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11 December 2014

Mr J. Duggleby
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AGL Energy Ltd
Level 22, 101 Miller St
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Dear James,

Soil quality monitoring and management
Compliance Report 4 – Irrigation
(Activities from 1 January to 4 July 2014)
Tiedman Irrigation Program

Please find enclosed the report titled Electromagnetic Induction Survey (December 2014) which is the addendum referred to in section 4.6 (page 36) of the above report.

The Electromagnetic Induction Survey was carried out at the end of the Tiedman irrigation program as part of the requirements of the original REF approval of 5 July 2012 and should be read in conjunction with the main report.

Yours Sincerely,

Paul McCardell
Director

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FODDER KING LIMITED

ELECTROMAGNETIC INDUCTION SURVEY

‘TIEDMANS’, TIEDMANS LANE, GLOUCESTER

LOTS 83 – 85 IN DP 979859

Client: Fodder King Limited
Level 1, 554 Marrickville Road
DULWICH HILL NSW 2203

Our Reference: 14157

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ISSUE	REV.	DATE	AUTHOR	APPROVED	ISSUED TO
1	0	5 Dec 2014	T. McLean & K. Leedham	K. Leedham	Draft to Client
2	0	8 Dec 2014	T. McLean & K. Leedham	K. Leedham	Draft to Client for Comment
3	FINAL	10 Dec 2014	T. McLean & K. Leedham	K. Leedham	Draft to Client for Comment
4	FINAL	11 Dec 2014	T. McLean & K. Leedham	K. Leedham	Draft to Client for Comment

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1.0 Introduction

Mitchel Hanlon Consulting (MHC) has been engaged by Mr Paul McCardell of Fodder King Limited (Fodder King) on behalf of AGL Energy (AGL) to prepare a report compiling the results of an Electromagnetic Induction (EM) Survey, soil sampling and analysis undertaken at 'Tiedman', Tiedman Lane, Gloucester, NSW.

1.1 Background

The site is identified as 'Tiedmans', Tiedmans Lane, Gloucester, within the locality of Forbesdale (Lots 83 – 85 in DP 979859).The site is currently used for irrigation and grazing. There are a number of CSG wells located on the property but none are operational at this time. The reuse of blended water (brackish produced water mixed with fresh water) is for irrigating crops and permanent pasture.

The site is located approximately 9 kms south of the township of Gloucester. Figure 1 (p8) depicts the site's location within NSW and Figure 2 (p9) illustrates the location of the site within the Gloucester Local Government Area.

An electromagnetic (EM) survey is required as part of the data collection and reporting for the AGL coal-seam gas irrigation trial project at the 'Tiedmans' property. The trial has been underway since late 2012 to assess the impacts of coal-seam gas water irrigation on crop production.

EM surveys are routinely used in agricultural settings for broadscale investigations of soil salinity. It may be a cost effective method of identifying potential accumulation of salts and impacts of trial amelioration techniques. The EM survey results were used to complement the regular soil sampling results that have been undertaken during the trial project.

2.0 Objectives and Scope of Works

2.1 Report Objectives

The main objectives of this report are to:

- Review existing soil and land information available for the site;
- Conduct an EM31 survey of the site to map the apparent electrical conductivity (EC_a) of soils of the site to an approximate depth of 1.5 m;
- Collection of soil samples for laboratory testing and validation of the EM31 survey;
- Use of the laboratory data in conjunction with the EM31 data and simple correlation regression analysis to assess the spatial extent of soil salinity across the site;
- Brief discussion of the suitability of EM survey as a method of monitoring soil salinity at the trial site.

It is understood that this report is an addendum to the main report titled *Soil quality monitoring and management. Report 4 – Irrigation (activities from 1 January to 4 July 2014), August 2014* and will be submitted to the Department of Trade and Investment – Resources and Energy for review to comply with the REF approval conditions.

2.2 Scope of Works

It is understood that Fodder King engaged the services of SMK Consultants Pty Ltd (SMK) to undertake the EM survey. It is also understood that Fodder King have engaged Dr Steven Lucas of The Tom Farrell Institute for the Environment (University of Newcastle) to undertake the necessary soil sampling. The soil sampling was undertaken at the same time as the EM survey with the aim of validating the EM survey results.

Mitchel Hanlon Consulting has subsequently been engaged to prepare an EM Survey report to collate the site EM survey data and soil sampling data collected to validate the survey information. The report discusses the data in the context of the trial aims and objectives.

This report has been prepared in conjunction with the previous EM survey results undertaken on the 21st April 2011 detailed within the report prepared by SoilFutures Consulting Pty Ltd (SoilFutures) in July 2011.

Mitchel Hanlon Consulting Pty Ltd

Plot Date: 4 December 2014

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EM SURVEY REPORT - 'TIEDMANS', 100 TIEDMANS ROAD, FORBESDALE

FIGURE 1

Mitchel Hanlon Consulting Pty Ltd

Plot Date: 4 December 2014

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EM SURVEY REPORT - 'TIEDMANS', 100 TIEDMANS ROAD, FORBESDALE

FIGURE 2

3.0 Previous Site Works

In 2011 SoilFutures were engaged by Fodder King to undertake an Electromagnetic Induction Survey, soil sampling, and analysis report on the irrigation trial site located within the property 'Tiedmans'. The aim of the works and subsequent report was to assess the spatial extent of soil salinity across the site prior to any soil amelioration or irrigation development.

A copy of the report prepared by SoilFutures has been included in Appendix A.

A summary of the conclusions of the SoilFutures report has been reproduced below.

3.1 Electromagnetic Survey (2011)

A summary of the conclusions of the SoilFutures report has been reproduced below [sic]:

> 'The EM31 (horizontal) survey and associated soil testing reveals that the Tiedman property is dominated by duplex soils of only low to moderate fertility, with poor internal drainage, and which are dominated by sodic, dispersive subsoils. Problems arose, possibly from the use of the GeoProbe, which may have mixed or compressed wet soils layers through its shaking motion when the jackhammer is turned on. Owing to the wet conditions at the time of the EM verification soil survey, the GeoProbe was the only way in which they could be taken.
>
> By culling data from the EM31 (horizontal) survey of 90 clearly outlying EC_a readings, it was possible to form a correlation regression relationship between soil salinity (expressed as EC_e) and apparent electrical conductivity (EC_a) from the EM31 machine. No other significant relationship existed with other measured soil parameters. This enabled a predictive model to be formed which, on the face of it, has an 83% predictive confidence for salinity. This model is only useful if it can be validated i.e. It has to be used in the field before any soil amelioration or irrigation takes place, to ensure that it does have both predictive capacity, and the capacity to monitor salinity levels when changes occur.
>
> To validate the correlation regression model, it will be necessary to take soil samples as for this project to a depth of 1.5 m in locations of known EC_a with a predicted EC_e value. Soil samples need only be analysed for electrical conductivity (EC) and texture. If the averaged salinity values for each profile fall within the range of predicted salinity, this model will be a highly valuable and cost saving tool for monitoring of any changes under a proposed

irrigation scheme where soil salinity values may increase over time.

If the model is verified, then it can be applied to determine spatially, the potential salinity build up in salinity before any irrigation commences. If the model is verified, employing serial EM31 (horizontal) surveys over time will become a cost effective way to measure changes in soil salinity over time. The model must be verified before any irrigation or soil ameliorants are applied, to achieve this aim.'

4.0 Methodology

4.1 Trial Description

The trial site is located on Lot 85 on DP979859 and is shown on Figure 2. The main trial area (Stage 1A) is approximately 12 ha, comprising of 16 plots of approximately 770 m^2. The plots were established in 2012/13.

The natural soils of the trial site are typical to the soil landscapes of the area. The soils are dominated by texture contrast soil including Kurosols and Sodosols. These soils are characterised by naturally low fertility, high sodicity, poor drainage and acidic pH. The natural characteristics of the soils limited their capacity for agricultural production in the past, despite the high rainfall of the Gloucester region.

Coal-seam gas (CSG) water produced from the AGL operations is brackish to slightly saline, with an electrical conductivity of over 4000 µs/cm. For CSG water to be reused, it is blended with fresh water to lower the EC to around 1500 µs/cm. The water is then irrigated onto the trial plots using a lateral move irrigator.

Over the period from 1/4/13 to 4/7/14 there was a total of 69.9 Ml of rainfall, supplemented by 54.2Ml of blended water averaging 1540us/m EC, applied to the main Stage 1A trial area.

In order to improve the soil capacity for crop production and for coal-seam gas water utilisation, a number of soil ameliorants were used in the trial plots. Four treatments were applied to four plots, with a total of 16 plots.

1. Treatment 1 – Shallow surface ripping and ameliorant incorporated to 240 mm;

2. Treatment 2 – Shallow surface ripping to 240 mm and ameliorant, + deep ripping and ameliorant incorporated to 650 mm;

3. Treatment 3 – Shallow surface ripping to 240 mm and ameliorant, + deep ripping and ameliorant incorporated to 950 mm;

4. Treatment 4 – Shallow surface ripping to 240 mm and ameliorant, + deep ripping and ameliorant incorporated to 1200 mm.

The deep ripped runs were spaced 1.5 m apart, and each run was approximately 20 cm wide. Compost, lime, gypsum and zeolite ameliorants were used.

Perennial Lucerne, annual triticale and forage sorghum crops have been planted in rotation in the trial plot areas. Moisture sensors were installed to monitor water irrigation scheduling and soil moisture. Plate 1 and Plate 2 show the trial site plots and irrigator system.

Plate 1: Stage 1A Trial Site – Facing West

Plate 2: Stage 1A Trial Site – Facing Southeast

4.2 Soil Landscape Information

Soil landscape information has been obtained from the *Soil Landscapes of the Dungog 1:100,000 sheet* (Henderson 2000). The majority of the property and the trial site area is defined by the Gloucester soil landscape (GOW). The soils of this landscape are generally moderately deep to deep Brown Sodosols, and shallow to deep Grey Kurosols. These soils are limited by strongly acidic pH, high potential for aluminium toxicity, low permeability, low fertility and high sodicity and dispersion.

The soil landscape boundaries as determined by Henderson (2000) have been detailed in Figure 3.

4.3 Electromagnetic Induction (EM) Survey

Electromagnetic Induction (EM) measures the apparent electrical conductivity (EC_a) of the soil. The EM31 instrument induces a current in the soil which is measured as a return signal and is logged by the machine. The current is influenced by a combination of soil properties. Field testing of soils at the time of the survey is required to determine if EM31 is an effective indicator of soil salinity.

The electrical conductivity readings are affected by factors including clay content, soil conductivity, moisture regime, organic matter, soil depth and vegetation cover. However, low readings usually correspond to sandy, gravelly soil or low moisture. High readings are usually related to clay content or soil salinity.

The site was visited on 23rd October 2014 by Mr Paul McCardell of Fodder King, Dr Steven Lucas of The Tom Farrell Institute for the Environment and Mr Jeremy Barr of SMK Consultants Pty Ltd for the purpose of undertaking the required EM survey and necessary soil sampling.

The methodology employed to undertake the EM survey and associated validation sampling was based upon the methodology utilised in the 2011 SoilFutures report.

An EM31 survey was conducted at the Tiedmans property by SMK Consultants Pty Ltd who provided raw EM31 data for MHC to analyse. In the horizontal mode which was used for this survey, the expected penetration of the EM31 is approximately 1.5 m.

The trial area surveyed was approximately 20 ha with a total of 2299 EC_a readings taken across the site (Stage 1A). An adjacent area of 4.1 ha (Stage 1B) was also surveyed to provide a comparison to background levels of salinity. Stage 1B is not part of the trial area and has not received soil ameliorants but has been irrigated with the blended irrigation water.

The raw EM31 data was converted into a map depicting relative apparent soil conductivity using Arcview (a GIS package). The map provides a focus for further investigation to determine the specific soil variations that are affecting electrical conductivity. Further investigation involves soil sampling of selected areas of soil variants identified on the EM map. The survey maps are presented in Figure 4 and Figure 5.

4.4 Soil Sampling for Validation of EM Survey

Ten soil sampling locations were sampled on the 23rd October 2014 by Dr Steven Lucas and Fodder King to provide data for the EM survey. Soil samples were taken manually using a hand auger to depths of 0-20 cm, 20-50 cm, 50-100 cm and 100-150 cm.

Soil sampling locations included CS2, CS4, CS6, CS8, CS10, CS12, CS14 and CS16 located within the trial plot area; and EM4 and EM5 from previous EM survey [Refer to Figure 7].

4.5 Soil Laboratory Analysis

Soil samples were analysed for pH (1:5 in water), electrical conductivity (EC, 1:5 in water), soil moisture (%), soil texture and bulk density as per standard soil laboratory methods at the University of Newcastle. A copy of the soil results is included in Appendix B.

Mitchel Hanlon Consulting Pty Ltd

Plot Date: 4 December 2014
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EM SURVEY REPORT - 'TIEDMANS', 100 TIEDMANS ROAD, FORBESDALE

FIGURE 3

5.0 Results

5.1 EM Survey

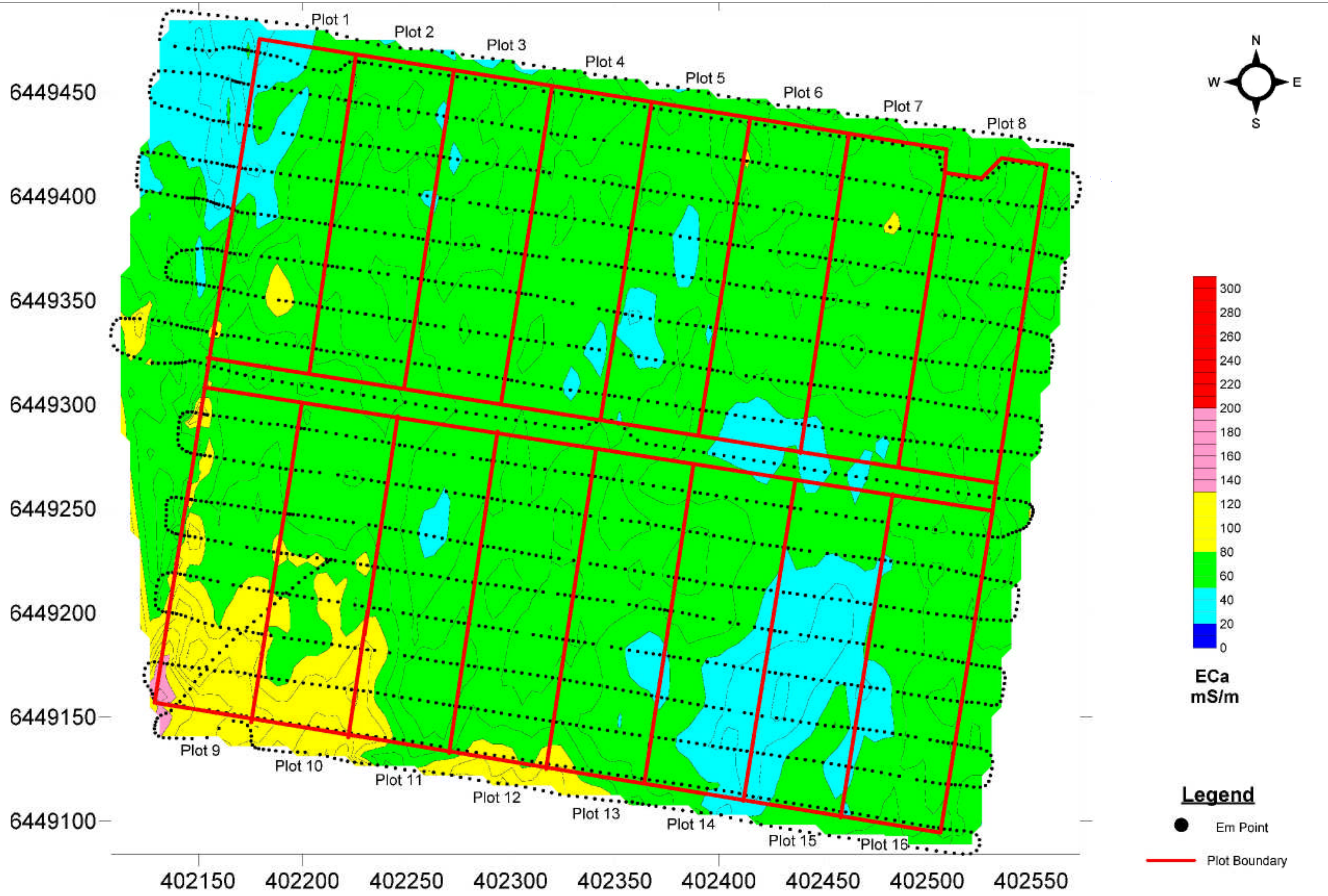
The site was visited on 23rd October 2014 by Mr Paul McCardell of Fodder King, Dr Steven Lucas of The Tom Farrell Institute for the Environment and Mr Jeremy Barr of SMK Consultants Pty Ltd for the purpose of undertaking the required EM survey and necessary soil sampling.

Figure 4 shows the raw EM survey data for the trial site area (Stage 1A). From the raw data, the apparent electrical conductivity (EC_a) generally ranges from 50-80 mS/m over the trial site. There is an area of higher EC_a in the southwest corner of the trial site which was identified previously in the 2011 EM survey. The increase in EC_a values in this area are consistent with this being the low point where any run-off is collected in Catch Dam 2.

The EM survey did not distinguish changes in EC_a between the individual trial plots, or between the 4 different treatment depths in the plots. This is potentially due to the broadscale nature of EM surveys. The EM survey receives an average of the EC_a over the 1.5 m of soil depth, and would not be of high enough resolution to differentiate between the deep and shallow treatments. It is not within the scope of this report to discuss the impacts of the trial soil ameliorations on reducing salinity impacts.

Figure 5 shows the raw EM survey data for the trial site area (Stage 1A) taken in 2011 prior to the trial establishment. In 2011, the raw data ranged from 20-50 mS/m. As previously noted, the area of high EC_a in the southwest corner of the trial area was evident in 2011 prior to the commencement of the trial. The results of the EM survey indicate that the EC_a may have increased over the trial site since 2011.

Figure 6 shows the raw data from the Stage 1B area. The EC_a of the baseline area appears to be lower than the trial plot area. The EC_a ranges between 20-50 mS/m on the eastern side of the area. The western side of the area is slightly higher and ranges between 50-80 mS/m. The higher values on the western side of the baseline site may be due to the slope of the site. The salinity in this area may be due to surface runoff or sub-surface movement of soluble salts.



Imagery and Cadastral Information Supplied by SMK Consultants, NSW Department of Lands, SIX Maps and Google Earth as such ALL Information is (including distances and locations) are APPROXIMATE

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EM 31 Survey - Horizontal Survey
AGL Trial Stage 1A
Gloucester
Surveyed October 2014
By Jeremy Barr

Mitchel Hanlon Consulting Pty Ltd

Fodder King Limited

EM SURVEY REPORT - 'TIEDMANS', 100 TIEDMANS LANE, FORBESDALE

FIGURE 4

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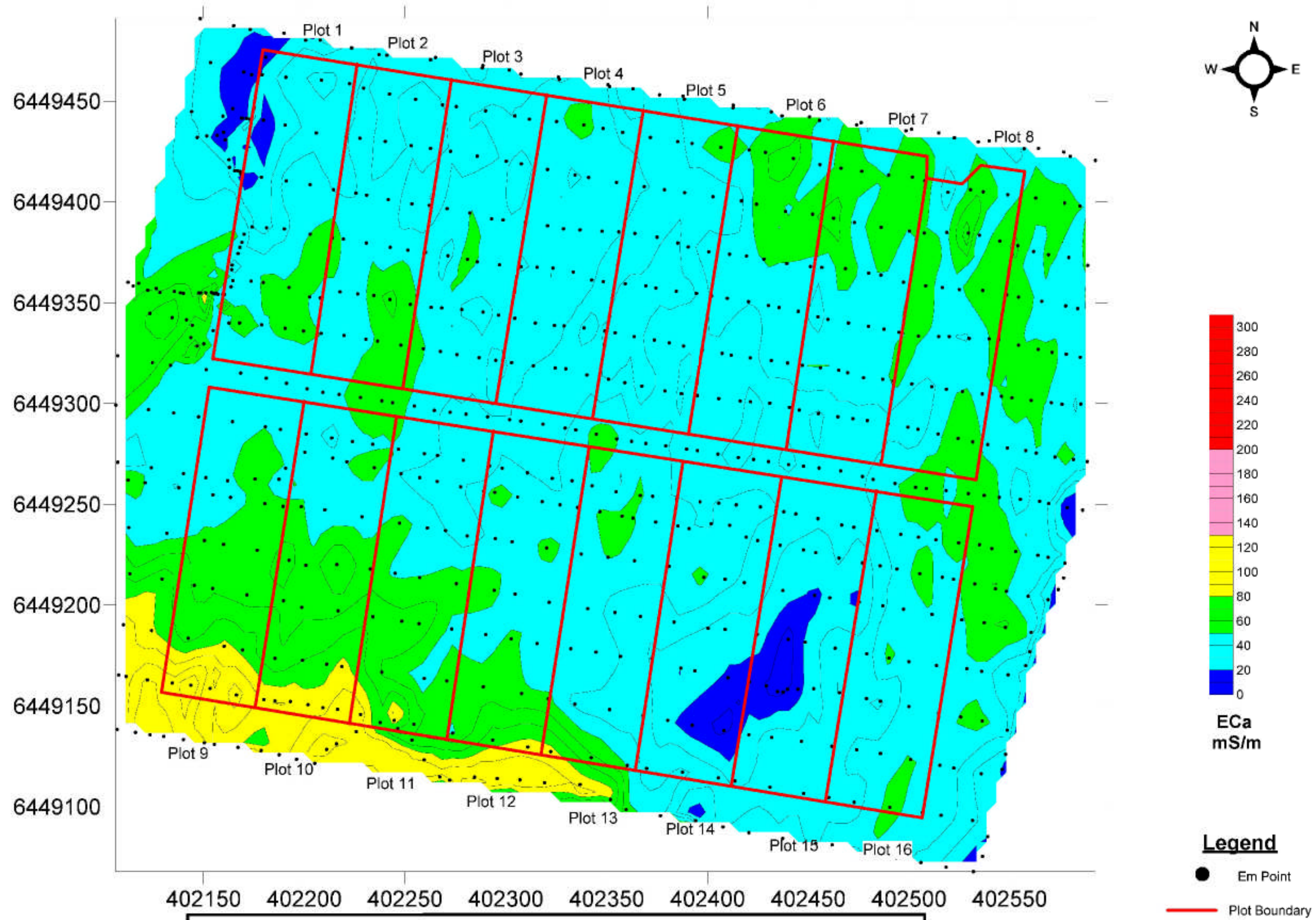

Imagery and Cadastral Information Supplied by SMK Consultants, NSW Department of Lands, SIX Maps and Google Earth as such ALL Information is (including distances and locations) are APPROXIMATE

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EM 31 Survey - Horizontal Survey
AGL Trial Stage 1A
Gloucester
Surveyed April 2011
By Jeremy Barr

Mitchel Hanlon Consulting Pty Ltd

Fodder King Limited

EM SURVEY REPORT - 'TIEDMANS', 100 TIEDMANS LANE, FORBESDALE

FIGURE 5

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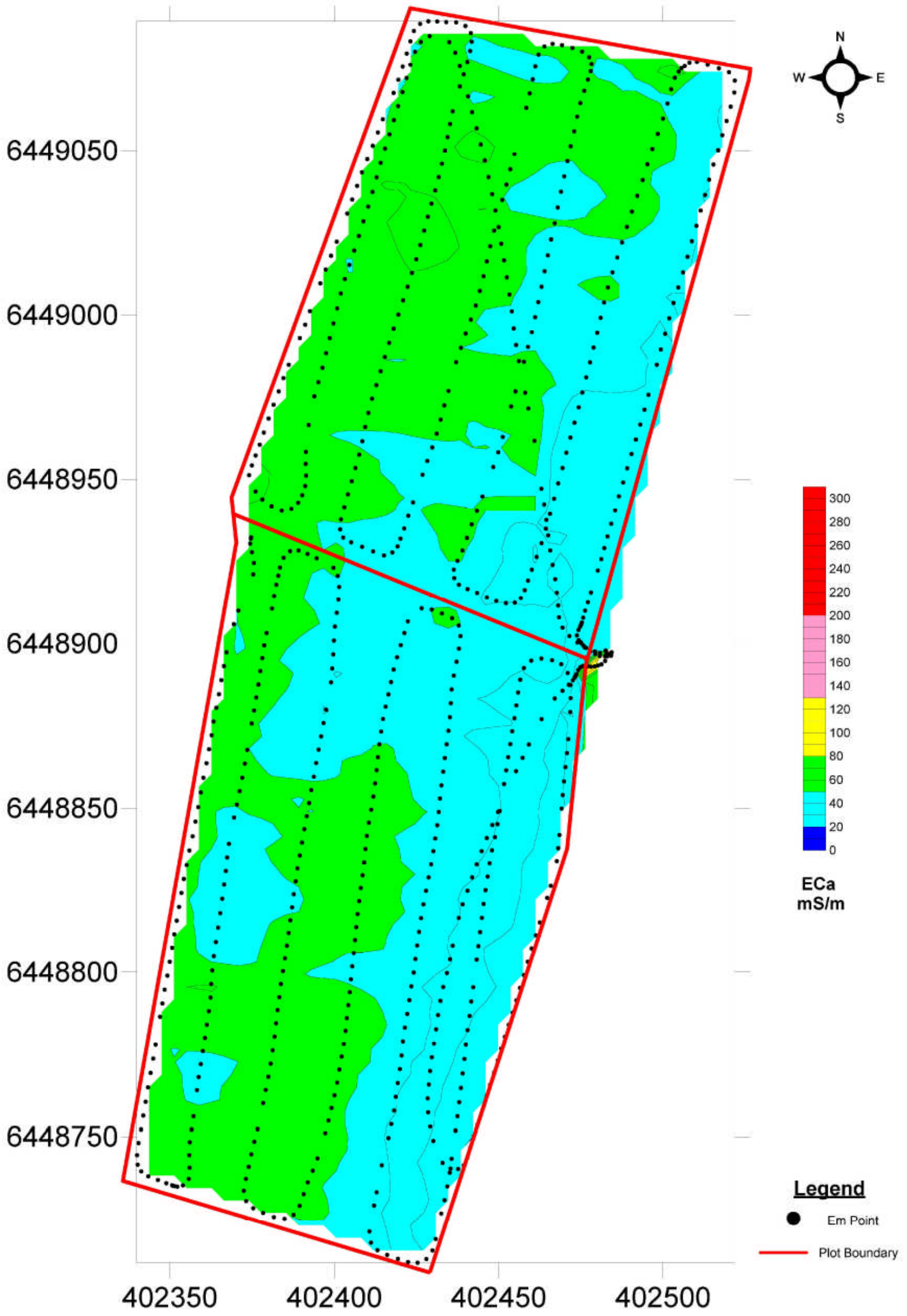

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EM 31 Survey - Horizontal Survey
AGL Trial Stage 1B
Gloucester
Surveyed October 2014
By Jeremy Barr

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Plot Date:10 December 2014
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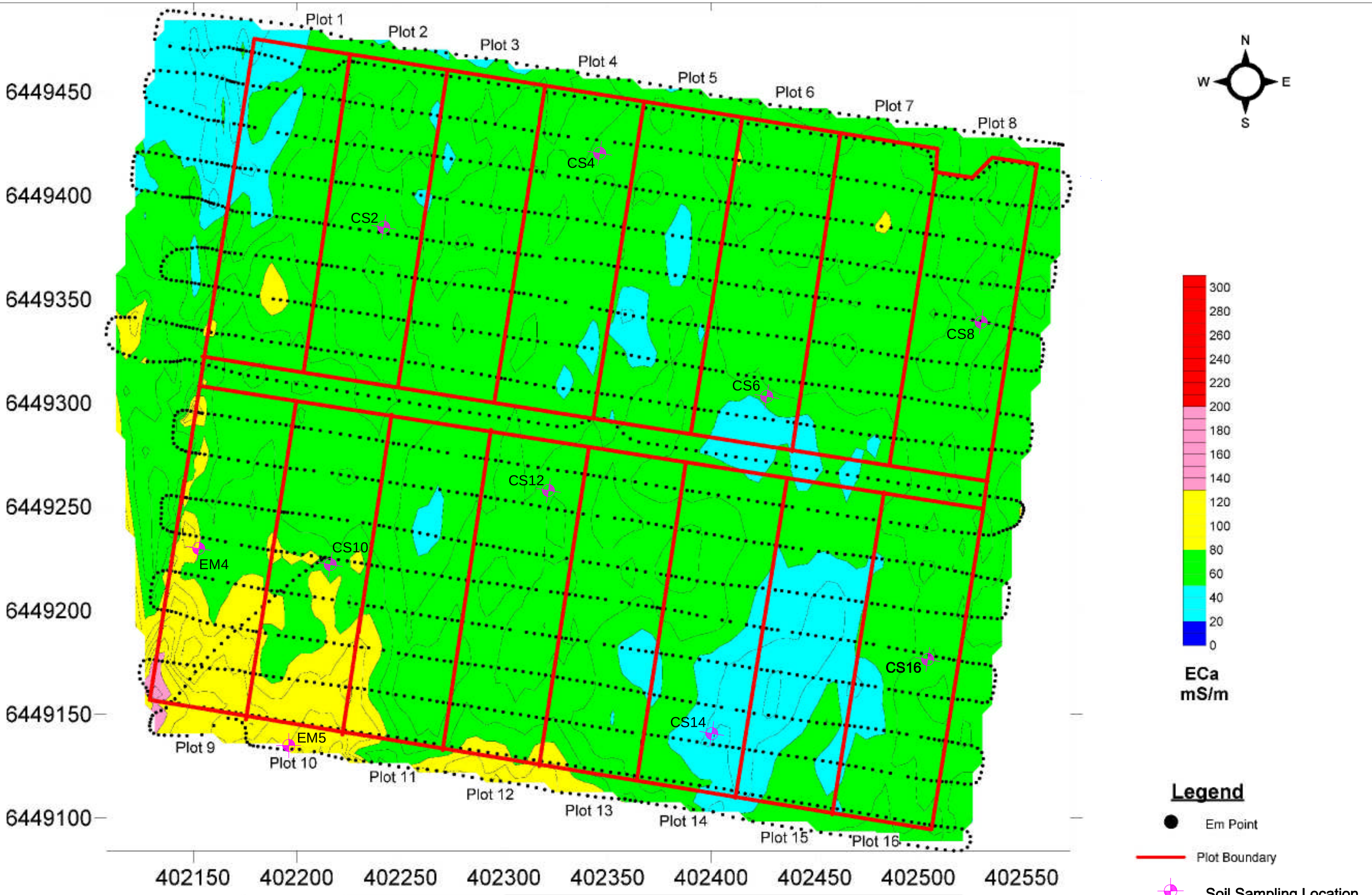
EM SURVEY REPORT - 'TIEDMANS', 100 TIEDMANS LANE FORBESDALE

FIGURE 6



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EM 31 Survey - Horizontal Survey
AGL Trial Plot Area A
Gloucester
Surveyed October 2014
By Jeremy Barr

Imagery and Cadastral Information Supplied by SMK Consultants, NSW Department of Lands, SIX Maps and Google Earth as such ALL Information is (including distances and locations) are APPROXIMATE

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Fodder King Limited

EM SURVEY REPORT - 'TIEDMANS', 100 TIEDMANS ROAD, FORBESDALE

FIGURE 7

Plot Date: 4 December 2014
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5.2 Soil Analysis

5.2.1 Soil Texture

Appendix B provides a copy of the soil test results of the sampling that was undertaken at the time of the EM survey. The soils in the north of the trial plot area generally have a clay loam surface soil texture, with a clay content of approximately 20-30%. The southern part of the trial plot area has surface soils with a sandy clay loam texture, with slightly lower clay content. The clay content across the trial site increases with depth to a medium clay (approximately 40-50% clay content.) Due to the consistency of the sub-surface clay content, it is considered that this soil parameter would not negatively impact the EM survey results.

5.2.2 Soil Moisture

The soil moisture of the trial plot soils was analysed as this parameter can potentially affect the apparent electrical conductivity (EC_a) output of the EM survey.

We note that in the two months prior to the April 2011 EM survey the rainfall for March and April, measured at Gloucester post office, was 242.9mm and exceeded the mean of 204.9mm by around 18%. This would have caused high soil moisture values at the time of sampling.

In contrast, in the 2 months prior to the October 2014 EM survey the rainfall for September and October was 48.0mm and was 59% below the mean of 118.4mm for those two months.

The soil moisture for the October 2014 EM survey ranged from 8.3% to 14.7% in the surface soils (0-20 cm). The soil moisture generally increased with depth, which is relevant to the increasing clay content of the sub-soils. The sub-surface soil moisture ranged from 10.8% to 18.1%. This is also considered to be a low level of soil moisture and is consistent with the low rainfall in the previous two months.

5.2.3 Soil pH

The soil pH in the surface soils ranged from pH 5.59 (moderately acidic) to 7.25 (neutral). The sub-surface soils ranged from pH 4.52 (very strongly acid) to 7.57 (mildly alkaline). The soil pH can have an impact on soil sodicity and increase the availability of exchangeable aluminium that can affect plant growth.

5.2.4 Soil Electrical Conductivity

The soil electrical conductivity (EC) was analysed to provide data to allow for regression analysis of the EM survey raw data. The surface soil EC ranged from 0.10 dS/m (low) to 0.23 dS/m (medium). The subsoil EC ranged from 0.11 dS/m (low) to 0.69 dS/m (high).

It is advised that these soil parameters are compared to the data collected during the trial period to assess any trends and potential impacts of CSG water irrigation.

5.3 Regression Analyses of EM Survey Data

5.3.1 Data Correlation

With any broadscale evaluation of soil parameters, it is useful to assess the EM survey data for its ability to predict the electrical conductivity of the trial site. To assess the correlation between the measured soil data and the EM survey data, a regression analysis was undertaken in Microsoft Excel.

The EM survey data were examined with reference to the measured soil chemical properties. Generally, the highest correlation occurs with salinity and soil moisture. If soil moisture is removed as a component of EC_a, then it can be assumed that the survey data is a suitable prediction of soil electrical conductivity.

The differences in soil moisture from the April 2011 survey to the October 2014 survey are likely to be important, and hence it is beneficial to evaluate the data in relation to soil moisture.

Simple correlation regressions of the soil laboratory data and the EC_a data from the EM survey were undertaken. The higher the R^2 value gained from the regression analysis, the greater the correlation between the data. Where a low R^2 value is obtained (<50%), there is high variation within the data set and low data correlation.

The equation for the regression line [which is usually expressed by the formula Y value = m (slope) x (X axis value) + b (Y intercept)], can be used to develop a predictive model based on the whole EM survey dataset, and maps can be produced showing the distribution of salinity, clay content or other measured soil attributes which have a high correlation with the EM survey data.

5.3.2 Regression Analyses

Figure 8 shows the regression analysis for the whole data set (using an average value from each of the 10 soil profiles obtained) of measured electrical conductivity data (EC_e). The R^2 value of the regression line is very low (0.021). The regression line outlines that there is poor correlation between the EM survey data and the measured EC_e data.

The data set was reviewed and three outlier points were removed from the data set to improve the data correlation. Figure 9 shows the revised data set regression line. The R^2 value increased to 0.63, however this still represents a high variability within the data set.

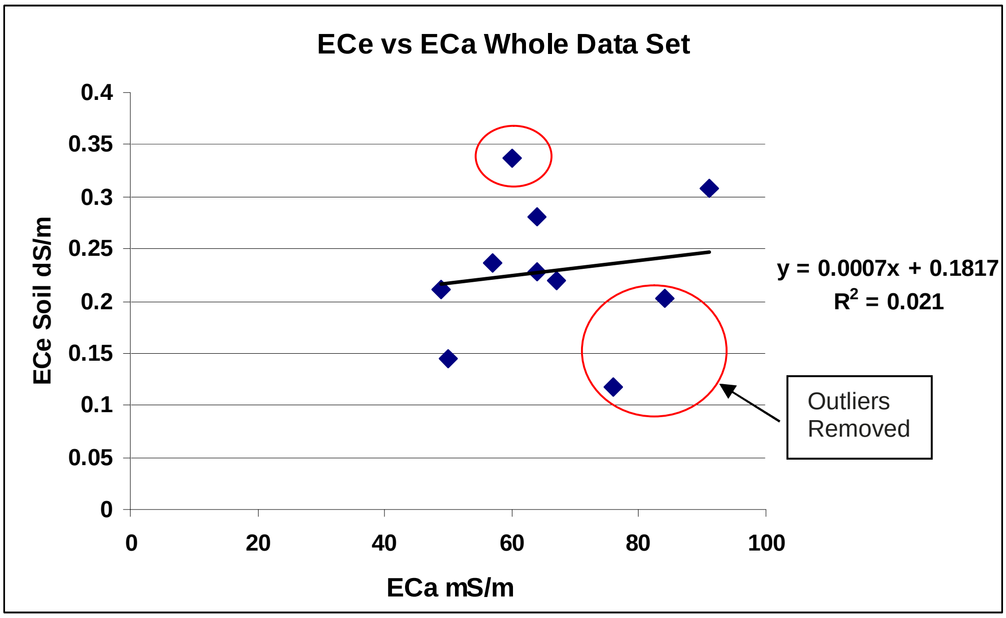


Figure 8: Measured Electrical Conductivity vs EM Survey Electrical Conductivity - Data Regression

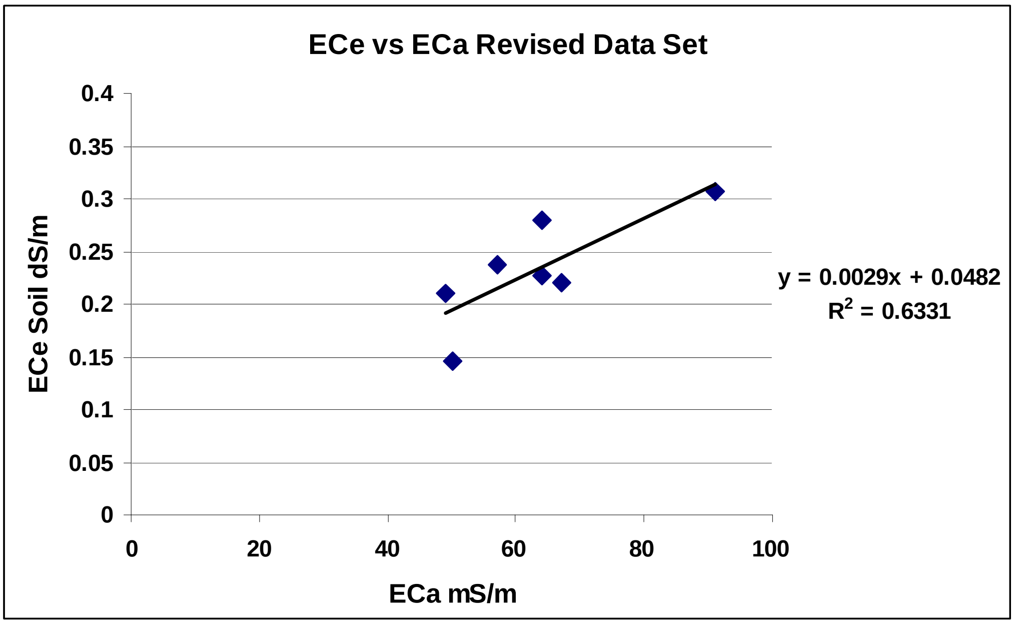


Figure 9: Measured Electrical Conductivity vs EM Survey Electrical Conductivity - Revised Data Set Regression

The measured soil moisture data was analysed with regards to the whole EM survey data set to assess the correlation. Figure 10 shows the correlation between the soil moisture and EM survey electrical conductivity (EC_a). The regression shows a low correlation between soil moisture and apparent electrical conductivity. This demonstrates that soil moisture is not an influencing factor on the EM survey data, however, moisture content can influence the results from different EM surveys taken at different times.

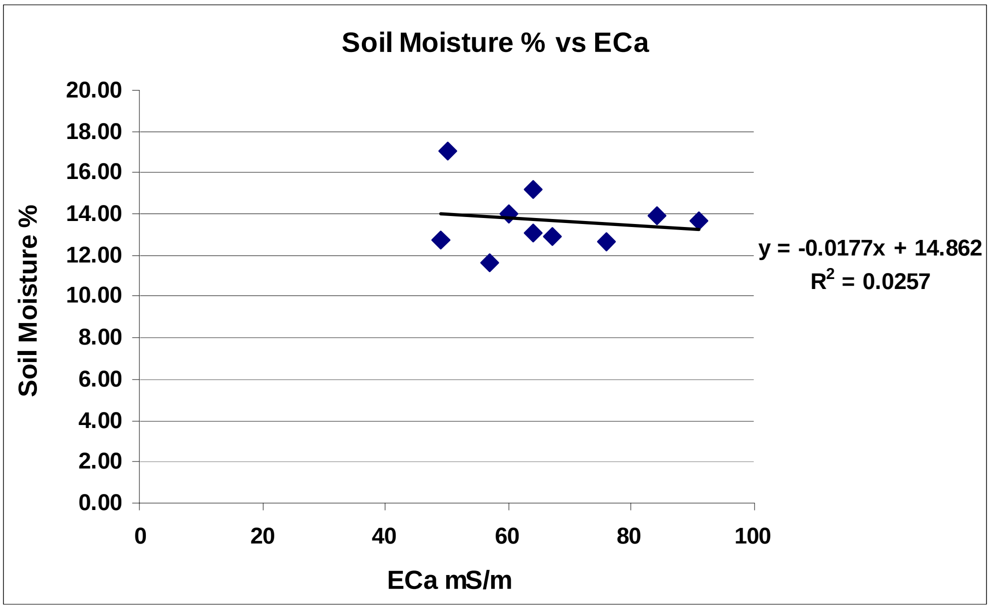


Figure 10: Measured Soil Moisture % vs EM Survey Electrical Conductivity - Whole Data Set Regression

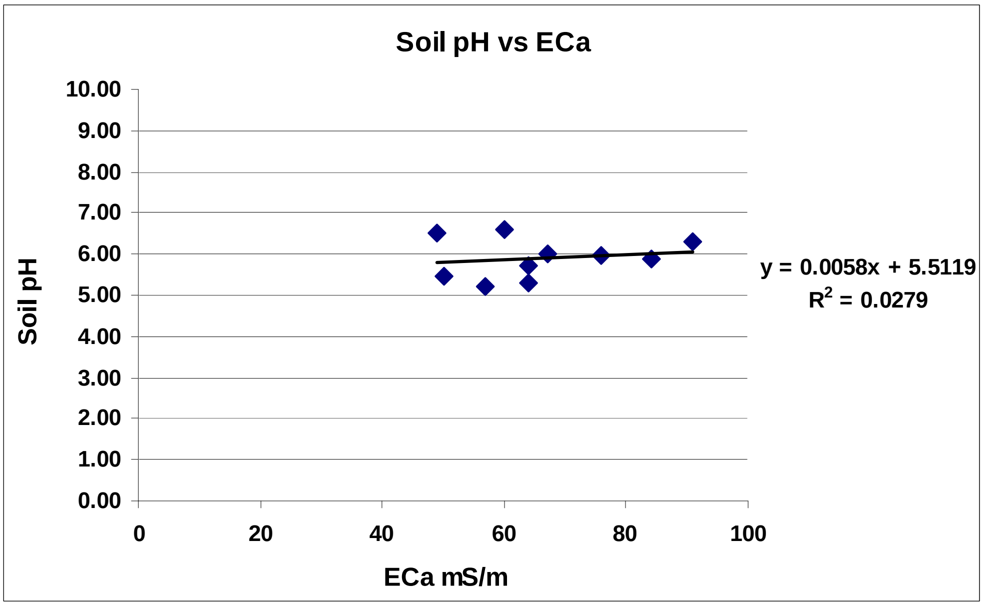


Figure 11: Measured Soil pH vs EM Survey Electrical Conductivity - Whole Data Set Regression

The measured soil pH data was analysed against the whole EM survey data set to assess the correlation. Figure 11 shows the correlation between the soil pH and EM survey electrical conductivity (EC_a). The regression shows a low correlation between soil pH and apparent electrical conductivity. This demonstrates that soil pH is not an influencing factor on the EM survey data.

5.3.3 Assessment of the Regression Results

The regression analysis demonstrated that the EM survey data is not highly correlated with the measured soil chemical data. The R^2 value of 0.63 between the measured electrical conductivity data (EC_e) and the EM survey electrical conductivity data (EC_a) represents that 63% of the soil salinity variability is described by the regression line. This was not seen to be a high enough correlation to undertake further data analysis. The EM survey data may not be strongly correlated enough to be able to predict soil salinity (EC_e) across the trial site.

The low correlation of results is potentially due to the small number of measured samples taken at the time of the EM survey. Ten (10) soil sampling locations were analysed in 2014 compared to 26 locations in 2011. The more sampling locations and subsequent measured data could potentially have improved the data correlation and confirmed that the EM survey is a suitable predictive tool for electrical conductivity assessment at the trial site. However, we note that the 2011 EM Report also encountered some difficulty in establishing an acceptable R^2 value for the larger number of locations.

6.0 Discussion of Data Analyses

From the 2014 EM survey data, the apparent electrical conductivity (EC_a) generally ranges from 50-80 mS/m over the trial site (Stage 1A). In 2011, the raw data ranged from 20-50 mS/m over the trial site. Generally, the EC_a appears to have increased over the trial site since 2011.

The EC_a of the Stage 1B area is generally lower than the Stage 1A area. In contrast, we understand that the calculated sodium concentrations from soil samples are lower in the Stage 1A area and higher in the Stage 1B area. The difference can be explained by the fact that the EM machine records the average of readings to a depth of approximately 1.5 metres whereas the salts in Stage 1B were concentrated in the top 100-200mm. In the Stage 1B area EC_a ranges between 20-50 mS/m on the eastern side. The western side of the Stage 1B area is slightly higher and ranges between 50-80 mS/m.

In Stage 1A the areas of increased EC_a levels in the southwest corner may be due to different soil moisture conditions or surface or sub-surface movement of soluble salts towards the catchment dam. However, we note that the 2011 EM survey had also detected elevated EC_a values in the southwest corner prior to the trial commencement.

There can be no direct salinity correlation between the 2011 survey and the 2014 survey due to the poor correlation of the measured and EM survey data in both years.

It is noted that the relevant mass balances have been provided by Fodder King and are discussed separately in the covering report.

The EM survey did not distinguish changes in EC_a between the individual trial plots, or within the deep ripped and natural areas of the trial plots. This is potentially due to the broadscale nature of EM surveys. It is difficult to discuss the impacts of the trial soil ameliorations on reducing salinity impacts with regards to the EM survey data. However, the measured soil data analysed during the trial period may provide further information on the individual plot trends.

The regression analyses of the whole EM survey data demonstrated that the R^2 value of the regression line is very low (0.021). The regression line indicates that there is poor correlation between the EM survey data and the measured EC_e data.

The data set was reviewed and three outlier points were removed from the measured EC_a data set to improve the data correlation. The R^2 value increased to 0.63, however this still represents a high variability within the data set (63% variability).

Whilst the EM survey data was not highly correlated to the measured data, the raw EM survey data does give a broadscale representation of electrical conductivity variation across the trial site. When compared to the 2011 survey data, there was an apparent increase in the electrical conductivity across the trial plots. It is recommended that the EM survey information is reviewed with regards to the ongoing soil monitoring at the site to confirm any increasing trends in soil salinity.

7.0 Conclusion

Mitchel Hanlon Consulting has been engaged by Fodder King Limited (Fodder King) on behalf of AGL Energy (AGL) to prepare a report compiling the results of an Electromagnetic Induction (EM) Survey, soil sampling and analysis undertaken at ‘Tiedmans’, Tiedmans Lane, Gloucester, NSW.

The site is identified as Lots 83 – 85 in DP 979859. The site is located approximately 9 kms south of the township of Gloucester.

The natural soils of the trial site are typical to the soil landscapes of the surrounding areas. The soils are dominated by texture contrast soil including Kurosols and Sodosols. These soils are characterised by naturally low fertility, high sodicity, poor drainage and acidic pH. In order to improve the soil capacity for crop production and for coal-seam gas water utilisation, a number of soil ameliorants were used in the trial plots.

The site was visited on 23rd October 2014 by Mr Paul McCardell of Fodder King, Dr Steven Lucas of The Tom Farrell Institute for the Environment and Mr Jeremy Barr of SMK Consultants Pty Ltd for the purpose of undertaking the required EM survey and necessary soil sampling.

The EM survey data was analysed using regression analyses in the Microsoft Excel program. The regression analysis demonstrated that the EM survey data is not highly correlated with the measured soil chemical data. The R^2 value of 0.63 between the measured electrical conductivity data (EC_e) and the EM survey electrical conductivity data (EC_a) represents that there is a 63% of the soil salinity variability is described by the regression line.

The low correlation of results is potentially due to the number of measured samples taken at the time of the EM survey. Ten (10) soil sampling locations were analysed in 2014 compared to 26 locations in 2011. The data correlation may have been improved by analysing the 26 original locations and confirmed that the EM survey is a suitable predictive tool for electrical conductivity assessment at the trial site. However, we note that, with a larger sample size of 26 locations in the 2011 EM survey, the authors experienced similar difficulties in establishing an R^2 value that was well correlated.

If good R^2 correlations can be established, Electromagnetic Induction (EM) surveys can be a cost-effective and rapid method of predicting electrical conductivity over a large area. In view of the variability identified in the two EM surveys it is not possible to make a conclusion as to what extent the ECa values have changed. Nevertheless, it is recommended that a follow up EM survey is conducted at, say 6 or 12 months at a period when prior rainfall conditions are similar to either the 2011 or 2014 survey.

8.0 References

Hazelton, P.A. and Murphy, B.M. (2007), *What Do All the Numbers Mean?, A Guide for the Interpretation of Soil Test Results,* CSIRO Publishing, Collingwood, Victoria;

Henderson, L. (2000) *Soil Landscapes of the Dungog 1:100,000 sheet*, Map and Report, Department of Land and Water Conservation, Sydney, NSW;

McDonald RC, Isbell RF, Speight JG, Walker J, Hopkins MS (1998) *Australian Soil and Land Survey Field Handbook*. (Australian Collaborative Land Evaluation Program: Canberra);

Rayment GE, Lyons DJ (2010) *Soil Chemical Methods – Australasia*, Australian Soil and Land Survey Field Handbook Series, CSIRO Publishing; and

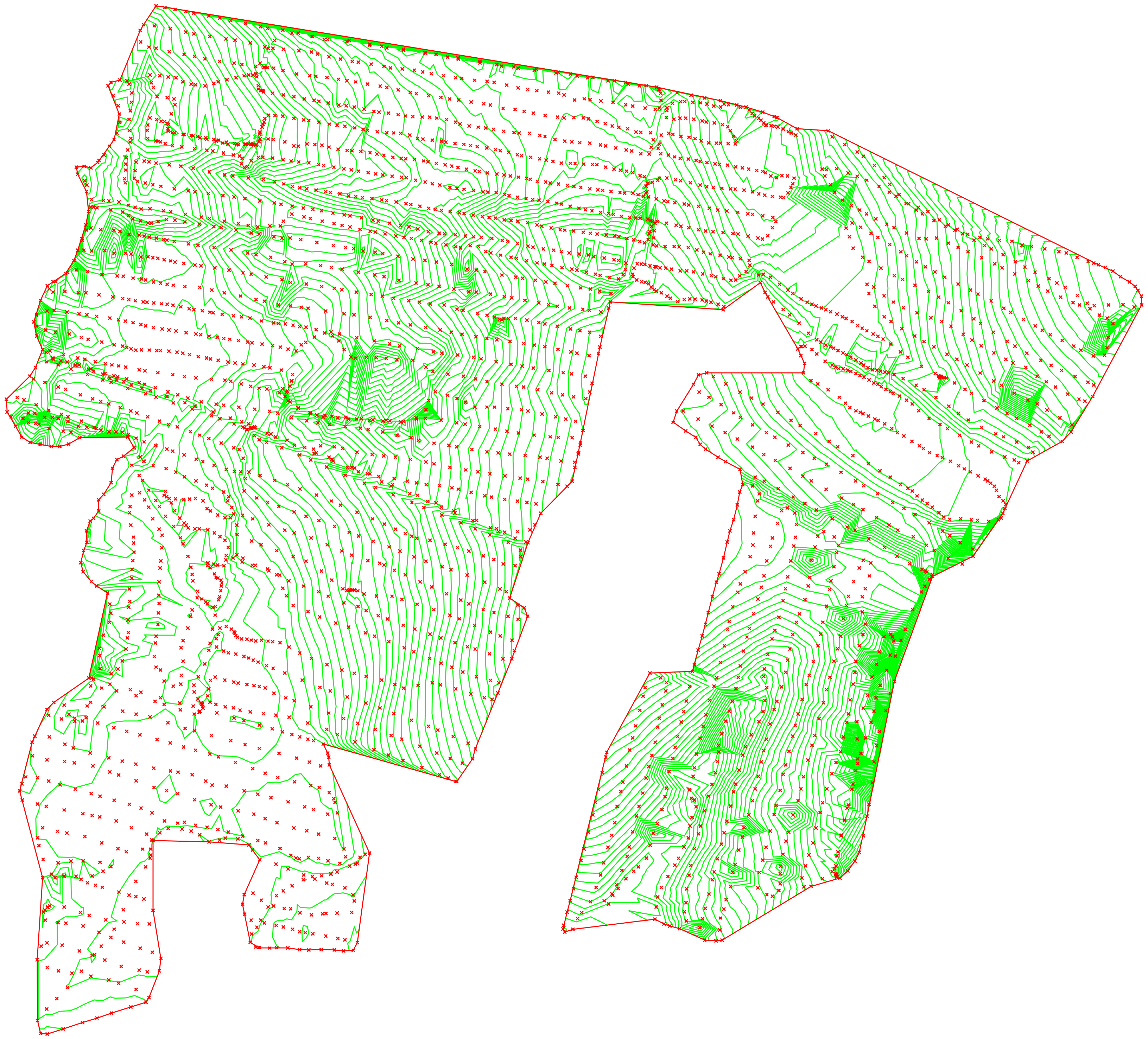
Soilfutures Consulting Pty Ltd (2011), *'Electromagnetic Induction Survey (EM31 Horizontal), Soil Sampling and Analysis for the Tiedman Property, Gloucester'*, Gunnedah, NSW

Appendix A SoilFutures Consulting Pty Ltd – Electromagnetic Induction Survey Report 2011

Attachment 2.

Electromagnetic Survey and Report

1. **Location and spot levels for EM31 survey**
2. **EM31 survey, soil sampling and analysis**



GN

MGA Zone 56

IMPORTANT NOTES & CAUTIONS :-

1. SURVEY BY SMK MOREE.
2. DATE OF SURVEY: 20-April-2011
3. APPROX MGA & AHD ONLY.

30 00 30 60 90 120 150 180 210 240 270 300

REDUCTION RATIO
A1: 1: 3000
A3: 1: 6000
A4: 1: 9000

Plot Date: 27 April 2011
J:\2011\11071 Fodder King Limited – Topo Detail Survey Gloucester\SMK\2011-04-21\SMK spot levels.dwg

Rv	DATE	REVISIONS	REC.	APPR.
A	27-04-11	INITIAL ISSUE		

SURVEY: SMK
DESIGN: N/A
DRAWN: SMK & M Hanlon
CHECKED: N/A
SURVEY/DESIGN FILE: n/a

A1

DATUM: approx AHD
ORIGIN:_____ RL:_____
CONTOUR INTERVAL:___m

APPROVED: PROJ.MAN

Mitchel Hanlon Consulting Pty Ltd
121 Bridge Street
P.O. Box 1568
Tamworth, NSW, 2340
Telephone:02-6762 4411
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ACN 104 693 736

Natural Resources
Planning
Surveying
Civil Engineering
Environmental Engineering

CLIENT: FODDER KING
PROJECT: AGL - GLOUCESTER - IRRIGATION TEST PLOT

SMK MOREE
EM SITE SURVEY

DATE: APRIL 2011
DRAWING No.: SHEET 1
Rv. A

SoilFutures Consulting Pty Ltd

ELECTROMAGNETIC INDUCTION SURVEY (EM31 HORIZONTAL), SOIL SAMPLING AND ANALYSIS FOR THE TIEDMAN PROPERTY, GLOUCESTER

Prepared for

FODDER KING LTD

COMMERCIAL IN CONFIDENCE

July 2011

Disclaimer

The information contained in this report is based on sources believed to be reliable. SoilFutures Consulting Pty Ltd, together with its members and employees accepts no responsibility for the results of incautious actions taken as a result of information contained herein and any damage or loss, howsoever caused, suffered by any individual or corporation.

The findings and opinions in this report are based on research undertaken by Robert Banks (BSc Hons, Certified Professional Soil Scientist, Dip Bus) of SoilFutures Consulting Pty Ltd, independent consultants, and do not purport to be those of the client.

Table of Contents

1. Introduction

1.1 Background

This report has been prepared in response to a request from Mr Paul McCardell of Fodder King Ltd for an Electromagnetic Induction (EM31 Horizontal mode) Survey, soil sampling, and analysis report for a property called the Tiedman Property at Gloucester, Owned by AGL and used for extraction of coal seam gas (Figure 1).

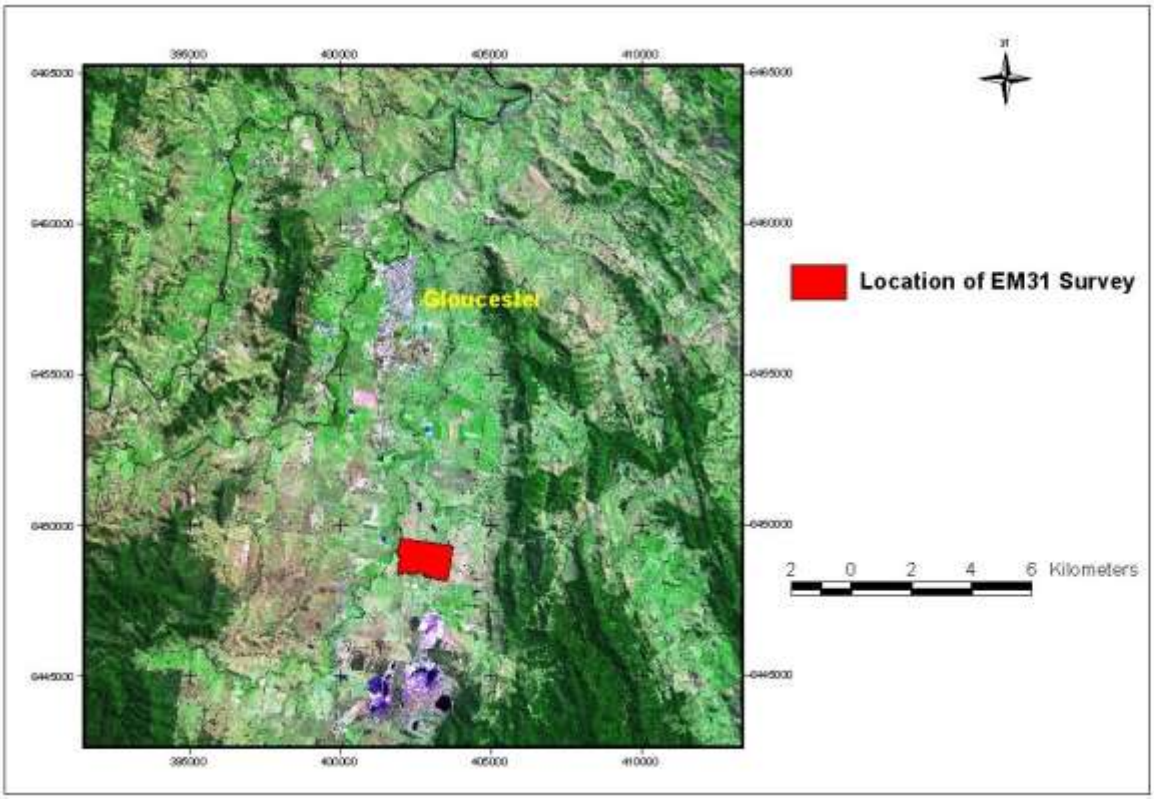

Figure 1: Location of proposed Tiedman property

The area of cleared land surveyed in question has an area of 192 Ha and is to the south of the township of Gloucester.

1.2 Report Objectives

The main objectives of this report are to:

1. Review existing soil and land information available for the site,

2. Conduct an EM31 survey (Horizontal mode) of the site to map the apparent electrical conductivity (EC_a) of soils of the site to an approximate depth of 2 m,

3. Collection of soil samples for laboratory testing and validation of the EM31 survey.

4. Use of the laboratory data in conjunction with the EM31 data and simple correlation regression analysis to assess the spatial extent of soil salinity across the site.

5. Determine the suitability of EM31 technology machine mode for monitoring potential accumulation of salts at an irrigation trial site to be developed by Fodder King.

2. Methods

2.1 Review of Existing Soil and Land Information

The most up to date and detailed broad scale public soil and land information for the site is well covered in Henderson (2000). Soil landscape boundaries are given below in Figure 2.

2.2 Electromagnetic Induction Survey for Salinity Mapping

Much research has been carried out into the use of Electromagnetic Induction (EM) technology for salinity investigation (Dooley *et al*, 2002) and it has been found that other variations including soil depth and textural changes are often determined using EM technology (Hafi *et al*, 2001). Resistive soils have a low Apparent Electrical Conductivity (EC_a), are low in stored salts and often correspond to sand or gravel lenses or bedrock highs in the landscape. High EC_a values generally correspond with high clay content, moisture and salinity. Where this is the case, EM31 is a cost effective way of stratifying soil sampling sites for salinity investigations.

The EM31 machine induces a current in the soil which is measured as a return signal and logged by the machine. The measured current, EC_a, is often proportional to soil texture or soil salinity or soil moisture, or a combination of these attributes. Field testing of soils is required to determine what the EM31 is actually measuring.

An EM31 survey was conducted at the Tiedman property by SMK Pty Ltd, Moree, who provided raw EM31 data for SoilFutures to analyse. In the horizontal mode which was used for this survey, the expected penetration of the EM31 is approximately 2 m.

The area surveyed was 94.1 Ha. A total of 3292 EC_a readings were taken across the site. The raw EM31 data was converted into an image of relative apparent soil conductivity in Arcview (a GIS package) and soil profile description and sampling sites were selected to represent the extremes of the range of EC_a zones within the survey (Figure 3).

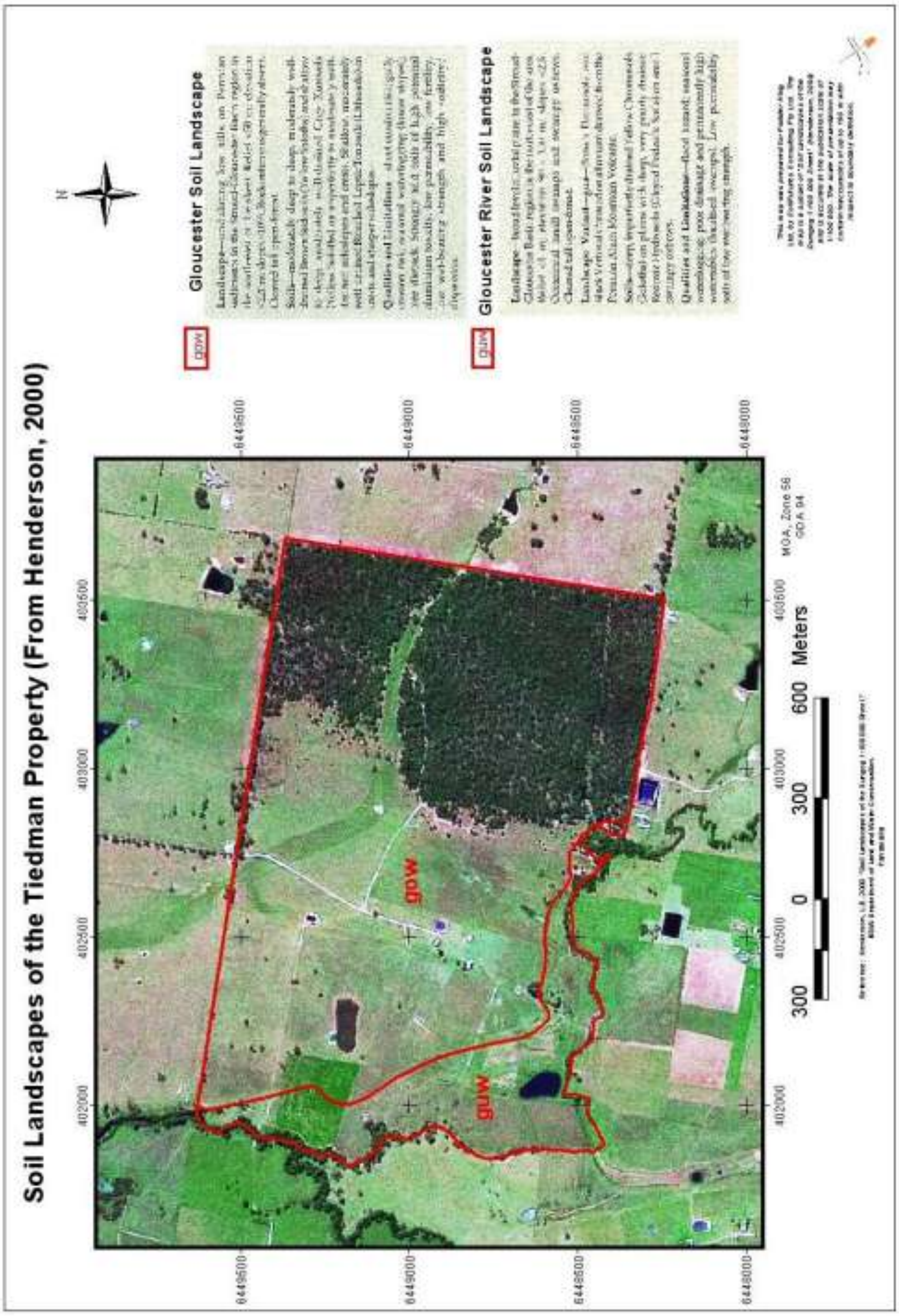

Figure 2: Soil Landscapes of the Tiedman Property, Gloucester

2.3 Soil Sampling for Validation of Electromagnetic Induction Survey

Ten soil profile description and sampling points were located based on the zoning of conductivity measurements (Figure 3). Soil description and sampling points were located within sites reflecting the range from low, medium and high relative EC_a.

Soil cores were taken to 1.5 m depth (within the bulk of the return signal of the EM31 in horizontal mode) and soils described and sampled using NSW Soil Data Cards. Soil descriptions were made according to CSIRO (2009) and soils were classified according to Isbell (2002). Field soil data were entered into SALIS (NSW Office of Environment and Heritage (OEH) soil database) for easy access and manipulation.

For EM31 validation soil samples were taken at each soil profile description site. Sample depths were 0 – 20 cm, 20 – 50 cm, 50 -100 cm, and 100 – 150 cm. Samples were retained for analysis by East West Enviroag Laboratories in Tamworth.

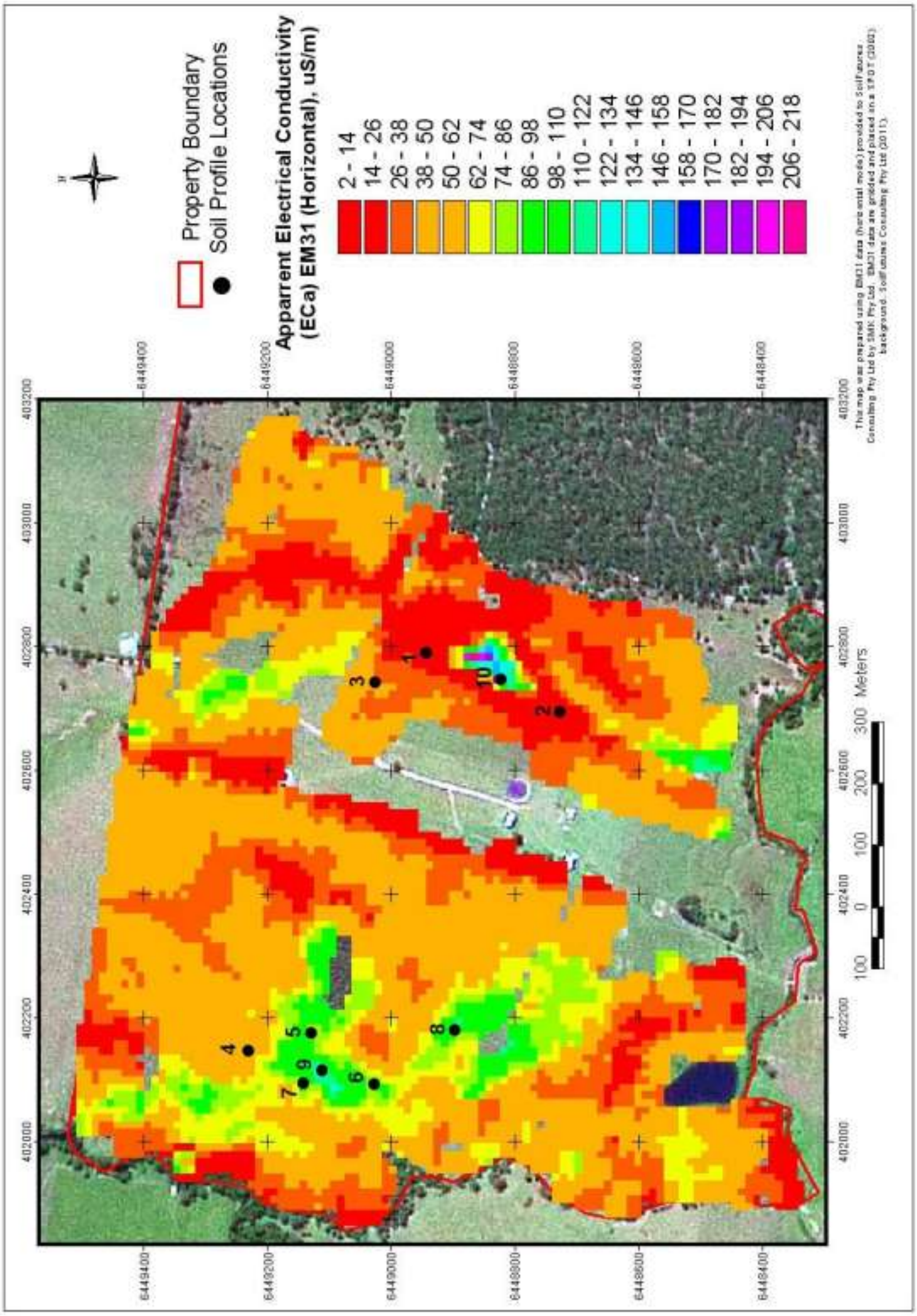

Figure 3: Raw EM31 data for Tiedman Block showing soil profile description and sampling sites

2.4 Soil Laboratory Analyses

Soil samples were analysed at East West Enviroag Laboratory in Tamworth. Soil samples from all soil profiles were tested for Soil Moisture Content, Bulk Density, Organic Carbon (OC), Electrical Conductivity (EC), pH, Emerson aggregate test (EAT), Cation Exchange Capacity (CEC) and exchangeable cations including aluminium.

An additional 16 soil data points measuring the same set of soil parameters down to 1.2 m was provided for EM Validation purposes by SoilFutures Consulting by Fodder King. Sample increments were 0 – 10 cm, 10 – 20 cm, 20 – 30 cm, 30 – 40 cm, 40 – 60 cm, 60 – 80 cm, 80 – 100 cm and 100 – 120 cm. The location of these trial samples is given in Figure 4 below.

East West Enviroag Laboratory in Tamworth is a National Australian Testing Authority (NATA) accredited laboratory for all of the above listed tests and as such meets OEH (EPA) requirements for reporting on suitability for effluent irrigation (EPA, 2004).

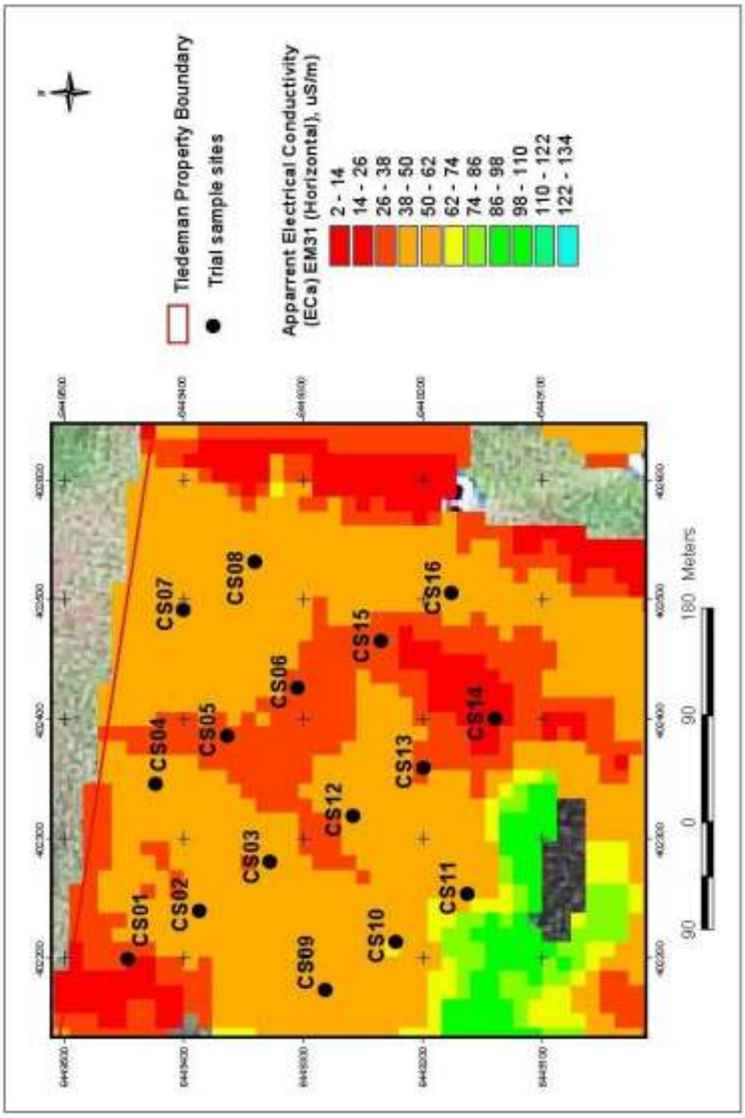

Figure 4: Raw EM31 data for Tiedman Block Trial site soil data points

2.5 Data Correlation

The laboratory data were received by SoilFutures Consulting, and checked for correlation with the EM31 data, with reference to all measured soil physical and chemical properties. Most commonly, the highest correlation occurs with salinity and soil moisture. If soil moisture is eliminated as a component of EC_a, then salinity generally dominates.

Measured soil laboratory data were used to do simple correlation regressions of the soil laboratory data and the EC_a data from the EM31 machine using Microsoft Excels' (MS Excel 2007) regression correlation and multiple regression capabilities. If a reasonable fit is achieved in doing this, then the data can be related back to the EC_a data by a formula. The measure of fit is called the R^2 Value – which shows how well a line fitted to the data describes the variation in the data. An R^2 value of 0.85 means that 85% of the soil salinity variability is described by the fitted line.

If a good fit is achieved, then the equation for the line [which is usually expressed by the formula Y value = m (slope) X (X axis value) + b (Y intercept)], can be used to develop a predictive model based on the whole EM31 dataset, and maps can be produced showing the distribution of salts (expressed as EC, EC_e [a measure of salinity effect on plants] or in Tons/Ha), clays or other measured soil attributes which have a high correlation with the EM31 values. Serial EM31 survey, following irrigation may then to be used to rapidly show changes in salinity if irrigation progresses.

3. Results and Discussion of Results

3.1 Existing Soil and Land Information

Soil Landscape mapping for the area has been carried out by Henderson (2000). The site is split between Gloucester soil landscape and Gloucester River Soil Landscape. Summaries of characteristics of these soil landscapes are given below as described by Henderson (2000)

Gloucester soil landscape is an undulating erosion landscape on Permian Coal measures of the Gloucester coal measures and the Dewrang group. 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, and have poor internal drainage, and are often acid, 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. This 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.

3.2 EM31 Survey and Soil Profile Locations

As shown in Figure 3 above, the EM31 survey revealed a range of EC_a from 1 to 220 millisiemens per metre (mS/m) across the site. This range was used to locate soil profile description and sampling pits across the site which represent the full spread of the range of EC_a data from the EM31 machine. The location of each profile description and sampling site chosen is given in Table 1 below.

Table 1: Location of Soil Profile Description Points and assciated EC_a values

Profile Number	Eastings	Northings	EC_a (mS/m)
EM1	402792	6448942	5
EM2	402697	6448726	22
EM3	402745	6449025	39
EM4	402150	6449230	56
EM5	402178	6449128	73
EM6	402096	6449027	90
EM7	402097	6449140	107
EM8	402183	6448896	120
EM9	402117	6449111	140
EM10	402750	6448821	190

3.2.1 Additonal Soil Data Points

Additional soil data points sampled by Fodder King for an irrigation trial were located according to Table 2 below. It should be noted that the data for the trial represent soil values only to 1.2 m and not to 1.5m, and that they are not located with specific reference to the EM31 survey.

Table 2: Location of additional soil data points provided by Fodder King

Core	Eastings	Northings	ECa (mS/m)
CS1	402200	6449446	35
CS2	402241	6449387	42
CS3	402281	6449327	51
CS4	402346	6449423	42
CS5	402386	6449363	26
CS6	402427	6449304	32
CS7	402492	6449399	58
CS8	402532	6449340	39
CS9	402174	6449281	50
CS10	402214	6449222	70
CS11	402255	6449163	43
CS12	402320	6449258	39
CS13	402360	6449199	34
CS14	402401	6449139	6
CS15	402466	6449235	36
CS16	402506	6449175	45

3.3 Field Soil Profile Data and Field Notes

Soils profiles at the site coincided with those described for Gloucester and Gloucester River soil landscapes as described in Henderson (2000). All soils described were harsh duplex soils, but ranging from Red Sodosols on hillcrests, ridges and upper slopes; to Brown and Yellow Sodosols on side slopes and footslopes; with Grey Sodosols dominating lower footslopes and drainage plains. Full soil profile descriptions and photographs are given in Appendix 1.

3.4 Laboratory Test Results and Interpretation

General comments on soil test results for all soil profiles are presented in Table 3 below. Raw laboratory soil data are presented in Appendix 2 with interpretations from Hazelton and Murphy (2007) in Appendix 3.

Table 3: Comments on Soil Tests results

Soil Test	Summary	Action Required
pH (1:5) and pH ($CaCl_2$)	All soil profiles described were neutral to strongly acid at the surface generally becoming more Acid with depth. Exceptions to this were soil profiles 8 and 9 which were in lower slope positions	Liming required for correction of surface soil pH
EC_e (derived from EC1:5)	Topsoils were all non-saline. Subsoils generally become increasingly saline in lower slope locations.	Monitor soil salinity
Bulk Density	Bulk density of all soil layers appeared to be in the moderate to high range with some exceptions for topsoils. Suggestion is that this may be an artefact of the coring method of profile extraction	Use soil pits and bulk density cores in future monitoring to avoid excessive compression of soils
Organic Carbon (C)	Topsoils were all in the moderate to very high range for organic carbon. Organic carbon content drops rapidly to low or very low levels below 20 cm	None
Cation Exchange Capacity (eCEC)	Topsoil CEC was generally low to very low. Deep subsoil CEC tended to be in the moderate range except for Profiles 1 and 10 which were higher up in the landscape and may have had significant mixing of sample mixing with C horizon or saprolite material	None

Table 2 Continued...		
Soil Test	**Summary**	**Action Required**
Exchangeable Potassium (K)	Exchangeable K (physical amount present) is generally low to moderate for all soil materials. As a % of CEC, however K generally in the moderate to high range with the exception of some lower slope subsoils.	May require regular monitoring if harvesting of stem material occurs, which rapidly depletes K
Exchangeable Calcium (Ca)	Exchangeable Ca (physical amount present) is universally low to very low across all soil profiles. As a % of CEC Ca in topsoils is low to moderate generally becoming low to very low in the subsoils.	Liming required to address
Exchangeable Magnesium (Mg)	Exchangeable Mg (physical amount present) is moderate to very high for all soil materials tested. As a % of CEC Mg is very high for all topsoils	May consider liming or gypsum applications as Magnesium can assist soil dispersion
Exchangeable Sodium (Na) And Sodicity	Exchangeable Na (physical amount present) is moderate to high for all topsoils and high to very high in all subsoils. As a % of CEC, all topsoils are classified as sodic except for the upslope profiles 1 and 10. All subsoils tested were sodic or strongly sodic	Ameliorant require correct poor drainage resulting from sodicity. Gypsum or lime will assist
Exchangeable Aluminium (Al)	Exchangeable Al as a % of cation exchange is variable for topsoils, ranging low to moderate and generally In the moderate to high range in deep subsoils.	None
Calcium Magnesium Ratio (Ca/Mg)	Ca is universally low or deficient across the site in all topsoils and subsoils tested.	Application of Lime
Emerson Aggregate Test (Dispersion)	Most topsoil materials are either aggregated or have only slight dispersion, with subsoils generally becoming highly dispersive at some level.	Drainage impedance will need to be corrected

3.5 Analysis of Soil Laboratory data and EM31 (Horizontal) data

As the EM31 (horizontal) data points represent an average apparent electrical conductivity (EC_a) reading for the surface 0 – 2 m, the soil chemistry parameters for the site were converted into averages over the depth of sampling for comparison.

A multiple regression of all measured and averaged soil laboratory parameters was done against EC_a. EC_a regressions against Soil Moisture Content, Bulk Density, Organic Carbon (OC), Electrical Conductivity (EC), Effective Electrical Conductivity (ECe) pH, Emerson aggregate test (EAT), Cation Exchange Capacity (CEC) and individual exchangeable cations had regression correlation R^2 values of less than 0.3, using the EM31 Data Validation set. Figure 5 below shows the regression of EC_a data with EC_e (salinity) data.

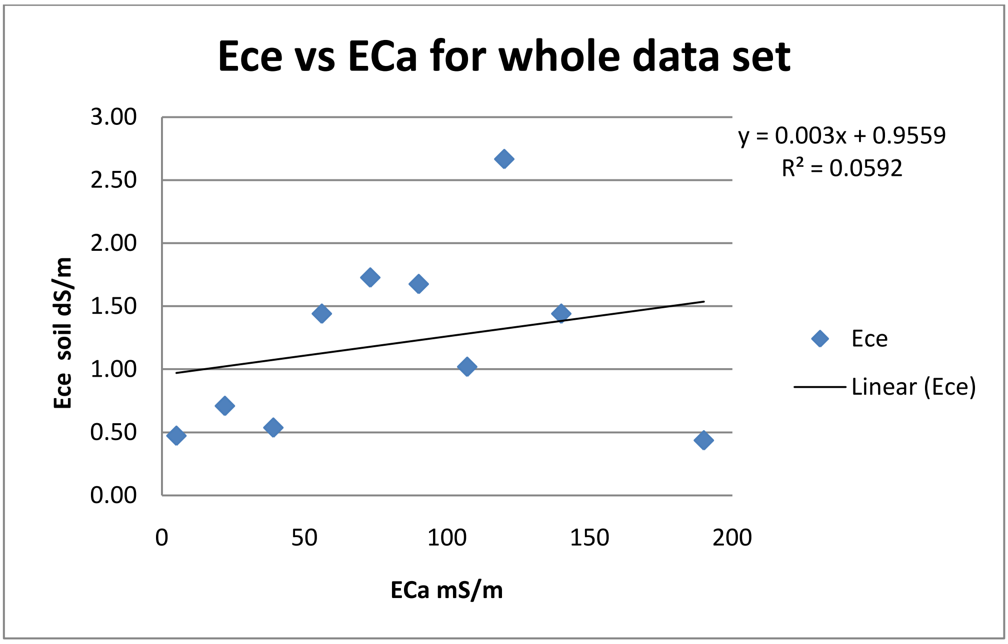

Figure 5: EC_a Data from EM31 (horizontal) regression against EC_e (salinity data)

A further set of multiple regressions was done with the Trial data set achieved the same result, with R^2 values lower than 0.4. Figure 6 below shows the regression of EC_a data with EC_e (salinity) data from the trial data set.

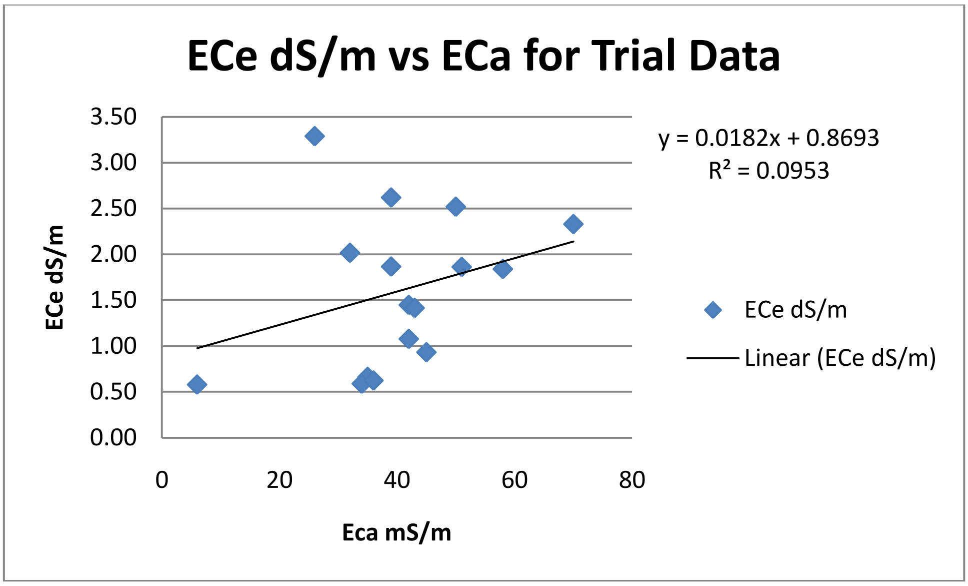

***Figure 6:** EC_a Data from EM31 (horizontal) regression against EC_e (salinity data) using trial site data*

The EM31 (horizontal) data was examined following the above multiple regressions. It was decided to remove all EM31 (horizontal) values for EC_a which were greater than 100mS/m from the analysis and re run single regressions against soil laboratory data. The reason that this was done is that the area of EC_a >100 mS/m was less than 0.5 Ha. The reduced ECa data were considered outliers from the survey as they were only 90 readings above 100 mS/m, representing a very small area of the property. When this was done an R^2 value of 0.83 was achieved as shown in Figure 7 below.

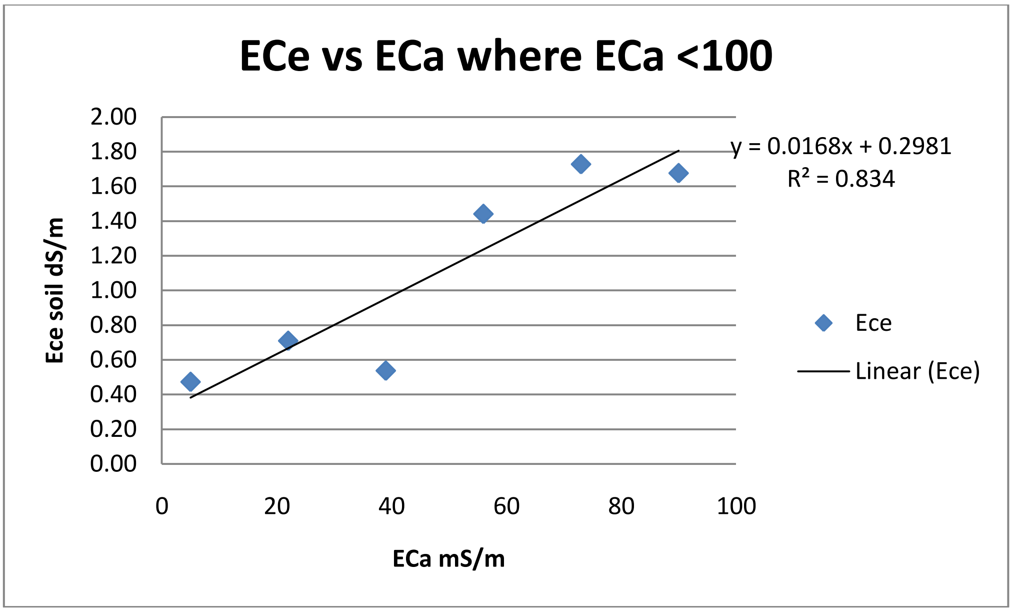

***Figure 7:** EC_a Data from EM31 (horizontal) regression against EC_e (salinity data) after removing ECa >100 mS/m.*

As figure 7 was derived using only 6 data points, it was decided to merge the trial site soil data and the EM31 soil profile data together. To achieve this, all data was averaged for each site and profile to a depth of 1.2 m so that they were comparable. All values regressed against EC_a had R^2 values <0.4. The regression for salinity is shown in Figure 8 below. No improvement in this relationship occurred when EC_a

>100 mS/m was removed from the regression.

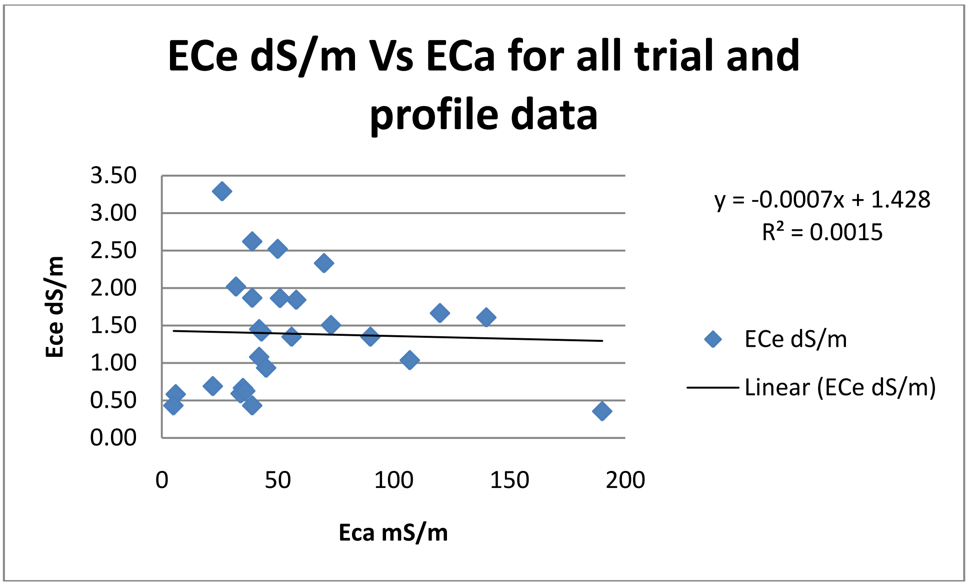

Figure 8: EC_a Data from EM31 (horizontal) regression against EC_e (salinity data) for combined profile and trial data sets

3.6 Use of Correlation Regression to create predicted salinity map.

The correlation regression data shown in Figure 7 were considered significant enough to attempt to convert the EC_a data from the EM31 (horizontal) machine to predicted soil EC_e (salinity) values across the site. As the EC_a data had been trimmed of all data points greater than 100 mS/m, only ECa data less than 100 mS/m were used in this model. The equation of the regression that was used is given below:

Predicted ECe (dS/m) = 0.0168 x ECa (mS/m) + 0.2981

The resulting data was converted into an image as shown in Figure 9 below. The resultant map shows that soil salinity averaged over 1.5 m soil depth should be <2 dS/m across most of the site surveyed.

It should be noted, that if this equation is then to be used as a model for monitoring salinity changes in future, it needs to be validated. Validation of the usefulness of the equation requires that areas of predicted EC_e be checked in the field to ensure that the equation is useful as a predictor of salinity.

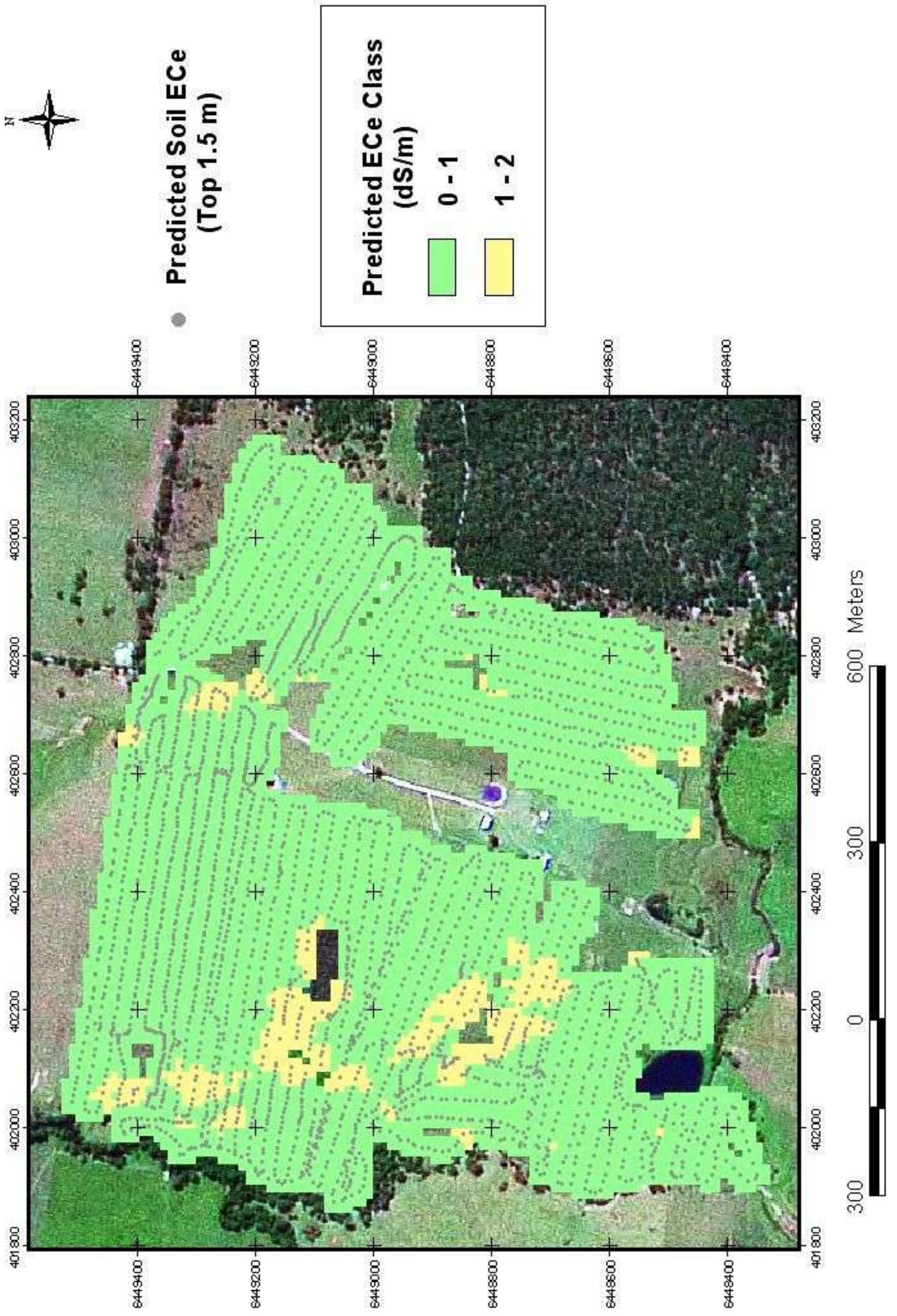

Figure 9: EC_a Data from EM31 (horizontal) regression against EC_e (salinity data) for combined profile and trial data sets

4. Discussion of Data Analysis

Figure 7 shows the only regression where the variation in relationship between the soil EC_e and EC_a data from the EM31 (horizontal) machine is explained by the fitted curve with any degree of predictive confidence. This means that 83.4% of the curve represents actual salinity (EC_e) in areas where EC_a<100mS/m. 6 profile points however is the absolutely minimum number of points to obtain a reasonably significant relationship in a regression correlation analysis. As such a low number of data points were used to construct a model of salinity variation across a site as in Figure 9, validation of the model is required if the equation is to be used in monitoring of salinity levels over time to test its effectiveness. As all other soil laboratory attributes have no clear relationship to $EC_{a,}$ a laboratory validation data set is only required to include Electrical Conductivity (EC) and field texture.

It is significant that there is poor correlation between EC_a and EC_e in areas where EC_a is higher than 100 mS/m. There were only 90 EC_a readings in this category (covering an area of < 0.5 Ha) so these sites were removed from the EC_a dataset and treated as outliers. As soil profile sampling reflected the full spread of the data, the resulting laboratory data appeared to have skewed any possible regression correlation of significance.

The agricultural trial site soil laboratory data was not useful in validating the EM31 survey. It is likely that this is because the agricultural trial was only sampled to 1.2 m rather than 1.5 m where it was assumed that the bulk of the return signal from the EM31 machine was coming from.

An EM31 machine in vertical mode gives a return signal over approximately 4 m depth of soil. In horizontal mode (with the machine turn sideways) the penetration is approximately 2 m. As most of the soils on the site were less than 2 m deep, it is reasonable to assume that the bulk of the return signal (EC_a) is from the 0 – 1.5 m depth range. It is most common for salts to be stored in subsoils so it is important to sample the bulk of the subsoil at any site for EM verification.

It was also observed during the sampling procedure that C horizon material and highly weathered rock was found in the lower depths of many of both the soil profile sites and the agricultural trial sites. The development of accurate lower subsoil EC_e values from these cores may well have been skewed as a result. EC_e is derived from the electrical conductivity of the soil (EC) multiplied by a textural adjustment factor which is low for clay and high for lighter materials as given in Hazelton and Murphy (2007). As much of the C horizon or highly weathered rock materials do not behave in the same way as soil aggregates, it is possible that treating these materials as soil (having soil structures as well as texture) may not be useful.

5. Conclusions and Recommendations

The EM31 (horizontal) survey and associated soil testing reveals that the

Tiedman property is dominated by duplex soils of only low to moderate fertility, with poor internal drainage, and which are dominated by sodic, dispersive subsoils. Problems arose, possibly from the use of the GeoProbe, which may have mixed or compressed wet soils layers through its shaking motion when the jackhammer is turned on. Owing to the wet conditions at the time of the EM verification soil survey, the GeoProbe was the only way in which they could be taken.

By culling data from the EM31 (horizontal) survey of 90 clearly outlying EC_a readings, it was possible to form a correlation regression relationship between soil salinity (expressed as EC_e) and apparent electrical conductivity (EC_a) from the EM31 machine. No other significant relationship existed with other measured soil parameters. This enabled a predictive model to be formed which, on the face of it, has an 83% predictive confidence for salinity. This model is only useful if it can be validated i.e. It has to be used in the field before any soil amelioration or irrigation takes place, to ensure that it does have both predictive capacity, and the capacity to monitor salinity levels when changes occur.

To validate the correlation regression model, it will be necessary to take soil samples as for this project to a depth of 1.5 m in locations of known EC_a with a predicted EC_e value. Soil samples need only be analysed for electrical conductivity (EC) and texture. If the averaged salinity values for each profile fall within the range of predicted salinity, this model will be a highly valuable and cost saving tool for monitoring of any changes under a proposed irrigation scheme where soil salinity values may increase over time.

If the model is verified, then it can be applied to determine spatially, the potential salinity build up in salinity before any irrigation commences. If the model is verified, employing serial EM31 (horizontal) surveys over time will become a cost effective way to measure changes in soil salinity over time. The model must be verified before any irrigation or soil ameliorants are applied, to achieve this aim. Example sampling points for model validation within the trial site area are given in Appendix 4.

6. References

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7. Appendices

Appendix 1: AGL – Tiedman Property – EM31 (Horizontal) Survey, Gloucester (2011)

Soil Profile Descriptions

Site location: Site 1 ECa 5uS/m

Profile details: AGL Tiedman - Gloucester - EM 31 (Hor) (1005257), Profile 1, recorded by Robert Banks on 09 Jun 2011

Map reference: MGA grid reference 402792E, 6448942N, MGA Zone 56; GDA Latitude -32.09164, GDA Longitude 151.96986; Dungog (9233) 1:100,000 map sheet

Terrain: residual crest; part of hillcrest within hills; local relief is low (30-90 m)

Hydrology: profile is imperfectly drained, run-on is none, runoff is moderate

Site condition: expected to be hardsetting when dry, ground cover is 100%

Soil type: Red Sodosol; medium, non gravelly, silty, clayey, moderate, no data available but sufficient knowledge (ASC); Soloth (Solod) (GSG)

Soil description

Layer 1, A1 horizon, 0 - 0.1 m: dark brown (brownish black) (7.5YR 3/2) light silty clay loam with massive structure, earthy fabric; field pH is 6; no layer notes recorded; abrupt (5-20 mm) boundary to...

Layer 2, B2 horizon, 0.1 - 0.9 m: yellowish red (bright reddish brown) (5YR 5/6) light clay with moderate pedality (sub-angular blocky, 20 - 50 mm), rough-faced peds; field pH is 6; no layer notes recorded; no boundary details recorded...

Layer 3, BCm horizon, 0.9 - 1.5 m: white (light grey) (5YR 8/1) clay with moderate pedality (sub-angular blocky, 20 - 50 mm), rough-faced peds; field pH is 6; no layer notes recorded; soil continues...

Site location: Site 2 ECa = 22uS/m

Profile details: AGL Tiedman - Gloucester - EM 31 (Hor) (1005257), Profile 2, recorded by Robert Banks on 09 Jun 2011

Map reference: MGA grid reference 402697E, 6448725N, MGA Zone 56; GDA Latitude -32.09359, GDA Longitude 151.96883; Dungog (9233) 1:100,000 map sheet

Terrain: waning lower slope; part of drainage depression within hills; local relief is low (30-90 m), slope is 2% (measured)

Hydrology: profile is poorly drained, run-on is

Land use: used for improved pasture, with improved pasture in general area

Site condition: expected to be hardsetting when dry, ground cover is 100%

Soil type: Brown Sodosol; medium, non gravelly, silty, clayey, very deep, sufficient data available (ASC); Soloth (Solod) (GSG)

Soil description

Layer 1, A1 horizon, 0 - 0.15 m: dark reddish brown (5YR 3/2) silty clay loam; field pH is 6; no layer notes recorded; clear (20-50 mm) boundary to...

Layer 2, A2e horizon, 0.15 - 0.25 m: dark reddish grey (greyish brown) (5YR 4/2) silty clay loam; field pH is 6; no layer notes recorded; abrupt (5-20 mm) boundary to...

Layer 3, B2 horizon, 0.25 - 0.95 m: yellowish brown (dull yellowish brown) (10YR 5/4) light clay with moderate pedality (angular blocky, 20 - 50 mm), rough-faced peds; field pH is 6; no layer notes recorded; gradual (50-100 mm) boundary to...

Layer 4, BC horizon, 0.95 - 1.5 m: very pale brown (light yellow orange) (10YR 8/3) light clay with weak pedality, rough-faced peds; field pH is 6; no layer notes recorded; soil continues...

Site location: Site 3 ECa = 39uS/m

Profile details: AGL Tiedman - Gloucester - EM 31 (Hor) (1005257), Profile 3, recorded by Robert Banks on 09 Jun 2011

Map reference

MGA grid reference 402745E, 6449025N, MGA Zone 56; GDA Latitude -32.09089, GDA Longitude 151.96937; Dungog (9233) 1:100,000 map sheet

Terrain: residual upper slope; part of hillslope within hills; local relief is low (30-90 m), slope is 3% (measured)

Hydrology: profile is imperfectly drained, run-on is low, runoff is moderate

Site condition: expected to be hardsetting when dry, ground cover is 100%

Soil type: Red Sodosol; (ASC); Soloth (Solod) (GSG)

Soil description

Layer 1, A horizon, 0 - 0.25 m: silty clay loam with moderate pedality (sub-angular blocky, 5 - 10 mm), rough-faced peds; field pH is 6.5; no layer notes recorded; no boundary details recorded...

Layer 2, A2 horizon, 0.25 - 0.4 m: silty clay loam with moderate pedality (sub-angular blocky, 5 - 10 mm), rough-faced peds; field pH is 6; no layer notes recorded; no boundary details recorded...

Layer 3, B horizon, 0.4 - 0.6 m: light clay; field pH is 6; no layer notes recorded; no boundary details recorded...

Layer 4, B horizon, 0.6 - 0.8 m: silty clay loam; field pH is 6; no layer notes recorded; no boundary details recorded...

Layer 5, BC horizon, 0.8 - 1.1 m: light clay; field pH is 6; no layer notes recorded; no boundary details recorded...

Layer 6, C horizon, 1.1 - 1.3 m: no soil texture recorded ; no layer notes recorded; soil continues...

Site location: Site 4 ECa = 56uS/m

Profile details: AGL Tiedman - Gloucester - EM 31 (Hor) (1005257), Profile 4, recorded by Robert Banks on 09 Jun 2011

Map reference: MGA grid reference 402150E, 6449230N, MGA Zone 56; GDA Latitude -32.08899, GDA Longitude 151.96308; Dungog (9233) 1:100,000 map sheet

Terrain: transportational minimal mid-slope; part of hillslope within low hills; local relief is low (30-90 m)

Site condition: expected to be hardsetting when dry, ground cover is 100%

Soil type: Yellow Sodosol; medium, non gravelly, silty, clayey, deep, sufficient data available (ASC); Soloth (Solod) (GSG)

Soil description

Layer 1, A1 horizon, 0 - 0.2 m: very dark brown (brownish black) (10YR 2/2) silty loam with massive structure, earthy fabric; field pH is 5.5; no layer notes recorded; clear (20-50 mm) boundary to...

Layer 2, A2e horizon, 0.2 - 0.3 m: greyish brown (greyish yellow brown) (10YR 5/2) silty loam with massive structure, earthy fabric; field pH is 5.5; no layer notes recorded; abrupt (5-20 mm) boundary to...

Layer 3, B2 horizon, 0.3 - 0.5 m: olive yellow (bright yellowish brown) (2.5Y 6/6) light clay with moderate pedality (angular blocky), rough-faced peds; field pH is 6.5; no layer notes recorded; gradual (50-100 mm) boundary to...

Layer 4, BC horizon, 0.5 - 1 m: pale yellow (light grey) (2.5Y 8/2) sandy clay with massive structure, earthy fabric; field pH is 7; no layer notes recorded; directly overlies bedrock

Site location: Site 5 ECa = 73uS/m

Profile details: AGL Tiedman - Gloucester - EM 31 (Hor) (1005257), Profile 5, recorded by Robert Banks on 09 Jun 2011

Map reference: MGA grid reference 402178E, 6449128N, MGA Zone 56; GDA Latitude -32.08991, GDA Longitude 151.96337; Dungog (9233) 1:100,000 map sheet

Terrain: depositional waning open depression; part of drainage depression within low hills; slope is 2% (measured)

Soil type

? ? Brown Sodosol; medium, non gravelly, silty, clayey, very deep, sufficient data available (ASC); Soloth (Solod) (GSG)

Soil description

Layer 1, 4A1 horizon, 0 - 0.15 m: dark greyish brown (greyish yellow brown) (10YR 4/2) silty loam with massive structure, earthy fabric; field pH is 6; no layer notes recorded; abrupt (5-20 mm) boundary to...

Layer 2, B2 horizon, 0.15 - 0.6 m: brown (dull yellowish brown) (10YR 5/3) light clay with moderate pedality (angular blocky), rough-faced peds; field pH is 5.5; no layer notes recorded; clear (20-50 mm) boundary to...

Layer 3, B22 horizon, 0.6 - 1.5 m: brown (dull yellowish brown) (10YR 5/3) light medium clay with moderate pedality (angular blocky), rough-faced peds; field pH is 8; no layer notes recorded; soil continues...

No Photograph Available

Site location: Site 6 ECa = 90uS/m

Profile details: AGL Tiedman - Gloucester - EM 31 (Hor) (1005257), Profile 6, recorded by Robert Banks on 09 Jun 2011

Map reference: MGA grid reference 402096E, 6449027N, MGA Zone 56; GDA Latitude -32.09082, GDA Longitude 151.96249; Dungog (9233) 1:100,000 map sheet

Terrain: transportational waning lower slope; part of hillslope within low hills; local relief is low (30-90 m)

Land use: used for improved pasture, with improved pasture in general area

Soil type: Grey Sodosol; medium, non gravelly, clay loamy, clayey, moderate, sufficient data available (ASC); Soloth (Solod) (GSG)

Soil description

Layer 1, A1 horizon, 0 - 0.2 m: brown (7.5YR 4/3) fine clay loam sandy with massive structure, earthy fabric; field pH is 6; no layer notes recorded; clear (20-50 mm) boundary to...

Layer 2, B2 horizon, 0.2 - 0.7 m: yellowish brown (dull yellowish brown) (10YR 5/4) light clay with moderate pedality (angular blocky), smooth-faced peds; field pH is 6; no layer notes recorded; gradual (50-100 mm) boundary to...

Layer 3, C horizon, 0.7 - 1.5 m: very pale brown (light grey) (10YR 8/2) no soil texture recorded ; field pH is 5.5; no layer notes recorded; no boundary details recorded...

Site location: Site 7 ECa = 107uS/m

Profile details: AGL Tiedman - Gloucester - EM 31 (Hor) (1005257), Profile 7, recorded by Robert Banks on 09 Jun 2011

Map reference: MGA grid reference 402097E, 6449140N, MGA Zone 56; GDA Latitude -32.0898, GDA Longitude 151.96251; Dungog (9233) 1:100,000 map sheet

Terrain: depositional waning lower slope; part of footslope within low hills; local relief is low (30-90 m), slope is 1% (measured)

Soil type: Grey Sodosol; medium, non gravelly, silty, clayey, very deep, sufficient data available (ASC); Soloth (Solod) (GSG)

Soil description

Layer 1, A horizon, 0 - 0.2 m: brown (dull yellowish brown) (10YR 4/3) silty clay loam with massive structure, earthy fabric; field pH is 6.5; no layer notes recorded; no boundary details recorded...

Layer 2, B2 horizon, 0.2 - 0.7 m: dark greyish brown (greyish yellow brown) (10YR 4/2) light clay with moderate pedality (angular blocky, 20 - 50 mm), rough-faced peds; field pH is 5.5; no layer notes recorded; no boundary details recorded...

Layer 3, B22 horizon, 0.7 - 1.5 m: light brownish grey (greyish yellow brown) (10YR 6/2) light medium clay with moderate pedality (angular blocky, 20 - 50 mm), rough-faced peds; field pH is 8; no layer notes recorded; soil continues...

Site location: Site 8 ECa = 120uS/m

Profile details: AGL Tiedman - Gloucester - EM 31 (Hor) (1005257), Profile 8, recorded by Robert Banks on 09 Jun 2011

Map reference: MGA grid reference 402183E, 6448896N, MGA Zone 56; GDA Latitude -32.09201, GDA Longitude 151.9634; Dungog (9233) 1:100,000 map sheet

Terrain: waning lower slope; part of footslope within low hills; local relief is low (30-90 m), slope is 1% (measured)

Hydrology: profile is poorly drained, run-on is high

Land use: used for improved pasture, with improved pasture in general area

Site condition: expected to be hardsetting when dry, ground cover is 100%

Soil type: Yellow Sodosol; medium, non gravelly, silty, clayey, deep, sufficient data available (ASC); Soloth (Solod) (GSG)

Soil description

Layer 1, 4A horizon, 0 - 0.2 m: dark reddish grey (greyish brown) (5YR 4/2) silty clay loam; field pH is 6; no layer notes recorded; clear (20-50 mm) boundary to...

Layer 2, B2 horizon, 0.2 - 0.8 m: olive yellow (bright yellowish brown) (2.5Y 6/6) light clay; field pH is 7; no layer notes recorded; diffuse (>100 mm) boundary to...

Layer 3, BC horizon, 0.8 - 1.5 m: light yellowish brown (dull yellow) (2.5Y 6/3) light clay; field pH is 8.5; no layer notes recorded; soil continues...

Site location: Site 9 ECa = 140uS/m

Profile details: AGL Tiedman - Gloucester - EM 31 (Hor) (1005257), Profile 9, recorded by Robert Banks on 09 Jun 2011

Map reference: MGA grid reference 402117E, 6448821N, MGA Zone 56; GDA Latitude -32.09268, GDA Longitude 151.96269; Dungog (9233) 1:100,000 map sheet

Terrain: open depression; part of footslope within low hills; local relief is low (30-90 m),

Soil type: Grey Sodosol; medium, non gravelly, silty, clayey, very deep, sufficient data available (ASC); Soloth (Solod) (GSG)

Soil description

Layer 1, A horizon, 0 - 0.2 m: dark yellowish brown (brown) (10YR 4/4) silty clay loam with massive structure, earthy fabric; field pH is 6.5; no layer notes recorded; no boundary details recorded...

Layer 2, B2 horizon, 0.2 - 1 m: greyish brown (greyish yellow brown) (10YR 5/2) light clay with moderate pedality (angular blocky, 20 - 50 mm), rough-faced peds; field pH is 6.5; no layer notes recorded; no boundary details recorded...

Layer 3, BC horizon, 1 - 1.5 m: grey (brownish grey) (10YR 6/1) light clay with moderate pedality (angular blocky, 20 - 50 mm), rough-faced peds; field pH is 7.5; no layer notes recorded; no boundary details recorded...

Site location: Site 10 ECa = 190uS/m

Profile details: AGL Tiedman - Gloucester - EM 31 (Hor) (1005257), Profile 10, recorded by Robert Banks on 09 Jun 2011

Map reference:; MGA grid reference 402750E, 6448821N, MGA Zone 56; GDA Latitude -32.09273, GDA Longitude 151.9694; Dungog (9233) 1:100,000 map sheet

Terrain: upper slope; part of hillslope within low hills; local relief is low (30-90 m), slope is 6% (measured)

Site condition: expected to be hardsetting when dry, ground cover is 100%

Soil type: Humose Red Sodosol; medium, non gravelly, silty, clayey, very deep, sufficient data available (ASC); Soloth (Solod) (GSG)

Soil description

Layer 1, A1 horizon, 0 - 0.2 m: dark reddish brown (5YR 3/2) silty clay loam with massive structure, earthy fabric; field pH is 6; no layer notes recorded; clear (20-50 mm) boundary to...

Layer 2, A2e horizon, 0.2 - 0.4 m: reddish brown (dull reddish brown) (5YR 4/3) silty loam with massive structure, earthy fabric; field pH is 6; no layer notes recorded; clear (20-50 mm) boundary to...

Layer 3, B2 horizon, 0.4 - 1 m: yellowish red (bright reddish brown) (5YR 5/8) light clay with strong pedality (angular blocky, 10 - 20 mm), rough-faced peds; field pH is 6; no layer notes recorded; gradual (50-100 mm) boundary to...

Layer 4, BC horizon, 1 - 1.3 m: black (5YR 2.5/1) light clay with moderate pedality (angular blocky, 20 - 50 mm), rough-faced peds; field pH is 6; no layer notes recorded; diffuse (>100 mm) boundary to...

Layer 5, C horizon, 1.3 - 1.5 m: light grey (light brownish grey) (5YR 7/1) light clay; field pH is 5.5; no layer notes recorded; soil continues...

Appendix 2: Soil Laboratory Data

Appendix 2: Soil Laboratory Data - Tiedman EM31 (Horizontal) Survey																						
Profile Number	Sample Depths	Electrical Conductivity	Texture Modifier	Ece	pH (H2O)	pH ($CaCl_2$)	Organic carbon	Moisture % Gravimetric	Bulk Density	Potassium Ex	Calcium Ex	Magnesium Ex me/100g	Sodium Ex me/100g	Aluminium Ex me/100g	Ex Potassium % me/100g	Ex Calcium %	Ex Magnesium %	Ex Sodium %	Ex Aluminium %	ECEC me/100g	Ca	EAT
EM1	0-20cm	0.05	8.60	0.43	5.12	4.35	3.29	25.3	1.13	0.71	4.26	4.83	0.53	0.35	6.67	39.9	45.2	4.96	3.27	10.7	0.88	8
EM1	20-50cm	0.03	8.60	0.26	5.26	4.09	0.75	20.0	1.70	0.30	1.28	5.75	0.49	0.94	3.46	14.6	65.7	5.56	10.7	8.76	0.22	5
EM1	50-100cm	0.07	8.60	0.60	4.96	3.82	0.45	21.6	1.81	0.31	0.21	4.68	0.65	2.10	3.93	2.6	58.9	8.20	26.4	7.95	0.04	3b
EM1	100-150cm	0.07	8.60	0.60	5.07	3.86	0.28	16.0	1.88	0.33	0.22	5.78	0.90	1.96	3.63	2.4	62.9	9.80	21.3	9.19	0.04	3b
em1	Profile Average	0.06	8.60	0.47	5.10	4.03	1.19	20.73	1.63	0.42	1.49	5.26	0.64	1.34	4.42	14.87	58.16	7.13	15.41	9.15	0.30	
EM2	0-20cm	0.03	8.60	0.26	5.32	4.45	1.31	20.3	1.47	0.21	1.78	1.39	0.33	0.22	5.39	45.1	35.4	8.39	5.71	3.93	1.28	3b
EM2	20-50cm	0.08	8.60	0.69	5.26	4.10	0.85	24.9	1.76	0.46	0.89	7.87	1.17	0.92	4.08	7.87	69.5	10.3	8.17	11.3	0.11	3b
EM2	50-100cm	0.13	8.60	1.12	5.18	4.07	0.71	19.9	1.89	0.29	1.03	8.44	1.34	1.05	2.40	8.47	69.4	11.0	8.67	12.2	0.12	2
EM2	100-150cm	0.09	8.60	0.77	5.17	3.98	0.45	20.1	1.86	0.39	0.35	7.19	1.18	1.29	3.72	3.39	69.2	11.3	12.4	10.4	0.05	2
em2	Profile Average	0.08	8.60	0.71	5.23	4.15	0.83	21.30	1.74	0.34	1.01	6.22	1.01	0.87	3.90	16.21	60.88	10.28	8.74	9.45	0.39	
EM3	0-	0.04	8.60	0.	5.5	4.52	2.62	19.4	1.14	0.75	3.51	5.68	0.44	0.18	7.14	33.2	53.8	4.16	1.71	10.6	0.	8

	20cm			34	0																62	
EM3	20-50cm	0.03	8.60	0.26	5.63	4.36	1.61	16.2	1.61	0.37	2.03	7.94	0.53	0.33	3.30	18.1	70.9	4.74	2.96	11.2	0.25	8
EM3	50-100cm	0.08	8.60	0.69	5.31	4.14	0.89	20.3	1.67	0.35	0.83	10.2	1.03	0.78	2.65	6.27	77.4	7.80	5.91	13.2	0.08	3b
EM3	100-150cm	0.10	8.60	0.86	5.33	4.16	0.43	15.4	1.02	0.42	0.59	11.6	1.37	0.72	2.83	3.98	79.0	9.33	4.87	14.7	0.05	3b
em3	Profile Average	0.06	8.60	0.54	5.44	4.30	1.39	17.83	1.36	0.47	1.74	8.85	0.84	0.50	3.98	15.38	70.27	6.51	3.86	12.40	0.25	
EM4	0-20cm	0.08	8.60	0.69	5.04	4.36	2.07	21.9	1.61	0.35	3.38	5.01	0.46	0.34	3.66	35.4	52.5	4.83	3.59	9.54	0.67	7
EM4	20-50cm	0.13	8.60	1.12	5.36	4.26	0.78	19.3	1.96	0.33	1.60	11.1	1.16	0.50	2.23	10.9	75.5	7.91	3.40	14.6	0.14	2
EM4	50-100cm	0.26	8.60	2.24	5.87	5.00	0.47	11.0	1.76	0.41	0.77	12.4	1.99	0.03	2.62	4.89	79.6	12.7	0.18	15.6	0.06	3b
EM4	100-150cm	0.20	8.60	1.72	6.44	5.87	0.34	6.2	2.11	0.19	0.48	11.0	2.05	0.00	1.36	3.50	80.2	14.9	0.03	13.7	0.04	7
em4	Profile Average	0.17	8.60	1.44	5.68	4.87	0.92	14.60	1.86	0.32	1.56	9.88	1.41	0.22	2.47	13.69	71.95	10.10	1.80	13.38	0.23	
EM5	0-20cm	0.20	8.60	1.72	4.84	4.30	1.66	21.8	1.49	0.30	1.51	2.83	0.37	0.41	5.50	27.8	52.2	6.85	7.60	5.41	0.53	3b
EM5	20-50cm	0.08	8.60	0.69	5.47	4.14	0.64	13.4	1.99	0.27	0.68	6.69	1.01	0.84	2.87	7.12	70.5	10.6	8.84	9.49	0.10	1
EM5	50-100cm	0.28	7.50	2.10	5.36	4.36	0.54	15.5	2.01	0.30	0.69	8.27	2.14	0.34	2.58	5.88	70.4	18.2	2.91	11.7	0.08	1
EM5	100-150cm	0.32	7.50	2.40	6.67	5.56	0.51	16.2	2.16	0.29	1.01	8.33	2.46	0.01	2.40	8.32	68.9	20.3	0.07	12.1	0.12	1
em5	Profile	0.22	8.05	1.73	5.59	4.59	0.84	16.73	1.91	0.29	0.97	6.53	1.49	0.40	3.33	12.28	65.52	14.01	4.86	9.68	0.21	

EM6	Average 0-20cm	0.05	8.60	0.43	5.43	4.40	1.72	17.3	1.30	0.48	2.37	2.95	0.33	0.29	7.55	36.8	46.0	5.09	4.57	6.42	0.80	7
EM6	20-50cm	0.15	8.60	1.29	4.57	3.59	0.92	24.8	1.64	0.28	1.61	7.33	1.29	3.59	1.96	11.4	52.0	9.13	25.5	14.1	0.22	3b
EM6	50-100cm	0.27	8.60	2.32	4.75	3.73	0.49	17.3	1.73	0.34	0.56	8.88	2.53	2.67	2.29	3.74	59.3	16.9	17.8	15.0	0.06	3b
EM6	100-150cm	0.19	14.00	2.66	5.17	4.07	0.36	8.2	1.99	0.32	0.54	6.03	2.33	1.06	3.07	5.21	58.7	22.7	10.3	10.3	0.09	5
em6	Profile Average	0.17	9.95	1.68	4.98	3.95	0.87	16.90	1.67	0.36	1.27	6.30	1.62	1.90	3.72	14.30	53.99	13.45	14.53	11.44	0.29	
EM7	0-20cm	0.05	8.60	0.43	5.40	4.37	1.93	15.2	1.64	0.24	2.87	4.11	0.38	0.34	3.04	36.2	51.8	4.73	4.27	7.93	0.70	2
EM7	20-50cm	0.18	8.60	1.55	5.11	4.29	1.11	21.1	1.67	0.32	2.58	10.2	1.35	0.42	2.18	17.4	68.5	9.09	2.85	14.8	0.25	3b
EM7	50-100cm	0.15	7.50	1.13	5.24	4.38	1.01	20.8	2.47	0.32	2.41	8.73	1.04	0.30	2.51	18.8	68.2	8.12	2.36	12.8	0.28	3b
EM7	100-150cm	0.13	7.50	0.98	6.50	5.93	0.77	19.7	2.30	0.36	3.26	15.7	3.55	0.01	1.59	14.2	68.6	15.51	0.03	22.9	0.21	1
em7	Profile Average	0.13	8.05	1.02	5.56	4.74	1.21	19.20	2.02	0.31	2.78	9.67	1.58	0.27	2.33	21.66	64.28	9.36	2.38	14.61	0.36	
EM8	0-20cm	0.07	8.60	0.60	5.71	4.65	2.17	22.0	1.37	0.31	3.14	4.99	0.50	0.12	3.40	34.6	55.1	5.57	1.32	9.06	0.63	8
EM8	20-50cm	0.30	8.60	2.58	6.51	5.78	0.65	19.2	2.10	0.40	3.06	11.8	2.07	0.01	2.29	17.6	68.1	12.0	0.04	17.3	0.26	2
EM8	50-100cm	0.21	8.60	1.81	9.10	8.26	0.22	15.3	1.33	0.43	4.40	12.6	4.13	0.00	1.98	20.4	58.4	19.2	0.01	21.5	0.35	3a
EM8	100-150c	0.66	8.60	5.68	8.32	7.58	0.19	15.1	2.09	0.41	1.85	9.38	3.72	0.00	2.66	12.0	61.1	24.2	0.01	15.4	0.20	3b

	m																					
em8	Profile Average	0.31	8.60	2.67	7.41	6.57	0.81	17.90	1.72	0.38	3.11	9.68	2.61	0.03	2.58	21.18	60.66	15.24	0.35	15.82	0.36	
EM9	0-20cm	0.08	8.60	0.69	5.15	4.51	1.52	25.4	1.66	0.28	2.90	2.96	0.37	0.19	4.25	43.3	44.1	5.45	2.88	6.70	0.98	8
EM9	20-50cm	0.10	8.60	0.86	5.25	4.18	0.66	16.4	2.12	0.19	2.15	5.54	0.80	0.66	2.08	23.0	59.4	8.52	7.05	9.33	0.39	2
EM9	50-100cm	0.38	8.60	3.27	6.10	5.38	0.30	14.3	2.10	0.19	1.44	7.73	2.28	0.01	1.59	12.4	66.4	19.6	0.09	11.6	0.19	3b
EM9	100-150cm	0.11	8.60	0.95	7.38	6.26	0.18	9.7	1.53	0.18	1.49	7.65	3.20	0.00	1.43	11.9	61.1	25.6	0.03	12.5	0.19	2
em10	Profile Average	0.17	8.60	1.44	5.97	5.08	0.67	16.45	1.85	0.21	1.99	5.97	1.66	0.22	2.34	22.63	57.74	14.78	2.51	10.05	0.44	
EM10	0-20cm	0.05	8.60	0.43	5.02	4.47	2.68	26.7	1.40	0.37	2.65	2.08	0.16	0.22	6.81	48.2	37.9	2.97	4.06	5.49	1.27	8
EM10	20-50cm	0.03	9.50	0.29	5.24	4.08	0.73	19.4	1.82	0.27	0.79	2.61	0.31	0.98	5.38	15.9	52.6	6.25	19.8	4.96	0.30	3b
EM10	50-100cm	0.04	8.60	0.34	4.86	3.82	0.41	17.0	2.12	0.28	0.22	3.37	0.49	2.23	4.20	3.41	51.1	7.39	33.9	6.59	0.07	3b
EM10	100-150cm	0.08	8.60	0.69	4.43	3.64	0.82	32.9	1.35	0.36	0.22	3.83	0.79	3.14	4.30	2.64	45.9	9.49	37.7	8.34	0.06	3b
em10	Profile Average	0.05	8.83	0.44	4.89	4.00	1.16	24.00	1.67	0.32	0.97	2.97	0.44	1.65	5.18	17.56	46.87	6.53	23.87	6.34	0.42	

Appendix 3: Interpreted Soil Laboratory Data

Appendix 3: Ranked Soil Laboratory Data Tiedman Em31 (Horizontal Survey

Profile Number	Sample Depths	ECe	pH (H2O)	pH ($CaCl_2$)	Organic carbon	Bulk Density	Potassium Ex me/100g	Calcium Ex me/100g	Magnesium Ex me/100g	Sodium Ex me/100g	Ex Potassium %	Ex Calcium %	Ex Magnesium %	Ex Sodium %	Ex Aluminium %	ECEC me/100g	Ca/Mg Ratio	EAT Dispersibility
EM1	0-20cm	Non-saline	Str Acid	Str Acid	V High	Low	High	Low	Moderate	Moderate	High	Moderate	V High	Non - Sodic	Low	Low	Ca Deficient	Aggregated
EM1	20-50cm	Non-saline	Str Acid	V Str Acid	Low	High	Moderate	V Low	Moderate	Moderate	Moderate	Low	V High	Sodic	Moderate	Low	Ca Deficient	Slightly Dispersible
EM1	50-100cm	Non-saline	V Str Acid	V Str Acid	V Low	High	Moderate	V Low	Moderate	Moderate	Moderate	V Low	V High	Sodic	High	Low	Ca Deficient	Slightly Dispersible
EM1	100-150cm	Non-saline	Str Acid	V Str Acid	Ext Low	High	Moderate	V Low	Moderate	High	Moderate	V Low	V High	Sodic	High	Low	Ca Deficient	Slightly Dispersible
EM2	0-20cm	Non-saline	Str Acid	Str Acid	Moderate	Moderate	Low	V Low	Moderate	Moderate	High	Moderate	V High	Sodic	Low	V Low	Ca Low	Slightly Dispersible
EM2	20-50cm	Non-saline	Str Acid	V Str Acid	Low	High	Moderate	V Low	Moderate	High	Moderate	V Low	V High	Strongly Sodic	Low	Low	Ca Deficient	Slightly Dispersible
EM2	50-100cm	Non-saline	Str Acid	V Str Acid	Low	High	Low	V Low	V High	High	Moderate	V Low	V High	Strongly Sodic	Low	Moderate	Ca Deficient	Highly Dispersible
EM2	100-150cm	Non-saline	Str Acid	V Str Acid	V Low	High	Moderate	V Low	Moderate	High	Moderate	V Low	V High	Strongly Sodic	Moderate	Low	Ca Deficient	Highly Dispersible
EM3	0-20cm	Non-saline	Str Acid	Str Acid	High	Low	High	Low	Moderate	Moderate	High	Moderate	V High	Non - Sodic	Low	Low	Ca Deficient	Aggregated
EM3	20-50cm	Non-saline	Mod Acid	Str Acid	Moderate	High	Moderate	Low	Moderate	Moderate	Moderate	Low	V High	Non - Sodic	Low	Low	Ca Deficient	Aggregated
EM3	50-100cm	Non-saline	Str Acid	V Str Acid	Low	High	Moderate	V Low	V High	High	Moderate	V Low	V High	Sodic	Low	Moderate	Ca Deficient	Slightly Dispersible
EM3	100-150cm	Non-saline	Str Acid	V Str Acid	V Low	Low	Moderate	V Low	V High	High	Moderate	V Low	V High	Sodic	Low	Moderate	Ca Deficient	Slightly Dispersible

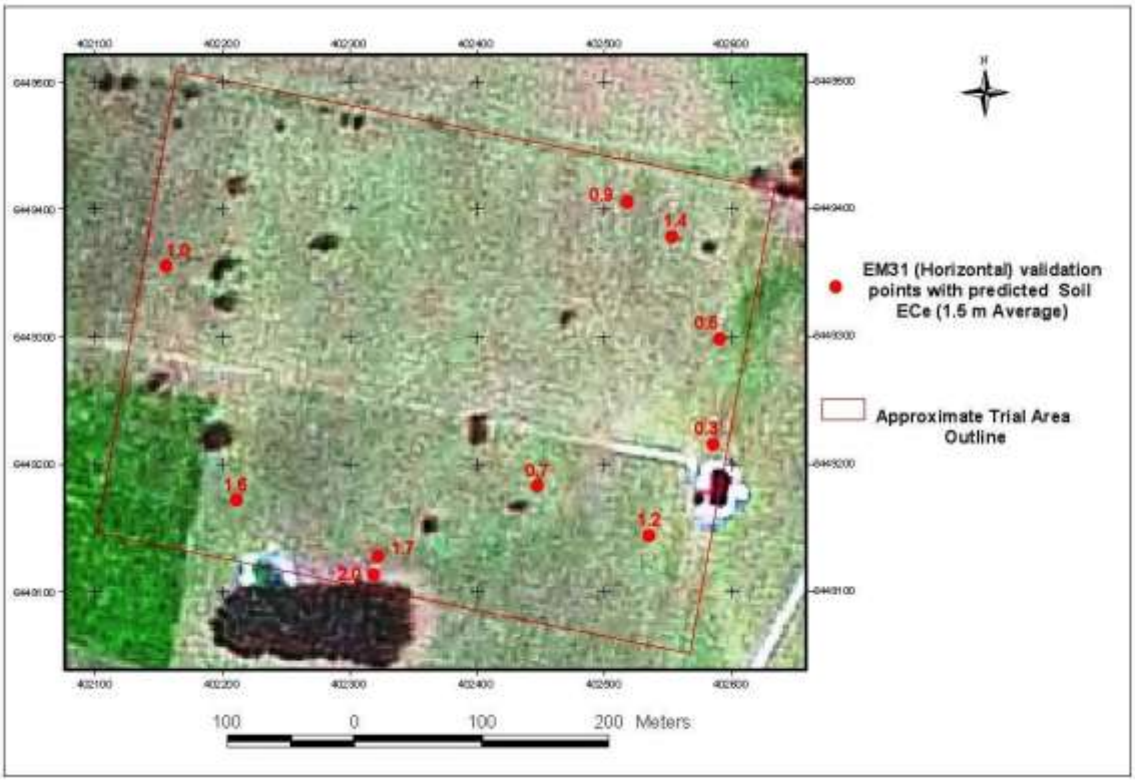
EM4	0-20cm	Non-saline	Str Acid	Str Acid	High	High	Moderate	Low	Moderate	Moderate	Moderate	Moderate	V High	Non -Sodic	Low	Low	Ca Deficient	Aggregated
EM4	20-50cm	Non-saline	Str Acid	Str Acid	Low	V High	Moderate	V Low	V High	High	Moderate	Low	V High	Sodic	Low	Moderate	Ca Deficient	Highly Dispersible
EM4	50-100cm	Slightly saline	Mod Acid	Mod Acid	V Low	High	Moderate	V Low	V High	High	Moderate	V Low	V High	Strongly Sodic	V Low	Moderate	Ca Deficient	Slightly Dispersible
EM4	100-150cm	Non-saline	Sl Acid	Neutral	Ext Low	V High	Low	V Low	V High	V High	Low	V Low	V High	Strongly Sodic	V Low	Moderate	Ca Deficient	Aggregated
EM5	0-20cm	Non-saline	V Str Acid	Str Acid	Moderate	Moderate	Low	V Low	Moderate	Moderate	High	Low	V High	Sodic	Low	V Low	Ca Deficient	Slightly Dispersible
EM5	20-50cm	Non-saline	Str Acid	V Str Acid	Low	V High	Low	V Low	Moderate	High	Moderate	V Low	V High	Strongly Sodic	Low	Low	Ca Deficient	Very Highly Dispersible
EM5	50-100cm	Slightly saline	Str Acid	Str Acid	V Low	V High	Moderate	V Low	V High	V High	Moderate	V Low	V High	Strongly Sodic	V Low	Low	Ca Deficient	Very Highly Dispersible
EM5	100-150cm	Slightly saline	Neutral	Sl Acid	V Low	V High	Low	V Low	V High	V High	Moderate	V Low	V High	Strongly Sodic	V Low	Moderate	Ca Deficient	Very Highly Dispersible
EM6	0-20cm	Non-saline	Str Acid	Str Acid	Moderate	Moderate	Moderate	Low	Moderate	Moderate	High	Moderate	V High	Sodic	Low	Low	Ca Deficient	Aggregated
EM6	20-50cm	Non-saline	V Str Acid	Ext Acid	Low	High	Low	V Low	Moderate	High	Low	Low	V High	Sodic	High	Moderate	Ca Deficient	Slightly Dispersible
EM6	50-100cm	Slightly saline	V Str Acid	V Str Acid	V Low	High	Moderate	V Low	V High	V High	Moderate	V Low	V High	Strongly Sodic	High	Moderate	Ca Deficient	Slightly Dispersible
EM6	100-150cm	Slightly saline	Str Acid	V Str Acid	Ext Low	V High	Moderate	V Low	Moderate	V High	Moderate	V Low	V High	Strongly Sodic	Moderate	Low	Ca Deficient	Slightly Dispersible
EM7	0-20cm	Non-saline	Str Acid	Str Acid	High	High	Low	Low	Moderate	Moderate	Moderate	Moderate	V High	Non -Sodic	Low	Low	Ca Deficient	Highly Dispersible
EM7	20-50cm	Non-saline	Str Acid	Str Acid	Moderate	High	Moderate	Low	V High	High	Moderate	Low	V High	Sodic	Low	Moderate	Ca Deficient	Slightly Dispersible
EM7	50-100cm	Non-saline	Str Acid	Str Acid	Moderate	V High	Moderate	Low	V High	High	Moderate	Low	V High	Sodic	Low	Moderate	Ca Deficient	Slightly Dispersible

EM7	100-150cm	Non-saline	Sl Acid	Neutral	Low	V High	Moderate	Low	V High	V High	Low	Low	V High	Strongly Sodic	V Low	Moderate	Ca Deficient	Very Highly Dispersible
EM8	0-20cm	Non-saline	Mod Acid	Str Acid	High	Moderate	Moderate	Low	Moderate	Moderate	Moderate	Moderate	V High	Sodic	Low	Low	Ca Deficient	Aggregated
EM8	20-50cm	Slightly saline	Neutral	Neutral	Low	V High	Moderate	Low	V High	V High	Moderate	Low	V High	Strongly Sodic	V Low	Moderate	Ca Deficient	Highly Dispersible
EM8	50-100cm	Non-saline	V Str Alkaline	V Str Alkaline	Ext Low	Moderate	Moderate	Low	V High	V High	Low	Low	V High	Strongly Sodic	V Low	Moderate	Ca Deficient	Slightly Dispersible
EM8	100-150cm	Moderately Saline	Str Alkaline	Sl Alkaline	Ext Low	V High	Moderate	V Low	V High	V High	Moderate	Low	V High	Strongly Sodic	V Low	Moderate	Ca Deficient	Slightly Dispersible
EM9	0-20cm	Non-saline	Str Acid	Str Acid	Moderate	High	Low	Low	Moderate	Moderate	Moderate	Moderate	V High	Sodic	Low	Low	Ca Deficient	Aggregated
EM9	20-50cm	Non-saline	Str Acid	V Str Acid	Low	V High	Low	Low	Moderate	High	Moderate	Low	V High	Sodic	Low	Low	Ca Deficient	Highly Dispersible
EM9	50-100cm	Slightly saline	Sl Acid	Sl Acid	Ext Low	V High	Low	V Low	Moderate	V High	Low	Low	V High	Strongly Sodic	V Low	Low	Ca Deficient	Slightly Dispersible
EM9	100-150cm	Non-saline	Sl Alkaline	Neutral	Ext Low	Moderate	Low	V Low	Moderate	V High	Low	Low	V High	Strongly Sodic	V Low	Moderate	Ca Deficient	Highly Dispersible
EM10	0-20cm	Non-saline	Str Acid	Str Acid	High	Moderate	Moderate	Low	Moderate	Low	High	Moderate	V High	Non - Sodic	Low	V Low	Ca Low	Aggregated
EM10	20-50cm	Non-saline	Str Acid	V Str Acid	Low	High	Low	V Low	Moderate	Moderate	High	Low	V High	Sodic	High	V Low	Ca Deficient	Slightly Dispersible
EM10	50-100cm	Non-saline	V Str Acid	V Str Acid	V Low	V High	Low	V Low	Moderate	Moderate	Moderate	V Low	V High	Sodic	High	Low	Ca Deficient	Slightly Dispersible
EM10	100-150cm	Non-saline	Ext Acid	Ext Acid	Low	Moderate	Moderate	V Low	Moderate	High	Moderate	V Low	V High	Sodic	V High	Low	Ca Deficient	Slightly Dispersible

Appendix 4: Suggested EM31 (Horizontal) Model Validation sample points

Appendix 4: Suggested EM31 (Horizontal) Model Validation Soil Sampling Points

Eastings	Northings	Measured Eca (mS/m)	Predicted Soil Average ECe Value over 1.5 soil column (dS/m)
402586	6449215	3	0.3
402591	6449298	13	0.5
402448	6449182	23	0.7
402519	6449405	33	0.9
402156	6449355	43	1
402536	6449143	53	1.2
402554	6449378	63	1.4
402211	6449171	75	1.6
402322	6449127	84	1.7
402319	6449112	99	2



Appendix B Soil Laboratory Results

Soil Sampling and Analysis at Tiedmans to provide EM Survey data

A report for Fodder King Ltd and AGL Gloucester
November 2014

Prepared by Dr Steven Lucas

The Tom Farrell Institute for the Environment

The University of Newcastle

"Regional solutions for a sustainable future"

Eight soil sampling locations were re-sampled on the 23 October 2014 by Dr Steven Lucas and Fodder King to provide data for the EM survey. Soil samples were taken manually using a hand auger to depths of 0-20 cm, 20-50 cm, 50-100 cm and 100-150 cm. Soil sampling locations included CS2, CS4, CS6, CS8, CS10, CS12, CS14 and CS16 located within Stage 1A; and EM4 and EM5 from previous EM survey.

Soil samples were analysed for pH (1:5 in water), Electrical Conductivity (EC, 1:5 in water), soil moisture (%), texture and bulk density as per standard soil laboratory methods (McDonald et al, 1998; Rayment and Lyons, 2010) at the University of Newcastle. Results from analyses are shown in Table 1.

			WET		**DRY**				**g/cm^3**		**dS/m**
ID	**cm**	**Tray wt (g)**	**T + Soil (g)**	**Soil (g)**	**T + Soil (g)**	**Soil (g)**	**Moisture %**	**Texture**	**BD**	**pH (1:5)**	**EC (1:5)**
CS2	0-20	8.2	683.4	675.2	627.4	619.2	8.3	CL	1.34	6.72	0.20
	20-50	8.3	529.5	521.2	454.9	446.6	14.3	MC	1.30	5.78	0.21
	50-100	8.3	649	640.7	545	536.7	16.2	MC	1.30	5.57	0.25
	100-150	NO SAMPLE	-								
CS4	0-20	8.2	715.5	707.3	637.4	629.2	11.0	CL	1.32	6.54	0.21
	20-50	8.3	705.6	697.3	614.5	606.2	13.1	MC	1.31	6.55	0.28
	50-100	8.1	808.9	800.8	692.4	684.3	14.5	MC	1.29	6.53	0.41
	100-150	8.2	577.8	569.6	478.7	470.5	17.4	MC	1.29	6.75	0.45
CS6	0-20	8.2	602.8	594.6	522.3	514.1	13.5	CL	1.33	6.23	0.23
	20-50	8.2	608.8	600.6	529.4	521.2	13.2	MC	1.28	5.32	0.31
	50-100	8.2	742.8	734.6	634.7	626.5	14.7	MC	1.27	5.49	0.33
	100-150	8.2	497.4	489.2	444.7	436.5	10.8	MC	1.28	5.76	0.25
CS8	0-20	8.1	777.6	769.5	710.5	702.4	8.7	CL	1.34	6.49	0.21
	20-50	8.1	650.9	642.8	577.7	569.6	11.4	MC	1.30	4.68	0.26
	50-100	8.1	597.9	589.8	510.4	502.3	14.8	MC	1.29	4.52	0.24
	100-150	NO SAMPLE	-								
CS10	0-20	8.1	640.4	632.3	568.2	560.1	11.4	CL	1.33	6.47	0.18
	20-50	8.1	544	535.9	452.9	444.8	17.0	MC	1.29	5.61	0.20
	50-100	8.1	610.5	602.4	529.7	521.6	13.4	MC	1.27	5.55	0.23
	100-150	NO SAMPLE	-								
CS12	0-20	8.1	555.4	547.3	500.5	492.4	10.0	SCL	1.31	7.25	0.19
	20-50	8.1	469.5	461.4	401.1	393	14.8	LMC	1.32	5.55	0.21
	50-100	8.1	587.7	579.6	499.7	491.6	15.2	MC	1.30	6.14	0.25
	100-150	8.1	682	673.9	608	599.9	11.0	MC	1.28	7.13	0.20
CS14	0-20	8.1	490	481.9	419.3	411.2	14.7	SCL	1.33	6.75	0.23
	20-50	8.1	605.3	597.2	535.4	527.3	11.7	MC	1.26	5.22	0.12
	50-100	8.2	230.7	222.5	178	169.8	23.7	MC	1.27	4.85	0.11
	100-150	8.2	276.7	268.5	228.1	219.9	18.1	MC	1.29	5.01	0.11
CS16	0-20	8.3	631.6	623.3	557	548.7	12.0	SCL	1.33	5.63	0.26
	20-50	8.2	586.2	578	501.7	493.5	14.6	MC	1.31	5.06	0.19
	50-100	8.2	542.8	534.6	456	447.8	16.2	MC	1.28	5.34	0.24
	100-150	8.2	388.1	379.9	319.4	311.2	18.1	MC	1.29	5.21	0.22
EM4	0-20	8.3	703.5	695.2	619.9	611.6	12.0	SCL	1.34	6.67	0.11
	20-50	8.2	455.4	447.2	403.1	394.9	11.7	MC	1.28	5.68	0.10
	50-100	8.2	490	481.8	421.9	413.7	14.1	MC	1.27	5.50	0.14
	100-150	NO SAMPLE	-								
EM5	0-20	8.2	460.5	452.3	412.8	404.6	10.5	SCL	1.35	5.59	0.10
	20-50	8.2	467.6	459.4	410	401.8	12.5	LMC	1.32	5.42	0.11
	50-100	8.2	500.3	492.1	422.4	414.2	15.8	MC	1.29	6.57	0.33
	100-150	8.2	548.6	540.4	463.3	455.1	15.8	MC	1.28	7.57	0.69

Texture Key

CL = clay loam

SCL = silty clay loam

LMC = light medium clay

MC = medium clay

Table 1: Soil analysis results

References

McDonald RC, Isbell RF, Speight JG, Walker J, Hopkins MS (1998) *Australian Soil and Land Survey Field Handbook*. (Australian Collaborative Land Evaluation Program: Canberra).

Rayment GE, Lyons DJ (2010) *Soil Chemical Methods – Australasia*, Australian Soil and Land Survey Field Handbook Series, CSIRO Publishing.