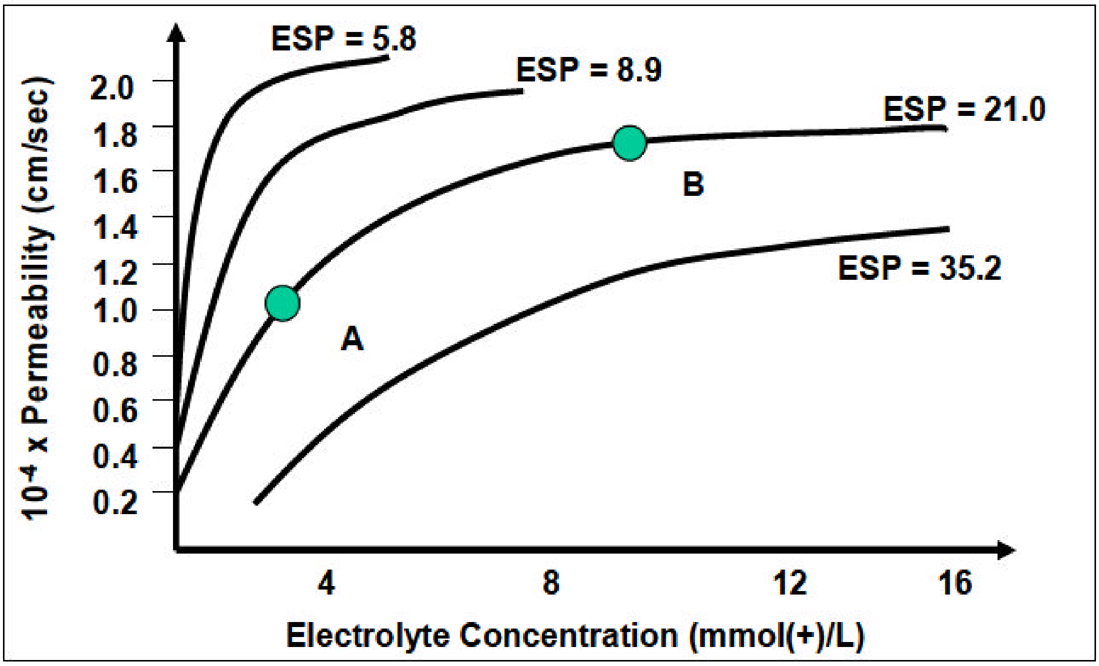


Figure 4.3: Permeability as a function of electrolyte concentration and soil ESP (Lucas, 2009)

Quirk (2001) states that when the irrigation water electrolyte concentration exceeds the C_{TH}, the soil appears granular and dries to a friable state (flocculated). Conversely, when irrigation water electrolyte concentration is less than the C_{TU}, the surface soil appears white (dispersed clay particles) and water remains pooled on the surface for extended periods (Quirk, 2001). Figure 4.3 shows permeability of a soil (same soil but with ESP's of 5.8, 8.9, 21 and 35 %) as a function of electrolyte concentration and soil ESP.

From the graph it can be seen that at low electrolyte concentrations (< 2 mmol(+)/L) all soils (of varying soil ESP) decrease in permeability. This is due to the electrolyte concentration being less than the C_{TU} and clay dispersion occurs. Dispersed clay particles translocate downwards through the soil profile and block soil pores in the upper 10 cm, resulting in a significant decrease in permeability.

At higher electrolyte concentrations (> 4 mmol(+)/L) greater permeability can be maintained. This is due to the electrolyte concentration being greater than the C_{TH} and a shift to clay flocculation occurs. Flocculated clay particles, while creating smaller pore spaces, can facilitate downward water movement through the soil profile to promote a leaching regime. Figure 4.3 also shows how soil permeability decreases with increasing soil ESP.

Therefore, the aim of managing soil structure is about creating a leaching regime that allows the removal of excess Na^+ from the soil profile. Table 4.2 highlighted the dynamic leaching of Na^+ and the relatively stable presence of Ca^{2+} and Mg^{2+} and is mainly due to the seasonal rainfall patterns at Gloucester and optimising irrigation application at appropriate times (by water balance calculation).

The soil structure in Stage 1A at this stage has significantly improved from the amendments and shows no indication of deleterious effects (such as clay particle dispersion) from the irrigation of blended water or periodic rainfall.

5. Performance of soils on the Stage 1B irrigation area

5.1. Irrigation area

The area selected for the Stage 1B area has no previous history of cropping or substantial soil improvement, although improved pasture was briefly irrigated in 2009 when small amounts of produced water were irrigated under an earlier REF approval (details provided in AGL, 2010). Some soil sampling and monitoring was completed as part of this earlier irrigation program.

The Stage 1B area is approximately 4.1 hectares in area and is located to the south of the Stage 1A trial area. See Attachment 2. A single composite soil sample was prepared from a series of samples collected along diagonal transects across plots AL1/2 and AL3/4 respectively. Soil samples were taken immediately prior to the start of the large rain event in November 2013 and after a period of extended blended water irrigation. Soil samples were taken manually using a hand auger to a depth of 200mm in order to minimise disturbance.

5.2. Baseline 3 – amended soil sampling and test results

A soil composite sample was taken on the 7th and 8th November 2013 and subsequently analysed. Soil samples were taken (transect approach) manually using a hand auger (to 10 cm soil depth) in order to minimise disturbance. The full suite of desired samples was extracted. The summarised soil test results are shown in Attachment 5.

5.3. Key findings – Baseline 3 (irrigated soils) vs Baseline 2 (irrigated soils)

Baseline 3 (irrigated soil) vs Baseline 2 (irrigated soil) key findings include (to 20 cm):

- Increase in soil EC (0.11 to 0.21 dS/cm)
- Increase in soil pH ($CaCl_2$) (4.8 to 5)
- Increase in soil ESP (8.2 % to 15 %) because Na^+ increased and Ca^{2+} and Mg^{2+} remained stable
- Organic carbon remained similar to Baseline 2 at around 2.9 %
- Ca^{2+} slightly increased from 820 to 880 mg/kg
- ECEC slightly increased from 8.7 to 10 meq/100g

These increases in shallow soil attributes are due to blended irrigation waters with relatively high sodium concentrations and relatively high pH. There was no deep leaching and limited rainfall during the monitoring period to reduce these increases in the shallow profile.

5.4. Key findings – Baseline 3 (irrigated soils) vs Baseline 1 (parent soil)

Baseline 3 (irrigated soil) vs Baseline 1 (parent soil) key findings include (to 20 cm):

- Increase in soil EC (0.21 to 0.26 dS/cm)
- Increase in soil pH ($CaCl_2$) (4.6 to 5)
- Decrease in soil ESP (17 % to 15 %)
- Organic carbon remained similar to Baseline 1 at around 2.9 %
- Ca^{2+} increased from 420 to 880 mg/kg due to lime addition
- ECEC increased from 6.3 to 10 meq/100g

6. Sedimentation, runoff and erosion control

A number of environmental protection measures were installed across the Stage 1A irrigation trial area to ensure that bare soils were not eroded during rainfall events and to ensure that soil and sediment was retained within the irrigation plot areas.

6.1. Protection measures

The following sedimentation, runoff and erosion control protection measures were installed for the Stage 1A trial irrigation area.

- Trial plot bunding and drainage to catch dams;
- Diversion banks to catch all runoff from the trial plots and divert it to the catch dams;
- Two catch dams with pumps and recycling pipework to collect any runoff from the trial area and recycle it back to the storage dam;
- Modern overhead spray irrigation system;
- Diversion drains to prevent the possibility of any overland runoff entering the trial area; and
- Spray-grassing of all structures.

The environmental protection measures were supplemented by the following monitoring locations which are in place to minimise sediment runoff and subsurface water migration:

- 10 soil moisture monitoring positions;
- 7 paired sets of piezometers to monitor for perched water
- 1 pair of piezometers to monitor for sub-surface leakage from the western catch dam;
- 6 rain gauges; and
- An automatic weather station.

6.2. Summary of weather and irrigation applied

The key information relevant to the performance of the sedimentation, runoff and erosion control measures during the reporting period is shown in Table 6.1

6.2.1. Rainfall

Rainfall for the reporting period totalled 230.8 mm, as recorded by the AGL weather station on Tiedmans. This compares with a total of 269.2 mm recorded at the Bureau of Meteorology (BOM) site at Gloucester Post Office (site no 60015). July rainfall was 71 % less than the mean, August rainfall was 84% less than the mean, September rainfall was 74 % less than the mean, October was 80 % less than the mean, November was 92 % greater than the mean and December was 79 % less than the mean. Total rainfall for the period (230.8 mm) was 43 % less than the mean (404.4mm) for the period.

6.2.2. Rain days

Out of the 184 days in the reporting period, 51 days (28 %) were wet. A wet day occurred when 0.2 mm (or more) of rainfall was registered in the Tiedmans weather station rain gauge.

6.2.3. Rainfall intensity

All of the rain events that occurred during the period were below the threshold level of 24.9 mm/hour which defines a 1 in 1 year rainfall event at Tiedmans. See FK (2012) *Soil Quality Monitoring and Management Program – Tiedman irrigation trial*. The highest hourly rainfall intensity rate was 8.6 mm/hour, which occurred on the 30/11/2013.

6.2.4. Blended water irrigation

Blended water irrigation occurred in all months except July.

Table 6.1 - Key weather and irrigation information

Key information	July	August	Sept	October	November	December	Total for period
Rainfall							
AGL weather station (mm)	14.6	4.2	13.0	13.6	163.6	21.8	**230.8 mm**
Bureau of Meteorology Gloucester Post Office (mm)	12.2	2.0	13.2	11.4	179.8	50.6	**269.2 mm**
Mean monthly rainfall at Gloucester Post Office (mm)	50.9	46.1	50.7	68.3	84.8	103.6	**404.4 mm**
Number of rain days (≥ 0.2mm recorded)	19	6	3	5	13	5	**51**
Percentage rain days	61 %	19 %	10 %	16 %	43 %	16 %	**28 %**
Highest rainfall days	4.6 mm (1/07/13)	20.8 mm (12/08/13)	12.6 mm (17/09/13)	6.2 mm (30/10/13)	31.0 mm (23/11/13)	8.4 mm (26/12/13)	**31.0 mm (23/11/13)**
Highest hourly rainfall rate (mm/hr)	1.6mm/hr (20/07/13)	2.4mm/hr (30/08/13)	2.2mm/hr (17/09/13)	1.4mm/hr (14/10/13)	8.6mm/hr (30/11/13)	3.6mm/hr (6/12/13)	**8.6mm/hr (30/11/13)**
Blended water irrigation application	0 mm	52.4 mm	55.6 mm	115.9mm	31.6mm	52.6mm	**308.1mm**
Total applied water. (rainfall plus blended water)	14.6 mm	56.6 mm	68.6 mm	129.5 mm	195.2 mm	74.4 mm	**538.9 mm**
Blended water salinity	1680 µS/cm	1680 µS/cm	1680 µS/cm	1680 µS/cm	1680 µS/cm	1680 µS/cm	**1680 µS/cm**

6.3. Performance under rainfall and irrigation

The combined application of rainfall and blended water irrigation totalled 538.9mm, which is approximately 33% higher than the mean rainfall for Gloucester. See Table 6.1.

6.3.1. Trial plot bunding and drainage to catch dams

All plot bunds performed to design requirement during the period. Some small non-draining low lying areas occurred at the inside corners of some of the northern plots but the area affected was not considered to be significant enough to warrant any remedial measures.

6.3.2. Diversion banks to catch runoff from the trial plots and divert it to the catch dams.

All diversion banks performed satisfactorily during the monitoring period.

6.3.3. Two catch dams with pumps and recycling pipework

Both Catch Dam 1 (CDE) and Catch Dam 2 (CDW) operated to design requirements and runoff from the trial plot area in the wettest month (November 2013) was collected and pumped back to the Blended Water Dam (TSD) on Tiedmans.

6.3.4. Overhead spray system

The irrigation system was managed in accordance with the operating procedures and blended water was applied when there was sufficient deficit available in the soil

6.3.5. Diversion drains

All diversion drains operated satisfactorily during the period and erosion had not occurred due to grassing of the drains and installation of silt traps at regular intervals.

6.3.6. Spray-grassing of all structures

All bund walls, diversion banks and diversion drains have a well-established grass cover and are mowed to ensure that there are no flow blockages.

The grassed aprons in front of the catch dams, in conjunction with geo-fabric netting, have prevented any erosion from occurring as well as preventing any siltation of the dams.

7. Stage 1A critical control point monitoring and response plan

7.1. Critical Control Points

The critical control points were nominated in the soil quality monitoring and management plan. Full details are provided in Fodder King (2012) *Soil Quality Monitoring and Management Program – Tiedman irrigation trial*.

Table 7.1: Stage 1A Irrigation Area Critical control points

Critical Control Point	Hazard	Trigger	Response	Mitigation	Risk
CSG Dam and Mixing Dam	Brackish overflow to landscape	Excessive rainfall	Record and report lost volume from storages	Continual monitoring of dam depth and salinity with maintenance of adequate freeboard	Low
Catch Dams	Brackish overflow to landscape	Excessive rainfall or irrigation	Keep dams empty at all times. Record and report lost volume from storages + halt irrigation	Continual monitoring of dam depth and salinity	Low
Soil moisture monitoring system	System failure	Sensor fault	Halt irrigation	Replace defective sensors	Low
Shallow piezometer water level	Perched water tables	Excessive rainfall and/or over-irrigation	Adjust irrigation rates	Review irrigation schedule	Low
Ameliorated soil in the irrigation area (1)	Increasing salinity	Soil salinity increase of more than 50% above the average value of the new baseline for the ameliorated soils	Review with agencies and if necessary: • Increase dilution of CSG water. • Adjust irrigation rates. • Install collection and recycling system.	6 monthly soil sampling	Low
Non -ameliorated parent soil (2)	Increasing salinity	Soil salinity increase of more than 50% above the average value of 0.12 dS/m (1:5) in the root zone to 1m depth	Review with agencies and if necessary: • Compare against external control site • Increase dilution of CSG water. • Adjust irrigation rates.	6 monthly soil sampling	Very Low

Key (1) – across the 16 ameliorated soil sampling sites.
(2) – across 5 proposed parent soil locations (four internal sites within each of the 4 soil treatment types plus one external control site)

Approximately 7 times the amount of blended irrigation water (32.45 ML) was applied during this reporting period (a full 6 months) compared to the previous reporting period (only 3 months) where 4.66 ML was applied.

None of the Critical Control Point trigger points were reached during the reporting period. See *Section 7.2 Salinity trend in ameliorated soil* for further discussion on salinity.

7.2. Salinity trend in ameliorated soil

There have been some changes in average soil EC. However, as shown in Table 7.2, the percentage changes in the weighted average EC values between Baselines 2, 3 and 4 have not exceeded the trigger point of a 50 % increase in EC over Baseline 2 (ameliorated soil).

The weighted average Baseline 4 EC was still 52 % below the Baseline 2 (ameliorated soil) EC. There has been a small (8 %) increase between Baseline 3 and Baseline 4.

Table 7.2 – Percentage change in average soil salinity between Baselines

			Percentage change between Baselines
	Baseline 2 EC	**Baseline 3 EC**	
Weighted average salinity (dS/m)	0.58	0.26	**-55%**
	Baseline 3 EC	**Baseline 4 EC**	
Weighted average salinity (dS/m)	0.26	0.28	**8%**
	Baseline 2 EC	**Baseline 4 EC**	
Weighted average salinity (dS/m)	0.58	0.28	**-52%**

Note: Weighted average salinity is calculated by taking the Ec value at each depth interval and assigning a weighting based on the number of samples taken at that interval, repeated for all intervals and totalled.

8. Conclusions

The summary conclusions for each of the trial areas are provided below, with the Stage 1A area being the main focus of the Tiedman irrigation program.

8.1. Stage 1A area

- A volume of 32.45 ML of blended water was irrigated across this area in the 6 months from 1 July to 31 December 2013
- Water balance management in conjunction with a number of environmental protective measures resulted in all blended water being consumed within the irrigation area.
- Salinity and sodium concentrations have increased in the shallow soil profile but have had a limited effect on improved soils at this time.
- Soil salinity for Baseline 4 is still below the ameliorated soil in Baseline 2.
- Piezometer behaviour indicates that there is no perched water accumulating in the shallow soil profile due to irrigation activities.
- The Exchangeable Sodium Percentages (ESP) for Baseline 4 are generally lower than the parent soil and the ameliorated soil, indicating that sodium is being mobilised downwards through the soil.
- Calcium and Magnesium levels have remained stable while the Sodium has been mobilised downwards, resulting in generally better soil quality for supporting crops, as measured by Effective Cation Exchange Capacity (ECEC).
- Soil structure has been significantly improved by amelioration and shows no indication of adverse effects, such as abnormal salinity or sodium accumulation, or clay particle dispersion, being caused by irrigation water.

8.2. Stage 1B area

- A volume of 11.45 ML of blended water was irrigated across this area in the 6 months from 1st July to 31st December 2013.
- Crop usage has been carried out by grazing of the area with an acceptable stocking rate.
- Salinity and sodium concentrations have increased at a higher rate than the Stage 1A area on the shallow improved soil.
- Piezometer behaviour indicates that there is no perched water accumulating due to irrigation.
- The Exchangeable Sodium Percentages (ESP) for Baseline 3 are generally lower than the parent soil.
- Calcium and magnesium levels have remained stable, resulting in generally better soil quality for supporting crops, as measured by Effective Cation Exchange Capacity (ECEC).

9. References

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Attachments

Attachment 1 – Stage 1A area plot layout

Attachment 2 – Stage 1B area plot layout

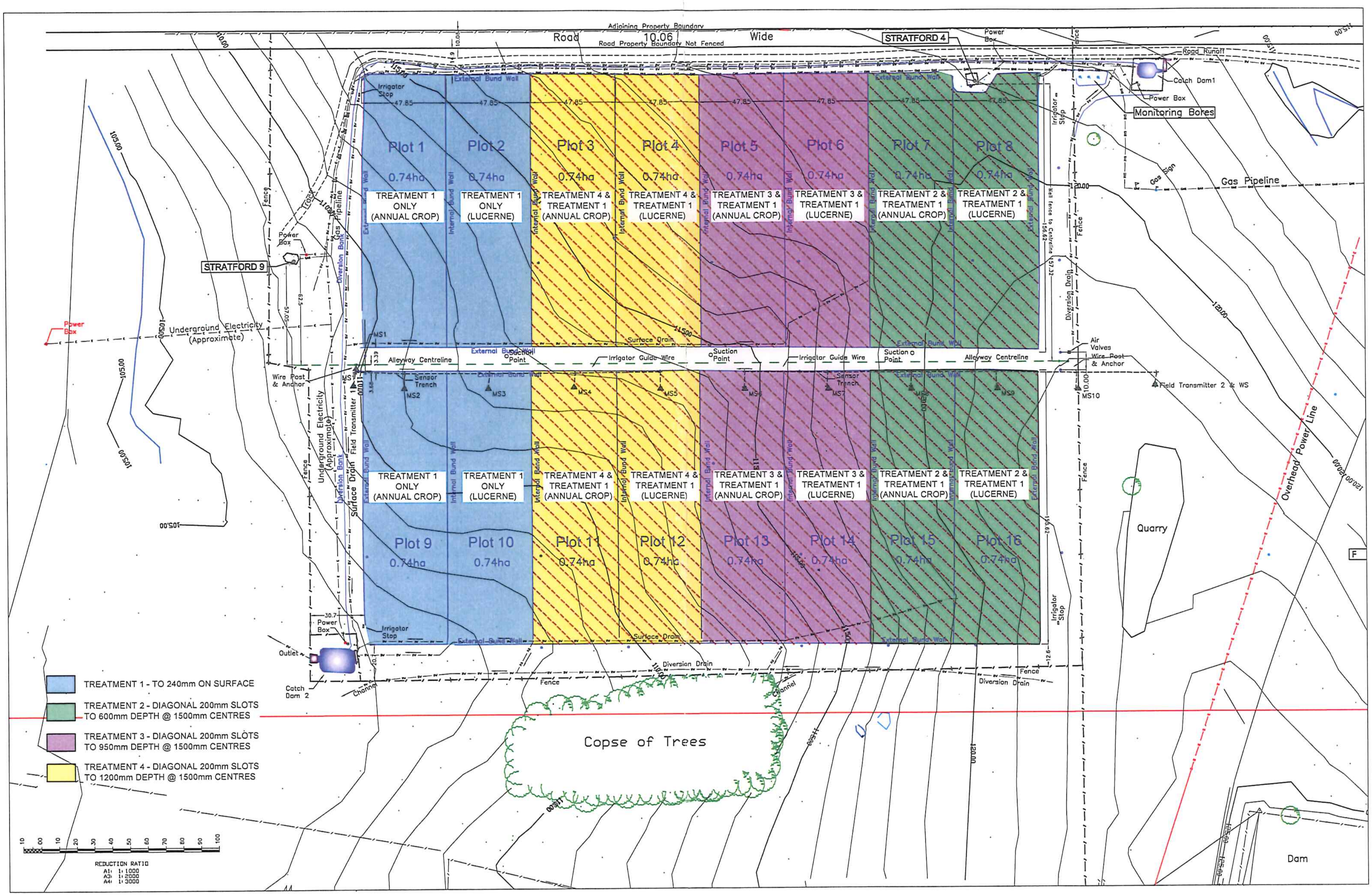
Attachment 3 – Stage 1A Baseline 4 soil test results

Attachment 4 – Stage 1A – Baseline 4 vs Baseline 3 comparisons

Attachment 5 – Stage 1B soil test results

Attachment 1.

Stage 1A area plot layout



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Rv	DATE	REVISIONS	REC.	APPR.
D	6-May-13	FINAL WAE (BY FODDER KING AND AGL)	FK	FK
C	24-Apr-13	SPLIT SHEET 01	FK	FK
B	5-Apr-13	PLOT AREA TEXT	FK	FK
A	7-Feb-13	INITIAL ISSUE	MH	MH

SURVEY: M Hanlon
DESIGN: M Hanlon
DRAWN: M Hanlon
CHECKED: M Hanlon
SURVEY FILE: J:\12161 Fetterplace Civil, AGL site, Gloucester\acad7\12161V02 WAE Survey 2012-12-20.acx

A1
DATUM: AHD
ORIGIN: PM55266 RL:124.736
CONTOUR INTERVAL: 0.25m
APPROVED: PROJ.MAN

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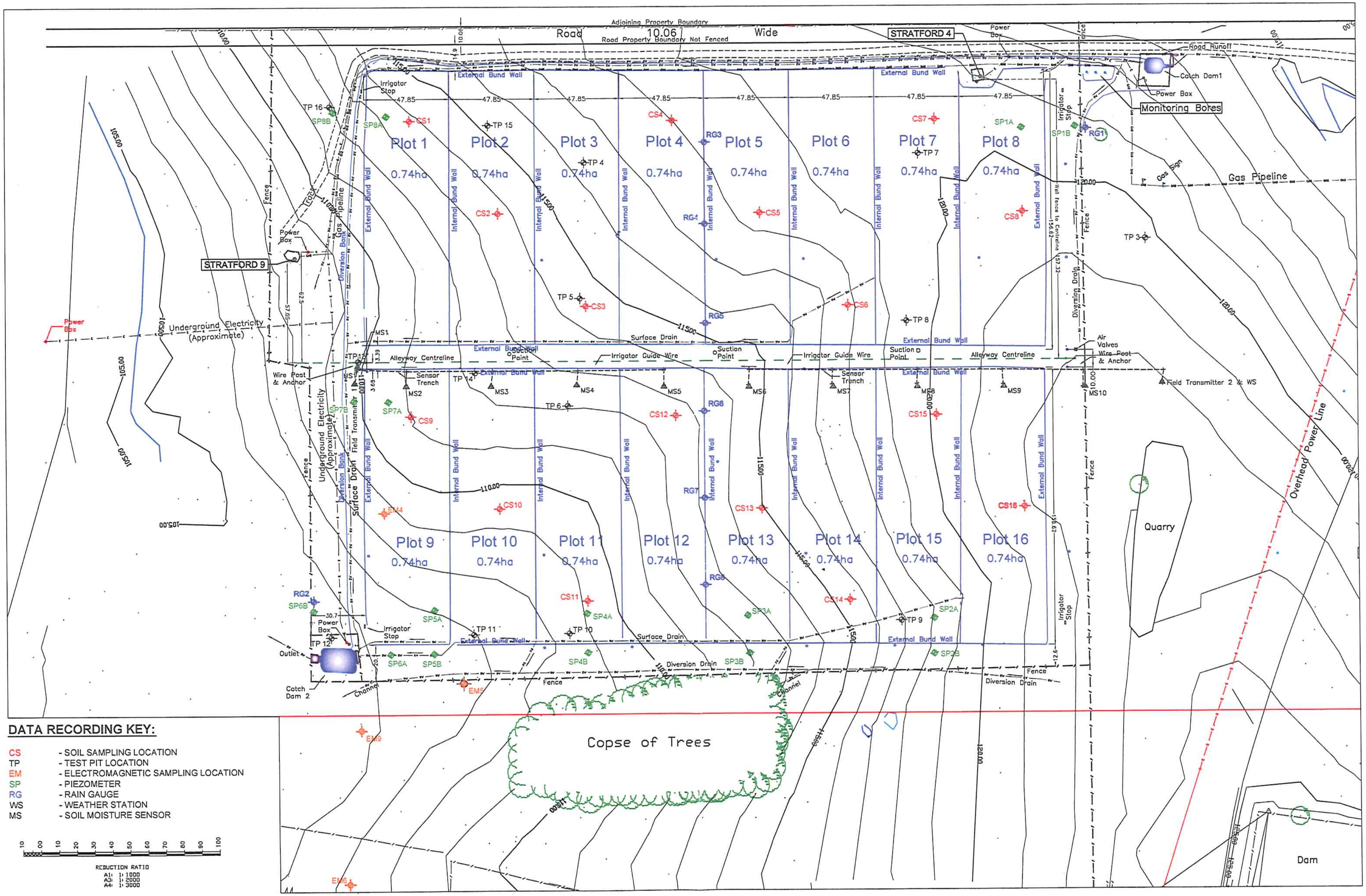
Natural Resources
Planning
Surveying
Civil Engineering
Environmental Engineering

ISO9001:2008 FS558072

CLIENT: FODDER KING & FETTERPLACE CIVIL
PROJECT: AGL - GLOUCESTER - IRRIGATION TEST PLOT

TIEDMANS IRRIGATION TRIAL
STAGE 1A TRIAL PLOT LAYOUT
WORKS AS EXECUTED

DATE: 7 February 2013
DRAWING No.: SHEET 01A
GLO-ENG-DWG-G-401
Rv. D



DATA RECORDING KEY:

- CS - SOIL SAMPLING LOCATION
- TP - TEST PIT LOCATION
- EM - ELECTROMAGNETIC SAMPLING LOCATION
- SP - PIEZOMETER
- RG - RAIN GAUGE
- WS - WEATHER STATION
- MS - SOIL MOISTURE SENSOR

REDUCTION RATIO
A1: 1:1000
A3: 1:2000
A4: 1:3000

Plot Date: 7 May 2013
J:\2012\12161 Fetterplace Civil, AGL, site, Gloucester\ACAD\WAE\12161 AGL WAE v01 2013-05-06.dwg

Rv	DATE	REVISIONS	REC.	APPR.
D	6-May-13	FINAL WAE (BY FODDER KING AND AGL)	FK	FK
C	24-Apr-13	SPLIT SHEET 01	FK	FK
B	5-Apr-13	PLOT AREA TEXT	FK	FK
A	7-Feb-13	INITIAL ISSUE	MH	MH

SURVEY: M Hanlon
DESIGN: M Hanlon
DRAWN: M Hanlon
CHECKED: M Hanlon
SURVEY FILE: Gloucester\acad\12161V02 WAE Survey 2012-12-20.xxx

A1
DATUM: AHD
ORIGIN PM55266 RL:124.736
CONTOUR INTERVAL: 0.25m
APPROVED: PROJ.MAN
J:\12161 Fetterplace Civil, AGL, site,

Mitchel Hanlon Consulting Pty Ltd
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121 Bridge Street, P.O. Box 1568, Tamworth, NSW, 2340
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ACN 104 693 736
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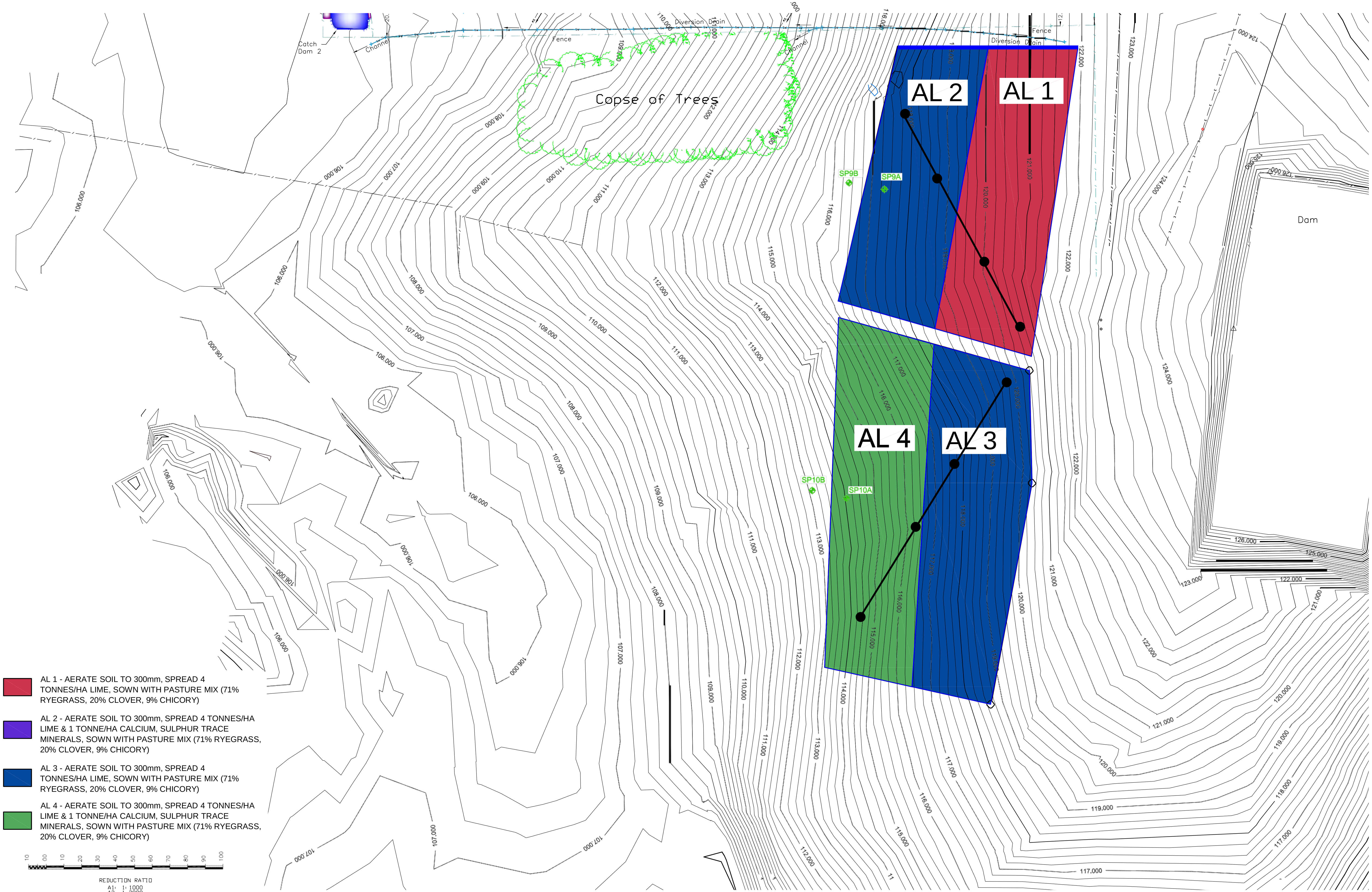
CLIENT: FODDER KING & FETTERPLACE CIVIL
PROJECT: AGL - GLOUCESTER - IRRIGATION TEST PLOT

TIEDMANS IRRIGATION TRIAL
STAGE 1A DATA RECORDING LOCATIONS
WORKS AS EXECUTED

DATE: 7 February 2013
DRAWING No.: SHEET 01B
Rv. D
GLO-ENG-DWG-G-402

Attachment 2.

Stage 1 B area plot layout



AL 1 - AERATE SOIL TO 300mm, SPREAD 4 TONNES/HA LIME, SOWN WITH PASTURE MIX (71% RYEGRASS, 20% CLOVER, 9% CHICORY)

AL 2 - AERATE SOIL TO 300mm, SPREAD 4 TONNES/HA LIME & 1 TONNE/HA CALCIUM, SULPHUR TRACE MINERALS, SOWN WITH PASTURE MIX (71% RYEGRASS, 20% CLOVER, 9% CHICORY)

AL 3 - AERATE SOIL TO 300mm, SPREAD 4 TONNES/HA LIME, SOWN WITH PASTURE MIX (71% RYEGRASS, 20% CLOVER, 9% CHICORY)

AL 4 - AERATE SOIL TO 300mm, SPREAD 4 TONNES/HA LIME & 1 TONNE/HA CALCIUM, SULPHUR TRACE MINERALS, SOWN WITH PASTURE MIX (71% RYEGRASS, 20% CLOVER, 9% CHICORY)

REDUCTION RATIO
A1: 1:1000
A3: 1:2000
A4: 1:3000

Plot Date: 27 June 2013
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Rv	DATE	REVISIONS	REC.	APPR.
B	27-Jun-13	AMENDMENTS AS PER EMAIL RECEIVED ON 27/6/13		
A	26-Jun-13	ADDITIONAL SHEETS AS PER EMAIL RECEIVED ON 24/6/13		

SURVEY: M Hanlon
DESIGN: M Hanlon
DRAWN: M Hanlon
CHECKED: M Hanlon
SURVEY FILE: J:\12161 Fetterplace Civil, AGL site, Gloucester\ccad7\12161V02 WAE Survey 2012-12-20.ccx

A1
DATUM: AHD
ORIGIN: PM55266 RL:124.736
CONTOUR INTERVAL: 0.25m
APPROVED: PROJ.MAN

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ISO9001:2008 FS555072

CLIENT: FODDER KING
PROJECT: AGL - GLOUCESTER - IRRIGATION TEST PLOT
TIEDMANS IRRIGATION TRIAL
STAGE 1B TRIAL PLOT LAYOUT

DATE: 7 February 2013
DRAWING No.: SHEET 05
Rv. B

Attachment 3.

Stage 1A Baseline 4 soil tests

STAGE 1A BASELINE 4 SOIL TEST RESULTS

AVERAGE	Depth	EC (1:5)	pH	NO3	Org-C	K	Ca	Mg	Na	Al	K	Ca	Mg	Na	Al	K	Ca	Mg	Na	Al	ECEC	Ca/Mg	ESP
N =	cm	dS/m	CaCl2	mg/kg	%	meq/100g	meq/100g	meq/100g	meq/100g	meq/100g	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	%	%	%	%	%	meq/100g	ratio	%
16	0-20	0.37	6.48			0.87	11.73	5.39	1.486	0.00	339	2351	655	342	0.0	4.4	60.1	27.7	7.8	0.0	19.5	2.3	7.8
12	20-40	0.28	5.74			0.57	7.91	6.55	1.189	0.14	223	1586	797	273	13.0	3.5	46.4	41.1	7.8	1.2	16.4	1.4	7.8
11	40 - 60	0.25	5.39			0.51	6.79	8.08	1.331	0.44	200	1361	982	306	39.0	3.0	38.5	48.0	8.1	2.4	17.2	0.9	8.1
8	60 - 80	0.22	5.55			0.47	6.08	8.94	1.440	8.86	185	1219	1087	331	78.0	2.8	35.0	50.3	8.0	3.9	17.8	0.8	8.0
8	80 - 100	0.22	5.49			0.45	5.52	8.960	1.595	0.07	174	1106	1089	367	6.0	2.8	34.0	53.4	9.5	0.4	16.6	0.8	9.5
4	100 - 120	0.25	6.00			0.37	5.96	9.70	1.918	0.01	146	897	1195	456	1.0	2.3	26.8	59.1	11.8	0.1	16.7	0.5	11.8

Maximum	Depth	EC (1:5)	pH	NO3	Org-C	K	Ca	Mg	Na	Al	K	Ca	Mg	Na	Al	K	Ca	Mg	Na	Al	ECEC	Ca/Mg	ESP
N =	cm	dS/m	CaCl2	mg/kg	%	meq/100g	meq/100g	meq/100g	meq/100g	meq/100g	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	%	%	%	%	%	meq/100g	ratio	%
16	0-20	0.25	5.50			0.34	18.50	9.48	1.96	0.01	563	3707	1152	451	1	6	71	35	10	0	28.3	4.09	9.7
12	20-40	0.16	4.52			0.96	15.90	11.40	1.67	0.82	375	3186	1386	384	74	6	71	70	12	8	22.4	3.42	12.1
11	40 - 60	0.17	4.27			0.95	16.40	13.34	2.14	3.86	371	3287	1621	492	347	5	68	61	14	18	24.1	2.88	13.6
8	60 - 80	0.15	4.25			0.70	10.80	15.22	2.74	5.61	274	2164	1850	630	505	5	53	67	11	22	25.1	1.47	10.9
8	80 - 100	0.15	4.26			0.83	9.66	15.10	3.02	0.43	325	1936	1835	694	39	5	60	76	15	2	21.5	2.17	15.2
4	100 - 120	0.14	5.15			0.44	10.40	11.30	2.46	0.04	172	1261	1374	566	4	2	32	67	12	0	19.9	0.59	12.4

Minimum	Depth	EC (1:5)	pH	NO3	Org-C	K	Ca	Mg	Na	Al	K	Ca	Mg	Na	Al	K	Ca	Mg	Na	Al	ECEC	Ca/Mg	ESP
N =	cm	dS/m	CaCl2	mg/kg	%	meq/100g	meq/100g	meq/100g	meq/100g	meq/100g	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	%	%	%	%	%	meq/100g	ratio	%
16	0-20	0.17	6.13			0.15	7.11	3.33	0.95	0	59	1425	405	218	0	1	54	17	6	0	12.0	1.56	6.2
12	20-40	0.13	4.42			0.28	2.49	3.19	0.87	0	109	499	388	200	0	2	15	21	4	0	8.9	0.22	3.9
11	40 - 60	0.11	4.33			0.23	2.05	4.83	1.00	0	90	411	587	230	0	2	9	24	4	0	10.1	0.15	4.4
8	60 - 80	0.13	4.05			0.31	1.15	4.82	0.97	0	121	230	586	223	0	2	5	34	7	0	12.1	0.08	6.6
8	80 - 100	0.13	4.05			0.29	1.00	4.19	0.90	0	113	200	509	207	0	2	5	27	7	8	10.8	0.07	7.3
4	100 - 120	0.14	4.14			0.32	3.08	7.50	1.43	0	125	617	912	329	0	2	18	54	11	7	13.3	0.27	10.7

Standard Deviation	Depth	EC (1:5)	pH	NO3	Org-C	K	Ca	Mg	Na	Al	K	Ca	Mg	Na	Al	K	Ca	Mg	Na	Al	ECEC	Ca/Mg	ESP
N =	cm	dS/m	CaCl2	mg/kg	%	meq/100g	meq/100g	meq/100g	meq/100g	meq/100g	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	%	%	%	%	%	meq/100g	ratio	%
16	0-20	0.08	0.47			0.34	3.39	1.69	0.31	0.00	132	680	205	72	0	1	4	4	1	0	5.15	0.61	1.2
12	20-40	0.07	0.99			0.23	4.28	2.54	0.20	0.26	89	858	309	47	23	1	16	14	2	2	4.56	0.94	2.3
11	40 - 60	0.07	1.10			0.21	4.07	2.52	0.34	1.15	82	816	306	77	104	1	15	11	2	5	4.40	0.73	2.3
8	60 - 80	0.06	1.25			0.16	3.45	3.07	0.55	1.93	63	692	373	127	174	1	17	12	1	8	4.20	0.52	1.4
8	80 - 100	0.06	1.00			0.18	2.99	3.56	0.66	0.15	70	599	432	153	13	1	16	14	3	1	3.80	0.63	2.6
4	100 - 120	0.13	1.02			0.05	3.25	1.69	0.44	0.02	20	330	248	119	2	0	7	7	1	0	3.29	0.17	0.9

Attachment 4.

Stage 1A – Baseline 4 vs Baseline 3 comparisons

Differences in average values between Baseline 4 (irrigated) and Baseline 3 (irrigated)

Depth cm	EC (1:5) dS/m	pH CaCl2	NO3 mg/kg	Org-C %	K meq/100g	Ca meq/100g	Mg meq/100g	Na meq/100g	Al meq/100g	K mg/kg	Ca mg/kg	Mg mg/kg	Na mg/kg	Al mg/kg	K %	Ca %	Mg %	Na %	Al %	ECEC meq/100g	ESP %
0-20	0.05	-0.16			-0.09	-3.14	-0.27	0.93	0.00	-36	-630	-33	213	0.0	0.3	-7.4	2.0	5.2	0.0	-2.58	5.25
20-40	-0.02	-0.27			-0.12	-2.54	-0.03	0.52	0.04	-46	-508	-4	121	4.0	-0.1	-9.2	4.7	4.0	0.6	-2.12	4.03
40 - 60	-0.01	0.08			-0.04	-0.12	0.81	0.54	0.05	-14	-25	98	125	5.0	-0.4	-3.2	1.4	2.9	-0.7	1.24	2.86
60 - 80	0.02	0.75			0.04	0.72	0.45	0.49	-0.29	15	144	54	112	-26.0	0.2	4.1	-2.0	2.0	-4.1	1.40	1.97
80 - 100	0.08	1.25			0.18	3.31	-1.56	0.30	-1.84	68	663	-190	69	-165.0	1.1	20.1	-11.0	1.6	-11.8	0.39	1.56
100 - 120	0.00	1.71			0.14	4.11	-0.04	0.58	-1.83	54	527	13	148	-164.0	0.7	14.6	-5.3	2.9	-12.8	1.70	2.86

Differences in average values between Baseline 3 (irrigated) and Baseline 2 (ameliorated)

Depth cm	EC (1:5) dS/m	pH CaCl2	NO3 mg/kg	Org-C %	K meq/100g	Ca meq/100g	Mg meq/100g	Na meq/100g	Al meq/100g	K mg/kg	Ca mg/kg	Mg mg/kg	Na mg/kg	Al mg/kg	K %	Ca %	Mg %	Na %	Al %	ECEC meq/100g	ESP %
0-20	-0.55	0.51	-117	0.40	-0.05	3.08	0.00	-0.48	0.00	-20	617	0	-111	-0.2	-1.0	7.5	-3.7	-2.7	0.0	2.55	2.54
20-40	-0.28	0.69	-23	0.62	0.06	3.19	-1.86	-0.89	-0.14	23	638	-226	-203	-12.3	0.4	17.5	-11.9	-5.0	-0.9	0.36	3.76
40 - 60	-0.19	0.01	-21	0.36	0.04	0.71	-1.66	-0.78	0.03	17	142	-201	-180	2.5	0.5	6.8	-4.1	-3.8	0.6	-1.66	5.24
60 - 80	-0.18	-0.46	-12	0.08	0.00	-0.07	-0.94	-0.71	0.70	0	-14	-114	-163	62.7	0.2	-0.7	-1.2	-3.4	5.1	-1.02	6.02
80 - 100	-0.25	-0.95	-26	-0.32	-0.14	-2.50	1.31	-0.56	1.35	-55	-500	159	-129	121.6	-0.9	-13.7	9.9	-2.9	7.6	-0.54	7.95
100 - 120	-0.15	-1.28	-5	-0.34	-0.14	-2.66	-1.18	-0.84	1.70	-54	-533	-143	-193	152.7	-0.5	-11.8	3.3	-3.2	12.1	-3.12	8.93

Differences in average values between Baseline 3 (irrigated) and Baseline 1 (parent soil)

Depth cm	EC (1:5) dS/m	pH CaCl2	NO3 mg/kg	Org-C %	K meq/100g	Ca meq/100g	Mg meq/100g	Na meq/100g	Al meq/100g	K mg/kg	Ca mg/kg	Mg mg/kg	Na mg/kg	Al mg/kg	K %	Ca %	Mg %	Na %	Al %	ECEC meq/100g	ESP %
0-20	0.25	2.18	41.30	1.87	0.64	12.33	-0.99	-0.22	-0.26	250	2471	-121	-51	-23	1	43	-36	-5	-3	11.50	2.5
20-40	0.20	1.62	27.40	1.62	0.27	8.90	-5.32	-1.16	-0.36	105	1784	-647	-266	-33	1	46	-36	-8	-3	2.33	3.8
40 - 60	0.11	0.69	21.05	1.30	0.18	5.62	-5.23	-1.50	-0.09	70	1126	-635	-346	-8	1	34	-27	-8	0	-1.02	5.2
60 - 80	0.01	0.00	15.46	0.90	0.07	3.91	-3.42	-1.68	0.74	26	783	-416	-387	67	0	23	-19	-10	5	-0.39	6.0
80 - 100	-0.03	-0.66	5.14	0.35	-0.07	1.39	-1.17	-1.50	1.51	-26	278	-142	-345	136	0	9	-8	-10	9	0.17	7.9
100 - 120	0.08	-0.80	4.41	0.17	-0.05	1.11	-1.46	-1.37	-2.71	-21	223	-178	-316	-243	0	7	-4	-8	5	-4.48	8.9

(Yellow) Denotes an increase in Baseline soil test values compared to previous Baseline soil test values

Attachment 5.

Stage 1B soil test results

STAGE 1 B – SOIL TEST RESULTS

Nutrient	Units	Result- Baseline 1	Result – Baseline 2	Result – Baseline 3
Chlorides	mg/kg	140	65	247
Electrical Conductivity	dS/m	0.21	0.11	0.26
pH ($CaCl_2$)	pH units	4.63	4.80	4.98
NO_3- Nitrogen extract	mg/kg	53.1	15.5	11.5
Phosphorous Colwell	mg/kg	82.8	40.9	37.9
Sulphur	mg/kg	10.0	14.4	46.0
Organic Carbon	%	2.82	2.98	
Copper ex	mg/kg	0.49	<0.5	0.9
Zinc ex	mg/kg	4.27	3.3	3.1
Manganese ex	mg/kg	32.9	22.0	28.0
Boron ex	mg kg	0.62	0.51	0.5
Potassium ex	mg/kg	145	224	267
Potassium ex	meq/100g	0.37	0.57	0.68
Calcium ex	mg/kg	429	820	895
Calcium ex	meq/100g	2.15	4.10	4.48
Magnesium ex	mg/kg	305	384	397
Magnesium ex	meq/100g	2.54	3.20	3.31
Sodium ex	mg/kg	245	163	345
Sodium ex	meq/100g	1.07	0.71	1.5
Aluminium ex	mg/kg	16.5	6.30	2.06
Aluminium ex	meq/100g	0.18	0.07	0.02
Ex Potassium	%	5.89	6.69	6.85
Ex Calcium	%	34.0	47.8	44.8
Ex Magnesium	%	40.3	37.3	33.1
Ex Sodium	%	16.9	8.26	15.0
Ex Aluminium	%	2.91	0.82	0.23
ECEC	Meq/100g	6.3	8.58	10.0