Soil quality monitoring and management

Report 1 – Pre Irrigation
(Activities to 31 March 2013)

Tiedman Irrigation Trial

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for AGL Upstream Investments Pty Ltd

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Executive Summary

This is Report 1 of a series of four (4) reports that will be undertaken during the Tiedman Irrigation Trial 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 of the crops to be irrigated.

Subsequent reports (Reports 2, 3 and 4) will provide information on the effect of irrigated blended water on the improved soils over the period of the trial. These reports are submitted in compliance with the approved Soil Quality Monitoring and Management Program.

The Tiedman Irrigation Trial (trial) will be carried out across two areas within the AGL Tiedman property known as Stage 1A and Stage 1B.

The Stage 1A trial 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 will be intensively monitored for soil, water and crop performance.

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

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

- the irrigation and mass balance methodology that will be used to manage and monitor the Stage 1A trial area;
- the Baseline 1 soil analysis of the parent soils in the trial area;
- the target specification for the ameliorated (Baseline 2) soils;
- the test results for the Baseline 2 soils;
- a summary of the key improvements effected;
- the locations of the soil and water monitoring points; and
- the sedimentation, runoff and erosion control measures installed.

The Baseline 2 (ameliorated) soil results largely met the desired target soil quality values prior to the commencement of irrigation.

The Stage 1B trial area is approximately 40 hectares of which around 10 to 20 hectares may be irrigated during the trial. The main irrigation area is made up of 4 plots that total approximately 4 hectares. This area will be used to evaluate irrigation application rates and irrigability of traditional shallow rooted pastures in comparison to the deeper rooted and more salt tolerant crops that have been established in the Stage 1A trial area. As well, the soil profile within the Stage 1A area has been treated to depth whereas the soil profile within the Stage 1B area has received much less preparation.

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 trial. The irrigation trial involves two main irrigation areas (the Stage 1A and Stage 1B areas). This report is the first compliance report for the irrigation program being the baseline assessment of soils after the soil treatments within the Stage 1A area and before the commencement of any irrigation of blended water. It also describes the soil conditions within the Stage 1B irrigation area. The two primary irrigation areas are shown in Figure 1.

The Stage 1A area is the major focus of the Soil Quality Monitoring and Management Program (SQMMP). This area will have 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 to be irrigated using a linear move irrigator. Crop types are lucerne, forage sorghum, triticale/oats and selected pasture types. It is expected that between 100 and 180 megalitres (ML) of blended water will be irrigated across this area during the trial period.

The Stage 1B area is where the lower salinity water in the produced water storage dams will be irrigated. Relatively minor volumes of produced water (up to approximately 15ML) will be irrigated across the Stage 1B area in the early stages of this trial. Some additional irrigation using blended water will occur for the balance of the trial period. The Stage 1B area is approximately 40ha, of which around 10-20 ha is planned to be irrigated using a travelling irrigator. Individual areas are expected to be rotated with the main crops to be grown to include a mix of annual and perennial pasture species.

There is an additional approved irrigation area (the Stage 2 area) which is approximately 15ha. This area is unlikely to be irrigated during the early stages of the irrigation activities and will only be used if irrigation application rates on the Stage 1A and Stage 1B areas are less than anticipated.

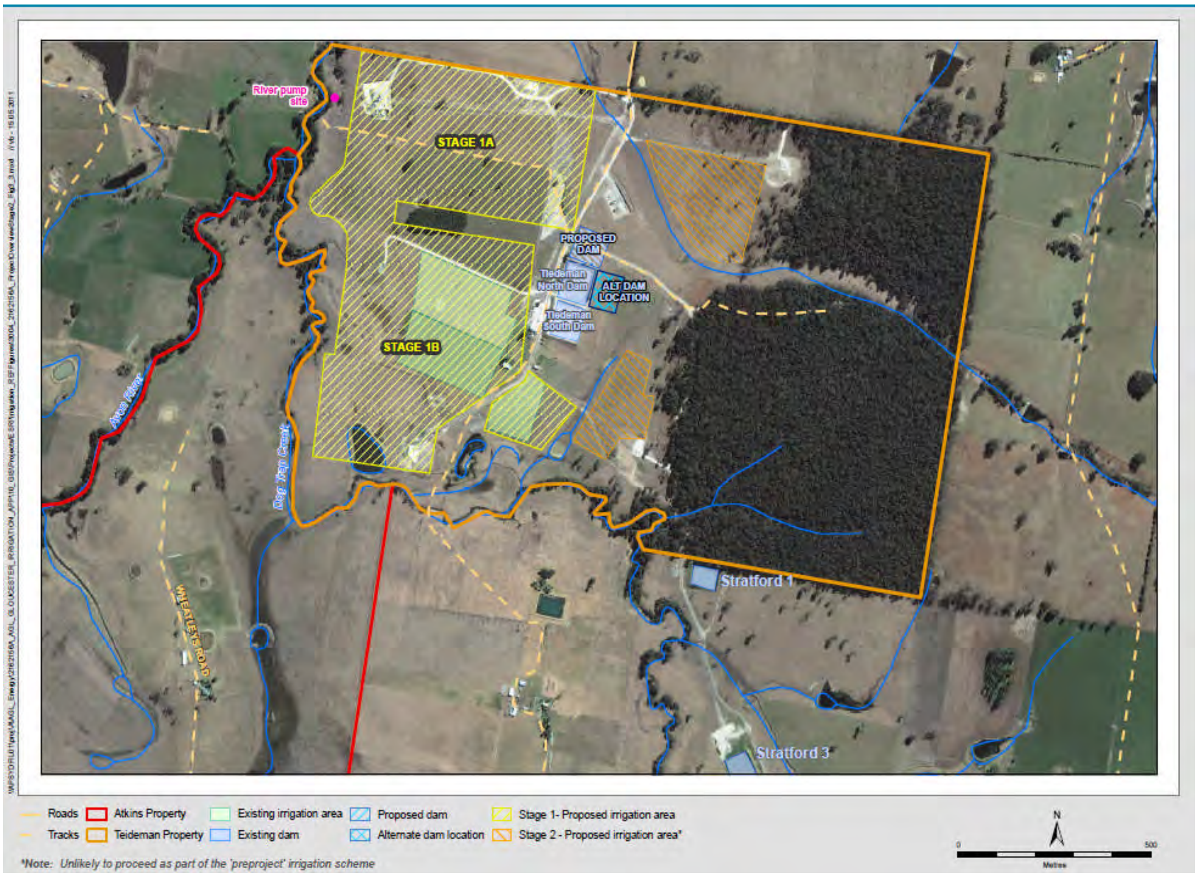

Figure 1: Gloucester Irrigation Areas for Exploration Produced Water

The Stage 1A, Stage 1B and Stage 2 irrigation areas are all located off the alluvial floodplain of the Avon River. The irrigation trial was approved in July 2012 after the Tiedman Irrigation Trial 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:

a) Develop and monitor the performance of soils on the irrigation area against baseline soil quality parameters;
b) Develop, manage and monitor the water and salt balance; and
c) 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:

a) Derive information on the performance of using blended water and improved soils to maximise the beneficial use of produced water. This trial will provide support data for the preparation of the main Extracted Water Management Plan (EWMP) for the Gloucester Gas Project;
b) Provide information to optimise the design of a water treatment and storage system to match the beneficial re-use system; and
c) In order to minimise the overall ‘footprint’ of the project on the surrounding landscape, the trial 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:

a) 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);
b) 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

Carry out a comprehensive baseline soil study to ascertain the characteristics of the parent soils in the trial irrigation area. This data was collected and reported as part of the irrigation trial design during 2011 (FK, 2011).

Amelioration and crop establishment

Based on the established parent soil characteristics and blended CSG water quality, carry out amelioration of the parent soil and establish trial crops.

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.

Report 1 (this report) covers 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.

Perched water piezometers
Paired piezometers to monitor the potential for the development of perched water zones have been installed inside and immediately outside (ie downgradient) of each of the soil treatment types. In the original SQMMP for the Stage 1A area, some 11 locations were nominated however the number of sites has been reduced to 8 because those on the northern side of the trial area were located upgradient of the plots and would have been substantially affected by road drainage (see Table 2 and Figure 5 for details of their positions in the trial area).

Irrigation Trial
Carry out the irrigation trial, including installation of all soil moisture monitoring equipment.

Carry out monitoring and data gathering
Undertake all detailed monitoring and data gathering, including regular soil sampling and testing, (Baseline soil studies 3 and 4) 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.

Report 2 will be carried out after the Baseline 3 soil studies and Report 3 will be carried out after the Baseline 4 soil studies. On completion of the trial in 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 (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 will be monitored. These include water balance, salt balance, nutrient balance, carbon balance and soil structure. Crop yield, crop persistence and crop health will also be determined to confirm the effectiveness of soil ameliorants and irrigation water quality.

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 will be based on the *Environmental Guidelines: Use of Effluent by Irrigation (DECC, 2004).*

The aim of irrigation management will be 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 will be continually monitored (in each treatment) using sensing and logging technology to track soil moisture patterns (surplus or deficit) due to both rainfall and irrigation. Irrigation will only be 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 will be used to guide the applied irrigation water and to monitor the water balance. In order to better manage the water balance, a low pressure overhead spray (linear) system has been installed as the irrigation method.

Salt, nutrient and carbon balances
The salt (sodium), nutrient (nitrogen and phosphorous) and soil carbon (Total C) balances will be determined during the Stage 1A Trial Irrigation Program. Monitoring and analysis of blended CSG water to be applied, soil chemistry and soil-water will 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), and detailed in Lucas (2009).

Soils with a high ESP (>6 due to irrigation over time) are susceptible to loss of structure because the SAR of rainwater shifts clay particle behaviour towards dispersion. The dispersed clay particles block micro-pores and decrease permeability and reduce the effectiveness of an irrigation area if not managed correctly. The ameliorated soil designed for the site comprises additional calcium (as $CaSO_4$ and $CaCO_3$) and organic matter which will have the effect of reducing soil ESP by buffering against clay dispersion, with the aim of maintaining soil structure.

Crop growth, persistance and health

Crop growth will be determined from measuring dry matter yield after harvest over successive cropping cycles. An important aspect of the trial is to establish ground cover as quickly as possible after installation to minimise the risk of erosion of bare ameliorated soil. The soil amelioration should encourage rapid establishment of crops after seeding.

Crop persistence will be measured by plant counts and monitored at regular intervals and crop health will be measured by leaf tissue analysis and monitored at regular intervals.

1.4. Stage 1B irrigation trial 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 freeboard in the dam for blending of the larger volumes of produced water. Relatively minor volumes of produced water (up to 20 ML over the whole period of irrigation) are expected to be irrigated across the Stage 1B area.

ii. As part of the trial, establish some shallow rooted pasture species to evaluate irrigation application rates and irrigability of these traditional pastures in comparison with the more salt tolerant and deeper rooted crops that are planned for the Stage 1A area. Blended irrigation water is to be used for this part of the trial.

A small travelling irrigator will be installed to irrigate this area.

2. Site characteristics

2.1. Previous land use

The main land uses in the Gloucester region are beef and dairy production, poultry, timber extraction, coal mining and tourism related to the use of the extensive parks and reserves in the area.

The project site (Tiedmans) is zoned rural and is predominantly used for beef cattle grazing, although historically the property was used for dairy production.

The original forest which covered most of this landscape has been cleared and replaced with improved pasture. A significant portion of the eastern Tiedmans property is still part of the original forest.

There has been limited cultivation, for cropping, in the Gloucester area which is probably due to inadequate fertility, sodicity and acidity of soils in the area.

2.2. Climate

Gloucester Shire Council quotes the average rainfall as 985 mm per year. The Bureau of Meteorology station in the area with the longest rainfall records is Gloucester Post Office (BoM station 060015) which has been operational since 1888. Its annual average rainfall is quoted by the Bureau of Meteorology (BOM) as 982.7mm. AGL established its own automatic weather station on Tiedmans which commenced recording data in July 2011.

Gloucester Shire Council cites the following statistics:

- average rainfall – 985 mm;
- average year round maximum temperature – 24.5 C;
- average year round minimum temperature – 10.5 C;
- average summer maximum temperature – 30 C; and
- lowest average minimum temperature – 2 C.

2.3. Geology

The site is situated within the Gloucester Basin which is a Permian coal basin. Most of the northern portion of the basin is located within the Avon River catchment with a small portion also within the Gloucester River catchment. The landforms of the area are characterised by north-south oriented linear ridges with intervening undulating lowlands and floodplains.

The geological strata of the Gloucester Basin (from youngest to oldest) can be summarised as:

- Unconsolidated alluvial deposits along the Avon River (Quaternary in age);
- Sedimentary rocks (including substantial coal measures at depth) of the Gloucester Coal Measures (Permian in age);
- Fractured basement rocks of the New England Fold Belt below the sedimentary rocks (Palaeozoic in age).

2.4. Soils

Soil landscape mapping of the area, where the project site is located, was carried out by Henderson (2000). The site is split between Gloucester Soil Landscape and Gloucester River Soil Landscape, as described below.

Gloucester Soil Landscape: *Consists of undulating erosion landscape on Permian coal measures of the Gloucester Coal Measures and the Dewrang group. The main parent materials in these groups include sandstone, siltstone, shale and conglomerate, with coal seams generally at depth. Soils are dominated by harsh texture contrast soils including Kurosols and Sodosols. These soils generally are sodic, have poor internal drainage, and are often acidic, with associated aluminium toxicity.*

Gloucester River Soil Landscape*: Is a stagnant alluvial landscape including broad level plains on quaternary alluvial deposits derived from the surrounding Permian and volcanic bedrocks. Soils are dominated by mottled Chromosols, minor Sodosols and some Hydrosols in areas of permanent waterlogging. The soil landscape tends to have seasonally high water tables and sporadic* *permanently high water tables (localised swamps) and generally has soils of very poor internal drainage.*

There have been a number of soil surveys on the Tiedmans property including FK, 2010 and FK, 2011. Comprehensive soil investigation work in conjunction with an electromagnetic (EM) soil survey was carried out for the irrigation trial area of Tiedmans and is reported in FK, 2011. This is discussed further in *Section 4.*

2.5. Topography

Regionally, the Gloucester Basin (in the Manning Valley catchment area that covers the Avon River catchment and the Gloucester River catchment) is a narrow valley running north-south close to the coast and a part of the Lower North Coast region. It is approximately 100 metres above sea level, at the base of the valley with the western edge formed by the Bucketts Range and the eastern edge formed by the Mograni Range.

The topography on Tiedmans varies from 110 metres to 130 metres Australian Height Datum and consists of grassy flats and gentle rises.

A detailed topographic survey was carried out for the whole of Tiedmans. See Attachment 1.

2.6. Hydrology

The Avon River originates to the south west of Gloucester and joins the Gloucester River to the north of the township of Gloucester. Waukivory Creek, Dog Trap Creek and Avondale Creek are the primary tributaries located within the Sub Catchment.

The hydrology of the project site is characterised by high rainfall, soils possessing low moisture infiltration rates, and undulating slopes leading to small alluvial plains adjacent to the Avon River, Waukivory Creek and Dog Trap Creek.

On the Tiedmans property there are three small catchments.

Catchment 1 consists of a watercourse which commences in the east conveying runoff water from the upper slopes adjacent to the ranges east of Tiedmans. This watercourse travels west through the forested area on Tiedmans and then heads in a north westerly direction through a neighbouring property to the Avon River.

Catchment 2 consists of slopes heading west towards the Avon and Dog Trap Creek. These slopes feed into a low lying swampy area which eventually drains north into Dog Trap Creek, just upstream of its confluence with the Avon.

Catchment 3 is in the southeast of Tiedmans. This catchment feeds a steep gully which heads south towards Dog Trap Creek.

Hydrological characteristics of the Avon River in the general area of the Tiedmans property are described in PB, 2012. The baseline water quality sampling program for all surface waters adjacent to the Tiedman property are provided in the baseline water quality report for the irrigation trial (PB, 2013).

2.7. Hydrogeology

Groundwater occurs in the shallow alluvial sediments associated with the floodplain of the Avon River, and in the fractured rock that underlies the Tiedman property. The shallow alluvial aquifers are the main beneficial aquifer across the catchment, although there is no usage of this aquifer in the local area. There is substantial groundwater monitoring in place across the local area. The baseline water quality sampling program for the water table aquifers adjacent to and beneath the Tiedman property are provided in the baseline water quality report for the irrigation trial (PB, 2013).

3. Irrigation and mass balance methodology for the Stage 1A irrigation area

3.1. Rainfall

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

3.2. Evapotranspiration

There is no evapotranspiration (see explanation in FK, 2011) data specific to the site so this will be interpolated from regionally available data through the *iWater* service.

3.3. Irrigation scheduling and water balance

The water balance provides the framework for:

- tracking irrigation applications and rainfall;
- estimating the amount and timing of irrigation applications;
- tracking inputs to calculate salt, nutrient and carbon balances in the receiving soil; and
- detecting trigger points to prevent adverse impacts on soil quality.

The water balance will be based on the *Environmental Guidelines: Use of Effluent by Irrigation (DECC, 2004)*, where:

Applied water (Qc) + Rainfall (Qr) ≤ Evapotranspiration (ET) + Percolation (P) + Runoff (R) where R is designed to be zero, therefore the daily water balance is:
$Qc \leq ET + P - Qr$

The Daily Irrigation Deficit will be:

$$\text{Daily Irrigation Deficit} = ET + P - (Qr + Qc)$$

Figure 2 summarises the trial irrigation components, irrigation approach and expected water balance for the Stage 1A area.

The aim of irrigation will be to maintain a soil moisture deficit within the optimal soil moisture range for crop growth (between wilting point and field capacity). Soil moisture will be continually monitored (in each treatment) using soil moisture sensors to track soil moisture patterns caused by irrigation and rainfall at different depths in the soil, depending on the soil treatment.

The four soil treatments are described in *Section 4.6 Baseline 2 - Target specification for amended soil*.

Irrigation will be applied when there is both a daily irrigation deficit and soil moisture deficit when compared to soil field capacity. The AGL on-site weather station data and rainfall forecasts will be used to guide the applied irrigation water and to monitor the water balance.

In order to better manage the water balance, a low pressure overhead spray (linear) system was adopted as the most appropriate irrigation method for Stage 1A. Plate 1 shows the newly installed linear irrigator.

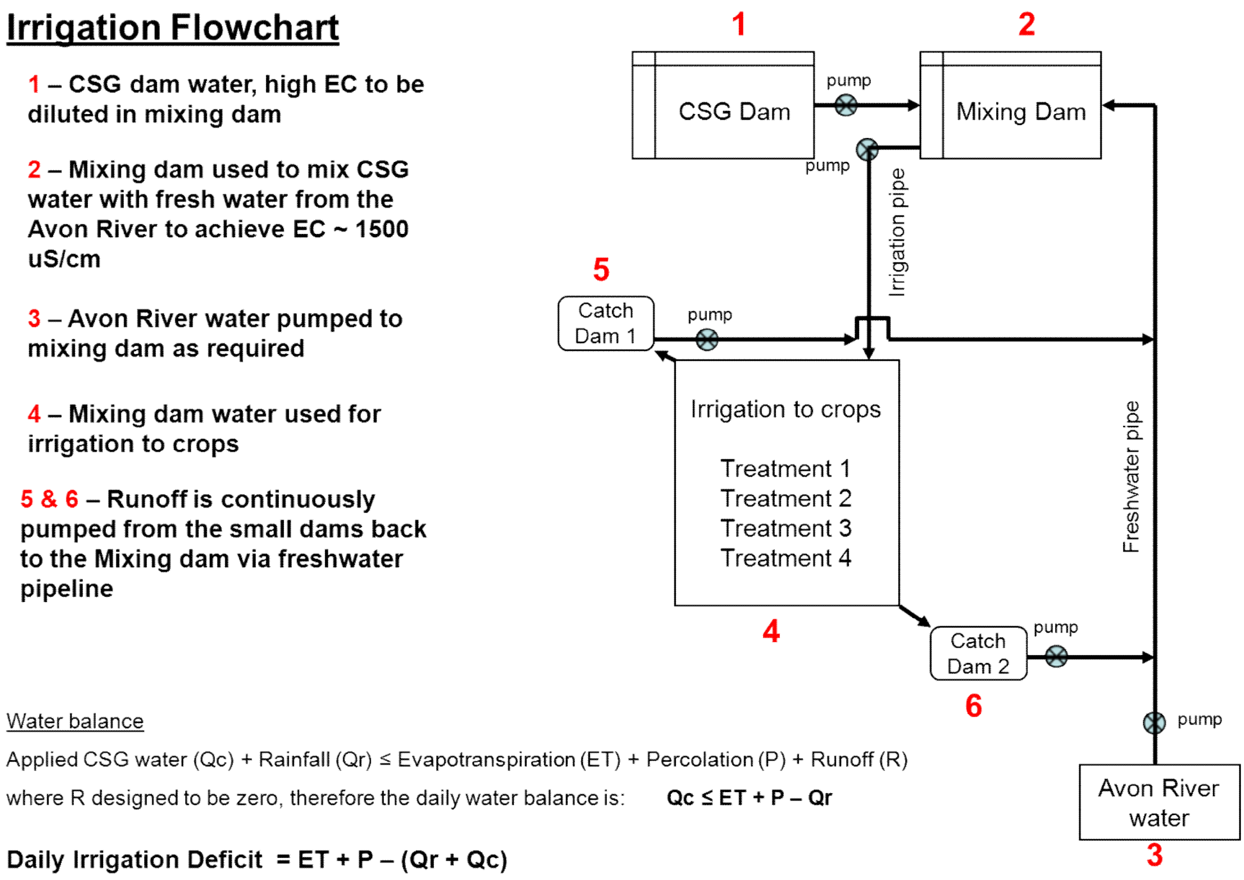

Figure 2: Irrigation flowchart for the Tiedman Trial

3.4. Irrigation water quality

Produced water from previous exploration and pilot testing programs associated with the Gloucester Gas Project has been stored in the Tiedmans North and Tiedmans South dams for several years pending the approval of this irrigation trial. The Tiedmans North dam is a produced water storage dam while the Tiedmans South dam has been identified as the primary (blended water) irrigation dam. A third dam (Tiedmans East) has recently been completed to take produced water from offsite storages (being the Stratford 1 and Stratford 3 dams), small flow testing programs at Craven 06 and Waukivory 03, and the proposed Waukivory pilot testing program. It is also currently used to store freshwater for blending purposes.

The water quality in these three dams is quite variable. The Tiedman North dam contains most of the produced water from the exploration programs and has the highest salinity, being around 4000µS/cm[1]. The water in the southern dam traditionally had a salinity of around 2800 Ec (to early 2013) but this was lowered to around 1700 Ec in preparation for the irrigation trial. Full details of the historical water quality in these dams are provided in PB, 2013.

A target blended water quality of 1500 Ec has been adopted for the irrigation trial.

3.5. Sodium, nutrient and carbon balance

The salt (sodium), nutrient (nitrogen and phosphorus) and soil carbon (as organic matter) balances will be determined during the Stage 1A Trial Irrigation Program. Monitoring and analysis of blended CSG water to be applied, soil chemistry and soil-water will 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.

Figure 3 provides a flow-chart example using sodium and Figure 4 demonstrates how sodium will be tracked with respect to the water balance and irrigation water quality. The same principle will be applied for all analytical parameters.

[1] Salinity throughout this report is discussed in terms of Electrical Conductivity (or Ec units) where for water 1 Ec unit = 1 µS/cm

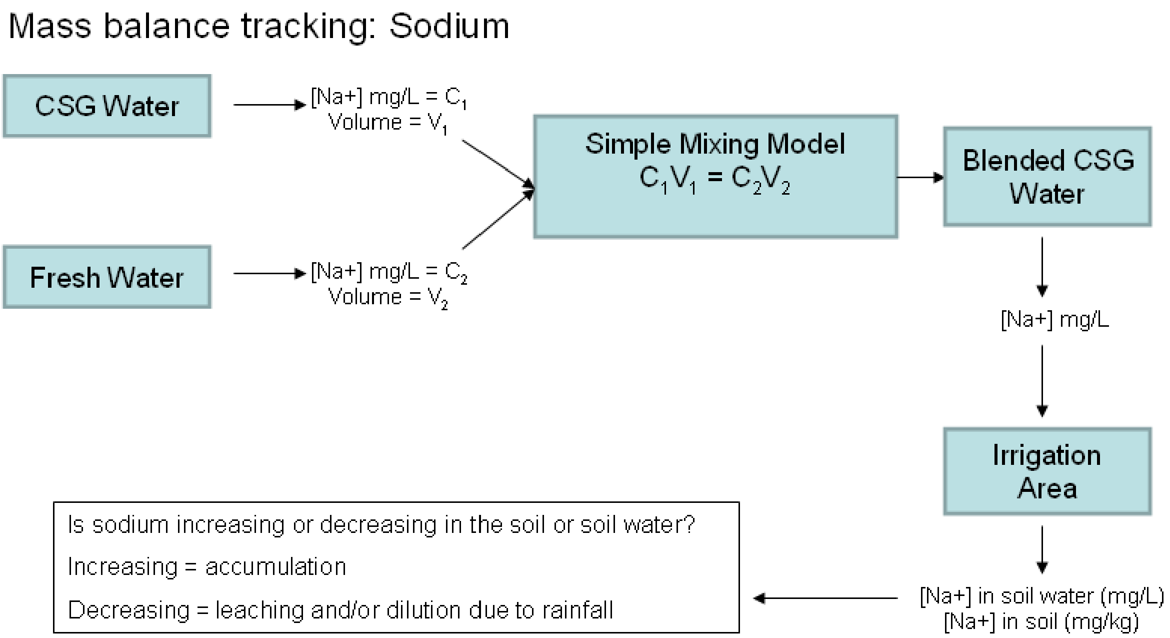

Figure 3: Flow-chart Sodium balance for irrigation of blended CSG water

Blended Irrigation (ML/day)	Applied Na+ (kg)	Applied Na+ (kg/m3)	Parameter	mg/L
0.000	0	0	[Na+]	600
0.000	0	0		
0.319	192	0.0026		
0.463	278	0.0038		
0.481	288	0.0039		
0.565	339	0.0046		
0.347	208	0.0028		
0.000	0	0		
0.000	0	0		
0.000	0	0		
0.429	257	0.0035		
0.603	362	0.0049		
0.590	354	0.0048		
0.277	166	0.0023		
0.000	0	0		
0.515	309	0.0042		
0.000	0	0		
0.000	0	0		
0.000	0	0		
0.486	292	0.004		
0.201	120	0.0016		
0.000	0	0		
0.603	362	0.0049		
0.622	373	0.0051		
0.610	366	0.005		
0.578	347	0.0047		
0.000	0	0		
0.000	0	0		
0.157	94	0.0013		
0.266	159	0.0022		
0.583	350	0.0048		
0.524	314	0.0043		

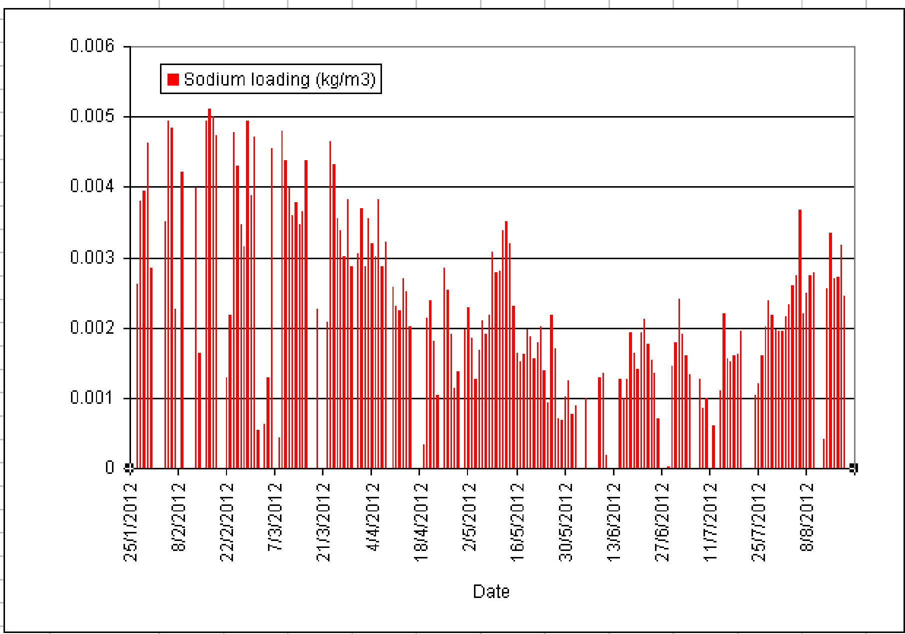

Figure 4: Spreadsheet for Sodium mass balance for irrigation of blended CSG water (based on daily irrigation volumes that could have been applied to Stage 1A since January 2012)

For example, if 3 ML of blended CSG water has been applied over the summer irrigation period it is possible to determine the daily sodium load applied and the subsequent change in soil sodium (after soil analysis).

The blended CSG water will have an approximate sodium content of 600 mg/L which means approximately 1800 kg of sodium would have been applied to the irrigation area (600 mg/L x 3 ML).

The volume of soil receiving irrigation is equivalent to 12 ha x 0.61 m which is 73200 m^3. If the soil has a density of 1.35 kg/ m^3 then there is 98820 kg of soil. Therefore 0.018 kg additional sodium has been applied to every kg of soil in the irrigation area. This may be leached to below the treatment zones during prolonged rainfall or accumulate in the subsoil during the trial however the combined irrigation water balance, soil moisture and soil monitoring strategy will allow early forecast of possible issues.

Plate 1. Low pressure overhead spray linear irrigator installed and ready for use on the Stage 1A irrigation area

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

In order to optimise the design of the irrigation trial and establish baseline soil data, the following information was collected as part of the irrigation trial design:

- Detailed location of all existing infrastructure on Tiedemans such as roads, dams, power lines, gas wells, gas gathering lines, monitoring bores, trees, fence lines and structures;
- Detailed topographic survey of the non-forested area of Tiedemans showing imposed buffer distances;
- Electromagnetic survey of the soils on the non-forested area to a depth of 1.5 metres;
- Test pits of the proposed trial plot area; and
- Soil coring and analysis of each of the individual trial plots.

The information from these studies is referred to as Baseline 1 – Parent Soil. The following information is summarised from the earlier design report (FK, 2011).

4.1. Baseline 1 - Detailed topographic survey

A detailed topographic survey of Tiedmans was carried out to provide the input data for the irrigation designer to develop the design of a centre-feed linear irrigator to service the trial plot area.

The detailed survey work was carried out on the 20th and 21st April 2011. Due to saturated surface soil conditions approximately 75% of the data gathering was executed on foot, while the balance was carried out in a 4WD utility.

Further infill survey data was collected on the 3rd June 2011. See Attachment 1.

Plate 2. Detailed topographic survey

4.2. Baseline 1 - Electromagnetic induction (EM) survey, soil sampling and analysis

The EM survey was carried out on the 20th April 2011, followed by soil validation sampling on the 9th June 2011 and subsequent laboratory analysis of the soils.

Wastewater re-use by irrigation of agricultural lands can result in the buildup of salts beyond the capacity of the soils to adsorb them and to remain productive.

EM surveys are a cost effective method of undertaking baseline soil analysis and for subsequent monitoring for changes brought about by irrigation. The EM machine induces a current in the soil remotely, from which there is a return signal which is measured as Apparent Electrical Conductivity (EC_a). The EC_a values are related to soil properties of texture, moisture content and salinity of the soils at the site.

Due to the relatively shallow nature of the soil, the EM machine was set up to collect apparent electrical conductivity of the soils to 1.5 metres depth.

Plate 3. Electromagnetic survey

Plate 4. EM soil core logging

After the EM survey was completed, 10 sites were selected as sampling points for validation of the EM results. Soil samples were taken at 10 selected locations and analysed at 4 depth intervals (0-20cm, 20-50cm, 50-100cm, 100-150cm) for the following characteristics:

- soil moisture content;
- bulk density;
- organic carbon;
- EC_e (electrical conductivity factored for soil texture class);
- pH;
- Emerson Aggregate test;
- cation exchange capacity; and
- exchangeable cations

For the Baseline 5 soil studies (to be completed in mid 2014) a second EM38 survey will be conducted to determine whether there have been any significant spacial changes in salinity over the course of the irrigation trial.

The essential outcomes from the 2011 report were as follows:

- there are two soil landscape classes on Tiedemans;
    - Gloucester soil landscape; and
    - Gloucester river soil landscape;
- the soil landscapes have been delineated; and
- a correlation equation was determined so that Apparent Electical Conductivity (EC_a) (as measured by the EM38 machine) could predict the Soil Salinity (EC_e) (as determined by laboratory testing) to a regression R^2 value of 83% - which is satisfactory for predicting EC_e from EC_a.

4.3. Baseline 1 - Test pits in the trial plot area

A series of test pits were carried out on the 21st April 2011 (6No) and 23rd May 2011 (10No).

The test pits were excavated (using a backhoe) with the aim of establishing the boundaries of the proposed trial plot area and as an aid in establishing a more specific location for the trial plots. The key features that were investigated were:

- soil profile;
- spacial consistency of the soil profile; and
- depth to rock.

Optimum design of the trial plots required a rock-free depth of approximately 1 to 1.2 metres.

Plate 5. Digging test pits

Plate 6. Inspecting soil profile in test pits

4.4. Baseline 1 - Trial plot soil coring, sampling and results

To further inform the design of each of the 16 trial plots, soil coring was undertaken on the 9th June 2011 to a target average depth of 1.2 metres. Undisturbed soil core samples were obtained by push tube method and a tracked Geoprobe drill rig.

In order to maximise representative coverage of the trial plot area the soil sampling locations were set up on a diagonal grid. The sample locations (CS1 to CS16) are shown in Attachment 2. A core sample was taken from the centre of one of three equal sub-plots and analysed at 8 depth intervals (0-10cm, 10-20cm, 20-30cm, 30-40cm, 40-60cm, 60-80cm, 80-100cm, 100-120cm) for:

- Electrical conductivity;
- Soil Texture class;
- EC_e (electrical conductivity factored for soil texture class);
- pH;
- Nitrogen;
- (Nitrate, Nitrite + Nitrate);
- Organic Carbon;
- Major nutrients (Ca, Mg, Na, K, Al);
- Exchangeable Cations(Ca, Mg, Na, K, Al); and
- Cation exchange capacity (ECEC).

In addition, Emerson aggregate tests (EAT) were carried out on the top 10 centimetres of soil at each core sample location and representative saturated hydraulic conductivity tests (SHC) were carried out for the soil texture classes as encountered in CS 4.

Plate 7. Taking soil-core samples

Plate 8. Taking soil-core samples

Key observations for the parent soils (Baseline 1) of the Stage 1A trial plot are:

- Soil texture classes – Five soil texture classes were encountered in the 1.2 metre core samples and they are listed in descending order of layering from the surface:
  - Clay Loam (CL) – all 16 core samples;
  - Light Clay (LC) – 2 core samples only;
  - Medium Clay (MC) – all 16 core samples;
  - Sandy Clay (SC) – 5 core samples only; and
  - Clay Loam, Sandy (CLS) – 15 core samples.
- Rock was encountered in one core sample location (CS7) at a depth of 1.1 metres.
- Based on the Soil Profile logs the average parent soil profile (Baseline 1) across the trial area was identified as follows:
  - Clay Loam – 135mm
  - Light Clay/Medium Clay – 640mm
  - Sandy Clay/Clay Loam Sandy – 425mm
- Salinity (EC_e) – Generally soil salinity levels were acceptable to the bottom of the Medium Clay layer. Where a layer of 'Clay Loam, Sandy' occurred as the bottom layer in a core sample the salinity was above acceptable levels (>2 dS/m) for EC_e.
- pH – The optimum (neutral) range is 5.5 – 7.5 pH. The test results fell within a range of 3.88 to 8.41, and averaged 4.67. Of the 128 samples tested for pH only 11 results (ie 8.6%) fell in the optimum range for pH, indicating that soils were mostly below the optimum range and acidic.
- Organic Carbon (OC) – Minimum organic carbon levels should be at least 2.5% throughout the soil profile in the active root zone. In the top 10 centimetres OC levels were acceptable for 14 out of 16 samples tested. In the 10-20cm layer only one sample out of 16 was above the optimum level. Organic carbon levels for the remaining 112 samples were well below the desired level, averaging only 0.83%.

- Major Nutrients (Nitrogen, Phosphorus, Potassium) – Key nutrients were all below the optimum levels required to successfully grow high water-using crops.
- Cation Exchange Capacity (CEC) - Many of the nutrients used by plants are in the form of cations. The CEC is a measure of a soil's ability to exchange and retain cations. The CEC is also a major factor affecting soil structure, nutrient availability and soil pH. The minimum recommended CEC value for intensively grown crops is 25. CEC levels in the samples taken in the trial area were all well below the recommended minimum, ranging between 5.35 and 23.4. The average CEC was 14.36. Only 9 samples out of 128 (7.0%) registered a value of 20 or more.
- Sodicity (Exchangeable Sodium Percentage) – ESP is a measure of soil sodicity. Sodic soils have an ESP greater than 4.5% and are considered to be non-sodic if the ESP is less than 1%. The average ESP of all 128 samples was 12.25%, indicating the majority of soil is sodic. Only 9 samples (7%) had an ESP less than 4.5%. Values ranged between 0.73 and 24.6. The CL, LC and MC soils had an average ESP of 10.74%, while the deeper CLS soils averaged significantly higher average values of 17.9%.
- Irrigability (Saturated Hydraulic Conductivity) – SHC is a measure of the ability of the soil to accept applied water (such as irrigation). A good range for irrigation is an SHC greater than 20 mm/hr. The SHC range for the samples taken from the trial area was between 0.02 and 0.50, with a weighted average of 0.14 mm/hr. If left unchanged these soils will not readily absorb even low amounts of water. The low irrigability was related to the high sodicity of these soils.

4.5. Irrigation plot layout

The Stage 1A trial irrigation layout was designed to ensure minimum buffer distances from the Avon River (40m), boundaries (10m), power lines (15m) and a copse of trees (10m). This created an irrigable area of 587m (oriented east-west) and 322m (oriented north-south). From within this area the final trial irrigation area was selected to satisfy the following trial requirements:

- Four soil treatments;
- Two crop systems (annuals and perennial);
- An individual plot size that could accomodate the typical range of agricultural operations; and
- 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.

This resulted in 16 individual trial plots with dimensions 156 metres x 47.85 metres. Each treatment and crop combinaton 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. See Attachment 3 for trial plot layout details.

4.6. Baseline 2 - Target specification for amended soil

Table 1 provides a summary of the Baseline 1 soil tests for the 16 core holes taken across the trial plot area.

The table summarises the soil parameters that were tested and aggregated for the three soil classes (ie layers) encountered. Layer 1 is the Clay Loam surface layer which is an average of 135mm thick, Layer 2 is the Light Clay/Medium Clay middle layer which averages 640mm thick and the Sandy Clay/Clay Loam, Sandy layer (Layer 3) takes up the remaining 425mm of the 1200mm length of the core samples extracted for testing.

The target improved soil values are indicated on the left and the actual average tested values for the three soil class layers are summarised, along with a comment next to each of the values as to whether the actual value is “OK”, “High” or “Low”.

The last column provides a list of soil additives that should be considered for improving each parameter tested, where improvement is required.

Table 1 – Specification for soil improvement

Test parameter	Units	Improved soil target value	Parent soil Layer 1 Clay Loam average value	Comment	Parent soil Layer 2 Light Clay/ Medium Clay average value	Comment	Parent soil Layer 3 Sandy Clay/ Clay Loam Sandy average value	Comment	Improvement source
Average Layer Depth	mm	-	135		640		425		-
Electrical conductivity	dS/m	**< 0.15**	0.06	OK	0.09	OK	0.17	High	
ECe	dS/m	**< 2.8**	0.50	OK	0.80	OK	3.66	High	
pH ($CaCl_2$)	pH units	**5.5 – 7.5**	4.62	Low	4.41	Low	5.05	Low	Lime, gypsum, compost
NO_3 – Nitrogen Ex	mg/kg	**> 15**	3.94	Low	1.97	Low	1.83	Low	Compost, zeolite
Organic Carbon	%	**>2.5**	3.03	OK	0.59	Low	0.19	Low	Compost
Potassium	mg/kg	**350**	168	Low	146	Low	120	Low	Compost
Calcium	mg/kg	**3500**	653	Low	316	Low	209	Low	Lime, gypsum, compost
Magnesium	mg/kg	**1800**	480	Low	1315	Low	1361	Low	Compost
Sodium	mg/kg	**< 100**	96	OK	469	High	669	High	Compost
Aluminium	mg/kg	**< 20**	15	OK	41	High	24	High	Lime, Compost
Ex Potassium	%	**1-5**	5.3	High	2.6	OK	1.8	OK	Compost
Ex Calcium	%	**65-80**	39	Low	12	Low	6	Low	Lime, gypsum, compost
Ex Magnesium	%	**10-15**	48	High	71	High	67	High	Compost
Ex Sodium	%	**< 4.5**	5	High	11	High	20	High	Compost
Ex Aluminium	%	**< 5**	2.1	OK	3.4	OK	2.0	OK	Compost
ECEC	meq/100g	**12-25**	8	Low	15	Low	16	Low	Zeolite,compost, lime, gypsum
Estimated water holding capacity	mm/m (RAW)	**150**	65	Low	55	Low	71	Low	Compost, zeolite
Water infiltration rate	mm/hr (SHC)	**25**	<1	Low	<1	Low	<1	Low	Compost, lime, gypsum

Parent soil values by texture class & target values for irrigated cropping

The ameliorant mix (to be used to treat the soils) was designed to improve:

- the water holding capacity,
- infiltration rate,
- nutrient retention, and
- organic matter content.

Required application rates to create a productive soil were based on recommendations in FK (2011) – the Baseline 1 study. The ameliorants will act to increase soil pH (currently acidic), increase Cation Exchange Capacity (CEC – currently low), decrease soil Exchangeable Sodium Percentage (ESP – currently high) and increase organic matter (currently low), all of which were noted as limiting factors to irrigation of crops. The ameliorant mix was expected to alter the parent soils in such a way as to buffer the deleterious impacts on soil structure and soil quality in view of estimated irrigation loads and water quality.

The key components selected for the ameliorant mix were:

- Composted feedlot manure;
- Lime;
- Gypsum; and
- Zeolite.

Compost

Compost is an effective tool for delivering improvements across a number of soil parameters. However, the specification for compost is unique to each supplier and only suppliers capable of providing a consistent line of product, backed up by nutrient testing, were considered for supply.

Lime/Gypsum

Lime and Gypsum are highly effective at improving pH, Calcium, Cation Exchange Capacity (ECEC), and water infiltration rates.

Zeolite

Zeolite is an inert mineral that is sometimes incorporated into composts. For the trial plot soils it will assist in improving Cation Exchange Capacity (ECEC), and increasing the water holding capacity of soils.

Treatment design

The following four soil treatments were adopted for the trial.

Treatment 1
Spread and incorporate to a depth of 240mm in all 16 trial plots:

- Composted feedlot manure – 50 tonnes/hectare; and
- Lime - 8 tonnes/hectare;
- Gypsum – 4 tonnes/hectare;
- Zeolite – 5 tonnes/hectare.

Treatment 2
Includes Treatment 1, plus the same treatment within excavated soil slots 200mm wide, at 1.5metre spacings and to a depth of 650mm

Treatment 3
Includes Treatment 1, plus the same treatment within excavated soil slots 200mm wide, at 1.5metre spacings and to a depth of 950mm

Treatment 4
Includes Treatment 1, plus the same treatment within excavated soil slots 200mm wide, at 1.5metre spacings and to a depth of 1200mm

Location of treatments

The location of the soil treatments was determined on the basis of environmental threat and depth to rock. The most likely environmental threat was egress water escaping from the trial plots (and entering the Avon River) during or just after the blended water has been irrigated.

Based on information from test pits and soil coring, it was determined that rock depths were likely to be shallowest on the ridge line where plots 7 and 8 are situated.

Treatment 1 was likely to represent the greatest risk of run-off egress out of the plots as it is the treatment resulting in the lowest effective depth of treatment. The plots with these treatments were therefore located closest to the egress catch drain and dam system.

Treatment 2 was the best match for the areas where there was expected to be shallow rock, as it had the shallowest slots (650mm).

Treatments 3 and 4 represented the least risk of run-off egress out of the plots as they are the treatments that resulted in the deepest effective depth of treatment (950 and 1200mm slots respectively). They were therefore located between Treatment 1 at the lowest point at the western end and Treatment 2 at the eastern end where there is the possibility of shallow rock.

Accordingly, the plots were allocated as follows:

- Treatment 1 only - Plots 1,2,9,10;
- Treatment 1 plus Treatment 2 – Plots 7,8,15,16;
- Treatment 1 plus Treatment 3 – Plots 5,6,13,14; and
- Treatment 1 plus Treatment 4 – Plots 3,4,11,12.

Plate 9. Typical ameliorated soil - Treatment 1, Plot 9

4.7. Baseline 2 – Amended soil sampling and test results

Following the application of the four treatments, soil sampling and testing were repeated to ascertain the soil quality for the Stage 1A Trial Irrigation Area prior to the commencement of blended water irrigation.

This analysis of the ameliorated soil (ie Baseline 2) becomes the new baseline for comparing subsequent soil quality monitoring and analysis and nutrient, sodium and carbon balances during the program.

The 16 soil sampling locations (see Attachment 2, CS1 – CS16) used in Baseline 1 were re-sampled and analysed. Soil samples were taken manually (14th January 2013) using a hand auger in order to minimise disturbance. The data collected served to highlight improvements in soil quality such as increasing soil pH (due to gypsum and lime), increasing the number of cation exchange sites (increased CEC) and increasing organic matter in the soil profile after amelioration.

As a result of the different treatment depths the core sample depth intervals were adjusted, resulting in a different total number of samples taken for analysis in accordance with the soil test parameters shown in Attachment 4.

4.8. Key findings **-** Baseline 2 (ameliorated soil) vs Baseline 1 (parent soil)

The soil quality characteristics resulting from the soil treatments are now quite different to those of the parent soil. Attachment 5 tabulates the differences in the average values for the tested soil parameters and the key points are summarised below.

4.8.1. Desirable increases

A number of beneficial increases were recorded from the Baseline 2 soil testing:

- pH – increased towards the desired range of 5.5 to 7.5.
- NO_3 – increased substantially above a target of 15mg/kg as a reflection of higher organic matter in the improved soil.
- Organic Carbon –increased substantially to depth and meets the minimum target of 2.5% near the surface.
- Calcium – has increased substantially but further adjustment was considered necessary. See *4.9 Baseline 2 – amended soil agronomic adjustments*.
- Cation exchange capacity (ECEC) – has increased and is in the optimum range to depth
- Calcium/Magnesium ratio – has substantially improved.
- Saturated hydraulic conductivity – has substantially improved.

4.8.2. Non desirable increases

One parameter (electrical conductivity, Ec) recorded increases above the target range. This was due to two contributing factors:

- High Ec of composted feedlot manure
- High Ec of Parent Soil Layer 3 (See Table 1)

Composted feedlot manure

The composted feedlot manure contained a high Ec value (11dS/m), which is typical for this type of product. The composted feedlot manure was applied at 50 tonne/ha, which was mixed to achieve a ratio of 3.5% of compost in the ameliorated soil.

In the trial design phase other composted manures (eg biosolids, municipal waste composts and chicken manure) which can have lower Ec values than feedlot manure, were considered for use in the trial. However the superior quality assurance systems, consistency of quality and repeatability of supply from feedlot sources were considered to be of greater overall benefit.

Parent Soil Layer 3

In regard to the Parent Soil Layer 3 (see Table 1), whilst extensive core sampling and test pits were carried out, it is still likely that the depth at which this layer begins is variable across the trial site and thus is a contributor to elevated Ec levels, post amelioration. It is concluded that some of this layer was brought closer to the surface because of the slotting and soil amelioration program.

Rainfall flushing

Between the collection of soil samples from the newly ameliorated soil on 14th January 2013 and the 30th April 2013, approximately 579 mm of rainfall was recorded by the AGL on-site weather station. As a result it is expected that the initial 'spike' in soil Ec levels will be substantially reduced by the time Baseline 3 soil testing is carried out in June 2013.

The successful establishment of the trial crops in late March and early April supports the suggestion that flushing from rainfall has been effective.

4.9. Baseline 2 – Amended soil agronomic adjustments

In the period after taking the Baseline 2 soil samples and subsequent crop establishment shallow (0-100mm) sampling and testing was carried out across the four treatment areas in order to ascertain the need for any final adjustment to the ameliorant prior to crop establishment.

These final adjustments were carried out subsequent to the collection of Baseline 2 soil samples and their improvement to the overall soil quality is expected to be reflected in the Baseline 3 soil testing results. The following adjustments were made to each of the four treatment areas.

Treatment 1 adjustment

- Lime – 1.75 tonnes/ha incorporated to 150mm depth
- Sow crops with Di Ammonium Phosphate fertiliser (DAP) at 50kg/ha

Treatment 2 adjustment

- Lime – 3.5 tonnes/ha incorporated to 150mm depth
- Sow crops with DAP at 50kg/ha

Treatment 3 adjustment

- Lime – 2.5 tonnes/ha incorporated to 150mm depth
- Sow crops with DAP at 50kg/ha

Treatment 4 adjustment

- Lime – 2.0 tonnes/ha incorporated to 150mm depth
- Sow crops with DAP at 50kg/ha

4.10. Perched water Piezometers

Eight (8) paired piezometers (See Attachment 2, SP1-SP8 and Figure 5) were installed in the Stage 1A area to monitor the potential for perched water to develop inside and immediately outside (ie downgradient) of each of the soil treatment types and also adjacent to the western catch dam (Catch Dam 2). The piezometers were generally installed to a depth of 400mm to 1200mm inside the area to be irrigated, depending on the treatment type, and 1200mm outside the area to be irrigated. Full details, including the piezometers in the Stage 1B area, are provided in Table 2 and Figure 5.

Table 2. Piezometer details

Piezometer (Stage 1A)	Easting	Northing	RL
SP1A	402540.4	6449385.4	119.62 GROUND 120.05 PIEZ_COLLAR 118.56 PIEZ_INVERT
SP1B	402570.3	6449381.3	119.23 GROUND 119.62 PIEZ_COLLAR 118.09 PIEZ_INVERT
SP2A	402447.4	6449119.9	118.09 GROUND 118.90 PIEZ_COLLAR 117.41 PIEZ_INVERT
SP2B	402444.2	6449100.1	118.44 GROUND 118.73 PIEZ_COLLAR 117.34 PIEZ_INVERT
SP3A	402344.4	6449137.8	112.65 GROUND 113.23 PIEZ_COLLAR 111.79 PIEZ_INVERT
SP3B	402342.0	6449116.6	112.05 GROUND 112.34 PIEZ_COLLAR 110.84 PIEZ_INVERT
SP4A	402255.0	6449153.3	109.22 GROUND 109.61 PIEZ_COLLAR 108.12 PIEZ_INVERT
SP4B	402252.0	6449131.3	108.81 GROUND 109.14 PIEZ_COLLAR 107.66 PIEZ_INVERT
SP5A	402170.6	6449168.5	106.95 GROUND 107.83 PIEZ_COLLAR 106.50 PIEZ_INVERT
SP5B	402166.5	6449144.2	106.41 GROUND 106.77 PIEZ_COLLAR 105.24 PIEZ_INVERT
SP6A	402103.5	6449178.6	105.53 GROUND 106.10 PIEZ_COLLAR 104.10 PIEZ_INVERT
SPFK 6B	402142.4	6449147.7	106.10 GROUND 106.74 PIEZ_COLLAR 104.69 PIEZ_INVERT
SP7A	402163.9	6449288.8	110.75 GROUND 111.74 PIEZ_COLLAR 110.24 PIEZ_INVERT
SP7B	402144.8	6449292.1	109.87 GROUND 110.20 PIEZ_COLLAR 108.72 PIEZ_INVERT

Piezometer (Stage 1A, cont)	Easting	Northing	RL
SP8A	402188.3	6449447.9	113.24 GROUND 114.17 PIEZ_COLLAR 112.68 PIEZ_INVERT
SP8B	402159.1	6449454.8	111.73 GROUND 112.09 PIEZ_COLLAR 110.57 PIEZ_INVERT
Piezometer (Stage 1B)	**Easting**	**Northing**	**RL**
SP9A	402407.2	6449010.9	118.26 GROUND 118.85 PIEZO_COLLAR 117.75 PIEZO_INVERT
SP9B	402387.5	6449016.9	117.30 GROUND 117.88 PIEZO_COLLAR 116.59 PIEZO_INVERT
SP10A	402363.9	6448833.5	114.89 GROUND 115.56 PIEZ_COLLAR 114.36 PIEZ_INVERT
SP10B	402344.2	6448840.6	113.81 GROUND 114.52 PIEZ_COLLAR 113.09 PIEZ_INVERT

Plate 10. Established Stage 1A trial crops prior to commencement of irrigation

Left – Triticale, late stage germination

Right – Lucerne, early stage germination

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

5.1. Irrigation plan

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

iii. Initially directly irrigate the lower salinity produced water in the Tiedman South dam so as to create space in the dam for blending of the larger volumes of produced water. Relatively minor volumes of produced water (up to 20 ML over the whole period of irrigation) are expected to be irrigated across the Stage 1B area.

iv. As part of the trial, establish some shallow rooted pasture species to evaluate irrigation application rates and irrigability of these traditional pastures in comparison with the more salt tolerant crops that are planned for the Stage 1A area. Blended irrigation water is to be used for this part of the trial.

A small travelling irrigator will be installed to irrigate this area.

5.2. Trial location

The area selected for the Stage 1B trial 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 trial 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 Figure 1). See Figure 5 for the location of the primary irrigation area within Stage 1B.

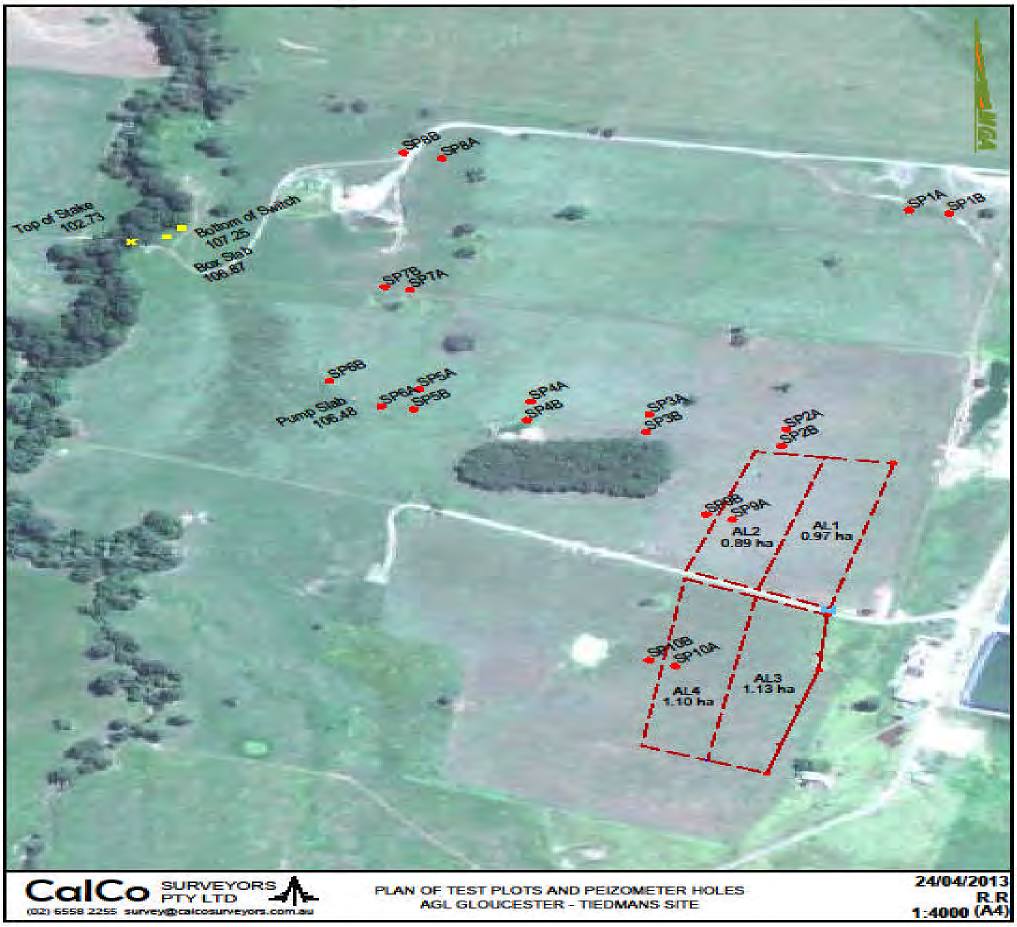

Figure 5: Stage 1B irrigation area and piezometer positions

5.3. Parent soil

Soil samples were taken from a transect across the Stage 1B area to a depth of 100mm. Samples were mixed and aggregated to form a representative sample for testing.

Key observations for the parent soils in Stage 1B are:

- Salinity (EC) – EC is low to moderate.
- pH – The optimum (neutral) range is 5.5 – 7.5 pH. The test results for the sampled soil registered 5.36, which is slightly acidic.
- Organic Carbon (OC) – Minimum organic carbon levels should be at least 2.5% throughout the soil profile in the active root zone. In the top 10 centimetres OC levels were acceptable, registering a value of 2.82%.
- Major Nutrients (Nitrogen, Phosphorus, Potassium) – Nitrogen values were acceptable. However Phosphorous and Potassium were lower than desired.
- Calcium is an important soil cation that enables the absorption of nutrients by plants. The soil test indicates calcium values are too low.
- Cation Exchange Capacity (CEC) - Many of the nutrients used by plants are in the form of cations. The CEC is a measure of a soil's ability to exchange and retain cations. The CEC is also a major factor affecting soil structure, nutrient availability and soil pH. An optimum CEC value is 25. CEC levels in the samples taken in the Stage 1B were all below the optimum value.
- Sodicity (Exchangeable Sodium Percentage) – ESP is a measure of soil sodicity. Sodic soils have an ESP greater than 4.5% and are considered to be non-sodic if the ESP is less than 1%. The ESP of the soil sample was 16.9%, indicating the soil is sodic.
- Irrigability (Saturated Hydraulic Conductivity) – SHC is a measure of the ability of the soil to accept applied water (such as irrigation). A good range for irrigation is an SHC greater than 20 mm/hr. The SHC was calculated to be less than 1mm/hr. The low irrigability is typical of the (non improved) parent soils and is related to the high sodicity of these soils.

Plate 11. Established Stage 1B trial pasture

5.4. Soil improvement

AGL engaged an agronomist to provide recommendations as to shallow soil improvements to enable the growing of improved pasture and improve the capacity of the soil to take in irrigation water.

As a result the following soil adjustments were carried out for the comparative pasture trial area:

- Lime – 4 tonnes/ha incorporated to 100mm depth
- Sow crops with Di Ammonium Phosphate (DAP) fertiliser at 100kg/ha

No substantial sub-surface soil improvements were carried out across this area except for aeration, liming, and 50% of the area having a trace mineral soil conditioner applied.

5.5. Crop establishment

The pasture mix was established on the 28th March 2013. See Plate 11.

5.6. Perched water piezometers

Paired piezometers (SP9a, SP9b, SP10a, and SP10b) were installed in the Stage 1B area (see Figure 5) to monitor the potential for perched water to develop inside and immediately outside (ie downgradient) 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.

Plate 12. Stage 1B paired piezometers

SP9b (foreground) and SP9a (background, in irrigation area)

6. Sedimentation, runoff and erosion control

As part of the irrigation trial site works, a number of protection measures were installed across the Stage 1A irrigation trial area to ensure that bare soils were not eroded during the high 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. They are shown in Attachments 3and 6:

- 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
- Spraygrassing of all structures.

Prior to the construction phase an extensive system of silt fences was installed to intercept any runoff during this period. These fences have now been removed.

These siteworks were supplemented by the following monitoring locations which are in place to minimise sediment runoff and subsurface water migration:

- 10 soil moisture monitoring positions;
- 8 paired piezometers;
- 6 rain gauges; and
- An automatic weather station.

6.2. Examples of sedimentation runoff and erosion control measures

Plate 13. Southern plot boundary bund

Plate 14. Catch Dam 1, diversion banks and temporary runoff & erosion protection

Plate 15. Catch Dam 2, diversion banks and temporary runoff & erosion protection

Plate 16. Stage 1A Typical paired piezomers
View north. SP3b (foreground) & SP3a (background in irrigation area)

Plate 17. Soil moisture sensor positions

View west. MS8 in foreground, then MS7, MS6, MS5, MS4, MS3, MS2

Plate 17. AGL automatic weather station

Plate 18. Linear irrigator automatic weather station

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

7.1. Data collection plan

AGL has a comprehensive data collection plan covering soil and water. Some of the data will be automatically generated by the weather station on the linear irrigator, the soil moisture sensing devices located in some of the plots and the control system on the linear.

Other data will be generated by collection of soil samples and subsequent testing, water samples (eg from the blended irrigation dam and the paired piezometers) or reading of gauges on the linear irrigator and rainfall gauges in the field.

7.2. Monitoring and response plan – Baseline 2

The trial trigger point monitoring and response plan for subsequent reporting is described in the FK 2012 and AGL 2012.

8. References

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Parsons Brinckerhoff (2013) *Gloucester Gas Project – Tiedman Irrigation Trial Baseline Water Monitoring Program,* Report PR_6306 for AGL Upstream Investments Pty Ltd.

Attachments

Attachment 1 – Topographic survey showing Stage 1A and Stage 1B irrigation areas

Attachment 2 – Stage 1A data recording locations

Attachment 3 – Stage 1A trial plot layout

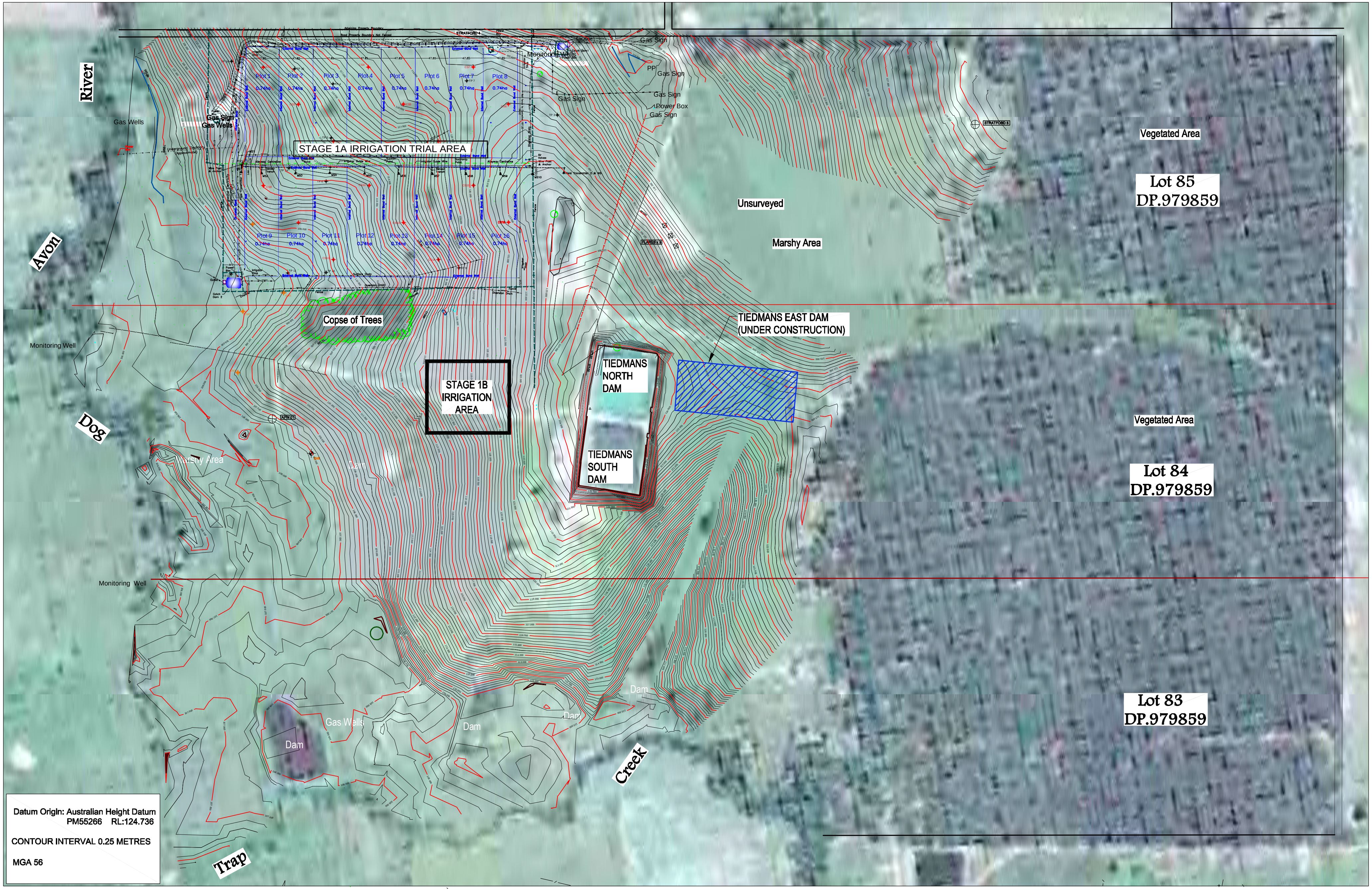
Attachment 4 – Soil analysis parameters

Attachment 5 – Soil analysis summary results

Attachment 6 – Sedimentation, runoff and erosion controls at Catch Dams

Attachment 1.

Topographic Survey showing Stage 1A and Stage 1B irrigation areas



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.
C	6-May-13	FINAL WAE (BY FODDER KING AND AGL)	FK	FK
B	24-Apr-13	ADDED DAM AND DAM NAMES	FK	FK
A	5-Apr-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\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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Natural Resources
Planning
Surveying
Civil Engineering
Environmental Engineering

ISO9001:2008
FS555072

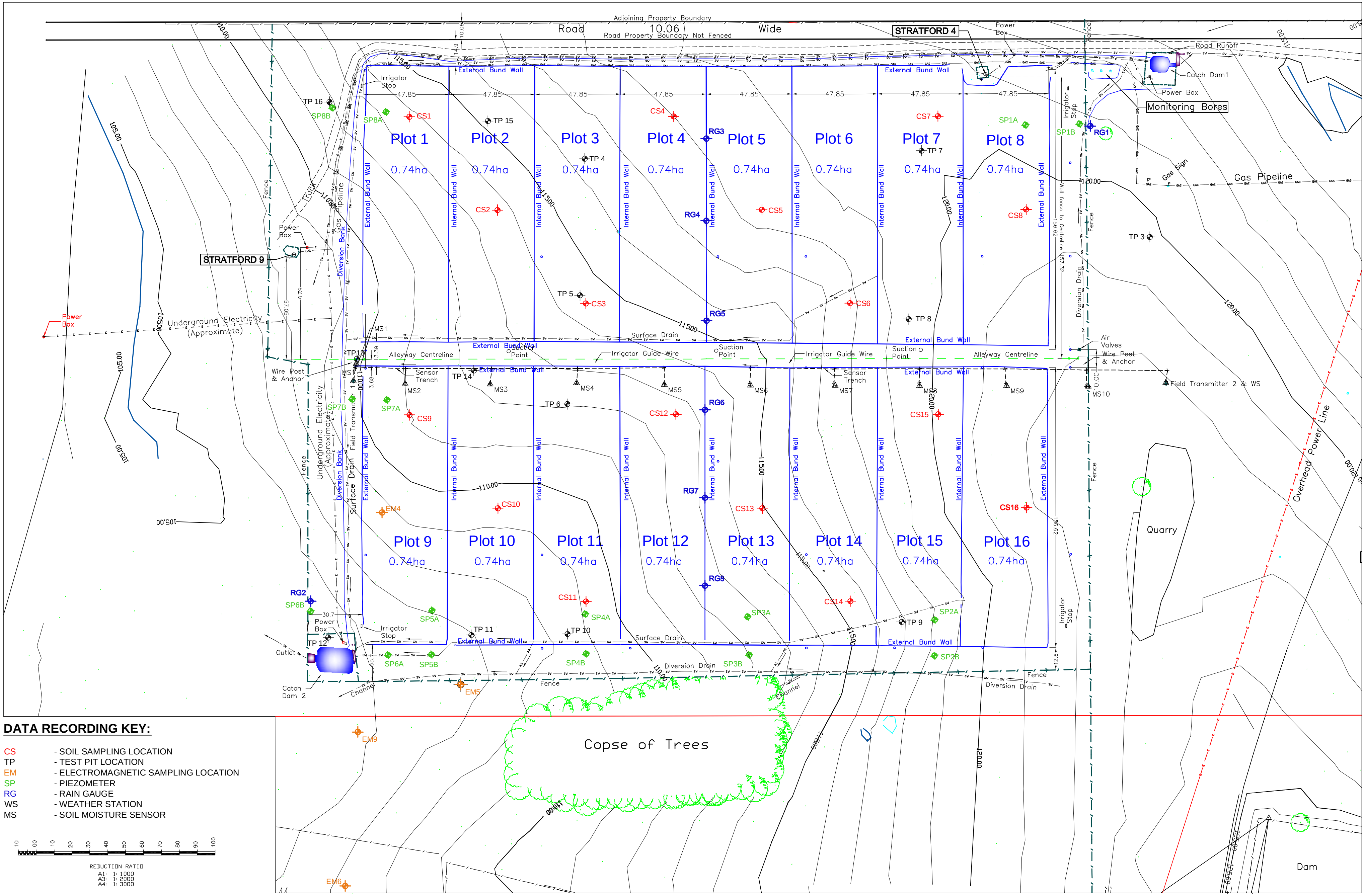
CLIENT: FODDER KING & FETTERPLACE CIVIL
PROJECT: AGL - GLOUCESTER - IRRIGATION TEST PLOT

TIEDMANS IRRIGATION TRIAL
STAGE 1A IRRIGATION TRIAL LOCATION
WORKS AS EXECUTED

DATE: 7 February 2013
DRAWING No.:
SHEET 02
GLO-ENG-DWG-G-403
Rv. C

Attachment 2.

Stage 1 A data recording locations



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: J:\12161 Fetterplace Civil, AGL site, Gloucester\ccad7\12161V02 WAE Survey 2012-12-20.ccx

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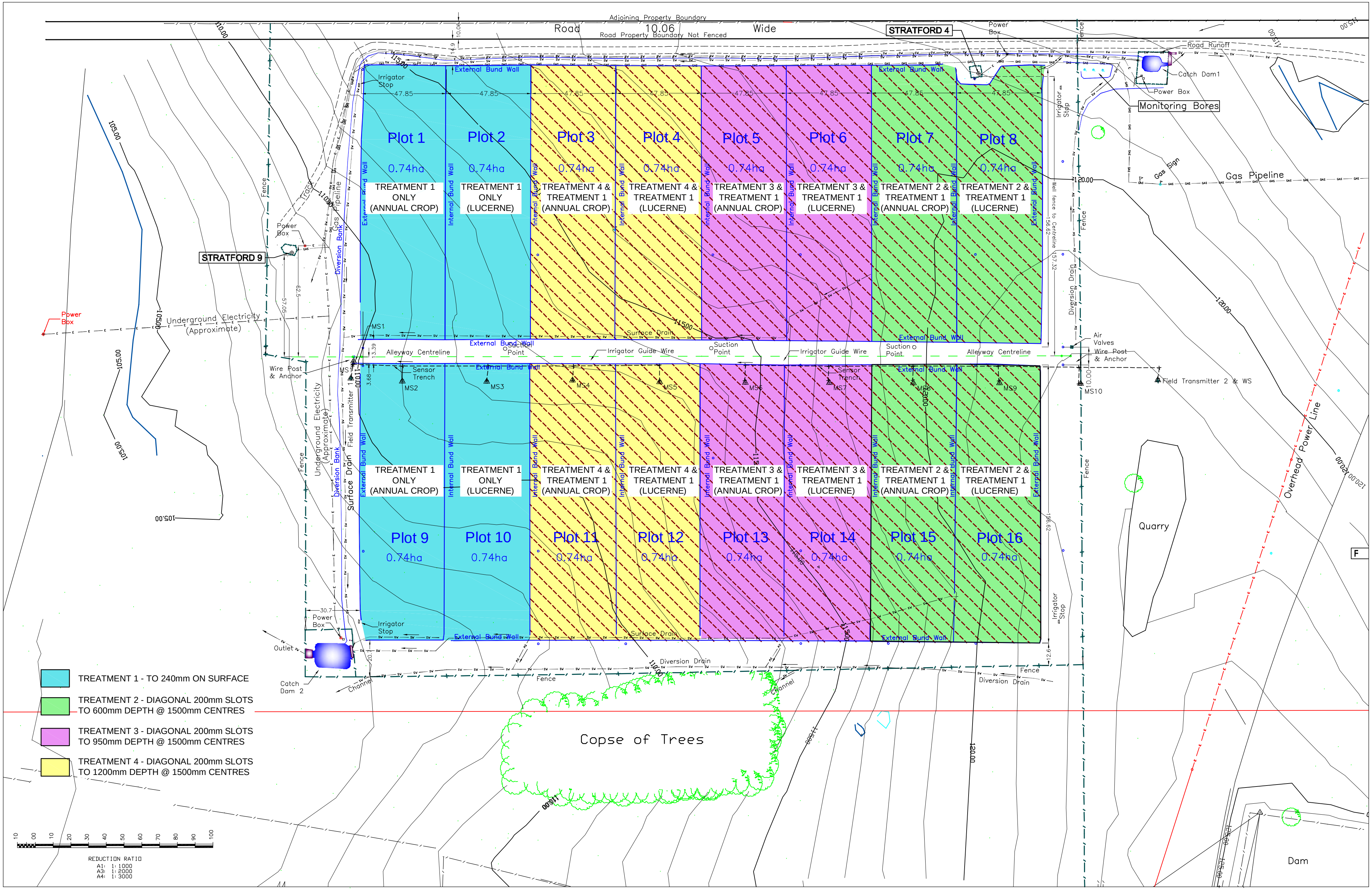
TIEDMANS IRRIGATION TRIAL
STAGE 1A DATA RECORDING LOCATIONS
WORKS AS EXECUTED

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

Attachment 3.

Stage 1A trial plot layout



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

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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

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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

Attachment 4.

Soil analysis parameters

Appendix 3

Suite 2: Stage 1A Trial Irrigation soil analysis

PARAMETER	UNITS
pH (1:5 Water)	-
pH (1:5 CaCl2)	-
Aluminium saturation	%
Organic Carbon (OC)	%
Nitrate nitrogen (NO3)	mg/kg
Phosphorous (Colwell)	mg/kg
Phosphorus Buffer Index (PBI-Col)	-
Available Potassium	mg/kg
Sulfate Sulfur (KCl 40)	mg/kg
Zinc (DTPA)	mg/kg
Copper (DTPA)	mg/kg
Iron (DTPA)	mg/kg
Manganese (DTPA)	mg/kg
Boron	mg/kg
Chloride	mg/kg
Electrical Conductivity	dS/m
Electrical Conductivity (sat. extract)	dS/m
Cation Exchange Capacity (CEC)	meq/100g
Aluminium (KCl)	meq/100g
Aluminium (KCl)	%

PARAMETER	UNITS
Calcium (amm-acet.)	meq/100g
Calcium (amm-acet.)	%
Magnesium (amm-acet.)	meq/100g
Magnesium (amm-acet.)	%
Sodium (amm-acet.)	meq/100g
Sodium (amm-acet.)	%
Potassium (amm-acet.)	meq/100g
Potassium (amm-acet.)	%
Exchangeable Sodium Percentage (ESP)	%
Ca/Mg ratio	-
K/Mg ratio	-
Soil texture	-
Soil colour	-

Physical analysis of amended soils to be determined:

bulk density, porosity, infiltration rate, field capacity/wilting point

Attachment 5.

Soil analysis summary results

Differences in average values between Baseline 2 (ameliorated) and Baseline 1 (parent) soils

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
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
0-20	0.80	1.66	158	1.5	0.69	9.25	-0.99	0.26	-0.26	270	1854	-121	59	-23	2	35	-33	-2	-3	8.95	2.11
20-40	0.48	0.93	51	1.0	0.21	5.72	-3.46	-0.27	-0.23	82	1146	-421	-63	-20	0	28	-24	-2	-2	1.97	0.91
40 - 60	0.30	0.69	42	0.9	0.14	4.91	-3.57	-0.72	-0.11	53	984	-434	-166	-10	1	27	-23	-4	-1	0.64	0.81
60 - 80	0.19	0.46	28	0.8	0.07	3.97	-2.49	-0.97	0.05	26	796	-302	-223	4	0	24	-18	-6	0	0.63	0.67
80 - 100	0.22	0.29	31	0.7	0.07	3.89	-2.47	-0.94	0.16	29	779	-300	-217	14	0	22	-18	-7	2	0.71	0.59
100 - 120	0.24	0.49	10	0.5	0.08	3.77	-0.28	-0.53	-4.40	33	756	-35	-123	-396	0	19	-7	-5	-7	-1.37	0.42

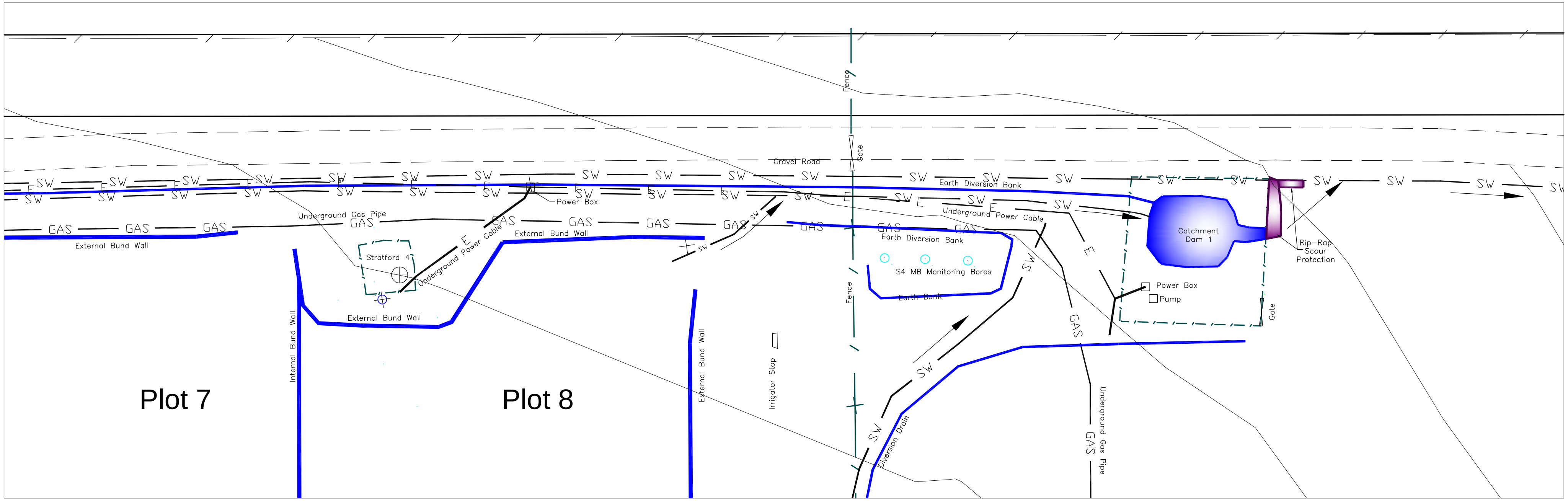
Denotes an increase in Baseline 2 soil test values compared to Baseline 1 soil test values

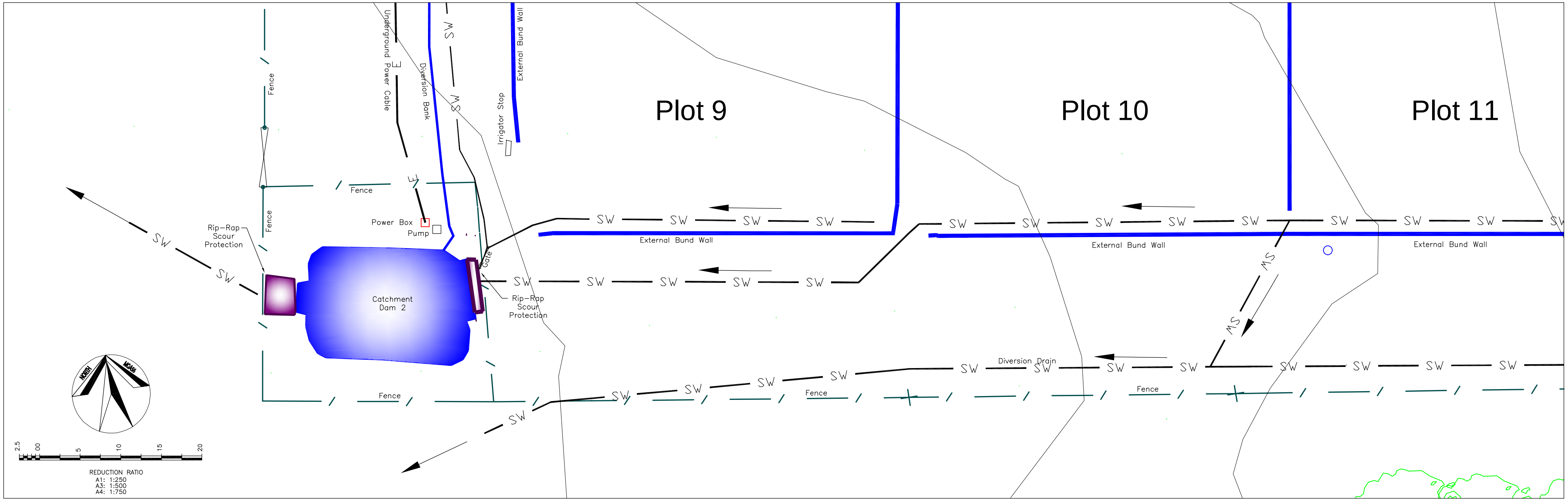
Differences in physical characteristics between Baseline 2 (ameliorated) and Baseline 1 (parent) soils

			Baseline 1		Baseline 2	
	Units	Range for Irrigation	0-10 cm	0-20 cm	0-10 cm	0-20 cm
Ksat	mm/hr	> 20	0.11	0.11	3.28	3.28
Bulk Density	kg/m3	1400 - 1700	1.25	1.21	1.33	1.33
Porosity	% v/v	35 - 55	54.3	51.4	50	50
Wilting point	% vol	crop dependent	26.8	26.8	23.8	23.8
Field capacity	% vol	crop dependent	40.1	40.1	38.4	38.4
Saturation	% vol	crop dependent	47.7	47.7	50	50

Attachment 6.

Sedimentation, runoff and erosion controls at Catch Dams





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

TIEDMANS IRRIGATION TRIAL
STAGE 1A CATCH DAM DETAILS
WORKS AS EXECUTED

DATE: 7 February 2013
DRAWING No.:
SHEET 03
GLO-ENG-DWG-G-404
Rv. C