EM-31 SOIL SURVEYING: FOR FARMERS

Farm 108 Additional

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CONTENTS

1. Introduction

The EM-31 instrument measures the electrical conductivity of soils. It is used to identify areas with soil profiles that are likely to use excessive amounts of water to grow crops. By identifying these areas, landholders are better able to design farm layouts and plan cropping programs to achieve the most efficient usage of water possible.

There are four main stages involved in performing an EM-31 survey:

- Field surveying
- Mapping
- Soil drilling and texturing
- Interpretation

This document is a description of the EM-31 survey technique. It summarises the basic theory behind the technique and how the survey is carried out. When the EM-31 survey is complete, an information package comprising six main components is supplied to the landholder:

1. Map showing the field survey coverage achieved by EM-31 operator over each paddock (Figure 1).
2. Raw maps (Figure 2).
3. Percentile maps with drill point locations (Figure 3).
4. Drilling report (Appendix A).
5. Map showing any areas found by the EM-31 survey to lack three metres of medium to heavy clay (Figure 4).
6. Description of the EM-31 survey technique (this document).

2. Field surveying

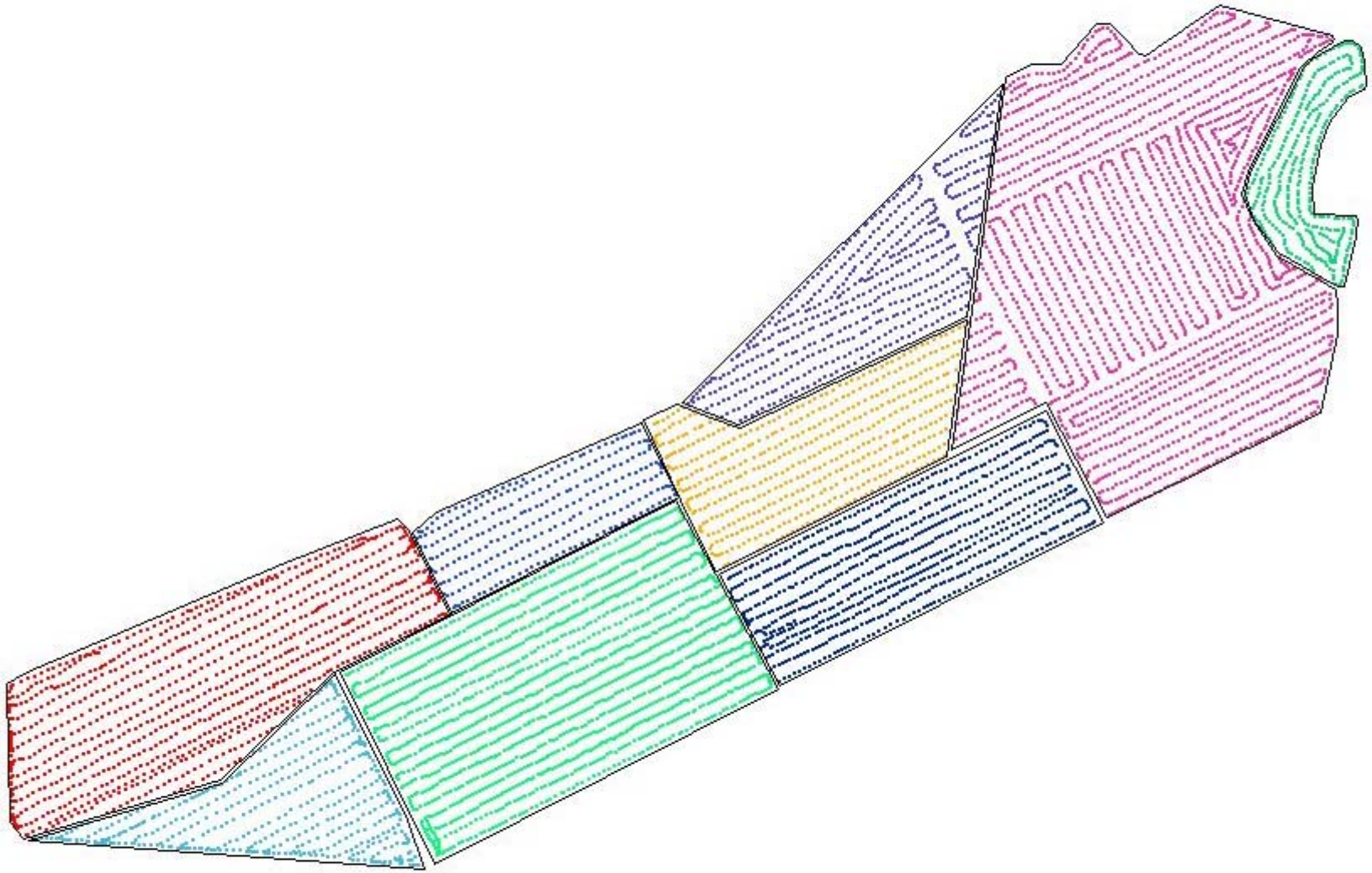
The EM-31 instrument is mounted on the front of a four-wheel motorbike. It is composed of three main sections, a transmitter, a receiver and a datalogger.

The transmitter sends a primary magnetic field into the soil profile, generating secondary magnetic fields to a depth of five metres. The strengths of these secondary magnetic fields, measured by the receiver, are a measure of the apparent electrical conductivity (ECa) of the soil profile.

ECa, measured in milli-Siemens per metre (mS/m), is affected by soil salinity, water content, texture and temperature. Within a field (see ***3.1*** for definition), salt and moisture conditions are generally uniform. Over the period of time taken to survey a field, temperature will also be relatively uniform. Thus, the lower the ECa of the soil profile within a field, the more likely it is that lighter textured soils are present.

Also mounted on the motorbike is a differential Global Positioning System (GPS). This is used to obtain the location of each ECa reading with an accuracy of less than one metre.

Figure 1: Farm 108 Additional EM-31 Coverage & Field Divisions



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90 0 90 180 Meters

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Paddocks are surveyed on approximately 20 metre transects at speeds of no greater than 20 kilometres per hour. Figure 1 shows the coverage achieved by the EM-31 operator over your farm. For every point in Figure 1, there is an associated ECa reading and position. ECa readings and GPS positions are recorded in the GPS datalogger and are later downloaded to a computer for the ECa readings to be mapped.

3. Mapping

Mapping of the data is carried out for direct comparison of EM-31 information to farm features such as rice bays and paddock boundaries. EM-31 maps enable planning of paddock or crop boundaries around areas likely to use excessive quantities of water to grow rice.

The computer software used to carry out EM-31 mapping, ArcView with mapping tool Spatial Analyst, was purchased from ESRI Australia. Coleambally Irrigation has worked closely with consultants from ESRI to automate the mapping technique in order to reduce the time required to map farms.

3.1 Identification of fields

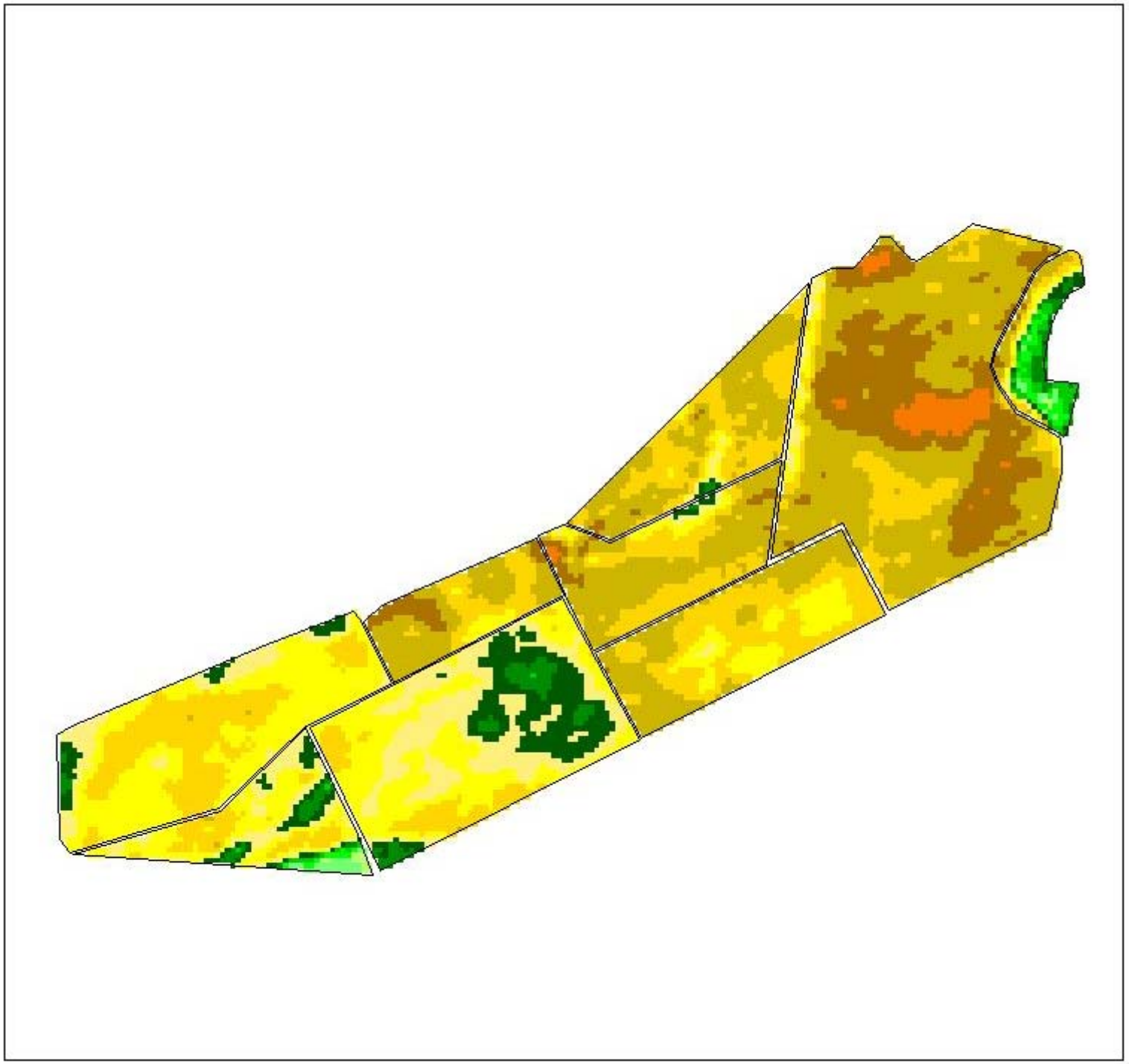
The survey data is separated into "fields" (as opposed to paddocks), which are based on cropping history. A field is defined as an area of land within which the same cropping history has occurred throughout.

Because the cropping history within a field is uniform, the salt and moisture characteristics of a field will also be fairly uniform. Salt and moisture conditions strongly influence soil electrical conductivity. By separating the data into fields, the variation of salt and moisture characteristics within the mapped areas is minimised, and changes in ECa are related more to soil texture. The lower the ECa readings in a field, the more likely it is that lighter textured soils are present in the soil profile.

ECa readings for paddocks that have not had crops grown on them for a significant period of time are higher than ECa readings for paddocks that have had crops (especially rice) grown on them. This is because irrigation has the effect of flushing salt present in the soil profile further down out of the range of measurement of the EM-31. If there are any paddocks on your farm that have had little or no irrigation, compare the ECa readings for these paddocks in Figure 2 to other irrigated paddocks.

Field boundaries may also be determined by the lie of the land. The lie of the land can affect salt and moisture characteristics and thus the conductivity of the soil profile in the same way as cropping history. For this reason, some areas may need to be mapped separately even if the cropping history is identical to nearby fields.

Aerial photographs taken over the past 10 years and EM-31 raw maps (described below) are used to identify fields. The boundaries of fields will not always be the same as farm paddock boundaries.



ECa (m S/m)

- 0 - 10
- 10 - 20
- 20 - 30
- 30 - 40
- 40 - 50
- 50 - 60
- 60 - 70
- 70 - 80
- 80 - 90
- 90 - 100
- 100 - 110
- 110 - 120
- 120 - 130
- 130 - 140
- 140 - 150
- 150 - 160
- 160 - 170
- 170 - 180
- 180 - 190
- 190 - 200
- 200 - 210
- 210 - 220
- 220 - 230
- 230 - 240
- 240 - 250
- 250 - 260
- 260 - 270
- 270 - 280
- 280 - 290
- 290 - 300
- 300 - 310
- 310 - 320
- 320 - 330
- 330 - 340
- 340 - 350
- 350 - 360
- 360 - 370
- 370 - 380
- No Data

Figure 2:
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EM-31 raw map

N

80 0 80 160 Meters

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3.2 Raw maps

Figure 2 is a raw map. In this map, classes with intervals of 10 mS/m are applied to the data. This map is used to help identify fields within a farm, and to enable basic interpretation of the data.

In interpreting the raw map, areas with ECa readings of 70 mS/m or lower are highly likely to have less then three metres of medium to heavy clay in the soil profile. Soil textures in areas with ECa readings greater than 70 mS/m are unknown until soil drilling and texturing has been carried out. Areas with ECa readings of 200 mS/m or greater could possibly contain concentrations of salt high enough to affect crop growth and yield.

3.3 Percentile maps

The second EM-31 map generated (Figure 3) is a percentile map. This map creates nine ECa classes for each field based on percentages of the gridded data. There are two methods of assigning ECa classes to percentile maps; 'standard' and 'reversed'.

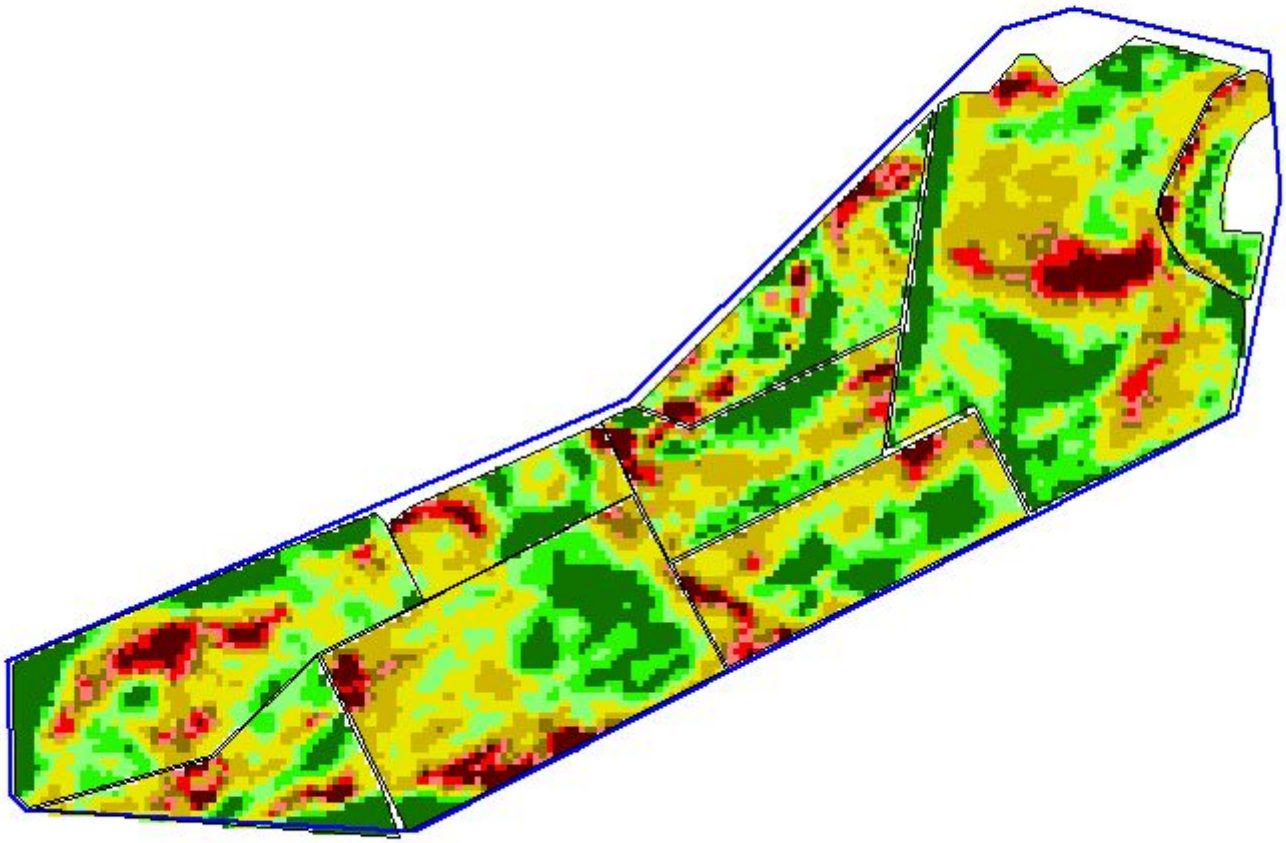
Standard percentile maps are created for fields in which the current rice soil classification is unrestricted. For standard maps, the percentage areas of the field represented by each colour are as follows:

- Dark red (lowest ECa) 0-3.5 %
- Mid red >3.5-6.5%
- Light red >6.5-8.5%
- Dark brown >8.5-11.5%
- Mid brown >11.5-28.5%
- Light brown >28.5-51.5%
- Light green >51.5-68.5%
- Mid green >68.5-81.5%
- Dark green (highest ECa) >81.5-100%

Reversed percentile maps are created for fields in which the current rice soil classification is marginal or unsuitable. For reversed maps, the percentage areas of the field represented by each colour are as follows:

- Dark red (lowest ECa) 0-18.5 %
- Mid red >18.5-31.5%
- Light red >31.5-48.5%
- Dark brown >48.5-71.5%
- Mid brown >71.5-88.5%
- Light brown >88.5-91.5%
- Light green >91.5-93.5%
- Mid green >93.5-96.5%
- Dark green (highest ECa) >96.5-100%

The percentage ranges for these classes have been designed so that the suitability of soils within fields for growing rice can be identified accurately, based on our current



Standard grid legend

- 0-3.5%
- 3.5-6.5%
- 6.5-8.5%
- 8.5-11.5%
- 11.5-28.5%
- 28.5-51.5%
- 51.5-68.5%
- 68.5-81.5%
- 81.5-100%

Figure 3:
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EM-31 Percentile
Map and drill points

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200 0 200 400 Meters

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Reversed grid legend

- 0-18.5%
- 18.5-31.5%
- 31.5-48.5%
- 48.5-71.5%
- 71.5-88.5%
- 88.5-91.5%
- 91.5-93.5%
- 93.5-96.5%
- 96.5-100%

soil knowledge. Unlike the raw map, the colours in a percentile map have no relationship to the absolute ECa readings; that is, dark red in one field will represent ECa readings different to those represented by dark red in another field.

Percentile maps provide guidance in selecting the most appropriate locations for soil drilling and texturing. In the mapping process, one drill point is selected in each ECa class, or colour. The results of the soil drilling and texturing are assumed to hold true for the entire area covered by that ECa class.

4. Soil drilling and interpretation

Because salt and moisture conditions influence ECa, EM-31 measurements cannot be generally related to soil texture. The proportions of clay, silt and sand existing within the ECa classes of a field are not known until soil drilling and texturing is carried out. Coleambally Irrigation investigated the possibility of using already-existing soil information to interpret EM-31 maps, but this is not possible because the drilling locations were estimated without the use of a GPS and cannot be accurately compared to EM-31 maps.

4.1 Soil Drilling

For a farm EM-31 survey, it is required that all fields in which rice can be grown are drilled. Contractors who tendered for and attained contracts with Coleambally Irrigation carry out the soil drilling. The contractors use differential GPS's to navigate to drill points selected during the mapping process.

The drilling is carried out to a depth of 3.6 metres with an auger of width about 10 centimetres. Soil samples are collected and textured every 0.3 metres down to 1.5 metres, and then every 0.5 metres to 3.6 metres. The contractors supply a report for each farm drilled detailing the farm number, landholder, drilling operator, date, paddock numbers, drill numbers, sample depths, sample colours and sample textures. Comments are also made on the presence of water, calcium carbonate, gypsum, mica and any other characteristics that may be of interest. For example, the presence of calcium carbonate and gypsum may indicate that the soil is porous. Soil characteristic abbreviations used in drill reports and their definitions are listed in Appendix 1.

4.2 Interpretation

If a drill hole contains three metres or greater of medium or heavy clay, the ECa class in which it occurs is deemed suitable for growing rice. If it contains less than three metres of medium or heavy clay, the ECa class is deemed unsuitable. The Rice Environmental Policy Advisory Group (REPAG) established this standard for the Murrumbidgee Region.

Within a field, it is expected that ECa will increase with the proportion of clay in the soil profile.

One drill point is selected in each ECa class in Figure 3. For fields currently classified as suitable for growing rice, drilling commences in the lowest class (dark red) and is

continued in ascending order of ECa class until a drill yields three metres or greater of medium to heavy clay. In this way, the number of soil drills carried out can vary for different fields. A field in which the soils all contain three metres of medium to heavy clay would only require one drill, while a soil with greater than 28.5 percent of soils not containing three metres of medium to heavy clay would require six or more drills (see ***3.3***). All ECa classes greater in value than the classes drilled are assumed to contain three metres of medium to heavy clay.

For fields currently classified as marginal (allowed to grow rice one year in four) or unsuitable (not allowed to grow rice), it is necessary to drill all ECa classes. This is because it is more likely that variations in salt conditions are influencing ECa in these fields and any anomalies (see below) must be identified. Unsuitable fields will only be drilled if requested by the landholder.

Areas lacking three metres of medium to heavy clay

Areas found by EM-31 surveys to lack three metres of medium to heavy clay are defined as follows:

- *For fields currently classified as suitable or marginal:* Up to four of the lowest ECa classes in Figure 3 (equating to around ten to twenty percent of the field) found to lack three metres of medium clay will have a red polygon traced around them (Figure 4). One or more of the higher ECa classes found to lack three metres of medium to heavy clay will have a pink polygon traced around them (Figure 4). Based on the EM-31 results, Coleambally Irrigation recommends that steps be taken to avoid growing rice in any areas lacking three metres of medium to heavy clay where there is a high rice water use. Priority should be given, however to areas with a red polygon traced around them (ie the first ten to twenty percent of the field with the lowest ECa values), as these areas within the field are likely to be using the most water.

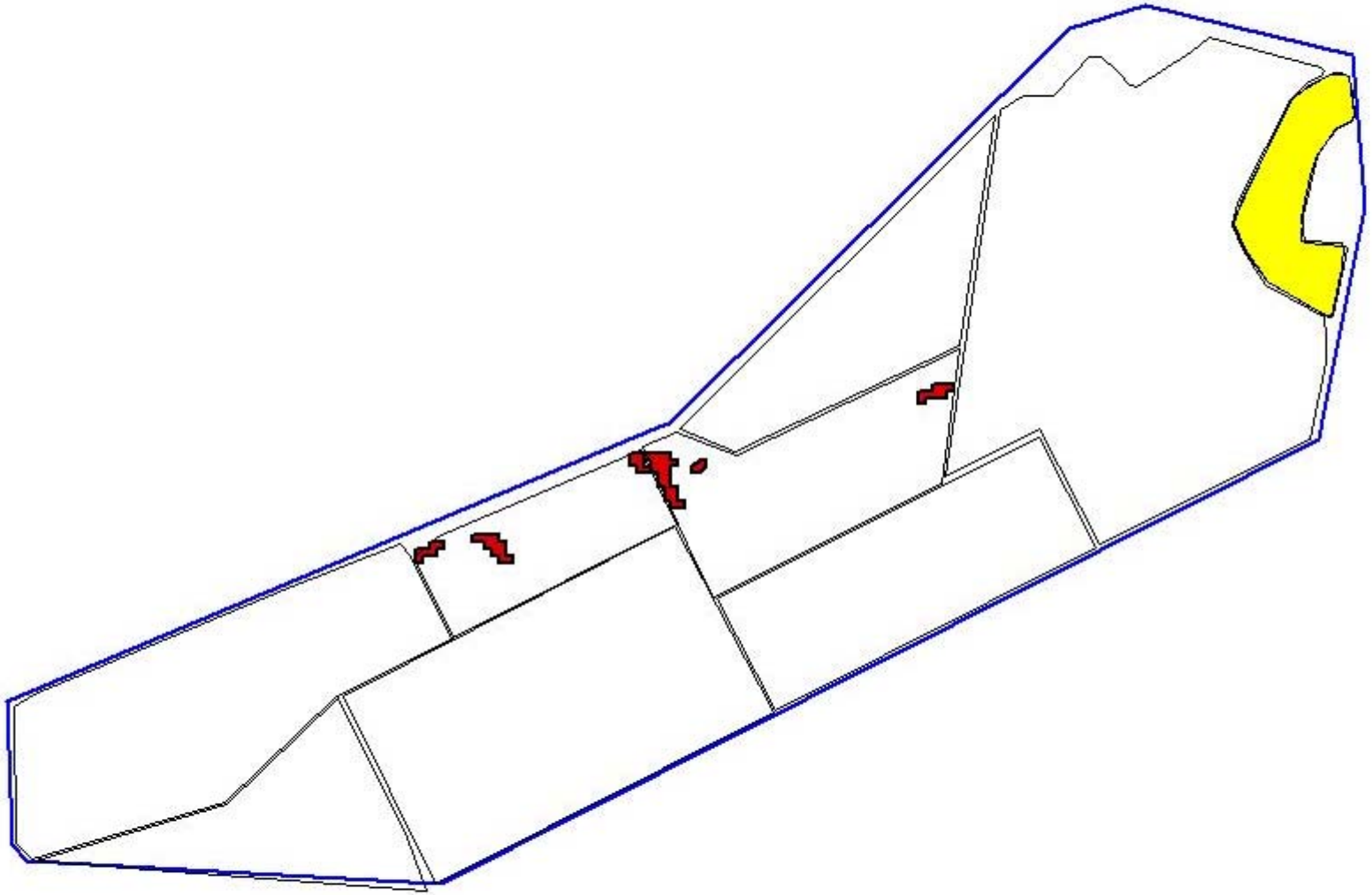
- *For fields currently classified as unsuitable:* ECa classes found to lack three metres of medium to heavy clay have a red polygon traced around them.

If marginal and unsuitable areas are found to contain three metres of medium to heavy clay, the rice classification of these areas can be changed. Rice soil classifications will only be altered however if a paddock rice water use test indicates that these areas will not use excessive amounts of water.

Anomalies

For a range of possible reasons, the proportion of clay in the soil profile sometimes does not correlate with ECa. This means that soils lacking three metres of medium to heavy clay for growing rice can sometimes occur in the classes not drilled.

Soils lacking three metres of medium to heavy clay can be particularly difficult to identify in fields that have not had rice grown in them for some time. This could be due to natural variation in the salt content of the soil. Where there is a high watertable however, varying levels of salt can be deposited within a field by capillary action.



Farm 108a
EM-31 Survey & Interpretation

N

100 0 100 Meters

EM-31 Results & Interpretation

- Lowest EM tacking 3m MC
- Remainder tacking 3m MC

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Where these deposits of salt are not flushed down through the soil profile by rice cropping, they can influence ECa such that it does not vary with soil type.

Anomalies can also occur if a nearby channel has been seeping water into the soil profile over a period of time. This water tends to follow lighter-textured soils. As the water then evaporates from the soil profile, it leaves deposits of salt, which elevate the ECa of the soil. In this way, soils unsuitable for growing rice can occur in classes with relatively high ECa and may not be identified.

For the above reasons, some landholders may opt to have all ECa classes drilled in paddocks currently classified as suitable for rice. In this way, anomalies can be identified and treated accordingly. For some fields it may be necessary to re-survey the field after it has had a crop of rice grown on it and the influence of salt on the EM-31 measurements is minimised. In Fig 4, any field where this is necessary is defined by a green polygon titled “To be resurveyed”.

Due to variation in field conditions, it can occur that different amounts of clay can occur within the area represented by an ECa class, particularly where parts of the class are separated by significant distance. This is an important fact to remember when interpreting EM-31 information.

Another factor to be taken into account when interpreting EM-31 maps and soil drilling results is the alteration of soil trends through cut and fill practices. Knowledge of cut and fill areas in fields can help in understanding features present in EM-31 maps.

5. Whole Farm Plans

For farms having Whole Farm Plans (WFP) designed, the interpretation maps will be forwarded to the WFP contractors. These maps are overlaid with paddock boundaries and other information to determine the best designs and cropping strategies for the farm.

6. Prior streams

There are three major prior stream systems traversing the Coleambally area, including the Coleambally and Kerarbury systems, and an older, undated system that passes through the Boona State Forest. There are also many smaller, less distinct prior streams in the area. Prior streams are typically composed of sand and other lighter materials sometimes underlain by gravel. If irrigated, prior streams can cause substantially higher crop water usage, even if only comprising a small proportion of a paddock.

EM-31 maps are displaying prior streams clearly and accurately. Prior streams often appear on EM-31 maps as curved strands different in colour to the surrounding paddocks. They may be characterised by ECa values less than 70, sometimes as low as 20. In many cases EM-31 surveys are defining prior streams with greater accuracy

than the current rice soil classification, allowing landholders to avoid prior streams by improving paddock boundaries.

Cleared linear depressions are also being identified by EM-31 due to their lighter soil textures. These tend to be more closely defined than prior streams.

7. Soil sodicity

Soil texture is not the only soil property affecting the volume of water used to grow rice crops. The sodicity of, or concentration of sodium ions in, the soil profile also affects the ability of a soil to hold water when under crop.

Coleambally Irrigation is storing samples from all drilling for analysis of sodicity if required. NSW Agriculture has proposed a three-stage classification scheme as follows:

1. Include the soil as suitable if the EM-31 ECa measurement is equal to or greater than 150 mS/m;
2. If ECa is <150, include the soil as suitable if the Exchangeable Sodium Percentage (ESP) of the top 60 cm of soil is greater than 6, or the ESP of the depth interval between 60 and 150 cm is greater than 12;
3. All other soils are excluded from rice growing.

Coleambally Irrigation will use this information to assist in rice soil classification.

Cemented or compacted layers may also occur in the soil profile. In areas with very little medium or heavy clay in the soil profile, the presence of compacted layers may prevent excessive rice water usage. Where recognised, the drilling contractors make note of “hard” layers in the soil profile.

APPENDIX 1: SOIL CHARACTERISTIC ABBREVIATIONS

TEXTURAL ABBREVIATIONS	
HC	Heavy Clay
MC	Medium Clay
LC	Light Clay
SiC	Silty Clay
SC	Sandy Clay
FSC	Fine Sandy Clay
FSCL	Fine Sandy Clay Loam
SiCL	Silty Clay Loam
CL	Clay Loam
SCL	Sandy Clay Loam
SiL	Silt Loam
L	Loam
LSCL	Light Sandy Clay Loam
SL	Sandy Loam
ClyS	Clayey Sand
LS	Loamy Sand
FS	Fine Sand
S	Sand
CS	Coarse Sand
FGvl	Fine Gravel
Gvl	Gravel

COLOUR ABBREVIATIONS	
R	Red
B	Brown
Y	Yellow
Gn	Green
G	Grey
W	White
Blk	Black

OTHER ABBREVIATIONS	
/c	With
cc	Calcium carbonate
gyp	Gypsum
Mn	Manganese
cem	Cemented
mic	Micas
mnr	Minor
+	And
mot	Mottled
Lt	Light
Dk	Dark
(+)	Bright
(-)	Dull

This document has been written to inform farmers in the CIA of the steps involved in carrying out EM-31 surveying and the related issues. Any enquiries on Coleambally Irrigation's EM-31 project should be directed to:

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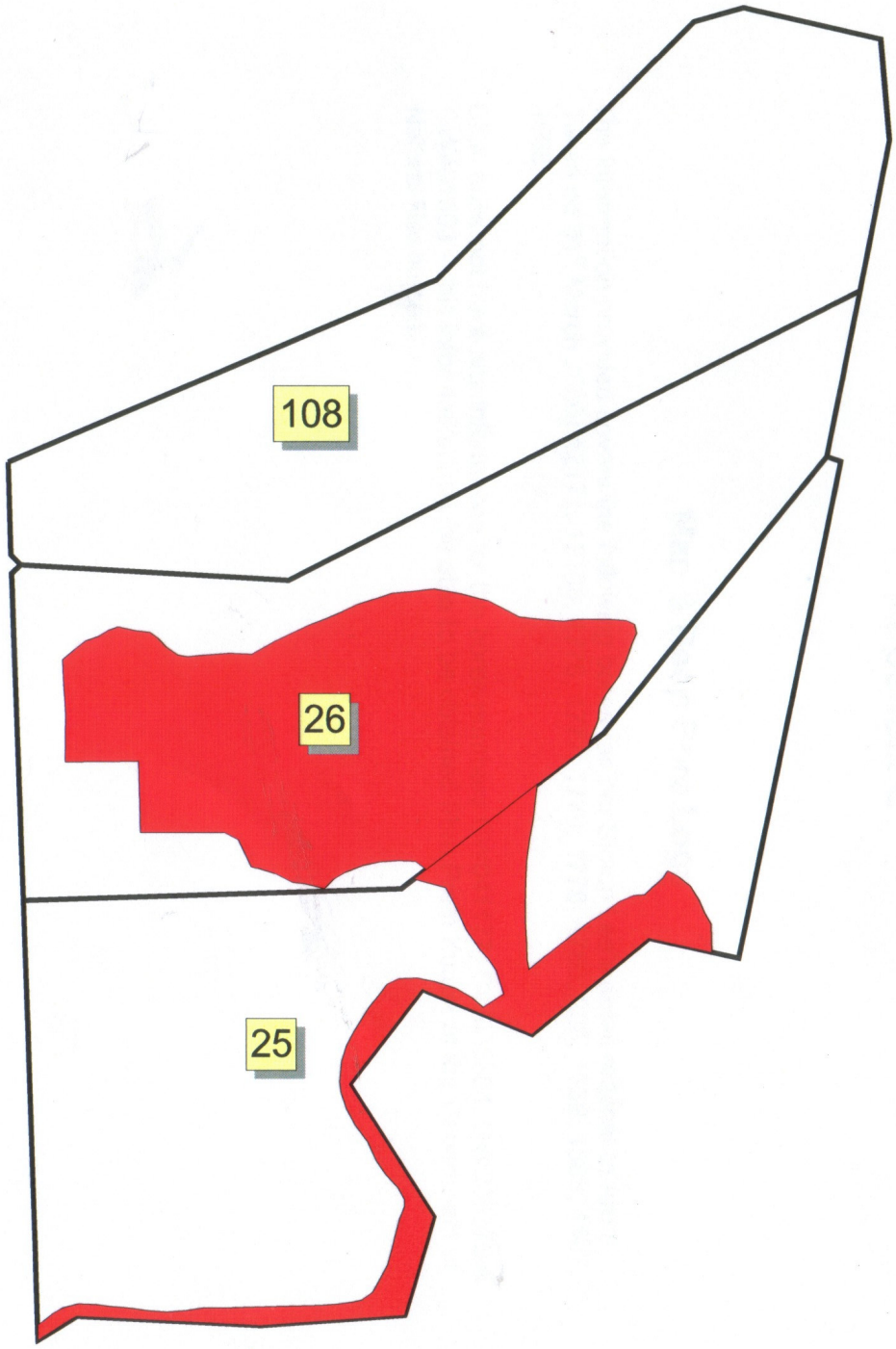
Farm 108 Additional
Farm 26 Additional
Farm 25 Additional
Rice Soil Suitability



N

100 0 100 200 Meters

Legend

- Suitable
- Marginal
- Unsuitable

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