PeritusAg Advisory

HIPCo DBC – Hughenden Irrigation Project
Soil Survey, Erosion and Salinity Management Report

18 June 2021

Contents

1 Introduction ... 3
2 Executive Summary ... 4
3 Soil Survey Methodology ... 8
4 Salinity Risk Assessment and Management ... 40
5 Erosion Risk Assessment and Management ... 44
6 Crop Management Strategies to Minimise the Potential for Salinity and Erosion ... 49

Tables

Table 2.1: Summary of the suitability of crops by survey site ... 7
Table 3.1: Summary of sites 4, 5 and 7 ... 18
Table 3.2: Summary of sites 1, 2 and 3 ... 19
Table 3.3: Crop suitability by soil survey site ... 20
Table 3.4: Summary of site one chemical attributes ... 23
Table 3.5: Summary of site two chemical attributes ... 26
Table 3.6: Summary of site three chemical attributes ... 29
Table 3.7: Summary of site four chemical attributes ... 32
Table 3.8: Summary of site five chemical attributes ... 35
Table 3.9: Summary of site seven chemical attributes ... 39
Table 4.1: Summary of salinity risk and potential management strategies ... 41
Table 5.1: Soil erodibility factor ... 47

Images

Image 1.1.1: Soil survey area ... 3
Image 2.1: Potential irrigation area ... 5
Image 3.1: CSIRO soil depth map showing variability across the proposed irrigation area ... 10
Image 3.2: CSIRO clay content map showing variability across the proposed irrigation area ... 11
Image 3.3: CSIRO soil pH map showing variability across the proposed irrigation area ... 12
Image 3.4: CSIRO soil erosivity map showing variability across the proposed irrigation area ... 13
Image 3.5 CSIRO soil sodicity map showing variability across the proposed irrigation area ... 14
Image 3.6: CSIRO soil conductivity showing salinity risk variability across the proposed irrigation area ... 15
Image 3.7: Site locations based on assessments using CSIRO soils maps ... 16
Image 3.8: Potential irrigation area ... 17
Image 3.9: Detailed description site one ... 22
Image 3.10: Detailed description site two ... 25
Image 3.11: Detailed description site three ... 28
Image 3.12: Detailed description site four ... 31
Image 3.13: Detailed description site five ... 34
Image 3.14: Detailed description site seven ... 38
Image 4.1: FGARA CSIRO electrical conductivity map ... 42
Image 4.2: FGARA CSIRO exchangeable sodium percentage map ... 43
Image 5.1: FGARA CSIRO erosivity prediction map ... 46

1 Introduction

Instructions

1.1 PeritusAg was retained to complete a survey of soils in the proposed irrigation area for the HIPCo project.

Brief Overview

1.2 The purpose of this report is to provide the following:

a) An understanding of the soil types and their characteristics in the proposed irrigation area.

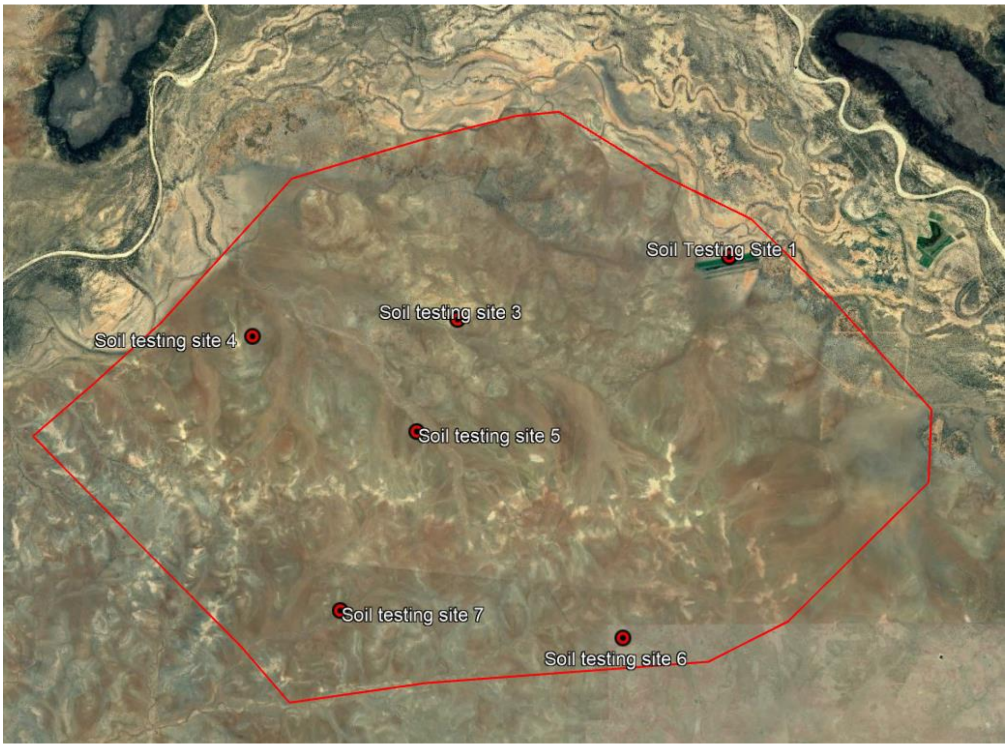
b) An understanding of areas that are suitable for crop production in the proposed irrigation area and what those crop types could be.

c) An understanding of what the soil management considerations are for their sustainable long-term use in the proposed irrigation area.

1.3 The observations and outcomes from this investigation will be used to guide a more detailed study during the next phase of the HIPCo Project being the Environmental Impact Study (EIS).

1.4 The survey area is a total of 15,000ha and is approximately 45km west of Hughenden. ***Image 1.1*** shows the proposed irrigation area that was identified during the Preliminary Business Case (PBC) and the selected soil survey sites.

Image 1.1.1: Soil survey area



1.5 When the sites were attended by PeritusAg, it was identified that site 6 was unsuitable for assessment due to the presence of mudstone and shale on the soil surface and, in consequence, was removed from the survey.

1.6 It is important to understand that if a project progresses, more detailed soil surveys will be required to meet the following criteria:

a) Assessment requirements to comply with becoming a coordinated project.

b) Higher level of detail prior to the final decision on soil suitability and location of specific farming blocks.

c) Ensuring the irrigated farming is located on the best/most appropriate soils to enable long-term sustainability.

2 Executive Summary

2.1 To evaluate the suitability of the soils in the proposed irrigation area, a soil survey was conducted with seven sites identified for detailed investigation.

2.2 Of the sites chosen, excavations were conducted at sites 1 – 5 and 7, as site 6 was considered unsuitable for cultivation due to the presence of mudstone and shale on the soil surface.

2.3 At each site, an excavation was conducted down to 1.5 – 1.8m or until the C horizon (parent material) was exposed.

2.4 Each excavated site was assessed for the following characteristics:

a) chemical analysis

b) physical assessment

c) identification and classification of the soil profile.

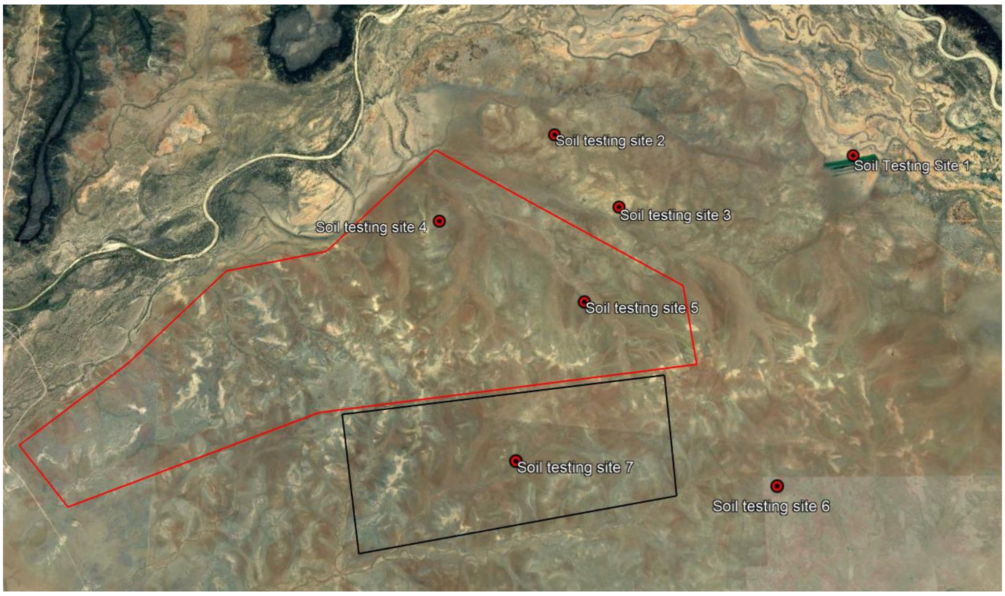
2.5 Through the soil survey process, the sites that were identified as the most suitable for pasture or annual crop production were sites 4, 5 & 7, while horticulture (trees etc.) were most suited to site 7.

2.6 The soils for sites 4, 5 & 7 were all manageable when using with modern soil and crop management strategies that promote increased soil health and maximising crop performance.

2.7 Sites 1 – 3 could be successfully irrigated with appropriate management techniques, however, in a greenfield scheme, the better soils are targeted for development.

2.8 Site 1 has had a history of some irrigated cropping, however, based on the soil survey, there are better soils in the area that would be more suited to irrigated farming.

Image 2.1: Potential irrigation area



2.9 The area outlined in black is the approximate area associated with site 7 and that is the most suitable for horticultural crop production, such as avocados, mangoes, citrus and camellia.

2.10 The area outlined in red is the approximate area associated with sites 4 and 5 and is the most suitable for pasture and broadacre crop production, such as rhodes grass pasture, forage crops, grain (sorghum and maize), cereal (wheat and barley) and pulse (mung beans and chickpeas) crops.

2.11 The approximate available areas are as follows:

a) horticulture – 2300ha

b) annual cropping/hay – 6100ha.

2.12 During the soil survey, the broader landscape was visually assessed for signs of salinity and erosion to add to data and observations made from the excavated sites.

2.13 Any incidences noted of salinity and erosion appear manageable on the proposed most suitable sites of 4, 5 and 7.

2.14 Points to note regarding salinity include:

a) sodicity (high sodium) in the full profile of site 1

b) sodicity in B and C horizons across all sites

c) high EC (total salt content) and chloride in lower parts of the soil profile for all sites

d) depth of the surface soil (where crops grow) varied from 350 – 900mm, with the most suitable sites ranging from 500 – 900mm deep.

2.15 In many of the sites, boron is either high or very high and may initially be a challenge for some crops that are sensitive to boron (such as citrus). Boron moves in the soil profile reasonably easily and it is expected that once permanent irrigation is installed, the boron levels will move through the profile towards the B horizon over time. The challenge of boron in these soils has been peer reviewed and the consensus is that the levels can be effectively managed like other sites further south.

2.16 Points to note regarding erosion include:

a) Erosion occurs currently in high traffic and low ground cover areas.

b) Slope length will drive broader soil erosion issues as water gains velocity and volume further down a long slope.

c) Managing extreme rainfall events will be challenging.

d) Erosion risk will increase once larger areas of native pasture are removed.

2.17 The erosion risks will need to be actively considered and managed as the removal of perennial pasture across a wider area will likely increase the risk of soil movement due to overland water flow.

2.18 Salinity and erosion mitigation strategies include the following:

a) choice of irrigation delivery system to meet soil constraints.

b) accurately matching irrigation depth with rooting depth.

c) avoiding irrigating into the lower soil profile where salinity risks are present or below the active root depth.

d) irrigation scheduling to match crop demand with application.

e) maintaining ground cover (grassed interrow, stubble retention, min/zero till).

f) managing on-farm drainage.

g) managing whole of scheme drainage.

2.19 Following on from the review of the specific soil sites and in consideration of the risk and management of salinity and erosion, ***Table 2.1*** summarises the suitability of the crops by survey site.

2.20 The crop suitability table considers three key aspects:

a) broad suitability (climate, soil, water use, markets)

b) commercial suitability (potential economic viability)

c) level of crop management skill required for successful production to occur.

2.21 For each of these key areas, a rate of low, medium and high has been used, where low relates to low suitability or low level of crop management skill and high relates to high suitability or high level of crop management skill.

Table 2.1: Summary of the suitability of crops by survey site

Site No	Crop	Suitability (L - M - H)	Commercial Suitability (L - M - H)	Crop Management Requirement (L - M - H)
1	Hay	M	M	H
	Grain crops	L	M	H
2	Hay	M	M	H
	Grain crops	L	M	H
3	Hay	M	M	H
	Grain crops	L	M	H
	Forage sorghum	M	M	H
	Maize/corn	L	M	H
4	Hay	M - H	M - H	L - M
	Grain crops	M - H	M - H	L - M
	Forage sorghum	M - H	M - H	L - M
	Maize/corn	M - H	M - H	L - M
5	Hay	H	M - H	L - M
	Grain crops	M - H	M - H	L - M
	Forage sorghum	M - H	M - H	L - M
	Maize/corn	M - H	M - H	L - M
	Cotton	M - H	M - H	L - M
7	Avocados	M - H	M	M - H
	Mangos	M - H	M - H	L - M
	Citrus	M - H	M - H	M
	Pecans	M	M	M - H
	Camellia	M - H	M - H	L - M
	Hay	H	M - H	L - M
	Grain crops	M - H	M - H	L - M
	Forage sorghum	M - H	M - H	L - M
	Maize/corn	M - H	M - H	L - M
	Cotton	M - H	M - H	L - M

3 Soil Survey Methodology

Methodology

3.1 As the HIPCo Project progresses through the Detailed Business Case (DBC) feasibility phase, a more detailed analysis of the soils in the proposed irrigation is required.

3.2 This section will focus on the soil sites selected for more detailed investigation and provide data and information that supports the following requirements:

a) soil suitability and limitations to irrigated crop production.

b) risk of salinity

c) risks associated with soil erosion.

3.3 The soil survey sites were selected using four key criteria:

a) agronomy: identification of sites that cover the broad soil variability, using available soil type data maps

b) available soils maps and imagery

c) local knowledge: use of landholder experience regarding site access, terrain, historical pasture performance, overland water flow etc.

d) cultural Heritage: Traditional Owners Representative (TOR) provided guidance and approval for excavation based on a surface inspection for significant cultural artefacts.

3.4 When at a specific site, the exact location to excavate was identified to ensure that it was representative of the general area, in terms of the following:

a) fence lines

b) high traffic areas (vehicles or stock routes)

c) slope

d) pasture growth

e) surface soil structure.

3.5 The excavation site was assessed by the TOR prior to the movement of any soil.

3.6 The excavation was performed by a wheeled loader with a front mounted bucket, owned and operated by the landholder.

3.7 The excavation process included the following steps:

a) removal of the top 100mm of soil which was placed in a mound.

b) the site was excavated down to a depth of 1500 – 1600mm or until 100 – 200mm of C horizon (parent rock material) was exposed.

c) once the site inspection was completed, the hole was filled back and levelled with the reserved topsoil being replaced evenly across the excavated area.

3.8 The soil profile assessment included the following steps:

a) identification of soil profile changes with horizon changes being marked with white spray-paint.

b) photographs of the profile with depths identified using a tape measure.

c) soil samples were collected for chemical analysis from each soil profile depth.

d) a field pH from each profile depth was taken.

e) each soil profile depth was characterised by colour using the Munsell Soil Colour Book.

f) soil texture for each depth increment was evaluated using the ribbon method.

g) the profile was also inspected more generally for structure and other defining features, and the presence of colour patterns (e.g. mottles).

Site Selection and Location

3.9 For the selection of the sites where soil assessments were made and soil samples were taken, we used CSIRO Digital Soil Mapping outputs for the Flinders Gilbert Agricultural Resource Assessment (FGARA). The maps provide information of the following attributes:

a) soil depth

b) clay content

c) soil pH

d) soil erosivity

e) sodicity and salinity in soil.

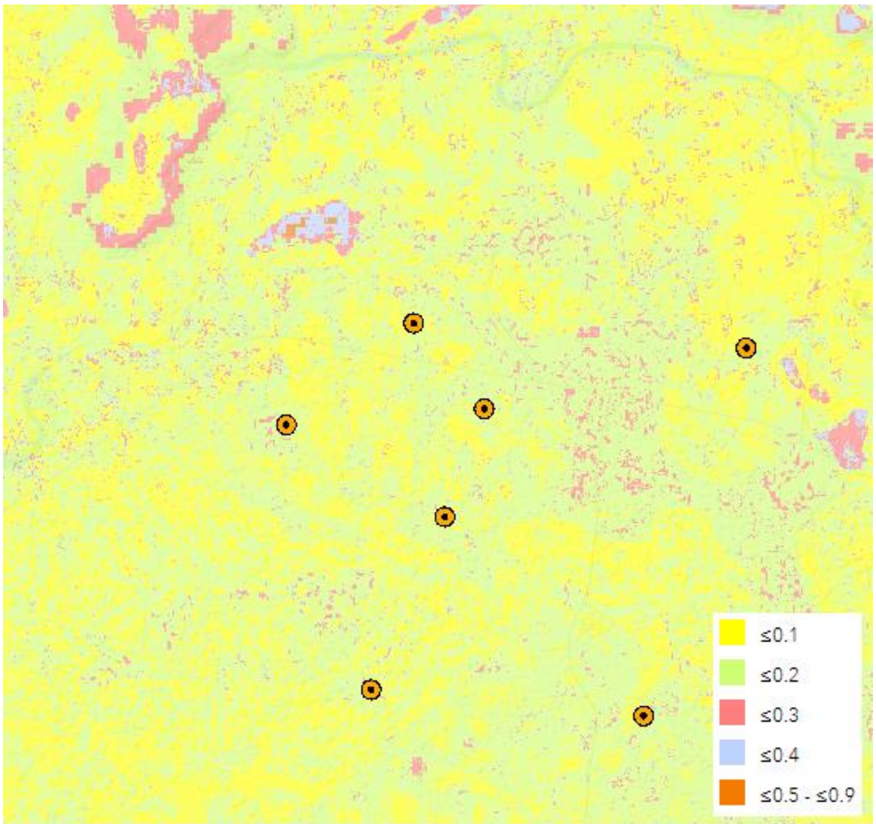
3.10 The CSIRO maps were produced using data from existing databases, new sensor measurements and novel spatial modelling.

3.11 For this project, the CSIRO maps provide a valuable starting point to understanding the uniformity of the soils prior to selecting sites for subsequent and initial subsurface investigations.

3.12 It was expected that the CSIRO maps would not provide accurate granular data (accurate high-resolution data) but would provide a reliable indication of what to expect during the excavations. This would enable reasonable planning for specific excavation sites and the soil characteristics found during the survey.

3.13 ***Images 3.1 – 3.6*** shows the various layers from the CSIRO maps and that were used to assist us in selecting the agronomic location for the sites.

Image 3.1: CSIRO soil depth map showing variability across the proposed irrigation area

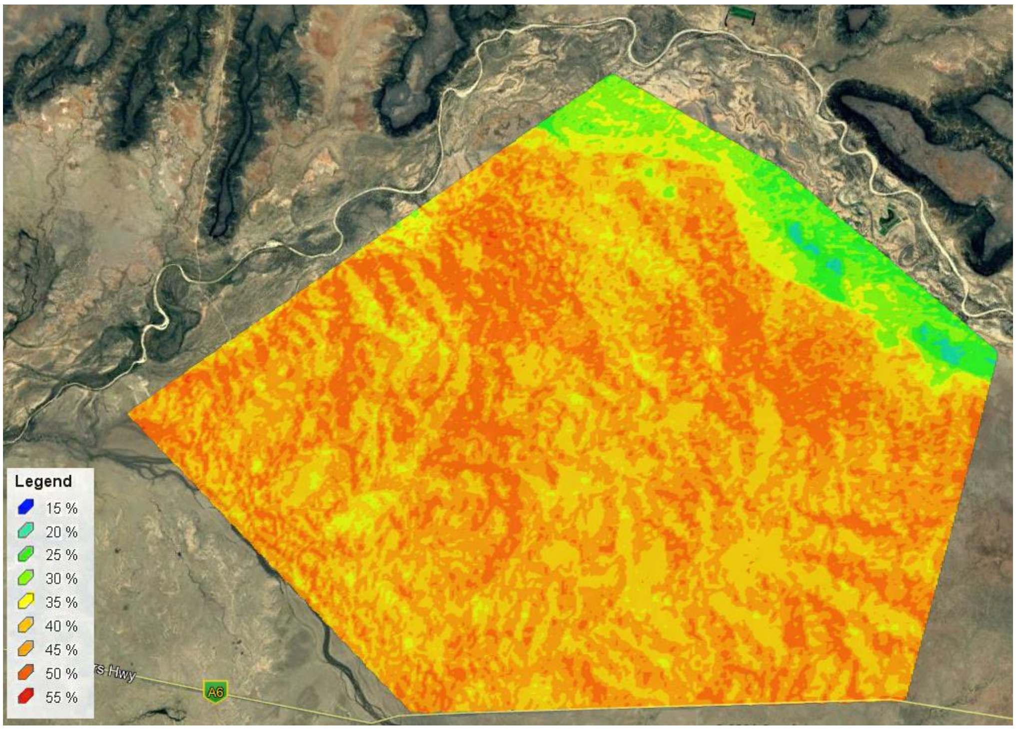


3.14 The dots on the map indicate the location of the soil excavation sites.

3.15 The map indicates that most of the proposed irrigation region has an A horizon (topsoil) depth of 100 – 300mm.

3.16 During the soil survey process, the A horizon depth was found to range from 300 – 900mm and as such this map was not found to be very representative of the site.

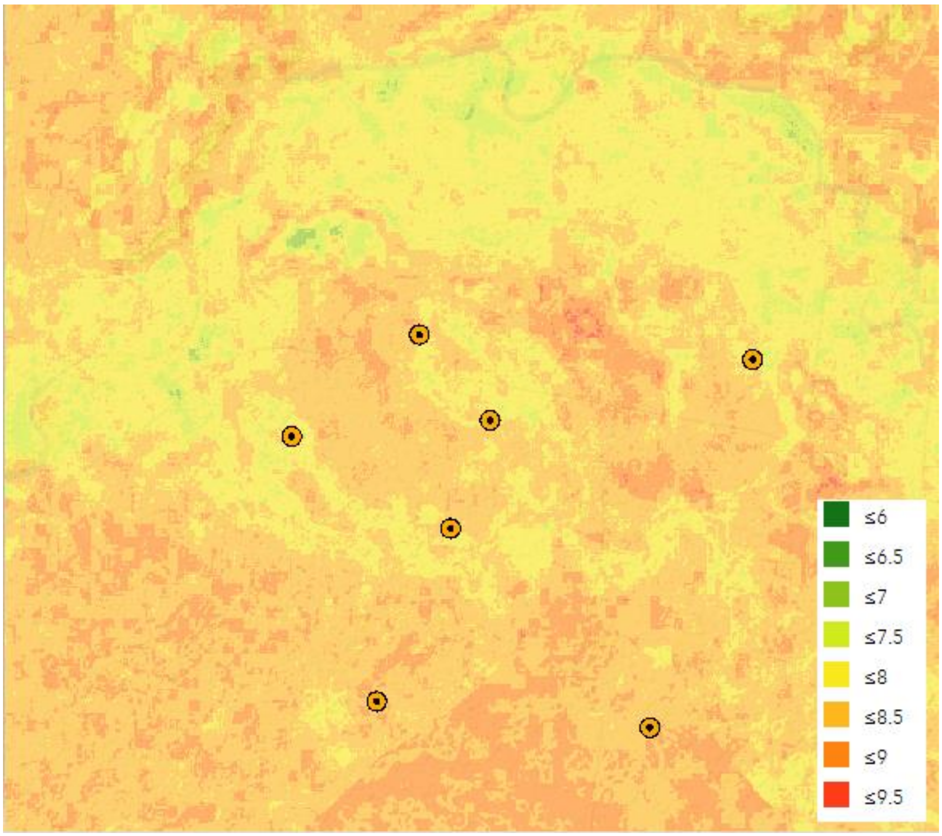
Image 3.2: CSIRO clay content map showing variability across the proposed irrigation area



3.17 The colour range in ***Image 3.2*** runs from blue to red as per the legend. The colours identify the heaviness of the clay with blue being the lightest clay and the red areas being the heaviest clay.

3.18 Of note, the soils closest to the Flinders River are lighter in clay content and, in consequence, are not well suited to flood irrigation, while the remainder of the proposed irrigation area ranges from 35 – 55% clay.

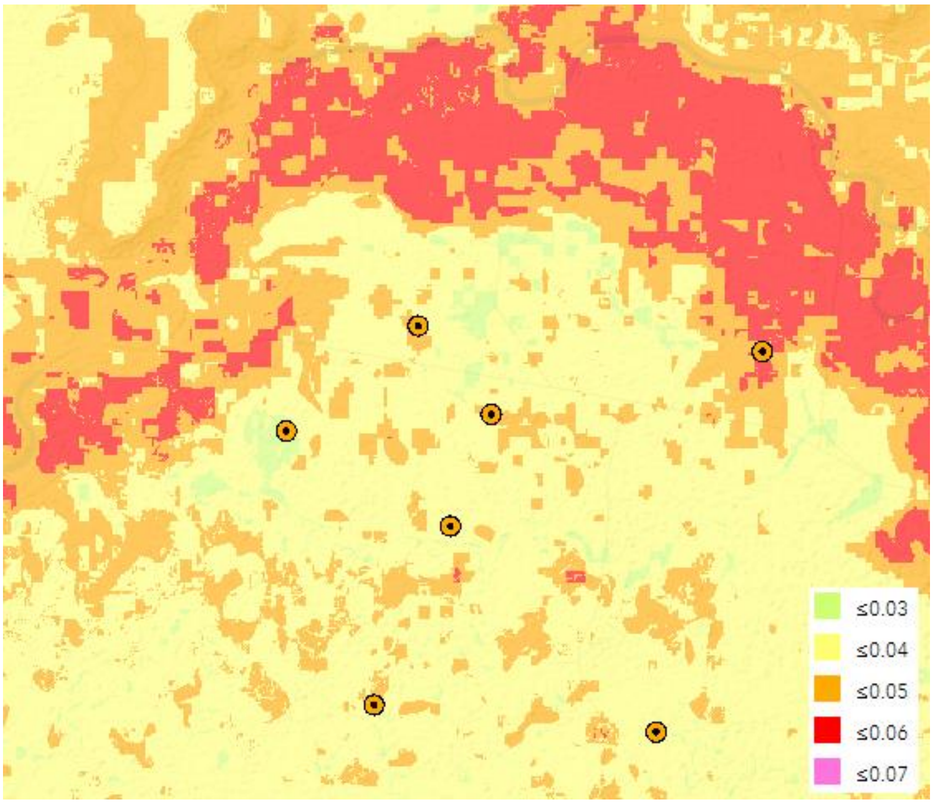
Image 3.3: CSIRO soil pH map showing variability across the proposed irrigation area



3.19 The map indicates that the expected soil pH ranges from7.5 – 9 across the proposed irrigation area.

3.20 This map was shown to be representative of the pH values that were recorded from the soil excavation sites.

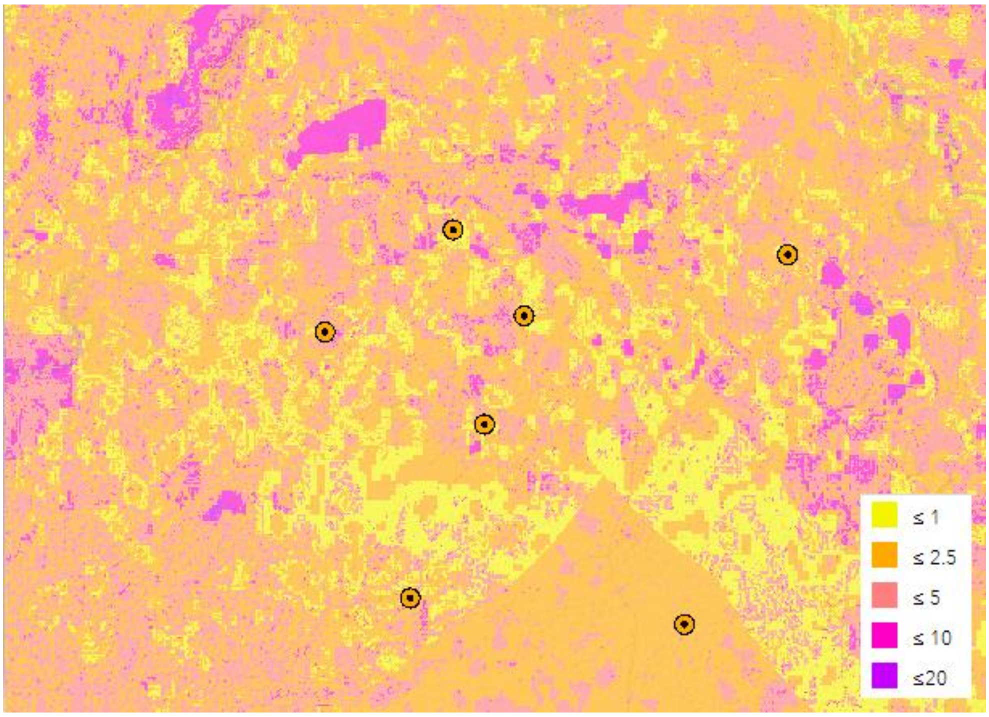
Image 3.4: CSIRO soil erosivity map showing variability across the proposed irrigation area



3.21 The erosivity map indicates that the soil erosivity is consistent across the proposed irrigation area ranging from 0.04 – 0.05.

3.22 The soil classification process used in the soil survey identified that the A horizon soil type was very consistent across the proposed irrigation area.

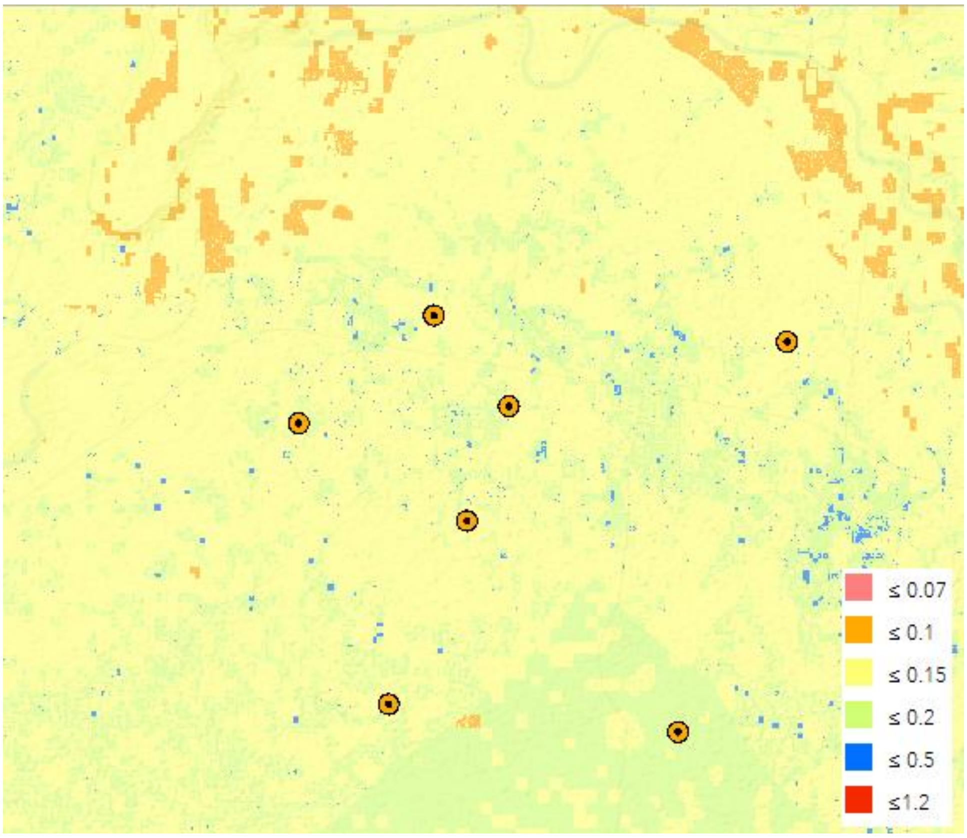
Image 3.5 CSIRO soil sodicity map showing variability across the proposed irrigation area



3.23 The map indicates that the risk of sodicity ranges from 1 - >20% across the proposed irrigation area.

3.24 The legend is showing the exchangeable sodium percentage in percent (%).

Image 3.6: CSIRO soil conductivity showing salinity risk variability across the proposed irrigation area



3.25 The risk of soil salinity, as measured by electrical conductivity (EC) is shown as ranging from 0.15 – 0.2 across the proposed irrigation area with only small areas with a very high EC value (up to 0.5).

Soil Site Selection

3.26 The objective of the soil survey was to ground truth the CSIRO maps and provide accurate soil characteristics data in discreet sites across a broad area. The key considerations used to decide on the soil sites 1 – 5 were as follows.

a) desire to have the irrigation area close to the proposed water storage location

b) ensure that the risk of impacting Cultural Heritage sites was low

c) using all existing map data and Google Earth images, attempt to select sites that would represent the range of soil across the area

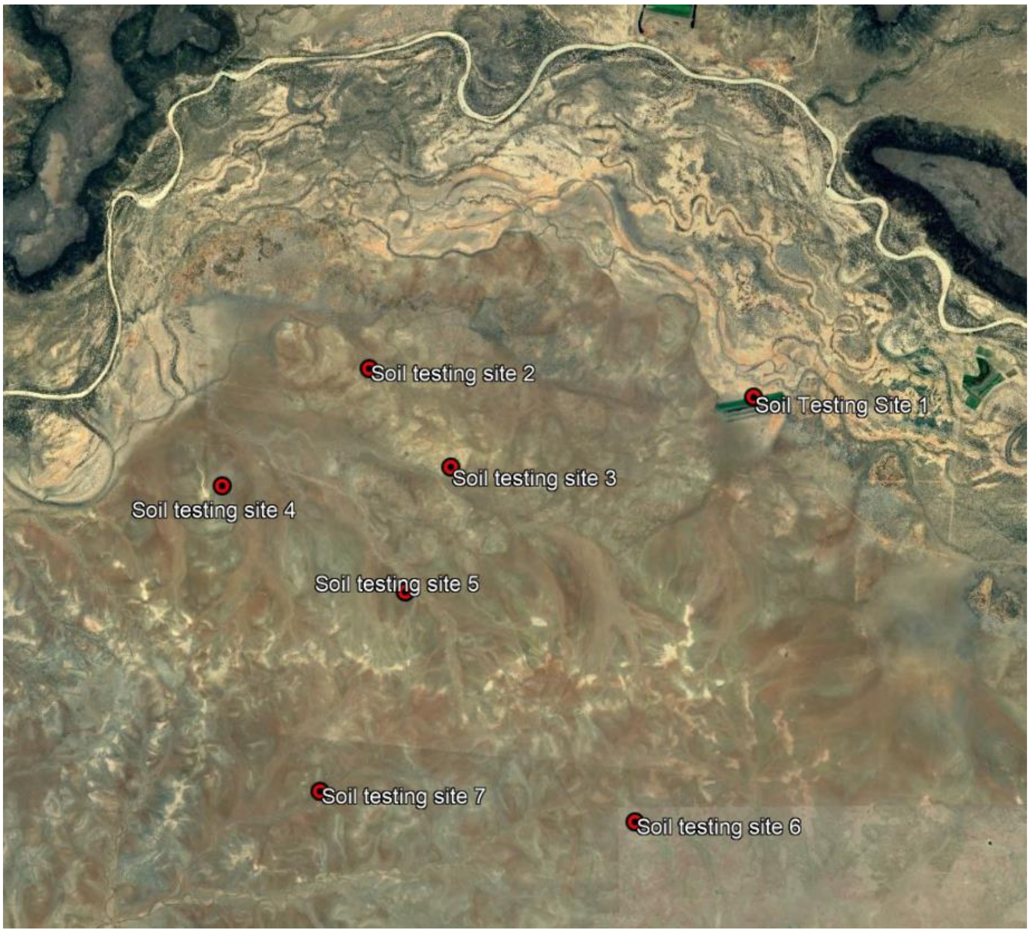
d) sites to cover an area of approximately 10,000 hectares.

3.27 The sites 6 and 7 were selected based on being higher up the landscape slope to gain an understanding of how consistent the soils were at a higher elevation and at a greater distance from the water storage location.

3.28 The CSIRO maps indicated that the soil characteristics across the proposed irrigation area were reasonably uniform.

3.29 ***Image 3.7*** shows the location of the seven sites selected for detailed site inspections from the CSIRO soils maps.

Image 3.7: Site locations based on assessments using CSIRO soils maps



3.30 During the initial site assessment with the landholder, site 6 was removed from the excavation process due to the presence of significant quantities of shale, stones and rocky outcrops on the surface. At this point in the assessment, a decision was made that this location would not be suitable for cultivation of irrigated crops.

3.31 The cultural heritage assessment by the TOR occurred just prior to the commencement of the site excavation. No significant artefacts were located at any of the sites. This meant no sites were required to be moved.

Summary of Soil Survey Results: Preferred Sites

3.32 From the soil survey and subsequent soil testing, we have identified three sites (4, 5 and 7) that are the most suitable for irrigated agriculture across the proposed irrigation area. ***Image 3.8*** is a Google Earth view of the potential irrigation cropping areas for MP and HPAg production.

3.33 The physical and chemical characteristics that make these three sites the most suitable are as follows:

a) depth of A horizon (500 – 900mm)

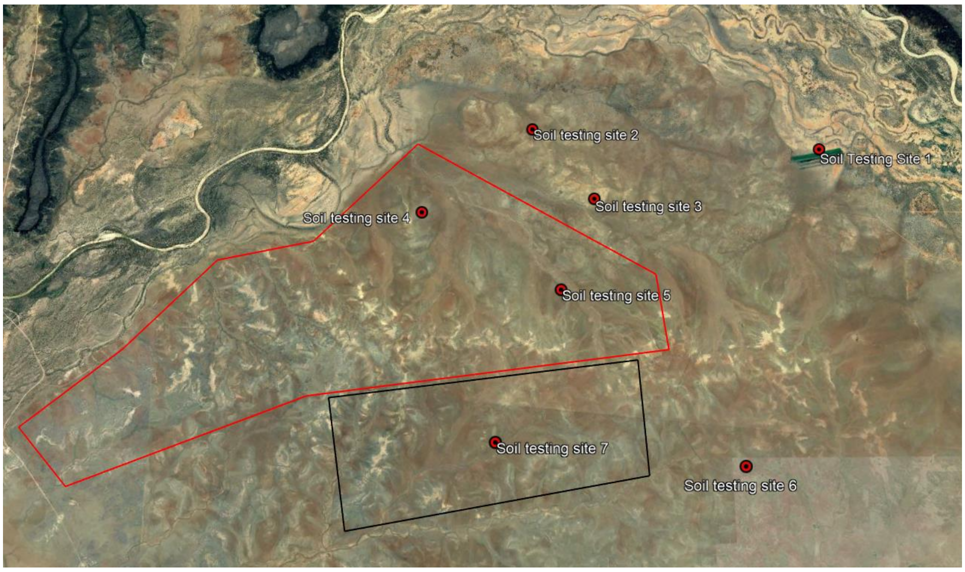
b) low – moderate salinity (EC, sodium and chloride)

c) manageable elemental chemistry

d) friable soil structure

e) good soil moisture holding capacity.

Image 3.8: Potential irrigation area



3.34 It was expected that the soil characteristics across the proposed irrigation area were reasonable uniform selected soil sites would prove to indicate some variability but not significant variability.

3.35 What was identified was that the sites further south improved in suitability compared to the northern sites.

3.36 A proposal for an additional soil survey to include additional soil sites in the DBC phase to cover more widely the proposed irrigation areas (red and black boundaries) has been submitted following the outcome of this initial soil survey activity.

3.37 To enable accurate boundaries to be drawn for MP and HPAg crop production, significant further work will be required. (Note: To comply with state planning requirements, it is anticipated that the EIS phase will require an in-depth soil survey of 4 - 16 soil sites for every 100 hectares).

3.38 In deciding on how to define potential irrigation zones, the following considerations were used.

a) if water is the limiting factor to irrigated area, selecting soil zones with the 'best' characteristics was deemed appropriate

b) the cost of additional delivery network pipes to move water further south was deemed to be not significant

c) the A horizon soil depth increased going south

d) locating perennial horticulture in the area with the deepest A horizon seemed appropriate. Horticulture is also more capable of paying higher pumping costs due to elevation.

e) locating annual crops or hay on the shallower A horizon seemed reasonable as these crops can all perform well in soils ranging from 350 – 500mm deep. Annual crops and forage producers are less capable of paying higher pumping costs due to reduced gross margins and locating them on the lower elevations was deemed reasonable.

3.39 The area outlined in black is the approximate area associated with site 7 that we consider will be suitable for horticultural crop production.

3.40 The area outlined in red is the approximate area associated with sites 4 and 5 that we consider will be suitable for broadacre crop production.

3.41 The approximate available areas are as follows:

a) horticulture – 2300ha

b) annual cropping/hay – 6100ha.

3.42 While we will discuss the characteristics of the soils in both areas in detail in subsequent sections of this report, ***Table 3.1*** provides a brief overview of each area, the issues associated with it, what they mean and how they will be managed, as well as the crops most suitable for growing.

Table 3.1: Summary of sites 4, 5 and 7

Sites	Area (Ha)	Characteristic	Management	Suitable Crops
4 and 5	6100	A horizon 500 - 750mm	Suitable for most crops	Hay pasture Grain crops Maize/corn Pulse crops Cotton
		Moderate sodium levels	Suitable for most crops and likely to decrease over time	
		Trace element deficiencies	Fertiliser program can correct	
		High sulphur	Suitable for most crops and likely to decrease over time	
		High boron	Suitable for most crops and likely to decrease over time	
		Cation imbalances	Fertiliser program can correct	
		B horizon high salinity	Avoid deep irrigations	
7	2300	A horizon 900mm	Suitable for most crops	Horticulture Hay pasture Grain crops Maize/corn Pulse crops Cotton
		Low - moderate sodium levels	Suitable for most crops and likely to decrease over time	
		Trace element deficiencies	Fertiliser program can correct	
		Very high sulphur	Suitable for most crops and likely to decrease over time	
		High boron	Suitable for most crops and likely to decrease over time	
		Cation imbalances	Fertiliser program can correct	
		B horizon high salinity	Avoid deep irrigations	

3.43 The physical and chemical issues identified across these three sites are common in inland Australia and are generally considered suitable for either dryland or irrigated farming.

3.44 The critical considerations for irrigated crop suitability relate to:

a) depth of suitable soil

b) physical structure of the soil (friability)

c) the chemical nutrient levels and balance are manageable with sound agronomic and crop management strategies.

3.45 In the case of these three sites, these three key factors are favourable to irrigated crop production.

Summary of Soil Survey Results: Least Preferred Sites

3.46 Sites 1, 2 and 3, while less suited to irrigated agriculture, are still suited to hay and some grain crops. However, these sites have characteristics that would require more specific management compared to sites 4, 5 and 7.

3.47 ***Table 3.2*** summarises the chemical and physical characteristics for sites 1 – 3 that make them the least preferred sites for irrigated crop production.

Table 3.2: Summary of sites 1, 2 and 3

Sites	Characteristic	Issue to Manage	Suitable Crops
1, 2 & 3	A horizon 350 - 500mm	Increased challenge for irrigation management	Hay pasture Grain crops Maize/corn
	Moderate - high sodium levels	Restriction on crop suitability and productivity	
	Trace element deficiencies	Fertiliser program can correct	
	High chloride	Potential to impact nutrient uptake and productivity in some crops	
	Moderate - high boron	Suitable for most crops and likely to decrease over time	
	Cation imbalances	Fertiliser program can correct	
	Soil structure	Friability and structure may be a longer-term issue	
	B horizon shallow with high salinity	Avoid deep irrigations which is harder with shallow A horizon	

3.48 There are agricultural regions of Australia where the issues listed above are managed in both dryland and irrigated cropping situations.

3.49 However, in a greenfield location, the more suitable/appropriate soils located within a reasonable distance of the water source should be given priority for development.

3.50 ***Table 3.3*** is a summary that indicates the overall suitability, commercial viability, and the level of crop management expertise for crops that may be grown on all six sites.

3.51 The suitability ratings for each crop at each site are low – medium – high (L – M – H). The ratings are provided as a guide only and were considered based on many crop production factors, whilst acknowledging only hay pasture has been commercially and successfully been produced in the region.

3.52 For each of these key areas, a rate of low, medium and high has been used, where low relates to low suitability or low level of crop management skill and high relates to high suitability or high level of crop management skill.

Table 3.3: Crop suitability by soil survey site

Site No	Crop	Suitability (L - M - H)	Commercial Suitability (L - M - H)	Crop Management Requirement (L - M - H)
1	Hay	M	M	H
	Grain crops	L	M	H
2	Hay	M	M	H
	Grain crops	L	M	H
3	Hay	M	M	H
	Grain crops	L	M	H
	Forage sorghum	M	M	H
	Maize/corn	L	M	H
4	Hay	M - H	M - H	L - M
	Grain crops	M - H	M - H	L - M
	Forage sorghum	M - H	M - H	L - M
	Maize/corn	M - H	M - H	L - M
5	Hay	H	M - H	L - M
	Grain crops	M - H	M - H	L - M
	Forage sorghum	M - H	M - H	L - M
	Maize/corn	M - H	M - H	L - M
	Cotton	M - H	M - H	L - M
7	Avocados	M - H	M	M - H
	Mangos	M - H	M - H	L - M
	Citrus	M - H	M - H	M
	Pecans	M	M	M - H
	Camellia	M - H	M - H	L - M
	Hay	H	M - H	L - M
	Grain crops	M - H	M - H	L - M
	Forage sorghum	M - H	M - H	L - M
	Maize/corn	M - H	M - H	L - M
	Cotton	M - H	M - H	L - M

3.53 We will discuss all sites in more detail, including soil management in the following sections of this report.

Detailed survey information for each site

Site One

3.54 Soil site 1 is a reddish-brown medium clay with an A horizon of 500mm deep.

3.55 This site would potentially be suitable for the following crops:

a) hay pasture

b) grain crops (sorghum, wheat, barley).

3.56 In this soil, the chloride levels in the A horizon are likely to negatively influence water and nutrient uptake resulting in some reduction in yield. The chloride levels in the lower profile would be considered a significant impediment to crop plant growth, while the EC level is likely to impede crop soil water use beyond the 500mm depth.

3.57 However, soil sodium levels are extremely high at depths beyond approximately 500mm and could lead to the soil dispersing on wetting. This could lead to failure of structures (banks, ring tank walls – built to contain water). Should the topsoil depth be reduced for whatever reason (e.g. to build raised beds), the resulting somewhat modified soil profile, on wetting, may cause changes which could make equipment movement exceedingly difficult. Special construction methods for such structures may be necessary to ameliorate such a problem.

3.58 Like most Australian soils, phosphorus is likely to be limiting for plant growth. Therefore, high levels of phosphatic fertiliser use would be essential for serious crop production.

3.59 Boron, a minor element, is high in the surface of this soil and may lead to toxicity issues if not managed effectively with irrigation and nutrient management strategies.

3.60 SOM (soil organic matter) is low at this site, as with others.

3.61 ***Image 3.4*** and ***Table 3.4*** summarise the soil survey site data for site 1.

Image 3.9: Detailed description site one

Project: HIPCo - DBC Site: 1

Location:
WGS84. 20°42’23.6”S 143°53’06.5”E

Described by: Lindsay Ward

Date: 9 March 2021

Site description

Geology: Alluvial

Landform Pattern: Colluvial plain

Element: Plain

Permeability: Moderately impermeable

Microrelief: Zero or none

Drainage: Gradual slope

Slope: <0.5%

Rock outcrops: Nil

Surface coarse fragments: Nil

Surface condition: Self mulching, periodic cracking

Disturbance: Grazing

ASC classification: Uf1.32

Profile morphology

Horizon	Depth (m)	Description
A1	0.0 to 0.50	Reddish brown (2.5YR 4/4) dry; no mottles; medium clay; no coarse fragments; no segregations; medium structure; ribbon 65mm, field pH 8.5 – 9; clear change to:
B21	0.50 to 1.20	Brown (7.5YR 5/3) dry; gypsum mottles; medium - heavy clay; no coarse fragments; no segregations; medium – strong structure; ribbon length 4 – 5cm; field pH 8.5 - 9; weak change to:
B22	1.20 to 1.60	Yellowish brown (10YR 5/4) dry; no mottles; light - medium clay; no coarse fragments; no segregations; medium – weak structure; ribbon length 4cm; pH 8.5 – 9.
C1		Parent material was not reached at this site.

Table 3.4: Summary of site one chemical attributes

Site No	Chemical Analysis	Test Result by Profile		
		A Horizon	**B1 Horizon**	**B2 Horizon**
One	Profile Depth (mm)	0 - 500	500 - 1200	1200 +
	pH	8.20	8.00	8.40
	EC (mS/cm)	0.47	3.13	1.66
	CEC (cmol/kg)	30.30	47.80	36.30
	Ammonium-N (mg/kg)	0.30	-	-
	Nitrate-N (mg/kg)	5.10	9.60	14.10
	Phosphorus (BSES) (mg/kg)	46.00	-	-
	Phosphorus (Colwell) (mg/kg)	5.00	11.00	13.30
	P Buffer Index (L/kg)	42.00	-	-
	Potassium (mg/kg)	120.00	99.00	120.00
	K/Cation %	1.00	0.50	0.80
	Calcium (mg/kg)	4131.00	6401.00	4324.00
	Ca/Cation %	68.00	67.00	60.00
	Magnesium (mg/kg)	675.00	732.00	665.00
	Mg/Cation %	18.60	12.80	15.30
	Sodium (mg/kg)	845.00	2160.00	2022.00
	ESP	12.14	19.67	24.24
	Ca:Mg	3.67	5.25	3.90
	Zinc (mg/kg)	0.41	-	-
	Copper (mg/kg)	0.72	-	-
	Iron (mg/kg)	5.50	-	-
	Sulphur (mg/kg)	30.00	-	-
	Chloride (mg/kg)	520.00	3050.00	2.11
	Boron (mg/kg)	1.10	-	-
	Organic Carbon (%)	0.31	0.16	0.31
	Organic Matter (%)	0.68	-	-

Site Two

3.62 Site 2 is a reddish-brown medium to heavy clay with an A horizon depth of 350mm.

3.63 This site would be potentially suitable for the following crops:

a) hay pasture

b) grain crops (sorghum, wheat, barley).

3.64 In this soil, the chloride levels throughout the profile are unlikely to seriously impede crop plant growth. However, the EC level is likely to impede crop soil water use beyond the 30cm depth. While the $EC_{1:5}$ is high throughout the profile, the chloride level is most likely a better indicator of crop performance and is unlikely to impede crop plant growth.

3.65 Soil sodium levels are extremely high at depths beyond approximately 35cm and could lead to the soil dispersing on wetting. This could lead to (structural) failure of structures (banks, ring tank walls – built to contain water). Should the topsoil depth be reduced for whatever reason (e.g. to build raised beds), the resulting somewhat modified soil profile, on wetting, may cause changes which could make equipment movement exceedingly difficult.
Special construction methods for such structures may be necessary to ameliorate such a problem.

3.66 Soil phosphorus is likely to be limiting for plant growth. However, high levels of phosphatic fertiliser use would be essential for serious crop production. Old theories suggest that if the potassium level is higher than that of sodium; there should be no issue with plant uptake of potassium in this case in the top 30cm.

3.67 Boron, a minor element, is very high in the surface of this soil and may lead to toxicity issues if not managed effectively with irrigation and nutrient management strategies.

3.68 SOM (soil organic matter) is low at this site, as with others. Decline in SOM has serious long-term effects on nutrient availability through increases in pH and water infiltration. Modern soil management (minimum or no till farming etc.) minimises such change.

3.69 ***Image 3.5*** and ***Table 3.5*** summarise the soil survey site data for site 2.

Image 3.10: Detailed description site two

Project: HIPCo - DBC   Site: 2

Location:
WGS84. 20°42’05.9”S, 143°48’49.6”E
Described by: Lindsay Ward
Date: 9 March 2021

Site description

Geology: Alluvial
Landform Pattern: Colluvial plain
Element: Plain
Permeability: Moderately permeable
Microrelief: Zero or none
Drainage: Gradual slope
Slope: <0.25%
Rock outcrops: Nil
Surface coarse fragments: Nil
Surface condition: Self mulching, periodic cracking
Disturbance: Grazing

ASC classification: Ug6.3

Profile morphology

Horizon	Depth (m)	Description
A1	0.0 to 0.35	Reddish brown (2.5YR 5/4) dry; no mottles; medium – heavy clay; no coarse fragments; no segregations; medium to strong lenticular structure; ribbon 80mm, field pH 8.5; clear change to:
B21	0.35 to 0.85	Brown (7.5YR 4/3) hard to wet; gypsum mottles; medium clay; no coarse fragments; no segregations; lenticular structure; ribbon 55mm, field pH 8.5; clear change to:
B22	0.85 to 1.25	Dark reddish brown (5YR 3/3) hard to wet; gypsum mottles; medium clay; no coarse fragments; no segregations; lenticular structure; ribbon 55mm, field pH 9; clear change to:
C1	1.25 to 1.5	Greenish grey (Gley 1 5/10Y) dry; decomposing shale/mudstone; gravelly clay shale; gravelly coarse fragments; no segregations; field pH 10.

Table 3.5: Summary of site two chemical attributes

Site No	Chemical Analysis	Test Result by Profile			
		A Horizon	B1 Horizon	B2 Horizon	C Horizon
Two	Profile Depth (mm)	0 - 350	350 - 850	850 - 1250	1250 +
	pH	7.80	7.80	8.10	8.00
	EC (mS/cm)	1.04	2.84	3.47	4.60
	CEC (cmol/kg)	48.10	65.10	59.80	83.30
	Ammonium-N (mg/kg)	0.10	-	-	-
	Nitrate-N (mg/kg)	5.80	-	10.00	7.10
	Phosphorus (BSES) (mg/kg)	129.00	-	-	-
	Phosphorus (Colwell) (mg/kg)	6.00	4.60	5.60	6.60
	P Buffer Index (L/kg)	77.00	-	-	-
	Potassium (mg/kg)	392.00	377.00	518.00	335.00
	K/Cation %	2.10	1.50	2.20	1.00
	Calcium (mg/kg)	8652.00	10,887.00	6822.00	11,925.00
	Ca/Cation %	90.00	84.00	57.00	72.00
	Magnesium (mg/kg)	299.00	449.00	571.00	543.00
	Mg/Cation %	5.20	5.70	8.00	5.40
	Sodium (mg/kg)	298.00	1380.00	4518.00	4212.00
	ESP	2.70	9.21	32.83	21.98
	Ca:Mg	17.36	14.55	7.17	13.18
	Zinc (mg/kg)	0.57	-	-	-
	Copper (mg/kg)	0.76	-	-	-
	Iron (mg/kg)	3.30	-	-	-
	Sulphur (mg/kg)	1000.00	-	-	-
	Chloride (mg/kg)	40.00	190.00	1150.00	1100.00
	Boron (mg/kg)	3.10	-	-	-
	Organic Carbon (%)	0.38	0.38	0.33	-
	Organic Matter (%)	0.84	-	-	-

Site Three

3.71 Site 3 is a brown, medium to heavy clay with an A horizon depth of 380mm.

3.72 This site would be potentially suitable for the following crops:

a) hay pasture

b) grain crops (sorghum, wheat, barley)

c) forage sorghum

d) maize/corn.

3.73 As with the other sites, the pH is very high at the surface and may lead to nutrient tie-ups, especially for elements such as zinc. Further, high pH will negatively impact the 'plant back interval' for many commonly used herbicides.

3.74 The relatively high cation exchange capacity (CEC), which is usually favourable, means many common agricultural products can be affected (bound to the clay) making them unavailable to plants e.g., glyphosate (desirable), as well as some residual herbicides (undesirable). Typically, low CEC soils are more problematic for agricultural production.

3.75 The Colwell phosphorus level is low (phosphatic fertiliser will be required). Colwell phosphorus is a measure of the amount of phosphorus that may be available to plants on clays of the type present at the surface of this profile. The Phosphorus buffer index could be described as moderately favourable, which means residual (unused) soil phosphorus should later be available to plants.

3.76 The soil magnesium level is high at the soil surface. Hence, crop seeding equipment capable of sowing into such soils should be selected to ensure successful crop establishment. Such equipment is readily available.

3.77 The soil sodium levels indicate that grain/forage sorghum is likely to be a more profitable cropping option than pulse crops resulting from expected improved crop performance and agronomic reasons.

3.78 Chloride levels are very favourable at the soil surface for crops. However, at depth, probably beyond 40cm, chloride levels (>1300) indicate that crop production could become difficult. However, considering the depth of unaffected surface soil, the problem at depth could be successfully managed with some irrigation methods, e.g., sprinkler or drip. While other irrigation methods, such as flood/furrow, could be detrimental to long-term crop production.

3.79 Boron, a minor element, is high in the surface of this soil and may lead to toxicity issues if not managed effectively with irrigation and nutrient management strategies.

3.80 ***Image 3.6*** and ***Table 3.6*** summarise the soil survey site data for site 3.

Image 3.11: Detailed description site three

Project: HIPCo - DBC   Site: 3

Location:
WGS84. 20°43'07.1"S, 143°49'44.2"E
Described by: Lindsay Ward
Date: 9 March 2021

Site description

Geology: Alluvial
Landform Pattern: Colluvial plain
Element: Plain
Permeability: Moderately permeable
Microrelief: Zero or none
Drainage: gradual slope
Slope: <1%
Rock outcrops: Nil
Surface coarse fragments: Nil
Surface condition: Self mulching, periodic cracking
Disturbance: Grazing

ASC classification: Ug6.3

Profile morphology

Horizon	Depth (m)	Description
A1	0.0 to 0.38	Brown (7.5YR 4/3) dry; no mottles; medium – heavy clay; no coarse fragments; no segregations; lenticular structure; ribbon 85mm, field pH 8; clear change to:
B1	0.38 to 0.80	Dark reddish brown (5YR 3/2) dry; gypsum mottles at lower depth of profile; slightly gravelly medium clay; gravel fragments towards bottom of profile; slightly lenticular structure; no segregations; ribbon 50mm; field pH 7.5; clear change to
C1	0.80 to 1.5	Greenish grey (Gley 1 5/10Y) dry; decomposing shale/mudstone; gravelly clay shale; gravelly coarse fragments; no segregations; field pH 10.

Table 3.6: Summary of site three chemical attributes

Site No	Chemical Analysis	Test Result by Profile		
		A Horizon	B Horizon	C Horizon
Three	Profile Depth (mm)	0 - 380	380 - 800	800 +
	pH	8.90	8.00	8.00
	EC (mS/cm)	0.16	3.23	4.10
	CEC (cmol/kg)	41.40	57.10	84.20
	Ammonium-N (mg/kg)	0.10	-	-
	Nitrate-N (mg/kg)	6.30	8.10	15.00
	Phosphorus (BSES) (mg/kg)	249.00	-	-
	Phosphorus (Colwell) (mg/kg)	10.00	5.90	8.00
	P Buffer Index (L/kg)	105.00	-	-
	Potassium (mg/kg)	357.00	339.00	178.00
	K/Cation %	2.20	1.50	0.50
	Calcium (mg/kg)	7182.00	8442.00	13,659.00
	Ca/Cation %	87.00	74.00	81.00
	Magnesium (mg/kg)	239.00	287.00	314.00
	Mg/Cation %	4.80	4.20	3.10
	Sodium (mg/kg)	598.00	2664.00	2940.00
	ESP	6.28	20.30	15.00
	Ca:Mg	18.03	17.65	15.19
	Zinc (mg/kg)	0.50	-	-
	Copper (mg/kg)	0.83	-	-
	Iron (mg/kg)	6.30	-	-
	Sulphur (mg/kg)	29.00	-	-
	Chloride (mg/kg)	53.00	1350.00	1770.00
	Boron (mg/kg)	1.30	-	-
	Organic Carbon (%)	0.50	0.47	-
	Organic Matter (%)	1.10	-	-

Site Four

3.81 Site 4 is a brown, medium clay with an A horizon depth of 750mm.

3.82 This site would be potentially suitable for the following crops:

a) hay pasture

b) grain crops (sorghum, wheat, barley)

c) maize/corn

d) pulse crops (mungbean, chickpea)

e) cotton.

3.83 Soil chloride levels in at least the top 75cm are favourable for cropping by not affecting soil water plant availability. Sodicity issues beyond 75cm could have implications on rooting depth and ultimately crop performance.

3.84 The high soil sulphur levels are most likely due to the presence of gypsum in the profile and should not be seen as being detrimental for most crop types.

3.85 Phosphorus levels are such that serious phosphatic fertiliser application will be required if developed for cropping.

3.86 Zinc is likely to be an issue especially because of the high pH, which will be exacerbated in the long term by organic matter decline from farming practices.

3.87 Boron, a minor element, is high in the surface of this soil and may lead to toxicity issues if not managed effectively with irrigation and nutrient management strategies.

3.88 ***Image 3.7*** and ***Table 3.7*** summarise the soil survey site data for site 4.

Image 3.12: Detailed description site four

Project: HIPCo - DBC   Site: 4

Location:
WGS84. 20°43’19.0”S, 143°47’11.4”E
Described by: Lindsay Ward
Date: 9 March 2021

Site description

Geology: Alluvial
Landform Pattern: Colluvial plain
Element: Plain
Permeability: Moderately permeable
Microrelief: Zero or none
Drainage: Gradual slope
Slope: <0.5 - 1%
Rock outcrops: Nil
Surface coarse fragments: Nil
Surface condition: Self mulching, periodic cracking
Disturbance: Grazing

ASC classification: Ug6.3

Profile morphology

Horizon	Depth (m)	Description
A1	0.0 to 0.75	Brown (7.5YR 4/3) dry; no mottles; medium clay; no coarse fragments; no segregations; friable structure; ribbon 85mm, field pH 8; clear change to:
B1	0.75 to 1.30	Brown (7.5YR 4/3) dry; gypsum nodules throughout; medium clay; friable structure; hard to wet; no segregations; ribbon 70mm; field pH 9; clear change to:
C1	1.30 to 1.60	Greenish grey (Gley 1 5/10Y) dry; decomposing shale/mudstone; gravelly clay shale; gravelly coarse fragments; no segregations; field pH 9.

Table 3.7: Summary of site four chemical attributes

Site No	Chemical Analysis	Test Result by Profile		
		A Horizon	B Horizon	C Horizon
Four	Profile Depth (mm)	0 - 750	750 - 1300	1300 +
	pH	8.20	8.10	8.10
	EC (mS/cm)	0.66	4.21	4.27
	CEC (cmol/kg)	62.90	96.30	91.90
	Ammonium-N (mg/kg)	0.10	-	-
	Nitrate-N (mg/kg)	2.30	6.50	12.00
	Phosphorus (BSES) (mg/kg)	129.00	-	-
	Phosphorus (Colwell) (mg/kg)	4.00	3.70	5.70
	P Buffer Index (L/kg)	172.00	-	-
	Potassium (mg/kg)	330.00	410.00	314.00
	K/Cation %	1.30	1.10	0.90
	Calcium (mg/kg)	11,658.00	15,012.00	14,277.00
	Ca/Cation %	93.00	78.00	78.00
	Magnesium (mg/kg)	255.00	456.00	398.00
	Mg/Cation %	3.40	3.90	3.60
	Sodium (mg/kg)	385.00	3762.00	3762.00
	ESP	2.66	16.99	17.81
	Ca:Mg	27.43	19.75	21.52
	Zinc (mg/kg)	0.47	-	-
	Copper (mg/kg)	0.78	-	-
	Iron (mg/kg)	6.30	-	-
	Sulphur (mg/kg)	470.00	-	-
	Chloride (mg/kg)	27.00	720.00	1100.00
	Boron (mg/kg)	1.50	-	-
	Organic Carbon (%)	0.48	0.38	-
	Organic Matter (%)	1.06	-	-

Site Five

3.90 Site 5 is a brown, medium clay with an A horizon depth of 500mm.

3.91 This site would be potentially suitable for the following crops:

a) hay pasture

b) grain crops (sorghum, wheat, barley)

c) forage sorghum

d) maize/corn

e) pulse crops (mungbean, chickpea)

f) cotton.

3.92 This site has a friable surface soil with favourable chemical analyses for plant growth to a metre for chloride.

3.93 Sodium is unlikely to be an issue for plant growth in the short term above 500mm but may become an issue as the physical characteristics of the soil change due to tillage. This impact can be managed with the aid of reduced tillage.

3.94 Any impact of the high sodium on potash availability may be latent.

3.95 Phosphorus is low as in other profiles, but the problem is not insurmountable.

3.96 The phosphorus buffer index is reasonably favourable.

3.97 The high calcium and sulphur levels would be associated with the presence of gypsum in the upper profile as well as deeper levels.

3.98 High magnesium at the surface may result in some difficulties with mechanical operations when the soil is moist/wet, such as at seeding. This issue can be managed with careful selection of seeding equipment.

3.99 Boron is very high at this location but manageable for most crops with sound irrigation and nutrient management.

3.100 Problems with this soil are mostly deeper than 50cm which should allow successful crop production.

3.101 ***Image 3.8*** and ***Table 3.8*** summarise the soil survey site data for site 5.

Image 3.13: Detailed description site five

Project: HIPCo - DBC Site: 5

Location:
WGS84. 20°43'19.0"S, 143°47'11.4"E
Described by: Lindsay Ward
Date: 9 March 2021

Site description

Geology: Alluvial
Landform Pattern: Colluvial plain
Element: Plain
Permeability: Moderately permeable
Microrelief: Zero or none
Drainage: Gradual slope
Slope: <0.5%
Rock outcrops: Nil
Surface coarse fragments: Nil
Surface condition: Self mulching, periodic cracking
Disturbance: Grazing

ASC classification: Ug6.3

Profile morphology

Horizon	Depth (m)	Description
A1	0.0 to 0.50	Brown (7.5YR 4/4) dry; no mottles; medium clay; strong friable structure; no segregations; ribbon 95mm; field pH 8,5; clear change to:
B1	0.50 to 1.00	Dark reddish brown (5YR 3/4) dry; gypsum mottles throughout profile; medium clay; hard to wet; no segregations; ribbon 70mm; field pH 8,5; clear change to:
C1	1.00 to 1.20	Greenish grey (Gley 1 5/10Y) dry; decomposing shale/mudstone; gravelly clay shale; gravelly coarse fragments; no segregations; field pH 9.

Table 3.8: Summary of site five chemical attributes

Site No	Chemical Analysis	Test Result by Profile		
		A Horizon	B Horizon	C Horizon
Five	Profile Depth (mm)	0 - 500	500 - 1000	1000 +
	pH	7.90	7.80	7.90
	EC (mS/cm)	0.69	4.29	4.84
	CEC (cmol/kg)	46.00	73.40	107.80
	Ammonium-N (mg/kg)	0.10	-	-
	Nitrate-N (mg/kg)	6.30	9.20	9.20
	Phosphorus (BSES) (mg/kg)	141.00	-	-
	Phosphorus (Colwell) (mg/kg)	5.00	6.80	8.00
	P Buffer Index (L/kg)	98.00	-	-
	Potassium (mg/kg)	532.00	636.00	564.00
	K/Cation %	3.00	2.20	1.30
	Calcium (mg/kg)	7401.00	9099.00	15,576.00
	Ca/Cation %	80.00	62.00	72.00
	Magnesium (mg/kg)	661.00	1206.00	1302.00
	Mg/Cation %	12.00	13.70	10.10
	Sodium (mg/kg)	486.00	3726.00	4050.00
	ESP	4.59	22.08	16.34
	Ca:Mg	6.72	4.53	7.18
	Zinc (mg/kg)	0.65	-	-
	Copper (mg/kg)	0.77	-	-
	Iron (mg/kg)	5.00	-	-
	Sulphur (mg/kg)	540.00	-	-
	Chloride (mg/kg)	65.00	1240.00	1300.00
	Boron (mg/kg)	4.50	-	-
	Organic Carbon (%)	0.30	0.29	-
	Organic Matter (%)	0.66	-	-

Site Six

3.102 Site 6 was not excavated due to the presence of significant shale rocks and outcrops on the soil surface.

3.103 From this visual assessment, it was decided that the area would not be suitable for cultivation and irrigated crops.

Site Seven

3.104 Site 7 is a dark reddish-brown medium clay with an A horizon depth of 900mm.

3.105 This site would be potentially suitable for the following crops:

a) horticulture

b) hay pasture

c) grain crops (sorghum, wheat, barley)

d) forage sorghum

e) maize/corn

f) pulse crops (mungbean, chickpea)

g) cotton.

3.106 A site with a deep A horizon (90 cm), favourable chloride levels, reasonable P levels throughout and a good phosphorus buffer index.

3.107 Sodium in the top 90cm is not problematic.

3.108 The high calcium and sulphur levels are associated with the distribution of gypsum throughout the entire profile (including the A horizon).

3.109 pH is such that it is unlikely to seriously impact micro-nutrient availability.

3.110 Soil boron levels are considered very high but should be able to be managed with sound irrigation and nutrient management.

3.111 ***Image 3.9*** and ***Table 3.9*** summarise the soil survey site data for site 7.

Image 3.14: Detailed description site seven

Project: HIPCo - DBC   Site: 7

Location:
WGS84. 20°46'30.2"S, 143°48'16.7"E
Described by: Lindsay Ward
Date: 9 March 2021

Site description

Geology: Alluvial
Landform Pattern: Colluvial plain
Element: Plain
Permeability: Moderately permeable
Microrelief: Possible gilgai
Drainage: Gradual slope
Slope: 0.5 – 1.0%
Rock outcrops: Nil
Surface coarse fragments: Nil
Surface condition: Self mulching, periodic cracking
Disturbance: Grazing

ASC classification: Ug6.3

Profile morphology

Horizon	Depth (m)	Description
A1	0.0 to 0.90	Dark reddish brown (5YR 3/3) dry; gypsum mottles throughout profile; medium clay; self-mulching friable structure; no segregations; ribbon 80mm; field pH 9; clear change to:
B1	0.90 to 1.50	Dark reddish brown (7.5YR 4/4) dry; gypsum mottles; medium clay; easy to wet; soapy feel when wet; no segregations; ribbon 75mm; field pH 8.5; clear change to:
C1	1.50 to 1.70	Greenish grey (Gley 1 5/10Y) dry; decomposing shale/mudstone; gravelly clay shale; gravelly coarse fragments; no segregations; field pH 8.

Table 3.9: Summary of site seven chemical attributes

Site No	Chemical Analysis	Test Result by Profile		
		A Horizon	B Horizon	C Horizon
Seven	Profile Depth (mm)	0 - 900	900 - 1500	1500 +
	pH	7.80	7.80	8.00
	EC (mS/cm)	2.24	3.61	3.43
	CEC (cmol/kg)	76.70	101.10	151.50
	Ammonium-N (mg/kg)	0.10	-	-
	Nitrate-N (mg/kg)	2.30	8.10	6.80
	Phosphorus (BSES) (mg/kg)	840.00	-	-
	Phosphorus (Colwell) (mg/kg)	9.00	9.80	7.40
	P Buffer Index (L/kg)	157.00	-	-
	Potassium (mg/kg)	402.00	492.00	236.00
	K/Cation %	1.30	1.20	0.40
	Calcium (mg/kg)	14,592.00	17,490.00	28,200.00
	Ca/Cation %	95.00	87.00	93.00
	Magnesium (mg/kg)	192.00	275.00	200.00
	Mg/Cation %	2.10	2.30	1.10
	Sodium (mg/kg)	244.00	2316.00	1902.00
	ESP	1.38	9.96	5.46
	Ca:Mg	45.60	38.16	84.60
	Zinc (mg/kg)	0.71	-	-
	Copper (mg/kg)	2.11	-	-
	Iron (mg/kg)	5.20	-	-
	Sulphur (mg/kg)	1330.00	-	-
	Chloride (mg/kg)	14.00	960.00	920.00
	Boron (mg/kg)	2.80	-	-
	Organic Carbon (%)	0.47	0.33	-
	Organic Matter (%)	1.03	-	-

Soil Survey Summary

3.112 Based on the analysis of the collected data, sites 4, 5 and 7 offer the best chance for successful irrigation development based on the profile inspections and chemical analyses results.

3.113 All sites have relatively deep A horizons (500 – 900mm) without serious constraints, although deeper layers (B horizon) present problems for root penetration and development for most plants other than very salt tolerant species.

3.114 With the use of good quality irrigation water and appropriate irrigation systems and scheduling methods, which do not result in plants drawing from the profile beyond the maximum root depth or A horizon, a successful irrigation development is feasible.

4 Salinity Risk Assessment and Management

Overview:

4.1 Following on from the specific site surveys, the next stage of the investigation was to understand and assess the risk of salinity impacting either crop production or flow-on environmental impacts.

4.2 The salinity risk assessment and management of the identified risks is critical to ensure that the irrigation project has a long-term sustainability focus for both agricultural production output and environmental impacts.

4.3 Both physical inspection and chemical analyses were used to assess the likelihood of salinity being problematic with any agricultural/horticultural irrigation development on the evaluated soils.

4.4 From this assessment process, there have been several key salinity risks identified. These are as follows:

a) high levels of sodium in all profile horizons in site 1.

b) high levels of sodium in B and C horizons in all sites that will limit root activity and impact soil stability.

c) high chloride levels in B and C horizons for all sites that will likely impact crop performance.

d) high EC levels in B and C horizons for all sites that indicate salinity/sodicity risk and will reduce the ability of plant root systems to grow.

4.5 The risks identified above are not dissimilar to those found in many other cropping regions of Australia. With the adoption of appropriate management strategies, salinity will not limit the potential for these soils to produce a range of crops or pose an environmental risk.

4.6 ***Table 4.1*** summarises the key identified risks and management strategies that could be considered to mitigate the risk.

Table 4.1: Summary of salinity risk and potential management strategies

Salinity risk	Management Strategy
Depth of A horizon	Identify areas with the deepest A horizon for further investigation and potential development
High sodium in A horizon	Identify areas with more suitable soil chemistry
High sodium, chloride or EC in B horizon	Identify areas with the deepest A horizon. Choose irrigation delivery systems that can accurately place water to match crop rooting depth. Manage irrigation scheduling to avoid over irrigation.
On-farm storages	Ensure any on-farm storages are not able to leak water into the B horizon.

4.7 The practical risk-management strategies that can be implemented on a ‘whole of area’ and ‘individual farm’ basis include the following:

a) Based on the salinity test results, classifying areas as either ‘Farm Lots’ or 'Horticulture Lots’ to ensure that the crops grown in those areas will be the most appropriate, will minimise the risk of salinity becoming a production limiting issue.

b) The variables involved in irrigation such as method of water application, scheduling and volume applied will have to be managed with one of the key objectives being to minimise the potential of salinity becoming an issue.

Description of Salinity Assessment Methodology:

4.8 The following parameters are considered in isolation and collectively when considering the risk of salinity in a soil:

a) salinity: a measure of the total soluble salts in a soil (includes all macro and micronutrients).

b) sodicity: the presence of sodium ions in a soil where the total amount present and the balance to other cations (Calcium, magnesium, potassium, hydrogen) is high.

c) sodium: a cation element that is present in soils and if present in high enough concentration will influence the sodicity and salinity of a soil.

d) chloride: an anion element that is present in soils as part of a compound element (calcium chloride, potassium chloride etc) and when levels become too high can impact plant growth and influence salinity levels.

4.9 In relation to all sites sampled, subsoil salinity for crop production can be assessed by both Electrical Conductivity ($EC_{1:5}$) and Chloride (Cl).

4.10 $EC_{1:5}$ is a measure of the quantity of salt i.e., kg salt/kg of soil.

4.11 EC is a measure of the total amount of salts in the soil (including soluble gypsum [$CaSO_4$]), whereas chloride is a measure of only the chloride salts in the soil (NaCl, $CaCl_2$ etc.).

4.12 When $EC_{1:5}$ is measured in the laboratory the soil is finely ground and mixed with a high ratio of free water (1:5 soil:water). Under these conditions, gypsum dissolves, leading to higher EC readings than would actually occur in native undisturbed soil conditions.

4.13 In contrast, chloride salts are highly soluble, even in the low soil:water ratios in the subsoil horizons and accumulate (due to the plant taking up water) at the root’s surface in damaging concentrations.

4.14 Research has shown gypsum is not damaging to crop growth and crop water extraction, although it can lead to high EC values on the soil test.

4.15 Chloride is a better measure than $EC_{1:5}$ when assessing the level of constraint due to subsoil salinity.

4.16 Crop water extraction is rarely observed from layers with chloride concentrations greater than 1300mg/kg.

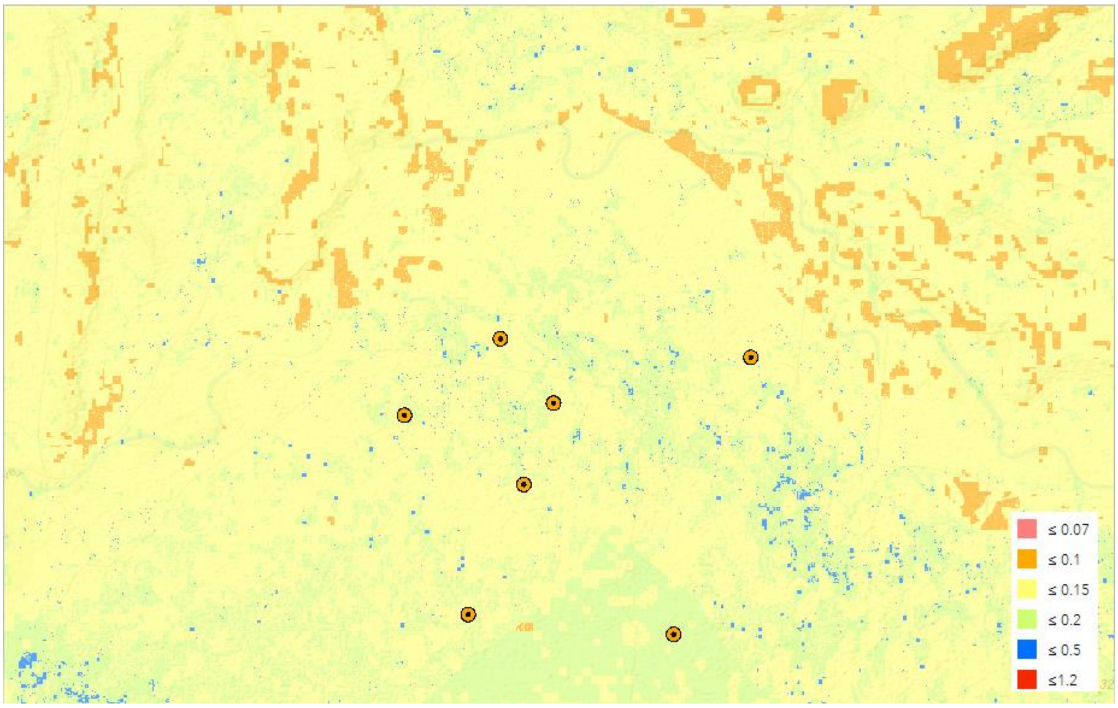
4.17 Winter cereals growth is impeded by chloride levels towards 300mg/kg and seriously impeded by levels beyond 500mg/kg.

4.18 Subsoil exchangeable sodium percentage (ESP%) is not a useful predictor of subsoil structure or likely crop performance.

Salinity Maps from DPI and DAF

4.19 The Flinders and Gilbert Agricultural Resource Assessment (FGARA) was conducted by the CSIRO. This review produced a significant report that incorporated a map layer of soil electrical conductivity (EC) (***Image 4.1***) and exchangeable sodium percentage (ESP) (***Image 4.2***).

Image 4.1: FGARA CSIRO electrical conductivity map

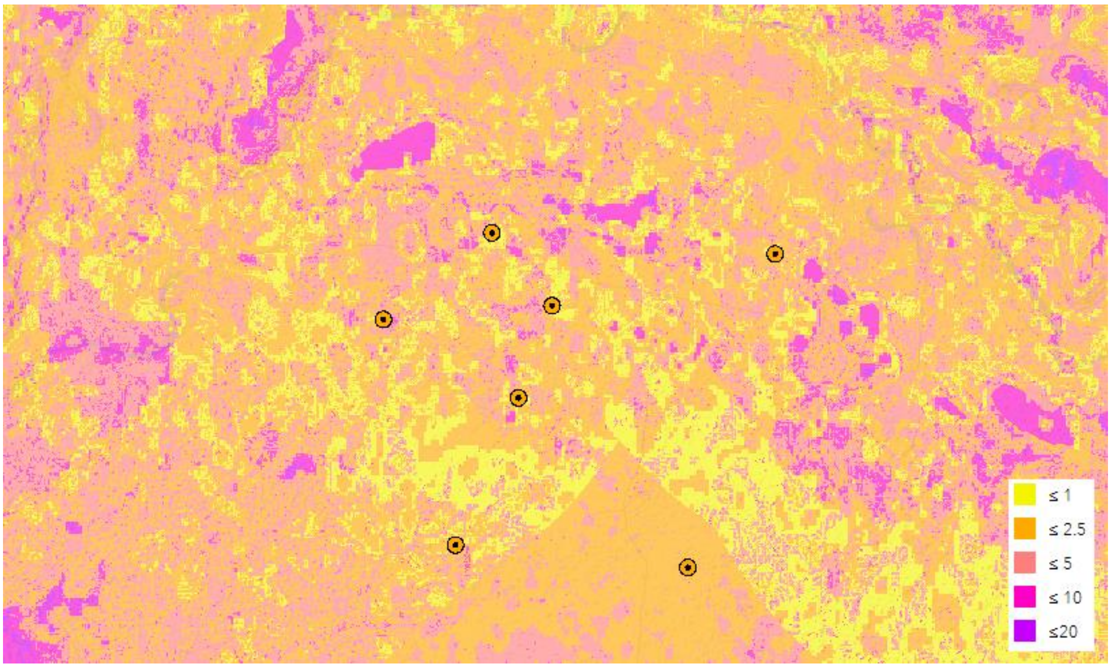


4.20 The round marks on the map identify the soil survey site locations. The legend in the lower right-hand corner provides the scale used to define the EC of the soils.

4.21 The FGARA EC map indicates that the proposed irrigation area has an EC range of the surface soil of 0.15 – 0.5dS/m with most of the area reading 0.15 – 0.2dS/m.

4.22 The lower EC soils are typically more suitable for irrigation crops with the higher values a possible risk of either salinity or sodicity.

Image 4.2: FGARA CSIRO exchangeable sodium percentage map



4.23 The round marks on the map identify the soil survey site locations. The legend in the lower right-hand corner provides the scale used to define the ESP of the soils.

4.24 The FGARA ESP map indicates that the proposed irrigation area has an ESP range of the surface soil of 1 - >20% with most of the area reading 1 – 5%.

4.25 The desired range for ESP is <5% for irrigation land to avoid crop yield impacts.

4.26 The map indicates significant variability of ESP across the proposed area where the survey test sites were located.

Salinity Risk Findings

4.27 Based on the individual site assessments, sodicity, rather than salinity, is likely to be an issue in the short term in the soil profiles assessed. Poor irrigation management could result in salt movement in the profile and accumulation at depths at or near the parent material with negative consequences.

4.28 For the proposed suitable sites (4, 5 and 7), the A horizon risk of salinity impacting crop production is either low or manageable, with the implementation of sustainable and good agricultural practices. Where there may be slightly raised sodium in the upper profile, appropriate crop or variety selection for annual crops should mitigate most of the risk to productivity.

4.29 Key considerations for long-term management of the risks include the following:

a) selection of the most appropriate irrigation delivery system

b) irrigation scheduling

c) managing the crop root profile and avoiding deep infiltration of water.

5 Erosion Risk Assessment and Management

Overview

5.1 Another important component of the assessment was to understand and assess the risk of the potential for erosion to impact either crop production or to have detrimental environmental impacts.

5.2 Our inspection observed that with the current land use of extensive cattle grazing, there is evidence of existing gully erosion from both formed and unformed property roadways and cattle pads. While the current land manager has employed various strategies to mitigate and repair this damage, the fact that it has occurred under a low impact land use raises the following critical issue:

a) What is the potential for erosion to occur with more intensive land use and what measures can be employed to minimise this risk?

5.3 Erosion control and management will require broad thinking in the short and long term for both individual farms and the entire proposed irrigation area.

5.4 In the short term, farm management practices such as maintaining ground cover, the strategic use of herbicides and minimum tillage techniques for annual crops will need to be employed.

5.5 In the context of the long term, broader land-form considerations will be necessary. By this we mean that 'whole of scheme' planning will need to account for the construction of grassed water courses, contour banks and paddock orientation with the objective of minimising the potential for erosion.

Description of Erosion Potential Assessment Methodology

5.6 A general appraisal of the landscape and soil characteristics, including soil tests, at each site was used as a basis of assessing erosion risk. Slope, slope length, erosivity maps and factors relating to plant growth.

5.7 All soil assessment locations except the last (site 7) were from the same catchment with an even low gradient slope towards the north.

5.8 The soils are predominantly Vertisols - friable cracking clays with an expected erosivity factor of 0.03 – 0.05. This erosivity factor range is on the low end of the scale.

5.9 The slope at most locations was ≤0.5%, mostly north, towards the Flinders River.

5.10 The slope length was measured on Google Earth as being up to 14km from the crest of the ridge in the south to the Flinders River towards the north.

5.11 The valley was extremely shallow in form, resulting in the scenario where the watercourse lacks definition (defined water courses, streams etc.). Evidence in the form of debris on fence lines and small shrubs, demonstrated that water concentrates in the valley floor, which is several hundred metres wide, with water depth being ≤700mm and maybe deeper in parts.

5.12 The slope length and relatively low angle gradient increases the risk of erosion occurring over a wide area based on extreme rainfall events. The issue raised by slope length on erosion results from no significant landscape structures (ridges, creeks, water flow paths etc.) that would naturally break up overland flow of water. This has the effect of water flow at the top of the ridge moving unobstructed towards the Flinders River picking up speed and water volume, thereby increasing the risk of erosion along this path.

5.13 The current land use is for extensive grazing of beef cattle on native grasslands. Grasslands occur mostly as treeless perennial tussock communities. Permanently grassed pastures have the effect of reducing the speed of water for most rainfall events and holding the soil together to minimise the risk of water erosion.

5.14 The diversity of pasture species and the current land management of these species has ensured that erosion, due to overland water flows, has been relatively minor. The diversity of pasture species has also worked to achieve this reduction in erosion, including:

a) Binding the soil surface particles to reduce soil movement.

b) Larger pasture species reduce the speed of water across the landscape.

c) Woody species that are hardier reduce the risk of early season rainfall from doing significant damage before other pasture species recover and regrow.

d) Grazing has been conducted in such a way as to manage the variety of pasture species.

5.15 Pasture species varied in accordance with recent grazing management.

5.16 The predominant grass species are:

a) Queensland Blue Grass (*Dichanthium sericeum*)

b) Bull Mitchell Grass near the Flinders River (*Astrebla squarrosa*)

c) Curley Mitchell Grass (*Astrebla lappacea*) on areas away from the river

d) Flinders Grass (*Iseilema* spp.)

e) Browntop (*Eulalia* spp.)

f) Native Millet (*Panicum decompositum*)

g) Tall Oat Grass (*Themeda* spp.).

5.17 The common broadleaf species include the following:

a) *Sclerolaena* spp. (Poverty Bushes or known commonly to be members of the Cooper Burr group)

b) Native Jute (*Corchorus trilocularis*)

c) Both species were evidenced at most sample sites.

5.18 The native legumes species observed included the following:

a) *Glycine* spp.

b) Maloga Bean (*Vigna lanceolata*)

c) *Sesbania* spp.

d) *Rhynchosia* spp.

5.19 There has been invasion in some parts by Prickly Mimosa (*Acacia farnesiana*). This woody weed is spread by cattle eating seed pods (a 'naturally' occurring high protein source) and disseminating the seeds in their faeces.

5.20 Gidgee (*Acacia cambagei*), a tree, occurs in patches across the landscape. It is considered non-invasive and is typically indicative of two things:

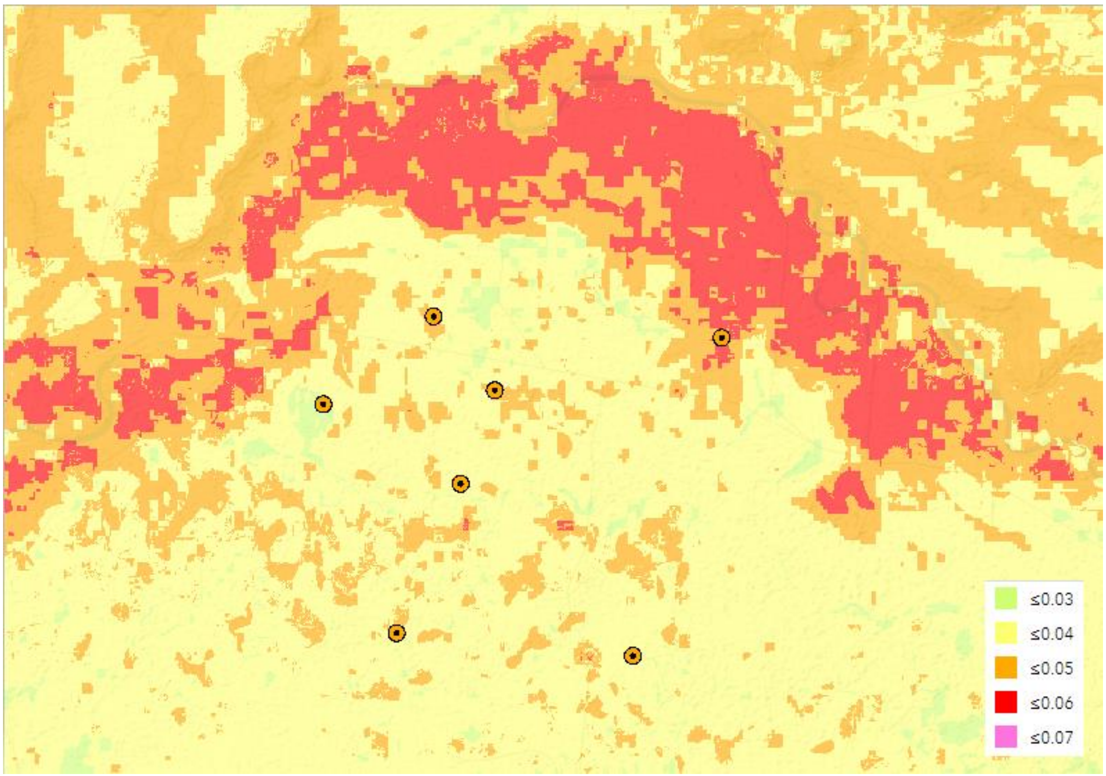
a) the annual rainfall is less than 500mm.

b) the soil is predominantly of sedimentary origin, at least at that location in the landscape.

Erosivity Maps

5.21 The Flinders and Gilbert Agricultural Resource Assessment (FGARA) was conducted by the CSIRO and produced a map layer of soil erosivity predictions (***Image 5.1***).

Image 5.1: FGARA CSIRO erosivity prediction map



5.22 The round marks on the map identify the soil survey site locations.

5.23 The legend in the lower right-hand corner provides the scale used to define the erosivity potential (K-factor) of the soils. The higher the K-factor, the more erosive the soil risk.

5.24 The FGARA erosivity map indicates that the proposed irrigation area has an erosivity range of the surface soil of 0.03 – 0.06 with most of the area being 0.04 – 0.05. The erosivity values for the proposed area are considered to be low.

5.25 Stewart et al (1975) developed a table indicating the general magnitude of the K-factor as a function of organic matter content and soil textural class (***Table 5.1***).

Table 5.1: Soil erodibility factor

	P_{om}(%)		
Textural Class	<0.5	2	4
Sand	0.05	0.03	0.02
Fine sand	0.16	0.14	0.10
Very finesand	0.42	0.36	0.28
Loamy sand	0.12	0.10	0.08
Loamy finesand	0.24	0.20	0.16
Loamy veryfine sand	0.44	0.38	0.30
Sandy loam	0.27	0.24	0.19
Fine sandyloam	0.35	0.30	0.24
Very fine sandy loam	0.47	0.41	0.33
Loam	0.38	0.34	0.29
Silt loam	0.48	0.42	0.33
Silt	0.60	0.52	0.42
Sandy clayloam	0.27	0.25	0.21
Clay loam	0.28	0.25	0.21
Silty clayloam	0.37	0.32	0.26
Sandy clay	0.14	0.13	0.12
Silty clay	0.25	0.23	0.19
Clay		0.13-0.2	

5.26 The relatively low erosivity values of the landscape are likely to be heavily influenced by the current land use, being grazing of cattle on native pasture.

5.27 The grazing strategy reduces the risk of excessive bare ground during periods of high rainfall, thereby decreasing the risk of broadscale erosion occurring.

5.28 If large areas are converted into irrigation paddocks, roadways etc., the risk of erosion is likely to increase without considered approach to landscape design and land management.

Limitations and Erosion Risk Management

5.29 Moderate rainfall events may be best controlled by surface cover (to provide maximum infiltration and thus minimise runoff).

a) ground cover is the first line of defence against erosion by reducing raindrop impact with the soil and maximising water infiltration.

b) strategic use of herbicides as a substitute for tillage for weed control should be one method of minimising loss of surface cover.

5.30 For annual crops, tillage practices will need to be carefully considered.

a) mechanical tillage or regular soil disturbance for weed control and other reasons, will result in a rapid loss of soil organic matter which will result in not only changes in pH and micro-nutrient availability, but also water stable aggregation (aggregate stability) of the soil. This negatively impacts rainfall/irrigation water infiltration into the soil.

b) in a hot tropical environment such as at Hughenden, such degradation is likely to be relatively rapid. In northwest New South Wales where such extremes of heat and rainfall are not so common, significant soil changes have been observed in less than seven years. At Hughenden, it is considered that this time period may be significantly reduced.

c) reduced tillage, minimum tillage or zero tillage would be the most appropriate soil management practices for annual crops.

5.31 Additional broader landform considerations for erosion management will be necessary, including some of the following as examples:

a) while surface cover is useful/essential on such Vertisols, mechanical measures, such as 'contour banks' in some form and grassed waterways, will be essential to control soil loss. Row orientation relative to the slope will also be critical.

b) contour rows are considered to best control/manage on-field runoff. A 'graded' contour would be preferred to move runoff from the field in an orderly manner.

c) raised beds may be required for certain types of horticulture to provide sufficient soil depth for the plants. Orientation of such beds will be important in limiting and controlling erosion and maximising infiltration of water into the profile.

5.32 Row orientation.

a) attempts to orient rows/furrows/mounds at right angles to the slope, with the idea that such furrows will each carry runoff from their own area, most often result in high soil and water loss with unmanageable eroded gullies in downslope areas.

5.33 Row length.

a) long graded 'contour' runs/rows can be prone to over-top and break with a domino effect down the slope with extreme negative consequences. Best control of runoff and erosion is likely to be from 'short' row lengths to allow water discharge into a well-designed, constructed and maintained waterway in manageable volumes.

5.34 Waterways/watercourses would normally be constructed at right-angles to the contour with side banks to contain the field runoff in a well grassed and maintained (slashed) area. Entry to the waterway from the side furrows/bays would have to be designed such that water from the waterway above does not try to enter the field.

5.35 The tussock forming grass species naturally occurring in the area would unfortunately be considered unsuitable for the base of the grassed waterway. Relatively short stoloniferous (surface runners) grasses are best for this task. Short or mowed grass offers less retardance to the water in the waterway and allows a greater rate of discharge. However, the erosivity of clean water is high, as is fast flowing water (low retardance). Hence, there are a series of compromises/trade-offs in this regard - depth versus width of the waterway.

5.36 The Creeping Blue Grasses (*Bothriochloa petusa* or *Bothriochloa insculpta*) may be good choices for the area as they are native to parts of the 'dry' tropics. However, their survival and success as waterway grasses will depend on management, including fertilisation. Any shallowing of the A horizon to construct the sides of the waterway is likely to be detrimental to long-term waterway grass management due to soil constraints. Hence, construction of the waterway walls would be best from topsoil from outside the watercourse itself.

5.37 It is considered that erosion management, both in-field and via waterways, could make or break any attempt to crop these lands, in perpetuity.

6 Crop Management Strategies to Minimise the Potential for Salinity and Erosion

Overview:

6.1 Our investigations have identified the potential for salinity and erosion issues to emerge on the irrigated areas of the project. Identifying these issues in advance conveys the significant advantage of being able to devise and implement crop management strategies to prevent these issues occurring.

6.2 With sound strategy and planning, all the key identified risks should be manageable using sustainable land management techniques and good agricultural practice for crop production.

6.3 One of the most, if not the most, critical strategy will be to plan and execute a 'whole of project' approach to mitigating elements such as land levelling, the construction of contour banks, drainage channels and what crops are appropriate in what areas.

6.4 If this work is not done before the irrigation area is under the control of individual operators, any mitigating strategies are likely to be unco-ordinated and not as effective as if undertaken initially.

6.5 The actions of individual operators will also be important in preventing salinity and/or erosion being an issue. To consider this further, we have divided the balance of this section into the following:

- irrigation Systems
- irrigation Application Management
- irrigation Area Surface Drainage/Land Levelling
- individual Farm Surface Drainage Management
- managing Extreme Rainfall Events
- surface Cover Management

Irrigation systems

Overview

6.6 Irrigation water application management will be paramount. Methods of application that result in the movement of soil water beyond the root zone will be detrimental, not only in the short term, because of the probability of salinity and sodicity related issues effectively destroying the soil profile for plant growth.

Surface/Flood Irrigation

6.7 The typical options for surface irrigation (known as flood irrigation) include the following.

a) flood furrow irrigation

b) bay flood irrigation

c) bank-less channel

d) border check irrigation

6.8 Surface irrigation is the most commonly used style of irrigation for broadacre cropping with the types of crops typically grown on this type of system include the following.

a) cotton

b) summer grains

c) winter cereals

d) pasture and forage crops

6.9 Surface irrigation can be relatively easy to design and to manage and can range from low to high cost for construction.

6.10 Flood irrigation methods offer the least water control of any method and can necessitate land levelling to a greater degree than other irrigation methods. With the risk of an irrigation event pushing water beyond the effective root zone, the likely movement of salts (sodium or chloride) into lower soil layers exists. If excess water is added to soil profiles that plant roots are not accessing, then the risk of lateral movement of water (and dissolved salts) downhill exists.

Overhead

6.11 The typical options for overhead irrigation include the following.

a) impact sprinklers

b) centre pivots irrigator

c) later move irrigator

d) low pressure boom irrigator

e) travelling irrigator

6.12 The types of crops typically grown on this type of system include the following.

a) cotton

b) summer grains

c) winter cereals

d) pasture and forage crops

e) annual horticulture crops

6.13 Overhead irrigation systems require more management and skill compared to surface irrigation but allow for greater flexibility in crop options and is typically more efficient with water than surface irrigation systems.

6.14 To a significant extent, the types of crops grown will have a significant influence on the irrigation method(s) chosen.

6.15 Broadacre and broadacre row crops lend themselves to overhead sprinkler systems such as centre pivot and lateral move.

6.16 These methods allow even application of water, can reduce the need for land levelling, and are far more efficient than flood irrigation. A modification of the sprinklers attached to these methods includes low energy sprinkler application (LESA) and low energy precision application (LEPA). The slope on the proposed irrigation land may, however, preclude use of these modifications.

6.17 The lateral move type irrigators may have significant benefit in being able to run on the contour or appropriate contour line. A disadvantage may be that the channel required to feed the lateral move irrigator may result in salinity/sodicity issues (saline seep as well as dispersion issues associated with soil sodium). Careful construction and construction methods when building such a channel could mitigate against this problem.

6.18 Under some circumstances, the use of a drag hose to feed the lateral move irrigator would overcome the potential problems associated with the channel leakage towards bedrock. However, the area irrigated from the one supply arrangement would be significantly reduced.

6.19 Per hectare irrigated, the centre pivot offers financial and operational management advantages over the lateral move irrigator in that only half the size machine is required for a given area and operational alignment issues are less. Alternatively, the lateral move irrigator offers benefits in terms of reduced erosion in wheel tracks (wheel tracks should be approximately on the contour) and field shape (all the field can be irrigated – a square). With the pivot, on the side of the hill, wheel tracks are mostly well off the contour, causing erosion, even in the absence of rainfall runoff.

6.20 For annual crops and pasture, the key considerations for irrigation systems include the following:

a) Consider the fit for purpose of the irrigation system based on.

i) water-use efficiency

ii) amount of soil movement during land levelling and drainage

iii) depth of root system

iv) ability to effectively only irrigate to the depth of the crop root system.

Micro Irrigation

6.21 The typical options for micro irrigation include the following.

a) drip tape

b) surface drip tube

c) sub-surface drop tube

d) under-tree sprinklers

e) drippers

6.22 The types of crops typically grown on this type of system include the following.

a) annual horticulture crops

b) perennial horticulture crops

c) trellis and vine crop

6.23 Micro irrigation is typically the most common form of irrigation system for horticulture in Australia due to the benefits of water use efficiency and crop productivity.

6.24 Tree crops lend themselves well to subsurface drip or permanent under-tree sprinklers which allows tailoring water application to plant needs which will vary according to age of tree, rainfall, harvest etc.

6.25 For tree crops, the key considerations for irrigation systems include the following:

a) drip irrigation may be slightly more efficient but may not allow for wider grassed areas along each row for erosion and salinity management.

b) under-tree sprinklers may allow greater control over interrow grassed areas and increase humidity within the orchard.

c) design of any system to ensure distribution uniformity is maximised and lateral end drainage is kept to a minimum.

d) automation of the irrigation system will also improve the efficiency of the chosen delivery system.

Conclusion

6.26 Irrigation system choice, crop type and depth of A horizon will all influence the potential impact of salinity becoming an increasing issue either on an individual farm, further down the slope or onto the Flinders River.

6.27 The decision on what is the 'best' irrigation system cannot be just about cost, ease of use or individual preference etc., as negative impacts on erosion and salinity are likely to be impacted across the scheme and not only on an individual developed property.

Irrigation Application Management

6.28 If irrigation water application were to approximate crop use, and fill to soil, to water holding capacity without leakage to depth, this would be the most efficient and least likely to result in deep percolation of water beyond rooting depth. This should supply the plants short-term needs.

6.29 The ability to do this in practice is very achievable with modern moisture monitoring equipment and irrigation management experience.

6.30 A consideration could be that a requirement be placed on the irrigation area making advanced soil moisture monitoring systems mandatory to minimise the risk of over-irrigation and deep drainage of water.

6.31 Deep drainage of applied irrigation water will have a negative impact on any sodicity or salinity issues in lower horizons in the soil profile, making depth of irrigation management critical not only for water use efficiency but also salinity management.

6.32 The management of irrigation water for any crop type or irrigation system is essentially the same based on several key considerations:

a) Only apply water based on crop use.

b) Ensure depth of an irrigation event does not move beyond the active root system.

c) Using rain forecasts, try to maximise rain events with respect to adding water to the profile, with the option of an irrigation to top-up following rainfall as required.

d) Use of multi-depth soil moisture sensor system with real-time access to aid in irrigation timing and duration decisions.

Irrigation area surface drainage/land levelling

6.33 It will be imperative that should the proposed irrigation area be offered to individual producers, that farm layout and boundaries should consider flood/surplus water management and disposal thereof across the entire irrigation area. This will require integration of watercourses/waterways to minimise possible erosion and runoff damage.

6.34 Similarly, farm roads and other access arrangements will require careful location, management and maintenance.

6.35 Developers of the scheme should at the planning and design stage account for such considerations. It could be worth considering community-maintained watercourses and supply channels.

6.36 Some of the key considerations for the irrigation scheme area design for drainage management and land levelling include the following:

a) consideration of whole of area design for overland flow water management.

b) scheme-based and managed drainage areas/zones.

c) location of specific farm types within the scheme, e.g., only

   i) pasture farms in higher risk areas

   ii) patchwork farm types for pasture and annual cropping

   iii) density of farms down the slope in a given area

   iv) location of formed roads, verges, drainage etc.

Individual farm surface drainage management

6.37 Land levelling to some extent is usually necessary when irrigating. However, the need for levelling will vary according to the method of irrigation with sprinkler (overhead) methods offering better water distribution than flood methods.

6.38 Land levelling can have side effects: reduction in the depth of the A horizon and nutrient redistribution.

6.39 Nutrients such as zinc will most often need to be replaced. One reason for this is the soil disturbance due to the levelling process will result in the loss of arbuscular mycorrhiza fungi (AMF) which is essential for the uptake of plant nutrients, in particular zinc, phosphorus, copper, sulphur.

6.40 A reduction in the effective depth of the A horizon will lessen the depth of 'better' soil for plant growth by lowering plant available water. Further, excessive levelling (shallowing) could result in the development of problems associated with the sub-soil constraints caused by salinity and sodicity mostly due to water movement into deeper layers.

6.41 For tree crops, the key considerations for drainage management and land levelling include the following:

a) ensuring surface drainage removes all free surface water after a rainfall event with minimal soil movement.

b) appropriate row mounding to increase the depth of the A horizon.

c) row orientation to match optimal direction for tree performance and overland water flow management.

6.42 For annual crops and pasture, the key considerations for drainage management and land levelling include the following:

a) ensuring surface drainage removes all free surface water after a rainfall event for overhead irrigation systems with minimal soil movement.

b) if considered suitable, ensure even flow of water across a field for flood/furrow irrigation situations.

c) row orientation to match overland flow water management.

6.43 Avoiding the ponding of water can have the added benefit of reducing the risk of deep drainage in localised areas that may result in the rising of salts in the profile and the inherent risk of salinity impacts on crop performance.

Managing extreme rainfall events.

6.44 Should heavy rainfall be predicted, reduced water applications for growing crops should be used to provide additional capacity in the soil profile to store moisture.

6.45 The design of the scheme regarding farm type location will aid in ensuring that volume and speed of water is managed in a similar manner to how the current pasture plants manage erosion currently.

6.46 Additionally, the whole of irrigation area erosion management and overland water flow strategy will be critical to manage and direct water flows across the modified landscape and minimise the risk of excessive erosion.

6.47 In situations where up to 700mm of surface water can build up on the landscape, the issue of erosion will be difficult to effectively eliminate, however, minimising the impact on the soil surface from any extreme rainfall event will be essential.

Surface Cover Management

6.48 Management that includes surface cover (actively growing crop, crop residue) is a primary erosion control. Fine-stemmed, semi-permanent grass type crops, e.g., Rhodes Grass and millet, have the greatest effect on erosion reduction, irrespective of soil type. Coarser stemmed plants and wide rows, e.g., sorghum or corn, have a lesser effect due to the amount of bare soil exposed relative to close row, fine-stemmed crops.

6.49 Surface cover alone will not effectively manage soil erosion with intensification of land use. Graded banks (earthworks of some form) will be required to convey runoff water from the field in an orderly manner. The frequency of such structures will be dependent on slope (%). Effectively, such earthworks are slope length control structures. Irrespective of crop type, i.e., tree crops or other crop types, 'contour banks' will be necessary with appropriately designed, constructed and maintained water disposal areas.

6.50 Maintaining actively growing plants will also ensure that subsoil moisture in highly sodic horizons does not increase, which can result in the effect of salts being pushed closer to the surface.

6.51 For tree crops, the option to use under-tree sprinklers would enable the inter-rows to remain grassed all year. This would have the following impact:

a) reduced risk of dust during the dry season

b) reduced risk of erosion during the early wet season

c) increase the horizontal spread of tree roots where deep root growth may be constrained due to chemical or physical soil characteristics.

d) reduce the risk of water moving through the A horizon and accumulating in the B and C horizons.

6.52 For annual crops, the critical factors to maintaining surface cover will be associated with tillage and stubble management practices.

6.53 For perennial pastures, once established, full ground cover should be achieved year-round.

6.54 For soils that have issues with salinity/sodicity in lower profiles, ensuring that these soils are actively cropped, and the profile moisture is used, is especially important to ensure salts do not rise closer to the surface.

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