Soil Quality Monitoring and Management Program

Tiedman Irrigation Trial

Prepared by Fodder King Ltd

for

AGL Upstream Investments Pty Ltd

9 October 2012

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1. Introduction

AGL Energy currently holds Petroleum Exploration Licence (PEL) 285 granted under the provisions of the *Petroleum (Onshore) Act 1991* for the undertaking of coal seam methane exploration. In accordance with the PEL a Review of Environmental Factors (REF) was submitted for assessment under Part 5 of the *Environmental Planning and Assessment Act* (1979) in 2011 for coal seam gas (CSG) irrigation activities. Conditional approval was granted by NSW Trade and Investment, Resources and Energy (DRE) on 5th July 2012 to conduct production water storage, blending and irrigation activities at the Tiedman property at Stratford near Gloucester as outlined in the submitted REF.

Condition 3, as stated in the REF approval (ref: OUT12/14515), stipulates that a comprehensive Soil Quality Monitoring and Management Program that satisfies Manager Environmental Operations (DRE), is to be developed and submitted prior to the commencement of the irrigation trial activities. This document has been prepared to satisfy this condition.

2. Location of Irrigation Areas

The approved irrigation areas are comprised of three stages, Stage 1A, Stage 1B, and Stage 2 areas, as shown in Figure 1.

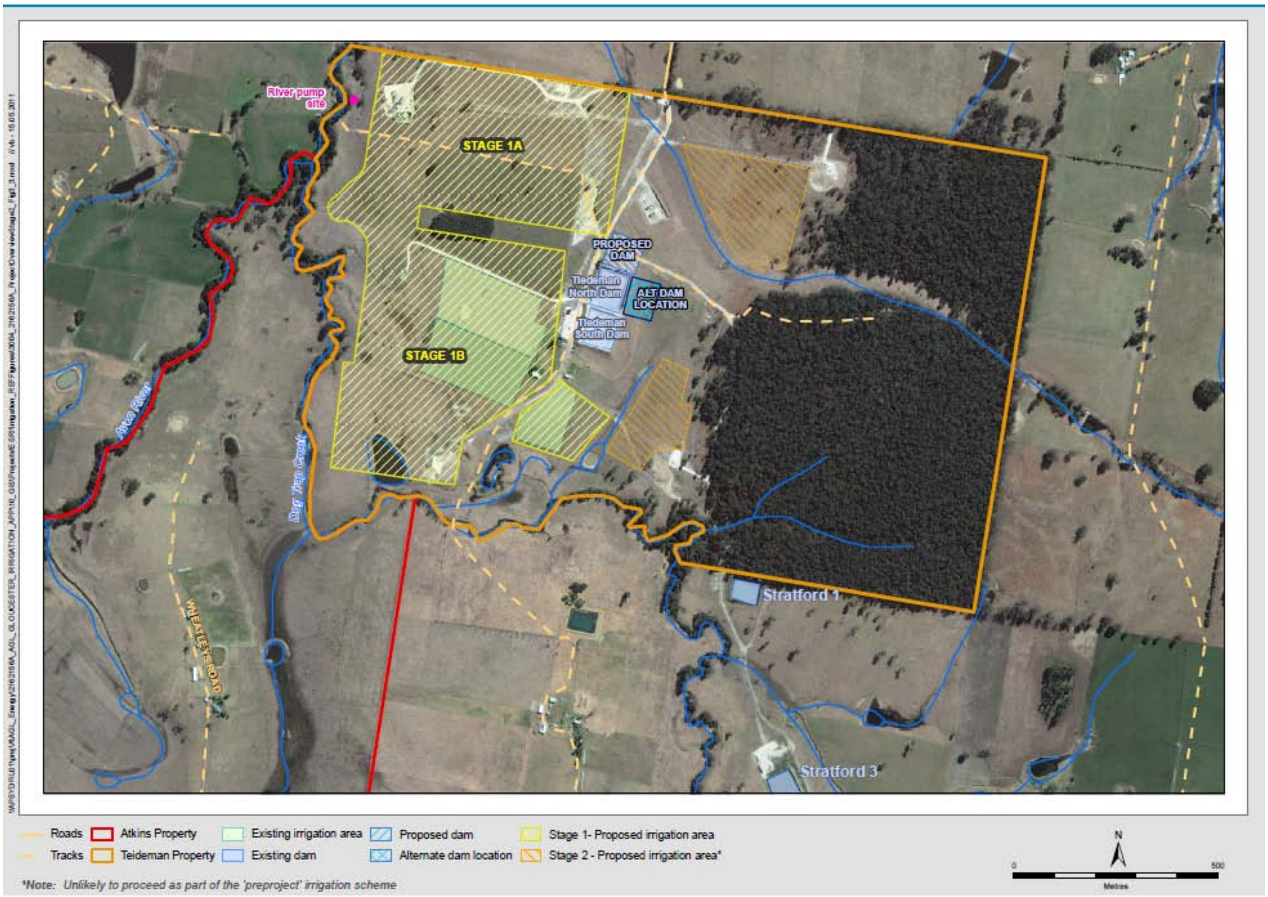

Figure 1: Gloucester Irrigation Areas for Exploration Produced Water

2.1 Stage 1A – Trial irrigation area

The Stage 1A area is the trial irrigation area that is the major focus of the Soil Quality Monitoring and Management Program. 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 22ha in total of which 12-15 ha is planned to be irrigated using a linear move irrigator. Crop types are expected to be lucerne, forage sorghum, oats and selected pasture types.

2.2 Other irrigation areas

The Stage 1B area will be where the lower salinity water in the produced water storage dams will be irrigated. Relatively minor volumes of produced water (between 10 and 20ML over the whole period of irrigation) are expected to be irrigated across the Stage 1B area in the early stages of this irrigation activity.

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.

The Stage 2 area is approximately 15ha. These areas are 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.

3. Irrigation trial Soil Quality Monitoring and Management Program Objectives

3.1. Soil Quality Monitoring and Management Program Objectives

The overall objectives of the Soil Quality Monitoring and Management Program 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.

3.2. Irrigation Trial Objectives - Stage 1A Area

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 Gloucester Project Extracted Water Management Plan;

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.

3.3. Irrigation Trial Objectives - Stage 1B and Stage 2 Areas

The objectives of the Stage 1B and Stage 2 areas are to:

a) Allow for the irrigation of the lowest salinity irrigation 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.

The remainder of this Soil Quality Monitoring and Management Program focuses on the Stage 1A irrigation trial area where between 50 and 60 ML of produced water is expected to be irrigated.

4 Stage 1A Irrigation Trial

4.1 Description

Soil investigation and management activities for the Stage 1A Irrigation Trial are broadly defined as:

- *Baseline 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 during 2011 (Fodder King, 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.

- *Ameliorated soil analysis*

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

- *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, and provide 6 monthly reports to DRE in accordance with REF approval conditions 3 and 6.

- *Final soil study*

  On completion of the trial, comprehensive soil sampling and testing will be undertaken (similar to the Fodder King baseline study done in the 2011) to establish the effect of irrigation on the ameliorated soil, prior to submission of a final report to DRE.

4.2 Baseline Data

Previous investigations by Fodder King (FK) (2011) have characterised the soils within the Stage 1A irrigation area. Existing soils within the Stage 1A irrigation area are described as clay loam and classified as Brown Sodosols. The soil samples were analysed for a standard chemical suite including soil and soil-water parameters designed specifically for agricultural assessment, in this case irrigation by blended CSG water.

In the Stage 1A Irrigation Trial, the aim is to ameliorate the existing soils to improve their capacity to receive irrigation of blended CSG water. Three sets of baseline data will be obtained:

4.2.1 Baseline 1

Soil data from FK (2011) will be used as baseline data for initial comparison to the ameliorated soils which will be irrigated during the trial. Soil samples will be taken at similar locations throughout the trial to compare spatial and temporal attributes. A summary of average, maximum, minimum and standard deviation of existing soil data from FK (2011) is shown in Appendix 1.

4.2.2 Baseline 2

The first analysis of the ameliorated soil will be the secondary baseline for comparing subsequent soil quality monitoring and analysis and nutrient, sodium and carbon balances during the program. The 16 soil sampling locations used in FK (2011) will be re-sampled and analysed. Soils samples will be taken manually using a hand auger in order to minimise disturbance to the crop area. Data will 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.

4.2.3 Baseline 3

The EM study (FK, 2011) highlighted texture, soil moisture and salinity profiles across the Tiedman property. There was little variation across the whole of the property. The EM study will be repeated after 24 months to determine any broader changes in soil characteristics brought about through soil improvement and intensive irrigation.

Information from a number of reports will also be drawn upon for interpretation and are summarised in Table 1.

Table 1: Reports used in developing the soil management and monitoring plan

Author	Report Title	Date	Report Content	Client
AECOM	Gloucester Gas Project, Environmental Assessment	11/11/2009	Main report on all environmental matters associated with the project.	AGL Gloucester LE Pty Ltd
Parsons Brinckerhoff Australia	Gloucester Operations Irrigation Proposal Review of Environmental Factors	April 2010	Proposal description, planning context, existing environment, environmental impacts and mitigation and environmental management	AGL Energy Limited
Parsons Brinckerhoff Australia	Gloucester Exploration program – Irrigation Proposal. Review of Environmental Factors	June 2011	Proposal description, planning context, existing environment, environmental impacts and mitigation and environmental management	AGL Energy Limited
AGL	Water Management Plan for the Tiedman Irrigation Program - Gloucester	14 May 2012	Support document for the Review of Environmental Factors	AGL Energy Limited
AECOM	Gloucester Gas Project: Submissions Report	24/5/2010	Summary and response to key issues from agencies, community and business groups and individuals	AGL Gloucester LE Pty Ltd
Fodder King Ltd	Technical Assessment of land in the Gloucester Basin for irrigation of CSG water	October 2010	Project scope, review of available information, government policy and guidelines, CSG risks, conceptual plan, feasibility and program, investment and operational issues	AGL Upstream Investments Pty Ltd
Fodder King Ltd	Preliminary Investigations and Design of an Irrigation Trial on land in the Gloucester Basin for irrigation of CSG water	September 2011	Scope of investigation and trial design, planning approval and guideline requirement, detailed site data, trial design, and trial program, procedures, monitoring, data collection and management	AGL Upstream Investments Pty Ltd

4.3 Soil Amelioration

Deep slotting was designed for the specific purpose of improving acid-sodic soils down to depths of as much as 1.3 metres. The preliminary soil testing for Tiedmans indicated that they are acidic as well as being sodic, and therefore candidates for this type of treatment.

Most irrigable crops able to survive in acidic soils have shallow root systems and their low water consumption rates would dictate much larger land areas for irrigation.

Deep slotting enables the thorough physical mixing of soil ameliorants such as organic matter, lime and/or gypsum into sodic soils at depths greater than 300 mm, which makes it a suitable match with deep rooted crops. A typical deep slotting example is provided in Figure 2 and is based on the average soil profile derived from the core sampling done within the trial plot area.

Incorporation of organic matter, which can be sourced locally as by-products from other industries, or delivered in bulk from specialist suppliers would have a beneficial effect on the parent soils by:

- adding key nutrients;

- increasing the cation exchange capacity;
- reducing sodicity; and
- improving the water holding capacity for the level of irrigation envisaged.

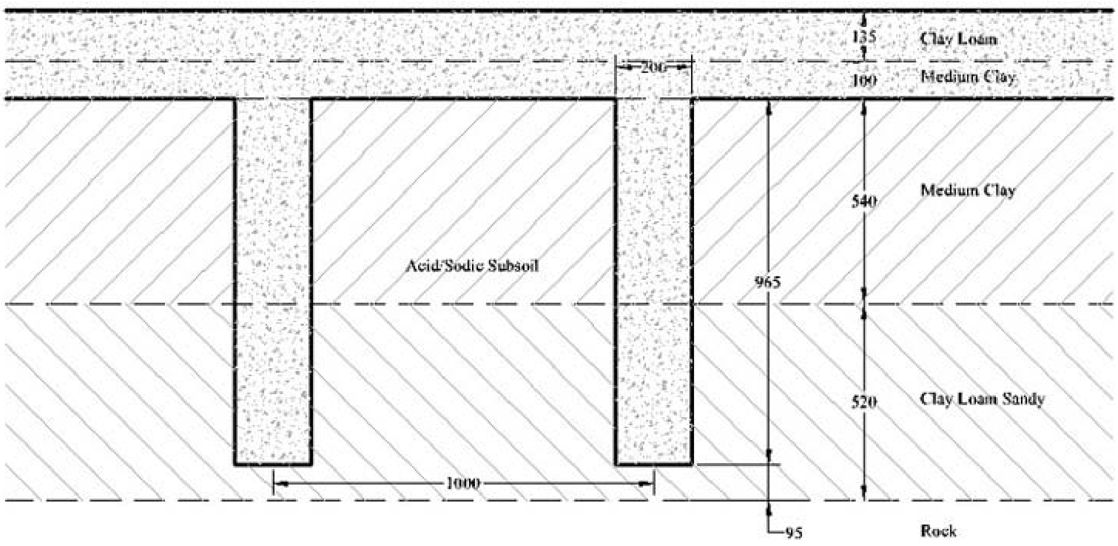

Figure 2: Sample Deep Slotting Cross Section based on Stage 1A Profile Logs

5 Soil Quality Monitoring

Water, soil and soil-water analysis suites will be used during the irrigation trial and will ensure consistency of monitoring, reporting and comparative interpretation. (Refer to Appendices 2 and 3).

5.1 Stage 1A Trial Irrigation area

The Stage 1A trial area will entail deep amelioration of soils over four treatment depths. The composition of the ameliorant to be incorporated into the irrigation area is shown in Table 2.

Table 2: Composition of ameliorant and loading rates

Material	Required application rate (Tonnes/ha)
Gypsum	4
Lime	8
Composted Feedlot Manure	50
Zeolite	5

The ameliorant has been designed to improve the water holding capacity, infiltration rate, nutrient retention and organic matter content of existing site soils. 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 ameliorants are expected to alter existing 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.

Figure 3 summarises the soil monitoring program and salinity tracking of potential surface runoff and Figure 4 shows the location of soil sampling sites, shallow perched water paired-piezometer sites and soil moisture monitoring locations.

These sites in Figure 4 were selected in order to:

- enable comparisons with the baseline soil sampling locations (CS1 – CS16);
- cover the general contour (differences in elevation) and expected drainage within the irrigation area;
- maintain the high sampling density of 1 sample/0.77 hectares; and
- have one sample point in each trial plot.

Soil sampling and analysis will occur every 6 months as part of the soil monitoring and reporting program.

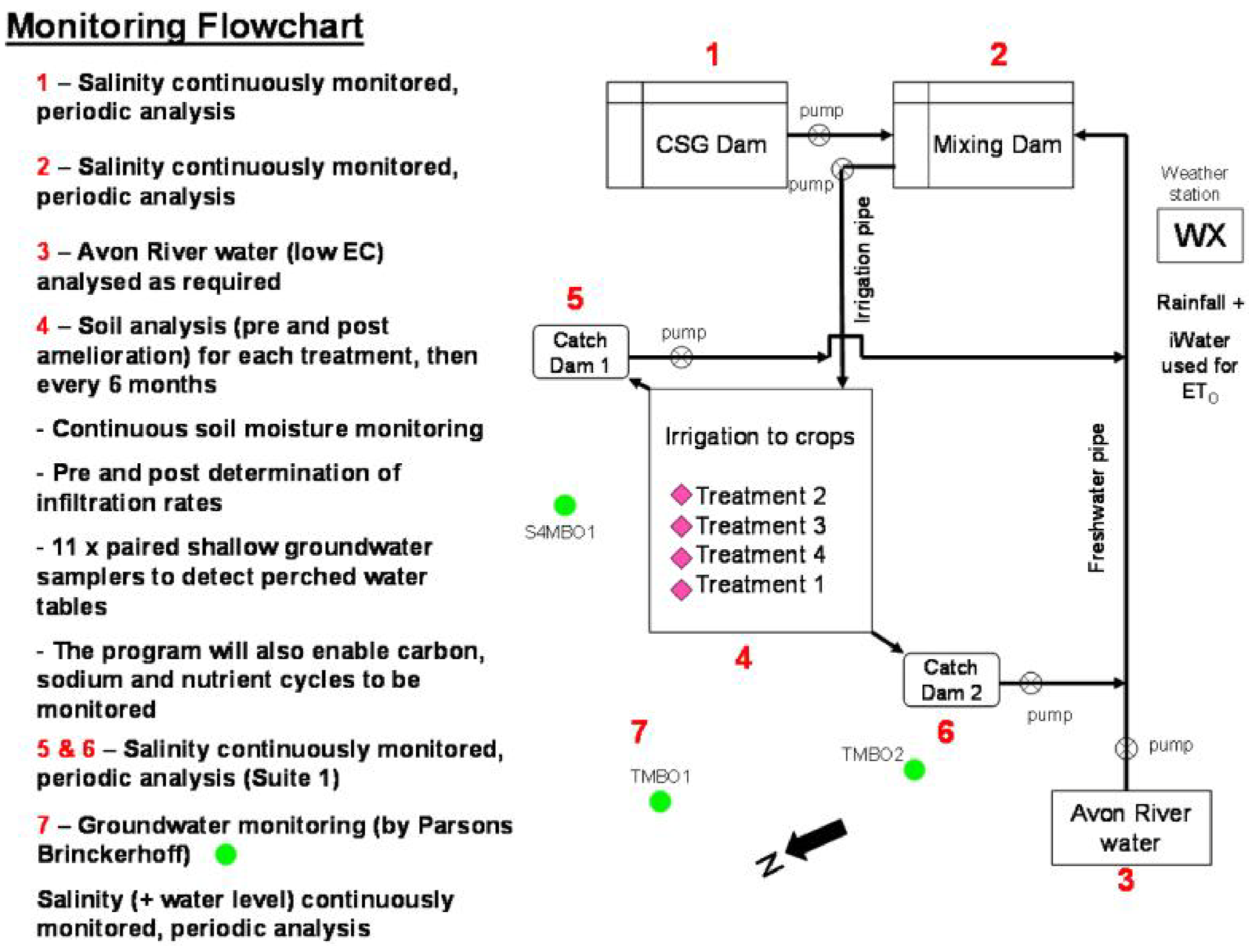

Figure 3: Soil monitoring program and salinity tracking pathways

The volume of the Catch Dams in Figure 3 was determined using the Rational Method. The Rational Method is commonly used to determine runoff (Q in m^3/s) from a range of sites and is expressed as:

$Q = CiA$

where C = runoff co-efficient, i = rainfall intensity and A = area.

Volume of runoff = Q x t = Flow rate x time; and was used to calculate the volume of the catch dams.

Typical runoff coefficients are shown below in Table 3 and the Intensity Frequency Duration (IFD) table for rainfall in the Stage 1A area is shown in Table 4.

Table 3: Runoff coefficients commonly used in hydraulic design

Land Use for < 25 year storm	**C**	**Land Use for > 25 year storm**	**C**
Paved Parking Area, <2% slope	0.85	Paved Parking area, >6% slope	0.97
Commercial, <2% slope	0.71	Commercial, >6% slope	0.90
Streets, <2% slope	0.70	Streets, >6% slope	0.89
Industrial, <2% slope	0.67	Industrial, >6% slope	0.87
Residential 1000m^2 block, loam soil <2% slope	0.22	Residential 1000m^2 block, loam soil >6% slope	0.47
Pasture, sandy soil, <2% slope	0.12	Pasture, loam soil, >6% slope	0.52
Meadow, sandy soil, <2% slope	0.10	Meadow, loam soil, >6% slope	0.44
Cultivated land, sandy soil, <2% slope	0.08	Cultivated land, loam soil, >6% slope	0.34
Forest, sandy soil, <2% slope	0.05	Forest, loam soil, >6% slope	0.20

Summarised from *Hydrologic Analysis and Design* by Richard McCuen (1989, Prentice-Hall Publishers), page 282.

Table 4: IFD data for the Stage 1A Trial Irrigation Area

Intensity-Frequency-Duration Table

Location: 32.100S 151.975E NEAR.. Tiedman Property Issued: 16/8/2012

Rainfall intensity in mm/h for various durations and Average Recurrence Interval

	Average Recurrence Interval						
Duration	1 YEAR	2 YEARS	5 YEARS	10 YEARS	20 YEARS	50 YEARS	100 YEARS
5Mins	81.0	104	134	151	174	205	229
6Mins	76.0	97.9	126	142	164	193	215
10Mins	62.1	80.0	102	116	134	157	175
20Mins	45.1	58.0	74.0	83.5	96.2	113	126
30Mins	36.6	47.0	60.0	67.6	77.8	91.3	102
1Hr	24.9	32.1	40.9	46.2	53.1	62.4	69.5
2Hrs	16.7	21.5	27.6	31.2	36.0	42.5	47.4
3Hrs	13.1	16.9	21.9	24.8	28.8	34.0	38.0
6Hrs	8.70	11.3	14.7	16.8	19.6	23.2	26.1
12Hrs	5.78	7.52	9.89	11.3	13.2	15.8	17.8
24Hrs	3.82	4.97	6.54	7.49	8.74	10.4	11.7
48Hrs	2.46	3.20	4.18	4.78	5.56	6.61	7.43
72Hrs	1.85	2.41	3.15	3.60	4.19	4.98	5.60

(Raw data: 32.16, 7.57, 2.42, 60.82, 15.52, 4.88, skew=0.09, F2=4.33, F50=16.07)

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Table 5 summarises the catchment attributes used to define catchment areas and runoff co-efficients used in the Rational Method calculation.

Table 5: Catchment attributes

Catchment areas	Area (ha)	Average Slope	C	% to Catch Dam 1	% to Catch Dam 2
16 plots x 0.77 ha	12.32	< 2 %	0.18	12.5	87.5
Cart track	0.39	< 2 %	0.60	0	100
Northern boundary diversion gutter	0.07	< 2 %	0.60	40	60
Southern boundary diversion gutter	0.17	< 2 %	0.60	0	100
Western boundary diversion bank area	0.31	< 2 %	0.60	0	100
Total Area	**13.26**	**< 2 %**	***0.20**	**10.5**	**89.5**
			* weighted average	average	average

Table 6 summarises the total runoff rate (Q) and volume of runoff from the Stage 1A irrigation area based on a 1 in 100 year event (11.7 mm/hr for 24 hours).

Table 6: Rational Method calculation

C	0.2	-
i	11.7	mm/hr
A	132600	m^2
Q	0.086	m^3/sec
Volume of runoff (in 1 hour)	310	m^3

Therefore a total catch dam volume of 310 m^3 will capture all of an 11.7 mm/hr storm. The approximate volume required for each catch dam is:

Catch Dam 1 = 10.5% x 310 m^3 = 33 m^3

Catch Dam 2 = 89.5% x 310 m^3 = 278 m^3

However, the aim of catch dams is not to capture all runoff from the Stage 1A area but rather act as a first-flush system to prevent brackish water from the irrigation area reaching the Avon River. To achieve this, the catch dams will be fitted with:

- continuous salinity loggers to monitor EC, and;
- depth-activated pumps to send captured runoff back to the mixing dam at a pump-rate of approximately 26 L/s.

The pump rate is not designed to empty the catch dams at a rate equal to the runoff rate from a large storm event. It is designed to capture the “first flush” from the irrigation area based on a 1 in 1 year event (24.9 mm in 1 hour, refer Table 4). This is important because any excess overflow during large storm events (such as 11.7 mm/hr over 24 hours) will have similar characteristics to overland flow from natural surrounding areas. This will be monitored by the salinity loggers in the catch dams.

Shallow perched water sampling (when and if present after rain events) will allow soil-water to be analysed and is anticipated to occur when soil moisture monitoring indicates saturated conditions. Perched shallow soil water (salient to soil monitoring) and soil analysis parameters for this program are shown in Appendices 2 and 3.

Figure 4: Stage 1A Trial Irrigation Area showing location of soil sampling site (CS), shallow groundwater samplers (SP, piezometers) and soil moisture sensors (MS)

5.2 Stage 1B Irrigation area

The soil sampling and monitoring for the Stage 1B area will follow a similar methodology to Stage 1A. Fewer samples will be tested due to the lower level of irrigation on this area, as discussed in section *3.3 Irrigation Trial Objectives – Stage 1B and Stage 2 Areas*.

Baseline soil sampling and testing has already been carried out. Within each reporting period, an aggregated soil sample will be compiled from the positions indicated in Figure 5. The aggregated sample will be tested in accordance with the parameters indicated in Appendix 3.

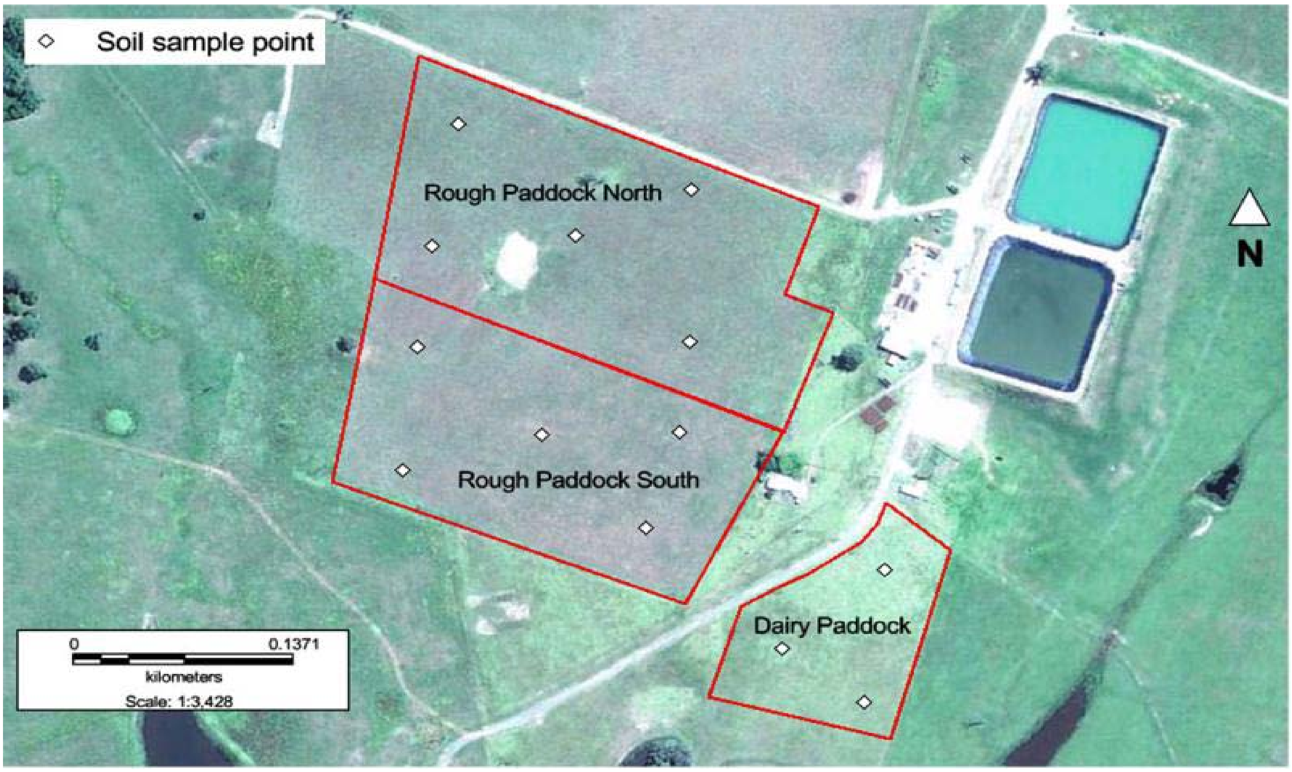


Figure 5: Stage 1B Irrigation Area showing location of soil sampling sites

6 Soil Quality Management

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.

6.1 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):

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 ≤ ET + P – Qr

The Daily Irrigation Deficit will be:

Daily Irrigation Deficit = ET + P – (Qr + Qc)

Figure 6 summarises the irrigation approach and water balance.

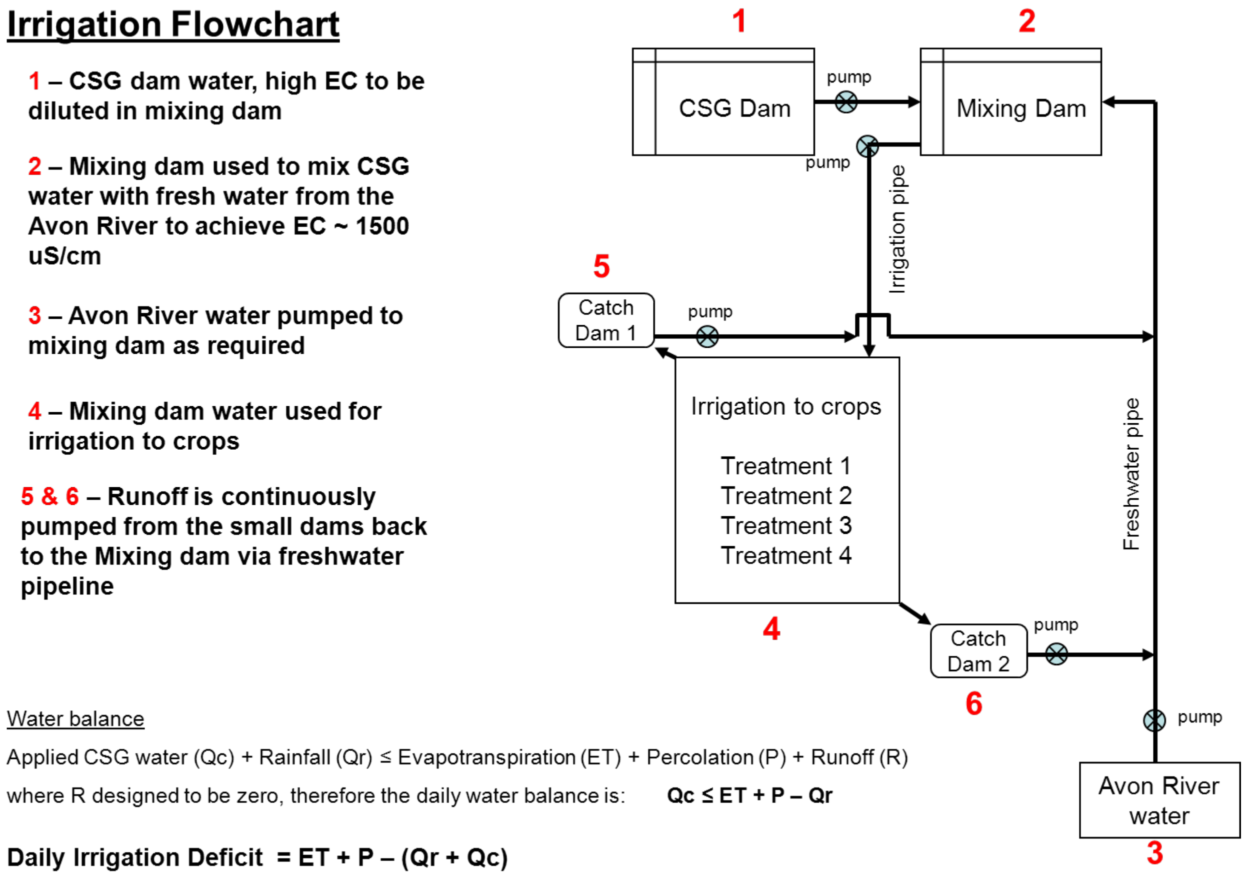


Figure 6: Irrigation flowchart for the Tiedman Trial

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 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 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 adopted as the irrigation method.

6.2 Salt, Nutrient and Carbon Balances

The salt (and specifically sodium), nutrient (nitrogen and phosphorous) 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 7 provides a flow-chart example using sodium and Figure 8 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.

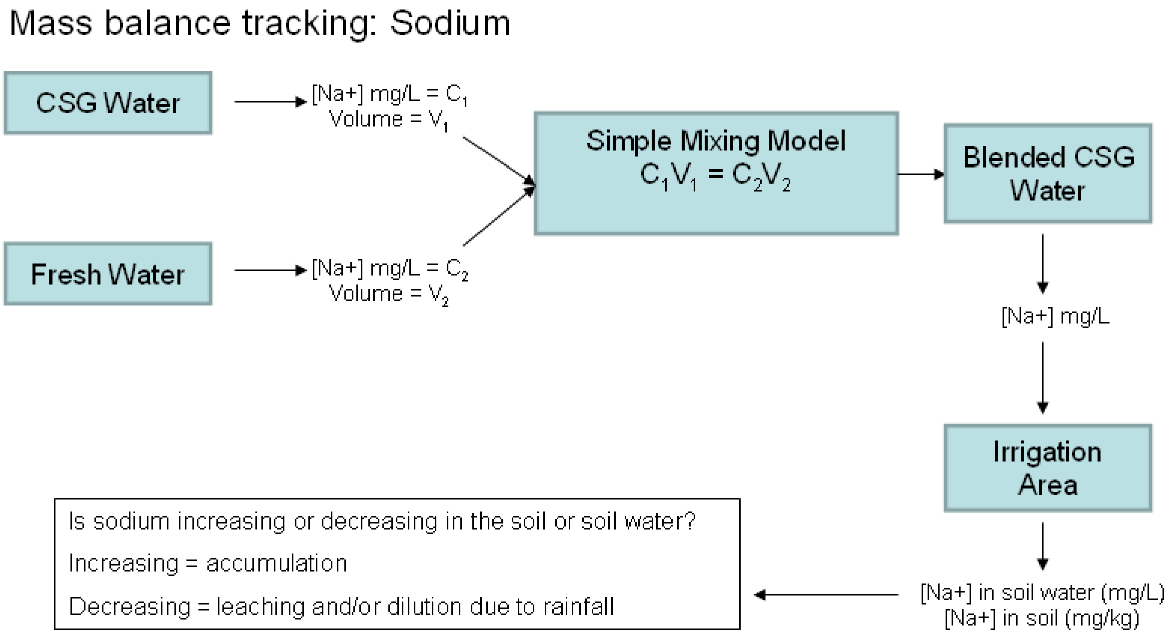
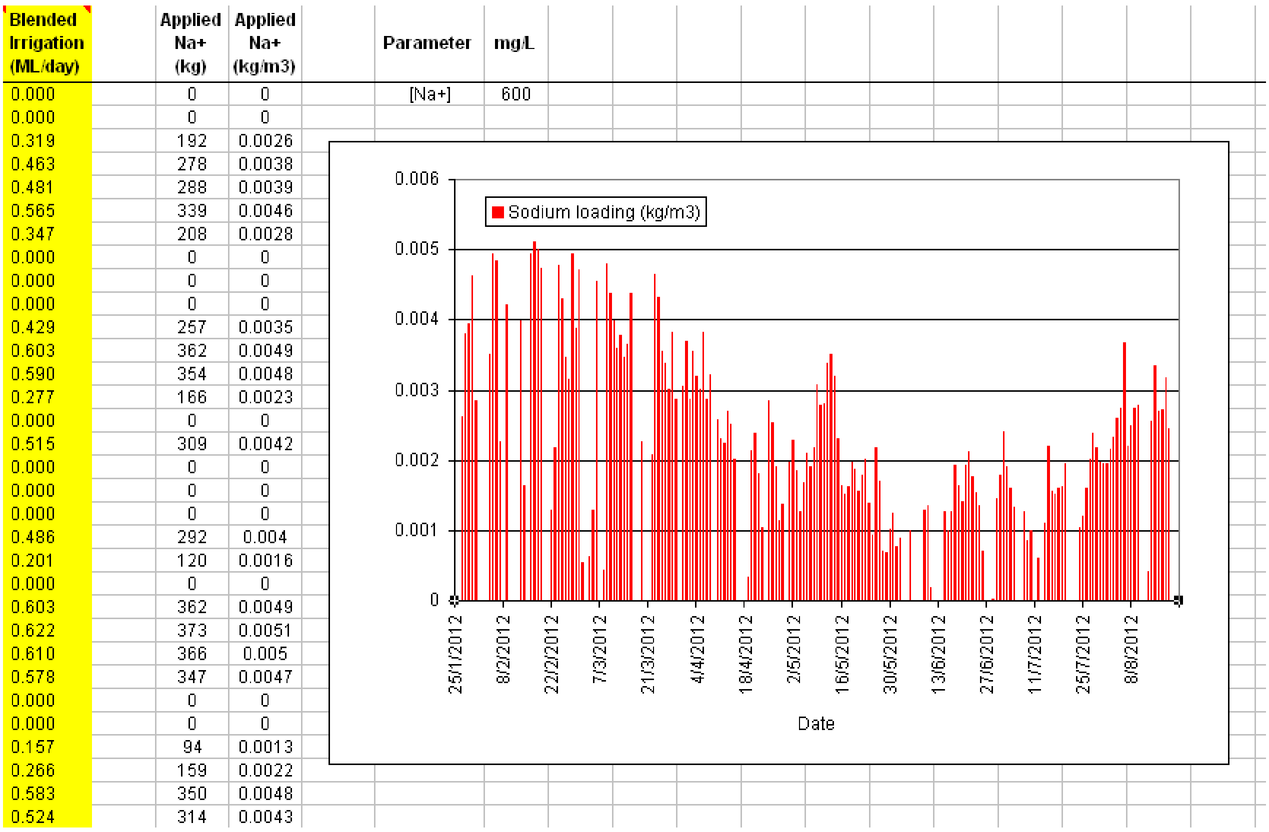


Figure 7: Flow-chart Sodium balance for irrigation of blended CSG water



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 8: 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.

6.3 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 discussed in the *Environmental Guidelines: Use of Effluent by Irrigation* (DECC, 2004).

However, while threshold limits are provided in the guidelines there is in fact a dynamic continuum that exists between soil ESP and the SAR of applied waters (Lucas, 2009). For example, soils with a low ESP are susceptible to an accumulation of sodium when irrigated (using saline water) over time. This has the effect of flocculating clay particles in the upper 20 cm of the soil profile and enhancing soil structure.

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. However, 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, thus maintaining soil structure.

6.4 Crop growth, persistence and health

Crop growth will be determined from measuring “dry 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.

Crop health will be measured by leaf tissue analysis and monitored at regular intervals.

7 Stage 1A Trial Trigger point monitoring and Response plan

There are a range of critical control points that will be monitored during the trial. These are summarised in Table 7 below.

Table 7: Stage 1A Trial 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 (See Appendix 1)	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 identified in Figure 4 (2) – across 5 proposed parent soil locations (four internal sites within each of the 4 soil treatment types plus one external control site)

Salinity will be continuously monitored in surface storages such as the blend water dam and the two catch dams, in accordance with the Water Management Plan for the Tiedman Irrigation Program. Soil moisture will also be continuously monitored (using depth-integrated sensing technology) within the irrigation plots and will provide insight into antecedent conditions prior to irrigation.

The number of paired piezometers at the edges of the trial area has been increased from the initial 4 stated in the AGL Water Management Plan (2012) (refer Figure 4 for site locations) to 11 paired piezometers. The 11 paired piezometers will monitor whether there is any leakage of irrigation water to form a perched water table both within the irrigation area and outside in the parent soil profile. Shallow piezometers will be constructed using a 0.3m long screened interval at 80 mesh (spearpoint filter) attached to an appropriate length of 50mm PVC casing. Each of the piezometers will be installed to the appropriate depth (between 0.3m and 1.5m) using a 60mm cookie-cutter type hand auger. Filter sand will be used to backfill to 0.2m above the top of the screened interval. The remainder of the borehole will be backfilled with bentonite pellets to minimise the seepage of irrigation water around the casing from surface.

Within the irrigation trial area, piezometers will be constructed in the deep slots and seated at the base of the respective slots. Outside of the trial area, piezometers will be to 1.5m depth in the sandy clay loam or to refusal on weathered rock. Each piezometer will be nominal 50mm diameter and extend 0.1 to 0.2m above surface. Each will be fitted with a plastic collar (around the PVC casing on the surface) and top cap to prevent ingress of rainfall or irrigation waters.

Soil quality trigger points will include EC_{se} and soil ESP because they indicate the potential for erosion. EC_{se} and soil ESP will be tracked over time to determine any changes in soil quality during the Trial. Soil samples will be taken from 16 locations within the irrigation area (refer Figure 4). Samples will be taken at 20 cm intervals down to the base of the respective treatment depth. For each of the four treatments, each depth interval from each soil sample location will be combined into a composite sample to provide a representative sample for analysis for that respective treatment (comprising four plots per treatment).

The soil chemistry is expected to be altered prior to the trial (due to ameliorants) and exhibit a degree of variability during the irrigation trial. However any significant increasing trend over several soil sampling and analysis periods would be reviewed after the two-year trial (4 soil sampling campaigns).

The surrounding parent soil will be monitored for salinity changes by taking samples adjacent to selected baseline sample locations (there will be one external control and two internal locations). Samples will be taken at the same depth intervals as the original baseline samples.

Ongoing monitoring will be carried out by a Technical Officer with on-site staff assisting in observing and recording daily operations. Short term “trigger points” will be observed and acted upon as required on an ongoing basis.

8 Soil Amelioration and Rehabilitation Plans

The existing soil in the Stage 1A area is a clay loam classified as a Brown Sodosol (FK, 2011) which will be ameliorated toward a Brown Dermosol (CSIRO Australian Soil Classification) prior to any irrigation activity. Each of the slotted profiles will have the ameliorated soil inserted and will also be incorporated across the top 24 cm of the entire area. Figure 8 and Figure 9 show examples of a Brown Sodosol and Brown Dermosol respectively.

Figure 8: Brown Sodosol

Figure 9: Brown Dermosol

(sourced from http://www.dpi.vic.gov.au/home)

By altering the soil characteristics and physical attributes the soil becomes more receptive to irrigation and as such the soil will be 'pre-habilitated'. Consequently, any subsequent measures that may be required to rehabilitate the soils resulting from the blended water quality profile are expected to be minimal.

9 Sedimentation and Erosion Control

9.1 Construction phase

9.1.1 Timing

To minimise the overall risk from rainfall during the construction phase of the Stage 1A trial irrigation area, the installation work will occur in the period of lowest mean rainfall in the Gloucester region, which is between July and November.

9.1.2 Silt Fencing

Prior to commencement of any works (i.e. soil disturbance), silt barriers will be installed downslope of the site. The fences will be installed as per the Gloucester Gas Project Environmental Management Plan and procedures. The barriers will be regularly checked and maintained during the construction period.

9.1.3 Installation Methodology

The Stage 1A trial irrigation area has been designed to have 16 individual trial plots. Each trial plot will be individually bunded to intercept any runoff and minimise erosion between the time that soil amelioration work is carried out and when crops are established.

Permanent diversion banks have been designed to prevent the ingress of water from external overland flows and these will be installed during the construction phase.

9.1.4 Spraygrassing of diversion banks

On completion of the internal trial bunds, trial area perimeter bunds and diversion banks they will be stabilised by application of Spraygrass.

9.1.5 Crop establishment

The trial crops will be established immediately after the trial plot installation work has been completed.

9.2 Operations phase

9.2.1 Plot bunding and drainage

As outlined in 9.1.3 above, there are 16 trial plots of 0.77 hectares in size. Each trial plot is bunded to prevent the ingress of external overland flows, to intercept any internal runoff and control the egress of any blended CSG water from the plots in the event of major rainfall events and to prevent the movement of water from one plot to the next.

The internal plot drainage has been designed to convey run-off from the internal non-trial areas (eg linear cart track) as well as any runoff from the trial plots. Regular checks and maintenance of the site drainage and bunds will be carried out regularly as part of the operational monitoring procedures.

9.2.2 Catch dams and recycle pumps

Two catch dams will be installed to collect runoff from inside the trial irrigation area. Each catch dam will be double lined in accordance current requirements, will have erosion protection, and will be fitted with float switch-activated pumps to keep the dams empty at all times. Any water collected in the dams (including first flush water from rainfall events) will be recycled by the pump system back to the blended water mixing dam.

Approximately 89% of runoff will flow to Catch Dam 2 and 11% will flow to Catch Dam.

9.2.3 Irrigation system to be used in the trial

The irrigation system to be used for the trial is a low pressure overhead spray linear move system. The system will be used to irrigate blended CSG water in accordance with the actual water balance data and the soil moisture sensing systems.

9.2.4 Wind speed and rainfall shutdown

The linear irrigator will be configured to automatically shut down for preset wind speeds and rainfall rates.

9.2.5 Silt Fencing

Silt fencing will remain in place as required during the operational phase of the irrigation activity and will be regularly checked and maintained as part of the operational monitoring procedures.

9.2.6 Live weather data gathering

The Tiedman site has its own automatic weather station. Weather data for the water balance and irrigation decision making is drawn from this station. The linear system will also have an inbuilt automatic weather station and this station will activate irrigator shut down in the event of high wind or rainfall.

9.2.7 Buffer distances

The Stage 1A trial irrigation area has been designed to provide minimum buffer distances to property boundaries, trees and the Avon River.

10 Reporting

10.1 Trial Irrigation Area (Stage 1A)

Reporting of all soil analysis and interpretation will be undertaken every six months, with three progress reports and a final report summarising trends in soil quality parameters and comparisons to baseline data. The first report (Report 1) will detail:

a) the baseline comparison (and differences) between the existing soils and the ameliorated soil to be used during the trial, and;

b) comparison of soil quality between the non-irrigated ameliorated soil and the irrigated ameliorated soil after approximately 3 months of irrigation.

Reports 2 and 3 will describe the temporal and spatial trends in soil quality parameters during the trial. These reports will also describe any soil management trends that require a response. Table 3 outlines the Critical Control Points where potential soil hazards may emerge along with a general Action and Response summary. If required at this stage, Trigger Response Plans will be prepared, then discussed with DRE and other agencies as required and appropriately enacted.

The final report (Report 4) will detail all soil analysis data obtained during the trial, describe the temporal and spatial trends in soil quality parameters and soil impacts; and report on the effectiveness of any Trigger Response Plans that may have been enacted.

Each report will record irrigation quantities applied along with water balance and salt loadings.

10.2 Other Areas (Stage 1B and Stage 2)

In addition to monitoring of the soil quality parameters (see Appendix 3), each report will record irrigation quantities and salt loadings if any irrigation occurs on these areas during each reporting period.

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Appendix 1

Stage 1A Trial Irrigation Area - Summary of existing soil quality

Average n = 16

Depth	ECe	EC (1:5)	pH	NO2	NO3	Org-C	K	Ca	Mg	Na	Al	ECEC
cm	dS/m	dS/m	CaCl2	mg/kg	mg/kg	%	meq/ 100g	meq/ 100g	meq/ 100g	Meq /100g	meq/ 100g	meq/100g
0 - 10	0.50	0.06	4.65	<0.1	4.1	3.15	0.43	3.32	3.82	0.39	0.16	8.1
10 - 20	0.58	0.07	4.46	<0.1	2.2	1.27	0.32	2.54	6.66	0.78	0.26	10.6
20 - 30	0.64	0.08	4.35	<0.1	2.6	0.62	0.39	2.07	10.73	1.49	0.50	15.2
30 - 40	0.77	0.10	4.40	<0.1	2.1	0.51	0.42	1.54	11.91	1.82	0.46	16.2
40 - 60	1.29	0.14	4.62	<0.1	2.9	0.38	0.37	1.29	12.50	2.29	0.47	16.9
60 - 80	2.47	0.19	4.81	<0.1	2.1	0.27	0.37	1.46	11.92	2.64	0.41	16.8
80 - 100	2.89	0.16	4.90	<0.1	2.4	0.25	0.34	0.82	11.69	2.80	0.39	16.0
100 - 120	3.73	0.17	5.09	<0.1	2.0	0.26	0.29	0.73	11.19	2.71	4.54	19.5

Maximum

Depth	ECe	EC (1:5)	pH	NO2	NO3	Org-C	K	Ca	Mg	Na	Al	ECEC
cm	dS/m	dS/m	CaCl2	mg/kg	mg/kg	%	meq/ 100g	meq/ 100g	meq/ 100g	Meq /100g	meq/ 100g	meq/100g
0 - 10	0.80	0.08	4.95	<0.1	6.8	6.34	0.76	6.00	5.17	0.87	0.65	10.9
10 - 20	1.70	0.22	4.72	<0.1	3.7	4.55	0.71	4.62	11.20	1.53	0.57	17.3
20 - 30	1.10	0.15	4.73	<0.1	3.9	0.92	0.65	3.57	16.50	2.98	1.57	22.2
30 - 40	1.20	0.16	5.12	<0.1	3.5	0.77	0.65	3.40	17.60	3.20	1.05	22.7
40 - 60	5.80	0.25	7.68	<0.1	4.4	0.8	0.53	7.21	15.90	3.95	1.39	20.0
60 - 80	7.80	0.39	8.41	<0.1	3.1	0.44	0.64	12.30	16.80	4.06	1.46	23.4
80 - 100	6.70	0.36	6.83	<0.1	3.3	0.36	0.67	2.21	16.20	4.59	1.71	20.6
100 - 120	6.70	0.29	7.2	<0.1	3.1	0.89	0.48	2.05	15.10	4.40	68.00	81.7

Minimum

Depth	ECe	EC (1:5)	pH	NO2	NO3	Org-C	K	Ca	Mg	Na	Al	ECEC
cm	dS/m	dS/m	CaCl2	mg/kg	mg/kg	%	meq/ 100g	meq/ 100g	meq/ 100g	Meq /100g	meq/ 100g	meq/100g
0 - 10	0.3	0.04	4.18	0.1	1.2	1.77	0.26	2.13	2.43	0.08	0.03	5.4
10 - 20	0.2	0.03	4.2	0	1.1	0.52	0.16	0.94	2.98	0.28	0.01	5.5
20 - 30	0.3	0.04	4.02	0	1.6	0.33	0.23	0.63	6.04	0.63	0.07	9.4
30 - 40	0.3	0.04	4.08	0	1	0.28	0.22	0.25	5.03	0.79	0.02	8.1
40 - 60	0.4	0.05	3.97	0	1.4	0.16	0.17	0.30	4.74	0.87	0.00	8.1
60 - 80	0.2	0.03	3.96	0	1	0.10	0.17	0.17	4.42	0.98	0.00	7.0
80 - 100	0.3	0.04	3.88	0	1	0.10	0.16	0.06	5.68	1.23	0.00	8.8
100 - 120	0.5	0.03	3.89	0	1	0.10	0.13	0.25	4.39	0.98	0.00	6.6

Standard Deviation

Depth	ECe	EC (1:5)	pH	NO2	NO3	Org-C	K	Ca	Mg	Na	Al	ECEC
cm	dS/m	dS/m	CaCl2	mg/kg	mg/kg	%	meq/ 100g	meq/ 100g	meq/ 100g	Meq /100g	meq/ 100g	meq/100g
0 - 10	0.14	0.01	0.20	<0.1	1.50	1.09	0.14	1.15	0.78	0.21	0.15	1.6
10 - 20	0.41	0.05	0.18	<0.1	0.87	0.93	0.14	1.00	2.37	0.37	0.17	3.0
20 - 30	0.26	0.03	0.23	<0.1	0.76	0.17	0.10	0.89	2.78	0.59	0.40	3.4
30 - 40	0.24	0.03	0.31	<0.1	1.01	0.15	0.12	0.80	3.28	0.76	0.34	3.7
40 - 60	1.27	0.06	0.89	<0.1	0.91	0.14	0.11	1.66	3.10	0.93	0.42	3.3
60 - 80	2.40	0.11	1.12	<0.1	0.80	0.10	0.15	2.92	3.24	0.89	0.42	3.9
80 - 100	2.20	0.09	0.93	<0.1	0.81	0.10	0.12	0.52	3.45	1.04	0.47	3.9
100 - 120	2.14	0.09	1.07	<0.1	0.76	0.24	0.11	0.46	3.36	0.98	16.93	17.0

Appendix 2

Suite 1: Water analysis for parameters of interest for Stage 1A Trial Irrigation soil monitoring

(The complete water analysis suite for all site waters is shown in the AGL Water Management Plan (2012))

PARAMETER	UNITS
Electrical Conductivity (EC)	dS/m
pH	no units
Chloride (Cl)	mg/L
Sodium (Na)	mg/L
Sodium Adsorption Ratio (SAR)	-
Total Alkalinity	mg CaCO3/L
Bicarbonate Alkalinity (HCO3)	mg CaCO3/L
Carbonate Alkalinity (CO3-)	mg CaCO3/L
Calcium Carbonate Saturation Index	-
Hardness	mg CaCO3/L
Aluminium (Al)	mg/L
Boron (B)	mg/L
Calcium (Ca)	mg/L
Copper (Cu)	mg/L
Fluoride (F)	mg/L
Iron (Fe)	mg/L
Magnesium (Mg)	mg/L
Manganese (Mn)	mg/L
Nitrate nitrogen (NO3)	mg/L
Phosphorus (P)	mg/L
Potassium (K)	mg/L
Sulfur (S)	mg/L
Zinc (Zn)	mg/L
Total Dissolved Solids (TDS)	mg/L

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