Soil & Groundwater Risk Assessment: Carlton Plain

Report prepared for 'Kimberley Agricultural Investment', Kununurra WA

Source: Google Earth

Soil Management Designs

In conjunction with ***Sustainable Soils Management*** and ***Kimberley Boab Consulting***

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EXECUTIVE SUMMARY

The conceptual farm plan for Carlton Plain – developed by Kimberley Agricultural Investment (KAI) in conjunction with Rich River Irrigation Developments – has been examined in relation to reconnaissance soil and groundwater information collated by WA Government for the area of interest. From a review of published soil and groundwater information, some general comments can be made about the likely management requirements for soil and groundwater at Carlton Plain where approximately 10,000 ha of land is under consideration for irrigated cropping.

There are two main ‘soil landscape’ units at Carlton Plain. The ~4,000 ha of deep loam soil upstream of about the mid-point of House Roof Hill has excellent potential for a broad range of irrigated crops. Much of the ~6,000 ha of clay-rich soil downstream of that point (some covered with a thin veneer of loam) appears to have favourable near-surface features but is limited by salinity constraints.

The deep loam soil has a low salinity hazard. If excessive recharge occurs and low-salinity water-tables rise, strips of deep-rooted perennials with high evapotranspiration capacity will be invaluable for protection of annual cropping land in-between the tree belts. Estimates will be developed regarding optimal proportions of perennials and annual crops (eg. cotton) across the development sites. Deep drainage is most easily controlled via use of pressurised irrigation rather than furrow irrigation, but where pressurised systems are not feasible the next best option is to utilise best-practice flood irrigation designs. This requires measurements of soil infiltration characteristics to optimise the length of runs. Flood irrigation development may require cuts into soil profiles, so a management plan will be implemented to ensure that topsoil rich in organic matter and nutrients is emplaced, where possible, on top of modified soil profiles following cut-fill operations.

Crop variability problems are highlighted by yield maps when harvesting crops such as cotton. To minimise the risk of excessive variability of crop growth within each field, detailed soil factor maps will be prepared so that issues such as sodicity, pH-imbalance and nutrient deficiency can be managed through variable-rate application of ameliorants such as gypsum, lime and fertilisers. Apart from boosting profitability through yield increases and optimisation of annual input costs, this approach will minimise the risk of agrochemicals being leached into the Ord River via under-field aquifers. Detailed soil mapping – typically carried out using inspection/sampling pits with a spacing of approx. 400 to 800 metres (possibly 100m spacing in complex areas) – also allows soil water holding capacity to be quantified so that Irrigation Management Units (IMUs) can be defined for use by irrigation system designers.

If cotton is to be the main annual crop on the deep loam soil at Carlton Hill, assistance with soil and water management is available through industry organisations such as Cotton Australia.

The clay soil west and north-west of House Roof Hill will be more difficult to manage. The combination of poor aquifer inter-connection with exit points, significant deep drainage associated with unusually wet ‘wet seasons’, and introduction of crops with less tolerance of salinity than the current vegetation almost certainly would cause saline water-tables to rise. The development of clay soil at the western end of Carlton Plain will require cautious planning and land uses with a strong tolerance of salinity.

1. INTRODUCTION

This document is a 'Soil and Groundwater Risk Assessment' for the Carlton Plain Irrigation Development.

The project is located approximately 40 km NW of Kununurra, Western Australia. It is bordered on the southern side by the Ord River and surrounds the prominent 'House Roof Hill'.

Kimberley Agricultural Investment Pty Ltd (KAI) is proposing to develop approximately 10,000 ha of land at Carlton Plain for flood irrigated annual crops (likely to be dry-season cotton) and tree crops. A conceptual plan has been prepared by Rich River Irrigation Developments (RRID) – see Appendix A.

There are three main components of this investigation:

1. Undertake a desktop review of existing soil and groundwater documentation pertaining to the Carlton Plain development area, in relation to the Carlton Plain farm design prepared by RRID for KAI. The nearby Mantinea Development proposed by KAI is considered in an accompanying report.
2. Undertake a risk management assessment process to specifically document and address soil and groundwater management issues, expected timing of impacts, and to quantify likely management requirements. The focus is on the lighter (Packsaddle-type) soils, rather than black soils for which substantial farming and management information already exists.
3. Consider groundwater-related implications for soils within the Carlton Plain development area, and adjacent non-development and/or conservation areas, including Ord River reserves, taking into account local climate information.

Staff from two companies with extensive experience in soil surveys and management for irrigated crop and tree production prepared the 'Soil and Groundwater Risk Assessment' for Carlton Plain, in conjunction with Dr Debra Pearce, Kimberley Boab Consulting Pty Ltd, Kununurra WA:

- Dr David McKenzie, Soil Management Designs, Orange NSW
- Dr Pat Hulme, Sustainable Soils Management, Warren NSW (groundwater / salinity assessment).

The Risk Management Framework used in this study is shown in Figure 1. The aim is to clearly identify all relevant soil- and groundwater-related risks associated with the proposed development. While the likely magnitude of the risks is taken very seriously, there is optimism regarding the assessment and management strategies that are available to deal professionally with all of the challenges that have been identified.

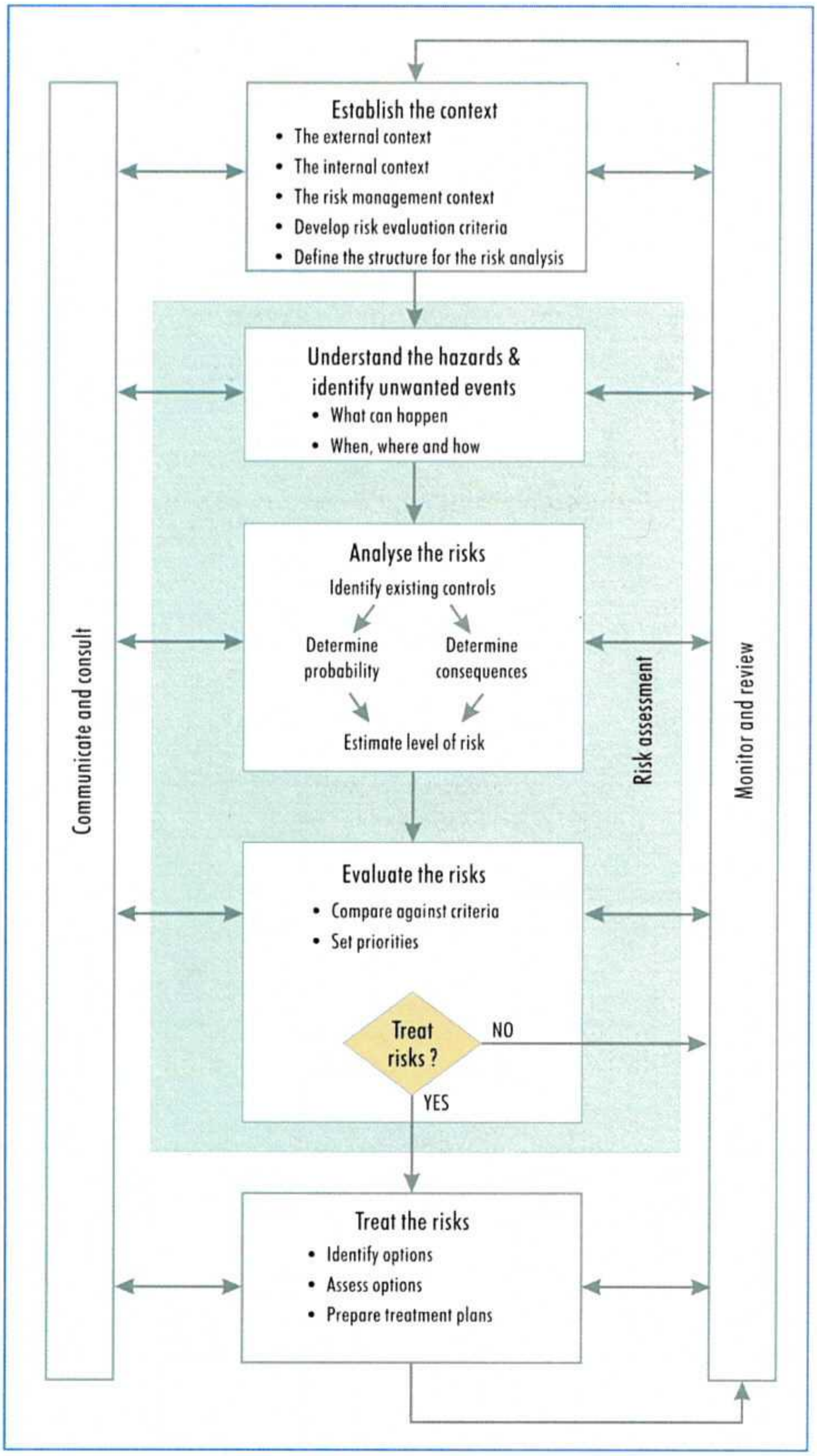


Figure 1 Risk management process. Source: AS/NZS ISO 31000:2009.

2. GROUNDWATER ASSESSMENT – PAT HULME

The Hulme report is presented as Appendix B – see attached

His main conclusions are as follows:

- The groundwater system beneath Carlton Plain consists of a valley of slowly permeable rock that has been infilled with as much as 24m of unconsolidated sediment. Much of the sediment in the downstream half of Carlton Plain and Mantinea was deposited in the sea bed (marine), while the sediment in much of the upstream half and strips beside the Ord River has been deposited by the river (alluvial). The marine sediment is much more saline than the alluvial sediment.
- The Ord River Palaeochannel, which conveys much of the groundwater flows beneath the Ord River Irrigation Area (ORIA), traverses the Weaber Plain and is not beneath Mantinea and Carlton Plain. As a result, the sediment beneath Carlton Plain is likely to have a much smaller capacity to convey groundwater than the sediment beneath ORIA.
- Both the analysis of trends in groundwater levels and the more detailed Ord Valley Airborne Electromagnetic (AEM) project conclude that there is a very large increase in the risk of irrigation induced salinity from the upstream end of Carlton Plain to the downstream end of the proposed irrigation development on this property.
- East of House Roof Hill, the majority of the proposed development has a 'Very Low' salinity hazard. A simple groundwater balance indicates that a shallow water table is unlikely to develop for decades under good water management.
- In contrast, much of the clay soil on the proposed development on Carlton Plain west of the north-western corner of House Roof Hill is rated as having 'Very High' salinity hazard, and is likely to develop a saline shallow water table after less than a decade of irrigation. The literature review indicates that it will be very difficult to avoid the development of a shallow water table in this area because there are likely to be periods – particularly unusually wet summers – when large deep drainage brings the water table close to the surface. The salinity threat in that sub-section of Carlton Plain means the affected zone is unsuitable for irrigated cotton and associated rotation crops.
- The finer resolution of the AEM salinity hazard map identifies a broad strip of deeper water table and Low salinity hazard along the Ord River that was not sampled by the test holes used to generate the depth to water table map.

Figure 2 shows the predicted salinity hazards at Carlton Plain and across the river at Mantinea.

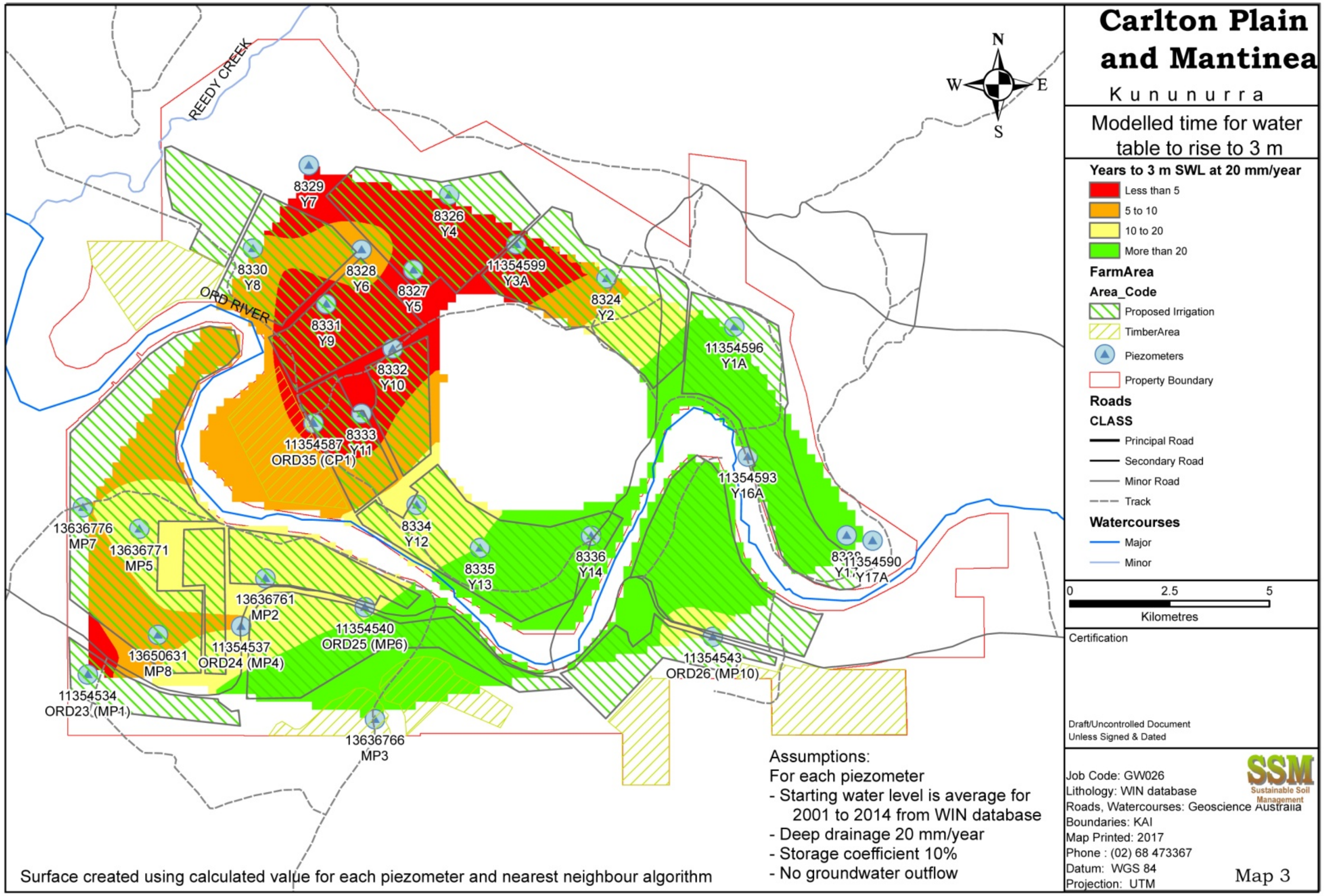


Figure 2 Modelled time for saline water table to rise to 3 metres; Carlton Plain is on the northern side of the Ord River (Hulme report – see Appendix B).

3. SOIL ASSESSMENT

3.1 Existing soil data and associated information

Stoneman soil survey

A soil survey was carried out by WA Government at Carlton Plain in the 1960s. The title of the subsequent report is: Stoneman TC (1988) *Carlton Plains Soil Survey in the Shire of Wyndham East Kimberley*. Department of Agriculture and Food, Western Australia, Report 76, 31p.

Stoneman's soil map is presented as Appendix C. For ease of discussion, a simplified version showing the main texture-based management groupings is shown below as Figure 3. The groupings are as follows:

- Alluvial Loams; including deep 'Group A Soils', and loam alluvium overlying Alluvial Clay (Winbidji Fine Sandy Loam)
- Alluvial Cracking Clays (Mantinea Clay).

The main messages from Stoneman (1988) are as follows:

- There are large areas of deep loams suitable for a broad range of crops.
- Favourable clays also exist, but they tend to become strongly saline as one moves west.

A limitation of the Stoneman report is that it that there was very little laboratory analysis of soil samples, and some of the soil sampling intervals were too broad, eg. 0-60cm.

Soil and Landscape Grid of Australia

Examination of the Surface Clay layer (0-5cm) in 'Soil and Landscape Grid of Australia' (http://www.clw.csiro.au/aclep/soillandlandscapegrid/) indicates no clear differences in %clay across the loam and clay areas mapped by Stoneman at Carlton Plain. This clearly is incorrect. Another limitation of the 'Soil and Landscape Grid of Australia' is that it does not provide estimates of salinity or soil stability in water. Therefore, this information is not useful for the current study.

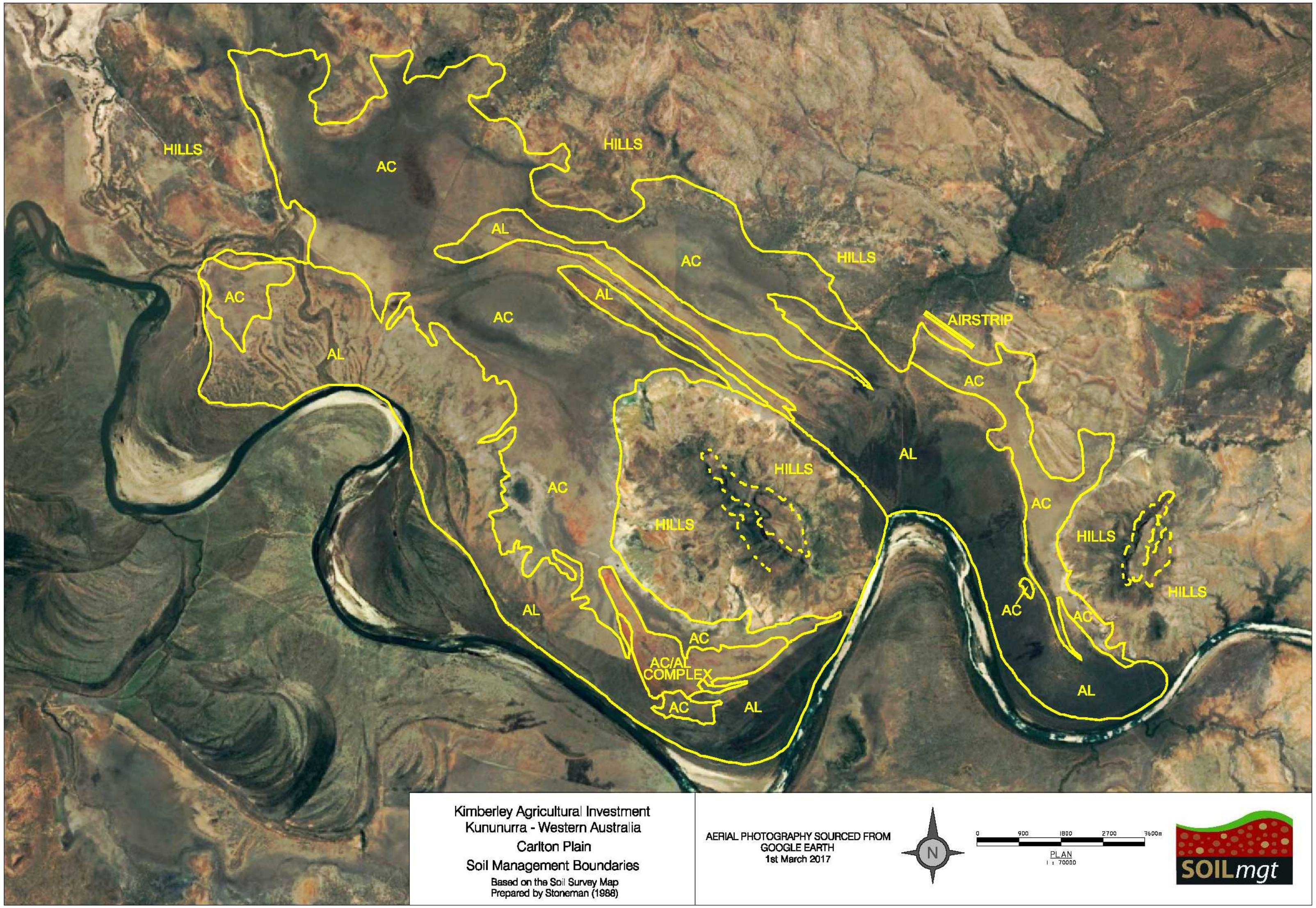


Figure 3 A simplified version of the Stoneman (2001) soil map (see Appendix B) showing the main texture-based management groupings at Carlton Plain: AL = alluvial loams (includes loams overlying deeply buried clay, and deep loams), AC = alluvial clays.

3.2 Additional soil data requirements to assist with management of possible adverse impacts (pre-development and for on-going monitoring)

The above discussion highlights a need for additional direct soil testing at Carlton Plain. The Stoneman soil survey is an incomplete reconnaissance study that lacks the required detail for a major new irrigation project.

Raper *et al.* (2015) have recommended in the more complex areas at nearby Mantinea that fine-scale soil surveying should be carried out to achieve a scale of 1:5000 which is recommended for irrigation development by McKenzie *et al.* (2008). This would require an inspection intensity of one site per 0.8ha to 4 ha.

David McKenzie's experience with soil surveying for new irrigation developments in the Kimberley suggests that a more practical and cost-effective approach is to use backhoe inspection pits on a flexible grid with ~400m spacing (approx. one pit per 16 ha; main focus on 0-1.5m soil profiles, but with soil sampling to a depth of 3m), and ~100m pit spacings in the more complex areas (1.5m deep pits). It may be best to commence with an ~800m pit spacing in the more uniform areas. Once development has occurred, extra soil information can be added via sampling guided by yield/yield gap/profitability mapping.

Landscape modelling to predict key soil factors via the use of remote sensing techniques (eg. AEM, Lidar, radiometrics) is invaluable where strong correlations exist between these signals and the factors of interest, eg. CEC profiles, salinity, dispersibility in water, pH and water-holding capacity. The extent to which geophysics and vegetation mapping can accurately predict soil factors other than salinity at Carlton Plain can only be determined following calibration via direct soil sampling.

Presentation of the soil information could be via the following layers:

Map 1. Airphoto with soil pit locations

Map 2. Elevation/slope data

Map 3. Readily Available Water (mm), upper 150cm

Map 4. Salinity – 6 depths

Map 5. pH ($CaCl_2$) – 6 depths

Map 6. Cation exchange capacity – 6 depths

Map 7. Soil dispersion: a) DI/ASWAT test, b) ESP, c) ESI – 6 depths

Map 8. Compaction severity (SOILpak score) – 4 depths

Map 9. Organic carbon – 6 depths

Map 10. Depth to clay in light-textured areas

Map 11. Depth to waterlogged (mottled) layer & drainage requirements (for possible use by drainage engineers)

Map 12. Irrigation Management Units for flood &/or pressurised irrigation zones (for use by irrigation design engineers)

Map 13. Soil management recommendations: lime application rates, depth of mechanical loosening, gypsum application rates

Map 14. Special measures to minimise erosion risk

Map 15. 'Australian Soil Classification' soil types.

3.3 Soil risks and recommended management responses

Tables 1a and 1b provide an overview of the types of soil-related problems that are likely to occur as part of the conversion of the existing soil and vegetation at Carlton Plain into a highly profitable and sustainable farming landscape.

Overviews of appropriate soil management responses also are provided.

Table 1a 'Alluvial Loam' soil risks and proposed management responses ('Group A Soils' and 'Winbidji Fine Sandy Loam')

Soil Issues – Loam topsoil	Likely Severity of Adverse Impacts		Management Responses to Risks	
	For KAI	**Regional**	**Pre- and during development**	**Post-development**
1 Hardsetting of surface soil after wetting and drying	Unknown severity – require soil survey data	n/a	n/a	Maintain as much surface cover as possible; maintain electrolytes via lime/gypsum
2 Compaction during development	If damaged, there is a long-term problem because of poor shrink-swell capacity	n/a	Where compaction is unavoidable during development, assess severity then deep rip at a suitable soil water content	May need follow-up deep tillage to complete the decompaction
3 Compaction by crop production machinery	Potential for this to be a major constraint	n/a	n/a	Controlled traffic farming systems will be essential
4 Dust creation during development	Regional loam topsoil already tends to be dusty and/or hardset because of damage by cattle Landforming is unlikely to make things worse		Where possible, carry out landforming at suitable soil moisture contents	Encourage as much surface cover as possible; maintain electrolytes via lime/gypsum to encourage aggregation of peds
5 Salinity, nutrient leaching associated with excessive deep drainage	There is a possibility of nutrient / agro-chemical leakage into Ord River (lateral movement south from alluvial areas into the river); salt export is less of a concern because there is a tidal influence in this section of the river so significant salt concentrations would already exist – see Figure 5. There may be perching of watertables by underlying clay layers in 'Winbidji Fine Sandy Loam'		Soil assessment to quantify hydrological properties	Maximise evapotranspiration by minimising duration of the soil being bare, particularly during the wet season. Monitor soil water content so that irrigation timing can be optimised
6 Excessive variability in water holding capacity within Irrigation Mgt. Units	Unknown risk – require soil survey data	n/a	Ensure that irrigation design is compatible with the distribution of contrasting "Irrigation Management Units'	Assess as part of long-term soil monitoring
7 Poor subbing of irrigation water into beds	Unknown risk – require soil survey data	n/a	Maybe add clay, eg. as done by dryland farmers on sandy soil near Esperance	Maintain as much surface cover as possible; maintain electrolytes via lime/gypsum
8 Poor seedbed conditions associated with cut/fill	Landforming cuts may be deep in the river meander areas	n/a	Need topsoil (0-10cm at least) stockpiling and re-application during landforming to make the most of natural organic matter	Maintain as much surface cover as possible; maintain electrolytes via lime/gypsum
9 Water erosion during storms	Water erosion is a possibility immediately after clearing Need to avoid sediment movement into Ord River		Develop an erosion and sediment control plan	Maintain as much surface cover as possible
10 Nutrient deficiencies	Likely – require soil survey data to obtain details	n/a	Add fertiliser prior to deep ripping so that it can be mixed deeply – important for immobile nutrients such as phosphorus	Add fertiliser in a way that satisfies plant requirements but minimises losses

Table 1b 'Alluvial Clay' soil risks and proposed management responses (Mantinea Clay)

Soil Issues – Cracking Clays	**Likely Severity of Adverse Impacts**		**Management Responses to Risks**	
	For KAI	**Regional**	**Pre- and during development**	**Post-development**
1 Waterlogging on flat fields ; crops such as cotton are prone to waterlogging damage	Potentially a major constraint	n/a	Need adequate slope and a suitable bed architecture to minimise rootzone waterlogging	Maintain high raised beds
2 Waterlogging associated with sodicity	Unknown risk – require soil survey data	n/a	Apply gypsum where required	Monitor dispersion, sodicity, add extra gypsum when appropriate
3 Compaction during development	Potentially a major but temporary constraint	n/a	Where compaction is unavoidable during development, assess severity then deep rip at a suitable soil water content	May need follow-up deep loosening to complete the decompaction (preferably via shrink-swell processes)
4 Compaction by crop production machinery	A major constraint if there is not effective guidance of machinery	n/a	n/a	Controlled traffic farming systems will be essential; convert cotton pickers from having dual wheels to in-line singles
5 Salinity – existing	Appears to be strongly saline near the western boundary	n/a	Only proceed with development in the salinity-hazard areas if the selected crops have the required tolerance of salinity.	
6 Salinity, nutrient leaching associated with excessive deep drainage	There is a possibility of nutrient / agro-chemical movement into Ord River; salt export is less of a concern because there is a tidal influence in this section of the river so significant salt concentrations would already exist – see Figure 5		Soil assessment to quantify hydrological properties	Maximise transpiration by minimising duration of the soil being bare, particularly during the wet season. Monitor soil water content so that irrigation timing can be optimised
7 Nutrient deficiencies	A likely constraint – require soil survey data to obtain details	n/a	Add fertiliser prior to deep ripping so that it can be mixed deeply – important for immobile nutrients such as phosphorus	Add fertiliser in a way that satisfies plant requirements but minimises losses
8 Poor seedbed conditions associated with cut/fill	Cut areas are likely to be sodic (require soil survey data to assess severity)	n/a	Apply gypsum where required	Monitor dispersion, sodicity, add extra gypsum when appropriate
9 Gilgai reformation after landforming	May be a problem; map zones currently gilgaied	n/a	n/a	Monitor elevations and re-grade when required (possibly in conjunction with gypsum re-application)
10 Water erosion during storms	A possible problem, but less of an issue than for Loams		Develop an erosion and sediment control plan	Maintain as much surface cover as possible
11 Acid sulfate soils in the study area – see Figure 4	Exposure of acid-generating subsoil in the western area if building drains would create toxic runoff – soil data are needed		Avoid acid sulfate soil excavation and/or drainage where possible.	Keeping acid sulfate soil inundated rather than oxidised controls the problem long-term

Figure 4 shows where acid sulfate soils (ASS) are thought to exist across northern Australia. Wilson *et al.* (2009) have noted that this information is only indicative because detailed and comprehensive data on ASS distribution and intensity are not available, and that more detailed investigation of ASS would be required for any proposed developments.

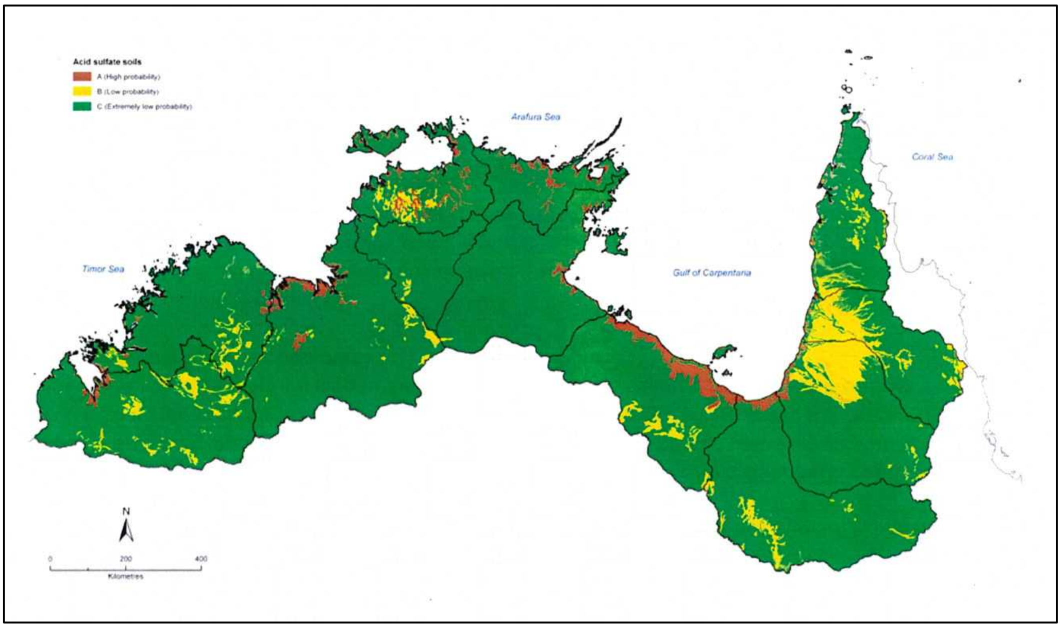


Figure 4 Potential distribution and severity of acid sulfate soil material (Wilson *et al.* 2009).

More is known about the extent to which saline water moves up the Ord River via ocean tides (Braimbridge and Malseed 2007). Figure 5 indicates the magnitude of the 'tidal reach' in the vicinity of Carlton Plain.

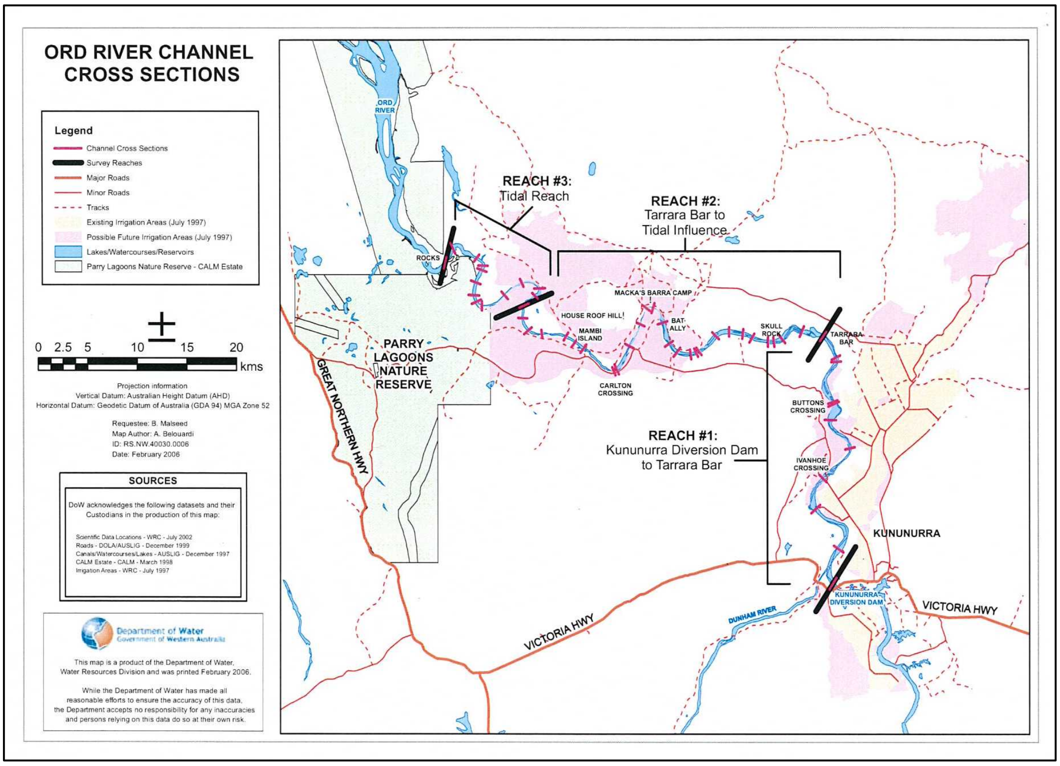


Figure 5 Extent of 'tidal reach' near the mouth of the Ord River (Braimbridge & Malseed 2007).

4. OPTIMAL LAND MANAGEMENT THROUGH INTEGRATION OF SOIL AND GROUNDWATER ASSESSMENTS

4.1 Suitability of Carlton Plain for irrigated cropping

The ~4,000 ha of deep loam soil upstream of about the mid-point of House Roof Hill has excellent potential for a broad range of irrigated crops. It has a low salinity hazard. If excessive recharge occurs and low-salinity water-tables rise, strips of deep-rooted perennials with high evapotranspiration capacity will be invaluable for protection of annual cropping land in-between the tree belts. Estimates will be developed regarding optimal proportions of perennials and annual crops (eg. cotton) across the development sites. Deep drainage is controlled more easily via use of pressurised irrigation, relative to furrow irrigation, although 'very wet' wet seasons tend to produce recharge events that can overwhelm the potential benefits from pressurised irrigation.

The ~6,000 ha of clay soil west and north-west of House Roof Hill will be more difficult to manage. The combination of poor aquifer inter-connection with exit points, significant deep drainage associated with unusually wet 'wet seasons', and introduction of crops with less tolerance of salinity than the current vegetation almost certainly would cause saline water-tables to rise. Excavation of deep drains to remove saline groundwater via the Ord River may be limited by the likely presence of acid sulfate soil. Therefore, development of clay soil at the western end of Carlton Plain will require cautious planning and land uses with a strong tolerance of salinity.

The salinity issues are discussed in more detail in Appendix B.

4.2 Suitability for flood irrigation per the RRID concept design plans

Where pressurised systems are not feasible, the next best option is to utilise best-practice flood irrigation designs. This requires measurements of soil infiltration characteristics to optimise the length of runs. Flood irrigation development often requires significant cuts into soil profiles, so a management plan will be implemented to ensure that topsoil rich in organic matter and nutrients is emplaced, where possible, on top of modified soil profiles following cut-fill operations.

Soil survey data will be needed to assist with the planning and implementation of the landforming.

4.3 Coordination of land management actions to maximise returns with minimal soil and water degradation

Crop variability problems are highlighted by yield maps when harvesting crops such as cotton. To minimise the risk of excessive variability of crop growth within each field, detailed soil factor maps will be prepared so that issues such as sodicity, pH-imbalance and nutrient deficiency can be managed through variable-rate application of ameliorants such as gypsum, lime and fertilisers. Apart from boosting profitability through yield increases and optimisation of annual input costs, this approach will minimise the risk of agrochemicals being leached into the Ord River via under-field aquifers.

Detailed soil mapping – typically carried out using inspection/sampling pits with a spacing of approx. 400 to 800 metres (possibly 100m spacing in complex areas) – also allows soil water holding capacity to be quantified so that Irrigation Management Units (IMUs) can be defined for use by irrigation system designers.

If cotton is to be the main annual crop at Carlton Hill, assistance with soil and water management is available through industry organisations such as Cotton Australia.

REFERENCES

Braimbridge M, Malseed B (2007) Ecological water requirements for the lower Ord River. (Department of Water, Government of Western Australia).

McKenzie NJ, Grundy MJ, Webster R, Ringrose-Voase AJ (2008) Guidelines for surveying soil and land resources, second edition (CSIRO Publishing: Collingwood).

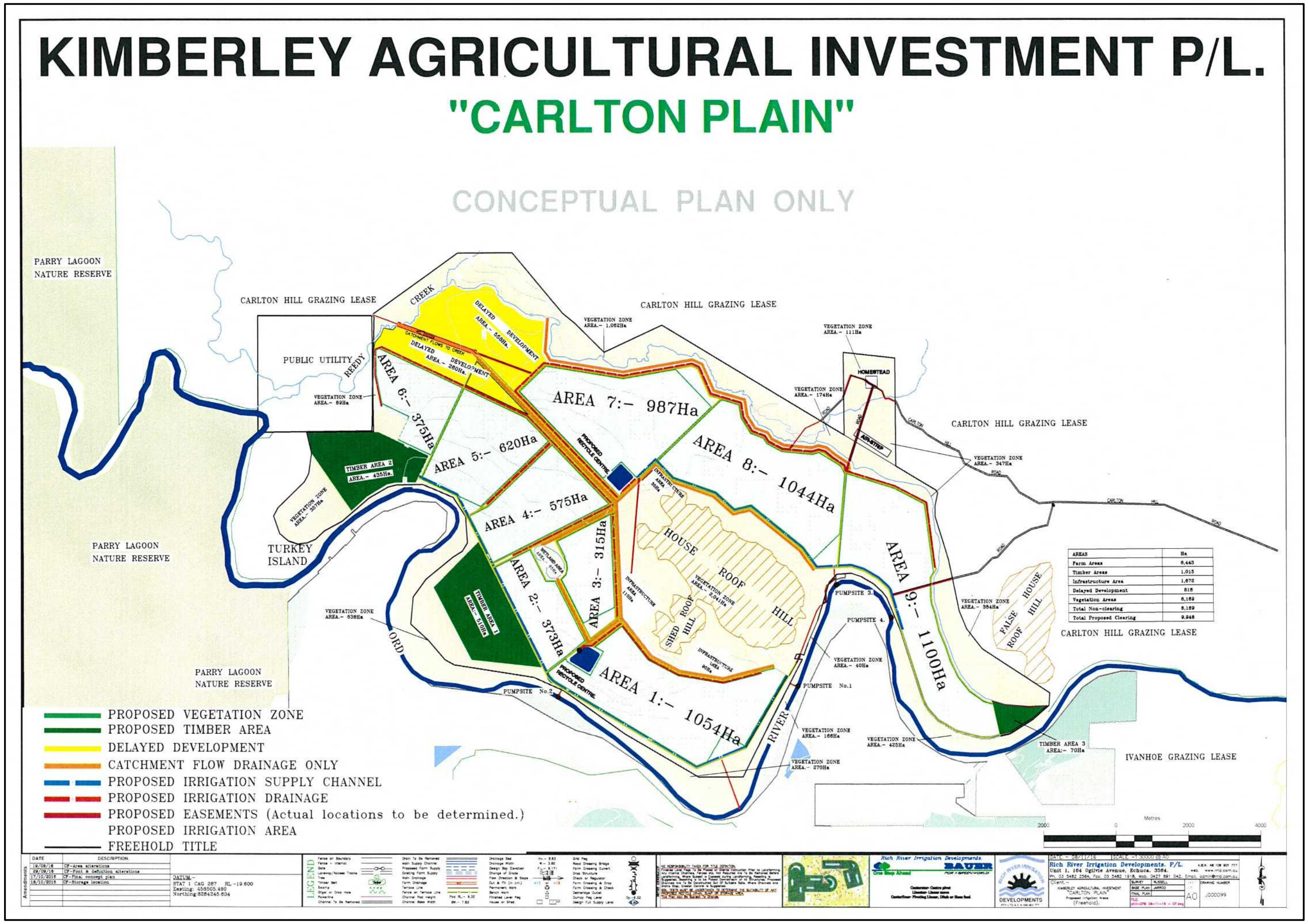
Raper P, George R, Schoknecht N (2015) Preliminary soil and groundwater assessment of the Mantinea Development area, East Kimberley, Western Australia. WA Department of Agriculture and Food, Report 389.

Stoneman TC (1988) Carlton Plains Soil Survey in the Shire of Wyndham East Kimberley. Department of Agriculture and Food, Western Australia, Report 76,.

Wilson P, Ringrose-Voase A, Jacquier D, Gregory L, Webb M, Wong M, Powell B, Brough D, Hill J, Lynch B, Schoknecht N, Griffen T (2009) Land and soil resources in northern Australia. Chapter 2, In: Northern Australia Land and Water Science Review. http://northernaustralia.gov.au/sites/prod.office-northern-australia.gov.au/files/files/Chapter_02-Land_and_Soil_Resources_in_northern_Australia.pdf

APPENDIXES

Appendix A: Study area boundaries and conceptual plans for Carlton Plain irrigation development (Rich River Irrigation Developments)



Appendix B: Hulme report: 'Groundwater Levels beneath Mantinea and Carlton Plain and Implications for Irrigation Development'

See attached

Appendix C: Stoneman soil map for Carlton Plain