

**TECHNICAL REPORT**

**COOLJARLOO WEST**

**WETLANDS, WATERCOURSES  
& GROUNDWATER  
DEPENDENT ECOSYSTEMS  
INVESTIGATION**

**OCTOBER 2013**

**FOR  
TRONOX PTY LTD**

## SYRINX ENVIRONMENTAL PL REPORT NO. RPT-1221-002 V1.1

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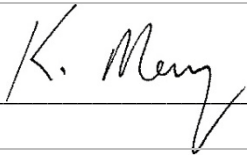
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**TABLE OF CONTENTS**

<b>PART 1: STUDY CONTEXT</b>	<b>1</b>
<b>1.0 INTRODUCTION</b>	<b>1</b>
1.1 PROJECT BACKGROUND	1
1.2 STUDY OBJECTIVES	3
1.3 SCOPE OF WORKS	3
1.4 RELATIONSHIP WITH OTHER STUDIES	4
1.4.1 Cooljarloo West Hydrogeological Assessment (WorleyParsons)	4
1.4.2 Detailed Soil Characterisation at Cooljarloo West (Soil and Water Consultants (SWC))	4
1.4.3 Flora and Vegetation Surveys (Woodman)	4
<b>2.0 SUMMARY OF EXISTING INFORMATION</b>	<b>5</b>
2.1 TOPOGRAPHY	5
2.2 GEOLOGY AND GEOMORPHOLOGY	5
2.3 HYDROGEOLOGY	6
2.4 SURFACE HYDROLOGY	6
2.5 WETLANDS	7
2.5.1 Geomorphic Wetland Classification	7
2.5.2 Wetlands regionally and locally	7
2.6 FLORA AND VEGETATION	8
2.6.1 Regional Vegetation	8
2.6.2 Local Vegetation	8
2.7 GROUNDWATER DEPENDENT ECOSYSTEMS (GDES)	9
2.7.1 GDEs within Cooljarloo West	10
<b>3.0 WETLAND &amp; GDE FIELD INVESTIGATIONS</b>	<b>11</b>

3.1	GENERAL APPROACH	12
3.1.1	Study Area	12
3.2	TARGET WETLANDS/UPLANDS FOR LOCATION OF VEGETATION TRANSECTS AND BORES IN STUDY AREA A	12
3.3	STRUCTURE	17
3.4	LIMITATIONS OF FIELD INVESTIGATIONS	17
	<b>PART 2: IDENTIFICATION OF WETLAND AND TERRESTRIAL GDES</b>	<b>18</b>
<b>4.0</b>	<b>GEOMORPHIC MAPPING &amp; VEGETATION CHARACTERISTICS</b>	<b>18</b>
4.1	OBJECTIVES AND RATIONALE	18
4.2	TOPOGRAPHIC VARIABILITY WITHIN STUDY AREA	19
4.3	PLANT INDICATORS OF GROUNDWATER DEPENDENCE	21
4.4	VEGETATION COMMUNITIES & PATTERNS	24
4.4.1	Dunes	26
4.4.2	Palusplain and Damplands	29
4.4.3	Floodplain systems	33
4.4.4	General Vegetation Patterns	35
4.5	EVALUATION OF WETLAND GEOMORPHIC MAPPING	35
<b>5.0</b>	<b>KEY FINDINGS OF WETLAND/GDE IDENTIFICATION</b>	<b>38</b>
	<b>PART 3: WETLAND &amp; GDE MECHANISMS</b>	<b>41</b>
<b>6.0</b>	<b>STRATIGRAPHY/HYDROLOGY CHARACTERISATION</b>	<b>41</b>
6.1	STRATIGRAPHIC SETTING	41
6.2	OBJECTIVES & RATIONALE	41
6.3	METHODOLOGY	43
6.3.1	Methodology Overview	43
6.3.2	Shallow Direct Push Drilling & Hand Augering	44

6.3.3	Groundwater Monitoring Bore Installation	45
6.3.4	Groundwater Sampling & Analysis & Groundwater Level Logger Installation	46
6.3.5	Watercourse (Surface Flow) Assessment	47
6.3.6	Watershed Analysis	48
<b>7.0</b>	<b>STRATIGRAPHY/LITHOLOGY ASSESSMENT</b>	<b>49</b>
7.1	MAJOR STRATIGRAPHIC UNITS	49
7.1.1	Bassendean Sands	49
7.1.2	Guildford Formation	50
7.2	LITHOLOGY, GRANULOMETRY & SOIL MOISTURE	50
<b>8.0</b>	<b>HYDROLOGY ASSESSMENT</b>	<b>52</b>
8.1	GROUNDWATER LEVELS	52
8.2	SURFACE FLOWS - MULLERING BROOK	55
8.3	WATERSHED ANALYSIS	56
<b>9.0</b>	<b>HYDROCHEMISTRY</b>	<b>58</b>
9.1	SOIL & SEDIMENT CHEMISTRY	58
9.2	GROUNDWATER CHEMISTRY	61
9.3	SURFACE WATER QUALITY - MULLERING BROOK	66
<b>10.0</b>	<b>KEY FINDINGS FROM STRATIGRAPHY/HYDROLOGY STUDY</b>	<b>67</b>
	<b>PART 4: CONCEPTUAL SITE MODEL</b>	<b>71</b>
<b>11.0</b>	<b>COOLJARLOO WEST CONCEPTUAL SITE MODEL</b>	<b>71</b>
11.1	HYDROGEOLOGY	72
11.2	SURFACE HYDROLOGICAL CONTROLS	75
11.3	VEGETATION	75
11.4	ECOSYSTEMS	76

11.4.1	Dunal System	79
11.4.2	Base of Slopes/Low Rises - Dry Heath	79
11.4.3	Wetland System	79
<b>12.0</b>	<b>VALIDATING THE CONCEPTUAL SITE MODEL</b>	<b>80</b>
	<b>REFERENCES</b>	<b>81</b>
	<b>APPENDICES</b>	<b>86</b>

## LIST OF TABLES

Table 1	Wetland types according to the geomorphic classification system.	7
Table 2	Groundwater dependent indicator species.	22
Table 3	Description of root system types.	23
Table 4	Known and inferred root depths of terrestrial, groundwater indicator and wetland species found on site.	25
Table 5	Characteristics of Key Stratigraphic Units Across the Site	41
Table 6	Monitoring bore completion details	46
Table 7	Summary of groundwater level loggers installed at Cooljarloo West	47
Table 8	Summary of particle size and soil moisture data (October 2012).	51
Table 9	Summary of groundwater level monitoring results.	54
Table 10	Surface water characteristics of Mullering Brook.	55
Table 11	Summary of soil and sediment chemistry data.	59
Table 12	Groundwater quality results.	65
Table 13	Mullering Brook water quality.	67
Table 14	Hydrogeological Properties of Key Units Across the Site.	74
Table 15	Relationship between main ecosystem units and vegetation communities, plant height and thickness of sand.	77

## LIST OF FIGURES

Figure 1	Location of the proposed mining area at Cooljarloo West.	2
Figure 2	Location and extent of study areas at the local (Study Area A) and regional scale (Study Area B).	13

Figure 3 Target areas selected for investigations showing local area of potential impact and location of transects.	14
Figure 4 Location of stratigraphy and hydrological bores.	16
Figure 5 Topography of the Proposal area showing general elevation (a) and relative elevation based on slope calculations (b).	20
Figure 6 Example of a) dampland, b) palusplain, c) creek and d) floodplain. Dunes or terrestrial environments are highlighted in white.	21
Figure 7 Examples of different root systems amongst Swan Coastal Plain shrubs (Dodd <i>et al.</i> , 1984).	23
Figure 8 Typical <i>Banksia</i> Low Woodland Community.	27
Figure 9 Typical <i>Allocasuarina humilis</i> and <i>Calothamnus quadrifidus</i> Open Dry Heath Community.	28
Figure 10 <i>Banksia armata</i> Open Heath Community.	29
Figure 11 Typical <i>Banksia telmatiaea</i> Wet Heath.	30
Figure 12 <i>Regelia ciliata</i> - <i>Melaleuca</i> spp. Open Wet Heath Community.	31
Figure 13 <i>Melaleuca preissiana</i> Open Woodland.	32
Figure 14 <i>Eucalyptus rudis</i> and <i>Melaleuca raphiophylla</i> Open Forest.	33
Figure 15 <i>Melaleuca lateritia</i> and <i>Melaleuca teretifolia</i> Tall Open Scrub.	34
Figure 16 Comparison of landform features generated by DEM with the wetland classification as per ENV (2010).	37
Figure 17 Breakdown of wetland and dryland vegetation associations based on Woodman (2013) and Syrinx survey data. Within the study area boundary, all dryland vegetation communities are classed as groundwater dependent.	39
Figure 18 Watershed components (Source: <a href="http://www.esri.com">www.esri.com</a> )	48
Figure 19 Clay and sand content versus moisture content at the Cooljarloo West area.	51
Figure 20 DEM generated streams for the Proposal area (1 m fill) showing respective catchment areas and sinks.	57
Figure 21 Major cations in soils of wetlands studied at Cooljarloo West.	60
Figure 22 Bicarbonate alkalinity variation with wetland type and aquifer.	64
Figure 23 Nitrogen variation with wetland type and aquifer.	66
Figure 24 Conceptual Site Model.	78

## LIST OF APPENDICES

APPENDIX 1 Transect profiles and associated vegetation communities.	86
APPENDIX 2 Bore logs from direct push and hand auger drilling programmes.	140

APPENDIX 3 Soil particle size distribution and soil moisture content (October 2012).	175
APPENDIX 4 Groundwater level logger results	184
APPENDIX 5 Soil analysis results.	187
APPENDIX 6 Groundwater field sampling information and analysis results.	191
APPENDIX 7 Groundwater electrical conductivity maps.	200
APPENDIX 8 Root Study.	208

# PART 1: STUDY CONTEXT

## 1.0 INTRODUCTION

Tronox Limited (Tronox, previously trading as Tiwest Pty Ltd) currently operates a mineral sands mine at Cooljarloo, 175 km north of Perth. Tronox is proposing to expand its mining operations to Cooljarloo West (the Proposal), located to the west of the existing Cooljarloo mine, within mining tenements E 70/2345 and E 70/2346 (Figure 1).

Syrinx Environmental PL (Syrinx) was contracted by Tronox to conduct wetland, watercourse and GDE investigations for the Cooljarloo West project area to support the environmental impact assessment process at a now confirmed Public Environmental Review (PER) level through Part IV of the Western Australian *Environmental Protection Act 1986* (EP Act). The Proposal has also been determined to be a 'controlled action' under the Environment Protection and Biodiversity Conservation Act 1999 (EPBC Act) and will be assessed in accordance with the bilateral agreement between the State and Federal governments. Details on the full Proposal and expected impacts is contained in the Scoping Document (Strategen, 2012).

## 1.1 PROJECT BACKGROUND

Tronox intends to extend the approximate 15-year dredge mine life of the Cooljarloo mine operations by developing additional resources at Cooljarloo West. Tronox has completed the exploration phase in 2012 with the identification and delineation of three ore bodies, Woolka (north and south), Kestrel and Harrier (Figure 1).

A key component of the conceptual mine plan at present is the movement of the existing dredge and (potentially) the ore processing plant (concentrator) from the Cooljarloo mine to Cooljarloo West and back again. Movement of the dredge between the two mines will likely be by flotation along an approximately 6 km long channel, requiring a corridor approximately 100 m wide to allow for the channel, a power line, pipeline and access road. Additional areas may also be required for the temporary storage of topsoil and overburden excavated from the channel.

The Proposal will be assessed under the PER process and the EPBC controlled action accredited process. The PER document is planned to be prepared and submitted to the Environmental Protection Authority (EPA) in late 2013 – early 2014 in order to enable final approvals to be obtained prior to the targeted production commencement date of 2016.

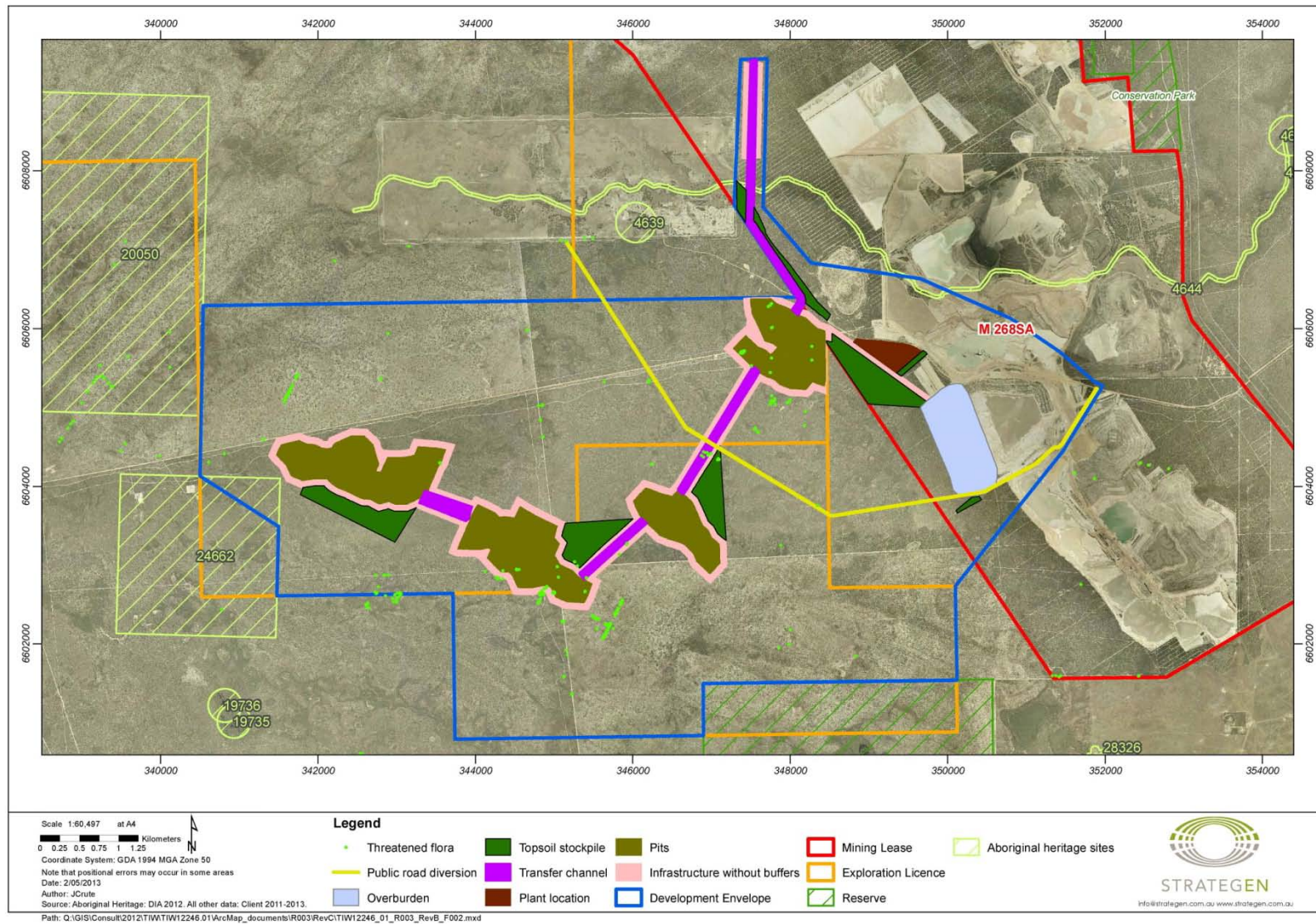


Figure 1 Location of the proposed mining area at Cooljarloo West.

Tronox has identified that the Proposal may result in the following environmental impacts to wetlands and watercourses in the vicinity of the ore bodies and the proposed channel:

- Excavation and dredge mining will intersect the water table as well as interrupt surface water flows – this may alter both surface and sub-surface flows to wetlands and watercourses;
- Excavation and dredge mining may expose potentially acid forming (PAF) material to oxygen – this may affect water quality of wetlands and watercourses;
- Excavation and dredge mining may intersect watercourses (e.g. Mullering Brook) and may also be required within wetland boundaries – this may affect surface water values and associated habitats;
- Abstraction of water for on-site water supply has the potential to affect wetlands and watercourses through groundwater drawdown;
- Runoff from disturbed areas may result in increased sediment transport to wetlands and watercourses; and
- Hydrocarbon and hazardous materials use has the potential to result in contamination of wetlands and watercourses (e.g. through spills).

As part of Tronox's progress with the Proposal, this report contains the results of baseline wetland, watercourse and groundwater dependent ecosystem (GDE) investigations which were conducted in order to enable assessment of these potential impacts. This work was undertaken in accordance with the Desktop Review and Detailed Method Statement prepared on behalf of Tronox (Syrinx 2012).

## 1.2 STUDY OBJECTIVES

The specific objectives of the wetland, watercourse and GDE study are to:

- Identify and characterise any wetlands, watercourses and GDE communities that may be affected by the Proposal, with particular emphasis on environmental values and regional representation;
- Identify the sensitivity of wetland, watercourse and GDE values to changes in groundwater levels and surface hydrology, beyond that expected to be experienced under natural conditions; and
- Contribute to development of wetland, watercourse and GDE impact mitigation strategies.

## 1.3 SCOPE OF WORKS

The scope for the wetland, GDE and watercourse study has been divided in three stages of work, with respective deliverables, as follows:

- Stage 1: Desktop Review and Detailed Method Statement;

- Stage 2: Wetland, Groundwater Dependent Ecosystem (GDE) and Watercourse Field Investigations and Report; and
- Stage 3: Report on Potential Impact Assessment and Impact Mitigation Strategies.

This document comprises the deliverable of Stage 2 of works and covers the findings of the Cooljarloo West field Investigations undertaken between September 2012 and July 2013. This report has been structured as to provide sufficient contextualisation to the field investigations without the need to repeat the desktop review and project setting information included in Stage 1.

## **1.4 RELATIONSHIP WITH OTHER STUDIES**

### **1.4.1 Cooljarloo West Hydrogeological Assessment (WorleyParsons)**

WorleyParsons has been engaged to conduct the baseline hydrogeological assessment of the Cooljarloo West area. As part of their scope, WorleyParsons have installed a network of monitoring bores targeting the superficial aquifer and conducted groundwater level and quality monitoring in the bore network. Additionally, aquifer permeability testing was conducted in selected bores.

Syrinx has used raw and processed data supplied by WorleyParsons as well as information provided as part of their Draft Cooljarloo West Hydrogeological Assessment Report (2012) prepared for Tronox.

### **1.4.2 Detailed Soil Characterisation at Cooljarloo West (Soil and Water Consultants (SWC))**

SWC were engaged as soil consultants for the project, and provided the analysis of stratigraphy across the proposal area based on Tronox drilling information and comparison with WorleyParsons and Syrinx individual bore data. Their data was used for calibration and extrapolation of findings in order to formulate a Conceptual Site Model for Cooljarloo West. A detailed soil study for the Proposal area was also conducted, which included the excavation of a series of deep and shallow trenches within the Proposal area for the purpose of assessing root density in relation to lithological layers, soil moisture profiles, and detailed lithological mapping. Within some of these trenches, Syrinx conducted root excavations to assess the likely penetration of species through the Guildford clays, and this component of work is included in this present report as APPENDIX 8.

### **1.4.3 Flora and Vegetation Surveys (Woodman)**

Woodman Environmental Consulting (WEC) has conducted vegetation surveys within the Cooljarloo West in 2009 and 2012 and is currently preparing a report to be submitted as part of this PER process (WEC, 2013). Syrinx has used the available 2013 vegetation mapping outputs from this study for comparison with the vegetation assemblages described for the transects traversed in the Proposal area, and to show the extent of terrestrial and wetland communities within Cooljarloo West. It should

be noted that the background information on the number of conservation flora and significant vegetation communities is based on the 2009 data as the updated data was not available at the time of preparation of this report.

## 2.0 SUMMARY OF EXISTING INFORMATION

The intent of this section is to briefly summarise the existing information base in relation to wetlands and GDE communities within the proposal area, which formed the basis of the methodology developed for the investigations described in this report.

For the complete desktop review and methodology statement the reader is referred to the Cooljarloo West Wetland and Watercourse Investigation: Detailed Method Statement (Syrinx 2012).

### 2.1 TOPOGRAPHY

The topography of the Cooljarloo West area is undulating and ranges between 50 m and 90 m AHD (ENV 2010). Detailed topographical information using LiDAR airborne topography data at 0.25 m resolution was used in this study to generate detailed contour information for assessment of surface water flows as well as wetland types and boundaries.

### 2.2 GEOLOGY AND GEOMORPHOLOGY

The regional geology and superficial stratigraphy of the northern Perth Basin is well documented (Playford, 1976; Kern, 1989; Rutherford *et al.*, 2005; Mory and Lasky, 1996) and in the Cooljarloo area superficially characterised in vertical profile by the presence of the Bassendean Sands at the surface (up to 30 m thickness), the Guildford Formation (henceforth referred to as simply the Guildford) below the sands (up to 50 m thickness), the Yoganup Formation containing heavy mineral sands below the Guildford Formation (up to 20 m thickness), the Ascot Formation (up to 30 m thickness) below the Yoganup and the Yarragadee Formation (up to 2000 - 4000 m thickness) below the Yoganup/ Ascot Formations.

Local stratigraphy/hydrological information suitable for wetland characterisation and evaluation has not previously been undertaken for the proposal area. Tronox have undertaken sediment logging in 1 m intervals as part of their exploration/resource drilling in the Cooljarloo West area and available data sets have been analysed as part of ongoing data review. Tronox's exploration drilling data is insufficiently resolved to allow detailed characterisation of the 0 - 5 m superficial formation. This is mainly due to the drilling method used and to the fact that the programme targeted characterisation of the heavy mineral ore bodies, at a depth of approximately 20 - 40 metres below ground level (mbgl), and not the superficial layers.

## 2.3 HYDROGEOLOGY

Parsons Brinckerhoff (2012) and WorleyParsons (2012) identified that there are two main regional aquifer systems in the project area, which were considered by these authors to be interconnected. They are the Superficial Formation, varying in depth from ground surface to approximately 50 mbgl, and the Yarragadee formation, at depths below 40 to 50 m.

The Superficial Formation is considered to constitute a single aquifer comprised of beds of sands and clays in alternate layers forming an unconfined to semi-confined anisotropic (i.e. with varying conductivity) groundwater system that flows generally in a westerly and south westerly direction (Kern 1989; WorleyParsons 2012). In areas where the Guildford Formation clays are absent, there appears to be good hydraulic connection between the Superficial Formation and the Yarragadee Formation.

The presence of clay lenses (associated with the Guilford Formation) and ferricrete gravel layers (associated with the Bassendean Sands) in near-surface forms act as confining layers and result in seasonal perched aquifers (Parsons Brinckerhoff 2011; WorleyParsons 2012).

The characteristics of the superficial sediments, including depth and thickness of aquifers and aquitards, which influence soil moisture and as such vegetation types, have been characterised further by WorleyParsons and Soil Water Consultants as part of the PER investigations.

Prior to this study, only limited superficial groundwater level and quality monitoring (one Tronox monitoring bore: OB04 and three DoW bores: Bore CS31, No 5, CS25 and CS26) have been conducted at the Cooljarloo West area. Detailed groundwater studies formed part of the WorleyParsons scope of work for this project. Results relevant to wetlands and GDE's within the proposal area are discussed in Section 8.0.

## 2.4 SURFACE HYDROLOGY

The surface hydrology of the proposal area is known to be dominated by watercourses originating on the Dandaragan Plateau and Arrowsmith Region (WorleyParsons 2012) with surface drainage being seasonal, with highly variable flows, generally peaking in July – August (Streamtec 2003). There are two main seasonal creeks that dissect the proposal area, flowing westward from the Gingin Scarp and terminating in wetlands occurring in interdunal depressions in the Bassendean Sands dunes. These are the Mullering Brook to the north of the identified ore bodies, and the Minyulo Brook to the south. These creeks form part of the Minyulo suite of consanguineous wetlands which are locally to regionally significant due to their stratigraphy and endemic flora (V&C Semeniuk Research Group 1994).

Water quantity and quality for the Mullering Brook as well as water levels and quality at Emu Lakes (part of the Minyulo Brook) have been historically monitored by Tronox and previously reported in Syrinx's desktop report (2012). Shallow stratigraphic information for these systems as well as depth to groundwater in their vicinity has not been undertaken prior to this current study. There is no specific literature on the permanent Dog Hole wetland located in the nature reserve, indicating that, potentially, this system has not yet been thoroughly characterised. Considering its distance from the nearest ore

body (approximately 2.5 km south east), detailed stratigraphic investigations were not conducted for this permanent water body.

## 2.5 WETLANDS

### 2.5.1 Geomorphic Wetland Classification

Wetland classification in Western Australia (WA) follows the geomorphic classification system of Semeniuk and Semeniuk (1995), which recognises landform types (e.g. basins, flats and channels) and extent of water permanence (e.g. permanent and seasonal). This categorisation of the water permanence associated with landform is presented in Table 1 below. In addition, wetlands are characterised by the extent and type of vegetation covering a particular wetland (peripheral, mosaic or complete cover) as well as wetland hydrological connectivity (low, intermediate and high connectivity).

**Table 1 Wetland types according to the geomorphic classification system.**

Water permanence	Landform				
	BASIN	FLAT	CHANNEL	SLOPE	HIGHLAND
Permanently inundated	Lake	-	River	-	
Seasonally inundated	Sumpland	Floodplain	Creek	-	
Intermittently inundated	Playa	Balkarra	Wadi	-	
Seasonally waterlogged	Dampland	Palusplain	Trough	Paluslope	Palusmont

In Australia generally, where wetlands interact with groundwater (perched or regional aquifers), they are further classified as a type of groundwater dependent ecosystem (GDE), (Hatton and Evans 1998; Richardson et al., 2011). GDEs and groundwater dependent species are further described in Sections 2.7 and 4.3.

### 2.5.2 Wetlands regionally and locally

V&C Semeniuk Research Group (1994) has described the wetlands and watercourses of the coastal region between Lancelin and Dongara which incorporates the proposal area. Wetlands within the proposal area are included in the Nambung Basin, and form part of the Mullering Wetlands chain (DPUD 1994).

Regionally, the wetlands form part of the Minyulo Suite, which has been described by V&C Semeniuk Research Group (1994) as a group of consanguineous wetlands (i.e. sharing similar climate, hydrology, geomorphology, geomorphic processes and developmental history) comprising the Mullering and Minyulo brooks, Emu Lakes and the microscale sumplands, damplands, and seasonal creeks located in the intermediate area between the brooks in the Bassendean Sands. Surface water in this suite can range from fresh to hyposaline with a typical pH range of 6.9 to 10 with water

maintained in wetlands through ponding, and groundwater rise (V&C Semeniuk Research Group 1994).

At the local scale, wetlands in the proposal area have been mapped and described by ENV (2010) as part of the Cervantes South wetland mapping and classification project. The aim of their project was to identify and delineate geomorphic wetland boundaries and to assign geomorphic classification according to Semeniuk and Semeniuk (1995) at a 1:25,000 scale.

## 2.6 FLORA AND VEGETATION

### 2.6.1 Regional Vegetation

The earliest mapping of vegetation in the proposal area was undertaken on a State-wide level at a scale of 1:1,000,000 by Beard (1979). In 2002, Shepherd *et al.* mapped and described vegetation system associations in Western Australia at a scale of 1:250,000, expanding on the mapping originally undertaken by Beard (1979). The mapping identifies the Proposal area and the surrounds as *Banksia* Low Woodland on coastal plain white sand, with numerous patches of *Hakea - Banksia* heath in swamps. This vegetation is typical of the undulating Bassendean Sands dune system and occupies almost all of the Cooljarloo West area and extends regionally to the north and south.

Other vegetation types found regionally include dunal thickets of *Acacia cyclops* and a low scrub dominated by *Acacia lasiocarpa* and *Melaleuca acerosa* interspersed with thickets of *Allocasuarina lehmanniana* on flats and interdunes and samphire on salt flats. These vegetation types are typical of Guilderton System. The drift sand dunes are also a feature of this system (Beard, 1997).

In addition to vegetation associated with the Bassendean Sands and Guilderton Systems, vegetation specific to the Jurien System is also found in the wider region. The Jurien system is typified by *Banksia prionotes* woodlands over tall shrubs of *Banksia sessilis* and *Calothamnus quadrifidus*, with patches of *Acacia spathulata* heath on shallow soils underlain with limestone.

### 2.6.2 Local Vegetation

In their review of the flora and vegetation data collected during previous surveys within the Cooljarloo West proposal area, Woodman (2012) described the flora and vegetation as diverse with a high number of conservation significant flora (four Threatened (T), eight Priority 1 (P1), seven Priority 2 (P2), 25 Priority 3 (P3) and eight Priority 4 flora).

A total of 22 structural plant communities were described and mapped within the project Cooljarloo West area including Forests, Woodlands, Thickets, Heaths and Samphire Salt Pans (WEC, 2009). The classification of these communities was further refined in the current vegetation survey (WEC, 2013 in preparation) where a total of 18 vegetation types comprising two super groups were identified. The resultant mapping is very similar to the map produced in 2009 with some of the vegetation

communities agglomerated and some split to better delineate similarities in species composition and habitat.

None of the plant communities recorded are listed Threatened Ecological Communities (TECs) or Priority Ecological Community (PEC) (WEC, 2009, 2013 in preparation).

It was noted that the community T5 (or 9a) (Cooljarloo Swamp, north of Proposal area) may correspond with the PEC 'Priority 1– 'Claypans with mid dense shrublands of *Melaleuca lateritia* over herbs' and may possibly represent a restricted community (WEC, 2009). Community W4 (or 6) (Open Low Woodland of *Banksia attenuata*, *B. menziesii* and *Melaleuca preissiana* over Low Heath) found within the Proposal area was considered as locally and possibly regionally restricted. Community W8 (15) (Woodland of *Eucalyptus decipiens* subsp. *decipiens* over mixed shrubs and herbs on grey sand on lower slopes), west of the Proposal area was also restricted within the Cooljarloo West broader area (representing only 11.6 ha) and may also be regionally restricted. Dominant plant communities recorded within the Cooljarloo West area and applicable to the Proposal area are:

- Heath dominated by a mix of species including *Banksia telmatiaea*, *Regelia ciliata* and *Melaleuca seriata* with occasional Scrub or Open Scrub of *Hakea obliqua* subsp. *parviflora* on grey or brown sand on lower slopes, flats and drainage basins; and
- Low Woodland to Low Forest of *Banksia attenuata* and *Banksia menziesii* with occasional *Eucalyptus todtiana* over Heath dominated by *Eremaea pauciflora* and/or *Hibbertia hypericoides* on brown or grey sand on lower to midslopes. (WEC, 2009)

The majority of the Proposal Area was mapped as being in Pristine condition, with little to no disturbance and an absence of introduced flora taxa.

## 2.7 GROUNDWATER DEPENDENT ECOSYSTEMS (GDEs)

According to the Australian groundwater-dependent ecosystem toolbox part 1: assessment framework (Richardson et al., 2011), GDEs are defined as 'ecosystems that require access to groundwater to meet all or some of their water requirements so as to maintain the communities of plants and animals, ecological processes they support, and ecosystem services they provide'. The toolbox recommends that three classes (types) of GDEs be adopted as follows:

- Aquifer and cave ecosystems (Type1): typically include karst (limestone caves) aquifer systems, fractured rock and saturated sedimentary environments. The hyporheic zone (region beneath and alongside a streambed where surface water and groundwater interactions occur) of rivers, floodplains and coastal environments are also included in Type 1 ecosystems.
- Ecosystems dependent on the surface expression of groundwater (Type 2): include wetlands, lakes, seeps, springs, river baseflow, coastal areas and estuaries. In these cases, groundwater extends above the earth surface, as a visible expression.
- Ecosystems dependent on subsurface presence of groundwater (Type 3): include terrestrial

vegetation that depends on groundwater fully or on a seasonal or episodic basis. In these cases, groundwater is not visible from the earth surface.

The above mentioned ecosystem types may rely on perched aquifers or on underlying aquifers. A perched aquifer can be defined as water that is separated from an underlying body of groundwater by an unsaturated low permeability unit. Perched aquifers are typically unconfined in nature and can form at shallow depths in the unsaturated zone, potentially resulting in surface expression. Perched water can also move laterally over the low permeability unit and discharge at the surface in the form of seeps (Richardson et al., 2011). The toolbox recognises that the implication of a GDE being potentially dependent on a perched aquifer is that it may be buffered from impacts of groundwater abstraction from underlying aquifers. It is also important to recognise, and correctly conceptualise, situations where abstraction occurs from a perched aquifer. In these cases, impacts to any associated GDEs may be significant, even if the amount of abstraction is relatively small (Richardson et al., 2011).

Unlike wetlands, terrestrial GDEs do not occupy specific landforms, but are rather determined by the type of interaction and dependence of the dominant plant species on groundwater. Groundwater dependent species are also recognised, however they may not be associated with groundwater dependent ecosystems as such (please see section 4.3).

### 2.7.1 GDEs within Cooljarloo West

Apart from the wetland classification and mapping studies by V&C Semeniuk Research Group (1994) and ENV (2010), the only regional study on groundwater dependent ecosystems of the North Perth Basin has been completed by Rutherford *et al.* (2005). This study was conducted in response to increases in allocation of groundwater resources in the Northern Perth Basin creating the need to identify and characterise GDE's to ensure their protection. The study was primarily desktop based taking into account regional scale understanding of the hydrogeology, the identification of perennial vegetation areas that may be GDE's based on depth to groundwater and groundtruthing of 100 sites.

The nearest GDE to the local proposal area was identified by Rutherford *et al.* (2005) as Site 76: Cooljarloo Spring. This area is located within the privately owned lot, approximately 800 m east of the tenement boundary E70/2345. The spring is described as being topographically controlled and coincident with the presence of Guildford sand and alluvium, with recharge to the superficial formation mainly by direct infiltration of rainfall. The watertable is close to the surface with the depth to water table between 0 to 5 m below ground level (Rutherford *et al.*, 2005).

No detailed field studies of groundwater dependent ecosystems have been completed previously in the Proposal area therefore proving to be a knowledge gap. The limited knowledge of groundwater species requirements remains a gap as most literature has focussed on terrestrial GDEs particularly tree species and shrub species of *Banksia* woodlands with very little understanding of the plant water use of wetland species.

Previous (and current, WEC, 2013) vegetation mapping indicates widespread wetlands and dunal systems in the Cooljarloo West area dominated by *Banksia* spp, many which are recognised as groundwater dependent. Therefore, on a *prima facie* basis, it can be assumed that the majority of Cooljarloo West contains ecosystems that have a strong likelihood of interacting with groundwater to some extent. However, whether these interactions occur with regional aquifers or perched systems or other subsurface throughflow processes is unknown. This is explored in this study.

### 3.0 WETLAND & GDE FIELD INVESTIGATIONS

The intention of the field investigation phase is ultimately to provide sufficient detail on wetland / watercourse /GDE values and the mechanisms underpinning them in order to assess the potential impacts of the proposed dredge extension and mining works.

Note, in this document, wetlands are separated from terrestrial groundwater-dependent ecosystems, although they are usually classed as a type of GDE. Because wetlands and watercourses dominate the proposal area, the hydrological mechanisms are likely to be more complex than species dependent on the deeper (rather than perched) aquifer/s, and the risks likely to be different to terrestrial GDE species. Hence, specific studies on wetland and terrestrial GDE's are required.

In essence, the investigations consider the following:

1. Wetland / Watercourse /GDE Characterisation & Function
  - How do the Cooljarloo West wetlands operate hydrogeologically, hydrochemically, and what physical properties underpin these functions?
2. Wetland / Watercourse Extent, Types and Relationships
  - What is the extent and type of wetlands within the proposal area and relationship between them?
  - What are the hydrological connections, if any, between the wetlands?
3. Wetland and GDE Values
  - How important/unique are the wetlands/GDE's?
  - What is the conservation significance of each of the wetlands and GDE's within a local regional and state context?
4. Wetland and GDE Sensitivity
  - What are the relative tolerances of ecological components to a range of possible impacts associated with mining (e.g., changes to water depth, changes to hydroperiod, changes to flow regimes, changes to water quality)?

Note, this report does not address the risk assessment phase, which is covered in a separate report.

### 3.1 GENERAL APPROACH

These investigations follow methodology contained within the Detailed Method Statement (DMS) (Syrinx 2012). A brief précis of the general approach is provided in this section, with more specific method outlines contained within relevant sections of this report. Where the methods varied from the DMS, this is noted and discussed accordingly.

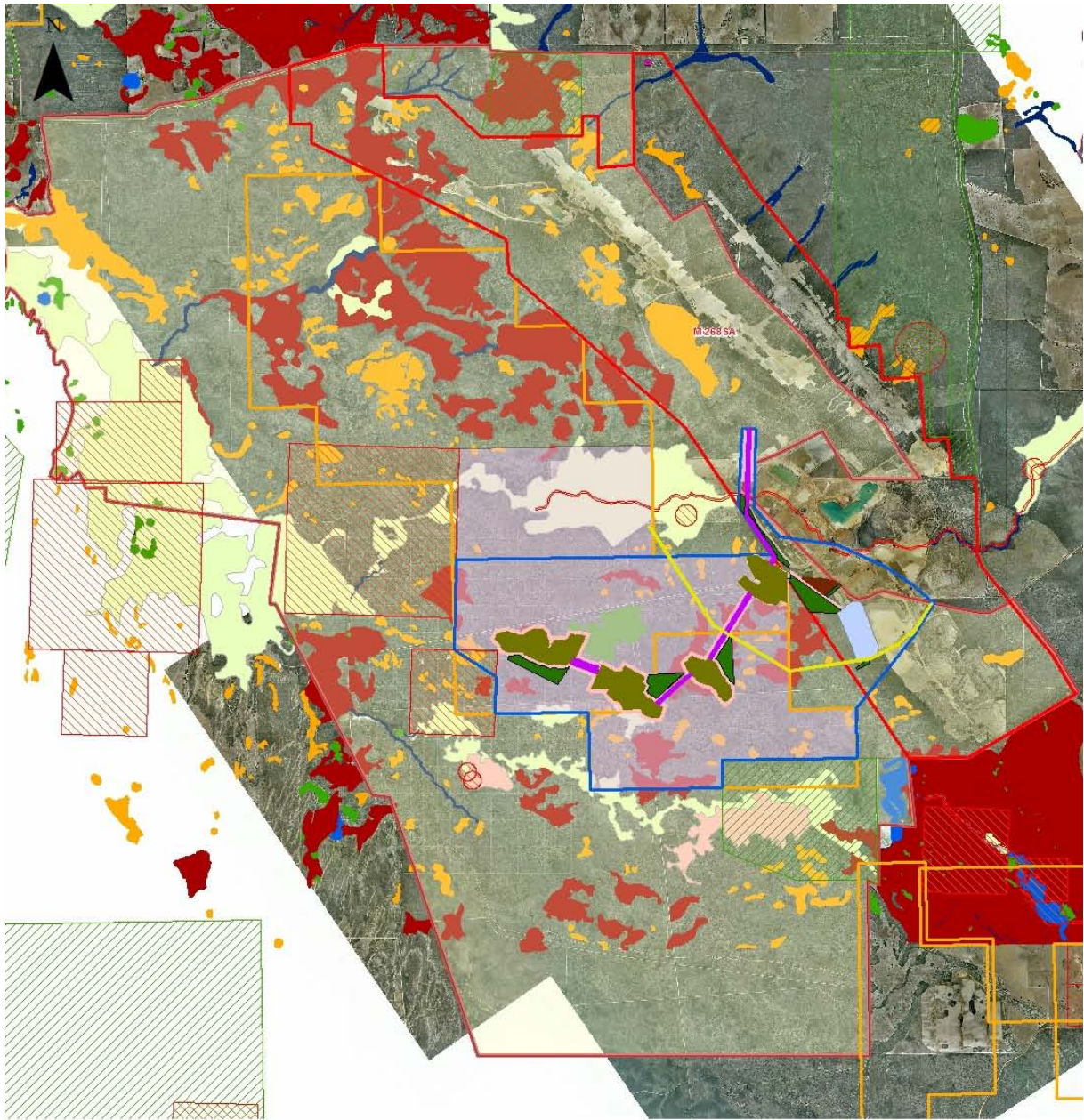
#### 3.1.1 Study Area

Given the large extent of the Cooljarloo West region, Syrinx adopted a field survey approach at two scales:

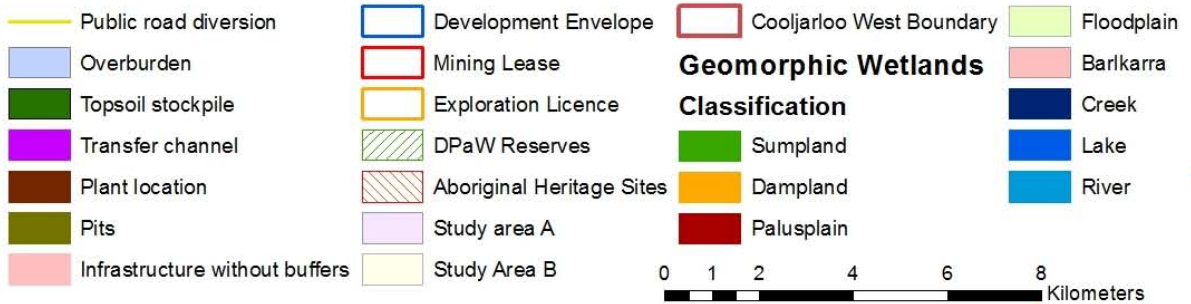
1. Local Area of Potential Impact (Study Area A which incorporates the Proposal area) - limited to the immediate catchment boundary to capture all areas potentially impacted by the proposed dredge ponds and associated channels. This area is delineated by Mullering Brook to the north and the northern branch of Minyulo Brook to the south (Figure 2) and is entirely within the approved exploration tenements and outside any indigenous and heritage areas. Detailed site investigations (vegetation, stratigraphy and hydrology) were conducted in this area. Note, this study boundary concurs with that of WorleyParsons for the parallel hydrogeological investigations.
2. Remaining Extent of Study Area (Study Area B) - the remaining areas within the Cooljarloo West area boundary as defined in Figure 2. Investigations in this broader area used a site reconnaissance method to assess regional representation of the wetlands and watercourses recorded in Study Area A. These investigations were used to provide a regional basis for assessing the relationships between wetlands in the area of potential impact and broader areas to each other (i.e. the consanguineous suite approach (V&C Semeniuk Research Group, 1994), the regional representation of wetland types, and, as a result, the conservation significance of individual wetlands that may be affected by the Proposal.

### 3.2 TARGET WETLANDS/UPLANDS FOR LOCATION OF VEGETATION TRANSECTS AND BORES IN STUDY AREA A

A number of wetlands and upland areas were selected for detailed vegetation, stratigraphic and hydrological studies. Thirteen sites were selected which were broadly representative of the suite of geomorphic wetlands and associated upland areas present within the investigation area, allowing for a duplicate of each geomorphic wetland (e.g. Palusplain, Dampland etc) where this was possible (e.g. there is only one Sumpland on site). The investigation sites (transects) are shown in Figure 3.



**Legend**



**Figure 2 Location and extent of study areas at the local (Study Area A) and regional scale (Study Area B).**

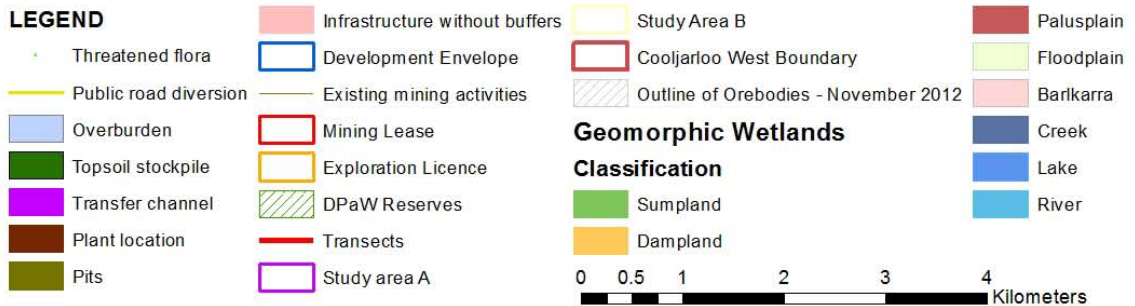
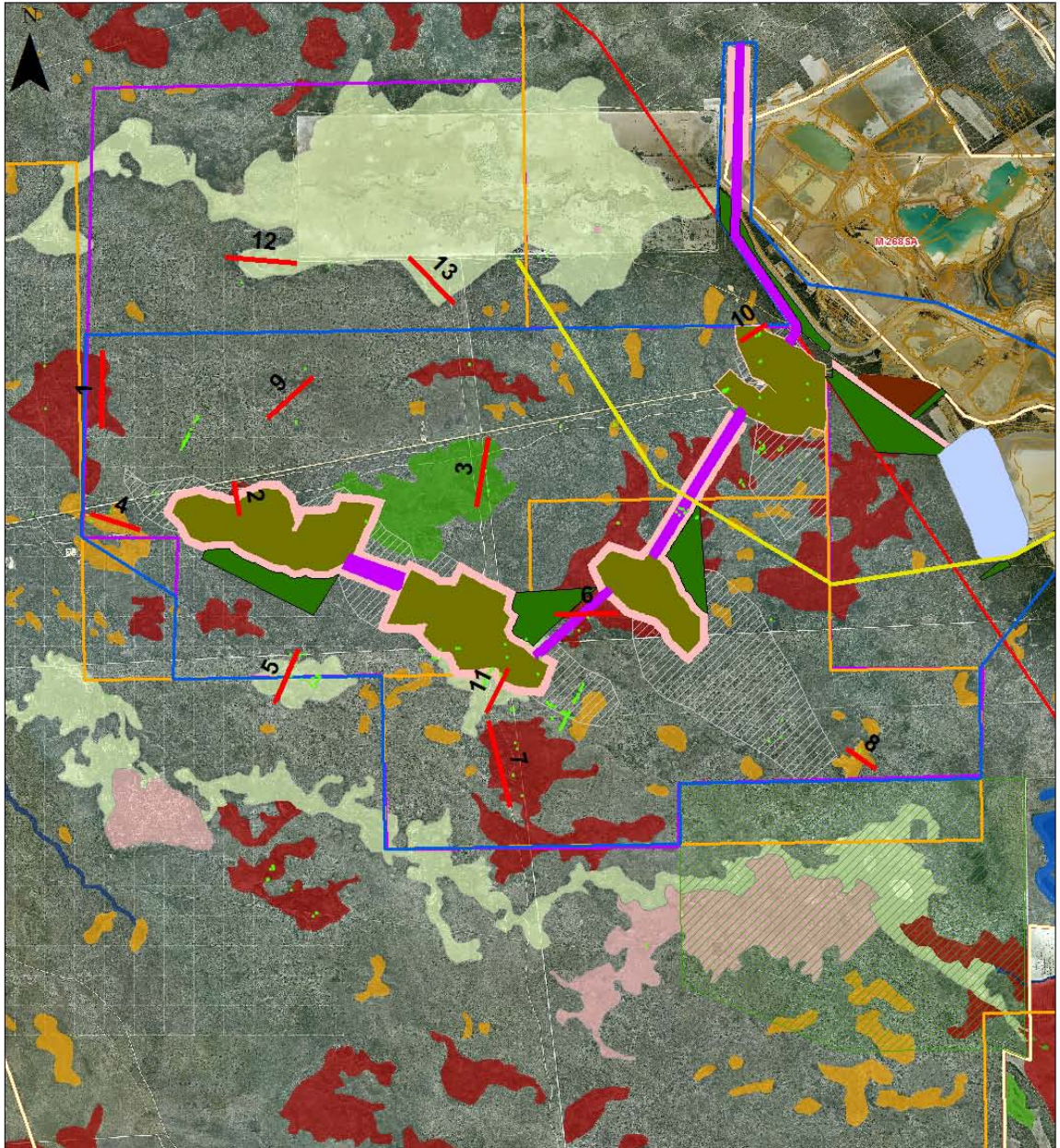


Figure 3 Target areas selected for investigations showing local area of potential impact and location of transects.

A series of permanent transects were established at each target wetland and extending into terrestrial sites (Figure 3). The selection of transect sites was based on the indicative proposed mine / orebody footprint and the available literature at that time (November 2012). Whilst changes have occurred in the proposed size and boundaries of the proposed mining footprint as a result of more resolved mine development planning (Figure 3), Syrinx considers the overall selection of transect locations adequate to describe and analyse surface and groundwater dependency of vegetation within the Proposal area.

Transects located within the likely mining footprint were extended to encompass areas outside of the orebody / dredge footprint to provide baseline data, as well as to enable future monitoring of potential impacts. A total of 13 transects were installed and used for the purpose of:

1. classifying broad vegetation communities,
2. identifying dominant wetland and GDE indicator species

The target wetlands and transects were also used to select bore and hand auger sample sites for stratigraphical / hydrological assessment. A similar transect approach was used for drilling and shallow piezometer installation locations within and around the identified wetlands and GDE's. Each transect included one or two bores (depending on the wetland size) located at the edges of the wetland and one or more additional hand auger holes located in the centre (Figure 4). The groundwater monitoring network was designed to capture shallow (<5 m) and deeper (up to 40 m) groundwater data that will provide insight into how stratigraphic phenomena (e.g. presence of clays, sands, etc) relate to hydrogeologic phenomena (e.g. presence of perched aquifers, etc) in areas where ecological mapping and monitoring has occurred.

As such, the target wetlands and transects within them provide information at a detailed scale that could be used to understand the inter and intra wetland complexities, and enable extrapolation of data to generate a conceptual site model of the study site.

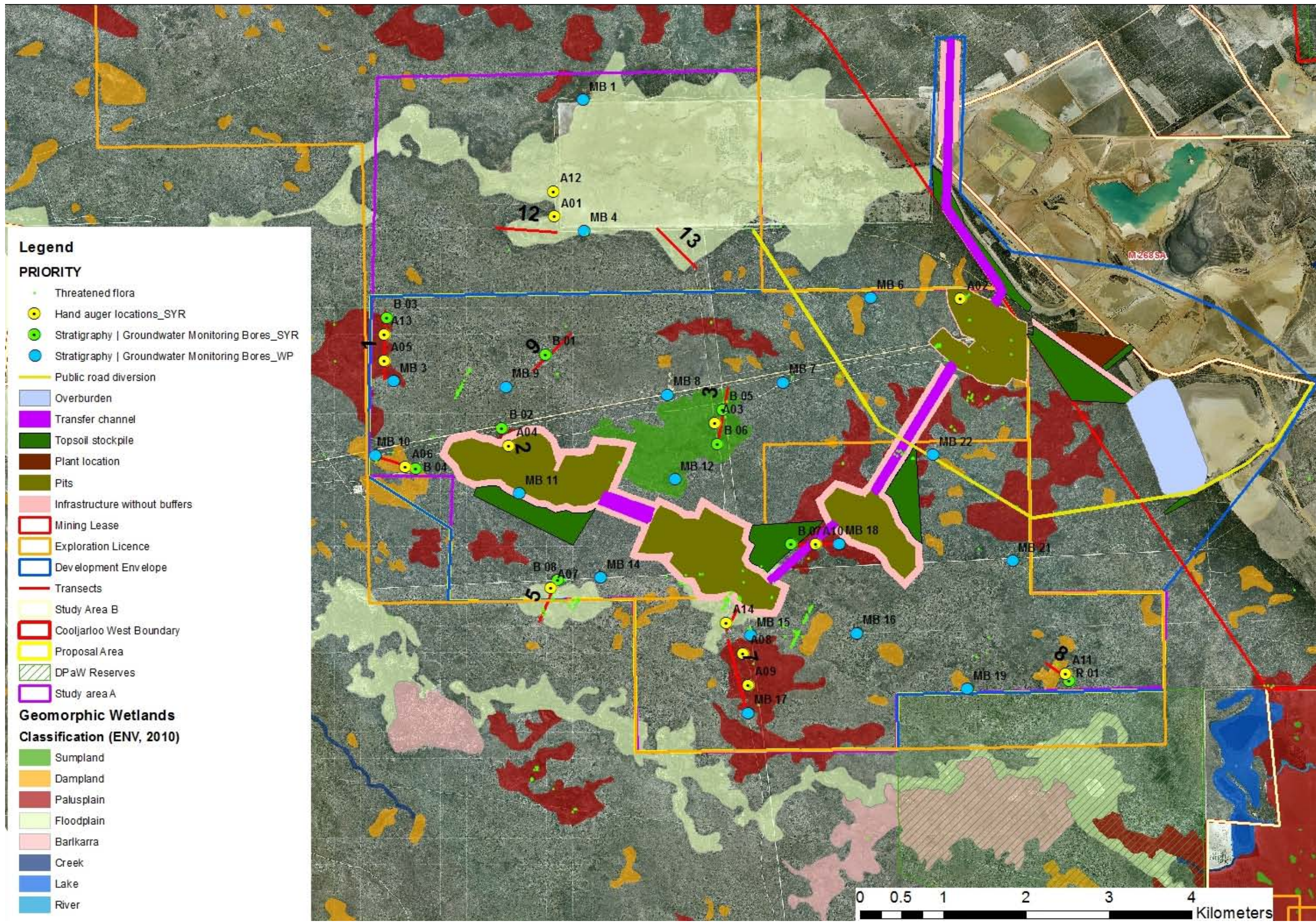


Figure 4 Location of stratigraphy and hydrological bores.

### 3.3 STRUCTURE

The discussion and interpretation of data obtained in this field investigation study essentially follows a scalar approach, working first from the subregional or site scale (Site Scale), to patterns within wetland groups (Wetland Scale), and where relevant, to analysis of variability within individual wetlands or other GDE ecosystems. In Part 4 (Conceptual Site Model), the approach is reversed with both fine scale and subregional data on vegetation, soils, hydrology used to build a broad picture of the mechanisms operating within the study area.

### 3.4 LIMITATIONS OF FIELD INVESTIGATIONS

It is important to note that the field investigations focused on the area surrounding the ore bodies as initially outlined in the Scope of Works. As the conceptual mine plan and pre-feasibility study developed, the mining footprint has been refined. As a result of these changes some of the studied wetlands and GDE communities are in the zone of direct impact (within ore bodies) while others are relatively far from the potential indirect impact zone (e.g. area potentially impacted by groundwater level changes and modified surface runoff properties). Notwithstanding the above, the selected locations for the field investigation include wetlands in the direct impact zone, in potential indirect impact zones and in areas not likely to be impacted by the Proposal (control sites). Therefore, locations are deemed appropriate as they cover the whole range of disturbance possibilities for the site.

The site investigations provided in this report give a snapshot of the Proposal area as studied between March 2013 and July 2013. It is important to note that hydrographs for the study area are not yet available since data has not been collected for a sufficiently long period, and because many of the superficial bores were dry over summer.

## PART 2: IDENTIFICATION OF WETLAND AND TERRESTRIAL GDEs

### 4.0 GEOMORPHIC MAPPING & VEGETATION CHARACTERISTICS

#### 4.1 OBJECTIVES AND RATIONALE

The existing mapping information (V&C Semeniuk Research Group (1994) for the region and ENV (2010) for the local study area) was based on aerial photographs and limited ground truthing; no detailed topographic data was available to confirm wetland types. At the basic level, wetlands are first classified on the basis of geometry and separated into basins, flats and channels, hence an appreciation of detailed topography is necessary to accurately map wetlands at the large scale where ground-truthing is not feasible. Secondly, wetlands are classified according to their hydrological regime into permanently inundated, seasonally inundated, intermittently inundated and seasonally waterlogged forms Semeniuk (1987, 1995). Hence, for basins the sequence is from lakes to sumplands to playas to damplands, and for flats is floodplain to barkarra to palusplain. In terms of vegetation controls, the hydrology and stratigraphy are normally more important than the form of the wetland; however, basin type wetlands tend to show a greater degree of species zonation due to the topographic variability at the edges.

Following a reconnaissance trip undertaken by Syrinx in August 2012 as well as the detailed site surveys in October 2012, there appeared to be considerably more variability within some wetland types than indicated in the ENV (2010) mapping, with boundaries of wetlands mapped as a single type appearing to encompass two or more wetland types. In order to support the impact assessment for the Proposal, Syrinx considered that a better understanding of wetland boundaries within the area of impact was necessary to:

- Assist in understanding to what extent the wetland geomorphic complexity explains the vegetation complexity in part or whole, and in turn the conservation values of the wetland system;
- Determine if there are any unusual wetlands within the Minyulo suite within the study area and/or other wetlands not mapped; and
- Determine if there are any incorrectly mapped wetlands that influence either the interpretation of the conceptual site model (CSM) developed for the area (Section 11.0) and/or the conservation significance of any particular wetlands.

Aside from geomorphic attributes, identification of wetlands and GDE's can be supplemented by vegetation studies, and in particular, presence or absence of known groundwater dependent indicator species.

The known groundwater dependency type of the selected species indicate the potential role of each water source (groundwater, surface water and soil water) in supporting vegetation on site whereas the root architecture of species indicates the probability of interaction with the regional groundwater table, based on the differential between root depth and depth to watertable. In addition to these, plant height can also be used as an indicator of the rooting depth and with that the depth of underlying soils, in this case sands (Silva and Rego, 2004; Bell, 2001; Candell and Zedler, 1995).

This section describes the influence of topography on the type and distribution of wetlands and GDE communities, the assessment of likely water dependency using indicator communities and species, and relationships between these factors.

## 4.2 TOPOGRAPHIC VARIABILITY WITHIN STUDY AREA

The topography, particularly detailed topography based on LiDAR, provides a good indication of the landform types present in the Proposal area. These landforms have an influence not only on the shape of the wetlands found but also on hydrology (e.g. extent of inundation or water logging and the creation of local water flows either through sheet flow or more concentrated surface water movement within swales and poorly defined creeks).

The topographical contours and the Digital Elevation Model (DEM) generated by LiDAR analysis of the Study Area A (which includes the Proposal area) were used to determine the type of wetlands present, as well as surface water flows (see Section 6.3.6). The classification of wetlands was then reviewed with reference to Semeniuk (1987, 1995), observed soil properties, and the GDE wetland species present.

The Proposal area as well the wider Cooljarloo West area has undulating terrain with high dunes to the east and smaller dunal ridges and rises on flats and open depressions to the west. The dunes and wetlands sit within the Bassendean Sands, which are aeolian sandy deposits (WorleyParsons 2013 and Part 3 below). The floodplain of Mullering Brook appears to be the flattest area locally and is distinctly different from the terrain surrounding Minyulo Brook, which is more undulating. Whilst basins are present within the Proposal area these are relatively poorly defined with broad and low elevation crests compared to those outside of the Proposal area (e.g. Emu Lakes and Dog Hole Lakes).

Most wetlands in the Proposal area and immediately south and north of the boundary are characterised by open depression landforms which gives rise to floodplain wetlands (e.g. Cooljarloo swamp where transect 12 is located) or palusplain wetlands (Transect 1, 6,11) (Figure 5 a). Several damplands exist on site, however, the basins appear to be poorly defined (Transects 2, 4, 5, 7, 8, 10 and to a small extent T9).

Figure 5 b was generated from the 1 m DEM to infer relative height of surface features based on slope analysis.

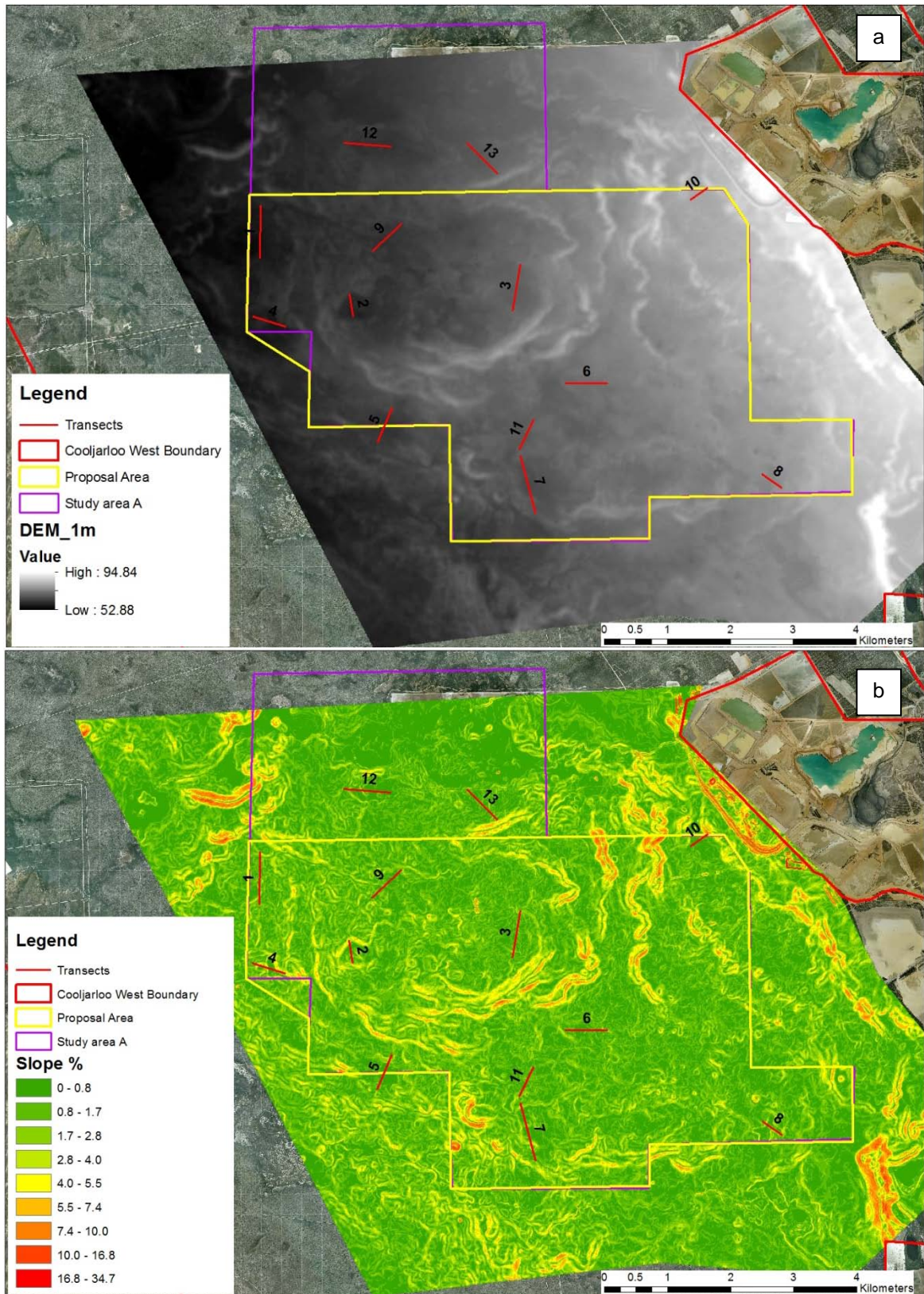
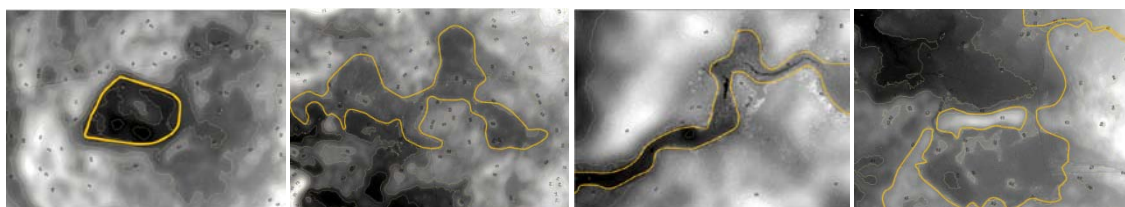


Figure 5 Topography of the Proposal area showing general elevation (a) and relative elevation based on slope calculations (b).

The image shows the gradation of dunal crests and slopes and small dunal rises within flat areas. This indicates a high degree of surface interconnectedness, relative flatness of the landscape, and the poorly defined nature of wetland geometry, particularly basins. Note, whilst higher resolution contours were available (0.25 m), these were determined to be already well represented by the DEM shading and hence were not added in the figure for ease of interpretation. Overall, all wetlands between the Mullering and Minyulo creeks appear to be hydrologically surface connected to some degree, particularly as the whole of the Proposal area and the surrounds slope westward.

Figure 6 shows examples of wetland and terrestrial ecosystems within Study Area A. Some of the features such as the basins have an irregular shape with small sandy rises interspersed in the basin. This adds another layer of complexity resulting in a diversity of vegetation communities. Similarly, a leptoscale (i.e. fine, <1ha) basin wetland may occur within a microscale palusplain, generating a mosaic of communities.



**Figure 6 Example of a) dampland, b) palusplain, c) creek and d) floodplain. Dunes or terrestrial environments are highlighted in white.**

### 4.3 PLANT INDICATORS OF GROUNDWATER DEPENDENCE

The terrestrial and wetland species with known water dependency identified in the literature review were compared to the species found at Cooljarloo West (WEC, 2009) to develop a list of known plant indicator species that respond to a particular water regime.

Given that the research on GDEs on the Swan Coastal Plain has considered mainly terrestrial ecosystems of *Banksia* Woodlands, the known groundwater dependency of most species stems from this vegetation assemblage. The known literature on groundwater dependency of species determined either by physiological means (i.e. xylem pressure potential or water uptake and the transpirational loss via stomatal conductance) or root architecture (i.e. arrangements of roots in space) and root depth was reviewed to compile a list of species relevant to the Proposal area, based on the species list generated by the Woodman vegetation assessment (2009).

Groundwater dependent plants (also known as phreatophytes) can be classified as obligate or facultative species depending on their water resourcing. Obligate species are deep rooted plants that only inhabit areas where they can access groundwater, either directly from the phreatic (saturated) zone or through the capillary fringe, to satisfy some proportion of their water requirements. Facultative species are deep rooted plants that inhabit areas where they can access groundwater either directly or through the capillary fringe to satisfy some proportion of their water requirements but also inhabit

areas where groundwater is not accessible and water requirements are met by available soil moisture alone. Vadose (unsaturated) zone or vadophytic species are those relying solely on available soil moisture and independent of groundwater.

The list of species identified as groundwater dependant through physiological research is presented in Table 2 together with the known water dependency and the reference link to where such species were classified. Comparing this to the dominant species on site, the majority of the Cooljarloo West species can be considered facultative or obligate groundwater dependent.

**Table 2 Groundwater dependent indicator species.**

Species	Literature References and Groundwater Dependency							
	Froend & Drake, 2006	Canham, Froend & Stock, 2009	Dawson & Pate, 1996	Groom, 2004	Veneklaas & Poot, 2003	Dodd & Bell, 1993	Benigno, 2012	Pate et al., 1984
<i>Banksia attenuata</i>	Facultative	Facultative			Facultative			
<i>Banksia ilicifolia</i>	Obligate	Obligate	Obligate	Vadose				
<i>Banksia littoralis</i>		Obligate						
<i>Banksia menziesii</i>	Facultative	Facultative						
<i>Banksia prionotes</i>	Facultative		Facultative					
<i>Corymbia calophylla</i>								Facultative
<i>Eremaea pauciflora</i>						Facultative		
<i>Eucalyptus tottiana</i>							Facultative	
<i>Strilingia latifolia</i>						Facultative		
<i>Melaleuca preissiana</i>	Vadose*							

\* perched aquifer

Terrestrial species

Wetland species

The use of root architecture studies (depth, form) is often used as a proxy in determining the likely interaction of plant species with deeper groundwater. Root types in the Swan Coastal Plain are often classified in accordance with Dodd *et al.* (1984) as shown in Figure 7 and described in Table 3. This typification is also adopted here. The shrub species examined by Dodd *et al.* (1984) exhibited variable root anatomy with many species exhibiting a dimorphic root system (Type 4). This observation was confirmed for species of *Banksia* spp-dominated communities of the Moore River region conducted by Syrinx and V&C Semeniuk Research Group (2000) and near Yanchep (Pate *et al.* 1998).

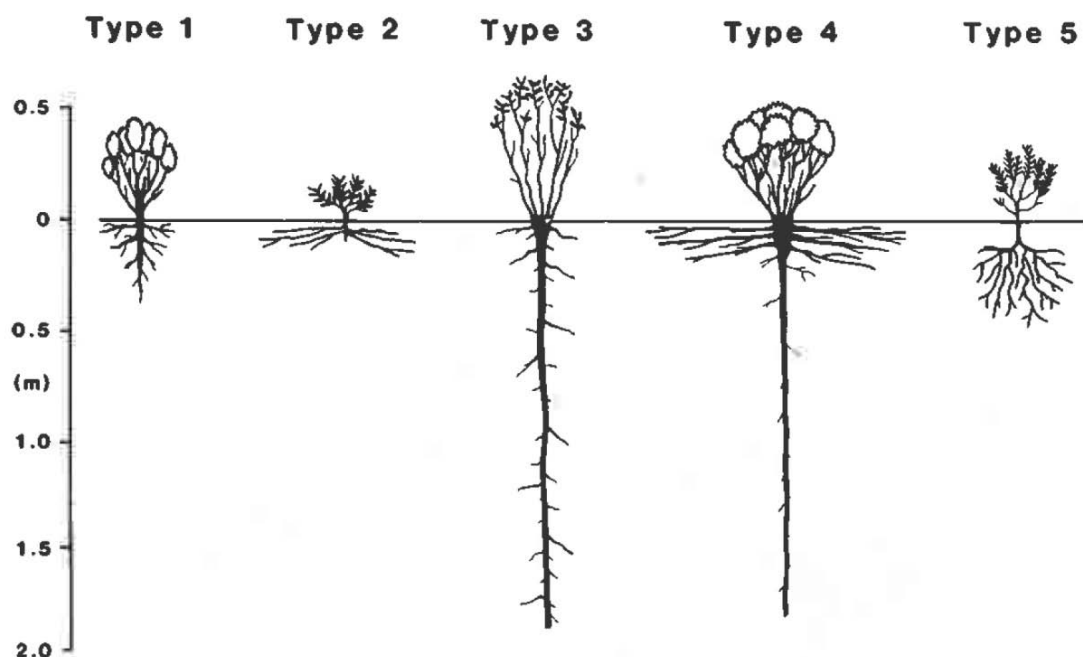


Figure 7 Examples of different root systems amongst Swan Coastal Plain shrubs (Dodd *et al.*, 1984).

Table 3 Description of root system types.

Root Type	Description (Cannon, 1949; Dodd <i>et al.</i> , 1984)
Type 1	Characterised by well developed primary and lateral roots, with neither system dominating noticeably over the other. Laterals distributed along length of tap root and the oldest, longest laterals usually present near the surface. Tap root mostly <1m in length.
Type 2	Characteristically shallow but laterally very extensive. Overall spread may be many times its depth. Potentially well equipped for absorbing moisture from occasional, shallowly-penetrating rain. Often being root parasites, where lateral spread confers increased likelihood of encountering suitable host roots.
Type 3	Characterised by distinct tap-root. In large mature plants the tap root is usually longer than 3m. Lack of extensive lateral root system apart from occasional long lived laterals up to 1m. Most laterals often short and fine and probably short-lived.
Type 4	Characterised by a thick tap root as per Type 3, but differed in developing extensive major laterals near the soil surface.
Type 5	Considered a specialised xerophytic (adapted to arid habitat) root type, being typically shallow and characterised by pronounced branching and forking of roots. Dominant tap root and horizontal laterals are absent. Root depth usually <1m, with root system exploiting intensively a relatively small volume of soil.

A dimorphic root system refers to a root distribution that includes shallow lateral roots (primarily for nutrient acquisition) and deep sinker roots, which access stored-soil moisture or groundwater (Dodd *et al.*, 1984; Dawson & Pate 1996). Dimorphic root morphology is beneficial in the nutrient poor and water-limited environment with lateral roots facilitating water uptake from upper horizons of the soil profile, optimising uptake of water during wet periods (Zencich *et al.*, 2002).

Most of the species with dimorphic root systems have a single main sinker (tap) root which extend to the water table. Type 3 and Type 4 species are considered to be variously groundwater dependant.

Known rooting depths for groundwater and wetland indicator species present on site are shown in Table 4 together with the root type as described by Dodd et al. (1984). The list indicates that the majority of plants within the proposal area have a potential groundwater relationship, although not necessarily with the regional groundwater table. A large percentage of species, excluding those of wetland habitats, have dimorphic root systems, which allow most species to exploit soil water in the vadose zone through an extensive lateral root network and a well developed tap root via which these species can access groundwater.

In contrast to terrestrial GDE species, most wetland species have shallow roots hence imply they must have access to saturated soils in summer within 1 m of the soil surface. However, not all wetlands are groundwater dependent, hence again the source of water supporting these species is not limited to rising groundwater tables, but rather may be perched water, surface run-off, or both. What they indicate is that where present, saturated soil conditions occur seasonally in these systems.

#### **4.4 VEGETATION COMMUNITIES & PATTERNS**

Apart from geomorphic attributes, wetland and GDE classification and assessment of values is also determined by vegetation type, diversity, structure and arrangement, hence detailed surveys along each transect were undertaken to assess this.

Along each of the study transects (Figure 3), a distance of more than 300 m was traversed to observe changes in vegetation communities along a particular topographic gradient and to record dominant groundwater indicator species (Table 2) at each point of change. The indicator species recorded at those sites were compared in terms of height and general habit.

Vegetation communities encountered along each transect at the change point were described using the Keighery (1994) structural classification system with three dominant species from each strata. These communities were then used to assess similarities between terrestrial and wetland habitats. In later sections of this report, the vegetation data was correlated with soil and groundwater data to inform the conceptual site model (Section 11.0).

The correlation between different community types and the zonation against topographic profile is presented in APPENDIX 1 together with lines representing average heights of trees and shrubs for that particular transect.

**Table 4 Known and inferred root depths of terrestrial, groundwater indicator and wetland species found on site.**

Species	Literature References - root depth and type									
	Dodd et al., 1984	Dodd & Bell, 1993	Dodd & Heddle, 1989	Rokich et al., 2001	Veneklaas & Poot, 2003	Groom et al., 2000; Groom, 2004	Canham, 2009	Menev & Pate, 1999; Menev, 2000	Pate et al., 1991	Dodd et al., 1984
<i>Acacia pulchella</i>						<1m*				Type 1
<i>Adenanthos cygnorum</i>		6.7m+				>2m*				Type 4
<i>Alexgeorgea nitens</i>									<1m*	Type 1
<i>Allocasuarina humilis</i>	>2m*									Type 4
<i>Banksia attenuata</i>				1.5m	>2m*		>8m			Type 4
<i>Banksia ilicifolia</i>							>8m			Type 4
<i>Banksia littoralis</i>										Type 4
<i>Banksia menziesii</i>				1.5m	>2m*		>8m			Type 4
<i>Banksia priototes</i>										Type 4
<i>Bosseaea eriocarpa</i>				0.40m <sup>#</sup>	<1m*					Type 4
<i>Calytrix flavescens</i>	>2m*					>2m*				Type 4
<i>Conostephium pendulum</i>			1-2m*		>2m*	<1m*				Type 5
<i>Eremaea pauciflora</i>		6-7m				>2m*				Type 4
<i>Gompholobium tomentosum</i>						1-2m*				Type 1
<i>Hibbertia huegelii</i>						1-2m*				Type 4
<i>Hibbertia subvaginata</i>						<1m*				Type 1
<i>Jacksonia floribunda</i>		6-7m				>2m*				Type 3
<i>Jacksonia sternbergiana</i>						>2m*				Type 4
<i>Leucopogon conostephioides</i>	<1m*				>2m*					Type 5
<i>Lyginia barbata</i>									<1m*	Type 1
<i>Petrophile linearis</i>						>2m*				Type 3
<i>Philothea spicata</i>						<1m*				Type 1
<i>Scholtzia involucreta</i>	1-2m*		1-2m*	0.59m <sup>#</sup>	1-2m*	1-2m*				Type 4
<i>Stirlingia latifolia</i>	>2m*				>2m*					Type 4
<i>Anarthria laevis</i>									<1m*	Type 1
<i>Astartea scoparia</i>						<1m*				Type 1
<i>Chaetanthus aristatus</i>								<1m*		Type 1
<i>Chordifex sinuosus</i>								<1m*	<1m*	Type 1
<i>Hypocalymma angustifolium</i>						<1m*				Type 1
<i>Hypolaena exsulca</i>								<1m*	<1m*	Type 1
<i>Meeboldina cana</i>								<1m*		Type 1
<i>Melaleuca seriata</i>						>2m*				Type 4
<i>Pericalymma ellipticum</i>						<1m*				Type 1
<i>Regelia ciliata</i>						<1m*				Type 1

\* Where not specified, rooting depths were based on Dodd et al. (1984) where shallow roots are < 1 m, medium roots are 1- 2 m, and deep roots are > 2 m. # indicates juvenile or seedling root length

Terrestrial species

Wetland species

The following section describes the type and distribution of vegetation communities in relation to the landforms described in Section 4.2. In general, vegetation communities encountered along each transect can be grouped into broad vegetation zones or types based on the dominant species in each stratum and the landform / topographic relief as follows:

- Dunes (including rises and slopes)
  - *Banksia* Low Woodland;
  - *Allocasuarina humilis* and *Calothamnus quadrifidus* Open Heath;
  - *Banksia armata* Open Low Heath
  
- Palusplains, Damplands
  - *Banksia telmatiaea* Heath
  - *Regelia ciliata* Open Heath

- Floodplains and Watercourses
  - *Melaleuca viminea* subsp. *viminea*, *M. lateritia* and *M. teretifolia* Tall Open Scrub, and
  - *Eucalyptus rudis* and *Melaleuca raphiophylla* Open Forest.

More detailed descriptions of communities encountered along each transect's length are presented in APPENDIX 1.

#### 4.4.1 Dunes

Vegetation associated with the dunal rises and slopes was dominated by Mixed *Banksia* Low Woodland communities and Dry Heath. The variation in the dominance of particular species changed with the slope with the lower slope having a more diverse canopy and higher plant density.

##### 4.4.1.1 *Banksia* Low Woodland

*Banksia* Low Woodland (Figure 8) is associated with dunal landforms particularly with the ridges and crests of dunes and extend to simple slope (slope adjacent to or above a flat or depression). Common indicator species found in the *Banksia* Low Woodland communities included *Banksia menziesii*, *B. attenuata*, *Eucalyptus todtiana*, *Eremaea pauciflora* var. *pauciflora*, *Hibbertia hypericoides* and *Dasypogon bromeliifolius*. Although not captured in the transects, *Banksia illicifolia* and *B. prionotes* were observed sporadically at the edge of these communities adjacent to heathland vegetation.

A gradual change in topography within this community leads to changes in dominance of particular species and the appearance of transitional species. For example, at the dune ridges, *Banksia attenuata* and *Banksia menziesii* dominate whilst on the lower slope of the dune *Eucalyptus todtiana* increases in dominance and *Nuytsia floribunda* trees become more common. This 'zonation' of communities was noted by Woodman in their vegetation community mapping of the area (WCE, 2013 in preparation). Trees appear more sporadic downslope whereas shrubs appear at higher densities with indicator species such as *Conospermum stoechadis* appearing close to the wetland boundary. Densities of sedges and herbs such as *Patersonia occidentalis* and *Dasypogon bromeliifolius* appear to increase somewhat as well.

This community was recorded in dryland sections of the site and at the start and or finish of most wetland transects at the transition between wetland and dryland habitats.



**Figure 8 Typical *Banksia* Low Woodland Community.**

The height of vegetation in the *Banksia* Low Woodland community ranged from 2.5 to 7 m for trees and 0.5 to 2 m for shrubs. There was no clear correlation between the landforms and the height of vegetation for this community indicating that hydrogeological processes were most likely responsible for these differences. However, in most instances it was noted that the *Banksia* appeared to be taller on dunes near large closed or open depressions and their height was decreasing with the height of the dune.

#### 4.4.1.2 *Allocasuarina humilis* and *Calothamnus quadrifidus* Open Dry Heath

This vegetation community (Figure 9) occurred on the lower slopes of flatter dunes as a transition community between the *Banksia* Woodlands and the *Banksia telmatiaea* Heath.

In addition to *Allocasuarina humilis* and *Calothamnus quadrifidus*, *Hakea trifurcata* and *Xanthorrhoea preissii* occur as other dominant species. This community was recorded in Transects 3, 6 and 9.



**Figure 9 Typical *Allocasuarina humilis* and *Calothamnus quadrifidus* Open Dry Heath Community.**

#### 4.4.1.3 *Banksia armata* Open Dryland Heath

*Banksia armata* var. *armata* Open Dryland Heath community (Figure 10) was not common in the study area and was found on low rises typified by hard lateritic soils. This community was recorded twice on site (Transects 7 and 11) but transects intercepted the same community. Other species found in this sub community are *Calothamnus hirsutus*, *Gastrolobium oxylobioides*, *Hakea obliqua* subsp. *parviflora*, *Banksia telmatiaea* and *Schoenus clandestinus*. The shrub height is low, averaging 50 – 60cm.



Figure 10 *Banksia armata* Open Heath Community.

#### 4.4.2 Palusplain and Damplands

##### 4.4.2.1 *Banksia telmatiaea* Wet Heath

*Banksia telmatiaea* Wet Heath is associated with palusplain flats and open and closed depressions on site. In terms of geomorphic classification these heaths are dominant on both palusplains and damplands and they occur on the edges of sumplands and floodplains. Indicator species common to this community include *B. telmatiaea*, *Hakea obliqua* subsp. *parviflora*, *Melaleuca seriata*, *Hakea trifurcata*, *Chordifex sinuosus* and *Lyginia imberbis*.

The height of the shrub layer varied from 1 m to 1.8 m with Transect 6 recording the tallest shrub strata. The majority of transects intercepted this particular community or similar, with the exception of Transects 2, 9 and 12. Transects representative of this community were Transects 3, 6, 10 and 13 (Figure 11).



**Figure 11 Typical *Banksia telmatiaea* Wet Heath.**

In areas that were positioned lower within the particular landform (or palusplain), *B. telmatiaea* becomes sparser and usually lower in height with species such as *Verticordia densiflora* var. *densiflora*, *Astartea scoparia* and *Calytrix aurea* increasing in dominance. A dwarf form of *Melaleuca raphiophylla* (up to 2 m tall) was recorded in these areas as well, although its presence was sporadic. Given that the surface soils in these areas were silty clayey sands and the likelihood of increased surface water inflow from surrounding areas high, seasonally waterlogged soils and surface ponding was likely, which in turn explains why *M. raphiophylla* grew in these areas. Transects that recorded this variation in species were Transects 5, 7 and 13.

#### 4.4.2.2 *Regelia ciliata* – *Melaleuca* spp. Open Wet Heath

This community was recorded throughout the study area and was associated with low lying open or closed depressions and flats where soils were clayey and the likelihood of seasonally wet soils as a result of surface runoff more likely. Common species found in this community include *Regelia ciliata*, *Melaleuca raphiophylla* (dwarf form), *Pericalymma ellipticum* var. *ellipticum*, *Melaleuca viminea* subsp. *viminea*, *Schoenus subfascicularis*, *Lepidosperma longitudinale* and *Chaetanthus aristatus*.

Sedges and rushes in this community are more common and more diverse than that of *Banksia telmatiaea* heaths although no sites formed dense thickets of these species.

Other species present within this community included *Banksia telmatiaea*, *Beaufortia squarrosa* and *Hakea obliqua* subsp. *parviflora*, however these were generally found on the outer edges of the *Regelia* community, and not considered dominant. Sporadic occurrences of *Melaleuca teretifolia* were also observed in small depressions with clayey silty sands prone to waterlogging. The height of plants in the community, particularly *Regelia ciliata*, appeared to be influenced by the presence of clay and subsequent surface waterlogging with shrubs appearing stunted (30cm) compared to those in the transitional zone with the *Banksia telmatiaea* which were up to 1.2 m high.

Transects 4, 5, 8 and 13 all recorded this community along its length (see Figure 12).



**Figure 12 *Regelia ciliata* - *Melaleuca* spp. Open Wet Heath Community.**

The state and federally listed species, *Andersonia gracilis* (Threatened - T) was recorded within a number of *Regelia* - *Melaleuca* communities, and is known to occur in winter wet areas (DEC 2013). *Andersonia gracilis* was recorded in Transects 3, 5, 8, 10 and 1.

#### 4.4.2.3 *Melaleuca preissiana* Open Woodland

*Melaleuca preissiana* Open Woodland captured as part of Transect 2, is located in a large closed depression surrounded by low dunes. The surface soils are light grey sands with increasing occurrence of fine sands and silts towards the centre of the depression.

This community is dominated by *Melaleuca preissiana* (10 m) Open Woodland with transitional species from the Banksia Low Open Woodland (e.g. *Banksia prionotes*, *B. menziesii*, *Jacksonia sternbergiana*) at the edges and dense *Schoenus subfascicularis* sedgelands towards lowest parts of the landform (Figure 13) where *Eucalyptus rudis* (12m) and *Melaleuca raphiophylla* (10 m) occur. The presence of large trees in this community, including the fringing *Banksia* woodland, indicates that groundwater or saturated soil (seasonal waterlogging/perching) is accessible to these species or that they represent a remnant of previous groundwater or surface water availability regime.

*Phlebocarya ciliata* and *Anarthria levis* were also recorded in this community at the edges with *Banksia* Woodland and *Lepidosperma longitudinale* sedgeland occurring sporadically in small patches in open areas where sands appeared to be more silty.

The composition of species found within this transect in this particular location within the landscape was not observed elsewhere within the Proposal area.



**Figure 13 *Melaleuca preissiana* Open Woodland.**

### 4.4.3 Floodplain systems

#### 4.4.3.1 *Eucalyptus rudis* and *Melaleuca raphiophylla* Open Forest

This community was found on flats or open depressions of the floodplains or areas receiving more concentrated surface water flow. The surface soils were sandy with some silt and clay present and were relatively loose.

This community was observed in Transect 7 where it appeared that the area was associated with a small drainage line (Figure 14). The community was bound by a Tall Closed Scrub of *Chamelaucium uncinatum*, and closer to the flat or dampland of *Acacia saligna* subsp. *lindleyi*, *Exocarpos sparteus*, *Regelia ciliata*, *Schoenus subfascicularis* and *Lepidosperma longitudinale*. Such a suite of species indicates that this area would be soil saturated or surface inundated for periods at a time during the wet season; however it should be noted that the height of the *E. rudis* (12m) and *M. raphiophylla* (10 m) and the mechanism by which these species utilise water (facultative) would suggest that these species would be supported by means other than ponding of water from seasonal rains and surface runoff.



**Figure 14 *Eucalyptus rudis* and *Melaleuca raphiophylla* Open Forest.**

#### 4.4.3.2 *Melaleuca lateritia* and *Melaleuca teretifolia* Tall Open Scrub

This community was captured in the floodplain associated with the Mullering Brook to the north of the Proposal area (Figure 15). The soils supporting this community were clayey grey sands at surface and had no ground or herb strata.

Dominant species of this community were *Melaleuca lateritia*, *Melaleuca teretifolia* and *Melaleuca viminea* subsp. *viminea* with scattered *Melaleuca raphiophylla* (dwarf form). Sedges of *Lepidosperma longitundinale*, and the rushes *Meeboldina coangustata* and *Meeboldina cana* were present within this community however their distribution was sporadic and appeared to be connected to more open shrubland areas and areas with small depressions.

The height of vegetation (1-2 m) appeared to be relatively even throughout the community.

In areas slightly higher in elevation and bordering this community *Regelia ciliata* was noted with *Banksia telmatiaea*, *Verticordia densiflora* var. *densiflora* and occasional *Astartea scoparia*. A small patch of *Eucalyptus rudis* subsp. *rudis* (13 m) trees was encountered on a low rise towards the outer edge of the floodplain immediately adjacent to *Banksia* Low Woodland community.



**Figure 15** *Melaleuca lateritia* and *Melaleuca teretifolia* Tall Open Scrub.

#### 4.4.4 General Vegetation Patterns

All 13 transects surveyed within the different wetland and upland ecosystems contained indicator species relatively typical of those communities elsewhere in the region. From the transect survey data analysed and the limited excavations undertaken, the presence or absence of indicator species, height of strata and zonation of communities appeared to correspond with microtopography and depth of overlying sands.

In terms of microtopography, the distribution of vegetation communities, dominant species and in some cases plant height within any particular transect or wetland appeared to correspond to even slight changes in elevation (less than 20cm). As the site is sloping towards the west (to the coast) no direct correlation to particular topographic contour and vegetation community could be made across the Proposal area; rather the variation was localised to each particular landform.

In addition to landforms and topography, changes in surface soil type (e.g. sand or sandy silts / sandy clays) and depth of sand also appeared to influence the zonation as well as the plant height of particular species. Dwarf forms of trees and shrubs (*Banksia* spp, *Melaleuca raphiophylla*, *M. preissiana*) were evident across the study area, but in particular to the west of the study boundary where surface sands were very shallow (<1 m).

In relation to wetland vegetation patterns, all wetlands are heterogeneous and in all cases the extent of vegetation is complete, i.e. >90% cover.

#### 4.5 EVALUATION OF WETLAND GEOMORPHIC MAPPING

To assess how well the current geomorphic wetland mapping (ENV, 2010) reflects the DEM data, the ENV (2010) wetland mapping layer was superimposed onto the DEM for the study area. These images are shown in Figure 16. This exercise was necessary to characterise wetlands and GDEs to a significantly greater resolution than previous studies in order to support impact assessment for the mining Proposal. This work included grouping of datasets for comparison of wetland stratigraphy, hydrology and vegetation characteristics and as a result verified or amended wetland classification and boundaries accordingly. Together with an assessment of dominant vegetation communities, this exercise shows the following:

1. Transect 1 in the NW is mapped as palusplain, but incorporates a distinctive leptoscale dampland immediately to the west of the transect, which in fact accounts for a significant portion of the mapped area.
2. Transect 2 is mapped as a palusplain, but is clearly a dampland. This is also supported by observations of the vegetation, as discussed in later sections.
3. Transect 3 is mapped as a sumpland, however is complex, appearing to contain a leptoscale basin wetland (dampland), evident at the 0.5 m contour resolution, within the palusplain.

4. Transect 4 is mapped as a dampland, and appears correct.
5. Transect 5 is mapped as floodplain, however appears to be a dampland.
6. Transect 6 is mapped as palusplain, and appears correct.
7. Transect 7 is mapped as palusplain and appears to be palusplain, but mainly at the outer edges of the mapped area, with the central portion being a floodplain containing small depressions. The floodplain is confined by the dunes to the west.
8. Transect 8 is mapped as a dampland, and appears correct.
9. Transect 9 was not mapped as a wetland which is correct since it is predominantly dune, however, it is dissected by a leptoscale palusplain.
10. Transect 10 is mapped as a dampland, and appears correct.
11. Transect 11 is mapped as a floodplain, however the vegetation indicates it most likely functions as a palusplain.
12. Transect 12 is mapped as a floodplain, and appears correct.
13. Transect 13 is mapped as a floodplain, however the vegetation indicates it most likely functions as a palusplain.

In essence, key differences in the actual arrangement and type of wetlands within the study area from previous mapping are associated with leptoscale wetlands (<100 m scale) and leptoscale channels that may dissect basin and flats and act as minor floodplains in high rainfall surface flows (see Section 8.3 for further discussion on this). Few basins are fully closed forms, and are defined by low or very low sandy rises along part of their edge (~200 mm), and by larger dunal ridges usually to the south or east. In effect, should surface water inundate these basins (which appears to be a very infrequent occurrence and not apparent in recent years), they would overflow on the low bank (usually to the west) and form part of broader palusplain or floodplain units.

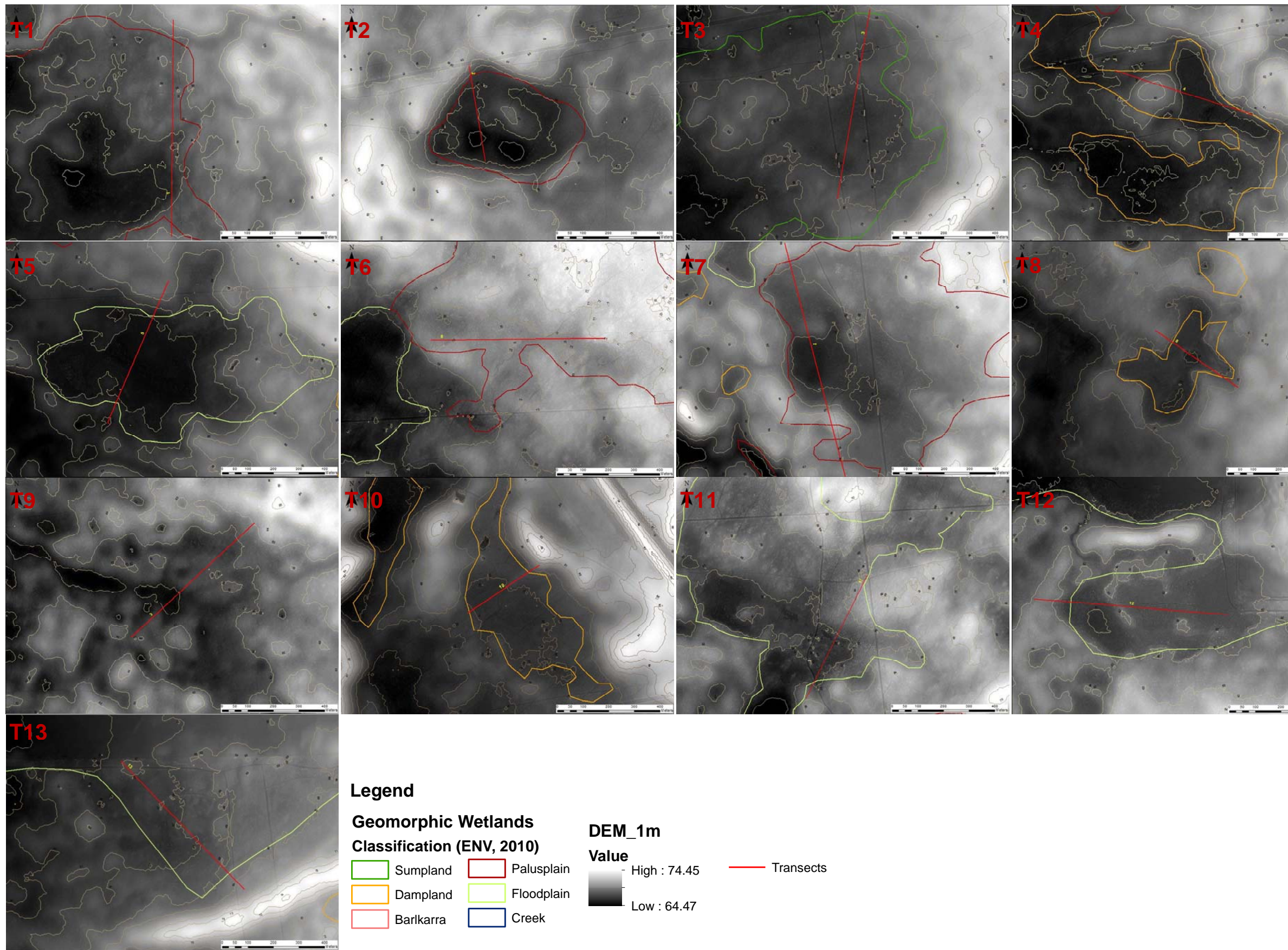


Figure 16 Comparison of landform features generated by DEM with the wetland classification as per ENV (2010).

## 5.0 KEY FINDINGS OF WETLAND/GDE IDENTIFICATION

### **Vegetation**

Comparison of previously mapped wetland classifications with the digital elevation model generated from higher resolution LiDAR data in this study, showed differences between landforms and the previous classification of wetlands. In general, basin wetlands are more common at the leptoscale.

In general, there were no clear relationships between vegetation communities and palusplain, dampland or sumpland wetland types, however floodplains and dunes were dominated by distinctive vegetation communities. Small scale representations of most wet heath communities and most wetland species were found within all geomorphic wetland types. This suggests factors other than surface topography and wetland geometry are likely to be better determinants of vegetation distribution within the wetlands.

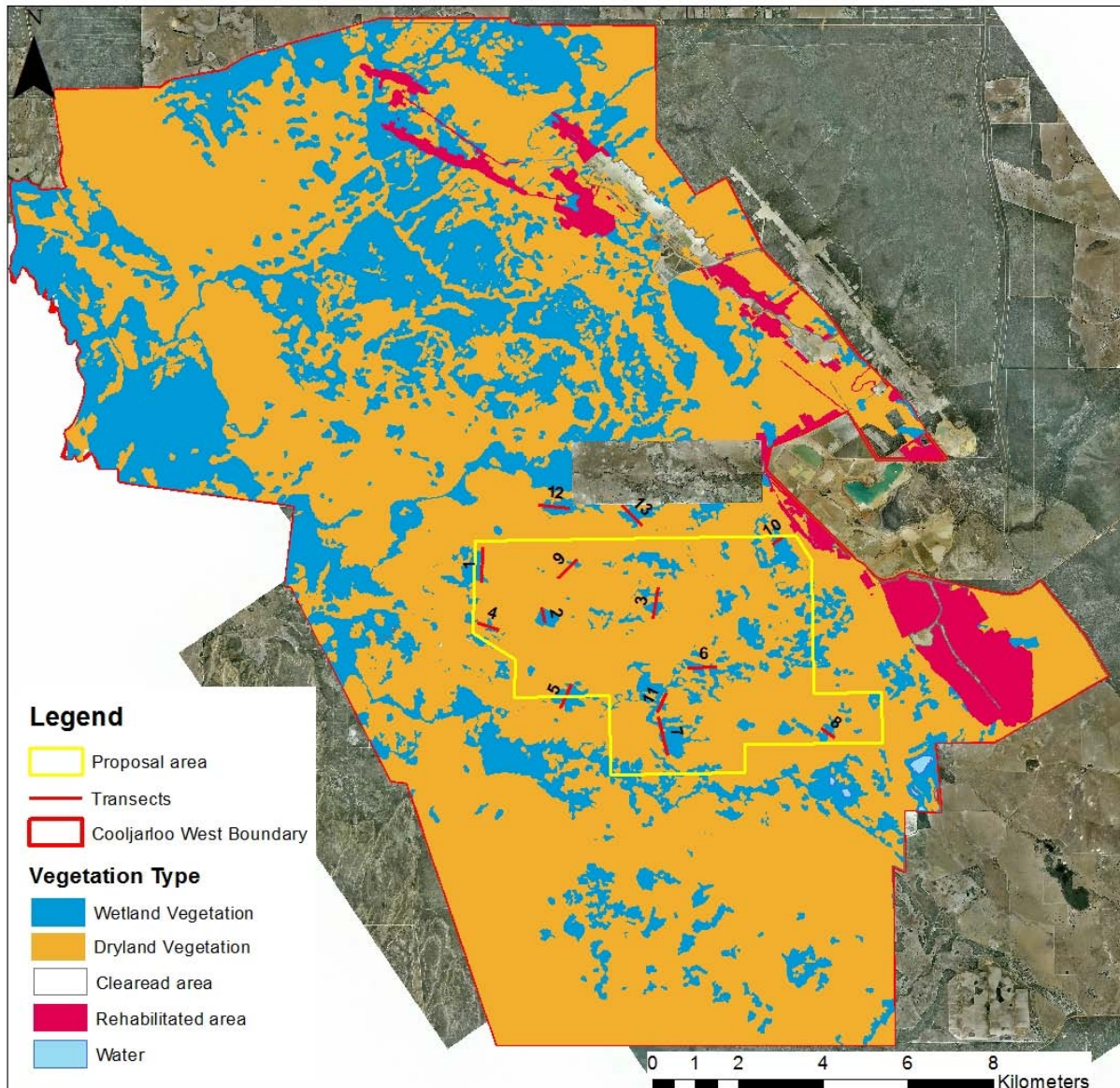
In terms of terrestrial GDE communities, all of which occur on dune crests or slopes or low sandy rises, there were distinctions, however certain species (*Banksia telmatiaea*), occurred both on lower dune slopes and throughout the various wetland types. Almost all of the dominant tree species (*Banksia menziesii*, *B. attenuata*, *B. illicifolia*, *B. prionotes*, *Eucalyptus todtiana*, *Corymbia calophylla*) are known groundwater dependent species (see Table 2).

Vegetation assessment, combined with topographic data and collation of Woodman vegetation community data, indicates that the entire Colljarloo West area (i.e. study area and beyond), are either wetlands (potentially groundwater dependent), or groundwater dependent dryland ecosystems.

### **Wetland Mapping**

The DEM maps generated from LiDAR data in Figure 5 show a potential disparity between the mapping and actual boundaries of wetlands.

Figure 17, which groups the dryland and wetland vegetation communities based on the Woodman's and Syrinx's transect data, also shows that whilst the location of wetlands is congruent with ENV (2010), the extent of the wetlands is much smaller. The Syrinx transect survey data showed the communities on the edges of the wetlands are transitional communities dominated by dryland species, and are not part of the wetland zonal sequence as such.



**Figure 17 Breakdown of wetland and dryland vegetation associations based on Woodman (2013) and Syrix survey data. Within the study area boundary, all dryland vegetation communities are classed as groundwater dependent.**

### ***Hydrological Implications***

The distribution and type of wetlands and the vegetation communities on both wetland and terrestrial landforms indicate a widespread connection with groundwater, either as a relationship with perched groundwater or with the regional watertable. This is explored in the next section of this report. In regard to surface flows and connections, the DEM mapping suggests that most wetlands would connect via surface flows and potentially subsurface flows in large rainfall events, or in prolonged rain duration periods, due to the topographical gradients and ill-defined basin morphologies.

For instance, ill-defined basins with low crests may in fact function as flats in large surface flow events or if groundwater rise (perched or otherwise) was the dominating mechanism and the inundation depth

exceeded the crest height. Similarly, where basins and flats are dissected by minor channels (for instance where ferruginised channels and flow paths were evident), the outer basins may only be, at most, saturated, not inundated, due to these preferential drainage channels. Alternatively, these same minor channels and in some cases subsurface channels may act to direct flows toward basins and/or floodplains such that these areas would recharge at the microscale earlier than zones outside of the channel influence.

## PART 3: WETLAND & GDE MECHANISMS

### 6.0 STRATIGRAPHY/HYDROLOGY CHARACTERISATION

#### 6.1 STRATIGRAPHIC SETTING

The broad stratigraphic setting reflects shoreline-estuarine depositional environments that supported deposition and accumulation of mineral sands in past (Pliocene to Quaternary) coastal or near coastal environments. At the project scale, this is reflected by the presence of (up to) three roughly east west striking subsurface trough-like structures reflecting palaeo-shorelines (*pers. comm.* SWC, 2013). Although it appears the stratigraphic setting may impact upon the groundwater at the site, there is no surface expression of the deeper stratigraphic controls.

There are four defined stratigraphic units at the site, listed with generic details (Davidson, 1995) in Table 5 below.

**Table 5 Characteristics of Key Stratigraphic Units Across the Site**

Unit Name	Maximum Thickness (m)	Approximate Depth in Study Area (mbgl)	Generic Depositional Environment	Relative age	Dominant Lithological Characteristic
Bassendean Sands	8	0 - 3	Fluvial, Estuarine, Shallow Marine	Quaternary	Sand dominated
Guildford Formation	35	3 - 30	Colluvial, Alluvial, Fluvial	Quaternary	Silt / clay dominated
Yoganup Formation	20	30 - 45	Shallow Marine, Estuarine	Pliocene	Sand dominated
Yarragadee Formation	1000	Below 45	Shallow Marine, Fluvial, Estuarine	Jurassic	Sand dominated

#### 6.2 OBJECTIVES & RATIONALE

The extent to which any disturbance of groundwater will impact on the wetland and non-wetland GDE's identified in the previous section will depend in turn on the extent of dependence these systems have on the superficial groundwater and/or on other soil moisture mechanisms. The key

factors understood from regional studies to potentially influence soil moisture availability within the various wetlands and non-wetland GDE's in the study area are as follows:

1. The known presence of perched water tables associated with clay lenses (within the Guilford Formation) and ferricrete gravel layers (within the Bassendean Sands) in near-surface layers in the region (WorleyParsons, 2012 and Parson Brinkerhoff, 2011).
2. The wetlands and watercourses are part of Minyulo suite of consanguineous wetlands and are generally thought to be maintained by perching and groundwater rise (V&C Semeniuk Research Group, 1994).
3. The two main seasonal creeks that dissect the study area (Mullering Brook to the north, Minyulo Brook to the south) dominate the surface hydrology. These watercourses originate on the Dandaragan Plateau and Arrowsmith Region (WorleyParsons, 2012).
4. There is evidence of groundwater upwelling (associated with springs) suggesting interconnectedness of aquifers, at least in some locations.

These factors were used to inform the methodology selected for assessing the hydrological and stratigraphic mechanisms underpinning wetland/other GDE type and distribution.

The characteristics of the superficial sediments, including depth and thickness of aquifers and aquitards, which influence soil moisture and as such vegetation types, have been characterised further by WorleyParsons and Soil Water Consultants as part of the Cooljarloo West PER investigations.

A detailed Method Statement (DMS) describing methodology for undertaking wetland and watercourse investigations within the Proposal area was prepared in November 2012 (Syrinx, 2012) as part of the first stage of works at Cooljarloo West. The sections below describe works undertaken in less detail; however, where changes in the methodology have occurred as a result of in the field observations, those methodologies are described in more detail. If required, the reader should refer to Syrinx (2012) for more clarification on the methodology described below.

Based on the review undertaken to date by Syrinx, the fundamental regional and local scale data associated with the wetland systems and potential GDEs in the project area are not available in the existing literature. At a regional scale, there is limited data available regarding the broad environmental considerations and at the local scale there is insufficient appreciation of what mechanisms underpin individual wetlands in the area, which is critical to understanding the potential impacts from mining related activities. As a result, this section is focused on addressing the following topics:

#### ***Regional scale***

- Identifying where geological and stratigraphical complexity may occur; and
- Determining the degree of importance of occurrences of geological and stratigraphical complexity on water movement.

#### ***Local scale***

- Assessing the hydrological connectivity between wetlands and aquifers potentially supporting wetlands;
- Determining the presence or location of localised hydrological inflows and outflows and the reasons for different responses; and
- Determining the relationships of GDE's and wetlands with hydrology and stratigraphy.

### ***Individual wetland scale***

- For targeted wetlands and GDE's, either those representative of the broader suite and/or those within the dredge impacts area (direct or indirect) that appear to vary in terms of their mechanisms, more detailed discussion to assess their significance to inform risk and impact assessment.

In addition to field stratigraphy and groundwater investigations, an understanding of surface hydrology was also considered to be important by Syrinx in the assessment of potential impacts. In the first instance, a review of available historical data of Mullering Brook was undertaken. The Minyulo and Mullering brooks are purported to have a key role in maintaining the hydrology of associated sumplands and damplands of the Minyulo suite through recharge of groundwater and flooding (V&C Semeniuk, 1994). The extent to which these creeks maintain the wetlands on a seasonal basis is not clear, and is complicated by the modifications to the Mullering Brook in particular as part of Tronox's current Cooljarloo operations (see Tiwest, 2012).

Surface water flows, including superficial hydrological connectivity among wetlands that do not constitute major drainage lines (i.e. creeks) in the area, are greatly influenced by topography. While regionally, surface water flows follow a westward direction, an understanding of surface flows at a local scale is lacking. This is of particular importance in assessing risk to wetlands that may be reliant on runoff recharge from higher grounds, especially in the vicinity of mine pits, channels, overburden and soil stockpiles where topography and surface hydrology are likely to be highly altered. Hence, a watershed analysis was also considered important to assess the likely flow paths and potential surface connections of wetlands and watercourses.

## **6.3 METHODOLOGY**

### **6.3.1 Methodology Overview**

The stratigraphy and hydrological field investigations at Cooljarloo West comprised:

- Shallow direct push drilling at 19 locations (max depth of 5 mbgl);
- Shallow hand augering at 14 locations (max depth of 4.5 mbgl);
- Sediment sampling and physical and chemical analysis from selected locations;

- Installation of 32 monitoring bores located within or directly adjacent to wetlands (carried out by WorleyParsons);
- Installation of water level loggers in selected bores (carried out by WorleyParsons); and
- Groundwater sampling and analysis of physical and chemical parameters (carried out by WorleyParsons and Tronox).

### 6.3.2 Shallow Direct Push Drilling & Hand Augering

The shallow drilling programme, aiming at acquiring high resolution lithological and stratigraphic information of the Bassendean Sands and upper Guildford Formation within selected wetlands, was carried out in two stages. The first stage employed a direct push probe (Geoprobe) and was completed in October 2012 and the second stage employed a hand auger and was completed in December 2012. During the shallow drilling programme, only sediment characterisation and sampling occurred as monitoring bore installation was carried out as part of the WorleyParsons' scope of works. As indicated in the detailed method statement (Syrinx 2012), selected bore locations are associated with vegetation transects so to provide a picture of relationships between soils and vegetation types.

Direct push drilling was conducted by Hagstrom drilling with Ecoprobe as sub consultants using a Geoprobe 7822 DT drill rig and 35 mm diameter probe casing for sample collection. Drilling supervision, borehole logging and sediment sampling was conducted by Syrxinx. Due to access concerns, one location that was originally to be drilled by direct push was alternatively hand augered using a 75 mm hand auger.

The bore holes completed by Syrxinx in December 2012 were drilled using an 85 mm hand auger with interchangeable clay/sand heads. During hand augering, observed lithologies were logged and sediment samples collected. Figure 4 shows the location of direct push drilled bore holes (indicated by 'B' or 'MB') and hand augered bore holes (indicated by 'A').

Once logging and sampling were complete, bore holes were backfilled with the drilled material.

Sediment samples from key lithologies of each bore hole were collected from the intact cores for physical and chemical analysis. Samples were collected in 250g jars, stored in ice on site and frozen until despatch to the CSBP Soil Laboratory and Curtin University Inorganic Geochemistry Group Laboratory for analyses. Physico-chemical parameters analysed included: particle size distribution, moisture content, pH, electrical conductivity, major cations (Na, Ca, Mg, K), anions (S, Si), carbonate content, organic carbon, nutrients (TN and TP) and selected bound metals (Mn, Fe and Al).

Note that not all samples collected were analysed. This was due to the fact that although local differences in thickness and depth of key lithologies were observed, in general, these key lithologies were uniform throughout the site, i.e. present in more or less all locations. In total, 34 samples from 12 bore holes were selected for analysis. Sample selection covered the four types of geomorphic wetlands present in the study area, i.e. sumpland, dampland, palusplain and floodplain.

### 6.3.3 Groundwater Monitoring Bore Installation

Nested monitoring bores were installed in selected wetlands in order to assess potential vertical connectivity between perched water tables in the Bassendean Sands and the slightly deeper superficial aquifer in the upper Guildford Formation. Installation of the groundwater monitoring bores locations was carried out by WorleyParsons in November 2012. Monitoring bore locations were selected in consultation with Tronox and WorleyParsons. Out of the 46 bores installed by WorleyParsons in the Cooljarloo West area, 32 were located within or in the vicinity of geomorphic wetlands and therefore are relevant to this study. A summary of screened units is provided below and bore locations are shown in Figure 4:

- 5 monitoring wells screened in the perching water table in the Bassendean Sands (<1.9 mbgl);
- 6 monitoring wells screened in the perching water table in the Bassendean Sands and slightly deeper across the transition with the Guildford Formation (1 – 4 mbgl);
- 10 monitoring wells screened in the regional water table in the upper Guildford Formation (4.5 – 22.8 mbgl); and
- 11 monitoring wells screened in the deeper Lower Guildford Formation (19 – 40 mbgl).

Monitoring bore installation and bore development methodologies are described in WorleyParsons (2013). Of relevance to groundwater quality interpretation is the fact that during well development chlorine and AMC Wellclean™ (≥98% sodium acid pyrophosphate) were used as dosing agents to break down the drilling muds and viscosifiers used during drilling.

All monitoring bores were constructed using 50 mm ID class 18 PVC, screened with 0.5 mm aperture and vested with centralisers across the screened interval. A summary of information on monitoring bores completed and, which are relevant to this study, including coordinate location, reduced level, screened depth and key geological formation targeted is shown in Table 6 (WorleyParsons, 2013). The bore identification (ID) terminology includes a prefix – bore number – suffix (e.g. B-03vs). The prefix 'B' indicates that bore locations were determined by Syrinx and were in addition to the 'MB' bore locations, which were determined by WorleyParsons in consultation with Syrinx and Tronox. The suffix 'VS' stands for very shallow, 'S' stands for shallow, 'I' for intermediate and 'D' for deep. These suffixes provide an indication of the depth of a screen interval in relation to other screen depths in the same set of nested bores.

**Table 6 Monitoring bore completion details**

Bore ID	Easting	Northing	RL	Screened Interval (mbgl)	Formation Screened
B03-VS	340750.9	6606030	58.565	0.4-0.9	Perching - Bassendean
B03-S	340750.7	6606028	58.659	1.9-2.6	Perching - Bass./Guildf.
B03-D	340750.5	6606026	58.536	8.0-17.0	Water Table - U. Guildford
B04-VS	341115.2	6604198	59.416	1.2-1.9	Perching - Bassendean
B04-S	341116.1	6604199	59.506	2.1-2.5	Perching - Bass./Guildf.
B04-D	341117.3	6604202	59.605	9.0-18.0	Water Table - Guildford
B05-VS	344821.2	6604921	69.147	0.8-1.4	Perching - Bassendean
B05-S	344821.4	6604919	69.075	1.7-2.4	Perching - Bass./Guildf.
B05-D	344821.7	6604917	69.001	8.8-17.8	Water Table - Guildford
MB01	343101.0	6608657	63.862	19.9-28.9	Yoganup
MB03-S	340832.4	6605270	58.492	1.5-4.0	Perching - Bassendean
MB03-D	340834.7	6605272	58.496	25.6-31.6	Yoganup
MB04-VS	343132.5	6607085	63.749	0.3-0.7	Perching - Bassendean
MB04-S	343125.9	6607088	63.787	1.9-2.9	Perching - Bass./Guildf.
MB04-I	343123.8	6607088	63.828	8.9-17.9	Water Table - U. Guildford
MB04-D	343121.8	6607088	63.777	19.8-25.8	U. Guildford Fm.
MB08-S	344116.7	6605099	66.945	1.0-4.0	Perching - Bassendean
MB08-I	344114.8	6605099	66.916	4.5-10.5	U. Guildford Fm.
MB08-D	344118.3	6605099	66.992	19.0-25.0	Yoganup
MB10	340568.8	6604377	59.166	20.0-38.0	L. Guildford/ Yoganup
MB12	344218.9	6604085	66.973	10.8-22.8	Water Table - U. Guildford
MB14-S	343300.1	6602887	67.712	6.9-15.9	Water Table - U. Guildford
MB14-I	343297.9	6602887	67.68	24.8-27.8	L. Guildford /Yoganup
MB14-D	343295.9	6602887	67.693	32.3-35.3	Yoganup
MB15-VS	345136.4	6602218	68.964	0.3-1.8	Perching - Bassendean
MB15-S	345136.3	6602220	68.982	16.0-19.0	U. Guildford
MB15-I	345135.9	6602222	68.958	23.5-26.5	L. Guildford /Yoganup
MB15-D	345135.6	6602224	69.034	37.4-40.4	Yoganup
MB17-S	345090.8	6601262	67.615	9.0-15.0	Water Table - U. Guildford
MB17-D	345090.5	6601264	67.606	27.0-33.0	Yoganup
MB18-S	346184.9	6603296	71.042	9.6-15.6	Water Table - U. Guildford
MB18-D	346182.5	6603294	70.859	31.5-37.5	Yoganup

#### 6.3.4 Groundwater Sampling & Analysis & Groundwater Level Logger Installation

The first and second rounds of groundwater level monitoring and sampling were undertaken by WorleyParsons in December 2012 and April 2013. Sampling methodologies and issues encountered during sampling are presented in their Cooljarloo West Hydrological Assessment Report (WorleyParsons, 2013). Field parameters monitored included water colour, turbidity, odour, flow rate, electrical conductivity, pH and temperature. Once purging was complete, samples were collected, labelled and stored in ice immediately until being despatched to ALS Environmental laboratory for physical and chemical analysis.

On the 14th December 2012, In-Situ Rugged Troll™ groundwater level loggers were installed by WorleyParsons staff in 18 bores to provide detailed long term monitoring data for the site. Twelve of these loggers were installed in nested bores on behalf of Syrinx to monitor perched and shallow water tables and assess vertical flows and connectivity between aquifers, groundwater-surface water interactions and potential relationships between groundwater dependent vegetation and groundwater levels.

Loggers were suspended within the bores and programmed to start recording at 30 minute intervals from 18:00hrs on 14 December 2012. Two In-Situ Rugged Baro Troll™ barometers were also installed in selected bores to record barometric pressure and compensate for changes in water level data due to barometric fluctuations. A list of loggers installed on site, including monitoring purpose and depth information is shown in Table 7 (WorleyParsons, 2013).

**Table 7 Summary of groundwater level loggers installed at Cooljarloo West**

Bore ID	Serial No.	Monitoring purpose	Depth of logger (m bTOC)	Groundwater depth (m bTOC)
B03-VS	323580	Wetland / Perched water table	1.5	DRY
B03-S	312987	Wetland / Perched water table	3.15	3.12
B03-D	324263	Wetland / Perched water table	17	10.40
B04-VS	323583	Wetland / Perched water table	2.4	DRY
B04-S	325467	Wetland / Perched water table	2.95	DRY
B04-D	323540	Wetland / Perched water table	17	7.17
B05-VS	325829	Wetland / Perched water table	2	DRY
B05-S	312922	Wetland / Perched water table	3	2.91
B05-D	325828	Wetland / Perched water table	16	13.04
MB04-VS	323541	Wetland / Perched water table	1.5	DRY
MB04-S	312985	Wetland / Perched water table	3	2.85
MB04-I	313049	Wetland / Perched water table	12	2.91
MB04-D	325826	Groundwater conditions	16	5.70
MB04-D_Baro	320261	Calibration	2.5	N/A
MB06-S	324268	Groundwater conditions	14	9.85
MB06-D	324254	Groundwater conditions	18	9.70
MB14-D	325832	Groundwater conditions	31	18.95
MB17-D	313124	Groundwater conditions	29	18.36
MB18-S	325838	Groundwater conditions	14	9.07
MB18-D_Baro	318637	Calibration	3	N/A

Notes: m bTOC = metres below Top of Casing; N/A = not applicable

### 6.3.5 Watercourse (Surface Flow) Assessment

Hydrological assessment of Mullering Brook was undertaken using historical data collected by Tronox. No quantitative data has been collected for Minyulo Brook in this study or previous studies, hence this watercourse, well south of the Proposal area, is not discussed in this section of this report, however was addressed as part of the previous Syrinx Desktop Study (Syrinx, 2012).

Tronox (Tiwest, 2012) have monitored the quantity and quality of flow in Mullering Brook, both entering (Brand) and exiting (Duffys) the Cooljarloo Mine tenement since 1996. Available stream flow and water quality data for Mullering Brook provided by Tronox (Tiwest, 2009; 2012), was reviewed in order to provide an understanding of the hydrological regime of the creek. As part of the review, total flow and flow duration in the creek was correlated to rainfall data from the Dandaragan West Meteorological Station (Bureau of Meteorology Station 9014).

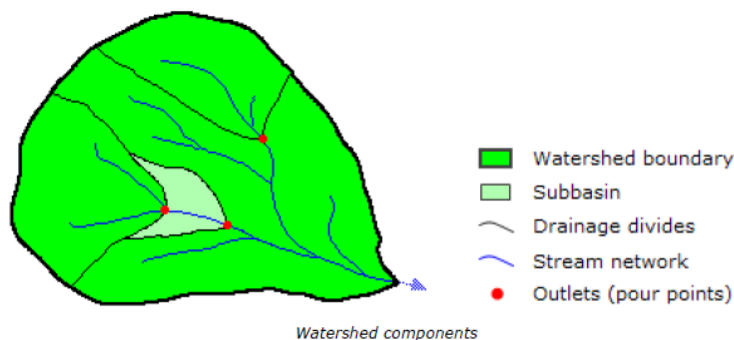
Tronox (Tiwest, 2012) have monitored water quality in Emu lakes, but as mentioned, no flow data is available for the northern branch of the Minyulo brook.

### 6.3.6 Watershed Analysis

In order to address this data gap, a desktop GIS based watershed analysis was conducted within the study area. The watershed analysis was not originally included in the DMS, however it was deemed a useful tool that would assist in the analysis of the direct and indirect effects of the mining activities on the functioning of the wetlands, particularly those adjacent to the mining footprint.

ArcGIS (version 10) with Spatial Analyst and ArcHydro tools, was used to create a Digital Elevation Model (DEM) from the 1 m spaced LiDAR (height) point data for the Proposal area obtained from Tronox. This data was then used to define watersheds (catchment areas), surface flows (streams) and sinks (low lying areas that act as terminal points to stream flow).

A watershed is the upslope area that contributes to surface water flow. The boundaries between watersheds are termed drainage divides (Figure 18). Each watershed area is comprised of many smaller sub-catchments (or 'subbasins') which contribute to the stream network.



**Figure 18 Watershed components (Source: [www.esri.com](http://www.esri.com))**

Often the errors in LiDAR data capture result in presence of many sinks and therefore processing of data is necessary to extrapolate the stream flow and direction. This is done by 'filling the sinks'. For this study, sinks were filled completely, up to 0.2 m, 0.5 m and 1 m in order to model the effect on accumulated flow and derive the most likely flow path for watercourses (streams) in the Proposal area

and the catchment areas these streams originate in. Streams were categorised using the number of joining branches, from primary to quaternary level.

Outputs from the watershed analysis were overlain on the Proposal and wider area aerial photograph, vegetation map and topography layers in order to confirm presence of streams and sinks and correlate vegetation types and stratigraphy along each transect to these features.

## **7.0 STRATIGRAPHY/LITHOLOGY ASSESSMENT**

The stratigraphy of soils at all locations drilled and hand augered was logged in detail and is presented in APPENDIX 2. General observations for the site are discussed below.

### **7.1 MAJOR STRATIGRAPHIC UNITS**

#### **7.1.1 Bassendean Sands**

The superficial presence of Bassendean Sands was continuous throughout the site, varying in thickness from 0.2 to 3.5 m in the locations studied. The Bassendean Sands were thinnest in low points of the landscape characterised by wetlands and thickest in high points characterised by dunes and ridges (it is known that the Bassendean Sands can be over 7 m thick in dunal locations on site). Sand description varied among locations and depth, but the differences found were broadly consistent across the site, with grain sizes varying from very fine to coarse, colour ranging from white, grey and yellow to brown, and grading varying from poorly to well graded. Organic material was present at all locations in varying quantities and most often limited to the top 0.2 m of top soil. The presence of a thin peat layer at approximately 0.3 – 0.5 mbgl was observed in one of the wetland locations. Extensive plant roots were present at all locations within this unit.

In several locations lateritic gravels occurred at varying depths and, variably across the site, the basal zones of the Bassendean Sands unit displayed evidence of diagenetic influence. Commonly, this was characterised by zones of ferruginisation. The ferruginisation observed was often associated with increasing silt, clay and moisture contents and likely related to the presence of seasonal perched water tables. Zones of ferruginisation are often associated with zones of nodular pisolite formation, which appears to transgress the depositional Bassendean Sands/Guildford Formation contact and occurs across both soils types. In most locations drilled in October 2012, the 0.1 to 0.2 m basal layer of the Bassendean Sands in direct contact with the Guildford Formation clays presented higher moisture content than the above sands.

Unique black, dark brown and green plastic clay layers, 0.2 - 0.3 m thick were observed at approximately 3 mbgl at locations MB4 (floodplain of the Mullering Brook) and A11 (dampland near DPaW reserve to the southeast). These clay layers were associated with saturated conditions directly above them, indicating a distinct confining layer and perched water table at these locations. These sediments may not be necessarily representative of the Bassendean Sands or Guildford units and

may represent more recent alluvium deposits associated with the floodplains of the Mullering Brook at MB4 and potentially Minyulo Brook at A11.

### 7.1.2 Guildford Formation

The Guildford Formation was present throughout the site and displayed broadly similar characteristics. Occurring at a depth of 0.2 mbgl in one of the palusplains studied and continuing to a depth of 5 mbgl at the deepest location drilled (it is known that the Guildford Formation can be as thick as 35 – 40 m in some locations of the Cooljarloo West area), the Guildford Formation was characterised by mottled, ferruginised clays, sandy silts, silty clays and clayey sands.

Sediments ranged in colour and most commonly being pale grey, orange, red and dark brown. Roots were observed at all locations drilled and to maximum depth of 3.5 m (deeper roots were observed as part of the detailed root architecture study). Moisture content was higher in the Guildford Formation than in the Bassendean Sands, but as previously discussed, moisture was directly associated with clay content, so superficial strata with higher sand content were often drier.

## 7.2 LITHOLOGY, GRANULOMETRY & SOIL MOISTURE

In total, 34 samples from 12 locations were analysed for particle sizing and moisture content to determine spatial variation and patterns within the Bassendean Sands and Guildford Formation (Table 8). The Bassendean Sands and Guildford Formation were separated based on the depth, field observations and the samples' clay content. A 10% clay content threshold was used to separate units.

Samples with clay content <10% were primarily classified as Bassendean Sands and samples with clay content  $\geq$ 10% were classified as Guildford Formation. This information was crosschecked with the bore logs and sample depth to ensure that a sample with low clay content in the Guildford Formation (i.e. a possible sand lens) was not erroneously classified as Bassendean Sands. One of the samples was taken in the interface between the Bassendean Sands and Guildford Formation and this sample was classified as Guildford because of its 13.3% clay content.

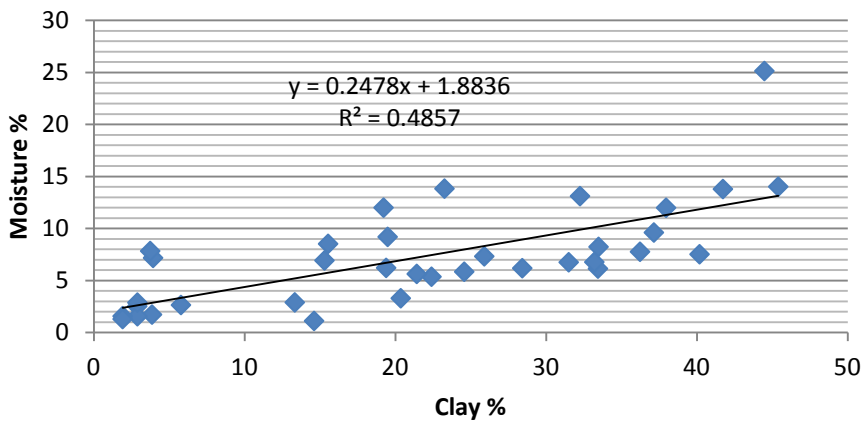
The Bassendean Sands samples showed lower moisture content than the Guildford Formation samples (as measured in October 2012) and a strong positive correlation was observed between clay content and moisture content and a negative correlation between sand content and moisture content Figure 19.

These results indicate that the superficial soils are basically free draining sands that have low water holding capacity and, as measured by SWC (2013), low plant available water (PAW), thus representing a short term water resource following rain events. The fine clays, on the other hand, retain moisture for longer periods, representing an important longer term water resource for plants. This has been confirmed by SWC (2013), whose studies showed the clays had a higher water holding capacity and higher PAW than the sands (SWC, 2013).

Table 8 Summary of particle size and soil moisture data (October 2012).

Locations		Bassendean sand			Guildford formation		
		B02, B03, B04, B05, MB08, MB14			B02, B03, B04, B05, B08, MB03, MB04 MB08, MB14, MB17, MB18		
Parameter	Units	Average	Min	Max	Average	Min	Max
Colour range	Munsell	White, grey, yellow, brown			Light grey, grey, pink, orange, red, brown		
Depth	(mBGL)	1.4	0.3	2.8	2.5	0.4	5
Clay	%	3.45	1.91	5.78	28.1	13.3	45.4
Silt	%	0.98	0.005	1.95	3.7	0.0	8.8
Fine Sand	%	31.0	23.9	44.6	27.0	11.2	49.6
Coarse Sand	%	64.6	48.7	73.3	41.2	24.4	58.2
Sand (total)	%	95.6	93.2	97.1	68.2	47.0	85.4
Moisture %	%	2.86	1.56	7.17	8.7	1.1	25.1

Clay content vs Moisture



Sand content vs Moisture

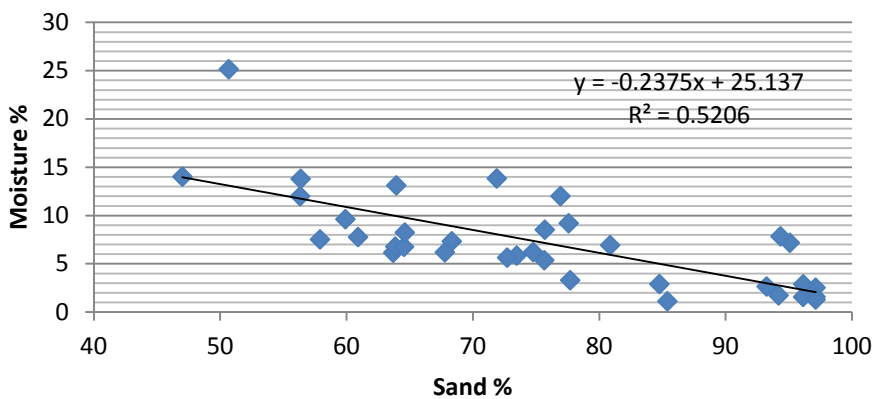


Figure 19 Clay and sand content versus moisture content at the Cooljarloo West area.

Individual bore lithology in relation to overlying vegetation community type and height of vegetation is shown in APPENDIX 1.

In general, a similar sequence of units was observed at all wetlands with the main variability between wetlands being the depth of overlying sands and percentage clay or sand content within the Guildford Formation. Ferruginisation in the interface between the Bassendean Sands and Guildford Formation was observed at all wetlands. In addition to the generalised ferruginisation, lateritic gravels were present at several locations including damplands (A02), sumplands (suggested dampland) (MB08, B05, B06), and floodplain (palusplain) (B08). Peat was associated with some of the damplands (A06).

Graphical outputs for soil moisture and granulometry are shown for each sample location in APPENDIX 3. The images show that similar trends in soil moisture distribution occur in different wetland types, regardless of the wetland type (i.e. palusplain, dampland etc) and that soil moisture is largely associated with particle size as expected.

## **8.0 HYDROLOGY ASSESSMENT**

### **8.1 GROUNDWATER LEVELS**

Groundwater levels were measured by WorleyParsons and Tronox between December 2012 and July 2013. Groundwater level data has been supplied by WorleyParsons and Tronox and a summary of bore locations, screened interval and static water levels measured are shown in Table 9. Groundwater level data from the level loggers is presented in APPENDIX 4. These data will be used for long term monitoring of groundwater levels at Cooljarloo West and used in future ongoing management.

Water level monitoring in the shallow and very shallow bores confirmed the occurrence of perching water tables in the Bassendean Sands being supported by the less permeable clayey sands of the Guildford Formation or heavy clays of recent alluvial origin present between the Bassendean Sands and the Guildford Formation. Water levels in these perched systems varied between 1.2 mbgl to 2.8 mbgl and tended to decrease from November to May. In fact, bores B03-S (1.9 - 2.6 mbgl screening), B04-S (2.1 - 2.5 mbgl screening) and B05-S (1.7 - 2.4 mbgl screening) dried completely in April 2013, additionally, bore MB4-s dried in May, indicating the seasonal availability of water in these perched systems. All remaining very shallow bores were dry between December and May but the majority recorded water in July, reflecting rainfall recharge of this system. Ongoing monitoring will assess the effect of seasonal rainfall on perched water levels at these locations.

Water levels in bores targeting the Upper Guildford Formation, or so called regional water table, (screened interval ranging from 4.5 mbgl to 22.8 mbgl) ranged from 2.09 mbgl at MB04-I to 15.6 mbgl at MB14-S. Bore MB14-S dried in April 2013, but had water in May 2013, likely indicating that the sandier horizon where the screen was placed was a confined sand lens within the Guildford Formation and disconnected from the regional water table.

Bores targeting the lower Guildford and Yoganup formations (screened interval ranging from 19.9 to 40.4 mbgl) had water levels varying from 2.9 mbgl at MB1 to 18.8 mbgl at MB15-D. All Yoganup bores had water levels above the screened interval.

Little variation in water levels occurred in bores targeting the Guildford and Yoganup Formations between November 2012 and July 2013 but in general a slight decrease in water levels (ranging from <0.1 m to 0.87 m) was observed. One exception was MB17-S (27 – 33 mbgl screening), which had water levels dropping by approximately 3.5 m.

Interestingly, static water levels in nested bores screening distinct depths and lithologies presented similar water levels during the monitored period, this is visible at nested bores MB14-I and MB14-D, MB15-I and MB15-D and MB18-S and MB18-D. Additionally, static water levels at these and other locations were recorded as being several metres higher than the bore screened interval (e.g. B04-D and MB03-D). This is likely associated with the lack of a confining unit between the two screened sections (e.g. MB17) at these locations or the occurrence of localised overburden pressure exerted by the clayey Guildford Formation on the groundwater within the Yoganup sands. The latter explanation has been reported by SWC (*pers. comm.* 2013) who has noted, from previous experience in the area, that due to this pressure, piezometers screened in the Yoganup sands are likely to show a potentiometric water level and not a true phreatic level. In addition, it has been suggested that groundwater levels at the superficial formation at the site should not be labelled as water table but instead as potentiometric surface (*pers. comm.* SWC, 2013).

At this stage, there is insufficient data to compile individual hydrographs for wetland and dune systems for the purpose of comparing wetting/drying cycles and ascertaining interactions between perched and deep aquifer sequences. For the period that monitoring data is available, standing water was recorded in the Mullering Brook floodplain between December 2012 and May 2013 but no water was recorded in July 2013. In contrast, perched water was recorded in July 2013 in wetlands that had been dry between November 2012 and May 2013. This was evident in damplands (B04 and B05) and palusplains (MB03 and MB15) (Table 9).

In general bores targeting the upper Guildford and Yoganup in all wetlands, showed little fluctuation between November 2012 and May 2013.

The presence of perched water in most wetland bores in winter 2013, along with evidence of an apparently continuous Guildford Formation clay sequence above the regional aquifer and underneath relatively shallow Bassendean Sands, strongly supports the view that these wetlands are largely supported by a perched aquifer system.

**Table 9 Summary of groundwater level monitoring results.**

Bore ID	Screened Interval (mbgl)	Formation Screened	Static Water Level (mbgl)						Static Water Level (mAHD)					
			Nov-12	Dec-12	Feb-13	Apr-13	May-13	Jul-13	Nov-12	Dec-12	Feb-13	Apr-13	May-13	Jun-13
B03-VS	0.4-0.9	Perching - Bassandean	DRY	DRY	DRY	DRY	DRY	DRY	DRY	DRY	DRY	DRY	DRY	DRY
B03-S	1.9-2.6	Perching - Bass./Guildf.	1.41	2.25	DRY	DRY	DRY	1.26	57.25	56.41	DRY	DRY	DRY	57.40
B03-D	8.0-17.0	Water Table - U. Guildford	9.61	9.63	9.72	9.79	9.83	9.89	48.93	48.91	48.82	48.75	48.71	48.65
B04-VS	1.2-1.9	Perching - Bassandean	DRY	DRY	DRY	DRY	DRY	1.59	DRY	DRY	DRY	DRY	DRY	57.83
B04-S	2.1-2.5	Perching - Bass./Guildf.	1.82	2.28	DRY	DRY	2.35	1.59	57.69	57.23	DRY	DRY	57.16	57.92
B04-D	9.0-18.0	Water Table - Guildford	6.44	6.42	6.47	6.48	6.50	6.51	53.17	53.19	53.14	53.13	53.11	53.10
B05-VS	0.8-1.4	Perching - Bassandean	DRY	DRY	DRY	DRY	DRY	1.17	DRY	DRY	DRY	DRY	DRY	67.98
B05-S	1.7-2.4	Perching - Bass./Guildf.	2.20	2.16	DRY	DRY	DRY	1.09	66.88	66.92	DRY	DRY	DRY	67.99
B05-D	8.8-17.8	Water Table - Guildford	12.31	12.33	12.37	12.42	12.42	12.46	56.69	56.67	56.63	56.58	56.58	56.54
MB01	19.9-28.9	Yoganup	2.88	2.91	3.14	3.17	3.25	3.13	60.98	60.95	60.72	60.69	60.61	60.73
MB03-S	1.5-4.0	Perching - Bassandean	DRY	DRY	DRY	DRY	DRY	1.78	DRY	DRY	DRY	DRY	DRY	56.71
MB03-D	25.6-31.6	Yoganup	10.22	10.23	10.32	10.36	10.39	10.46	48.28	48.27	48.18	48.14	48.11	48.04
MB04-VS	0.3-0.7	Perching - Bassandean	DRY	DRY	DRY	DRY	DRY	DRY	DRY	DRY	DRY	DRY	DRY	DRY
MB04-S	1.9-2.9	Perching - Bass./Guildf.	1.21	2.16	2.66	2.77	DRY	2.59	62.58	61.63	61.13	61.02	DRY	61.20
MB04-I	8.9-17.9	Water Table - U. Guildford	2.09	2.18	2.81	2.96	3.09	2.58	61.74	61.65	61.02	60.87	60.74	61.25
MB04-D	19.8-25.8	U. Guildford Fm.	5.05	5.01	4.98	5.11	5.17	5.02	58.73	58.77	58.80	58.67	58.61	58.76
MB08-S	1.0-4.0	Perching - Bassandean	DRY	DRY	DRY	DRY	DRY	2.05	DRY	DRY	DRY	DRY	DRY	64.90
MB08-I	4.5-10.5	U. Guildford Fm.	DRY	DRY	DRY	DRY	DRY	DRY	DRY	DRY	DRY	DRY	DRY	DRY
MB08-D	19.0-25.0	Yoganup	14.94	14.97	15.02	15.09	15.07	15.12	52.05	52.02	51.97	51.90	51.92	51.87
MB10	20.0-38.0	L. Guildford/ Yoganup	11.26	11.28	11.39	11.47	11.47	11.51	47.91	47.89	47.78	47.70	47.70	47.66
MB12	10.8-22.8	Water Table - U. Guildford	10.18	10.18	10.26	10.26	10.83	10.31	56.79	56.79	56.71	56.71	56.14	56.66
MB14-S	6.9-15.9	Water Table - U. Guildford	12.89	15.60	15.79	DRY	15.79	15.78	54.82	52.11	51.92	DRY	51.92	51.93
MB14-I	24.8-27.8	L. Guildford /Yoganup	18.28	18.26	18.35	18.37	18.40	18.44	49.40	49.42	49.33	49.31	49.28	49.24
MB14-D	32.3-35.3	Yoganup	18.32	18.31	18.40	18.43	18.45	18.48	49.37	49.38	49.29	49.26	49.24	49.21
MB15-VS	0.3-1.8	Perching - Bassandean	DRY	DRY	DRY	DRY	DRY	1.75	DRY	DRY	DRY	DRY	DRY	67.21
MB15-S	16.0-19.0	U. Guildford	10.09	10.24	10.30	10.33	10.31	9.74	58.89	58.74	58.68	58.65	58.67	59.24
MB15-I	23.5-26.5	L. Guildford /Yoganup	18.62	18.60	18.69	18.77	18.73	18.76	50.34	50.36	50.27	50.19	50.23	50.20
MB15-D	37.4-40.4	Yoganup	18.67	18.64	18.73	18.80	18.75	18.82	50.36	50.39	50.30	50.23	50.28	50.21
MB17-S	9.0-15.0	Water Table - U. Guildford	11.46	12.13	14.55	14.64	14.55	14.97	56.16	55.49	53.07	52.98	53.07	52.65
MB17-D	27.0-33.0	Yoganup	17.61	17.59	17.66	14.67	17.63	17.67	50.00	50.02	49.95	52.94	49.98	49.94
MB18-S	9.6-15.6	Water Table - U. Guildford	8.44	8.45	8.54	8.43	8.59	8.61	62.60	62.59	62.50	62.61	62.45	62.43
MB18-D	31.5-37.5	Yoganup	8.34	8.35	8.43	8.61	8.49	8.52	62.52	62.51	62.43	62.25	62.37	62.34

## 8.2 SURFACE FLOWS - MULLERING BROOK

Mullering Brook is a highly ephemeral first-order stream (smallest in the scale of 1 to 12 in the stream order classification) and has its source at the Gingin Scarp. The creek flows in a westerly direction across the Brand Highway and the Tronox Central Mining area before dissecting the Cooljarloo West area. Within the Tronox Central Mining area, the Mullering Brook channel has been diverted to accommodate mining operations, and rehabilitation has been undertaken over the years in order to prevent sediment transport and water quality impact in the creek downstream of the mining area.

A summary of flows, sediment loads and rainfall data upstream and downstream of the existing Cooljarloo Central Mining area are presented in Table 10. No flows were recorded in 2006 when the Mullering Brook channel diversion occurred. Chemistry data is discussed in Section 9.3.

Results show that flows and sediment loads in the creek are intermittent and highly variable from year to year. From 2007 to 2011, flow duration and total flow have been positively correlated to number of rainy days and total rainfall, demonstrating that flows are controlled by rainfall in the catchment. The timing and magnitude of stream flow has shown to be closely related to rainfall duration and intensity in autumn and winter. On average, peak flows, flow rates and flow duration values are lower exiting the mine, indicating that water is lost to infiltration and evaporation as it crosses the mine site. Water loss along the mine site has decreased since 2007, possibly indicating that the diversion channel is becoming less permeable as fines accumulate in its bed.

**Table 10 Surface water characteristics of Mullering Brook.**

Year	Peak Flow Rate (m <sup>3</sup> /sec)		Total Flow (Megalitres)		Flow Duration (days)		Sediment Load (Tonnes)		Rainfall Data*		
	BRAND [Upstream of Mine]	DUFFYS [Downstream of Mine]	BRAND	DUFFYS	BRAND	DUFFYS	BRAND	DUFFYS	Number of rainy days	Total rainfall (mm/year)	
1996	7.26	N/A	2,173	N/A	104	N/A	96.40	N/A	N/A	N/A	
1997	0.19	N/A	82.2	N/A	61	N/A	1.11	N/A	N/A	N/A	
1998	1.2	N/A	459.4	N/A	113	N/A	8.55	N/A	N/A	N/A	
1999	22.91	N/A	7016	N/A	169	N/A	1074.6	N/A	N/A	N/A	
2000	1.87	N/A	681.8	N/A	90	N/A	17.43	N/A	N/A	N/A	
2001	0.22	0.124	88.6	26.1	74	11	0.47	3.6	77	527	
2002	0.485	0.267	63.3	18.2	68	3	0.73	13.2	97	533.8	
2003	6.2	2.853	1804	1076	109	73	107.9	197.7	89	648.2	
2004	0.18	0.149	93.7	77.7	74	33	2.03	80.6	89	536.3	
2005	8.137	5.162	2283	2024	151	134	89.8	1366.0	74	635	
2006	- no flow recorded -										
2007	0.179	0.391	139.9	16.2	76	19	1.17	19.7	87	532	
2008	0.334	0.435	136.9	104.7	94	34	1.00	84.2	92	594.5	
2009	1.147	1.213	582.8	471.6	101	68	6.06	492.3	92	523.4	
2010	0.057	0.218	10.2	32.5	11	24	0.02	74.3	53	357	
2011	0.406	0.78	118.4	195	79	71	0.50	156.5	84	631	
2001 - 2011 Statistics	Mean	1.7	1.2	427.9	404.2	81.8	47.0	21.0	248.8	83.4	551.8
	Median	0.4	0.4	127.7	91.2	77.5	33.5	1.1	82.4	88.0	535.1
	Max	8.1	5.2	2283.0	2024.0	151.0	134.0	107.9	1366.0	97.0	648.2
	Min	0.1	0.1	10.2	16.2	11.0	3.0	0.02	3.6	53.0	357.0

\*Bureau of Meteorology Station 9014 Dandaragan West  
N/A = not assessed

Sediment loads exiting the mine site are significantly higher than those entering the mine site. High sediment loads can be attributed predominantly to movement of sediment resulting from the creek

diversion in 2006. It is expected that sediment loads exiting the existing mine lease decrease as the diverted channel bed and embankments stabilise with time.

WorleyParsons (2013) note that the monitoring data suggests that stream flow is predominantly controlled by rainfall within the catchment, although groundwater may seasonally contribute to stream flow on a local level. This indicates that the hydrology at the site is likely to be dominated by infiltration and evaporation, with run-off linked to high intensity rainfall events. As such, the Mullering Brook at least is likely to only contribute significantly to the hydrological maintenance of the wetlands in the study area during peak flood events that engage the broader floodplains and associated wetlands.

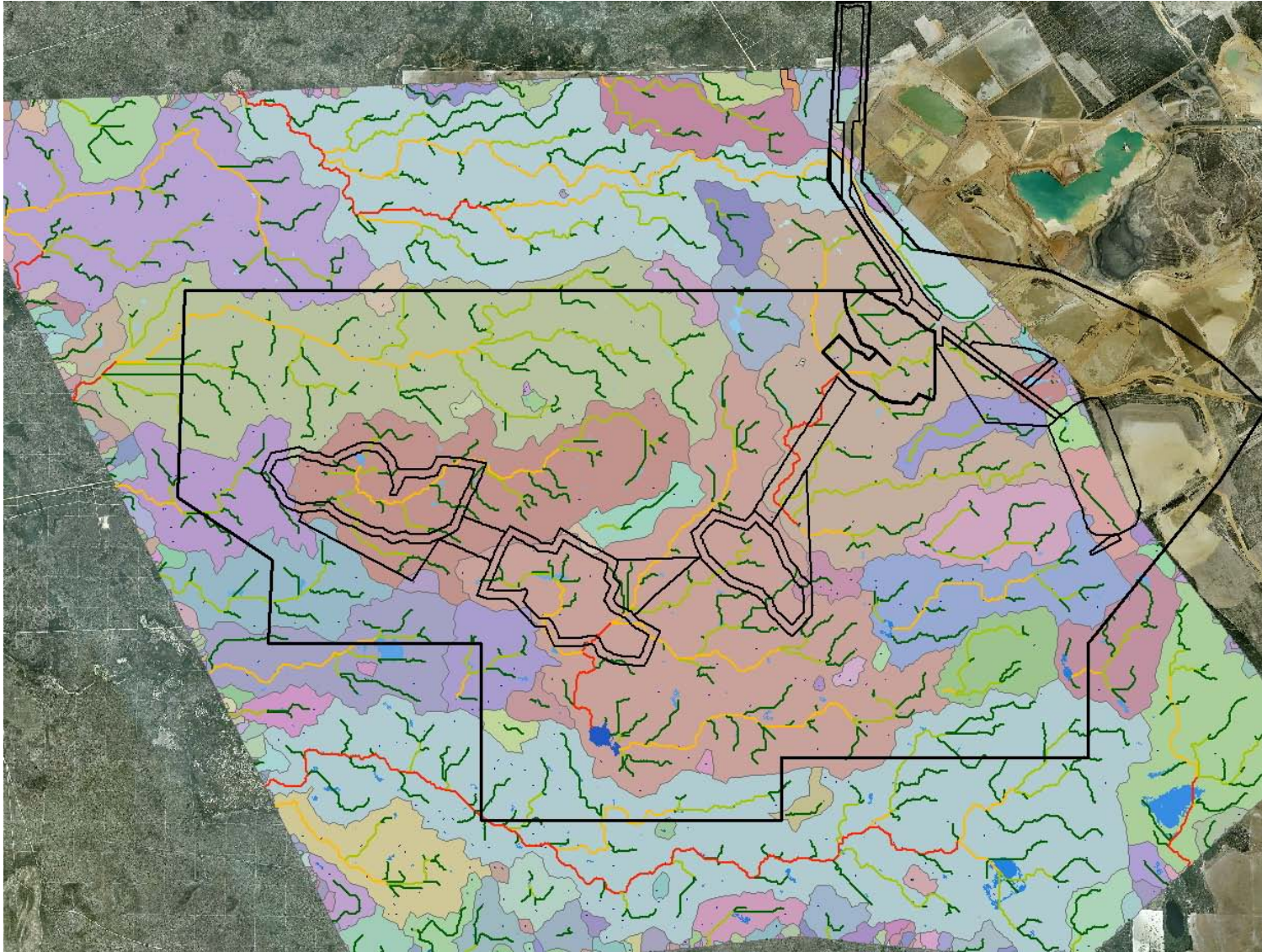
### 8.3 WATERSHED ANALYSIS

Graphical outputs from the DEM watershed analysis is given in Figure 20 with the streams coloured based on the hierarchy of the connecting branches and assigned to their respective catchments. The differences in the number and length of the streams created by using different infill of DEM is due to the presence of sinks. The remaining sinks after the fill process are shown in blue (blue indicates high input and light blue low input) in Figure 20.

A comparison of the streams generated from the two differently filled DEMs showed that for the 0.2 m filled DEM there are fewer and shorter streams, with many terminating within the Proposal area extent. The streams produced from the completely filled DEM always terminated at the edge of the DEM towards the coast. The field observations by Syrinx and the vegetation types associated with the watercourses and swales on site did not support either scenario. Therefore, the 1 m filled DEM was processed to generate streams and their overall flow direction.

Streams generated from the 1 m filled DEM fit closely with the observed vegetation patterns on site and are likely to be the main surface flow patterns. However, given that the surface Bassendean Sands on site are permeable, most rainfall events are likely to infiltrate, rather than run-off. Hence, the flows depicted in Figure 20 would indicate water movement once these sands are fully saturated (likely in peak rainfall events or periods of continuing rainfall). Flows would then flow into surrounding areas downgradient towards the west, with water pooling in basins or areas on flats where the thickness of sand is low (or the Guilford formation is close to the surface).

There are 46 sink areas in the 1.0 m filled DEM. These sinks correspond to 'wetter' areas of wetlands and topographical depressions on site. The vegetation that occurred at the sinks was generally much taller and contained riparian species such as *Melaleuca raphiophylla* and *Eucalyptus rudis*.



**Figure 20 DEM generated streams for the Proposal area (1 m fill) showing respective catchment areas and sinks.**

## 9.0 HYDROCHEMISTRY

### 9.1 SOIL & SEDIMENT CHEMISTRY

In total, 34 soil samples from 12 locations were analysed for chemical parameters. A summary of soil quality is shown in Table 11 and the full set of results is presented in APPENDIX 5. The Bassendean Sands and Guildford Formation were separated based on the depth, field observations and the samples' clay content as described in Section 7.2.

Electrical conductivity (EC) and pH (both measured at 1:5 soil to solution ratio) were both lower in the Bassendean Sands than in the Guildford Formation, with EC ranging from 0.005 to 0.023  $\mu\text{S}/\text{cm}$  in the Bassendean and from 0.023 to 0.723  $\mu\text{S}/\text{cm}$  in the Guildford. Average pH in the Bassendean and Guildford samples were 6.31 and 7.5, respectively. The highest EC and pH values measured on site were at location MB4 at depths of 1.6 and 3.2 mbgl, on the Mullering Brook floodplain directly south of the cleared farmland.

In general, nutrients, carbon (organic and total), major cations (Na, Ca, K and Mg) and metal concentrations were higher in the Guildford Formation samples than in the Bassendean samples. One exception was Colwell phosphorus (i.e. bioavailable phosphorus), which had a slightly higher average concentration in the Bassendean Sands (1.43 mg/kg) than in the Guildford clays and clayey sands (1.2 mg/kg). Carbonate content was below the method's detection limit (0.5%) in all samples and therefore all carbon present was assumed to be organic.

Ammonium and nitrate nitrogen concentrations ranged from 0.5 to 7.0 mg/kg and 0.5 to 2.0 mg/kg, respectively, across all locations and depths. Total nitrogen and total phosphorus ranged from 0.005 to 0.03% and 2.25 to 43.4 mg/kg, respectively, across all locations and depths. The low nutrient content observed in this study is consistent with the literature on Swan Coastal Plain soils (Beard, 1984), with nutrient content often related to organic carbon content.

Average iron and aluminium concentrations in the Guildford samples tended to be an order of magnitude higher than in the Bassendean Sands samples. This higher concentration of iron and aluminium in the Guildford was expected and is in agreement with the red and brown mottling and strong ferruginisation observed in the samples in the field.

In general, soil parameters analysed varied consistently across the site and the variability in sediment chemistry observed at different depths within one wetland was generally greater than that observed between wetlands, considering the same stratum analysed.

**Table 11 Summary of soil and sediment chemistry data.**

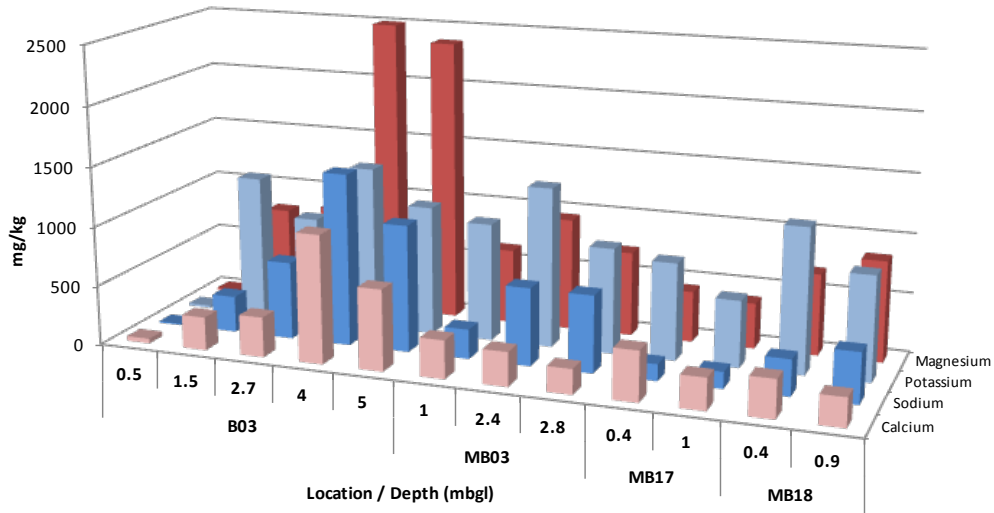
Locations		Bassendean sand			Guildford formation		
		B02, B03, B04, B05, MB08, MB14			B02, B03, B04, B05, B08, MB03, MB04 MB08, MB14, MB17, MB18		
Parameter	Units	Average	Min	Max	Average	Min	Max
Electrical Conductivity	mS/cm	0.013	0.005	0.023	0.242	0.023	0.723
pH Level (CaCl <sub>2</sub> )	pH	5.63	5.4	6	6.8	5.8	7.6
pH Level (H <sub>2</sub> O)	pH	6.31	6	6.5	7.5	6.3	8.5
Organic Carbon (CSBP Lab)	%	0.21	0.13	0.35	0.27	0.14	0.62
Ammonium Nitrogen	mg/Kg	1.21	0.5	2.0	3.0	1.0	7.0
Nitrate Nitrogen	mg/Kg	0.50	0.5	0.5	0.77	0.50	2.00
Total Nitrogen	%	0.01	0.005	0.01	0.009	0.005	0.030
Phosphorus Colwell	mg/Kg	1.43	1.0	3.0	1.2	1.0	3.0
Phosphorous (total)	mg/kg	4.11	2.25	6.75	23.5	9.4	43.4
Potassium Colwell	mg/Kg	22.7	16	38	70.0	32.0	172.0
Potassium	mg/kg	34.3	20.2	67.5	911.6	205.5	1590
Magnesium	mg/kg	24.4	5	45.0	912.1	171	2660
Calcium	mg/kg	34.06	13.45	52.5	301.2	33.4	1075
Sodium	mg/kg	18.88	10.85	26.1	639.8	79	2725
Total Carbon (Curtin Lab)	mg/kg	523.5	154.1	848.3	767.3	134.8	3958
Carbonate	%	BDL*	-	-	BDL*	-	-
Aluminium	mg/kg	1857.3	217.5	4400	47606	18250	78000
Silicon	mg/kg	134.4	75.5	215.5	1237	695	1640
Sulfur	mg/kg	8.61	3.6	18.15	41.0	9.8	134.5
Manganese	mg/kg	10.53	2.95	16	14.1	6.6	40.3
Iron	mg/kg	716.4	223.5	2160	19673	4045	55500

\* BDL = below detection limit (CO<sub>3</sub>< 0.5%)

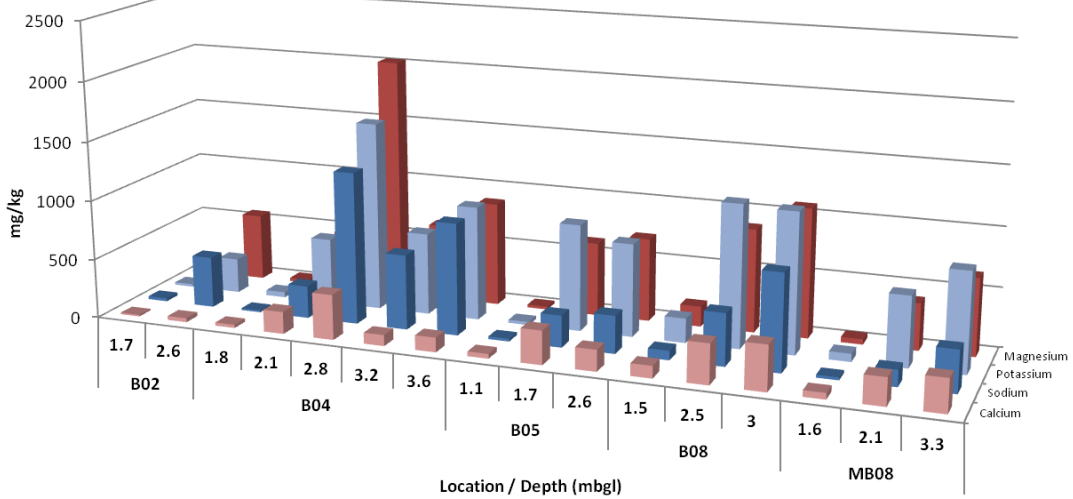
Major cations in the superficial sands are low irrespective of wetland type (Figure 21). In the damplands, higher concentrations of sodium (1280 mg/kg), potassium (1600 mg/kg), and magnesium (1025 mg/kg) were observed at B04 – 2.8 mbgl. In the Palusplains, similarly high concentrations were observed at B03 at 4 and 5 mbgl, calcium and magnesium concentrations were also high, relative to other samples, at these location (Ca = 500 – 1000 mg/kg and Mg = 2370 – 2660 mg/kg). The highest sodium concentrations were observed in the floodplain of the Mullering Brook at 1.6 mbgl (1630 mg/kg) and 3.2 mbgl (2725 mg/kg).

Similar patterns were observed for organic carbon, nutrients and metals, with median and mean values for these parameters being broadly similar across all wetland types. Variations in soil chemistry appear to be caused by micro scale differences resultant from sampling, (i.e. a sample taken from an area with higher clay content or ferruginised material at a certain depth) rather than reflective of different hydro geochemical processes specific to a certain type of wetland (i.e. palusplains vs damplands)

Palusplains - major cations in soils



Damplands - major cations in soil



Floodplain - major cations in soil

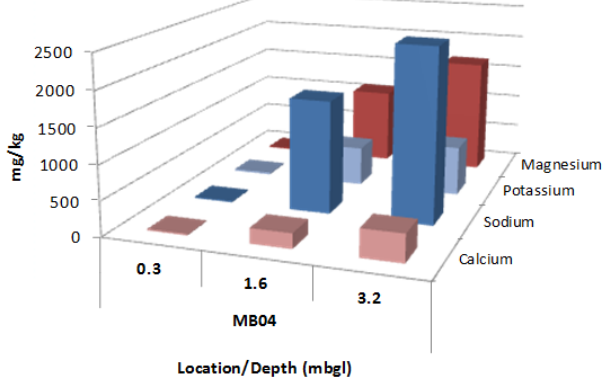


Figure 21 Major cations in soils of wetlands studied at Cooljarloo West.

## 9.2 GROUNDWATER CHEMISTRY

Groundwater samples were collected for physicochemical analysis from 36 bores in December 2012 and from 34 bores in April 2013. Groundwater analysis results from each of the screened formations have been grouped and summarised results are shown in Table 12 and discussed below. For field sampling information and complete analysis results please refer to APPENDIX 6.

Field notes from December 2012 (1<sup>st</sup> round of groundwater chemistry monitoring) and April 2013 (2<sup>nd</sup> round of groundwater chemistry monitoring) sampling are provided below (WorleyParsons, 2013):

In December, the majority of the bores were successfully sampled, however;

- The following bores were dry during the first monitoring period, so no samples were collected, B03-VS, B04-VS, B05-VS, MB03-S, MB04-VS, MB08-S, MB08-I, MB15-VS and MB16-VS;
- B03-S, B04-S, B05-S and MB04-S purged dry and did not recharge at a sufficient speed. It was therefore necessary to collect water quality samples from the purged water at these bores;
- B04-D and MB11-S also purged dry, but had sufficient recharge for samples to be taken directly, although it was not possible to purge 3 times the volume of the bore in these locations. At MB15-I the recharge was slower but it was possible to collect a sample 1.75 hour later; and
- MB14-S purged dry and did not recharge over a 3 day period. No sample was collected from this bore for water quality analysis.

In April, the majority of bores were successfully sampled, however:

- The following bores were dry during the second monitoring period, so no samples were collected: B03-VS, B03-S, B04-VS, B04-S, B05-VS, B05-S, MB03-S, MB04-VS, MB08-S, MB08-I, MB14-S, MB15-VS and MB16-VS. MB04-S did not have enough volume for a sample to be collected.
- Bores MB15-S and MB16-S purged dry but recharged at sufficient speed for samples to be collected.
- Bore MB17-S purged dry after 0.5L purging volume and did not recharge at sufficient speed. It was therefore necessary to collect a sample from the 0.5L purged water.

This information is important in interpreting groundwater chemistry results, particularly in screened sections targeting drier and less permeable strata, where bores were either purged dry and not recharged or where the recharge was very slow. These samples add a confounding factor to the data analysis as they are likely to be contaminated by the chlorine (sodium hypochlorite) and AMC

Wellclean™ (sodium acid pyrophosphate) solutions used during well development. This issue is further discussed below.

In general, little variation was observed in groundwater quality between the December 2012 and April 2013 monitoring events. However, results indicate that parameters are stabilising over time and remnants of cleaning agents used during well development are being diluted and flushed. On average, the perched groundwater in the Bassendean / Guildford interface was more acidic and more saline (higher electrical conductivity (EC) and total dissolved solids (TDS)) than the groundwater in the upper Guildford and lower Guildford/Yoganup. Bicarbonate alkalinity, sodium, potassium, nutrients, metals and total cations followed the same trend of higher average concentrations in the Bassendean Sands and showed decreasing concentrations with depth. Concentrations of sulfate, chloride, magnesium and total anions were on average highest at the upper Guildford, then decreased at the Bassendean Sands and were lowest at the lower Guildford/Yoganup.

The key parameters of interest are salinity and nutrients, as they are most likely to impact wetland and surface water health as well as vegetation distribution.

### ***EC and TDS***

Perching groundwater in the Bassendean Sands was brackish to saline (2180 – 10500 mg/L TDS), while in the upper Guildford it was fresh to saline (318 – 14400 mg/L TDS) and in the lower Guildford / Yoganup groundwater was fresh to brackish (159 – 3410 mg/L TDS). In all instances, the major ions making the TDS content of the groundwater were sodium and chloride ions, followed by sulfate > magnesium > similar levels of potassium and calcium. In general, the lower Guildford and Yoganup had slightly higher calcium and bicarbonate alkalinity (CaCO<sub>3</sub>) concentrations than the upper Guildford. Graphical outputs for EC values at the different bores can be seen at APPENDIX 7.

Bores MB4-D and MB4-I, targeting different depths of the upper Guildford and located south of the Mullering Brook and adjacent to the farmland, showed the highest EC (22,000 and 19,000 µS/cm, respectively) of all bores with an increasing trend in EC from December 2012 to April 2013. In line with the high EC, bores MB04-D and MB04-I also had the highest concentrations of TDS, with particularly high sulfate, sodium, chloride and magnesium ions. These bores were well purged and results possibly reflect groundwater salinisation as a result of recent agricultural practices, including clearing of native vegetation along the Mullering Brook and its upper catchment. The similar salinity and ionic signature suggest a single aquifer is stretching between the two screening depths of the upper Guildford at this location. Groundwater at MB4-S (targeting perched water in the Bassendean), on the other hand, was less saline than at the deeper bores, corroborating the fact that groundwater at MB4-S comprises a distinct perched system.

Bores B03-S, B04-S and B05-S targeting perching water in the Bassendean/Guildford interface showed high EC (8,600 to 16,100 µS/cm) in December 2012. This is possibly related to the fact that these bores had little water and were purged dry at the time of sampling, with samples being taken from wellbore purged water and likely contaminated by remnant cleaning solutions used in well development. These bores remained dry until the April 2013 sampling event.

Bores B04-D and B05-D, targeting the upper Guildford (8.8 – 18 mbgl screened interval) had consistently high EC in December and April, with values ranging from 5,110 to 10,600  $\mu\text{S}/\text{cm}$ . Bores MB15-S and MB15-I, in south of the study area and targeting the upper and lower Guildford, respectively, had consistently high EC with values ranging from 5670 to 5780  $\mu\text{S}/\text{cm}$  and from 4740 to 5250  $\mu\text{S}/\text{cm}$ , respectively. These bores were well purged and therefore are more likely to represent true saline conditions at these locations. These salinity levels well exceed the threshold of the vegetation communities in the vicinity of these bores, hence it is highly unlikely that this water is being accessed by these plants. The dominant community near B04 is Banksia Woodland, comprising *B. prionotes*, *B. menziesii*, *B. attenuata* and many other species known to be intolerant to even low level salinity.

Bore MB17-S, targeting the upper Guildford (9 – 15 mbgl screened interval) and located in a palusplain at the southernmost part of the study area, showed consistently high EC between December 2012 (12,100  $\mu\text{S}/\text{cm}$ ) and April 2013 (10,100  $\mu\text{S}/\text{cm}$ ). It is important to note however that the December sample had an intense chlorine odour, indicating possible contamination of the chlorine solution used during well development. The April sample consisted of the 0.5L purged wellbore volume and therefore may not be representative of conditions in the aquifer.

### **Nutrients**

Total phosphorus and reactive phosphorus (phosphate) concentrations were found to be abnormally high throughout and especially in the Bassendean Sands, and upper Guildford Formations. In general concentrations decreased from December 2012 to April 2013. These abnormally high concentrations of phosphorus are believed to be remnant AMC Wellclean™, which is composed of  $\geq 98\%$  sodium acid pyrophosphate, therefore providing a possible explanation for the high phosphorus (and phosphate) concentrations found in bores. The higher concentrations were usually found in screened intervals where little water was present (i.e. perching systems, less subject to dilution/flushing) or low permeability sediments occurred (i.e. clayey horizons with slow recharge and less subject to flushing). Total phosphorus concentrations in the upper Guildford and lower Guildford/Yoganup are believed to be in the lower ranges of values reported for April 2013, that is, 0.13 mg/L at MB04-D and 0.04 mg/L at MB10. Further monitoring would be required to verify true phosphorus concentrations in the groundwater.

Total nitrogen and total Kjeldahl nitrogen concentrations were higher in the Bassendean Sands and upper Guildford than in the lower Guildford / Yoganup. Concentrations generally decreased between December 2012 and April 2013, indicating stabilisation in water quality in the bores. Most of the total nitrogen was composed of organic nitrogen, followed by ammonia and by a smaller proportion of  $\text{NO}_x$  ( $\text{NO}_3\text{-N} + \text{NO}_2\text{-N}$ ).

The highest concentrations of total nitrogen were observed at the perching Bassendean / upper Guildford bores B05-S (14.8 mg/L), B03-S (9.7 mg/L) and B04-S (7.4 mg/L) in December 2012. The highest concentration of total nitrogen at the upper Guildford was observed at MB17-S (10.4 mg/L) in

December 2012. Similar to the EC, TDS, and phosphorus observations, these results may be impacted by the cleaning products used in well development.

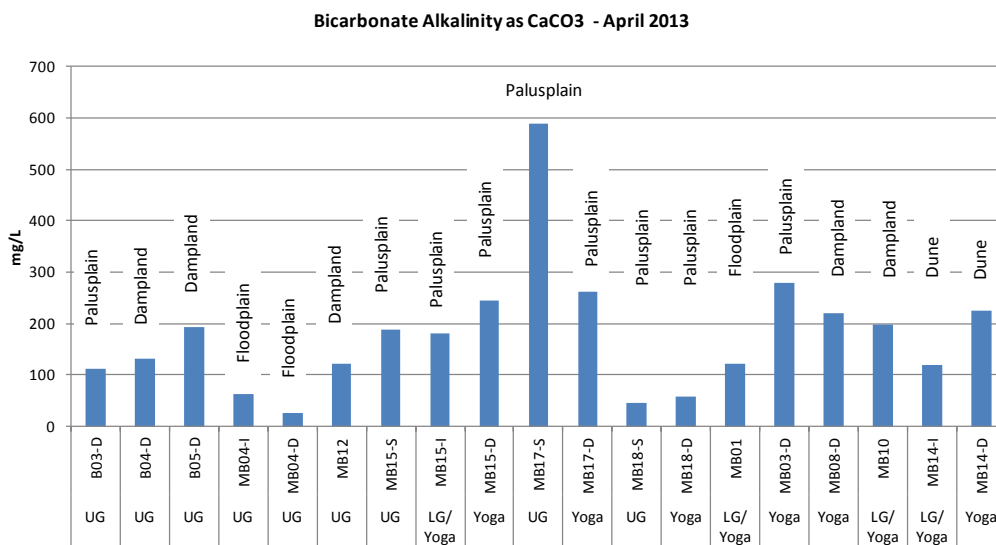
Between December and April, bores B03-D and B04-D located at the westernmost part of the study area and targeting the upper Guildford, had concentration of total nitrogen decreasing from 2.9 to 1.1 mg/L and from 4.2 to 1.8 mg/L, respectively. In other bores targeting the upper Guildford, including B05-D, MB04-I, MB12, MB15-S, concentrations of total nitrogen increased between December and April with the highest concentrations observed at MB04-I (4 mg/L) and MB12 (4.2 mg/L).

All bores targeting the lower Guildford and Yoganup formations had total nitrogen concentrations below 0.4 mg/L in April 2013, with the exception of MB15-I (1.1 mg/L).

**Inter-wetland Variation**

Variations in groundwater chemistry do not appear to be related to wetland type, but more influenced by depth and geographical location. As discussed previously, little information could be collected from perched groundwater. Similar to what was observed for soil chemistry, variations due to depth within a single wetland were often greater than those observed for similar depths (or aquifer units) at different wetlands. This greater variation due to depth and location within the study area can be seen for EC values at APPENDIX 7. To support this observation, bicarbonate alkalinity and nitrogen species were further analysed and results are discussed below.

When analysing bicarbonate alkalinity in groundwater at individual wetlands and groups of wetlands (Figure 22), it can be seen that the highest concentrations were observed in bores MB3D and MB17D, both targeting the Yoganup (noting that MB17 appears to be a contaminated bore), in palusplains located at the western and southernmost locations of the study area, respectively. In contrast, the lowest alkalinity was observed in the floodplain of the Mullering Brook, in bores MB04-I and MB04-D, both targeting the upper Guildford.



**Figure 22 Bicarbonate alkalinity variation with wetland type and aquifer.**

Table 12 Groundwater quality results.

Sampling event		Dec-12						Apr - 13 *			
Formation screened		Perching Bass/Guildford		Upper Guildford		Lower Guildford / Yoganup		Upper Guildford		Lower Guildford / Yoganup	
		Average	Range	Average	Range	Average	Range	Average	Range	Average	Range
Analyte	Units										
pH Value	pH Unit	5.93	5.16 - 7.49	6.03	5.45 - 6.64	7.2	6.42 - 7.61	6.74	5.86 - 7.36	7.16	6.17 - 7.89
Sodium Adsorption Ratio	-	47.0	19.1 - 72.5	22.7	5.24 - 45.4	12.4	7.54 - 21.5	21	4.99 - 48	10	3.15 - 15.4
Electrical Conductivity @ 25°C	µS/cm	10313	3350 - 16100	8237	489 - 21100	2730	1660 - 4740	6233	501 - 22200	2223	244 - 5250
Total Dissolved Solids (Calc.)	mg/L	6712.5	2180 - 10500	5351	318 - 13700	1771	1080 - 3080	4052	326 - 14400	1444	159 - 3410
Total Hardness as CaCO3	mg/L	557.5	151 - 836	875	43 - 3430	284	134 - 452	721	33 - 3780	295	29 - 906
Bicarbonate Alkalinity as CaCO3	mg/L	598.5	335 - 820	192	33 - 585	223	64 - 518	165	26 - 590	141	30 - 279
Total Alkalinity as CaCO3	mg/L	598.5	335 - 820	192	33 - 585	223	64 - 518	165	26 - 590	141	30 - 279
Sulfate as SO <sub>4</sub> - Turbidimetric	mg/L	124	122 - 126	400	14 - 900	73	60 - 81	193	1 - 935	58	5 - 104
Chloride	mg/L	1917	810 - 3120	2586	117 - 7660	726	441 - 1360	1880	104 - 7880	571	46 - 1410
Calcium	mg/L	74	21 - 140	46	4 - 133	55	18 - 82	48.2	5 - 147	53.4	4 - 183
Magnesium	mg/L	90.5	24 - 122	185	8 - 753	40	19 - 63	145.9	5 - 828	39.3	4 - 109
Sodium	mg/L	2703	541 - 4820	1566	79 - 3590	453	313 - 945	1252	86 - 4300	364.7	39 - 735
Potassium	mg/L	62.5	24 - 95	41.1	4 - 91	13.800	9 - 22	23.8	5 - 68	10.3	3 - 22
Silicon	mg/L	NA	NA	NA	NA	NA	NA	34.72	12.9 - 78.2	18.0	6.04 - 46.1
Aluminium	mg/L	39.02	0.08 - 71.2	8.129	0.02 - 42	2.355	0.02 - 22.3	2.89	<0.01 - 28.2	0.10	<0.01 - 0.44
Antimony	mg/L	0.048	0.001 - 0.103	0.009	0.002 - 0.031	0.007	0.002 - 0.017	NA	NA	NA	NA
Arsenic	mg/L	0.262	0.018 - 0.438	0.074	0.001 - 0.311	0.105	0.002 - 0.724	0.04	<0.001 - 0.262	0.01	<0.001 - 0.1
Barium	mg/L	0.311	0.072 - 0.858	0.034	0.002 - 0.068	0.068	0.009 - 0.144	0.12	0.006 - 0.402	0.10	0.026 - 0.452
Beryllium	mg/L	0.024	0.021 - 0.028	0.013	0.001 - 0.048	0.019	0.011 - 0.027	0.01	<0.001 - 0.014	0.01	<0.001 - 0.01
Boron	mg/L	0.125	0.06 - 0.23	0.115	0.08 - 0.19	0.079	0.05 - 0.16	NA	NA	NA	NA
Cadmium	mg/L	0.0010	0.0008 - 0.0013	0.0002	0.0001 - 0.0004	0.0002	0.0002 - 0.0002	0.0005	<0.0001 - 0.0008	<0.0001	<0.0001
Cerium	mg/L	0.143	0.038 - 0.329	0.020	0.003 - 0.056	0.004	0.003 - 0.005	NA	NA	NA	NA
Chromium	mg/L	1.02	0.4 - 2	0.314	0.001 - 2.43	0.258	0.002 - 1.19	0.13	<0.001 - 0.617	0.003	<0.001 - 0.007
Cobalt	mg/L	0.006	0.003 - 0.011	0.007	0.001 - 0.021	0.003	0.001 - 0.007	NA	NA	NA	NA
Copper	mg/L	0.31	0.001 - 0.805	0.042	0.002 - 0.253	0.034	0.001 - 0.135	0.02	<0.001 - 0.056	0.00	<0.001 - 0.003
Ferric Iron (Fe III)	mg/L	38.35	0.55 - 83.2	3.320	0.41 - 10.7	1.94	0.35 - 4.93	5.07	<0.05 - 18.2	0.21	<0.05 - 0.49
Ferrous Iron (Fe II)	mg/L	0.3	0.21 - 0.39	0.809	0.08 - 4.29	1.00	0.07 - 2.2	1.25	<0.05 - 4.37	2.42	<0.05 - 7.6
Iron (Dissolved)	mg/L	42.44	0.76 - 83.2	5.310	0.36 - 21.5	2.89	0.25 - 10.9	2.16	<0.05 - 19	2.17	<0.05 - 6.74
Fluoride	mg/L	0.4	0.2 - 0.6	0.309	0.1 - 0.8	0.225	0.1 - 0.4	0.33	<0.1 - 0.8	0.19	<0.1 - 0.3
Gallium	mg/L	0.018	0.009 - 0.03	0.004	0.002 - 0.009	0.004	0.004 - 0.004	NA	NA	NA	NA
Lanthanum	mg/L	0.015	0.003 - 0.035	0.007	0.003 - 0.022	NA	NA	NA	NA	NA	NA
Lead	mg/L	0.013	0.008 - 0.021	0.003	0.002 - 0.006	0.002	0.002 - 0.002	0.002	<0.001 - 0.002	<0.0001	<0.001
Lithium	mg/L	0.022	0.018 - 0.03	0.015	0.003 - 0.045	0.010	0.003 - 0.028	NA	NA	NA	NA
Manganese	mg/L	4.94	0.416 - 9.04	1.103	0.078 - 4.37	0.233	0.102 - 0.865	0.72	0.052 - 3.15	0.29	0.008 - 0.749
Molybdenum	mg/L	0.012	0.006 - 0.018	0.005	0.003 - 0.007	0.006	0.001 - 0.026	NA	NA	NA	NA
Neodymium	mg/L	0.030	0.006 - 0.068	0.005	0.001 - 0.01	0.001	0.001 - 0.001	NA	NA	NA	NA
Nickel	mg/L	0.037	0.008 - 0.077	0.015	0.002 - 0.036	0.008	0.002 - 0.018	0.01	<0.001 - 0.084	0.004	<0.001 - 0.008
Rubidium	mg/L	0.025	0.021 - 0.03	0.027	0.006 - 0.08	0.015	0.01 - 0.019	NA	NA	NA	NA
Selenium	mg/L	0.26	0.02 - 0.72	0.028	0.02 - 0.05	0.013	0.01 - 0.02	0.04	<0.01 - 0.05	<0.01	<0.01
Strontium	mg/L	0.376	0.201 - 0.669	0.449	0.046 - 2.24	0.413	0.097 - 0.749	NA	NA	NA	NA
Thorium	mg/L	0.043	0.01 - 0.107	0.003	0.001 - 0.006	0.002	0.001 - 0.004	0.005	<0.001 - 0.008	<0.001	<0.001 - 0.005
Tin	mg/L	0.012	0.007 - 0.016	0.006	0.001 - 0.014	0.005	0.002 - 0.007	NA	NA	NA	NA
Titanium	mg/L	0.285	0.03 - 0.52	0.114	0.02 - 0.27	0.057	0.01 - 0.14	NA	NA	NA	NA
Uranium	mg/L	0.081	0.001 - 0.159	0.050	0.006 - 0.123	0.014	0.002 - 0.061	NA	NA	NA	NA
Vanadium	mg/L	0.665	0.01 - 1.19	0.278	0.06 - 0.77	0.130	0.02 - 0.41	NA	NA	NA	NA
Yttrium	mg/L	0.041	0.012 - 0.085	0.004	0.001 - 0.007	0.003	0.001 - 0.005	NA	NA	NA	NA
Zinc	mg/L	0.134	0.008 - 0.301	0.030	0.007 - 0.11	0.037	0.007 - 0.056	0.02	<0.005 - 0.046	0.01	<0.005 - 0.013
Zirconium	mg/L	0.259	0.225 - 0.317	0.034	0.006 - 0.107	0.032	0.006 - 0.058	NA	NA	NA	NA
Ammonia as N	mg/L	0.0825	0.01 - 0.12	0.174	0.05 - 0.39	0.160	0.01 - 0.25	0.23	<0.01 - 0.97	0.18	0.02 - 0.54
Nitrite as N	mg/L	0.06	0.04 - 0.08	0.120	0.01 - 0.42	<0.01	<0.01 - 0.09	0.04	<0.01 - 0.06	<0.01	<0.01
Nitrate as N	mg/L	1.09	0.01 - 2.11	0.098	0.01 - 0.47	<0.01	<0.01 - 0.09	0.18	<0.01 - 0.55	0.05	<0.01 - 0.05
Nitrite + Nitrate as N	mg/L	1.13	0.01 - 2.15	0.151	0.01 - 0.89	<0.01	<0.01 - 0.09	0.20	<0.01 - 0.61	0.05	<0.01 - 0.05
Total Kjeldahl Nitrogen as N	mg/L	9.5	5.2 - 13.6	2.856	0.8 - 9.5	0.15	0.1 - 0.2	2.23	0.1 - 6.7	0.42	<0.1 - 1.1
Total Nitrogen as N	mg/L	10.6	7.4 - 14.8	2.967	0.8 - 10.4	0.15	0.1 - 0.2	2.27	0.1 - 6.7	0.42	<0.1 - 1.1
Total Phosphorus as P	mg/L	3543	2410 - 4710	304.8	1.24 - 1220	0.590	0.03 - 1.15	139.97	0.02 - 1350	7.36	0.02 - 42.4
Reactive Phosphorus as P	mg/L	269.3	10.1 - 521	64.51	0.67 - 238	11.03	0.01 - 30.9	60.12	<0.01 - 390	7.91	<0.01 - 39
Total Anions	meq/L	54.5	18.1 - 100	82.80	4.25 - 236	26.6	16.1 - 43.6	65.01	4.46 - 242	20.37	2.0 - 45.6
Total Cations	meq/L	130.5	28.8 - 227	86.59	4.4 - 227	26.0	16.7 - 49	69.50	4.99 - 264	22.02	2.35 - 50.6
Ionic Balance	%	32.0	5.49 - 54	6.52	1.06 - 34.2	3.1	0.49 - 5.79	4.41	0.4 - 7.23	4.18	1.34 - 7.07

NA - not analysed

\* All bores targeting perched watertables in the Bassendean sands were dry in April 2013

Variability in nitrogen species (as previously discussed, NO<sub>x</sub> was below the limit of reporting for the majority of samples) was most pronounced between aquifer units, with the highest concentrations occurring in bores targeting the upper Guildford Formation. In April 2013, concentrations of total nitrogen and total kjeldahl nitrogen (ammonia + organic nitrogen)  $\geq 1$  mg/L were observed in all bores targeting the upper Guildford, irrespective of wetland type (Figure 23). The only exception was seen at bore MB18-S located in a palusplain at the easternmost location of the study area. In general the high nitrogen values observed at locations B04-D (dampland), B05-D (dampland), MB04-I (floodplain) and MB15-S (palusplain) correlate well with elevated salinity observed at these locations, demonstrating a greater influence of geographic location rather than wetland type in groundwater quality at the superficial aquifer.

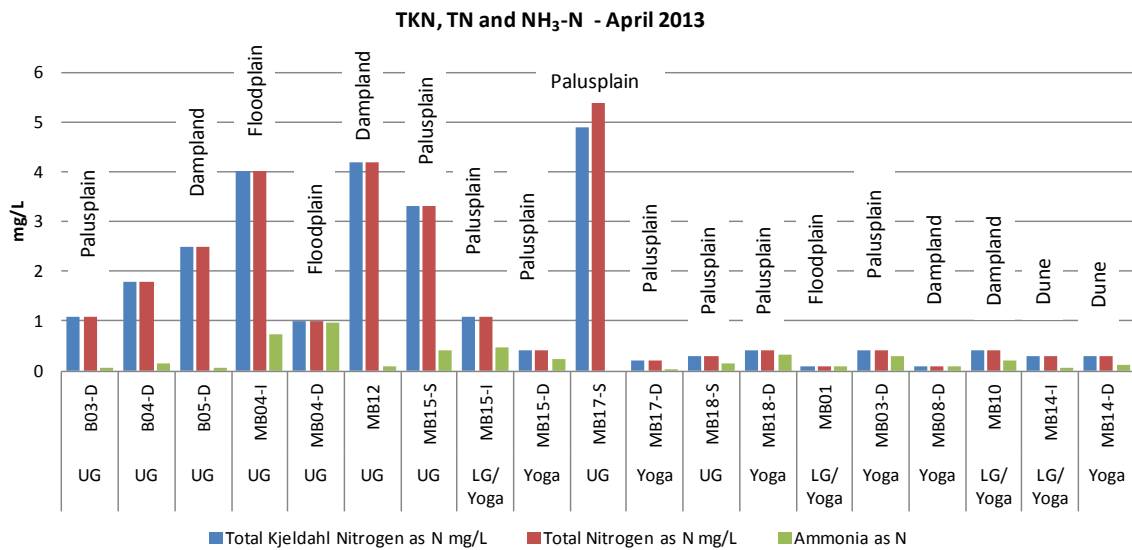


Figure 23 Nitrogen variation with wetland type and aquifer.

### 9.3 SURFACE WATER QUALITY - MULLERING BROOK

Water quality monitoring data for the Mullering Brook for 2008 and 2012 is summarised in Table 13. Results indicate higher electrical conductivity (EC) and total dissolved solids (TDS) concentrations entering the mine site at Brand than those exiting the site at Duffys. The high EC and TDS concentrations at Brand are attributed to the fact that the Mullering Brook catchment east of the Brand station is dominated by shallow groundwater seepage, susceptible to salinisation as a result of vegetation clearing in the upper catchment (Tiwest, 2010).

All heavy metal concentrations entering and exiting the mine site were in general below detection limits, with the exception of iron, aluminium, manganese, titanium and zinc, which present low concentrations (Tiwest, 2012).

Apart from nitrate, measured in 2008, no recent nutrient monitoring is available for Mullering Brook; the 2008 data show nitrate concentrations decreasing from Brand to Duffy.

**Table 13 Mullering Brook water quality.**

Analyte	Unit	July-Aug 2008						Feb - Nov 2012			
		Brand (N=13)			Duffys (N=5)			Brand (N=1)	Duffys (N=6)		
		Avg	Min	Max	Avg	Min	Max	One sample	Avg	Min	Max
EC	uS/cm	5515	2600	9300	2522	150	5200	4100	792	72	3400
pH		6.5	2.7	7.1	6.51	6.1	7.3	7.1	7.2	6.8	7.6
TDS	mg/L	3408	1500	6000	1601	97	3300	2300	1462	72	3800
CO3	mg/L	<1	-	-	<1	-	-	<5	<5	-	-
HCO3	mg/L	61.0	35	100	39.8	6	76	63	31.2	12	68
Cl	mg/L	1592	630	3000	737.8	33	1600	1300	237	13	1100
SO4	mg/L	122.9	45	220	56	6	110	77	16.7	4	63
Na	mg/L	821.5	270	1500	392.2	19	830	650	118.8	11	520
K	mg/L	23.6	7.7	44	12.02	1.1	25	50	10.7	0.5	46
Ca	mg/L	27.4	13	53	21.04	1	47	27	6.2	0.3	24
Mg	mg/L	120.5	40	240	61.16	1.2	130	91	17.9	0.3	73
Fe	mg/L	2.1	0.82	5	1.55	0.3	3.3	3.2	0.61	0.05	1.5
Fe total	mg/L	2.8	1.5	5.4	3.26	0.8	5	6.6	49.8	4.4	88
Al	mg/L	0.120	-	-	0.018	-	-	0.2	0.95	0.09	2.9
Cd	mg/L	<0.001	-	-	<0.001	-	-	<0.01	<0.002	-	-
Cr	mg/L	<0.001	-	-	0.002	-	-	<0.01	<0.005	-	-
Cu	mg/L	<0.005	-	-	<0.005	-	-	<0.01	<0.005	-	-
Mn	mg/L	<0.001	-	-	<0.001	-	-	0.19	0.11	0.06	0.16
Ni	mg/L	<0.005	-	-	<0.005	-	-	<0.02	<0.02	-	-
Ti	mg/L	<0.01	-	-	0.01	-	-	0.02	0.061	0.024	0.1
Zn	mg/L	0.009	-	-	0.018	-	-	<0.02	<0.02	-	-
Pb	mg/L	<0.001	-	-	<0.001	-	-		<0.02	-	-
NO3	mg/L	-	-	-	-	-	-	2.5	1.25	0.5	2.5
Si	mg/L	-	-	-	-	-	-	8.4	3.65	1.9	6.6

## 10.0 KEY FINDINGS FROM STRATIGRAPHY/HYDROLOGY STUDY

The various mechanisms underpinning wetlands and GDE's within the Cooljarloo site and study area specifically are summarised below.

### Mechanisms Maintaining Wetlands & GDE's

Dominant lithological conditions across the site are broadly consistent.

The general stratigraphic picture shows a relatively uniform layering of Bassendean Sands overlying Guildford Clays over deep Yoganup Sands, which holds the regional groundwater table. The Bassendean Sands vary from thin (<0.2 m) to up to 10 m in dunal ridges. The Guildford clays are of varying thickness, in the main greater than 5 m and forming an effective aquiclude, which supports a seasonal perched aquifer and is likely to prevent major root intrusion.

The main differences in lithology across different wetland types were:

- depth of overlying Bassendean Sands
- percentages of sand and clay within the Guildford

These two key features were strong determinants of vegetation height, with dwarf forms of trees and shrubs occurring where the Bassendean sands were thinnest (1 m or less), *and* the underlying Guildford Formation was dominated by a high clay percentage, which created a distinct impeding layer. This is shown for individual transects in APPENDIX 1.

Soil moisture and winter perching of water at the Bassendean/Guildford interface, rather than the regional aquifer, appears to be the dominant factor influencing wetland and dunal vegetation in this location. Hence, maintenance of wetlands and GDE communities is reliant on rainfall recharge, both directly and via watercourse and subsurface flows from upgradient areas. Shallow perched water tables (~2.0 mbgl) associated with heavy clays bands were observed in two localities during drilling, one in proximity to the Mullering Brook to the north and the other close to the DEC reserve and Dog Hole wetland to the south, though that is not inconsistent with literature pertaining to the regional stratigraphy in the Northern Perth Basin (Kern 1989) and associated with localised superficial alluvial, colluvial deposition.

The extent of saturation within wetlands appears to be controlled topographically as discussed in Section 4.5, as well as directly related to sand and clay content within the upper Guildford and more importantly within the soil fractions accessible to plant roots. While the sands saturate quickly during rainfall, they only provide short term water storages. The higher clay and silt content layers, on the other hand, enable long term storage of moisture, which may be critical in supporting vegetation over the dry period.

Wetland areas supporting tall vegetation, e.g. A04 (palusplain/dampland over ore body) and A09 (floodplain/palusplain) appear to be related to the presence of thicker Bassendean Sands (1.5 to > 2.5 m) occurring in localised depressions. These thicker sandy horizons which are subject to water logging and flooding may represent a more suitable environment for the growth of deep rooted wetland trees such as the tall *M. raphiophylla* and *E. rudis* observed at these locations.

It appears that the influence of surface waters entering the study area via the Mullering and Minyulo Brooks is limited, albeit crucial, in maintaining water availability in their own creek courses and associated floodplains and, in the case of the Minyulo Brook, its adjacent palusplains and balkarras. These two systems appear to be largely disconnected from the wetlands located between them, as far as surface water flows are concerned.

From the stratigraphy and groundwater level results it appears that the main factor influencing water availability in the geomorphic wetlands in the study area, apart from the Minyulo and Mullering Brooks themselves, are:

- the presence of the Guildford Formation, which forms a largely impermeable layer beneath the shallow Bassendean Sands; and
- meteoric recharge, which refills these interdunal flats and depressions on a yearly basis. This recharge is responsible for generating the perched water tables formed in the Bassendean /Guildford interface and possibly those formed in the shallower sandy facies of the Guildford.

### Groundwater Salinity

The elevated salinity and especially elevated concentrations of Na<sup>+</sup> and Cl<sup>-</sup> ions and nutrients (especially phosphorus) in the groundwater in the perched Bassendean and upper Guildford do not directly correlate with elevated concentrations of ions and nutrients in the soil. Discounting those bores affected by remnant contamination from the dosing agents used in well development, the high salinity in bores targeting the upper Guildford appears to be realistic at MB04, B04 and B05 and MB15. No reliable water quality result could be obtained for the perched systems at this stage as most bores were dry or had little water present. Groundwater in the lower and Guildford / Yoganup was less saline and contained less nutrients than the above units.

The high salt content in groundwater has significant implications in understanding wetland and GDE hydrological mechanisms, since in almost all cases, salinity levels exceed the tolerance threshold of most species on site and *Banksia* and other Proteaceae in particular, at least in the months recorded. Tolerant species would include *Melaleuca raphiophylla*, *M. preissiana*, *M. viminea* and *Eucalyptus rudis*.

### Soil and Groundwater / Surface Water Chemistry

No clear relationship can be inferred between soil chemistry and groundwater chemistry as a result of this investigation. This is in part due to the fact that soil samples were collected from shallower depths than those where bores are screened and, in the case of similar depths, groundwater was not present at these bores during the monitoring period. Notwithstanding the above, given the similarity in groundwater chemistry results across all wetlands (i.e. variability in groundwater parameters mostly related to depth and geographical location rather than to specific wetland type) as well as the similarity in soil chemistry results (chiefly associated with depth/formation and particle size, rather than specific wetland types) it appears unlikely that groundwater chemistry or soil chemistry are key factors in determining wetland vegetation distribution in the study area. Vegetation distribution appears to be chiefly associated with physical factors such as soil particle size (sand and clay content at varying depths) and moisture, which is in turn also dictated by particle size and meteoric recharge.

Saline groundwater observed within the Mullering Brook floodplain may be related to salinity observed in the surface water. Additionally, the farmland to the north of the sampling location within the floodplain has been largely cleared, which may potentially impact on groundwater salinity.

Interestingly, the shallowest bore in this floodplain showed the lowest levels of salt in December 2012. No sample from this bore was available for April 2013.

Apart from these observations at the Mullering Brook, no clear relationships between surface water and groundwater could be observed in the study area, including areas to the south, closer to the Minyulo brook.

## PART 4: CONCEPTUAL SITE MODEL

### 11.0 COOLJARLOO WEST CONCEPTUAL SITE MODEL

This section of the report briefly discusses the key results of the current and historic investigations and presents the Conceptual Site Model (CSM) for the Proposal area.

The aim of the CSM is to illustrate the relationships between the topography, stratigraphy, groundwater, surface water and vegetation to identify the hydrological connectivity between the wetland systems and the superficial aquifer in the Proposal area and beyond. The CSM allows for identification of data gaps and its purpose is to aid in the environmental impacts risk assessment.

The Cooljarloo West Conceptual Site Model has been developed based on regional and site specific literature as well as the results of the recent investigations conducted by Syrinx and by other consultants (Woodman, SWC, WorleyParsons and Parsons Brinckerhoff) at Cooljarloo West. The model provides a high level understanding of the site and existing relationships among stratigraphy, hydrogeology and wetland (and groundwater dependent) vegetation. The model is intended to be used as instrument for understanding risks to wetlands and GDEs on site and therefore contribute to the impact assessment process.

In reference to this study (notably impacts of mining on vegetation, GDEs and wetlands) the major stratigraphic units of relevance within the study site are the Bassendean Sands and the Guildford Formation. Although described in greater depth in Section 7.0 this is primarily due to the largely impermeable nature of the Guildford Formation, and the aquiclude formed by the sharp contact between the upper Guildford Formation and the basal Bassendean Sands. Conceptually, this aquiclude (which is dominantly non leaky) approximately 10 - 30 m thick between the Bassendean Sands and the Yoganup Formation, results in no or limited vertical hydrogeological connection between different stratigraphic units in contact with the Guildford Formation. This aquiclude is, however, irregularly punctuated with discontinuous sand lenses (sandier portions of the Guildford) that also impact upon the site hydrogeology as it relates to vegetation and biological processes (see Section 11.1).

At all localities investigated in this study the Guildford Formation lies conformably and directly, although at different depths below ground level, below the Bassendean Sands. In all cases the transition from the Bassendean Sands to the Guildford is represented by a stark difference in grain size, and a sharp boundary. In the context of this investigation, it is highly likely that the different lithological characteristics observed between the two units will result in significantly different prevalent hydrogeological conditions (see Section 11.1) between the two stratigraphic units.

- The shallow (i.e. <5 mbgl) investigations undertaken by Syrinx did not result in identification of any sand lens, or very low clay content units within the Guildford, however the formation is

known (Davidson 1995) to contain variably sized lenses of sand dominated materials. At the site these lenses were only identified through the deeper drilling programmes, nominally the WorleyParsons hydrogeological drilling programme (WorleyParsons 2013) and the Tronox Site exploration drilling programme, the results of which form the subsurface site model regulated by Soil Water Consultants. From these sources, the sand lenses appear to be variable in size (though occur within the range of 2 - 6 m vertical thickness) yet do not appear to display any significant degree of lateral continuity. These sand lenses likely hold water, and may be important in the context of plant available moisture at the site, as described in Section 11.1 below.

## 11.1 HYDROGEOLOGY

Hydrostratigraphically, there are two dominant aquifers at the Cooljarloo West site, the upper Superficial (regional water table) and the deeper Yaragadee Aquifer. Apart from these two dominant aquifers, seasonal superficial perched aquifers occur throughout the site. All water intersected in the wetland, and GDE investigation occurs within the seasonal perched aquifers and the Superficial Aquifer, which are consequently, the only two aquifers of importance in the context of this investigation.

The specific hydrogeological characteristics of the site which relate to GDEs, wetlands and vegetation appear to be strongly controlled by the site stratigraphy. Consequently, the soils within the Bassendean Sands and the Guildford Formation display significantly different hydrogeological characteristics.

As per alignment to the stratigraphic sequences observed at the site, the broadly homogeneous (and relatively shallow) soils of the Bassendean Sands are hydrogeologically characterised by a single dominant lithology, notably the sands, with a minor hydrogeological variant being sands which display secondary diagenetic influences. Diagenetic influences are typically characterised by zones of ferruginisation. Ferruginisation ranges from massive ferruginisation with resultant nodularisation and lateritisation to staining, though is often observed as a partially friable coffee rock progenitor. Changes to primary porosity and permeability due to ferruginisation are considered likely to have an effect on water storage properties of soils, as the loss of porosity results in the longer storage of water within the soil structure. Other types of secondary soil impact include the enrichment of soils with organic matter (potentially as localised peaty horizons), which may also impact upon water storage characteristics of soils that influence plant available moisture.

Within the Guildford Formation, there are two dominant hydrogeological zones, where the fines dominated silt and clay unit form a zone with significantly different aquifer properties than the sporadically occurring sand lenses. Key (observed and inferred) properties for the above hydrogeological zones are listed in Table 14. The two dominant controls on availability of water (which have implications to vegetation distribution and GDE health) appear to be:

- the thickness of overlying sands (or depth to clay layer); and

- seasonal characteristics of groundwater including recharge and storage expressed either in terms of a "proper" piezometric surface or as the capillary fringe (water stored around fine particles between the phreatic and the vadose zones).

**Table 14 Hydrogeological Properties of Key Units Across the Site.**

Unit Name	Inferred relative aquifer properties	Dominant Recharge Mechanism	Key wetting & drying characteristics	Implications for plant soil available moisture
Bassendean Sands	High permeability.  High porosity.  High hydraulic conductivity.	Meteoric surface recharge.  Minor downward drainage.  Dominant drainage will be laterally (down hydraulic gradient) along Bassendean Sands / Guildford Formation contact.	Unconfined aquifer subject to seasonal wetting and drying.  Rapid draining.	Moisture will be available to plants for short periods post rain events.
Bassendean Sands with Diagenetic Influences	Lower permeability than primary sands (still quite high).  Lower porosity than primary sands (still quite high).  High - moderate hydraulic conductivity (likely less than primary sands).	Meteoric surface recharge.  Minor downward drainage.  Dominant drainage will be laterally (down hydraulic gradient) along Bassendean Sands / Guildford Formation contact.	Unconfined aquifer subject to seasonal wetting and drying.  Likely slower draining due to diagenetic /secondary impacts on permeability and porosity of primary sands  Potentially non linear storativity related mechanisms due to secondary impacts on permeability / porosity of primary sands.	Moisture may be available to plants for longer periods post rain events given diagenetic influences.
Guildford Formation Silt and Clay Dominated Unit	Very low permeability.  High porosity.  Very low hydraulic conductivity.	Semi confining aquiclude/aquitard.  Potentially minor downward migration of water from Bassendean Sands.  Potentially minor upward migration of water from Yoganup Formation	Although this unit of the Guildford Formation contains a moderate degree of storativity (suggesting interstitial and porewaters are present within the unit) it is likely fluid flow processes will not be active due to the highly impermeable nature of soils.	Moisture will be available to plants for longer periods post rain events and may represent a significant source of plant available water, though water more tightly held in pore space; usage likely facultative
Yoganup Formation	Main host of superficial aquifer.  High permeability.  High porosity.  High hydraulic conductivity	Unconfined Aquifer.  Downward recharge from upgradient areas where Guildford is thinner.  Potential upward leakage from the Yarragadee.	Saturated zone.	Water available to plants in phreatic zone and capillary fringe (but whether plants access this aquifer is questionable – possibly limited to areas where overlying Guilford is thin).

## 11.2 SURFACE HYDROLOGICAL CONTROLS

Two creeks lie adjacent to the Proposal area, the Mullering Brook to the north and Minyulo Brook to the south. Surface drainage is seasonal, with highly variable flows, generally peaking in July – August (Streamtec 2003). Water quantity and quality investigations at these systems have been limited to a desktop level, but relied on long record of field sampling and analysis undertaken by Tronox. It is considered that the Mullering Brook will be directly impacted by the Proposal as the dredge and concentrator transfer channel will transect its current course along the eastern boundary of the existing mine. These impacts will occur in proximity to existing impacted areas of the brook. The Minyulo Brook and associated Dog Hole wetland are located approximately 2.5 km south of the proposed Harrier mine pit and therefore these systems are not considered likely to be impacted by the Proposal as far as surface hydrology is concerned.

The topographic impact of local dunal and interdunal (i.e. wetland) systems represents a control on surface runoff. Vector analysis shows the potential for surface runoff, most significantly large rainfall events, to flow from the higher topography dunes towards the low lying interdunal depressions. These flows appear to be short and intercepted by a series of open and small depressions (wetlands) on site. Two of the sites, one within the direct impact zone and another south of the mine, are identified as possibly receiving a larger amount of runoff. This is congruent with the vegetation communities found at these locations with sedgeland and riparian tree species of *Melaleuca raphiophylla* and *Eucalyptus rudis* present.

However, given the rapid recharge characteristics of the Bassendean Sands within the higher topographic regions of the site, it is unlikely that average seasonal rainfall events will lead to surface flows in the Bassendean Sands aside from the seasonal short-term flows occurring in natural creek lines as those observed in the Mullering Brook.

Consequently, surface saturation/inundation in the low lying wetland areas is likely due mainly to both direct meteoric inputs and lateral migration of perched groundwater along the Bassendean Sands / Guildford Formation interface. This lateral migration leads to the near-surface hydrological connection between wetlands as described by Tinley (1992) and V&C Semeniuk Research Group (1994). These authors considered that many of the wetlands in this area were interconnected, with flow being from wetland to wetland and then into shallow ephemeral drainage lines in a westward direction, which was confirmed via watershed analysis of the site.

## 11.3 VEGETATION

The vegetation types observed on site are varied and correspond closely to the broad landforms they are situated, i.e. wetland, dryland dunes and transitional environments at the base of slopes and on low rises. However the differences in the underlying stratigraphy and water availability (influenced by landform and climate) have an even stronger influence on vegetation diversity.

In general, there were no clear relationships between vegetation communities and palusplain, dampland or sumpland wetland types, but floodplains and dunes were dominated by distinctive vegetation communities. However, small scale representations of most wet heath communities and most wetland species were found within all wetland types corroborating the stronger influence of stratigraphy and the extensive perched aquifer system on wetland and GDE distribution.

In terms of terrestrial GDE communities, all of which occur on dune crests or slopes or low sandy rises, there were distinctions, however certain species (*Banksia telmatiaea*), occurred both on lower dune slopes and throughout the various wetland types. Almost all of the dominant tree species (e.g. *Banksia menziesii*, *B. attenuata*, *B. illicifolia*, *B. prionotes*, *Eucalyptus todtiana*, *Corymbia calophylla*) are known to be groundwater dependent species, at least in certain sites (see Table 2).

#### 11.4 ECOSYSTEMS

Integration of the above site characteristics has resulted in the derivation of a simplified model combining vegetation assemblage, topography, stratigraphy and hydrogeology as these factors pertain to moisture availability, plant function and resulting community health. This model is seen in Figure 24.

Within the model there are three simplified terrestrial and wetland ecosystems, within which there are a number of subsets, which are detailed in Table 15. The vegetation communities are primarily determined by the underlying thickness of Bassendean Sands, and the subsets are based on topography and litho-stratigraphy. These variables, though in particular lithology, are considered to most impact upon hydrogeological properties of the three ecosystems, and therefore of most significance from the perspective of plant available moisture.

The conceptual model is derived from the detailed information collected along transects for selected wetlands, discussed in detail in Parts 2 and 3. Integration of all pertinent elevation, soil, hydrology and vegetation information for each transect is provided in APPENDIX 1. This information provides a more detailed synthesis of this study, and the data behind the conceptual model.

Table 15 Relationship between main ecosystem units and vegetation communities, plant height and thickness of sand.

Ecosystem	Terrestrial / Wetland Classification	Ecosystem Type	Broad Vegetation Association	Landform	Woodman vegetation codes (2013)	Approximate tree height (m)	Approximate shrub height (m)	Base of Bassendean sand (m)
Terrestrial Ecosystem	Dunes	Dry Woodlands	<i>Banksia</i> Low Woodlands	Dune crests, rises and slopes	17, 18	2.5 - 7	0.2- 1	>2
		Dry Heaths	<i>Allocasuarina humilis</i> and <i>Calothamnus quadrifidus</i> Open Heath	Lower slope of dunes	7	up to 5m (only <i>Nuytsia floribunda</i> )	1.5	1 - 2
			<i>Banksia armata</i> Open Low Heath	Small lateritic rises and plains		no trees	0.2 - 0.5	Not determined
Wetland ecosystem	Palusplains and Damplands	Wetland Woodlands	<i>Melaleuca preissiana</i> Open Woodland	Closed depression / Basin	6	10 - 15	1 - 1.5	>2
		Wetland Heaths	<i>Banksia telmatiaea</i> Heath	Open depressions and flats	1	no trees recorded but sometimes on small rises Mallees and <i>Banksia</i> occur	0.3 - 1.2	0.7-1.5
			<i>Regelia ciliata</i> - <i>Melaleuca</i> Open Heath	Closed and open depressions (basins) and flats	5	up to 2m ( <i>Melaleuca raphiophylla</i> , dwarf or shrub form)	0.2 - 1.4	0.4-1
	Floodplains and Watercourses	Wetland Woodlands	<i>Eucalyptus rudis</i> and <i>Melaleuca raphiophylla</i> Open Forest	Flat, Open or closed depression	9b, 6	7 - 15	none	>2
		Wetland Scrub	<i>Melaleuca viminea</i> subsp. <i>viminea</i> , <i>M. lateritia</i> and <i>M. teretifolia</i> Tall Open Scrub	Flat, Open depression, Creek	9a	no trees	1 - 2	0.4 - 1

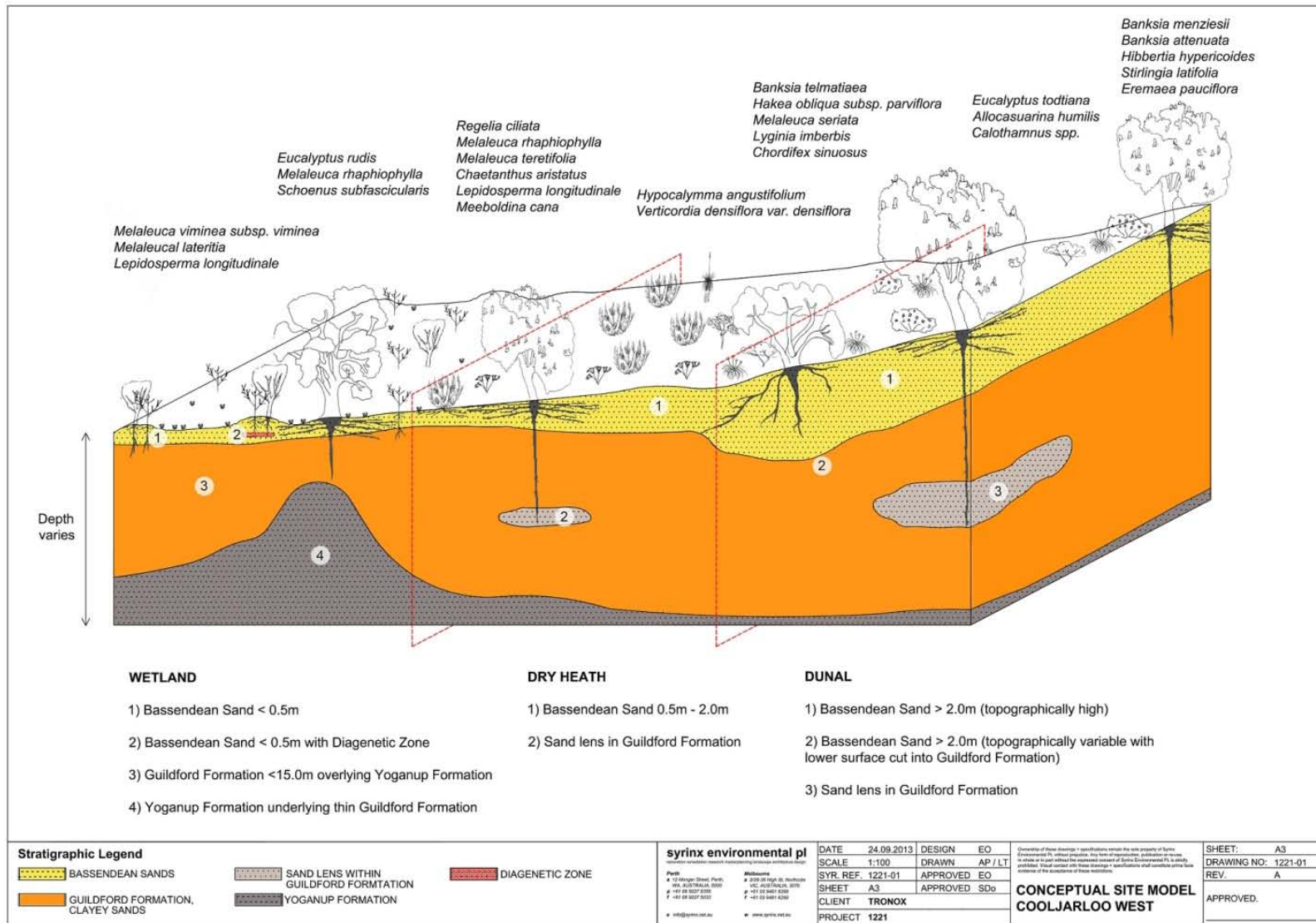


Figure 24 Conceptual Site Model.

#### 11.4.1 Dunal System

The Dunal Ecosystem is characterised by those areas where the surface Bassendean Sands are characterised by relatively thick (at least 2 m thickness) deposits.

Across the site there are three subsets within this ecosystem. These variants are:

- Where the thickness of the Bassendean Sands deposit is at least 2 m thick (often in topographically high areas),
- Where the Bassendean Sands exist in at least 2 m thick (in both topographically high and low areas) and the unit cuts / etches into the upper surface of the Guildford Formation, and
- Where a sand lens occurs within the Guildford Formation.

The Dunal system is characterised by *Banksia* Low Woodland and Open Heath communities.

#### 11.4.2 Base of Slopes/Low Rises - Dry Heath

The Dry Heath Ecosystem is characterised by those areas where the surface Bassendean Sands are characterised by deposits between 0.5 m and 2 m thick.

Across the site there are two subsets within this ecosystem. These variants are:

- Where the thickness of the Bassendean Sands deposit is between 0.5 and 2 m thick, and
- Where the thickness of the Bassendean Sands deposit is between 0.5 and 2 m thick and there are underlying sand lenses present within the Guildford Formation.

The Dry Heath Ecosystem is characterised by *Banksia* or *Regelia* Heath.

#### 11.4.3 Wetland System

The Wetland Ecosystem is characterised by those areas where the surface Bassendean Sands are characterised by deposits with thicknesses typically less than 0.5 m.

Across the site there are two subsets within this ecosystem. These variants are:

- Where the thickness of the Bassendean Sands deposit is less than 0.5 m, and,
- Where the thickness of the Bassendean Sands deposit is less than 0.5 m and there is evidence of significant diagenetic activities that have impacted upon primary soil properties.

## 12.0 VALIDATING THE CONCEPTUAL SITE MODEL

The CSM suggests that the general hydrological regimes supporting both wetland and terrestrial ecosystems within the study area are dominated by recharge from rainfall and surface water flows, with the primary mechanisms being via perching of water at the Guildford Clays/Bassendean Sand interface, longer-term storage of plant available moisture in the upper Guildford clays and via intermittent flooding from the two main watercourses (Minyulo and Mullering brooks). In the main, the depth and continuity of the Guildford clays act to prevent root penetration into the deep aquifer and the depth of sands (determined by the contours of the basal Guildford clays as well as the surface contours) dictate water availability and vegetation response, including the height of vegetation. The CSM suggests that that wetlands and groundwater dependent vegetation at Cooljarloo West are reliant on perching groundwater as opposed to the regional superficial aquifer (Yoganup Formation).

However, during these investigations and in work by others as part of this PER (WorleyParsons and SoilWater Consultants), the following exceptions to this may or do apply in certain areas:

1. The potentiometric surface generally sits above the groundwater table at Cooljarloo West, indicating upward pressure of the aquifer. In areas where the Guildford clays are thinner, this may act to maintain saturation of the clays and sands above the clays during summer.
2. Similarly, where the Guildford clays are thin, penetration of roots through the clays and into the Yoganup Sands is conceivable.
3. In some areas (outside of areas of impact) springs associated with connection of the aquifers occur, and in these locations the ecosystems and supporting vegetation are dependent on groundwater proper.

As such, further line of evidence studies were undertaken to:

1. Assess if and where roots may penetrate the clays and to what extent this may be important to their overall hydrologic maintenance.
2. Assess the extent of the thin clays and assess root penetration and root mass within the clays.

The detailed methodology and results of the root studies are contained in APPENDIX 8 Root Study.

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## APPENDICES

### APPENDIX 1 Transect profiles and associated vegetation communities.

TRANSECT 1



Community 1: *Banksia attenuata* Low Open Woodland with Scattered *Eucalyptus tottiana* over Open Heath of *Eremaea pauciflora* var. ? *pauciflora*, *Melaleuca* ? *clavifolia* and *Stirlingia latifolia*



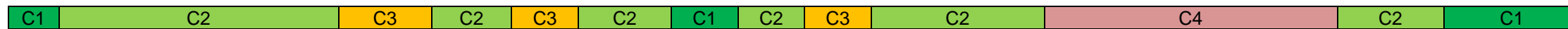
Community 2: Scattered *Banksia menziesii* over *Hakea obliqua* subsp. *parviflora* Tall Open Shrubland with Scattered *Xanthorrhoea preissii* over Open Heath of *Banksia telmatiaea*, *Daviesia incrassata* and *Melaleuca seriata* over Very Open Sedgeland of *Anarthria gracilis*



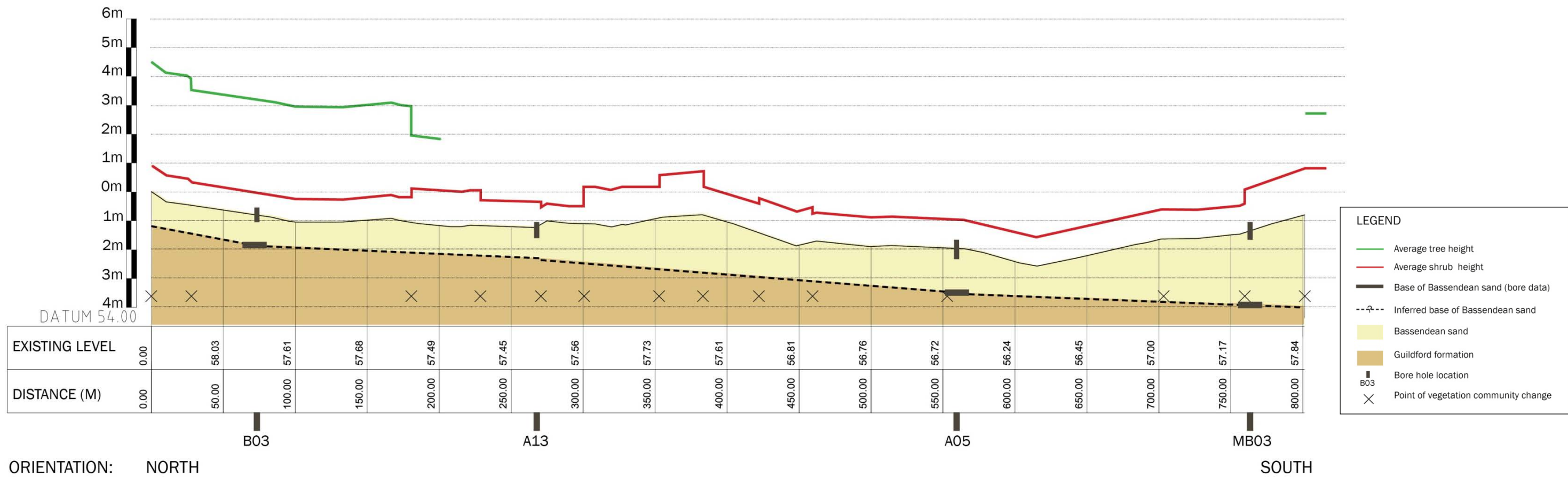
Community 3: Closed Low Heath of *Banksia telmatiaea*, *Hakea costata* and *Melaleuca seriata*



Community 4: Open Low Heath of *Banksia telmatiaea* and *Regelia ciliata* over Very Open Sedgeland of *Anarthria laevis*



TRANSECT 1

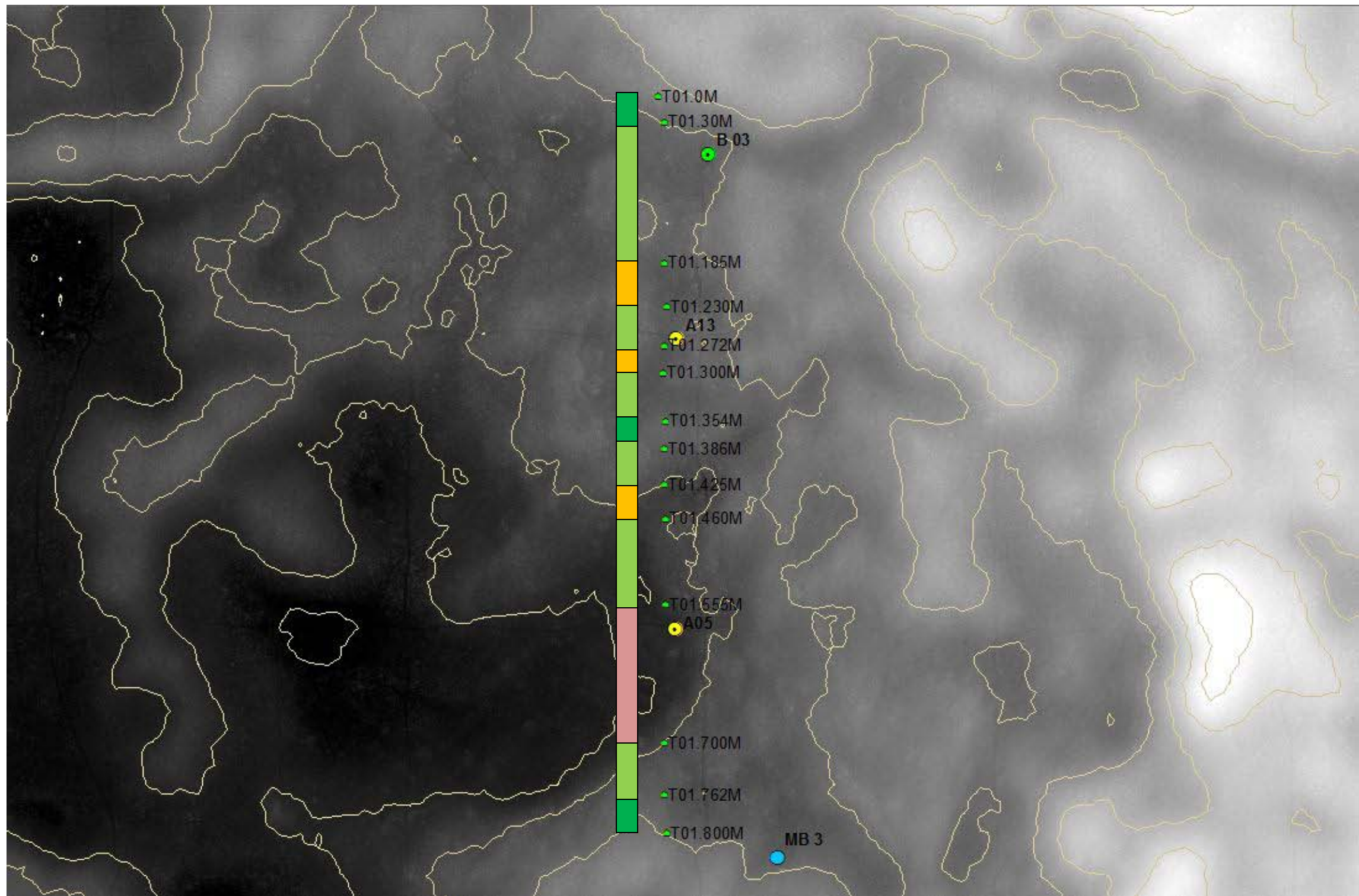


COMMUNITY 1	
Family	Species
Casuarinaceae	<i>Allocasuarina humilis</i>
Proteaceae	<i>Banksia attenuata</i>
Proteaceae	<i>Banksia telmatiaea</i>
Fabaceae	<i>Bossiaea eriocarpa</i>
Ericaceae	<i>Conostephium pendulum</i>
Myrtaceae	<i>Eremaea pauciflora</i> var. ? <i>pauciflora</i>
Myrtaceae	<i>Eucalyptus todtiana</i>
Proteaceae	<i>Hakea obliqua</i> subsp. <i>parviflora</i>
Fabaceae	<i>Jacksonia foliosa</i>
Myrtaceae	<i>Melaleuca</i> ? <i>clavifolia</i>
Proteaceae	<i>Stirlingia latifolia</i>

COMMUNITY 2	
Family	Species
Anarthriaceae	<i>Anarthria gracilis</i>
Proteaceae	<i>Banksia telmatiaea</i>
Proteaceae	<i>Conospermum stoechadis</i>
Fabaceae	<i>Daviesia incrassata</i>
Myrtaceae	<i>Eremaea asterocarpa</i>
Proteaceae	<i>Hakea obliqua</i> subsp. <i>parviflora</i>
Myrtaceae	<i>Melaleuca seriata</i>
Iridaceae	<i>Patersonia occidentalis</i>

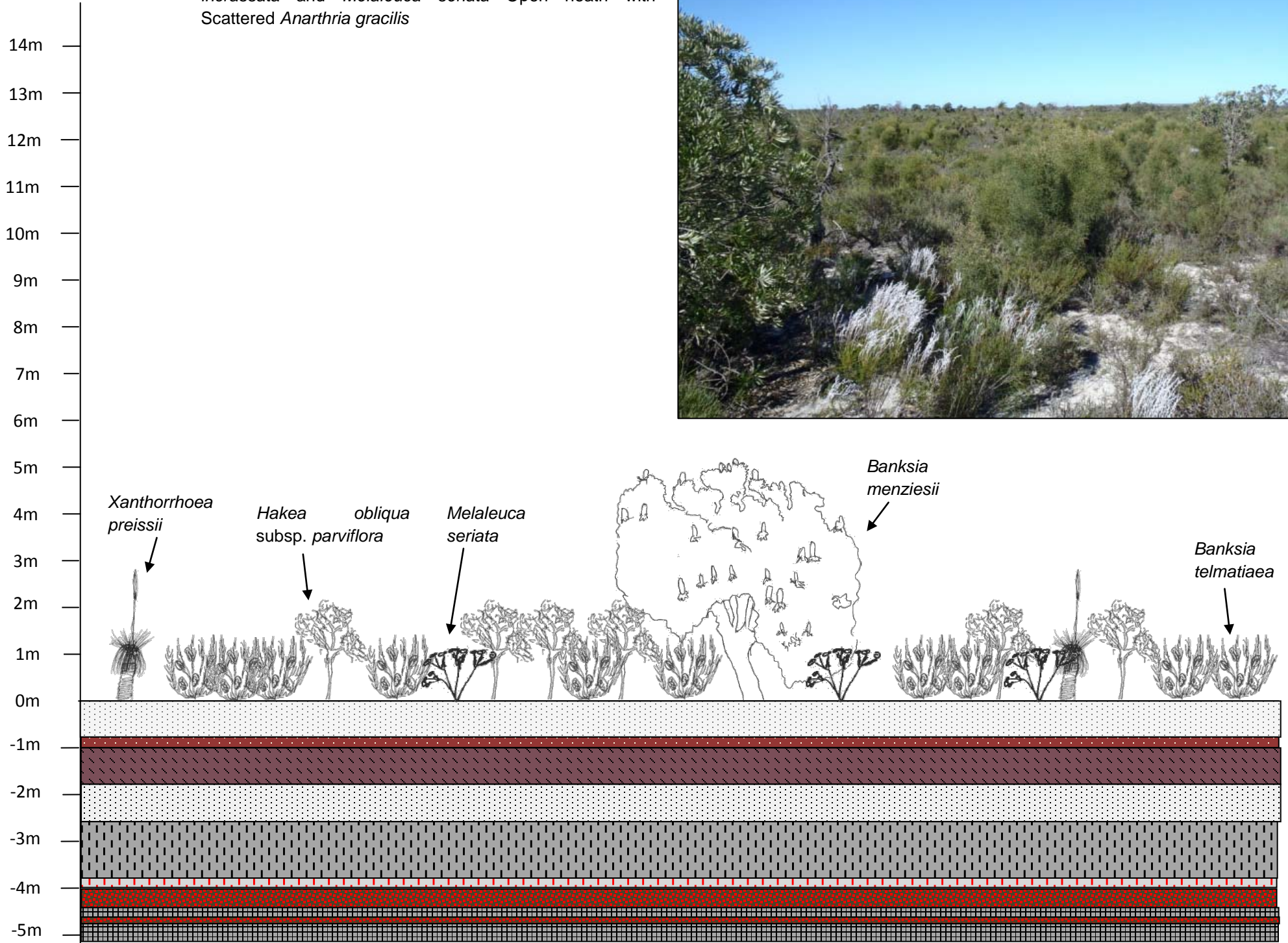
COMMUNITY 3	
Family	Species
Myrtaceae	<i>Astartea</i> ? <i>scoparia</i>
Proteaceae	<i>Banksia telmatiaea</i>
Myrtaceae	<i>Calytrix</i> ? <i>angulata</i>
Proteaceae	<i>Hakea costata</i>
Myrtaceae	<i>Melaleuca seriata</i>
Myrtaceae	<i>Verticordia</i> ? <i>drummondii</i>
Myrtaceae	<i>Verticordia densiflora</i> var. <i>densiflora</i>

COMMUNITY 4	
Family	Species
Anarthriaceae	<i>Anarthria laevis</i>
Proteaceae	<i>Banksia telmatiaea</i>
Myrtaceae	<i>Regelia ciliata</i>



# B03 Transect 1

**T1 30-** Scattered *Banksia menziesii* over *Hakea obliqua* subsp. *parviflora* Tall Open Shrubland with Scattered *Xanthorrhoea preissii* over *Banksia telmatiaea*, *Daviesia incrassata* and *Melaleuca seriata* Open heath with Scattered *Anarthria gracilis*

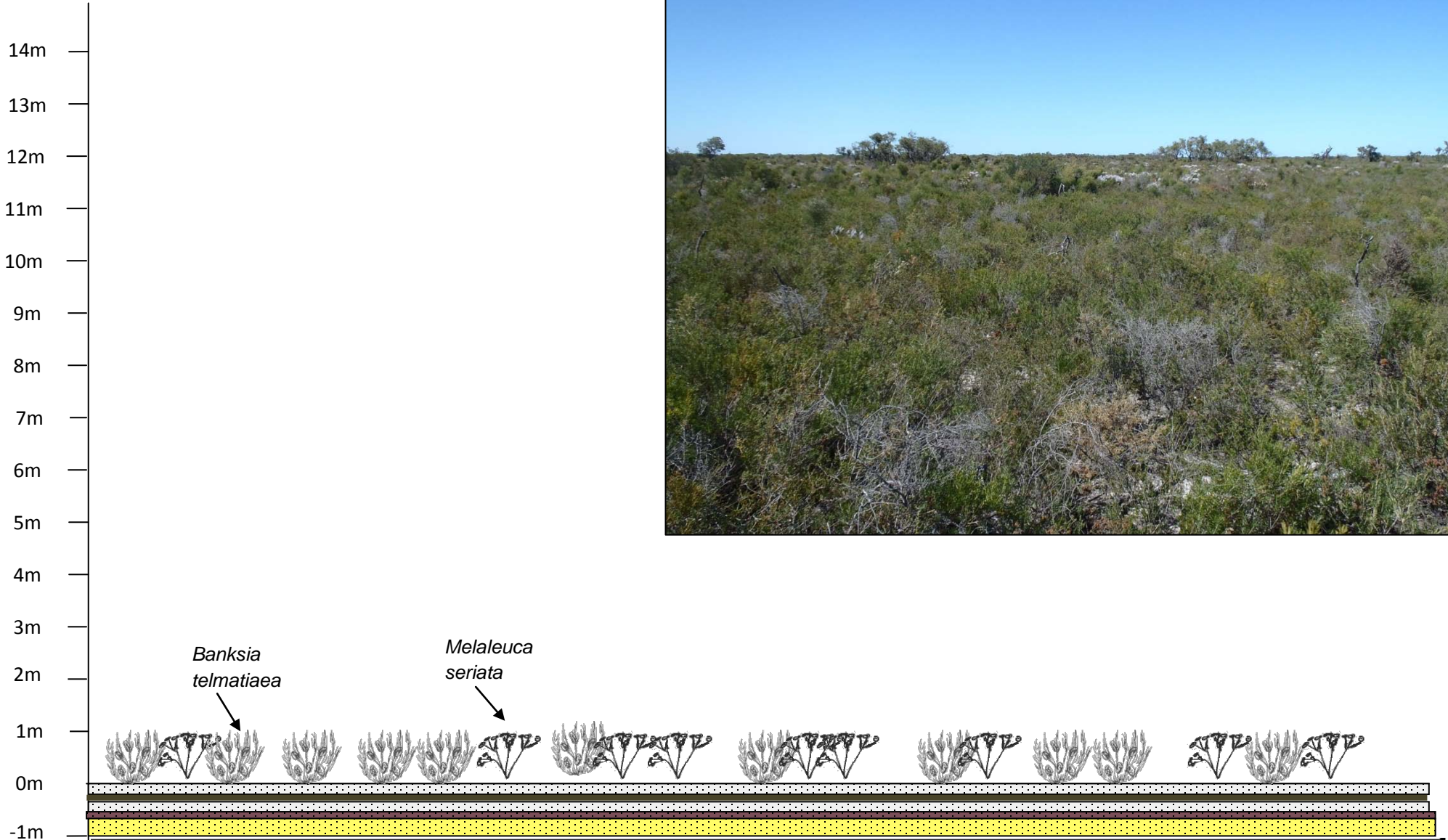
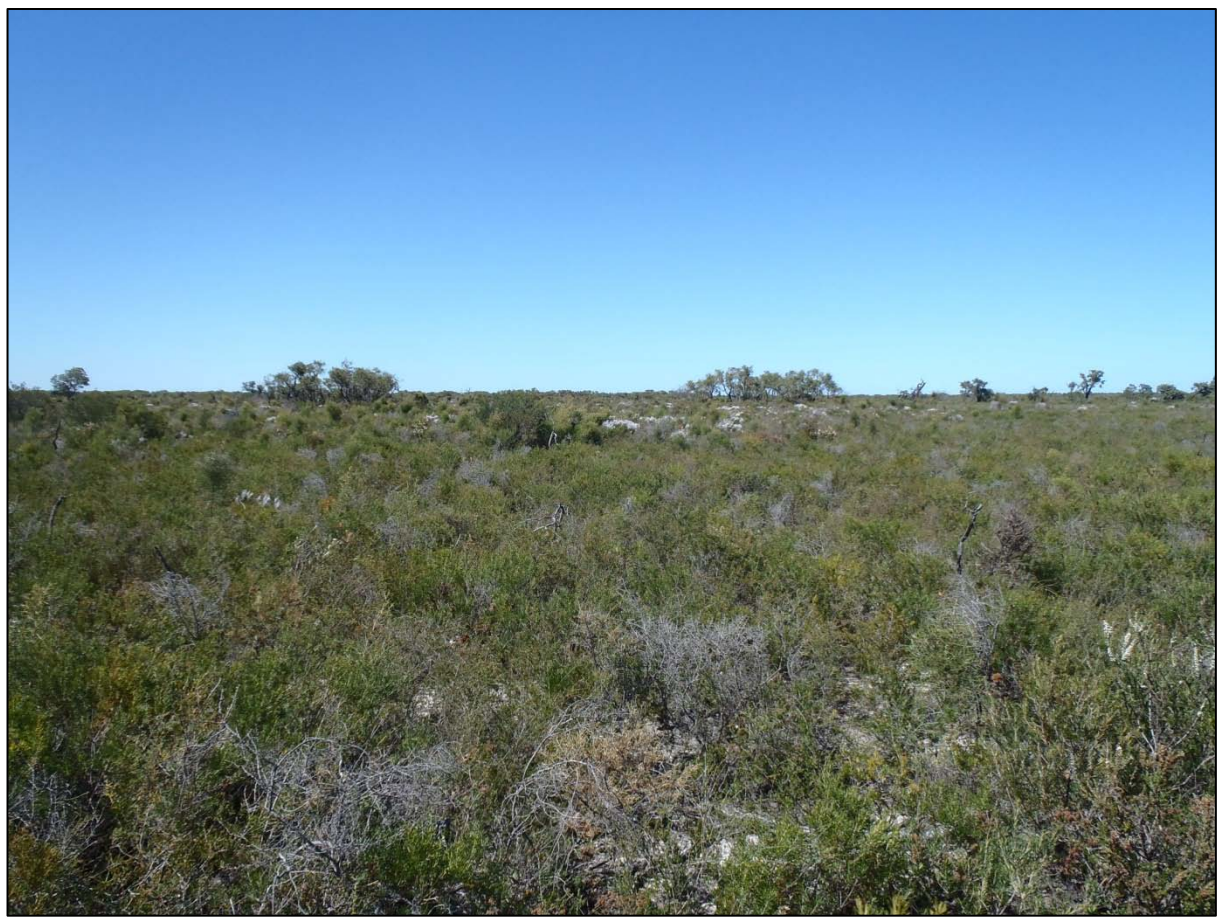


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Depth (m)	Graphic Log	Classification Symbol	Material Description	Samples Tests Remarks	PID (ppm)	Additional Observations
0		SP	SAND, fine, uniform, rounded, pale white-pale grey, dry.			
1		SP	SAND, medium, yellow-mottled dark red, slightly moist.			
1		SP-SC	SAND WITH CLAY, medium plasticity, medium, red-grey, slightly moist.			
2		SP	SAND, fine to medium, pale white-pale grey, slightly moist.			
3		CL	CLAY WITH SAND, medium plasticity, fine to medium, grey, slightly moist.			
4		CL	CLAY WITH SAND, medium plasticity, fine to medium, grey-mottled red, slightly moist.			
4		SP-SC	SANDY CLAY, high plasticity, fine to medium, dark brown-mottled red, slightly moist.			Highly ferruginised layer.
4		CH	CLAY, high plasticity, fine to medium, grey, slightly moist.			
4		SP-SC	SANDY CLAY, high plasticity, fine to medium, dark brown-mottled red, slightly moist.			Highly ferruginised layer.
4		CH	CLAY, high plasticity, fine to medium, grey, slightly moist.			
5			Borehole B03 terminated at 5m			

# A13 Transect 1

T1 272m- *Banksia telmatiaea*, *Hakea costata*  
*Melaleuca seriata* Closed Low Heath

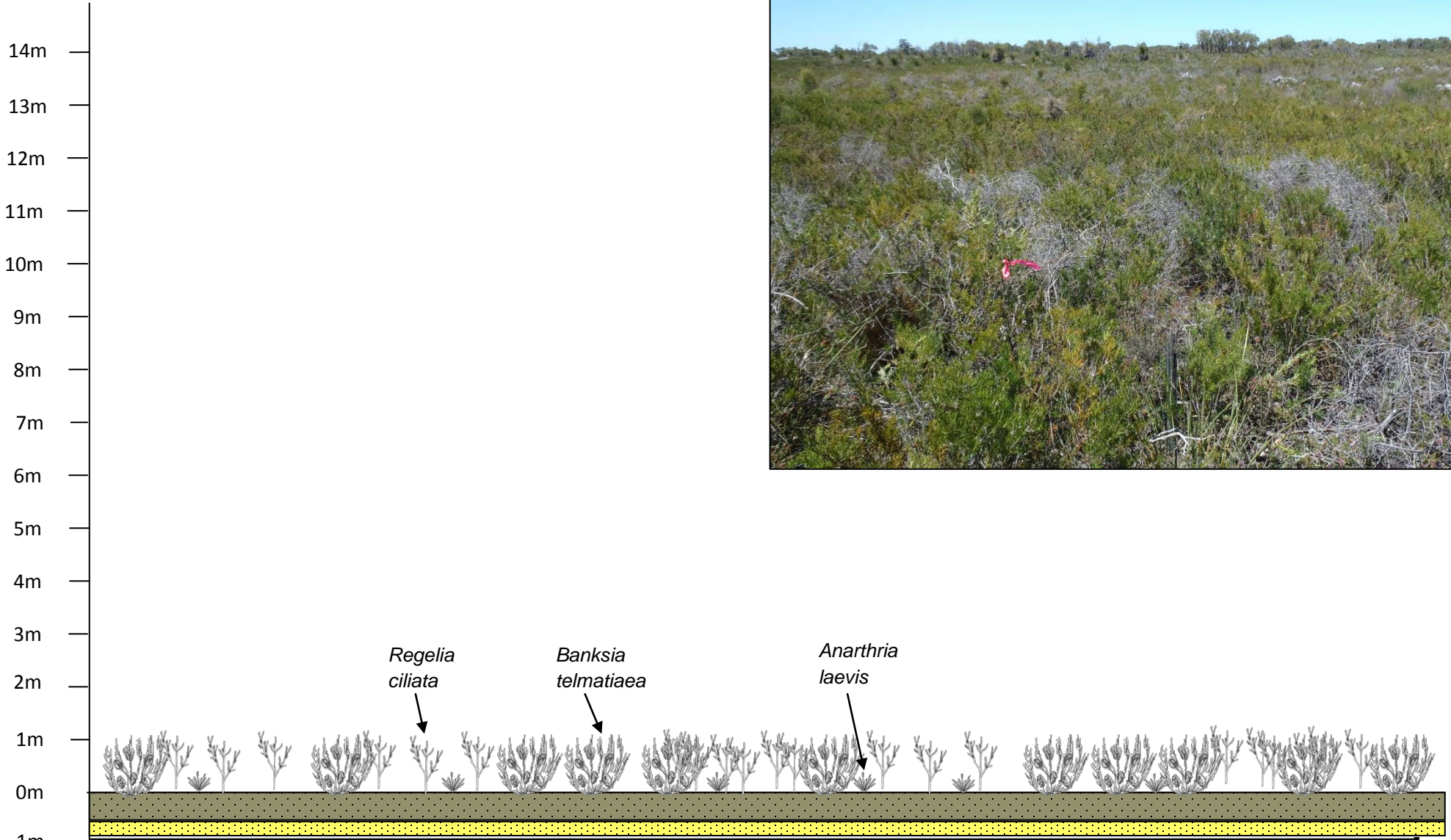


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Depth (m)	Graphic Log	Classification Symbol	Material Description	Samples Tests Remarks	PID (ppm)	Additional Observations
		SW	SAND, fine, uniform, white-pale grey, dry.			Contains fine roots throughout the material; fibrous. Layer contains a lot of Organic Matter and roots
		SP	SAND, fine to medium, poorly graded, dark brown-grey, moist			
		SW	SAND, fine, uniform, white-pale grey, dry.			
		SW	SAND, fine, poorly graded, grey-red, dry.			
		SP	SAND, fine to medium, poorly graded, yellow, dry.			
1			Borehole A13 terminated at 0.85m			Contains several small fragments of well-cemented coarse sand (red & dark brown in colour due to extensive ferruginisation)
2						Contains several small fragments of well-cemented coarse sand (red & dark brown in colour due to extensive ferruginisation)

**A05 Transect 1**

T1 555m – *Banksia telmatiaea* and *Regelia ciliata* Open Low Heath over *Anarthria laevis* Scattered Sedges

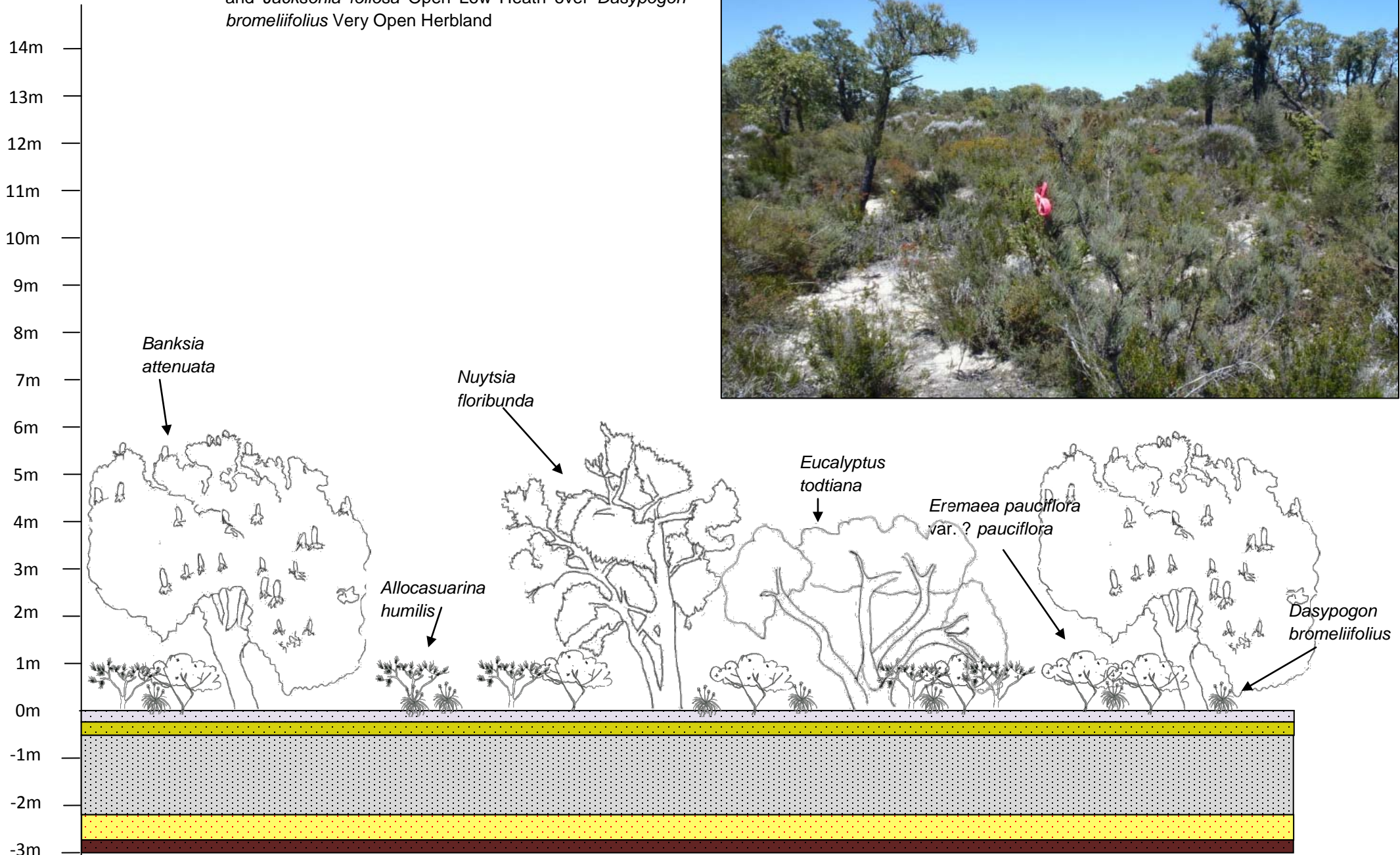


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Depth (m)	Graphic Log	Classification Symbol	Material Description	Samples Tests Remarks	PID (ppm)	Additional Observations
0.0 - 0.9	[Brown dotted pattern]	SP	SAND, fine to medium, poorly graded, pale brown-yellow, slightly moist to dry.			Contains fine roots throughout the material
0.9 - 1.0	[Yellow dotted pattern]	SP	SAND, coarse, well graded, yellow, slightly moist			Contains larger fragments (~1/cm <sup>3</sup> ) of well-cemented coarse sand; dark brown/red in colour (extensively ferruginised). Fragments are widespread throughout the layer.
1.0			Borehole A05 terminated at 0.9m			

**MB03 Transect 01**

**T1 800m-** *Banksia attenuata* Low Open Woodland with Scattered *Eucalyptus tottiana* and *Nuytsia floribunda* over *Allocasuarina humilis*, *Eremaea pauciflora* var. ? *pauciflora* and *Jacksonia foliosa* Open Low Heath over *Dasypogon bromeliifolius* Very Open Herbland



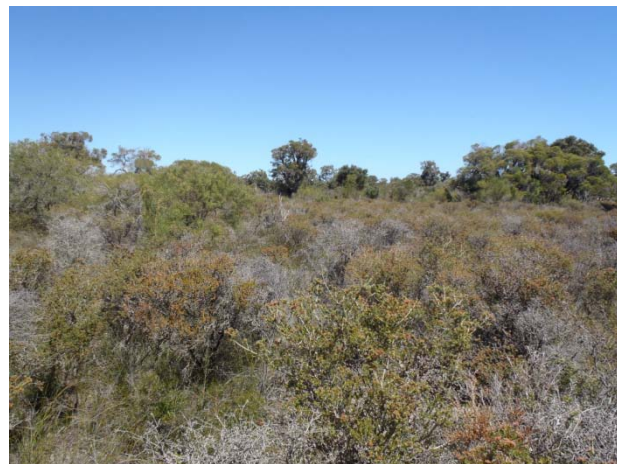
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Depth (m)	Graphic Log	Classification Symbol	Material Description	Samples Tests Remarks	PID (ppm)	Additional Observations
0.0 - 0.2	[Dotted pattern]	SP	SAND, fine, uniform, grey-white, dry to slightly moist.			
0.2 - 0.4	[Yellow dotted pattern]	SP	SAND, fine, poorly graded, yellow-pale brown, dry.			Contains small fragments (0.4-0.8mm <sup>3</sup> in size, brown in colour).
0.4 - 1.0	[Grey dotted pattern]	SP	SAND, fine to medium, grey-pale brown, slightly moist.			
1.0 - 1.8	[Grey dotted pattern]					
1.8 - 2.2	[Yellow dotted pattern]	SP	SAND, fine to medium, poorly graded, yellow-mottled red, slightly moist.			Some ferruginisation throughout the material.
2.2 - 2.7	[Dark red-brown dotted pattern]	SP	SAND, fine to medium, mottled dark red-brown, slightly moist.			
Borehole MB03 terminated at 2.7m						

TRANSECT 2



Community 1: *Banksia attenuata* and *Banksia menziesii* Low open Woodland with Scattered *Melaleuca preissiana* and *Nuytsia floribunda* over Scattered *Adenanthos cygnorum* over *Hibbertia hypericoides*, *Allocasuarina humilis* and *Stirlingia latifolia* Shrubland over *Anarthria laevis* and *Lepidosperma longitudinale* Very Open Sedgeland



Community 2: *Melaleuca subtrigona* and *Scholtzia ? laxiflora* Open Heath over *Schoenus subfascicularis* Sedgeland



Community 3: *Melaleuca raphiophylla* Open Woodland with Scattered *Banksia prionotes* and *Banksia menziesii* over *Jacksonia sternbergiana* Tall Open Shrubland over *Schoenus subfascicularis* Open Sedgeland

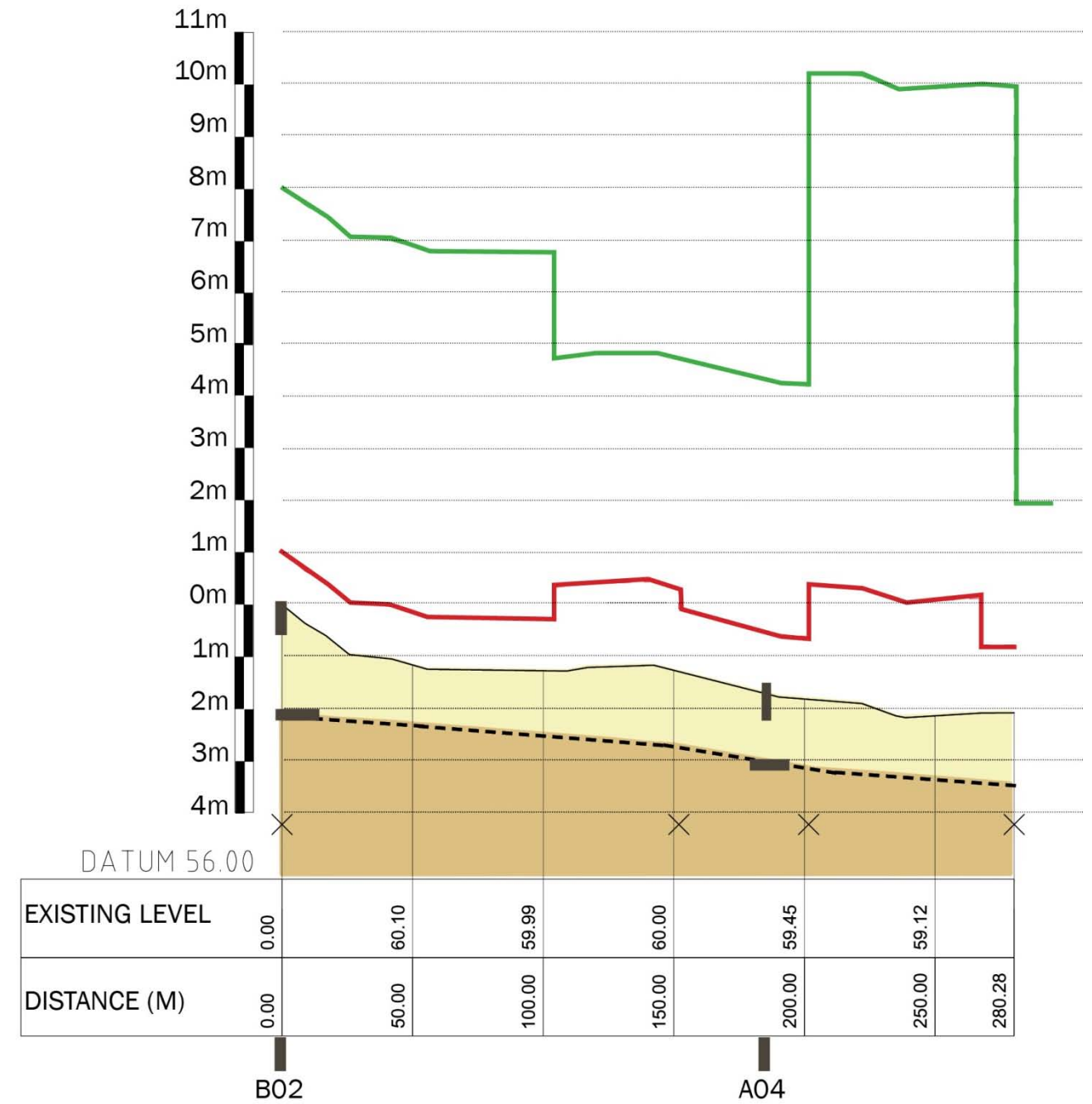


Community 4: *Eucalyptus rudis*, *Melaleuca preissiana* and *Melaleuca raphiophylla* Open Woodland over *Schoenus subfascicularis* and *Lepidosperma longitudinale* Sedgeland

**NOTE: Wetland observed to the east of the Transect**

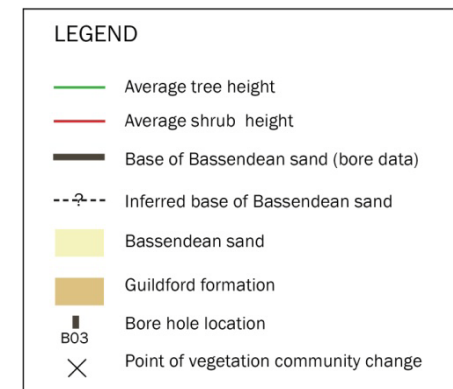


TRANSECT 2



ORIENTATION: NORTH - N.WEST

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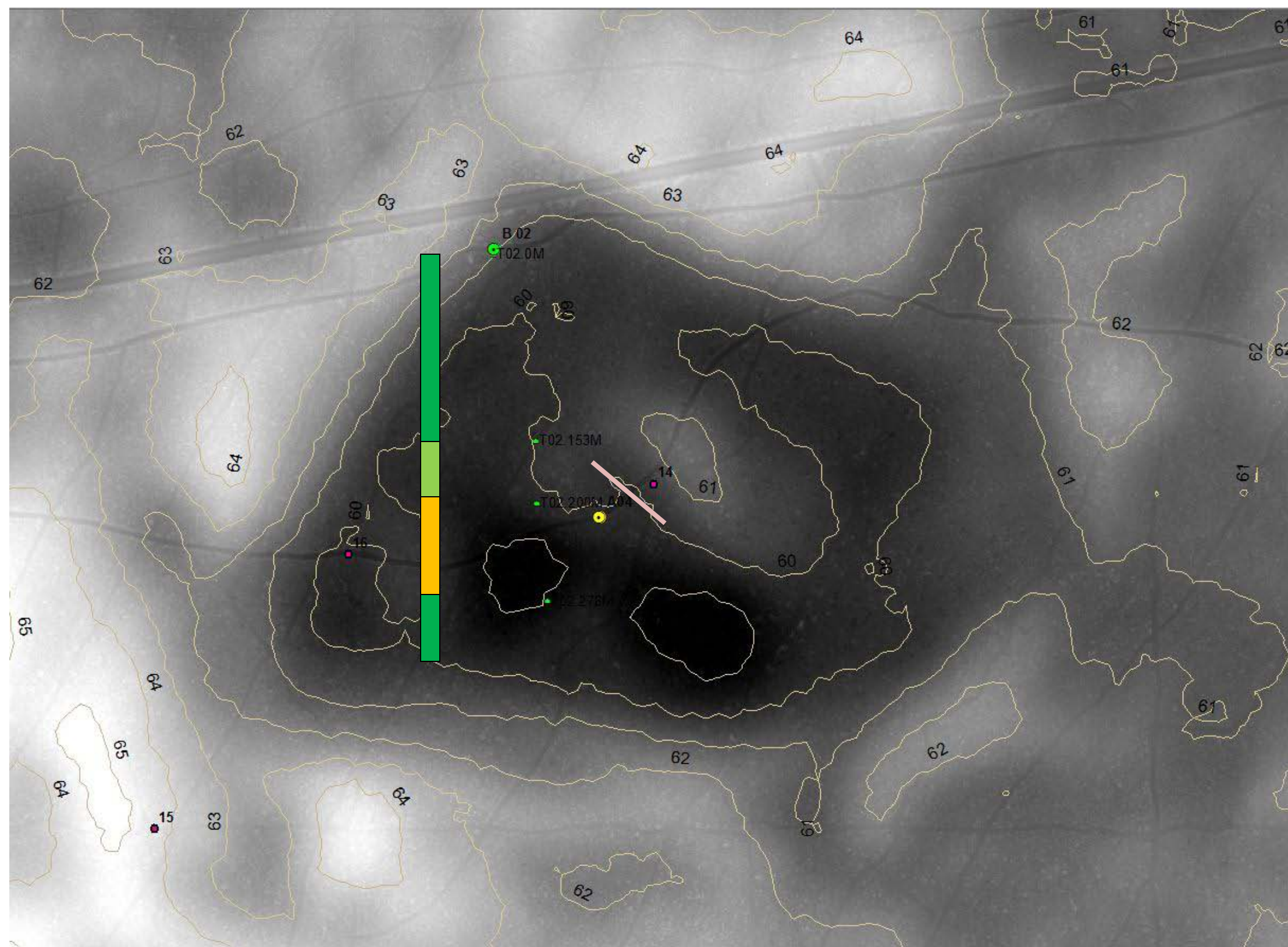


COMMUNITY 1	
Family	Species
Casuarinaceae	<i>Allocasuarina humilis</i>
Anarthriaceae	<i>Anarthria laevis</i>
Proteaceae	<i>Banksia attenuata</i>
Dilleniaceae	<i>Hibbertia hypericoides</i>
Dilleniaceae	<i>Hibbertia subvaginata</i>
Cyperaceae	<i>Lepidosperma longitudinale</i>
Myrtaceae	<i>Melaleuca preissiana</i>
Loranthaceae	<i>Nuytsia floribunda</i>
Proteaceae	<i>Stirlingia latifolia</i>

COMMUNITY 2	
Family	Species
Myrtaceae	<i>Melaleuca subtrigona</i>
Cyperaceae	<i>Schoenus subfascicularis</i>
Myrtaceae	<i>Scholtzia ?laxiflora</i>

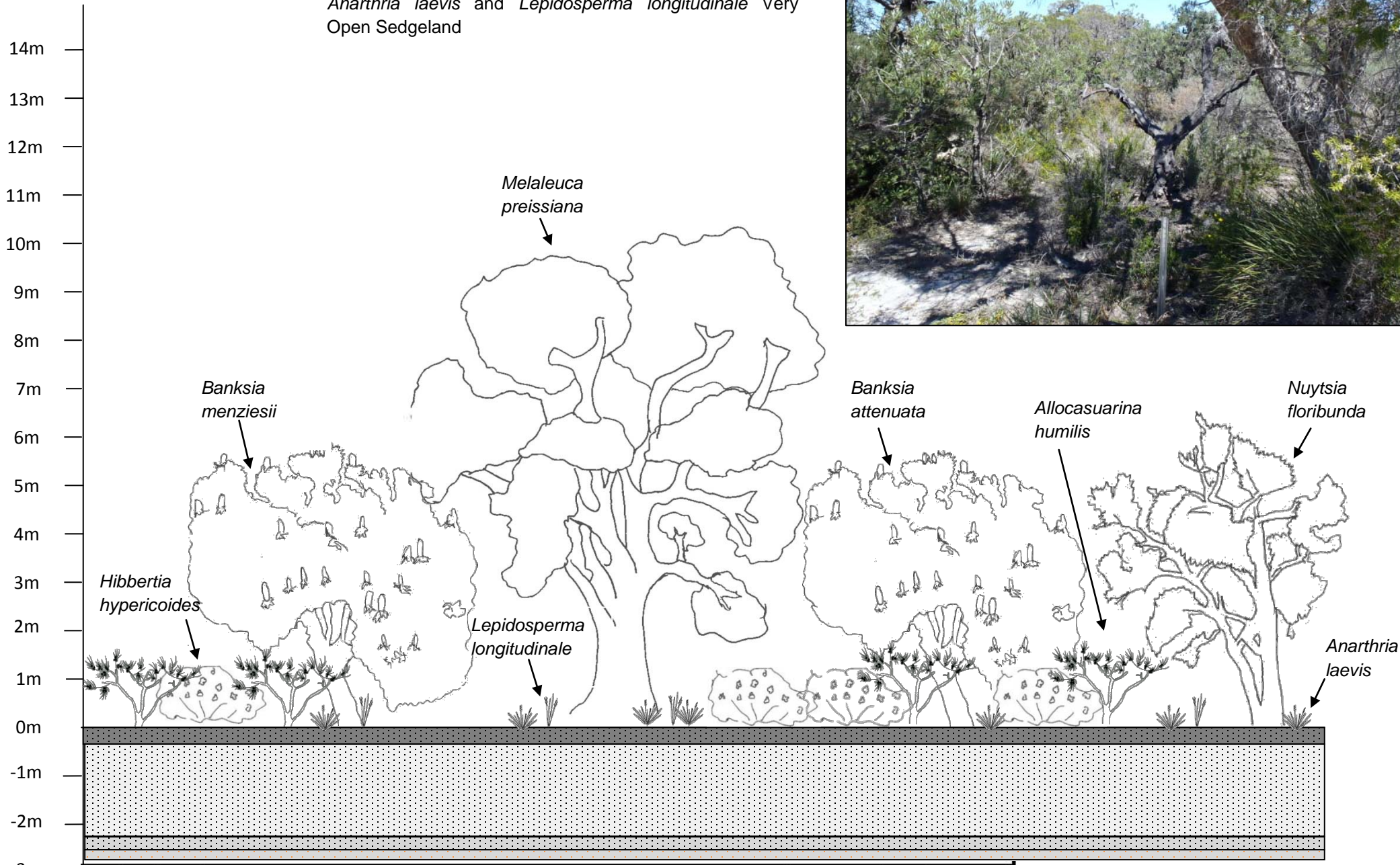
COMMUNITY 3	
Family	Species
Haemodoraceae	<i>Conostylis aculeata</i>
Fabaceae	<i>Jacksonia stembergiana</i>
Myrtaceae	<i>Melaleuca raphiophylla</i>
Cyperaceae	<i>Schoenus subfascicularis</i>

COMMUNITY 4	
Family	Species
Fabaceae	<i>Acacia saligna</i> subsp. <i>lindleyi</i>
Haemodoraceae	<i>Conostylis aculeata</i>
Myrtaceae	<i>Eucalyptus rudis</i>
Cyperaceae	<i>Lepidosperma longitudinale</i>
Myrtaceae	<i>Melaleuca preissiana</i>
Myrtaceae	<i>Melaleuca raphiophylla</i>
Cyperaceae	<i>Schoenus subfascicularis</i>



**B02 Transect 2**

**T2 0m** - *Banksia attenuata* and *Banksia menziesii* Low open Woodland with Scattered *Melaleuca preissiana* and *Nuytsia floribunda* over *Hibbertia hypericoides*, *Allocasuarina humilis* and *Stirlingia latifolia* Shrubland over *Anarthria laevis* and *Lepidosperma longitudinale* Very Open Sedgeland

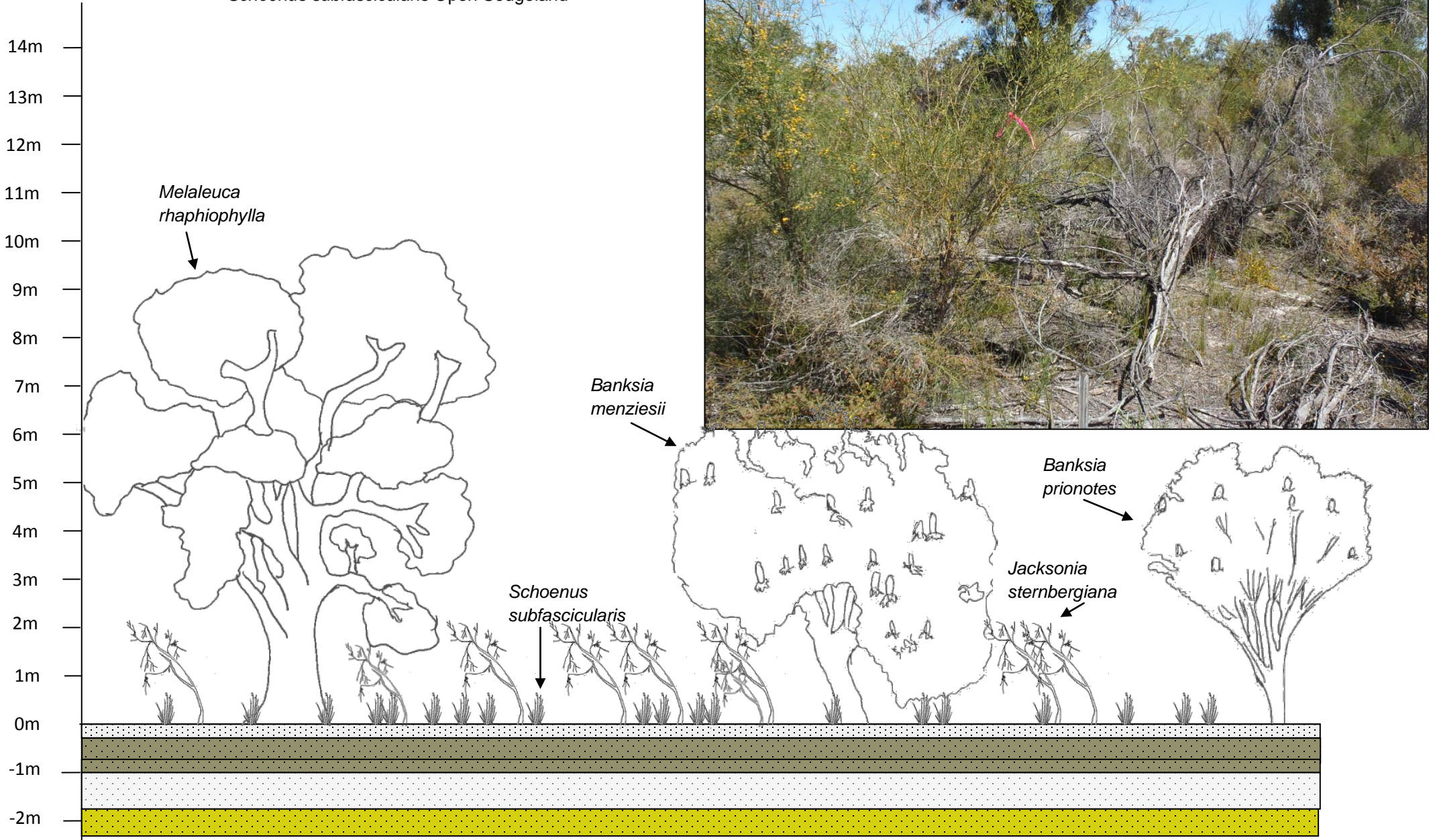


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Depth (m)	Graphic Log	Classification Symbol	Material Description	Samples Tests Remarks	PID (ppm)	Additional Observations
0.0 - 0.5	[Dotted pattern]	SP	SAND, medium, well graded, rounded, dark grey-brown, dry.			
0.5 - 2.0	[Dotted pattern]	SP	SAND, fine to medium, well graded, sub-rounded, white-pale grey, dry.			
2.0 - 2.2	[Dotted pattern]	SP	SAND, fine to medium, well graded, pale grey-brown, slightly moist to dry.			Contains smaller fragments of varying colours (approximately 2mm*3 in size). Some ferruginised sediment spread throughout the material.
2.2 - 2.6	[Dotted pattern]	SM	SAND, fine to medium, grey-mottled orange, slightly moist.			
2.6 - 3.0	[Dotted pattern]		Borehole B02 terminated at 2.6m			

**A04 Transect 2**

**T2 200m** - *Melaleuca raphiophylla* Open Woodland with Scattered *Banksia prionotes* and *Banksia menziesii* over *Jacksonia sternbergiana* Tall Open Shrubland over *Schoenus subfascicularis* Open Sedgeland



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Depth (m)	Graphic Log	Classification Symbol	Material Description	Samples Tests Remarks	PID (ppm)	Additional Observations
0.0 - 0.1	[Dotted pattern]	SP	SAND, fine to medium, uniform, white-pale grey, slightly moist.			Contains fine roots in the top 0.1m; fibrous Contains larger fragments of well-cemented, fine-grained Silty Sand; fine roots also present throughout Contains large fragments of moderately-consolidated Silty Clay (grey in colour)
0.1 - 0.2	[Dotted pattern]	SP	SAND, fine to medium, poorly graded, pale brown-yellow, slightly moist.			
0.2 - 0.3	[Dotted pattern]	SP	SAND, fine to medium, poorly graded, pale brown-yellow, moist.			
0.3 - 1.75	[Dotted pattern]	SP	SAND, fine to medium, poorly graded, pale grey-white, slightly moist.			
1.75 - 2.0	[Yellow dotted pattern]	SP	SAND, fine to medium, poorly graded, yellow-pale brown, slightly moist.			
			Borehole A04 terminated at 1.75m			

TRANSECT 3



Community 1: Scattered *Eucalyptus tottiana* and *Nuytsia floribunda* over *Banksia telmatiaea*, *Allocasuarina humilis* and *Hibbertia hypericoides* Low Shrubland over *Alexgeorgea nitens* Open Sedgeland

Community 2: *Hakea obliqua* subsp. *parviflora* Open Shrubland over *Banksia telmatiaea*, *Calothamnus quadrifidus* subsp. *angustifolius* and *Calytrix ? aurea* Open Low Heath over *Chordifex sinuosus*, *Lyginia imberbis* and *Tricostularia neesii* var. *elatior* Open Sedgeland

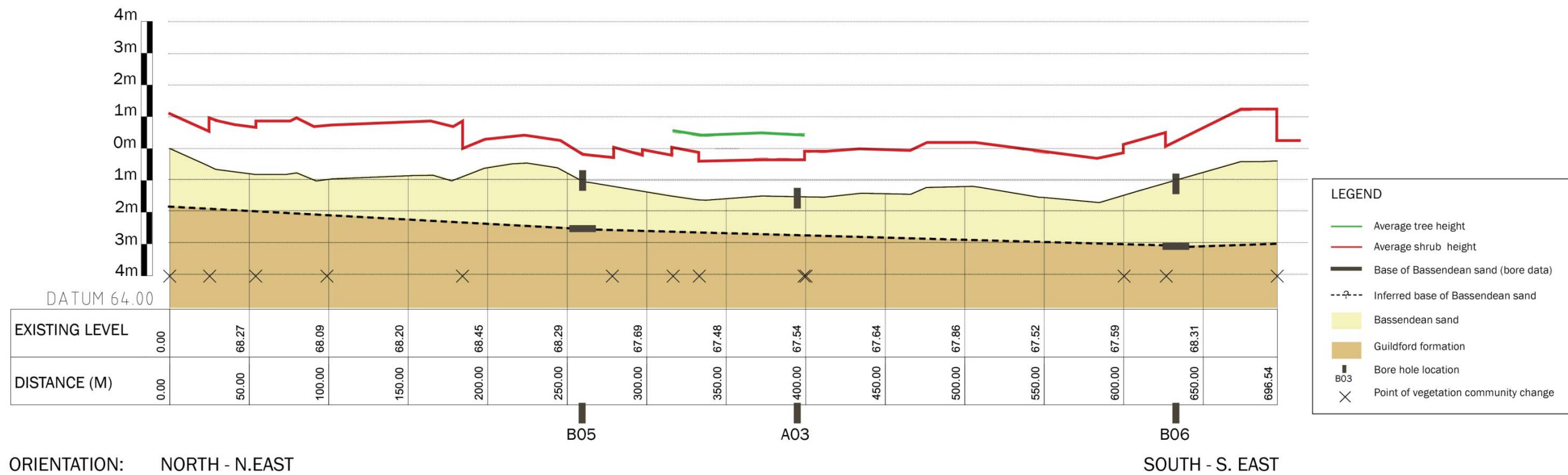
Community 3: *Allocasuarina humilis*, *Calothamnus quadrifidus* subsp. *angustifolius* and *Scholtzia ? laxiflora* Shrubland over *Dasypogon bromeliifolius* Very Open Herbland over *Mesomelaena pseudostygia* Open Sedgeland

Community 4: Scattered *Melaleuca raphiophylla* (dwarf) over *Regelia ciliata* and *Hakea obliqua* subsp. *parviflora* Closed Heath over *Chordifex sinuosus* Open Sedgeland

Community 4: Scattered *Melaleuca raphiophylla* (dwarf) over *Astartea ? scoparia* and *Melaleuca seriata* Closed Heath over *Lepidosperma longitudinale* Open Sedgeland with *Conostylis aculeata* Very Open Herbland



TRANSECT 3



**LEGEND**

- Average tree height
- Average shrub height
- Base of Bassendean sand (bore data)
- Inferred base of Bassendean sand
- Bassendean sand
- Guildford formation
- Bore hole location
- Point of vegetation community change

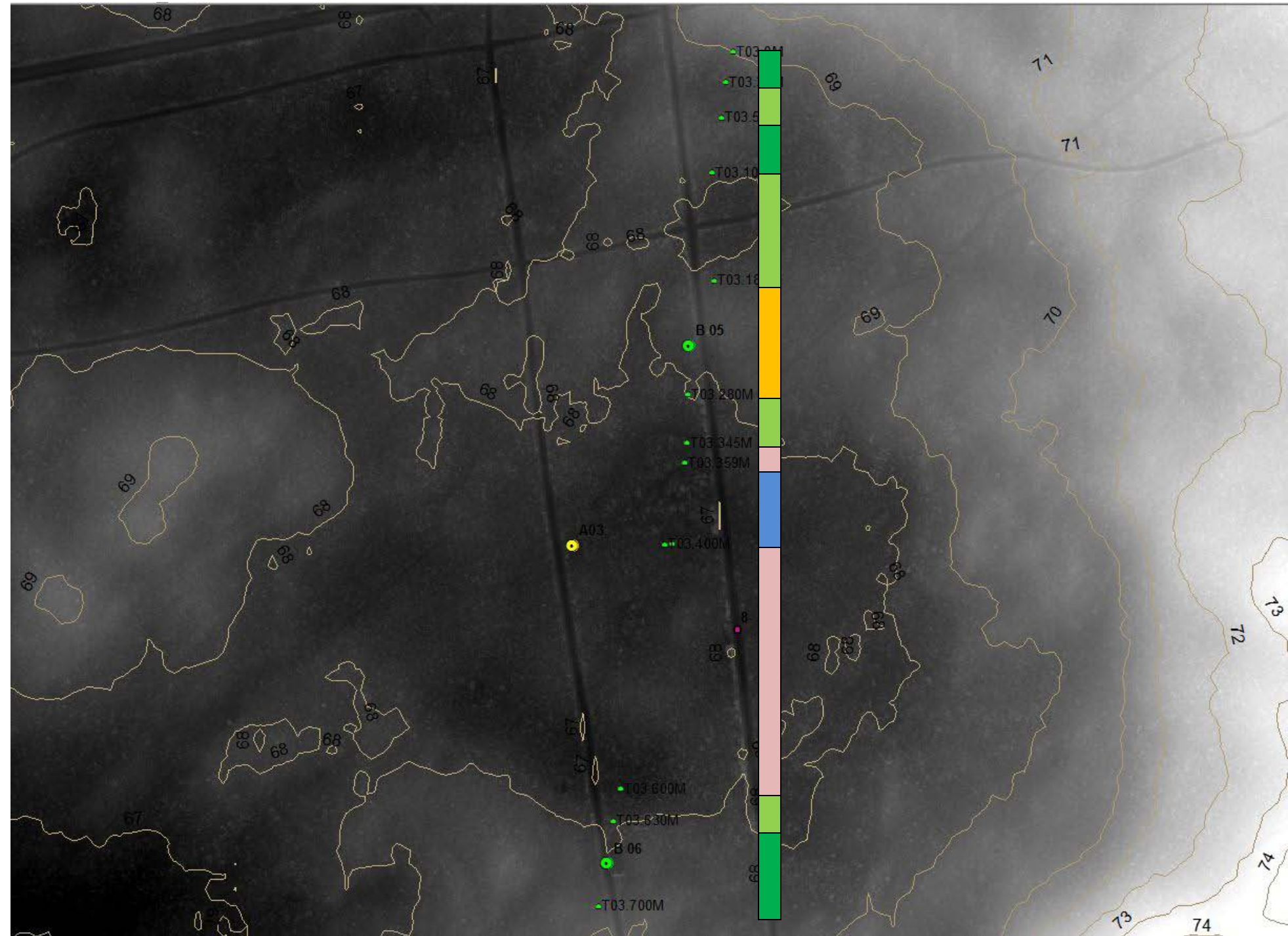
COMMUNITY 1	
Family	Species
Restionaceae	<i>Alexgeorgea nitens</i>
Casuarinaceae	<i>Allocasuarina humilis</i>
Proteaceae	<i>Banksia telmatiaea</i>
Myrtaceae	<i>Calothamnus quadrifidus subsp. angustifolius</i>
Myrtaceae	<i>Eremaea pauciflora var. ? pauciflora</i>
Proteaceae	<i>Hakea obliqua subsp. parviflora</i>
Dilleniaceae	<i>Hibbertia hypericoides</i>
Myrtaceae	<i>Melaleuca seriata</i>

COMMUNITY 2	
Family	Species
Proteaceae	<i>Banksia telmatiaea</i>
Myrtaceae	<i>Calothamnus quadrifidus subsp. angustifolius</i>
Myrtaceae	<i>Calytrix ?aurea</i>
Restionaceae	<i>Chordifex sinuosus</i>
Proteaceae	<i>Hakea obliqua subsp. parviflora</i>
Anarthriaceae	<i>Lyginia imberbis</i>
Cyperaceae	<i>Tricostularia neesii var. elatior</i>

COMMUNITY 3	
Family	Species
Casuarinaceae	<i>Allocasuarina humilis</i>
Myrtaceae	<i>Calothamnus quadrifidus subsp. angustifolius</i>
Dasypogonaceae	<i>Dasypogon bromeliifolius</i>
Cyperaceae	<i>Mesomelaena pseudostygia</i>
Myrtaceae	<i>Scholtzia ?laxiflora</i>
Proteaceae	<i>Stirlingia latifolia</i>

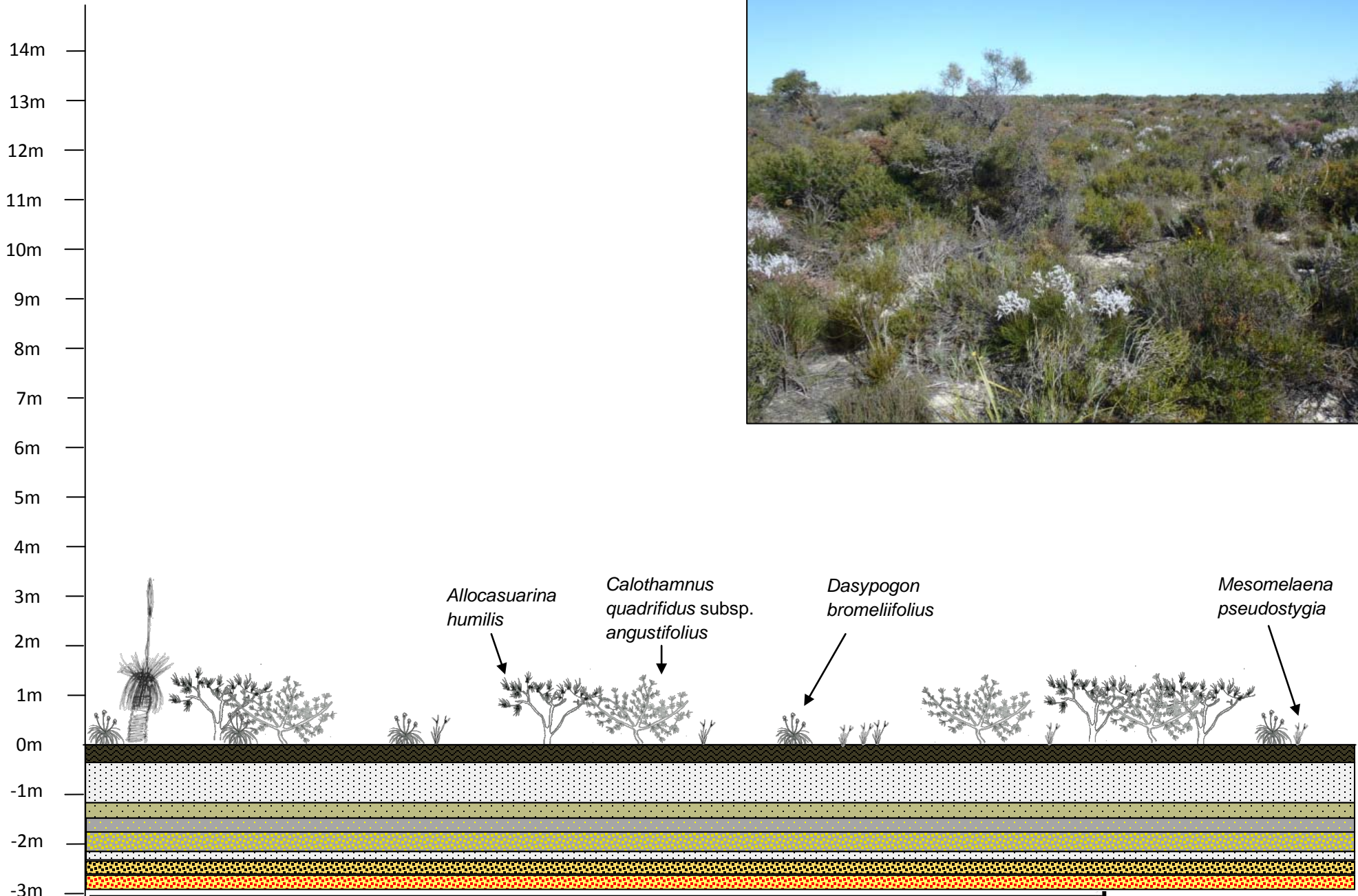
COMMUNITY 4	
Family	Species
Restionaceae	<i>Chordifex sinuosus</i>
Proteaceae	<i>Hakea obliqua subsp. parviflora</i>
Myrtaceae	<i>Melaleuca seriata</i>
Myrtaceae	<i>Regelia ciliata</i>

COMMUNITY 5	
Family	Species
Myrtaceae	<i>Astartea ?scoparia</i>
Haemodoraceae	<i>Conostylis aculeata</i>
Cyperaceae	<i>Lepidosperma longitudinale</i>
Myrtaceae	<i>Melaleuca raphiophylla</i>
Myrtaceae	<i>Melaleuca seriata</i>



# B05 Transect 3

T3 185m *Allocasuarina humilis*, *Calothamnus quadrifidus* subsp. *angustifolius* and *Scholtzia ? laxiflora* Shrubland over *Dasypogon bromeliifolius* Very Open Herbland over *Mesomelaena pseudostygia* Open Sedgeland

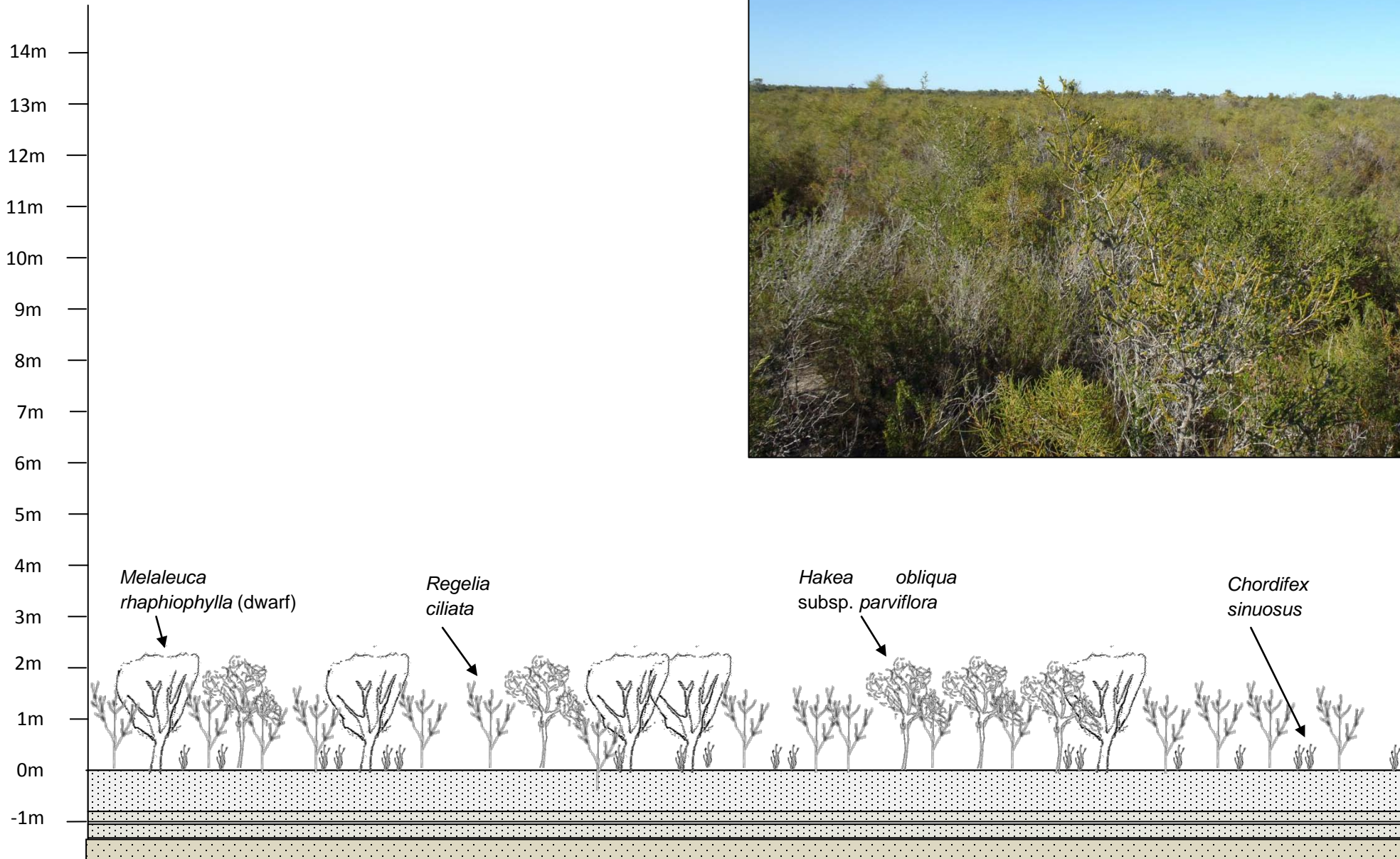


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Depth (m)	Graphic Log	Classification Symbol	Material Description	Samples Tests Remarks	PID (ppm)	Additional Observations
0			TOPSOIL, fine to medium, dark brown-brown, dry.			
0.5		SP	SAND, fine, uniform, white-pale grey, dry.			
1.0		SP	SAND, fine to medium, pale grey-pale yellow, dry.			Contains some small fragments (Approximately 2mm <sup>3</sup> , red or black in colour).
1.5		SM	SAND, fine to medium, grey-mottled yellow, slightly moist to dry.			Extensive ferruginisation in parts.
2.0		SM	SANDY CLAY, low plasticity, fine, grey-mottled dark yellow, moist to slightly moist.			Highly friable sediment.
2.2		SP	SAND, fine, white-pale grey, dry.			
2.4		SP-SM	SANDY CLAY, low plasticity, fine to medium, poorly graded, orange-white, slightly moist.			
2.6		SM	SANDY CLAY, low plasticity, fine, yellow-mottled red, slightly moist.			Highly ferruginised sediment.
2.8			Borehole B05 terminated at 2.8m			

**A03 Transect 3**

T3 397m-Scattered *Melaleuca raphiophylla* (dwarf) over *Regelia ciliata* and *Hakea obliqua* subsp. *parviflora* Closed Heath over *Chordifex sinuosus* Open Sedgeland

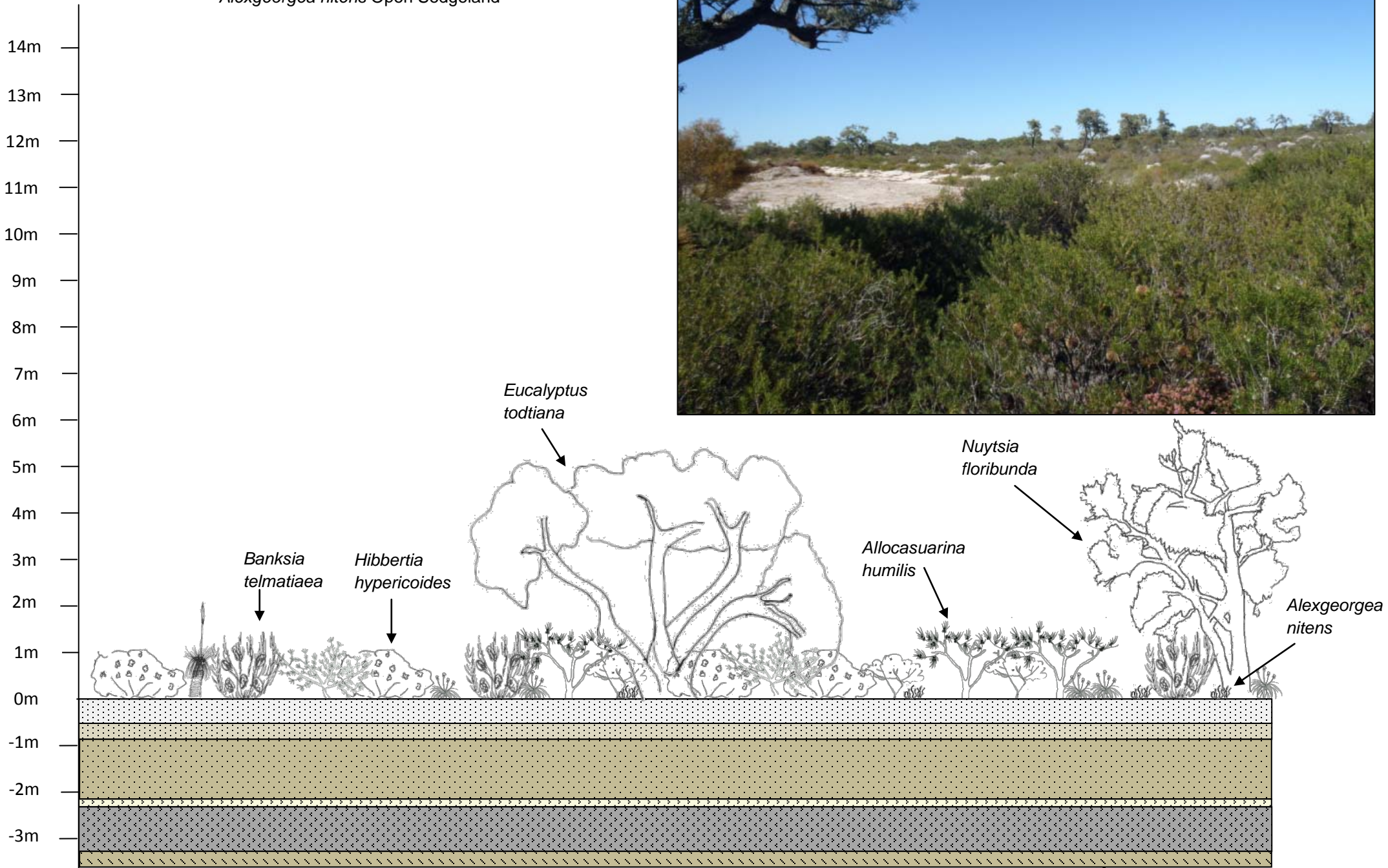


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Depth (m)	Graphic Log	Classification Symbol	Material Description	Samples Tests Remarks	PID (ppm)	Additional Observations
0 to 1.6	[Dotted pattern]	SP	SAND, fine, uniform, white-pale grey, dry.			Contains fine roots in the top 0.1m; fibrous
1.6 to 1.8	[Dotted pattern]	SP	SAND, fine, uniform, pale yellow-white, dry.			
1.8 to 2.0	[Dotted pattern]	SP	SAND, fine to medium, uniform, yellow-white, dry.			
2.0 to 2.5	[Dotted pattern]	SP	SAND, fine to medium, poorly graded, brown-grey, slightly moist.			Contains some small fragments of lightly-cemented fine-grained sands (grey in colour)
2.5 to 3.0			Borehole A03 terminated at 1.6m			

**B06 Transect 3**

**T3 630m-**Scattered *Eucalyptus tottiana* and *Nuytsia floribunda* over *Banksia telmatiaea*, *Allocasuarina humilis* and *Hibbertia hypericoides* Low Shrubland over *Alexgeorgea nitens* Open Sedgeland



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Depth (m)	Graphic Log	Classification Symbol	Material Description	Samples Tests Remarks	PID (ppm)	Additional Observations
0.0 - 0.5	[Dotted pattern]	SP	SAND, fine, uniform, white-pale grey, dry.			Contains some fine roots (~1mm width)
0.5 - 1.0	[Dotted pattern]	SP	SAND, fine to medium, poorly graded, brown-pale grey, dry.			Contains dark brown & red fragments of varying sizes.
1.0 - 1.5	[Dotted pattern]	SP	SAND, fine to medium, grey-yellow, slightly moist.			
1.5 - 2.0	[Dotted pattern]	SP	SAND, fine to medium, grey-yellow, slightly moist.			
2.0 - 2.5	[Cross-hatched pattern]	SC-SM	CLAYEY SAND, medium plasticity, medium, yellow-grey, dry to slightly moist.			Extremely friable material.
2.5 - 3.0	[Cross-hatched pattern]	SC-SM	CLAYEY SAND, low plasticity, fine, grey, dry.			
3.0 - 3.5	[Cross-hatched pattern]	SP-SC	SAND WITH CLAY, medium plasticity, fine to medium, grey-yellow, slightly moist to dry.			Contains small white crystalline structures (approximately 2mm*3 in size) throughout the material.
3.5 - 4.0	[Cross-hatched pattern]		Borehole B06 terminated at 3.5m			

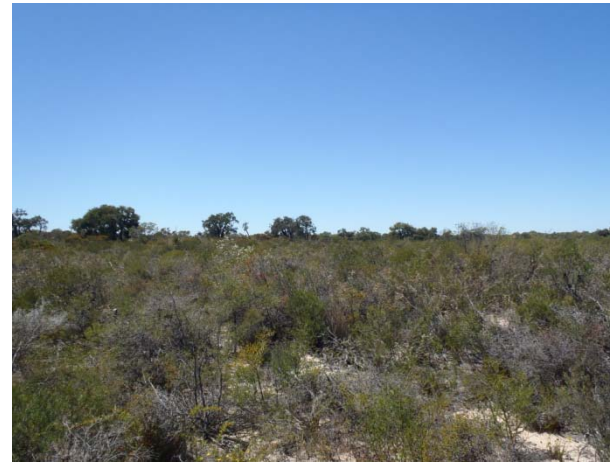
TRANSECT 4



Community 1: *Banksia prionotes*, *Banksia menziesii* and *Banksia attenuata* Low Open Woodland with Scattered *Eucalyptus todtiana* over *Eremaea pauciflora* var. ? *pauciflora*, *Melaleuca seriata* and *Hypocalymma xanthopetalum* Shrubland



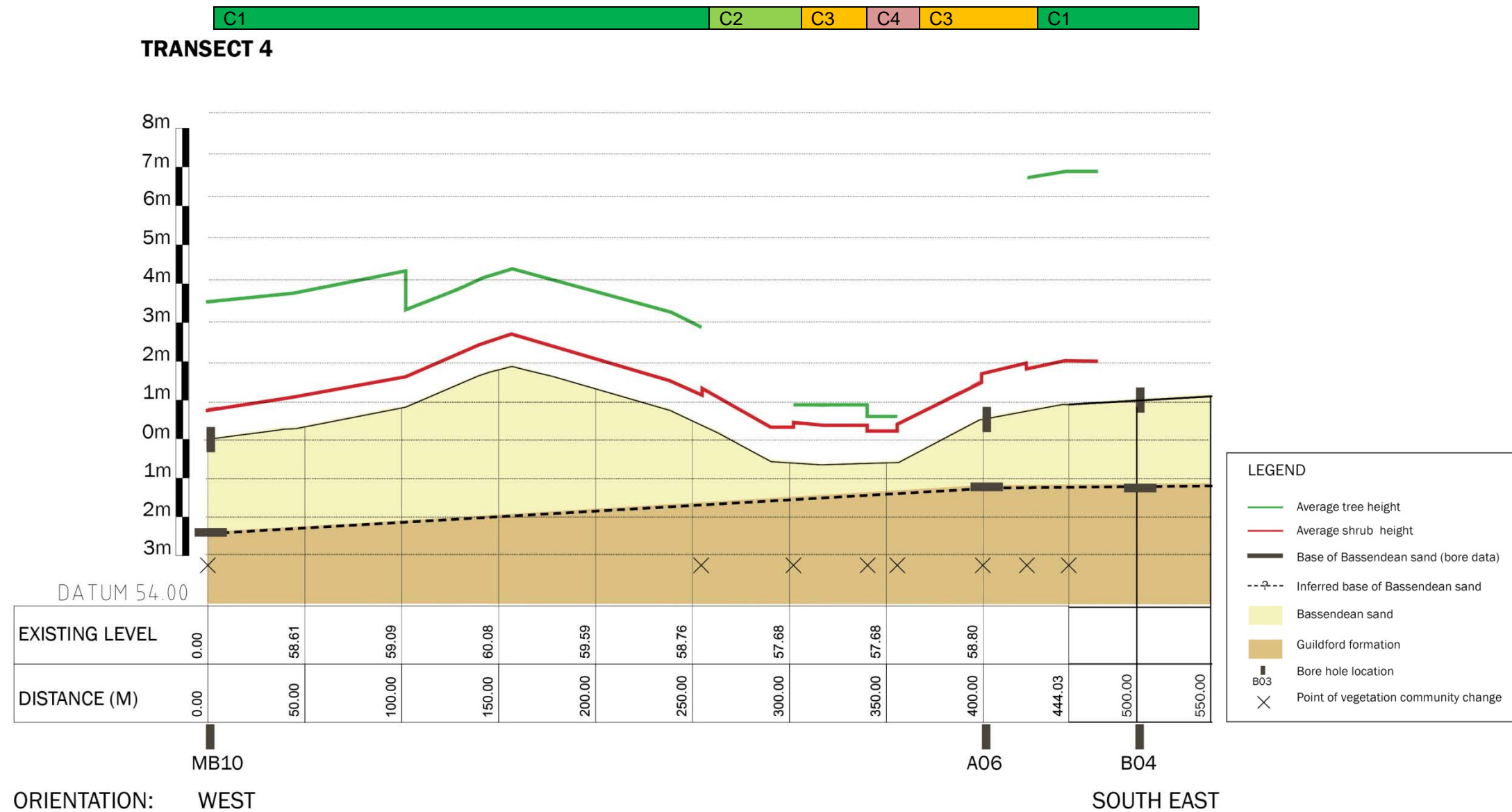
Community 2: *Banksia telmatiaea* and *Beaufortia squarrosa* Closed Heath over *Chordifex sinuosus* and *Tricostularia neesii* var. *elator* Very Open Sedgeland with *Patersonia occidentalis* Very Open Herbland



Community 3: Scattered *Melaleuca raphiophylla* (dwarf) over *Pericalymma ellipticum* var. *ellipticum* and *Banksia telmatiaea* Open Heath over *Chordifex sinuosus* Very Open Sedgeland



Community 4: Scattered *Melaleuca teretifolia* over *Petrophile seminuda* Low Open Shrubland over *Meeboldina cana*, *Schoenus subfascicularis* and *Lepidosperma longitudinale* Open Sedgeland

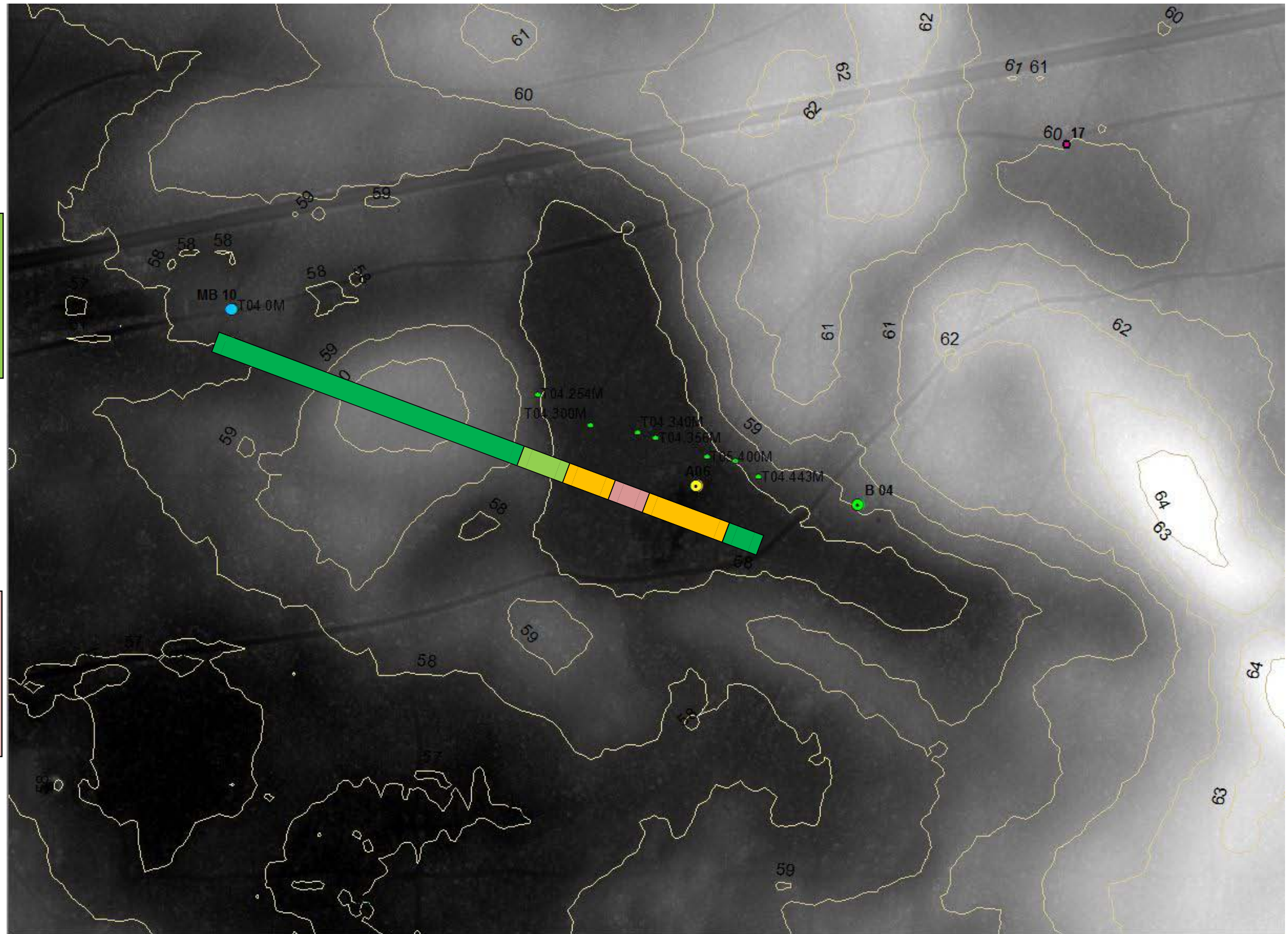


COMMUNITY 1	
Family	Species
Proteaceae	<i>Banksia attenuata</i>
Proteaceae	<i>Banksia menziesii</i>
Proteaceae	<i>Banksia prionotes</i>
Myrtaceae	<i>Eremaea pauciflora</i> var. ? <i>pauciflora</i>
Myrtaceae	<i>Eucalyptus todiana</i>
Myrtaceae	<i>Melaleuca ?clavifolia</i>

COMMUNITY 2	
Family	Species
Proteaceae	<i>Banksia telmatiaea</i>
Myrtaceae	<i>Beaufortia squarrosa</i>
Restionaceae	<i>Chordifex sinuosus</i>
Iridaceae	<i>Patersonia occidentalis</i>
Cyperaceae	<i>Tricostularia neesii</i> var. <i>elator</i>

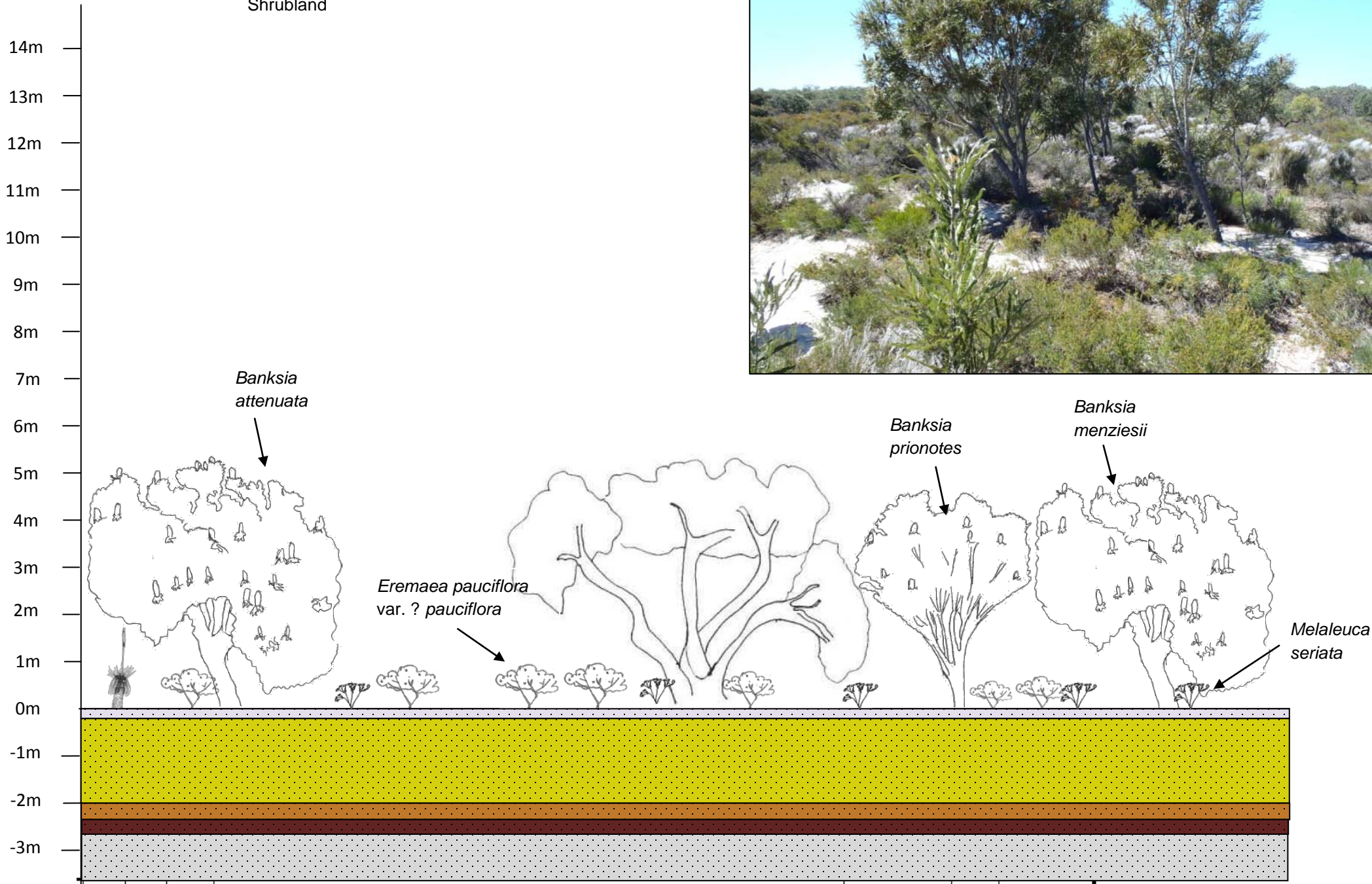
COMMUNITY 3	
Family	Species
Proteaceae	<i>Banksia telmatiaea</i>
Restionaceae	<i>Chordifex sinuosus</i>
Myrtaceae	<i>Melaleuca raphiophylla</i>
Myrtaceae	<i>Pericalymma ellipticum</i> var. <i>ellipticum</i>
Myrtaceae	<i>Regelia ciliata</i>

COMMUNITY 4	
Family	Species
Cyperaceae	<i>Lepidosperma longitudinale</i>
Restionaceae	<i>Meeboldina cana</i>
Myrtaceae	<i>Melaleuca teretifolia</i>
Proteaceae	<i>Petrophile seminuda</i>
Cyperaceae	<i>Schoenus subfascicularis</i>



**MB10 Transect 04**

**T4 0m-***Banksia prionotes*, *Banksia menziesii* and *Banksia attenuata* Low Open Woodland with Scattered *Eucalyptus todtiana* over *Eremaea pauciflora* var. ? *pauciflora*, *Melaleuca seriata* and *Hypocalymma xanthopetalum* Shrubland

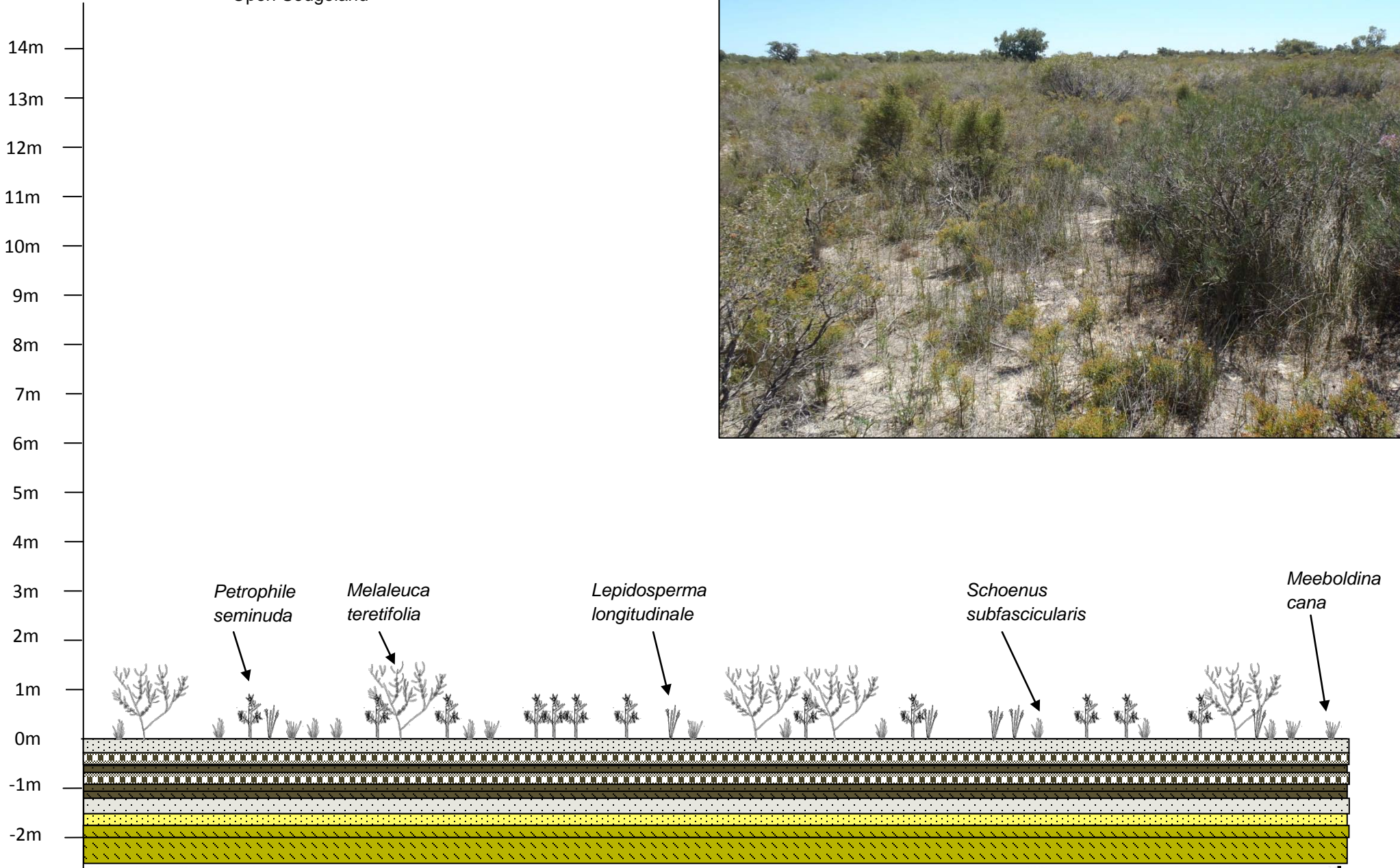


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Depth (m)	Graphic Log	Classification Symbol	Material Description	Samples Tests Remarks	PID (ppm)	Additional Observations
0.0 - 0.2	[Dotted pattern]	SP	SAND, fine, grey-pale white, dry.			
0.2 - 2.0	[Yellow dotted pattern]	SP	SAND, medium, yellow-pale brown, slightly moist to dry.			
2.0 - 2.5	[Brown dotted pattern]	SP	SAND, medium to coarse, grey-dark orange, slightly moist.			Some ferruginisation through out the material.
2.5 - 2.8	[Dark brown dotted pattern]	SP	SAND, medium, red-brown, slightly moist.			Highly ferruginised material.
2.8 - 3.0	[Dark brown dotted pattern]	SP	SAND, fine to medium, red-brown, slightly moist.			Sand
3.0 - 3.5	[Grey dotted pattern]	SP	SAND, coarse, grey-brown, slightly moist.			Some ferruginised material present, (however less widespread than in other layers).
Borehole MB10 terminated at 3.5m						

**A06 Transect 4**

**T4 340m** – Scattered *Melaleuca teretifolia* over *Petrophile seminuda* Low Open Shrubland over *Meeboldina cana*, *Schoenus subfascicularis* and *Lepidosperma longitudinale* Open Sedgeland

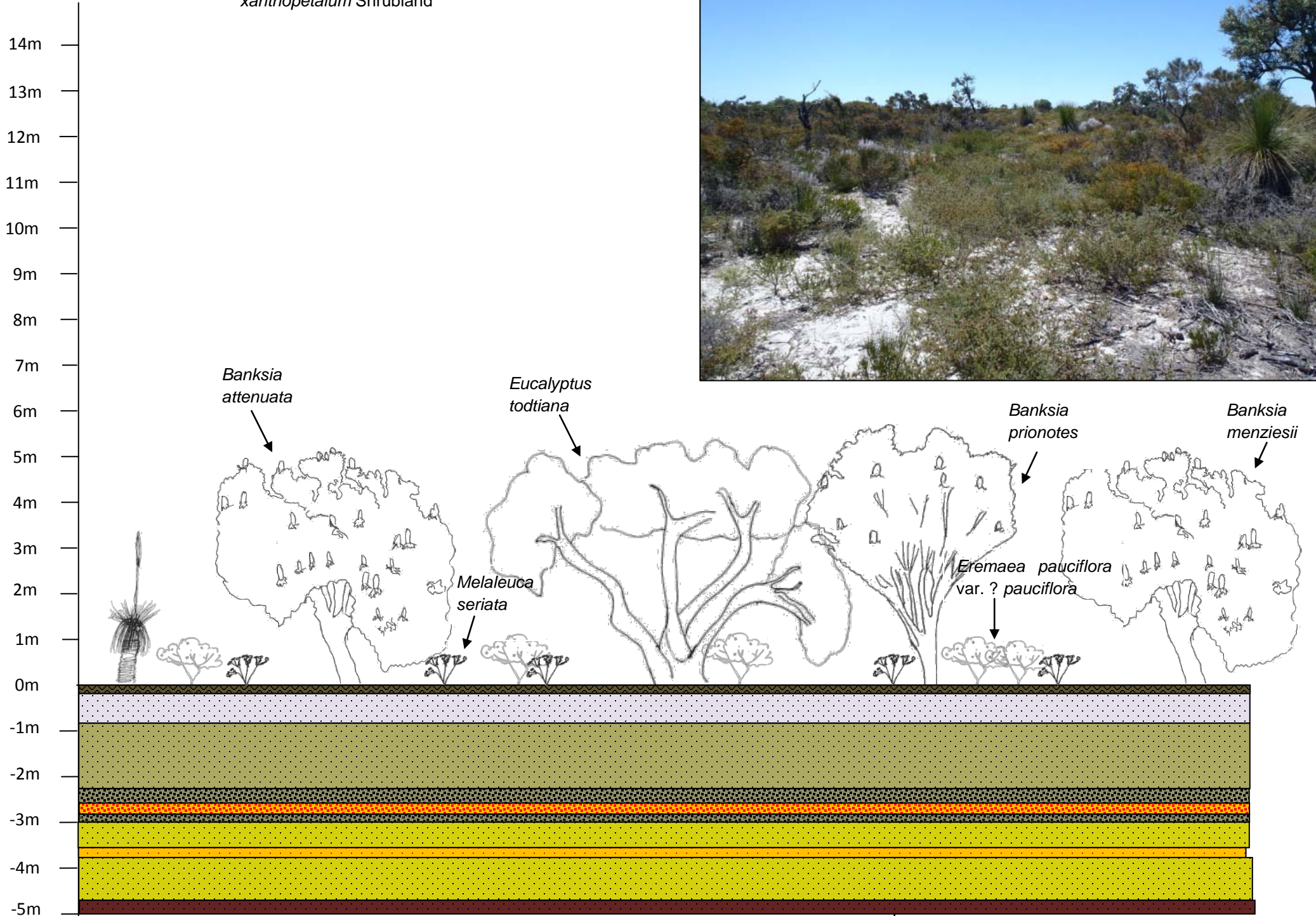


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Depth (m)	Graphic Log	Classification Symbol	Material Description	Samples Tests Remarks	PID (ppm)	Additional Observations
0.0 - 0.1	[Dotted pattern]	SP	SAND, fine, uniform, white-pale yellow, slightly moist.			Contains fine roots in the top 0.1m; fibrous
0.1 - 0.2	[Cross-hatched pattern]	PT	FIBROUS PEAT, fine to medium, poorly graded, dark brown, slightly moist.			
0.2 - 0.3	[Dotted pattern]	SW-SM	SAND, fine to medium, well graded, dark brown-yellow, slightly moist.			
0.3 - 0.4	[Cross-hatched pattern]	PT	FIBROUS PEAT, low plasticity, fine to medium, poorly graded, dark brown, moist.			
0.4 - 0.5	[Dotted pattern]	SP	SAND, medium, poorly graded, dark brown-yellow, slightly moist.			Contains fine root material
0.5 - 0.6	[Diagonal lines]	ML	SAND WITH CLAY, high plasticity, medium to coarse, poorly graded, dark yellow-brown, slightly moist.			Contains clay material within the layer
0.6 - 0.7	[Dotted pattern]	ML	SAND, fine to medium, poorly graded, yellow-white, dry to slightly moist.			Contains larger fragments of poorly-cemented coarse-grained sand (fibrous under a small amount of pressure)
0.7 - 0.8	[Dotted pattern]	SW	SAND, medium to coarse, poorly graded, yellow, slightly moist.			Contains some clay material
0.8 - 0.9	[Diagonal lines]	SM	SAND WITH CLAY, medium plasticity, fine to medium, poorly graded, pale brown-yellow, slightly moist.			Contains some clay material; small fragments of well-cemented ferruginised Silty Sand are also abundant throughout the layer
0.9 - 1.0	[Diagonal lines]	SM	SAND WITH CLAY, medium plasticity, fine to medium, poorly graded, brown-yellow, slightly moist.			
1.0 - 1.7			Borehole A06 terminated at 1.7m			
1.7 - 2.0						
2.0 - 2.5						
2.5 - 3.0						

**B04 Transect 4**

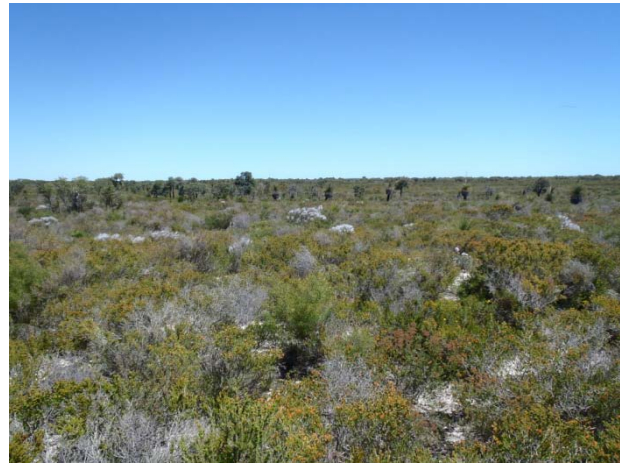
**T4 443m** *Banksia prionotes*, *Banksia menziesii* and *Banksia attenuata* Low Open Woodland with Scattered *Eucalyptus todtiana* over *Eremaea pauciflora* var. ? *pauciflora*, *Melaleuca seriata* and *Hypocalymma xanthopetalum* Shrubland



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Depth (m)	Graphic Log	Classification Symbol	Material Description	Samples Tests Remarks	PID (ppm)	Additional Observations
0			TOPSOIL, fine, uniform, brown, dry.			
0-1		SP	SAND, fine, grey-white, dry.			
1-2		SP	SAND, fine, grey-yellow, moist to slightly moist.			
2-2.5		SW-SC	SANDY CLAY, medium plasticity, medium to coarse, poorly graded, brown-yellow, moist.			Contains some root material (of varying sizes)
2.5-3		SW-SC	SANDY CLAY, medium plasticity, medium to coarse, poorly graded, orange-mottled red, moist.			Strongly ferruginised sediment.
3-3.5		SM	SANDY CLAY, medium plasticity, medium, poorly graded, brown-yellow, moist.			Contains some root material (of varying sizes)
3.5-4		SP-SM	SAND, high plasticity, medium, yellow-brown, slightly moist.			
4-4.2		SP-SM	SAND, fine to medium, orange-mottled red, moist.			Strongly ferruginised sediment.
4.2-4.5		SP-SM	SAND, fine, yellow-brown, slightly moist to dry.			Some ferruginised bands present within the material.
4.5-5		SP-SM	SAND, fine, red-brown, slightly moist.			Strongly ferruginised throughout.
5			Borehole B04 terminated at 5m			

TRANSECT 5



Community 1: *Hakea trifucata*, *Eremaea pauciflora* var. ? *pauciflora* and *Acacia pulchella* Open Heath

Community 2: Scattered *Xanthorrhoea preissii* over *Banksia telmatiaea*, *Hakea trifurcata* and *Melaleuca seriata* Open Low Heath

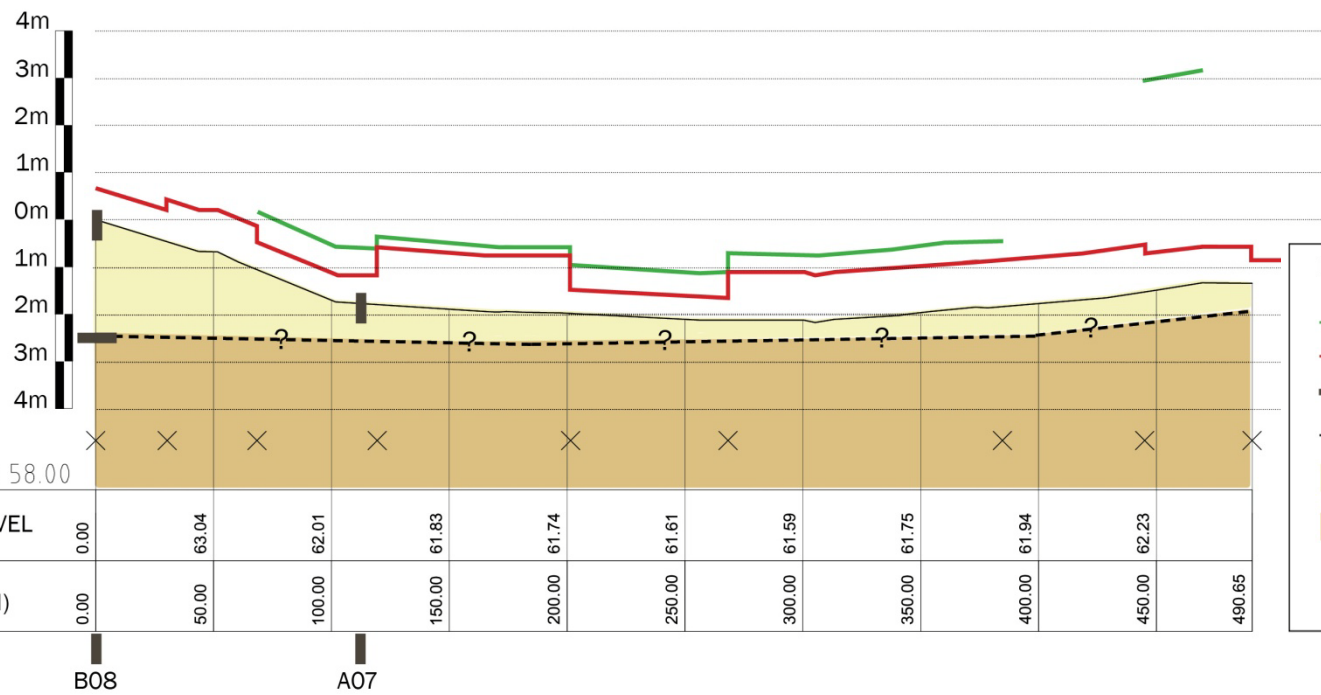
Community 3: Scattered *Melaleuca raphiophylla* (dwarf) over *Banksia telmatiaea*, *Hakea obliqua* subsp. *parviflora* and *Melaleuca seriata* Open Low Heath

Community 4: Scattered *Melaleuca raphiophylla* (dwarf) over *Banksia telmatiaea*, *Hakea obliqua* subsp. *parviflora* and *Pericalymma ellipticum* var. *ellipticum* Shrubland over *Lyginia imberbis*, *Schoenus* sp. A3 Ciliate Sheaths (K.R. Newbey 9402) and *Chordifex sinuosus* Open Sedgeland

Community 5: Scattered *Melaleuca raphiophylla* (dwarf) over *Regelia ciliata* and *Pericalymma ellipticum* var. *ellipticum* over *Phlebocarya ciliata* Very Open Herbland



TRANSECT 5



DATUM 58.00

B08

A07

**LEGEND**

- Average tree height
- Average shrub height
- Base of Bassendean sand (bore data)
- Inferred base of Bassendean sand
- Bassendean sand
- Guildford formation
- Bore hole location
- × Point of vegetation community change



Community 6: Scattered *Melaleuca raphiophylla* (dwarf) over *Regelia ciliata* and *Banksia telmatiaea* Open Heath

Community 7: *Banksia telmatiaea* and *Melaleuca seriata* Open Heath over Scattered *Chordifex sinuosus*



Community 8: Open Shrub Mallee of *Eucalyptus todtiana* with Scattered *Banksia attenuata* and *Banksia menziesii* over *Allocasuarina humilis* and *Jacksonia sternbergiana* Shrubland

ORIENTATION: NORTH EAST

SOUTH WEST

COMMUNITY 1	
Family	Species
Fabaceae	<i>Acacia pulchella</i>
Proteaceae	<i>Conospermum stoechadis</i>
Myrtaceae	<i>Eremaea pauciflora</i> var. ? <i>pauciflora</i>
Proteaceae	<i>Hakea trifurcata</i>

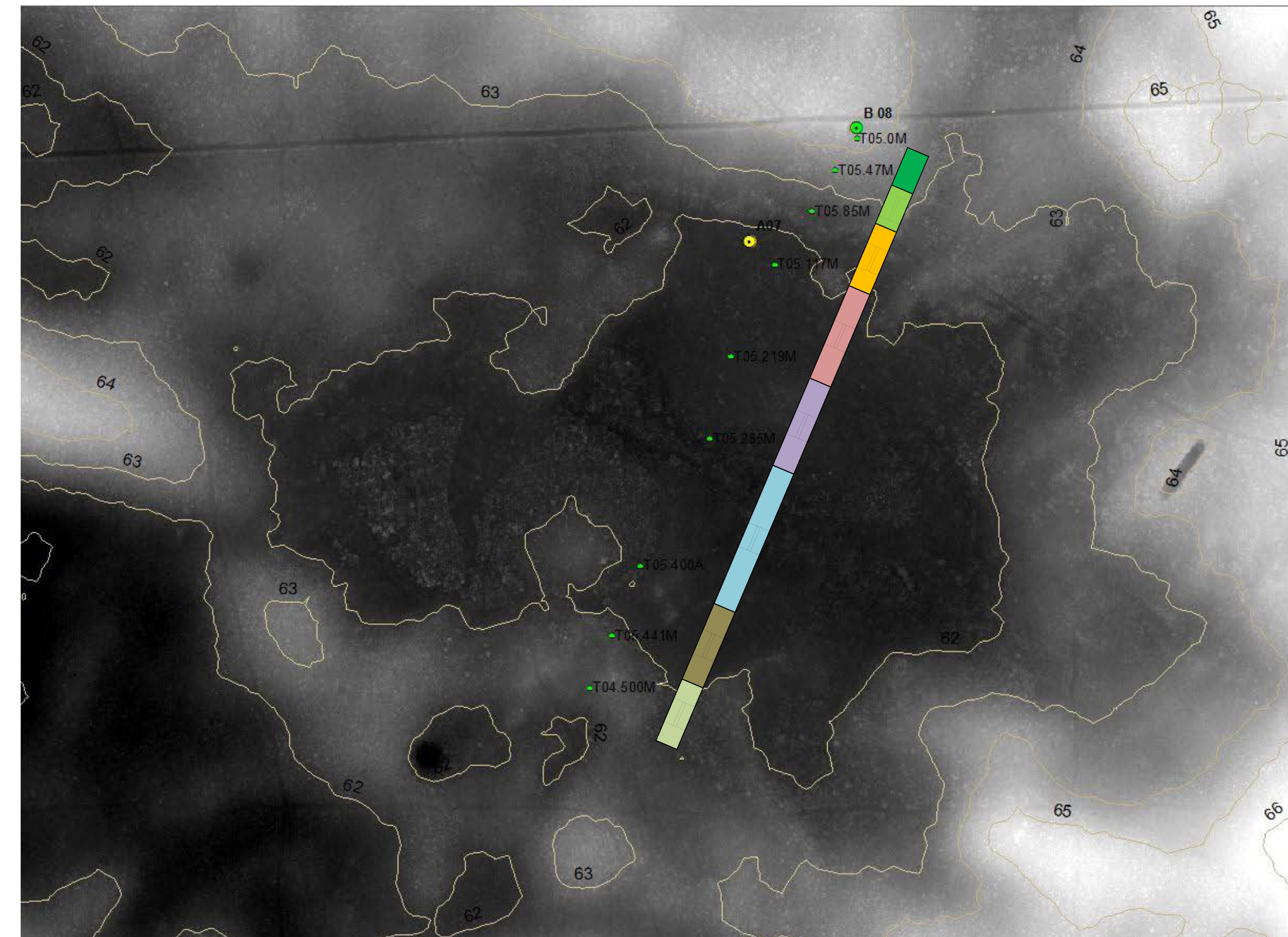
COMMUNITY 2	
Family	Species
Proteaceae	<i>Banksia telmatiaea</i>
Proteaceae	<i>Hakea costata</i>
Proteaceae	<i>Hakea trifurcata</i>
Myrtaceae	<i>Melaleuca seriata</i>

COMMUNITY 3	
Family	Species
Proteaceae	<i>Banksia telmatiaea</i>
Myrtaceae	<i>Calytrix ?aurea</i>
Proteaceae	<i>Hakea obliqua</i> subsp. <i>parviflora</i>
Myrtaceae	<i>Melaleuca raphiophylla</i>
Myrtaceae	<i>Melaleuca seriata</i>
Myrtaceae	<i>Pericalymma ellipticum</i> var. <i>ellipticum</i>
Myrtaceae	<i>Verticordia densiflora</i> var. <i>densiflora</i>

COMMUNITY 4	
Family	Species
Ericaceae	<i>Andersonia gracilis</i>
Proteaceae	<i>Banksia telmatiaea</i>
Restionaceae	<i>Chordifex sinuosus</i>
Proteaceae	<i>Hakea obliqua</i> subsp. <i>parviflora</i>
Anarthriaceae	<i>Lyginia imberbis</i>
Myrtaceae	<i>Melaleuca raphiophylla</i>
Myrtaceae	<i>Pericalymma ellipticum</i> var. <i>ellipticum</i>
Myrtaceae	<i>Regelia ciliata</i>
Cyperaceae	<i>Schoenus</i> sp. A3 <i>Ciliate Sheaths</i> (K.R. Newbey 9402)

COMMUNITY 5	
Family	Species
Myrtaceae	<i>Melaleuca raphiophylla</i>
Myrtaceae	<i>Pericalymma ellipticum</i> var. <i>ellipticum</i>
Haemodoraceae	<i>Phlebocarya ciliata</i>
Myrtaceae	<i>Regelia ciliata</i>

COMMUNITY 6	
Family	Species
Myrtaceae	<i>Regelia ciliata</i>
Fabaceae	<i>Acacia saligna</i> subsp. <i>lindleyi</i>
Myrtaceae	<i>Astartea ?scoparia</i>
Proteaceae	<i>Hakea varia</i>
Cyperaceae	<i>Lepidosperma longitudinale</i>
Myrtaceae	<i>Melaleuca raphiophylla</i>
Myrtaceae	<i>Melaleuca seriata</i>
Cyperaceae	<i>Schoenus</i> sp. A3 <i>Ciliate Sheaths</i> (K.R. Newbey 9402)
Myrtaceae	<i>Verticordia densiflora</i> var. <i>densiflora</i>

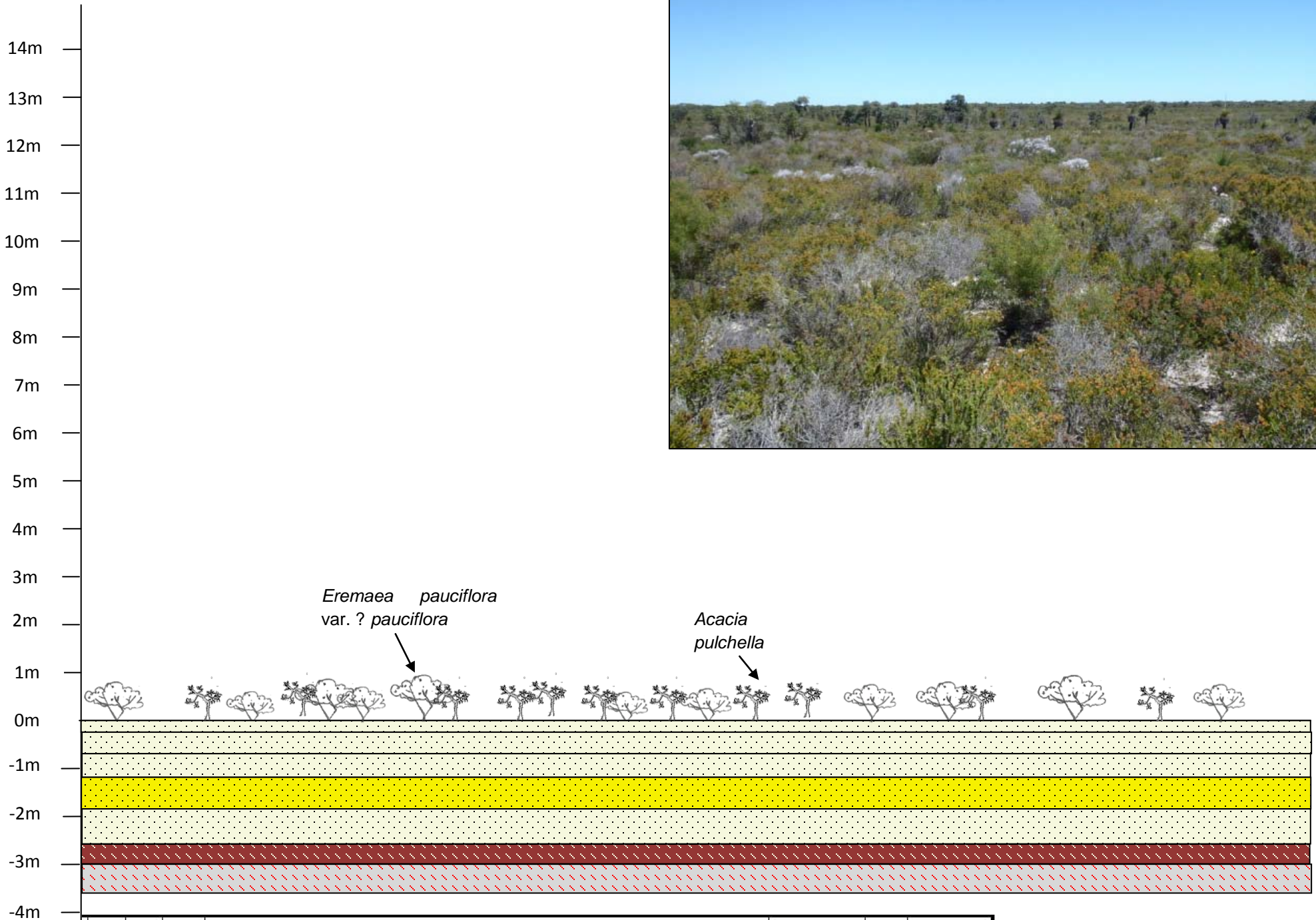
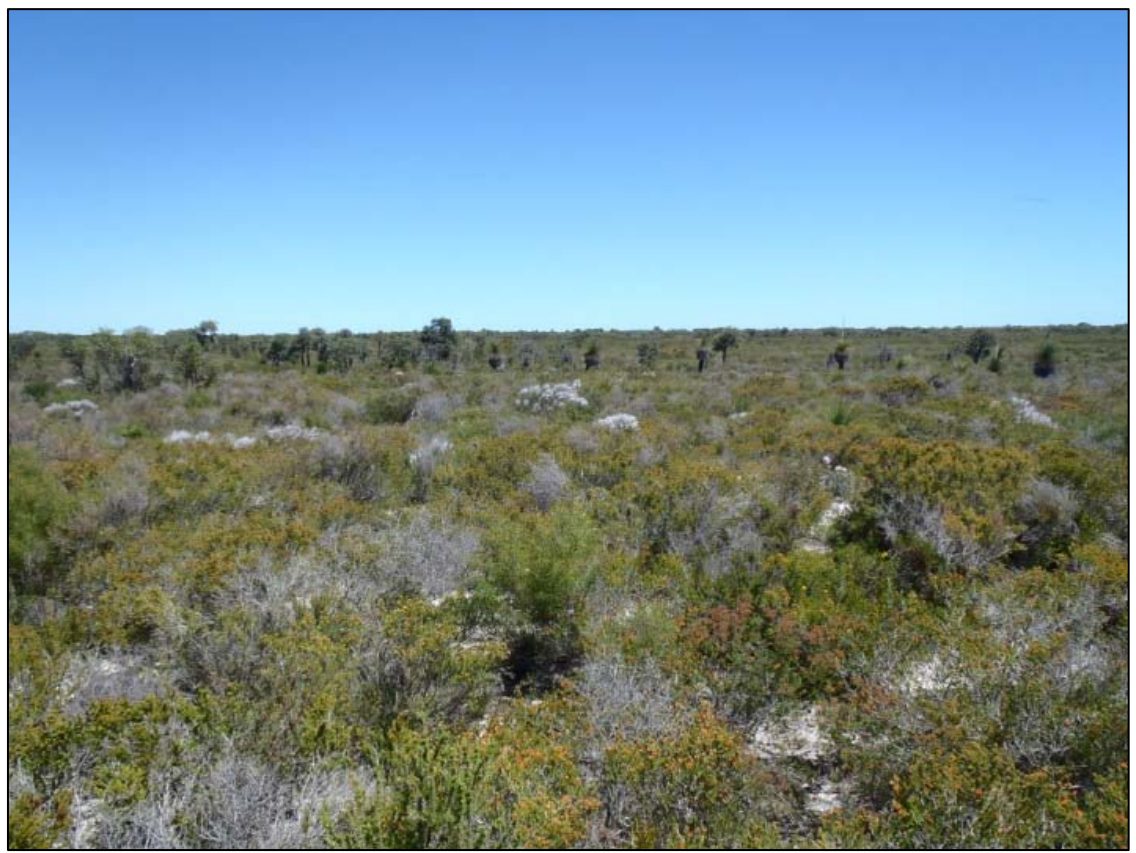


COMMUNITY 7	
Family	Species
Proteaceae	<i>Banksia telmatiaea</i>
Restionaceae	<i>Chordifex sinuosus</i>
Myrtaceae	<i>Melaleuca preissiana</i>
Myrtaceae	<i>Melaleuca seriata</i>
Cyperaceae	<i>Schoenus</i> sp. A3 <i>Ciliate Sheaths</i> (K.R. Newbey 9402)
Xanthorrhoeaceae	<i>Xanthorrhoea preissii</i>

COMMUNITY 8	
Family	Species
Casuarinaceae	<i>Allocasuarina humilis</i>
Myrtaceae	<i>Eucalyptus todiana</i>
Fabaceae	<i>Jacksonia sternbergiana</i>

# B08 Transect 5

T5 0m - *Hakea trifurcata*, *Eremaea pauciflora* var. ?  
*pauciflora* and *Acacia pulchella* Open Low Heath

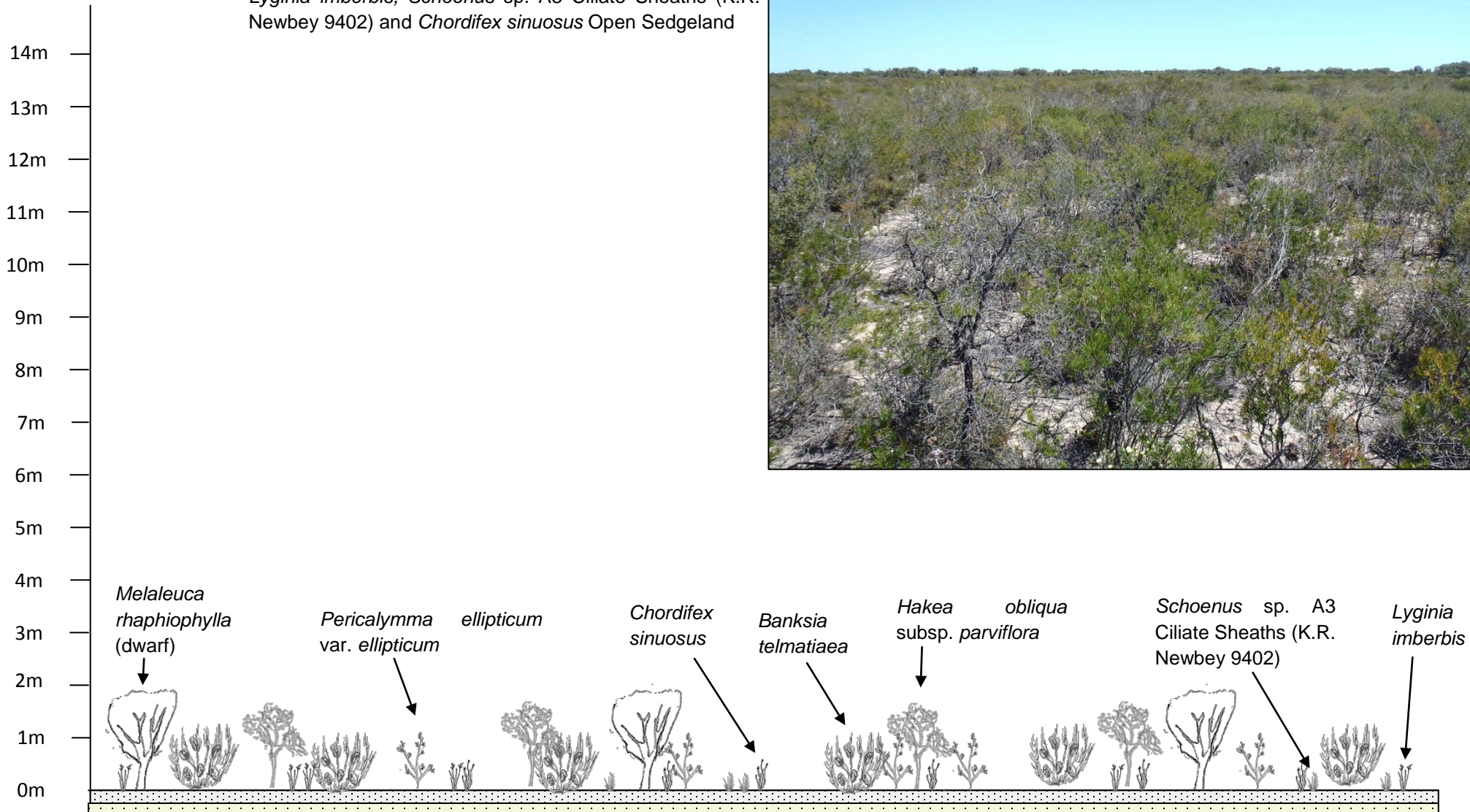


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Depth (m)	Graphic Log	Classification Symbol	Material Description	Samples Tests Remarks	PID (ppm)	Additional Observations
0		SP	SAND, fine, uniform, pale yellow-pale grey, dry.			
0.5		SP	SAND, fine to medium, poorly graded, rounded, yellow-pale grey, dry.			
1		SP	SAND, fine, uniform, yellow-pale grey, slightly moist to dry.			Contains small roots (~1mm width); friable when broken under pressure.
1.5		SP	SAND, fine to medium, dark yellow-yellow, dry.			
2		SP	SAND, fine, yellow-grey, slightly moist.			Allocthonous pisolites are present within the material.
2.5		SP-SC	SAND WITH CLAY, medium plasticity, fine to medium, yellow-mottled dark red, moist to slightly moist.			Increasingly widespread ferruginisation throughout the material, leading to increasing nodulisation; some clays contained within the sediment.
3		SP-SC	SAND WITH CLAY, medium plasticity, fine to medium, well graded, grey-mottled dark red, slightly moist.			Extensive mottling & some nodulisation (ferruginous); contains small white crystalline structures throughout.
3.5			Borehole B08 terminated at 3.5m			
4						

**A07 Transect 5**

**T5 117m** – Scattered *Melaleuca raphiophylla* (dwarf) over *Banksia telmatiaea*, *Hakea obliqua* subsp. *parviflora* and *Pericalymma ellipticum* var. *ellipticum* Shrubland over *Lyginia imberbis*, *Schoenus* sp. A3 Ciliate Sheaths (K.R. Newbey 9402) and *Chordifex sinuosus* Open Sedgeland



Depth (m)	Graphic Log	Classification Symbol	Material Description	Samples Tests Remarks	PID (ppm)	Additional Observations
0.0 - 0.1	[Dotted pattern]	SP	SAND, fine, uniform, white-pale grey, dry.			Contains fine roots in the top 0.1m; fibrous
0.1 - 0.5	[Dotted pattern]	SM	SAND, fine to medium, poorly graded, yellow-grey, slightly moist.			Contains some fine root material.
0.5 - 1.0			Borehole A07 terminated at 0.5m			

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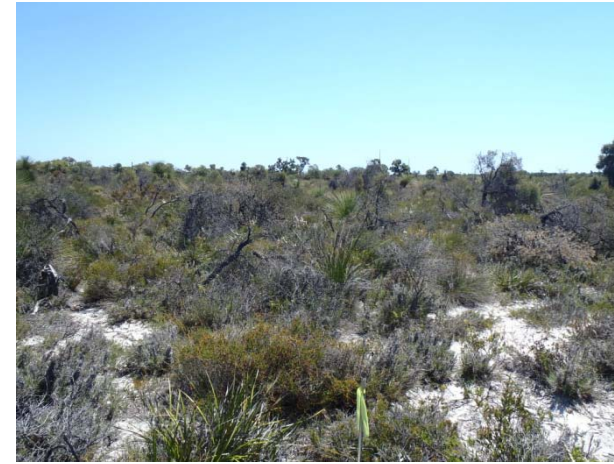
TRANSECT 6



Community 1: *Allocasuarina humilis*, *Calothamnus quadrifidus* subsp. *angustifolius* and *Hakea trifurcata* Open Heath



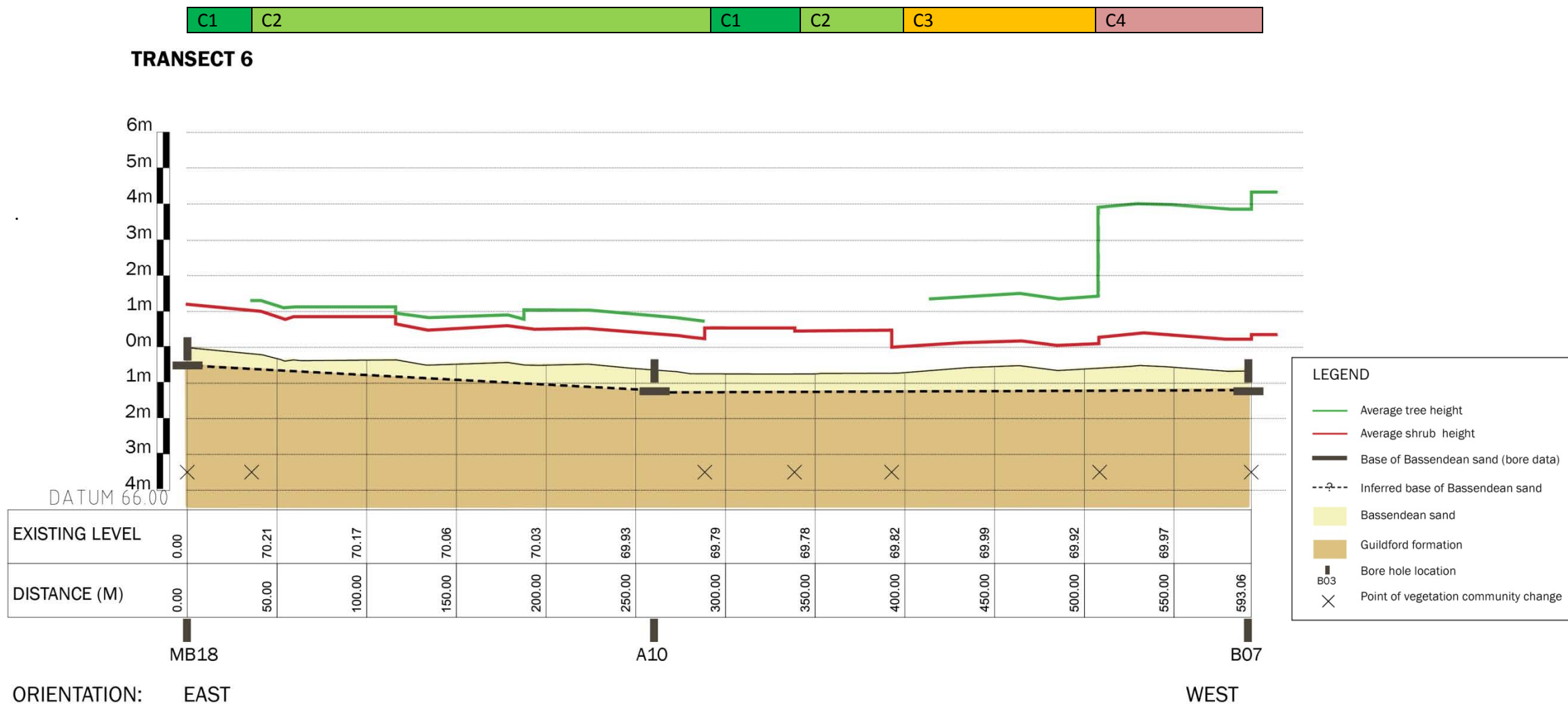
Community 2: *Melaleuca rhapsiophylla* (dwarf) Tall Scrub over *Banksia telmatiaea* and *Melaleuca seriata* Closed Heath over *Chordifex sinuosus* Very Open Sedgeland



Community 3: Scattered *Banksia attenuata* over Scattered *Xanthorrhoea preissii* over *Eremaea pauciflora* var. ? *pauciflora* and *Allocasuarina humilis* Low Shrubland over *Patersonia occidentalis* and *Dasypogon bromeliifolius* Very Open Herbland with *Mesomelaena pseudostygia* and *Schoenus* sp. A3 Ciliate Sheaths (K.R. Newbey 9402) Very Open Sedgeland



Community 4: Scattered *Banksia attenuata*, *Banksia menziesii* and *Nuytsia floribunda* over Scattered *Xanthorrhoea preissii* over *Eremaea pauciflora* var. ? *pauciflora*, *Hibbertia hypericoides* and *Allocasuarina humilis* Shrubland over *Dasypogon bromeliifolius* Very Open Herbland

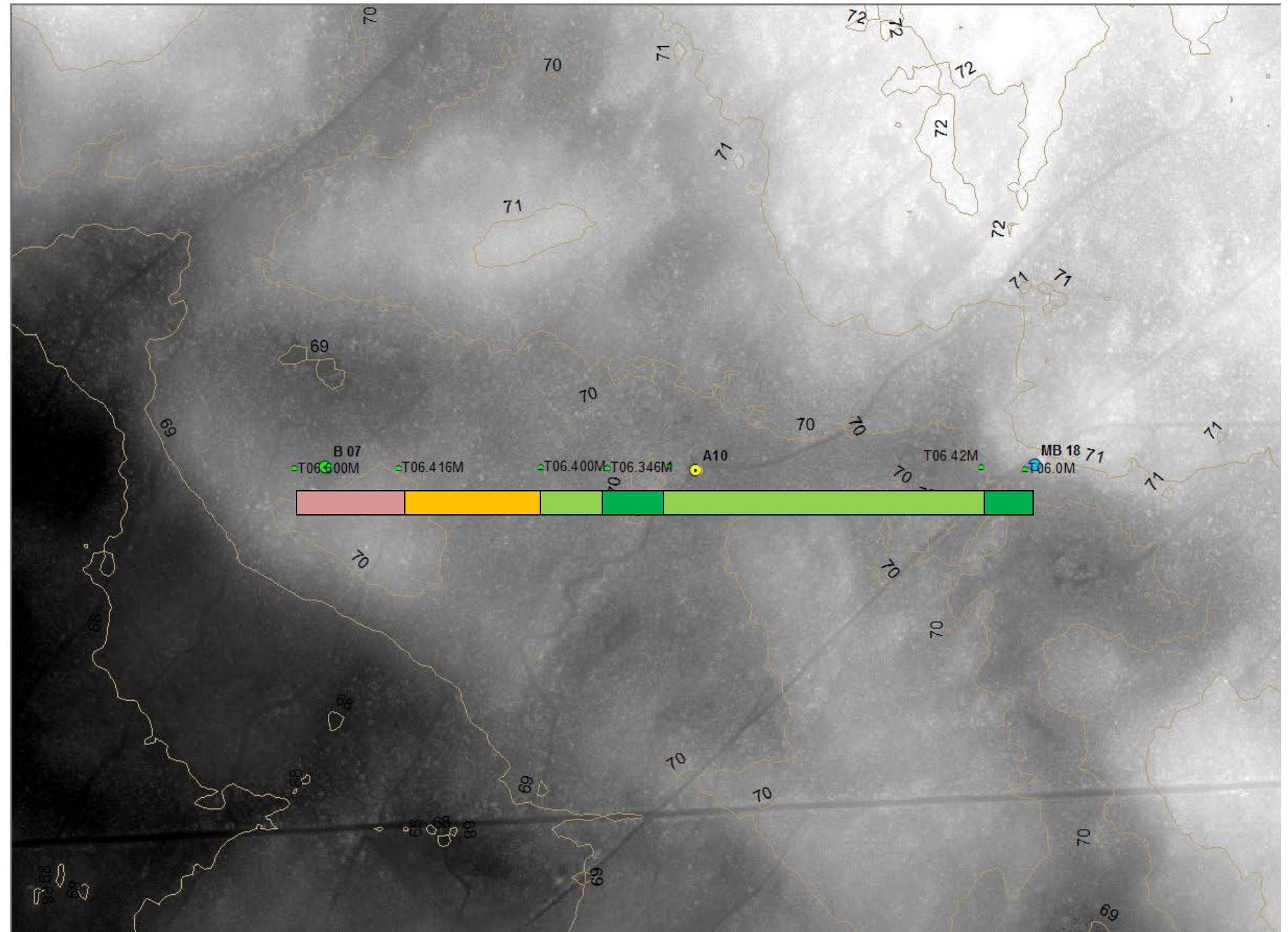


COMMUNITY 1	
Family	Species
Casuarinaceae	<i>Allocasuarina ?lehmanniana</i>
Casuarinaceae	<i>Allocasuarina humilis</i>
Proteaceae	<i>Banksia telmatiaea</i>
Myrtaceae	<i>Calothamnus quadrifidus subsp. angustifolius</i>
Dasyopogonaceae	<i>Dasyopogon bromeliifolius</i>
Proteaceae	<i>Hakea trifurcata</i>
Myrtaceae	<i>Melaleuca seriata</i>
Cyperaceae	<i>Mesomelaena pseudostygia</i>

COMMUNITY 2	
Family	Species
Proteaceae	<i>Banksia telmatiaea</i>
Restionaceae	<i>Chordifex sinuosus</i>
Myrtaceae	<i>Melaleuca raphiophylla</i>
Myrtaceae	<i>Melaleuca seriata</i>

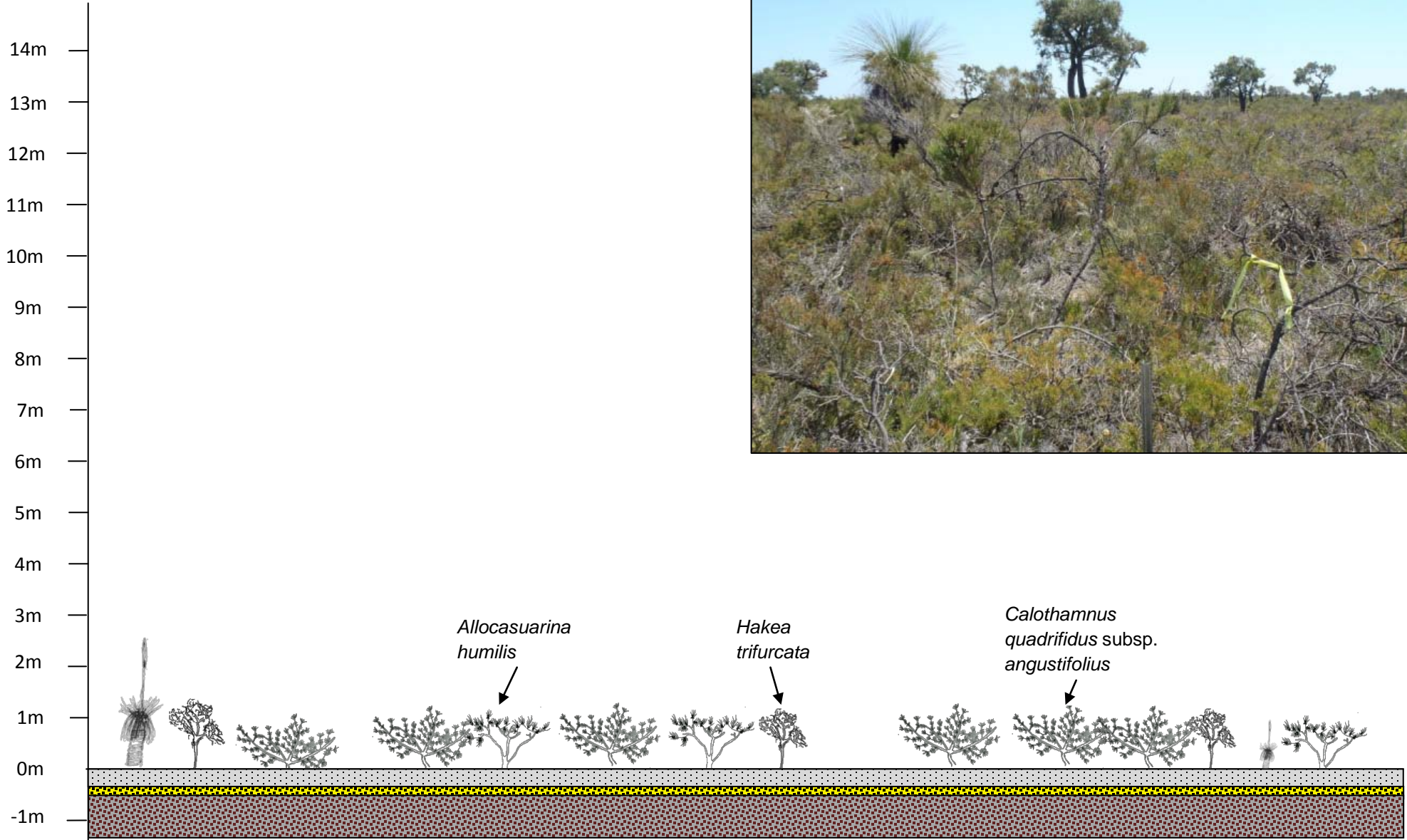
COMMUNITY 3	
Family	Species
Cyperaceae	<i>Mesomelaena pseudostygia</i>
Iridaceae	<i>Patersonia occidentalis</i>
Cyperaceae	<i>Schoenus sp. A3 Ciliate Sheaths (K.R. Newbey 9402)</i>

COMMUNITY 4	
Family	Species
Casuarinaceae	<i>Allocasuarina humilis</i>
Myrtaceae	<i>Calothamnus quadrifidus subsp. angustifolius</i>
Dasyopogonaceae	<i>Dasyopogon bromeliifolius</i>
Myrtaceae	<i>Eremaea pauciflora var. ? pauciflora</i>
Fabaceae	<i>Gastrolobium oxylobioides</i>
Dilleniaceae	<i>Hibbertia hypericoides</i>
Myrtaceae	<i>Melaleuca ?clavifolia</i>
Xanthorrhoeaceae	<i>Xanthorrhoea preissii</i>



# MB18 Transect 6

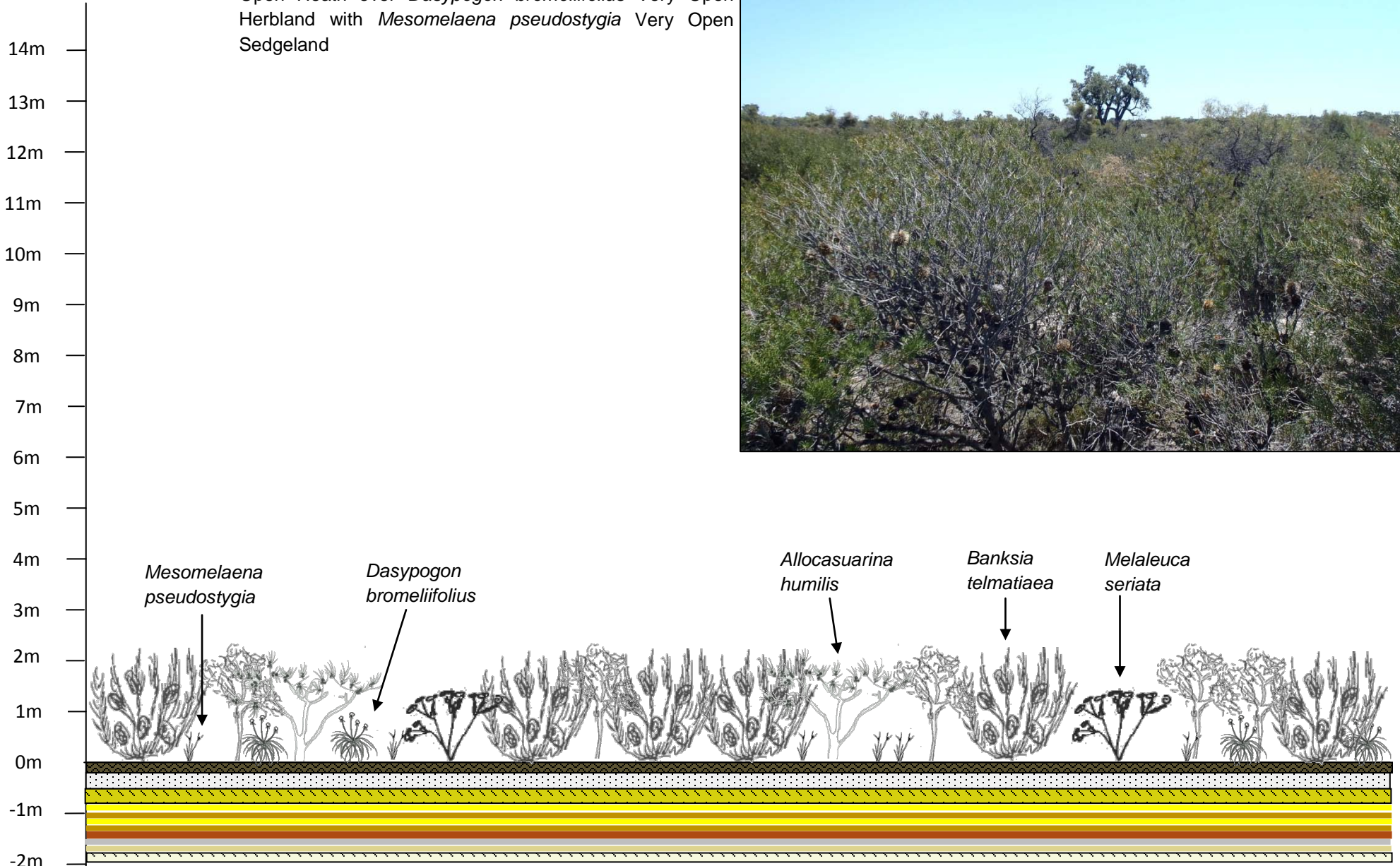
T6 0m *Allocasuarina humilis*, *Calothamnus quadrifidus* subsp. *angustifolius* and *Hakea trifurcata* Open Heath



B O R E  L O G  D E S C R I P T I O N	Depth (m)	Graphic Log	Classification Symbol	Material Description	Samples Tests Remarks	PID (ppm)	Additional Observations
				SP-SM	SAND, fine, uniform, pale grey-brown, dry.		
			CL	SANDY CLAY, high plasticity, fine to medium, poorly graded, dark yellow-brown, moist			Contains some roots (~3mm wide and 30mm long) Extensively ferruginised and mottled
			CL	SANDY CLAY, medium plasticity, fine to medium, poorly graded, grey-mottled dark red, slightly moist to moist.			
	1			Borehole MB18 terminated at 1.1m			

**A10 Transect 6**

**T6 300m-** *Banksia telmatiaea*, *Hakea trifurcata* and *Allocasuarina humilis* Tall Open Scrub Over *Allocasuarina* ? *lehmanniana*, *Melaleuca seriata* and *Hakea trifurcata*  
 Open Heath over *Dasypogon bromeliifolius* Very Open  
 Herbland with *Mesomelaena pseudostygia* Very Open  
 Sedgeland

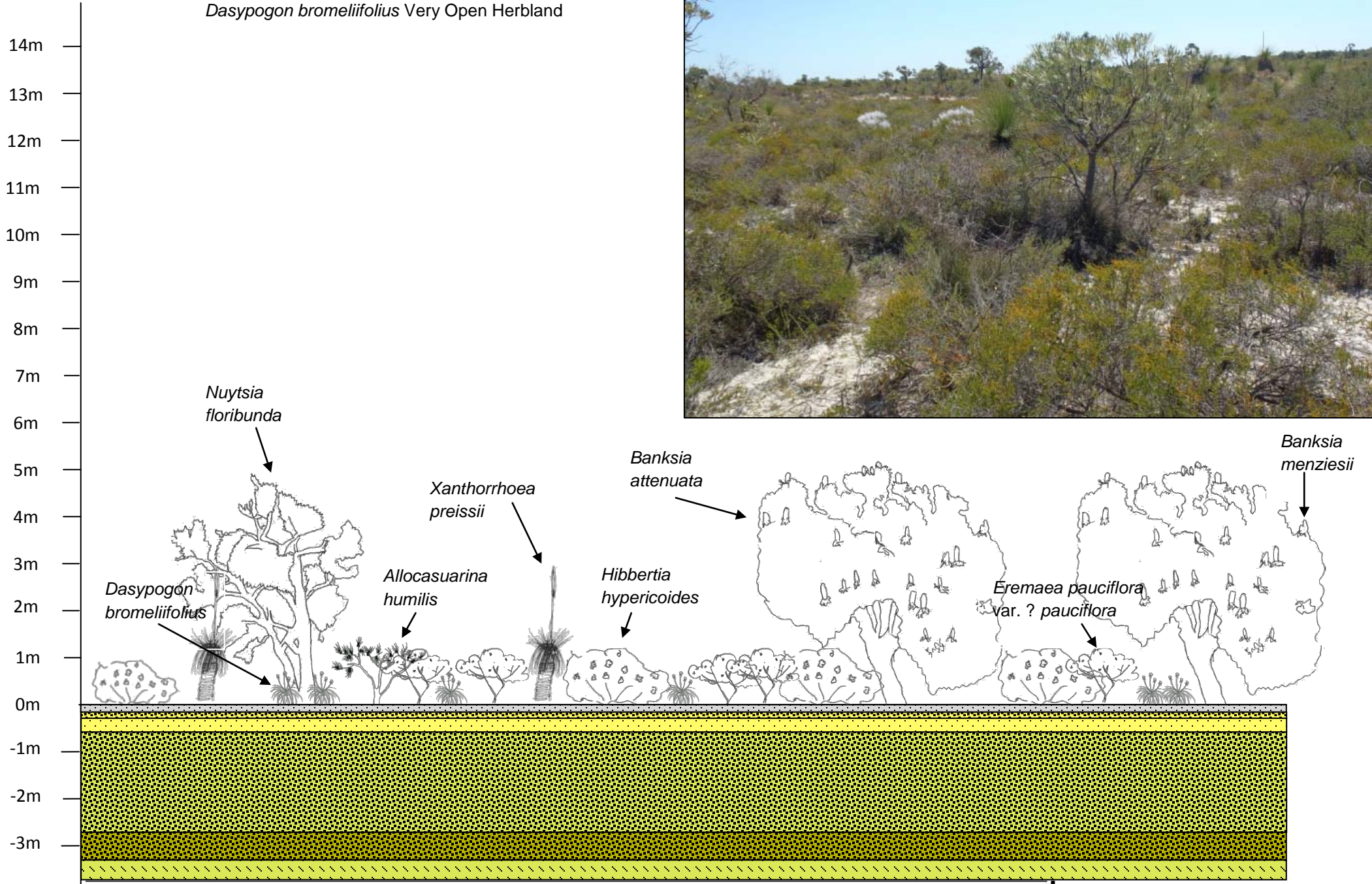


Depth (m)	Graphic Log	Classification Symbol	Material Description	Samples Tests Remarks	PID (ppm)	Additional Observations
0		SP	TOPSOIL, fine to medium, poorly graded, brown, slightly moist to dry.			
0			SAND, fine, uniform, pale grey-white, moist.			
0.5		SP-SC	SAND WITH CLAY, high plasticity, fine, poorly graded, pale yellow-brown, moist.			Material is partially ferruginised in places (resulting in a dark-red colouring); also contains fine root material throughout the layer, and small white crystalline structures sparsely across the layer.
1		SP	SAND, coarse, uniform, yellow, moist.			
1		CL	SANDY CLAY, high plasticity, fine, poorly graded, pale yellow-brown, moist.			
1		SP	SAND, coarse, uniform, yellow, moist.			
1		SP-SC	SAND WITH CLAY, high plasticity, fine, poorly graded, pale yellow-brown, moist.			
1		SP-SC	SAND WITH CLAY, medium plasticity, fine, poorly graded, yellow-red, moist to slightly moist.			
1		SC	CLAYEY SAND, high plasticity, medium, poorly graded, grey, slightly moist.			
1		SP-SC	SAND WITH CLAY, medium plasticity, fine to medium, poorly graded, grey-yellow, slightly moist.			
1		SP-SC	SAND WITH CLAY, medium plasticity, fine to medium, poorly graded, grey-yellow, slightly moist.			
2			Borehole A10 terminated at 2m			
3						Material is partially ferruginised in places (resulting in a dark-red colouring); also contains fine root material throughout the layer, and small white crystalline structures sparsely across the layer.
4						Material is partially ferruginised in places (resulting in a dark-red colouring); also contains fine root material throughout the layer, and small white crystalline structures sparsely across the layer.
5						Contains fine root material throughout the layer, some ferruginisation across the layer.
6						Contains fine root material throughout the layer. Contains some clay within the layer.

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**B07 Transect 6**

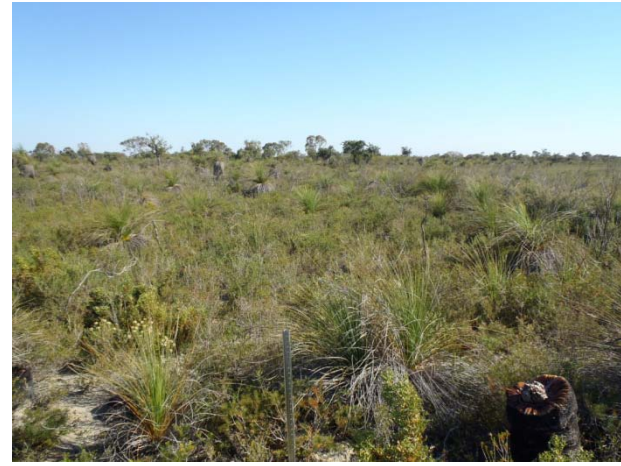
**T6 416m-** Scattered *Banksia attenuata*, *Banksia menziesii* and *Nuytsia floribunda* over Scattered *Xanthorrhoea preissii* over *Eremaea pauciflora* var. ? *pauciflora*, *Hibbertia hypericoides* and *Allocasuarina humilis* Shrubland over *Dasygogon bromeliifolius* Very Open Herbland



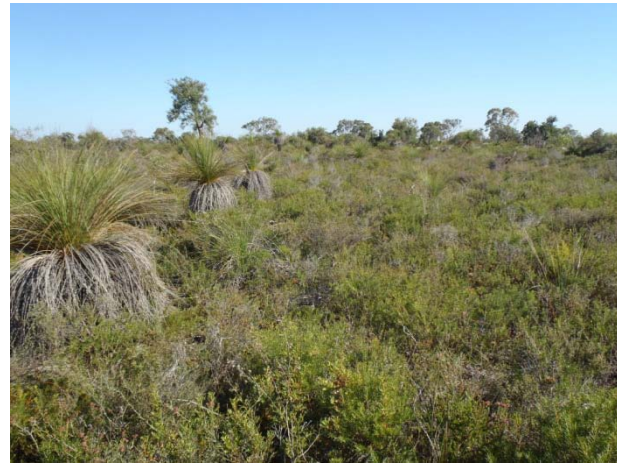
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Depth (m)	Graphic Log	Classification Symbol	Material Description	Samples Tests Remarks	PID (ppm)	Additional Observations
0.0 - 0.2	[Dotted pattern]	SP-SM	SAND, fine, uniform, pale grey-brown, dry.			
0.2 - 0.5	[Dotted pattern]	SC	SANDY CLAY, high plasticity, fine to medium, poorly graded, dark yellow-brown, slightly moist.			Contains some fine roots (~1mm width)
0.5 - 1.0	[Dotted pattern]	SM	SAND, medium, yellow, slightly moist.			
1.0 - 2.8	[Dotted pattern]	SM	SANDY CLAY, low plasticity, fine to medium, poorly graded, pale grey-yellow, slightly moist.			Extensive ferruginisation throughout.
2.8 - 3.2	[Dotted pattern]	GM	SANDY CLAY, low plasticity, medium, yellow-dark grey, dry.			Contains small white crystalline structures (approximately 2mm*3 in size) throughout the material.
3.2 - 3.5	[Dotted pattern]	SP-SC	SAND WITH CLAY, low plasticity, medium, poorly graded, pale grey-yellow, slightly moist.			Extensive ferruginisation throughout.
3.5 - 4.0	[Dotted pattern]		Borehole B07 terminated at 3.5m			

TRANSECT 7



Community 1: Scattered *Xanthorrhoea preissii* over *Banksia armata*, *Banksia telmatiaea* and *Melaleuca seriata* Open Low Heath over *Lepidosperma longitudinale* Very Open Sedgeland.



Community 2: Scattered *Xanthorrhoea preissii* over *Banksia telmatiaea*, *Calothamnus quadrifidus* subsp. *angustifolius* and *Melaleuca seriata* Closed Low Heath



Community 3: *Eucalyptus tottiana* Very Open Shrub Mallee with Scattered *Banksia attenuata* *Calothamnus quadrifidus* subsp. *angustifolius*, *Hibbertia hypericoides* and *Acacia pulchella* Open Heath



Community 4: Scattered *Eucalyptus rudis* over *Chamelaucium uncinatum* Closed Tall Scrub



Community 5: *Acacia saligna* subsp. *lindleyi*, *Regelia ciliata* and *Exocarpos sparteus* Closed Tall Scrub over *Schoenus subfascicularis* Very Open Sedgeland



Community 6: *Eucalyptus rudis* and *Melaleuca raphiophylla* Open Forest over Scattered *Acacia saligna* subsp. *lindleyi* and *Exocarpos sparteus*



Community 7: Open Woodland of *Melaleuca raphiophylla* over *Acacia saligna* subsp. *lindleyi* Tall Shrubland over *Banksia telmatiaea* and *Verticordia densiflora* var. *densiflora* Shrubland



Community 8: Scattered *Melaleuca raphiophylla* (dwarf) and *Acacia saligna* subsp. *lindleyi* over *Banksia telmatiaea* and *Verticordia densiflora* var. *densiflora* Open Heath



Community 9: Scattered *Acacia saligna* subsp. *lindleyi* over *Hakea obliqua* subsp. *parviflora*, *Banksia telmatiaea*, *Astartea ? scoparia* and *Verticordia densiflora* var. *densiflora* Open Low Heath



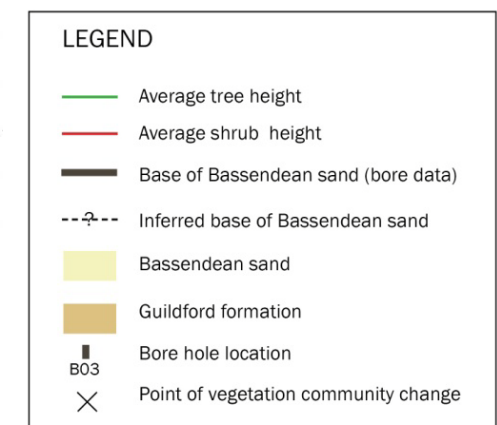
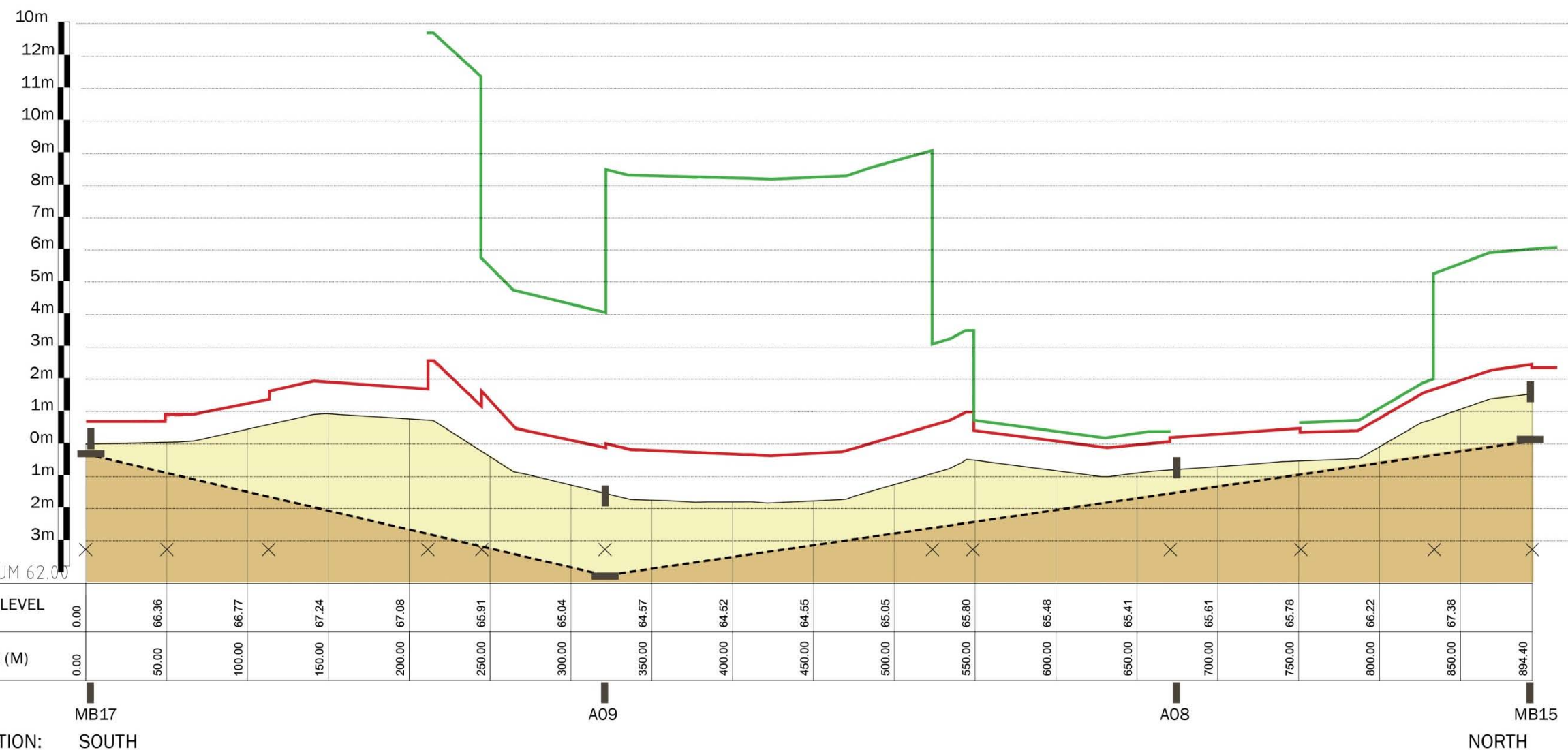
Community 10: *Melaleuca teretifolia* and *Pericalymma ellipticum* var. *ellipticum* Tall Open Shrubland over *Banksia telmatiaea* and *Astartea ? scoparia* Closed Heath



Community 11: *Eucalyptus tottiana* Very Open Tree Mallee with Scattered *Banksia attenuata* over Scattered *Jacksonia sternbergiana* over *Eremaea pauciflora* var. ? *pauciflora* and *Jacksonia foliosa* Open Heath over *Dasyopogon bromeliifolius* Very Open Herbland



**TRANSECT 7**



DATUM 62.00

MB17

A09

A08

MB15

ORIENTATION: SOUTH

NORTH

COMMUNITY 1	
Myrtaceae	<i>Astartea ?scoparia</i>
Proteaceae	<i>Banksia armata</i>
Proteaceae	<i>Banksia telmatiaea</i>
Cyperaceae	<i>Lepidosperma longitudinale</i>
Myrtaceae	<i>Melaleuca seriata</i>
Xanthorrhoeaceae	<i>Xanthorrhoea preissii</i>

COMMUNITY 2	
Family	Species
Fabaceae	<i>Acacia pulchella</i>
Myrtaceae	<i>Astartea ?scoparia</i>
Proteaceae	<i>Banksia telmatiaea</i>
Myrtaceae	<i>Calothamnus quadrifidus subsp. angustifolius</i>
Myrtaceae	<i>Melaleuca seriata</i>
Proteaceae	<i>Petrophile brevifolia</i>
Xanthorrhoeaceae	<i>Xanthorrhoea preissii</i>

COMMUNITY 3	
Family	Species
Fabaceae	<i>Acacia pulchella</i>
Myrtaceae	<i>Calothamnus quadrifidus subsp. angustifolius</i>
Myrtaceae	<i>Eucalyptus tottiana</i>
Dilleniaceae	<i>Hibbertia hypericoides</i>

COMMUNITY 4	
Family	Species
Myrtaceae	<i>Chamelaucium uncinatum</i>

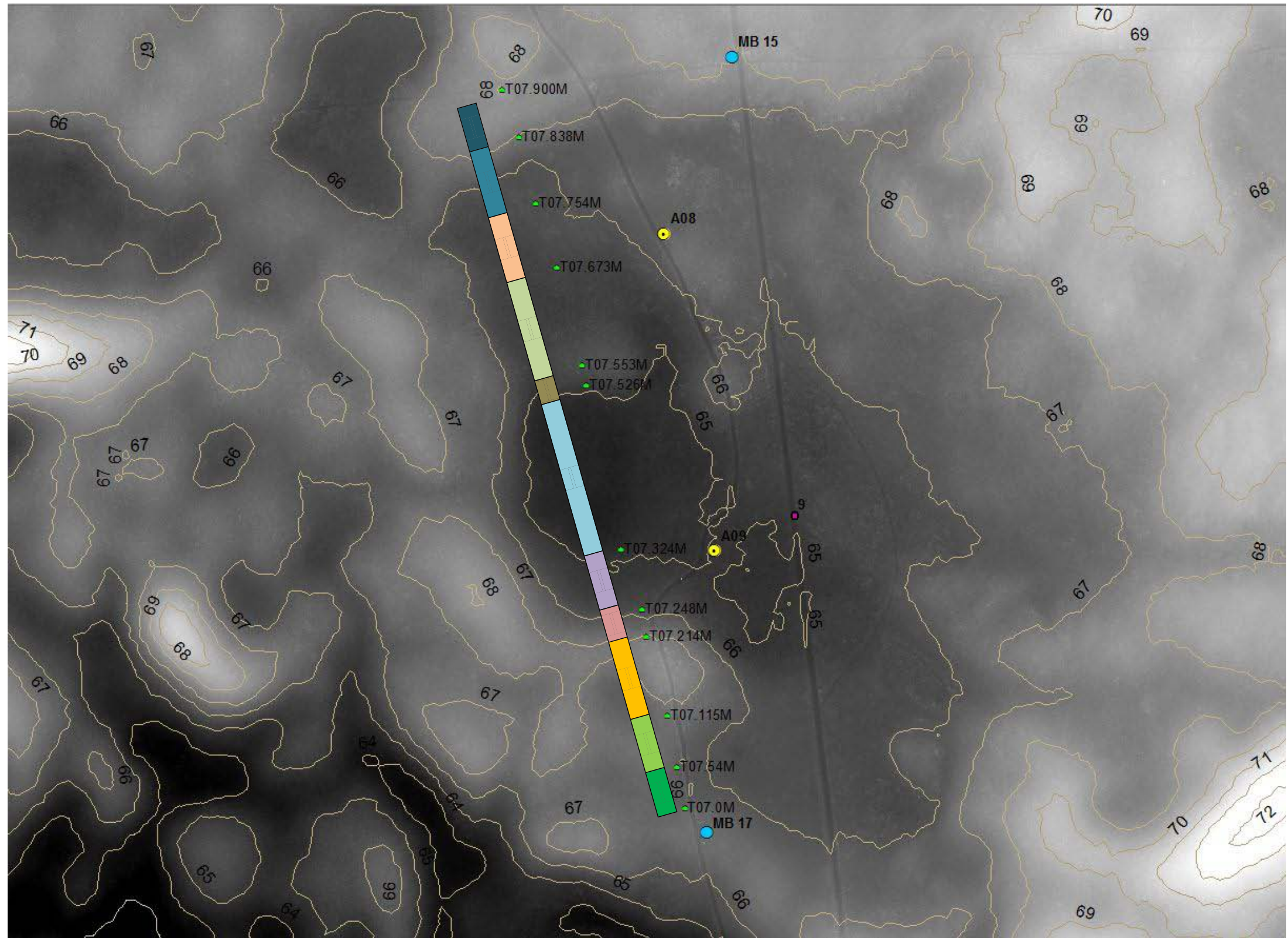
COMMUNITY 5	
Family	Species
Fabaceae	<i>Acacia saligna subsp. lindleyi</i>
Santalaceae	<i>Exocarpos sparteus</i>
Myrtaceae	<i>Regelia ciliata</i>
Cyperaceae	<i>Schoenus subfascicularis</i>

COMMUNITY 6	
Family	Species
Myrtaceae	<i>Eucalyptus rudis</i>
Santalaceae	<i>Exocarpos sparteus</i>
Myrtaceae	<i>Melaleuca raphiophylla</i>

COMMUNITY 7	
Family	Species
Fabaceae	<i>Acacia saligna subsp. lindleyi</i>
Myrtaceae	<i>Melaleuca raphiophylla</i>

COMMUNITY 8	
Family	Species
Proteaceae	<i>Banksia telmatiaea</i>
Myrtaceae	<i>Melaleuca raphiophylla</i>
Myrtaceae	<i>Verticordia densiflora var. densiflora</i>

COMMUNITY 9	
Family	Species
Myrtaceae	<i>Astartea ?scoparia</i>
Proteaceae	<i>Banksia telmatiaea</i>
Proteaceae	<i>Hakea obliqua subsp. parviflora</i>
Proteaceae	<i>Petrophile brevifolia</i>
Myrtaceae	<i>Verticordia densiflora var. densiflora</i>

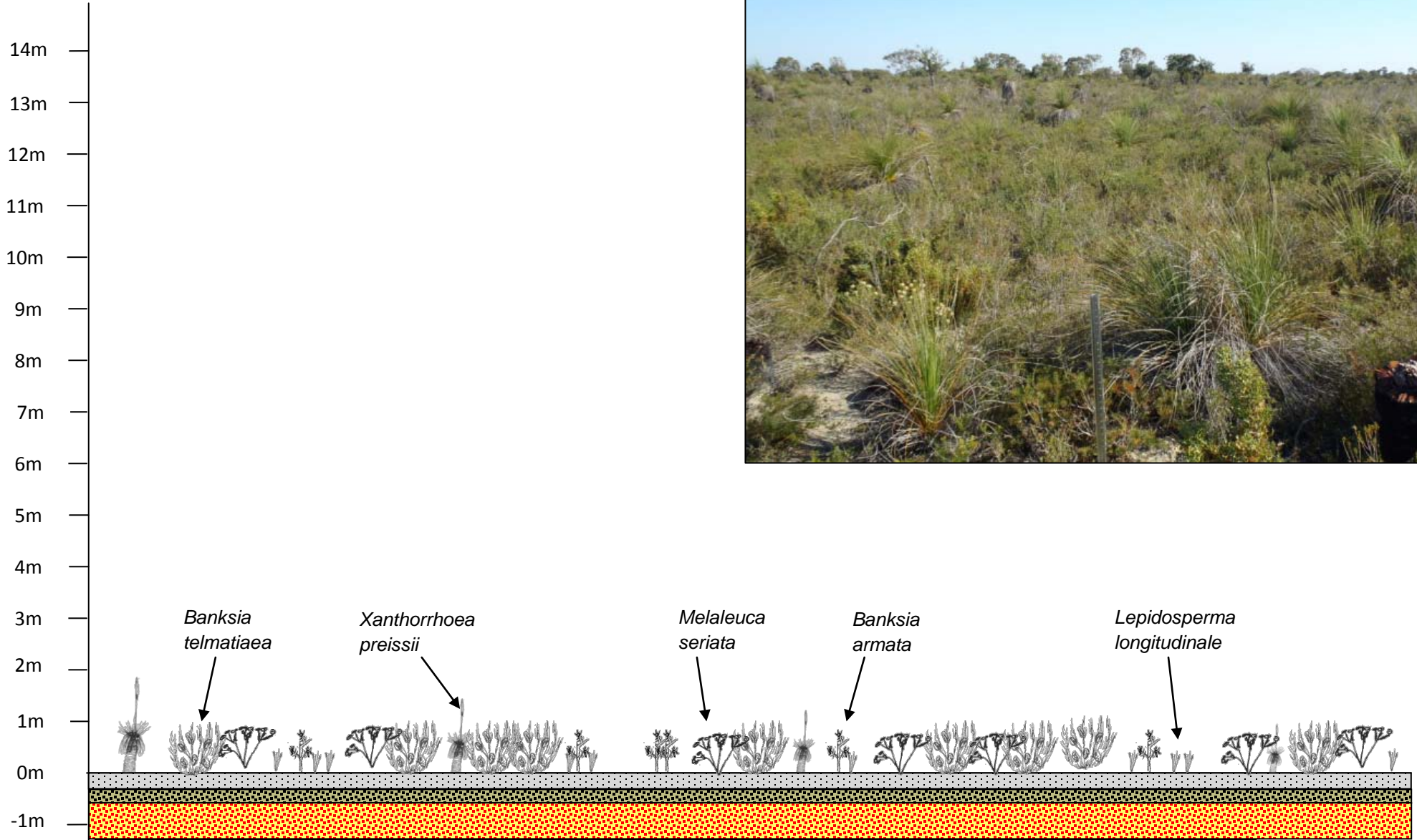
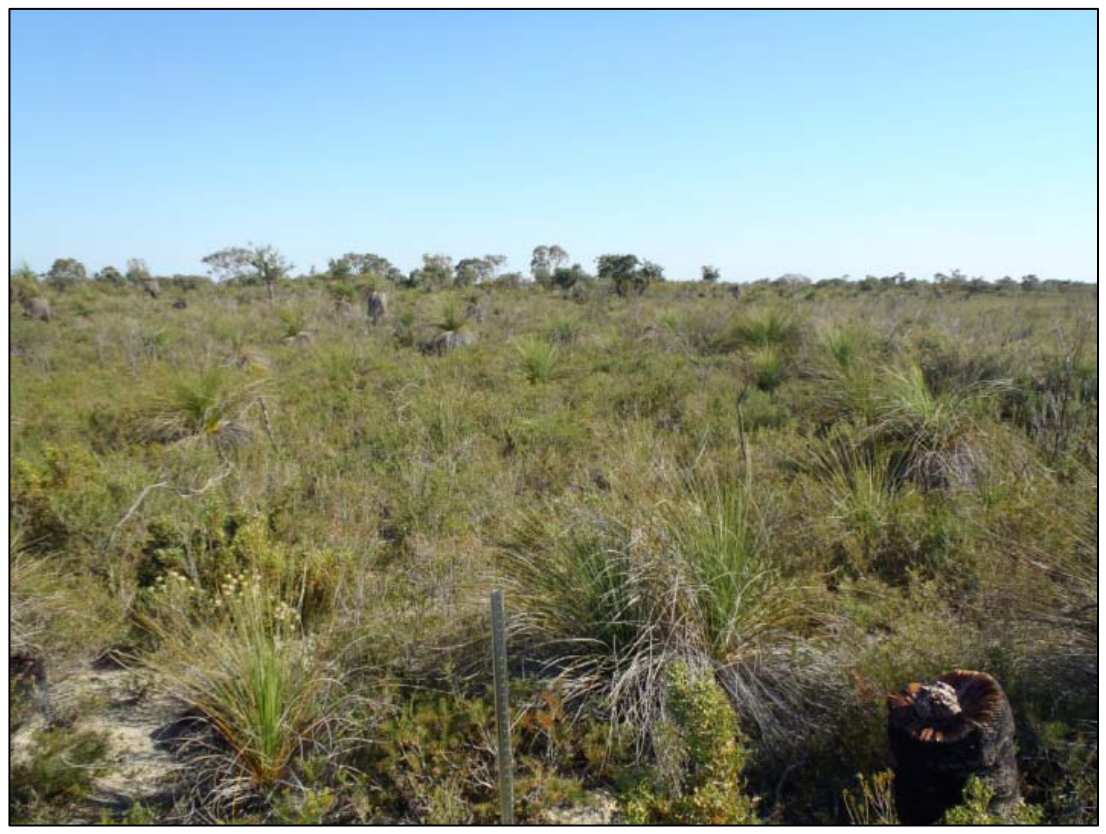


COMMUNITY 10	
Family	Species
Myrtaceae	<i>Astartea ?scoparia</i>
Proteaceae	<i>Banksia telmatiaea</i>
Myrtaceae	<i>Melaleuca teretifolia</i>
Myrtaceae	<i>Pericalymma ellipticum var. ellipticum</i>

COMMUNITY 11	
Family	Species
Dasypogonaceae	<i>Dasypogon bromeliifolius</i>
Myrtaceae	<i>Eremaea pauciflora var. ? pauciflora</i>
Myrtaceae	<i>Eucalyptus tottiana</i>
Fabaceae	<i>Jacksonia foliosa</i>
Fabaceae	<i>Jacksonia sternbergiana</i>

# MB17 Transect 7

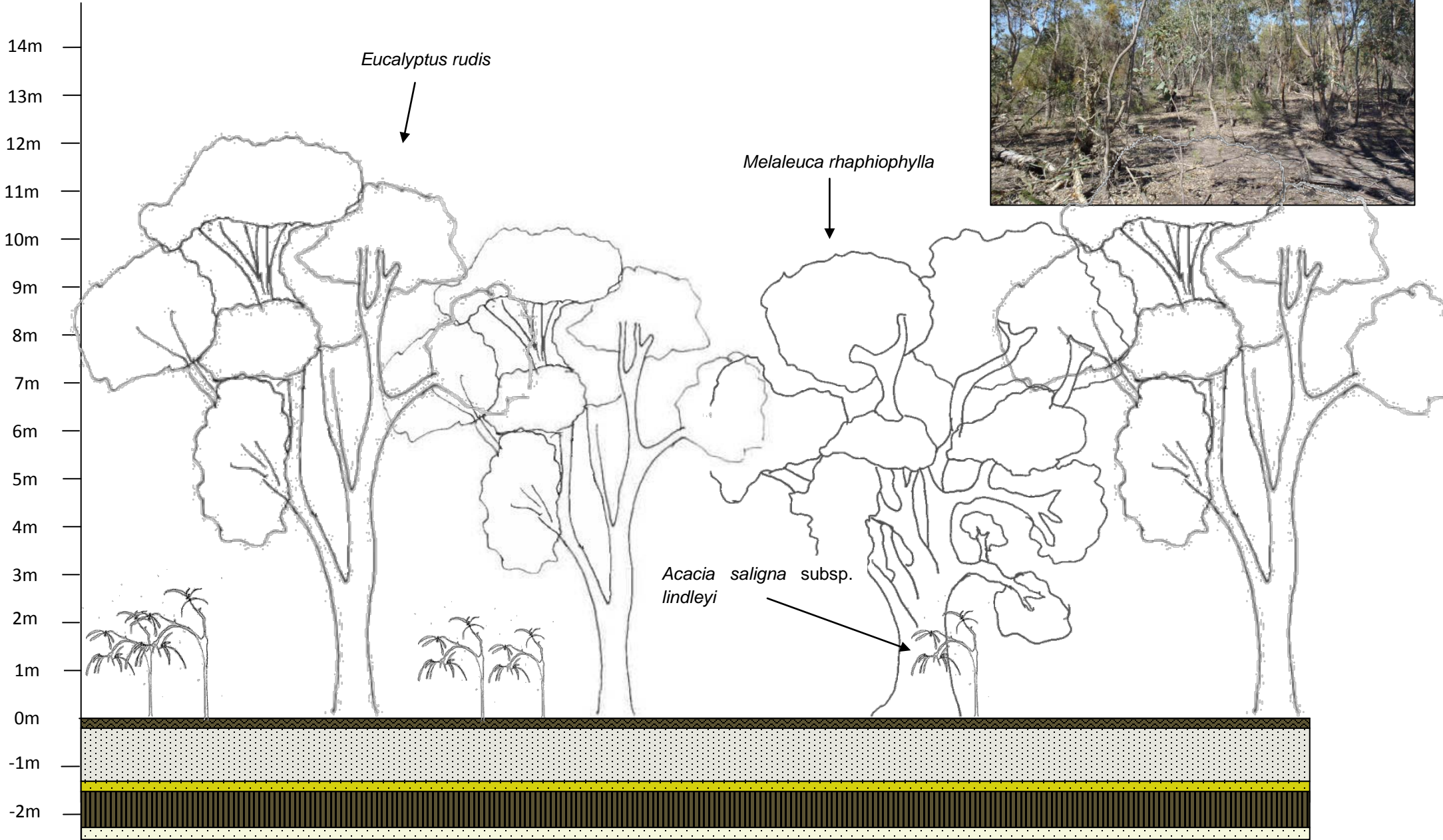
T7 0m Scattered *Xanthorrhoea preissii* over *Banksia armata*, *Banksia telmatiaea* and *Melaleuca seriata* Open Low Heath over *Lepidosperma longitudinale* Very Open Sedgeland.



B O R E  L O G  D E S C R I P T I O N	Depth (m)	Graphic Log	Classification Symbol	Material Description	Samples Tests Remarks	PID (ppm)	Additional Observations
				SP	SAND, fine, uniform, pale grey-brown, dry.		
			SP-SC	SANDY CLAY, low plasticity, fine to medium, yellow-pale grey, slightly moist.			
			SP-SC	SANDY CLAY, low plasticity, fine to medium, yellow-mottled dark red, slightly moist to dry.			
	1						Extensive ferruginisation occurring in bands; extremely friable
				Borehole MB17 terminated at 1.3m			

**A09 Transect 7**

**T7 324m** – *Eucalyptus rudis* and *Melaleuca raphiophylla*  
 Open Forest over Scattered *Acacia saligna* subsp. *lindleyi*  
 and *Exocarpos sparteus*

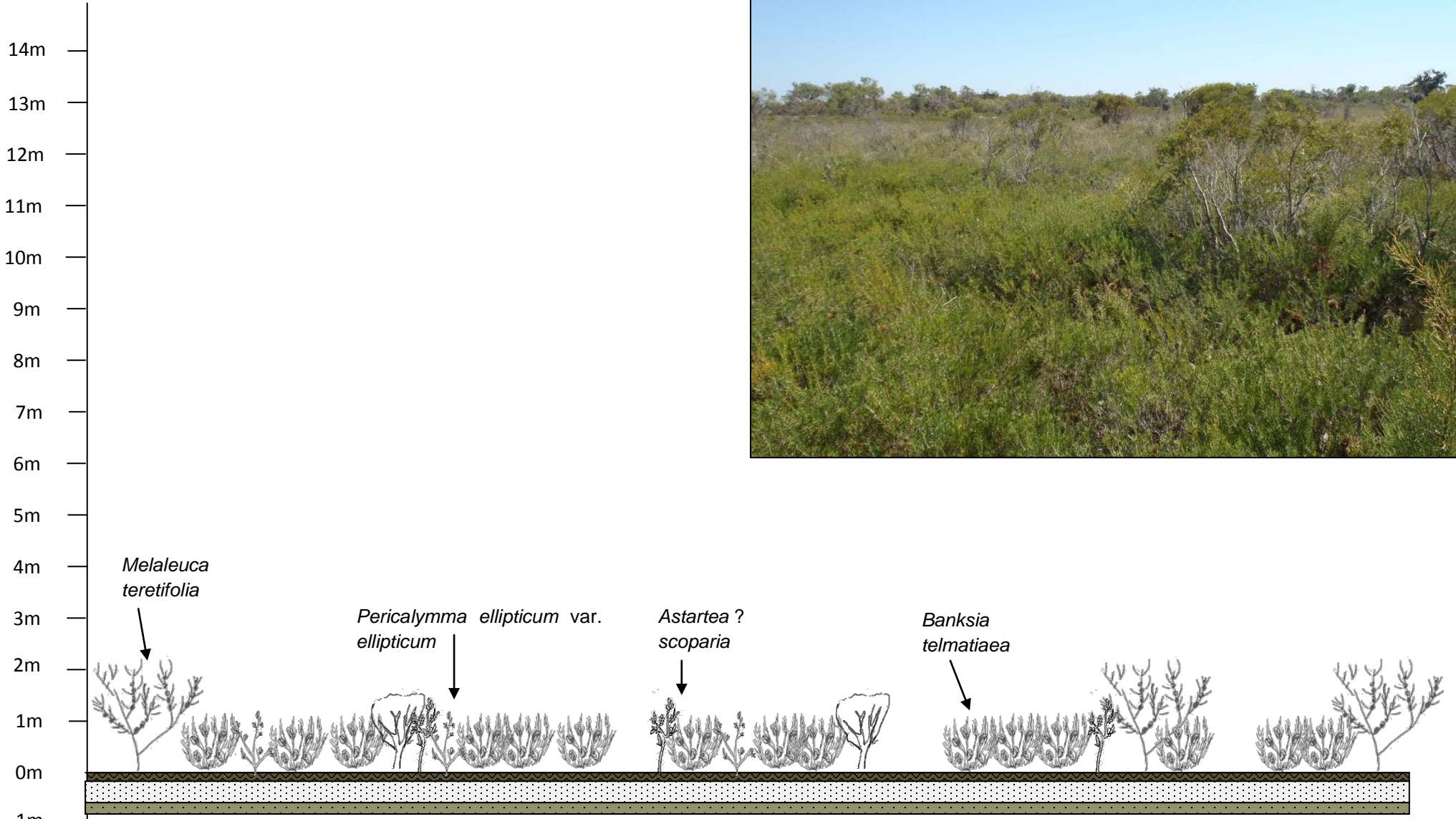


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Depth (m)	Graphic Log	Classification Symbol	Material Description	Samples Tests Remarks	PID (ppm)	Additional Observations
0			TOPSOIL, fine to medium, poorly graded, brown, slightly moist to dry.			Large amounts of fine-grained root material present throughout the layer
1		SW	SAND, fine, uniform, white-yellow, dry.			
2		SP	SAND, fine to medium, poorly graded, yellow-brown, slightly moist.			Friable under low levels of applied pressure Contains small fragments of well-cemented coarse sand (yellow/brown in colour)
2.4		SM	SILTY SAND, fine to medium, poorly graded, brown, slightly moist.			
2.4		SW	SAND, fine to medium, well graded, yellow-grey, slightly moist.			
2.4			Borehole A09 terminated at 2.4m			

**A08 Transect 7**

**T7 754m** *Melaleuca teretifolia* and *Pericalymma ellipticum* var. *ellipticum* Tall Open Shrubland over *Banksia telmatiaea* and *Astartea ? scoparia* Closed Heath



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Depth (m)	Graphic Log	Classification Symbol	Material Description	Samples Tests Remarks	PID (ppm)	Additional Observations
0.0 - 0.1	[Brown dotted pattern]		TOPSOIL, fine to medium, poorly graded, brown, dry.			
0.1 - 0.8	[White dotted pattern]	SP	SAND, fine, uniform, white-pale grey, dry.			Contains some fine root material throughout the layer.
0.8 - 1.0	[Brown dotted pattern]	SM	SAND, fine to medium, poorly graded, brown-yellow, dry.			Contains large fragments of well-cemented ferruginised silty sand.
1.0	[White dotted pattern]		Borehole A08 terminated at 0.8m			

TRANSECT 8



Community 1: *Banksia telmatiaea*, *Hypocalymma angustifolium* and *Melaleuca seriata* Closed Low Heath

Community 2: Scattered *Hakea obliqua* subsp. *parviflora* over *Regelia ciliata* Closed Heath

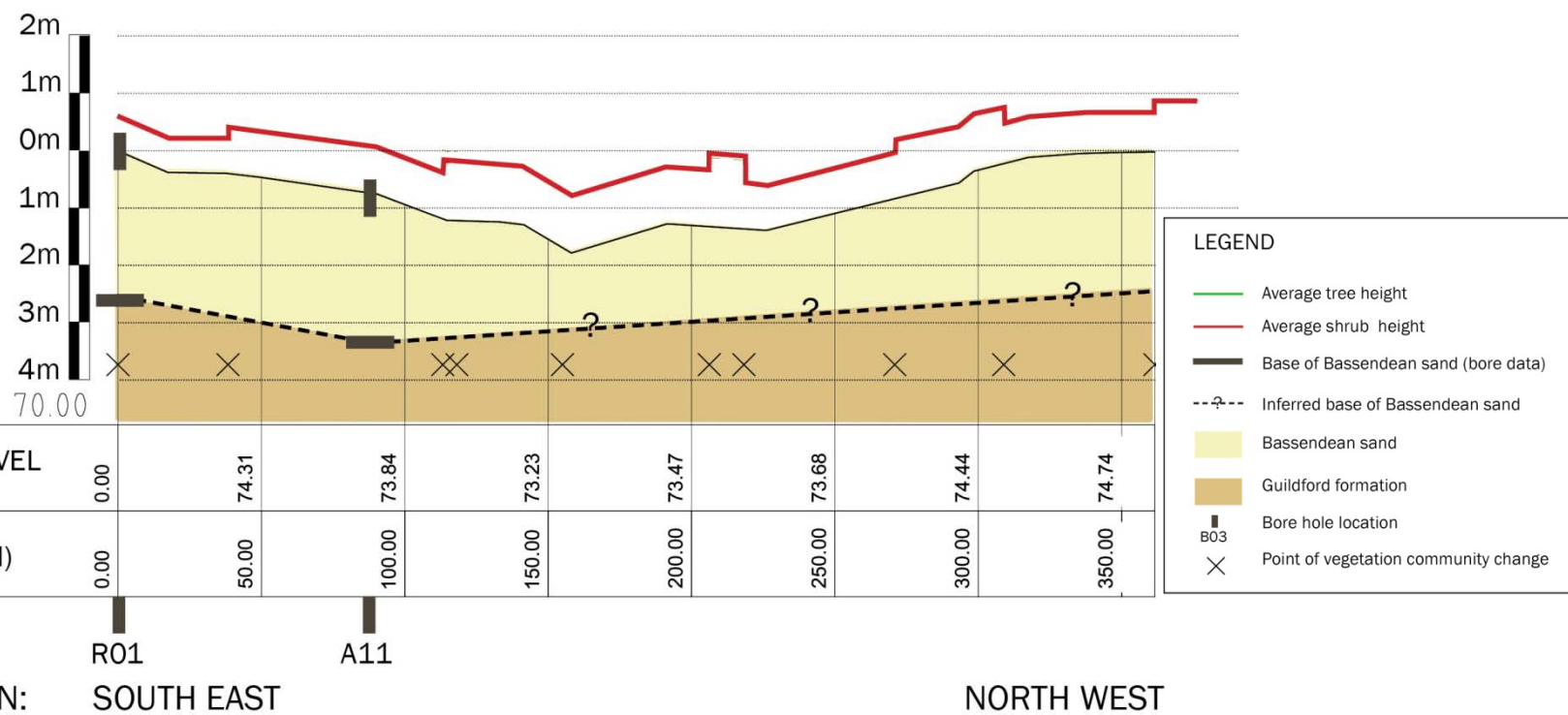
Community 3: *Melaleuca raphiophylla* (dwarf) and *Acacia saligna* subsp. *lindleyi* Tall Open Shrubland over *Banksia telmatiaea* Closed Heath over *Lepidosperma longitudinale* Very Open Sedgeland

Community 4: Scattered *Hakea obliqua* subsp. *parviflora* over *Melaleuca viminea* subsp. *viminea* and *Banksia telmatiaea* Closed Heath over Scattered *Lepidosperma longitudinale*

Community 5: Scattered *Melaleuca raphiophylla* (dwarf) over *Melaleuca teretifolia*, *Banksia telmatiaea* and *Calothamnus quadrifidus* subsp. *angustifolius* Closed Heath over *Gahnia trifida* Very Open Herbland



TRANSECT 8



Community 6: Scattered *Banksia attenuata* and *Banksia menziesii* over *Banksia telmatiaea* and *Regelia ciliata* Closed Heath over *Phlebocarya ciliata* Very Open Herbland

Community 7: Scattered *Hakea obliqua* subsp. *parviflora* over *Banksia telmatiaea* and *Calytrix ? aurea* Open Heath



Community 8: Scattered *Nuytsia floribunda* and *Xanthorrhoea preissii* over *Calothamnus quadrifidus* subsp. *angustifolius*, *Calothamnus hirsutus* and *Hibbertia hypericoides* Open Low Heath

COMMUNITY 1	
Family	Species
Proteaceae	<i>Banksia telmatiaea</i>
Myrtaceae	<i>Calothamnus hirstus</i>
Myrtaceae	<i>Hypocalymma angustifolium</i>
Myrtaceae	<i>Melaleuca seriata</i>

COMMUNITY 2	
Family	Species
Proteaceae	<i>Hakea obliqua subsp. parviflora</i>
Myrtaceae	<i>Regelia ciliata</i>

COMMUNITY 3	
Family	Species
Fabaceae	<i>Acacia saligna subsp. lindleyi</i>
Proteaceae	<i>Banksia telmatiaea</i>
Cyperaceae	<i>Lepidosperma longitudinale</i>
Myrtaceae	<i>Melaleuca raphiophylla</i>

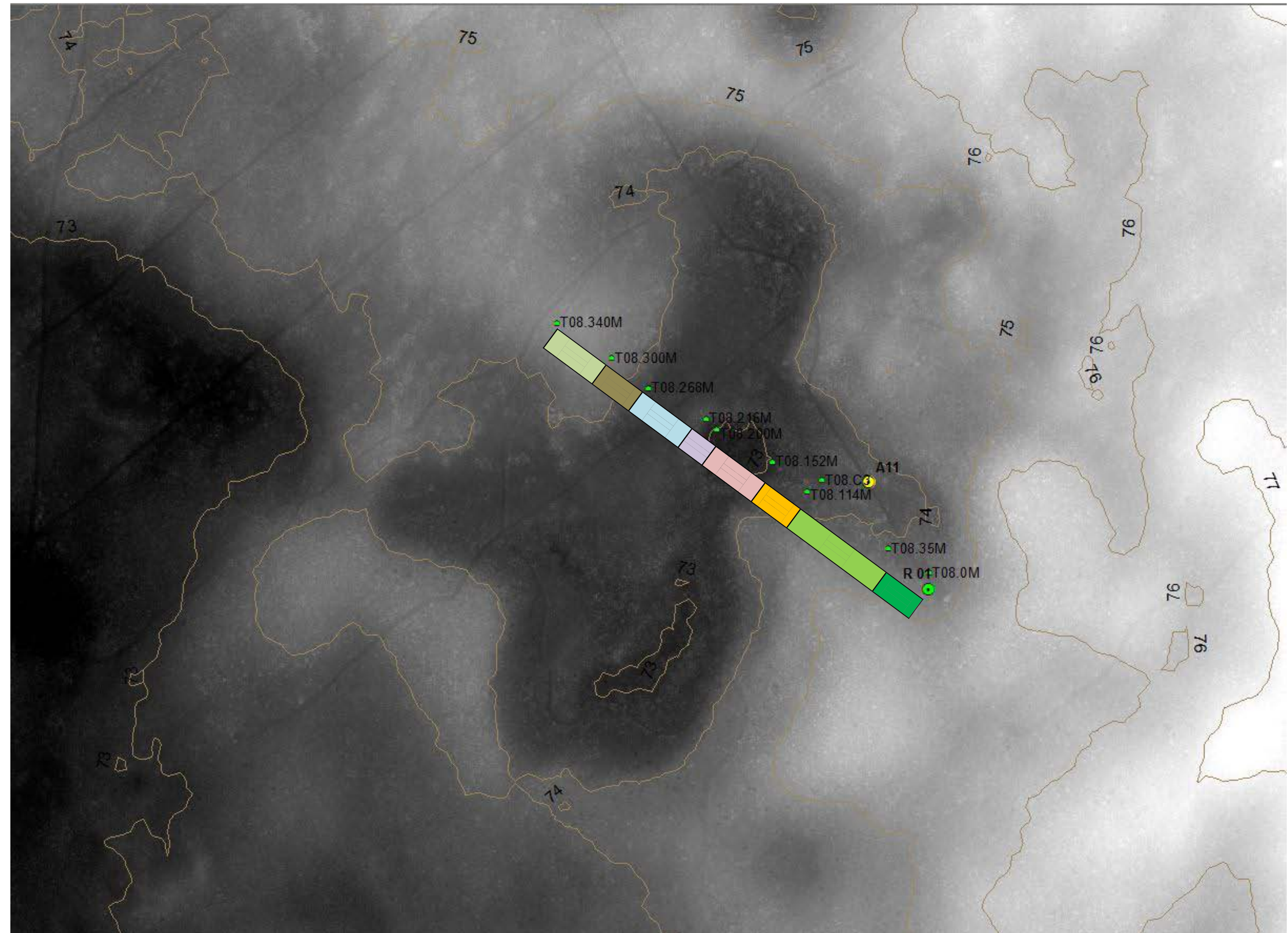
COMMUNITY 4	
Family	Species
Proteaceae	<i>Banksia telmatiaea</i>
Proteaceae	<i>Hakea obliqua subsp. parviflora</i>
Myrtaceae	<i>Melaleuca viminea subsp. viminea</i>

COMMUNITY 5	
Family	Species
Proteaceae	<i>Banksia telmatiaea</i>
Myrtaceae	<i>Calothamnus quadrifidus subsp. angustifolius</i>
Cyperaceae	<i>Gahnia trifida</i>
Myrtaceae	<i>Melaleuca raphiophylla</i>
Myrtaceae	<i>Melaleuca teretifolia</i>

COMMUNITY 6	
Family	Species
Proteaceae	<i>Banksia telmatiaea</i>
Haemodoraceae	<i>Phlebocarya ciliata</i>
Myrtaceae	<i>Regelia ciliata</i>

COMMUNITY 7	
Family	Species
Proteaceae	<i>Banksia telmatiaea</i>
Myrtaceae	<i>Calytrix ?aurea</i>

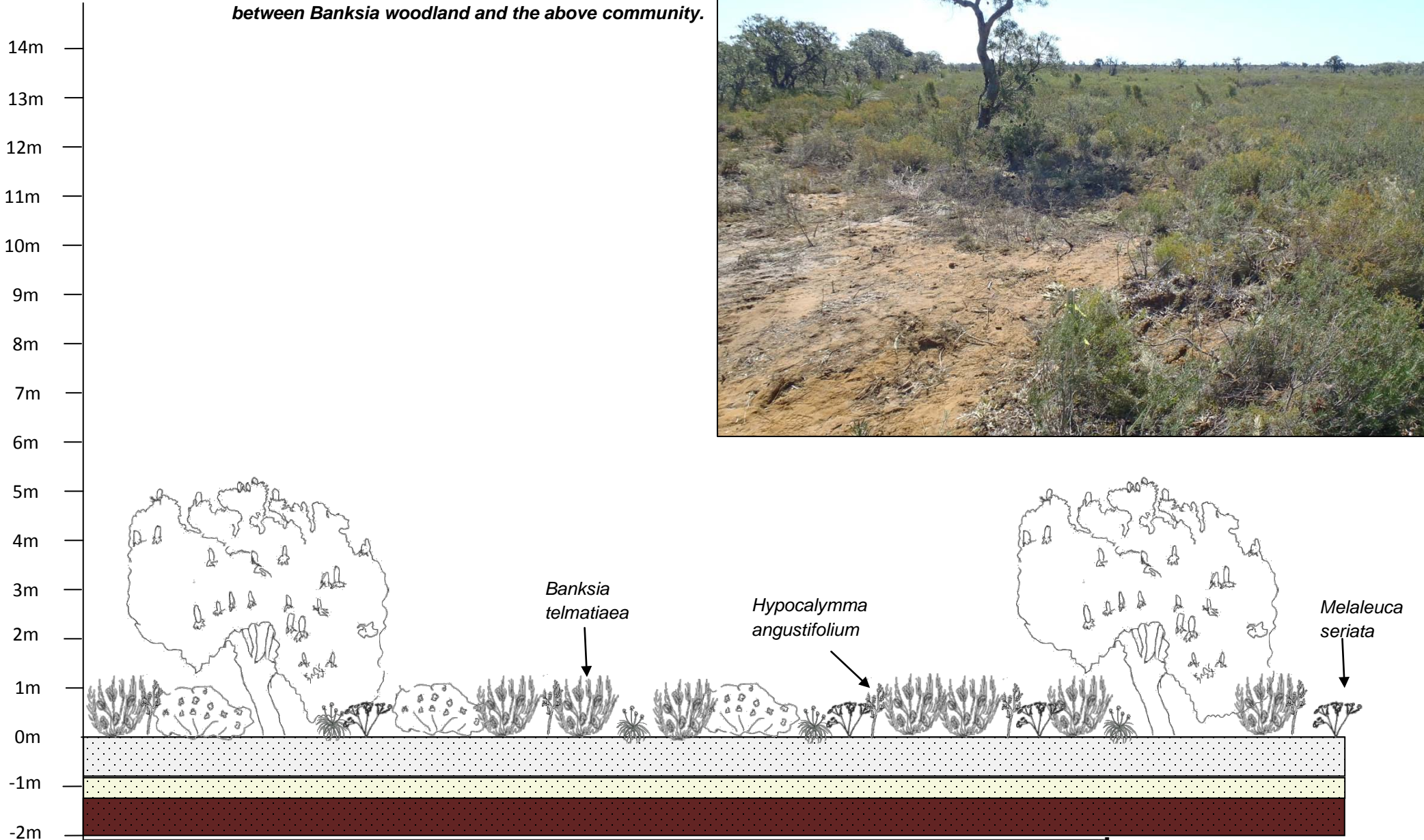
COMMUNITY 8	
Family	Species
Myrtaceae	<i>Calothamnus hirstus</i>
Myrtaceae	<i>Calothamnus quadrifidus subsp. angustifolius</i>
Myrtaceae	<i>Calytrix leschenaultii</i>
Fabaceae	<i>Gastrolobium oxylobioides</i>
Dilleniaceae	<i>Hibbertia hypericoides</i>
Xanthorrhoeaceae	<i>Xanthorrhoea preissii</i>



**R01 Transect 8**

**T8 0m-** *Banksia telmatiaea*, *Hypocalymma angustifolium* and *Melaleuca seriata* Closed Low Heath

**NOTE:** The bore was located within in a transition zone between *Banksia* woodland and the above community.

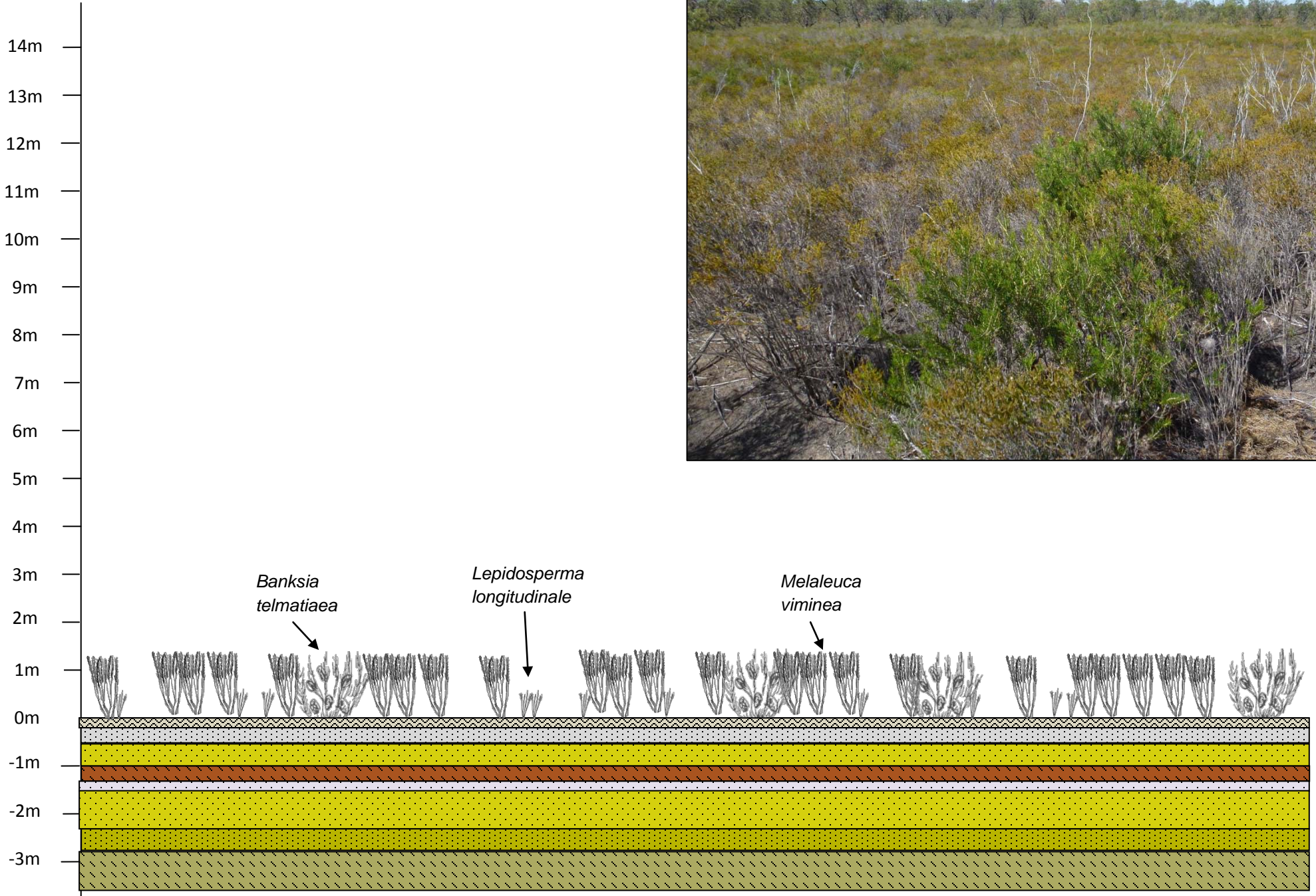
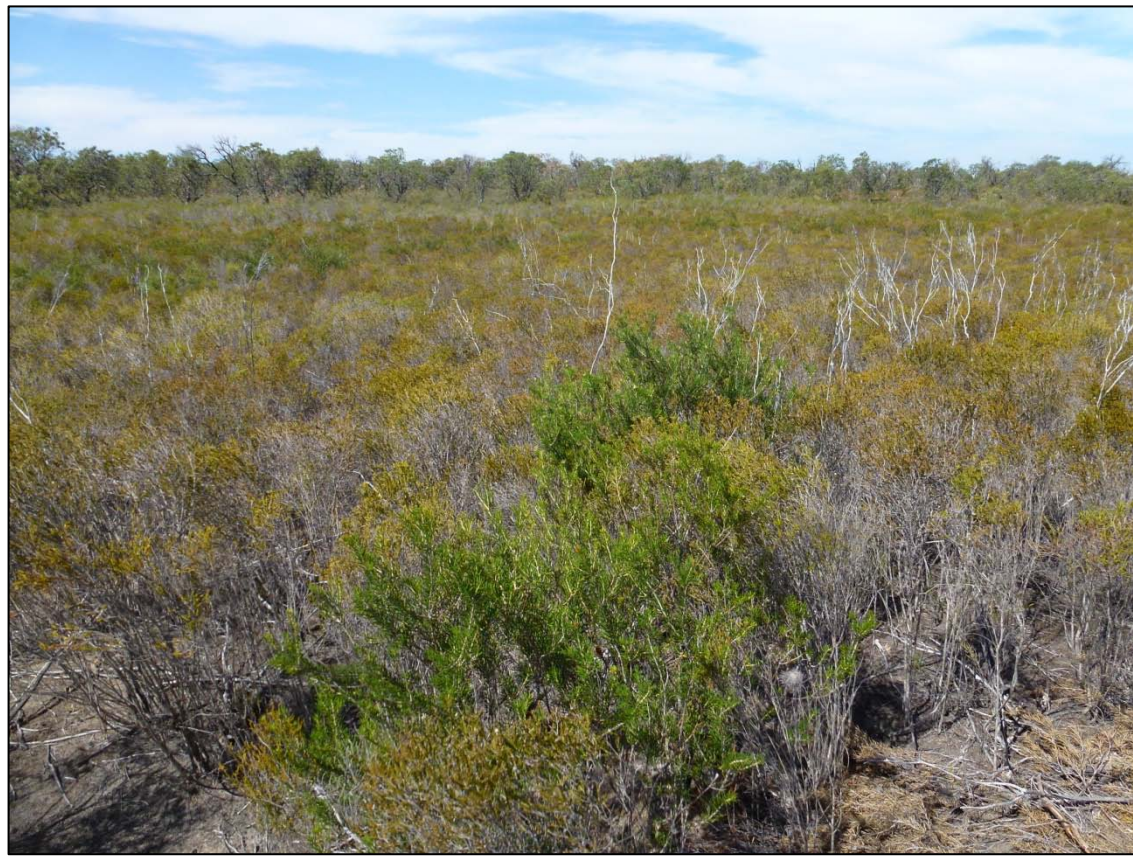


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Depth (m)	Graphic Log	Classification Symbol	Material Description	Samples Tests Remarks	PID (ppm)	Additional Observations
0		SP	SAND, fine, uniform, white-pale grey, dry.			Contains plant roots of varying sizes.
1		SP	SAND, fine, uniform, yellow-pale grey, dry.			
2		SP	SAND, medium to coarse, uniform, dark brown-dark red, slightly moist.			Contains small, white crystalline structures (approximately 3mm <sup>3</sup> in size); also contains some small roots
Borehole R01 terminated at 2m						

# A11 Transect 8

*Melaleuca viminea* and *Banksia telmatiaea* Closed Heath over *Lepidosperma longitudinale* Very Open Sedgeland



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Depth (m)	Graphic Log	Classification Symbol	Material Description	Samples Tests Remarks	PID (ppm)	Additional Observations
0			TOPSOIL, fine to medium, poorly graded, brown-grey, slightly moist to dry.			
0.5		SP	SAND, fine to medium, poorly graded, pale grey-brown, slightly moist to dry.			Large amounts of fine-grained root material present throughout the layer
1		SP	SAND, fine, uniform, yellow-brown, slightly moist.			
1.5		SP-SC	SAND WITH CLAY, medium plasticity, fine to medium, poorly graded, red-yellow, slightly moist.			Contains fragments of poorly-cemented fragments of slightly-ferruginised, fine-grained sand.
2		SW	SAND, fine, uniform, dark grey-white, slightly moist.			Poorly-sorted layer, contains large fragments of well-cemented, moderately-ferruginised, fine-grained sand.
2.5		SW	SAND, fine, uniform, yellow-pale brown, moist.			Poorly-sorted, contains fragments of poorly-cemented Silty Clay (yellow/brown in colour), as well as a large amount of fine-grained root material
3		SP	SAND, medium, poorly graded, yellow-dark brown, wet.			Moderately/Well-sorted: contains small fragments of well-cemented, fine-grained Silty Sand (brown/black in colour)
3.5		SP-SC	SAND WITH CLAY, low plasticity, medium to coarse, poorly graded, green-pale grey, saturated.			Moderately-sorted: contains fragments of well-cemented, coarse-grained Silty Sand (grey in colour).
4			Borehole A11 terminated at 3.9m			

TRANSECT 9



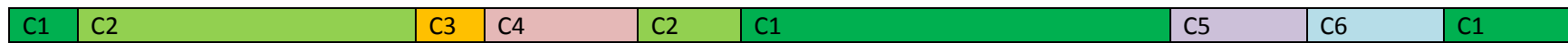
Community 1: Scattered *Banksia attenuata* over Open Low Shrubland of *Eremaea pauciflora* var. ? *pauciflora*, *Calothamnus quadrifidus* subsp. *angustifolius* and *Daviesia incrassata* over *Dasyogon bromeliifolius* Very Open Herbland

Community 2: Low Woodland of *Banksia attenuata*, *Banksia menziesii* and *Eucalyptus tottiana* over Shrubland of *Banksia telmatiaea*, *Daviesia incrassata* and *Conospermum stoechadis* over Scattered Herbs of *Dasyogon bromeliifolius* and *Patersonia occidentalis*.

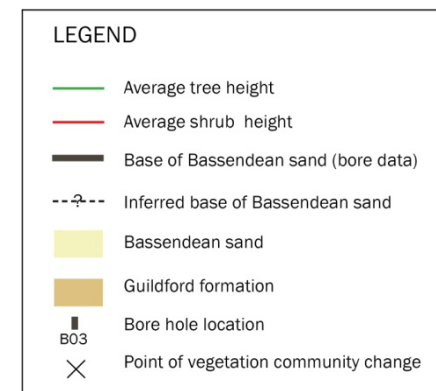
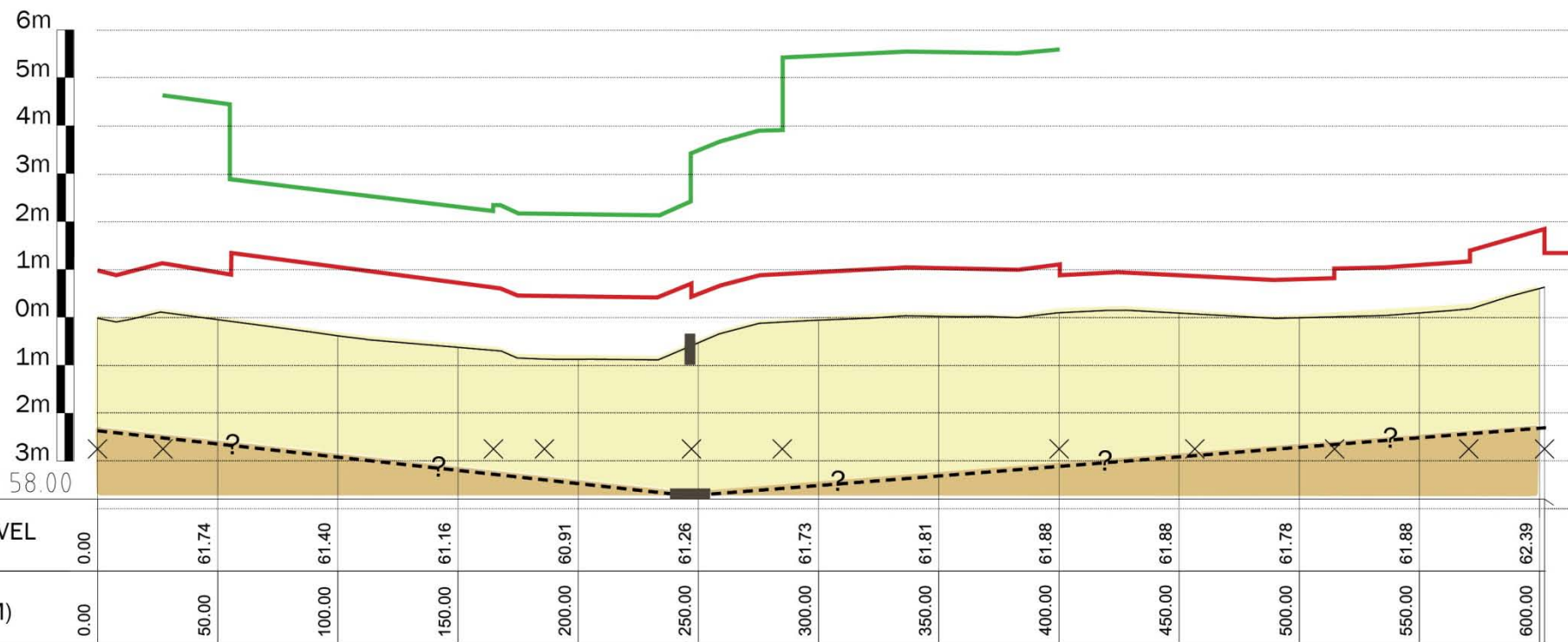
Community 3: Low Open Woodland of *Banksia attenuata* and *Banksia menziesii* over Shrubland of *Beaufortia squarrosa* and *Banksia telmatiaea*

Community 4: Scattered *Banksia menziesii* over Open Heath of *Adenanthos cygnorum*, *Melaleuca seriata* and *Hakea obliqua* subsp. *parviflora* over Very Open Herbland of *Stirlingia latifolia* with Very Open Sedgeland of *Tricostularia neesii* var. *elatior*

Community 5: Open Low Heath of *Calothamnus quadrifidus* subsp. *angustifolius*, *Eremaea pauciflora* var. *lonchophylla* and *Verticordia densiflora* var. *densiflora* over Very Open Sedgeland of *Lepidosperma longitudinale*



TRANSECT 9



Community 6: Open Low Heath of *Calytrix ? aurea*, *Verticordia densiflora* var. *densiflora* and *Melaleuca seriata*

ORIENTATION: SOUTH WEST

NORTH EAST

COMMUNITY 1	
Family	Species
Fabaceae	<i>Acacia pulchella</i>
Casuarinaceae	<i>Allocasuarina humilis</i>
Myrtaceae	<i>Calothamnus quadrifidus subsp. angustifolius</i>
Dasygogonaceae	<i>Dasygogon bromeliifolius</i>
Fabaceae	<i>Daviesia incrassata</i>
Myrtaceae	<i>Eremaea pauciflora var. ? pauciflora</i>
Fabaceae	<i>Jacksonia foliosa</i>
Cyperaceae	<i>Mesomelaena pseudostygia</i>
Xanthorrhoeaceae	<i>Xanthorrhoea preissii</i>

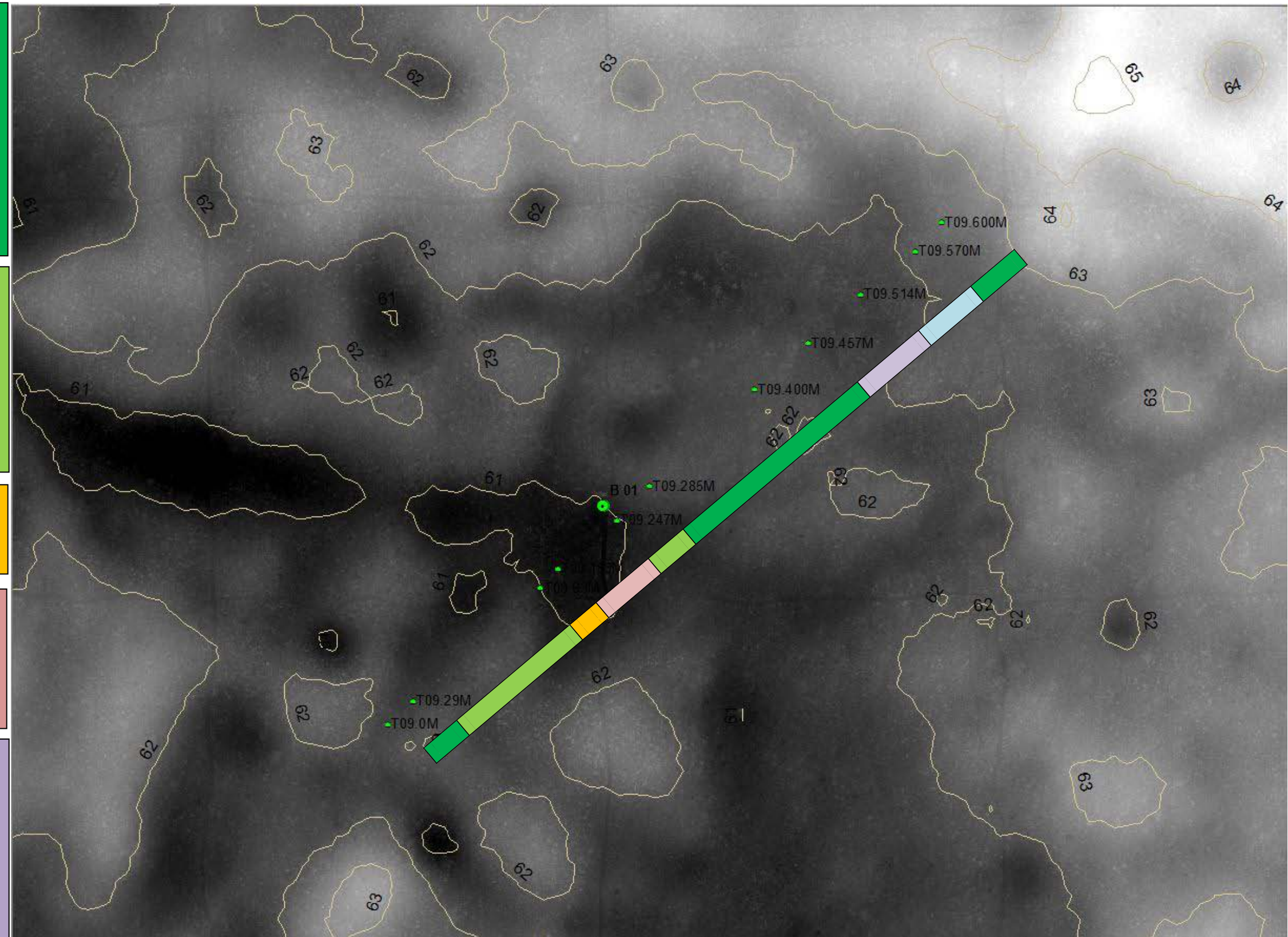
COMMUNITY 2	
Family	Species
Proteaceae	<i>Banksia attenuata</i>
Proteaceae	<i>Banksia menziesii</i>
Proteaceae	<i>Banksia telmatiaea</i>
Dasygogonaceae	<i>Dasygogon bromeliifolius</i>
Fabaceae	<i>Daviesia incrassata</i>
Myrtaceae	<i>Eucalyptus tottiana</i>
Dilleniaceae	<i>Hibbertia hypericoides</i>

COMMUNITY 3	
Family	Species
Proteaceae	<i>Banksia telmatiaea</i>
Myrtaceae	<i>Beaufortia squarrosa</i>

COMMUNITY 4	
Family	Species
Proteaceae	<i>Adenanthos cygnorum</i>
Myrtaceae	<i>Melaleuca seriata</i>
Proteaceae	<i>Stirlingia latifolia</i>
Cyperaceae	<i>Tricostularia neesii var. elatior</i>

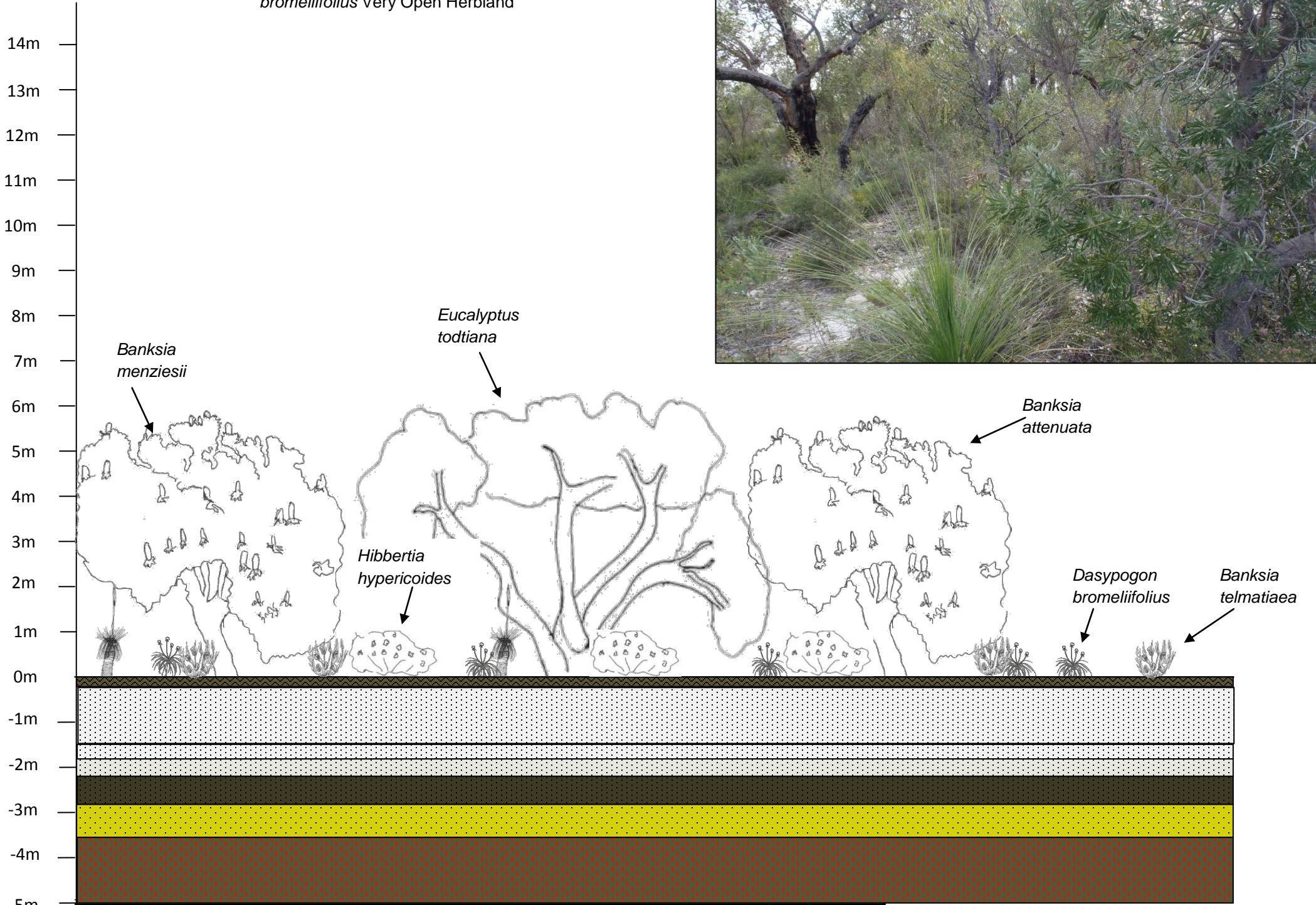
COMMUNITY 5	
Family	Species
Myrtaceae	<i>Calothamnus quadrifidus subsp. angustifolius</i>
Myrtaceae	<i>Calytrix ?aurea</i>
Myrtaceae	<i>Eremaea pauciflora var. lonchophylla</i>
Cyperaceae	<i>Lepidosperma longitudinale</i>
Myrtaceae	<i>Melaleuca seriata</i>
Proteaceae	<i>Petrophile seminuda</i>
Myrtaceae	<i>Verticordia densiflora var. densiflora</i>

COMMUNITY 6	
Family	Species
Fabaceae	<i>Acacia pulchella</i>
Myrtaceae	<i>Calytrix ?aurea</i>
Fabaceae	<i>Daviesia incrassata</i>
Proteaceae	<i>Hakea costata</i>
Myrtaceae	<i>Melaleuca seriata</i>
Myrtaceae	<i>Verticordia densiflora var. densiflora</i>



**B01 Transect 9**

**T9 247m-** *Banksia attenuata* and *Banksia menziesii* Low Woodland with *Eucalyptus todtiana* Very open Tree Mallee over *Hibbertia hypericoides*, *Banksia telmatiaea* and *Daviesia incrassata* Low Shrubland over *Dasypogon bromeliifolius* Very Open Herbland



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Depth (m)	Graphic Log	Classification Symbol	Material Description	Samples Tests Remarks	PID (ppm)	Additional Observations
0	[Topsoil symbol]		TOPSOIL, fine to medium, poorly graded, brown, dry.			
1	[Sand symbol]	SP	SAND, fine, uniform, white-pale grey, dry.			
2	[Sand symbol]	SP	SAND, fine, uniform, white-pale grey, slightly moist to dry.			
2	[Sand symbol]	SP	SAND, fine, poorly graded, white-yellow, slightly moist.			Contains some small pisolites.
2	[Sand symbol]	SP	SAND, fine, poorly graded, pale brown-dark brown, dry to slightly moist.			Contains small fragments (~2-3m*3) varying in colour.
3	[Sand symbol]	SP	SAND, fine, poorly graded, yellow-brown, dry to slightly moist.			
4	[Clayey sand symbol]	SM	CLAYEY SAND, low plasticity, fine to medium, poorly graded, pale brown-mottled red, slightly moist.			Ferruginised material present throughout.
5			Borehole B01 terminated at 5m			

TRANSECT 10



Community 1: Low Open Woodland of *Banksia attenuata* and *Eucalyptus tottiana* over Open Low Heath of *Eremaea pauciflora* var. ? *pauciflora*, *Daviesia incrassata* over Very Open Herbland of *Stirlingia latifolia* and *Patersonia occidentalis*



Community 2: Scattered *Nuytsia floribunda* over Open Heath of *Banksia telmatiaea*, *Xanthorrhoea preissii* and *Calothamnus quadrifidus* subsp. *angustifolius* over Very Open Sedgeland of *Lepidosperma longitudinale*, *Chordifex sinuosus* and *Lyginia imberbis*



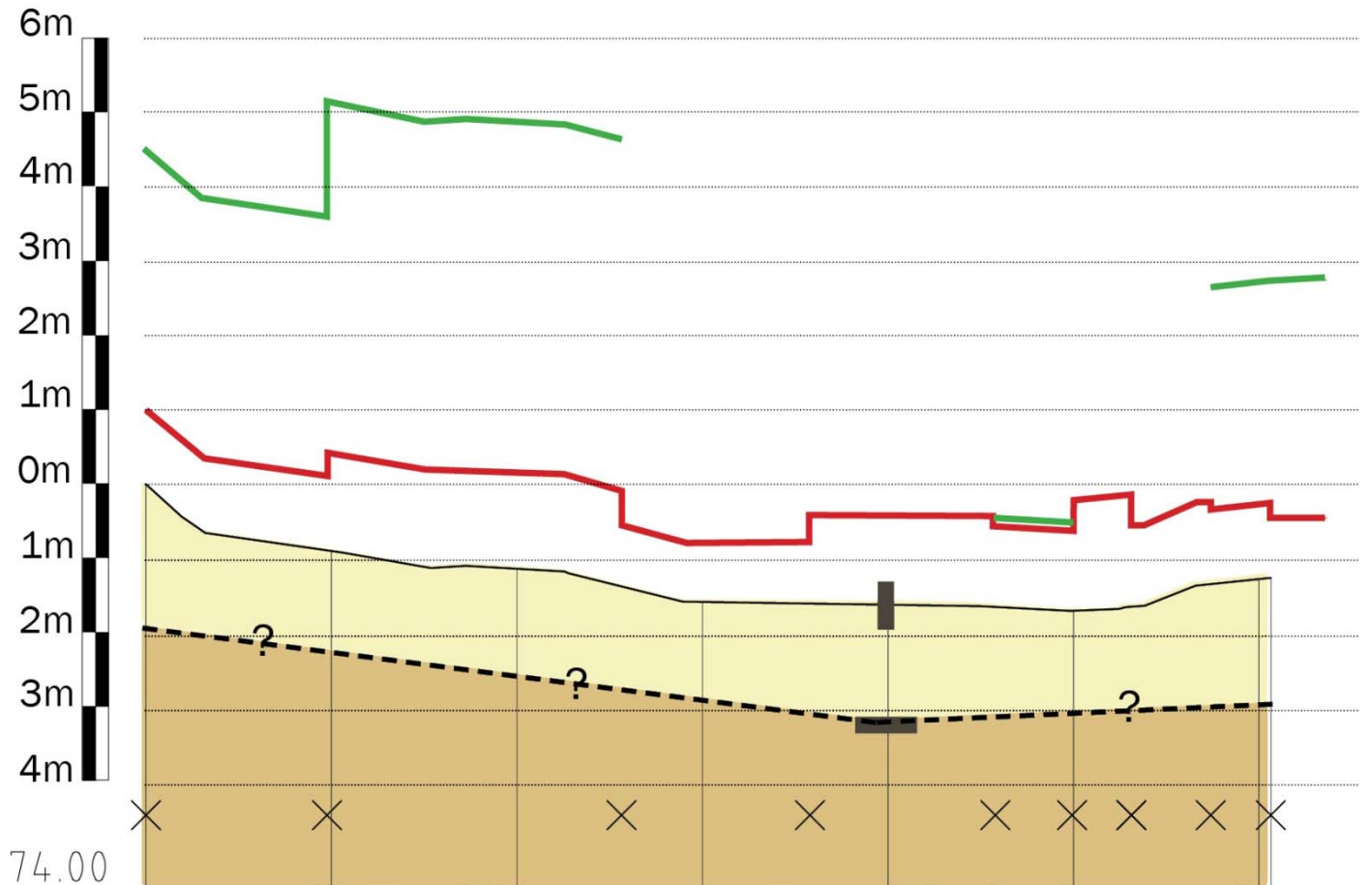
Community 3: Scattered Shrubs of *Melaleuca raphiophylla* (dwarf) over Open Low Heath of *Banksia telmatiaea*, *Melaleuca seriata* and *Hakea obliqua* subsp. *parviflora* over Scattered Sedges of *Chordifex sinuosus*, *Chaetanthus aristatus* and *Lyginia imberbis*



Community 4: Closed Heath of *Banksia telmatiaea* and *Regelia ciliata* over Very Open Sedgeland of *Chordifex sinuosus* and *Schoenus* sp. A3 Ciliate Sheaths (K.R. Newbey 9402)

C1 C2 C3 C4 C3 C4 C3 C2 C1

### TRANSECT 10



DATUM 74.00

EXISTING LEVEL	0.00	78.59	78.35	77.90	77.86	77.78	78.21
DISTANCE (M)	0.00	50.00	100.00	150.00	200.00	250.00	300.00

A02

ORIENTATION: SOUTH WEST NORTH EAST

**LEGEND**

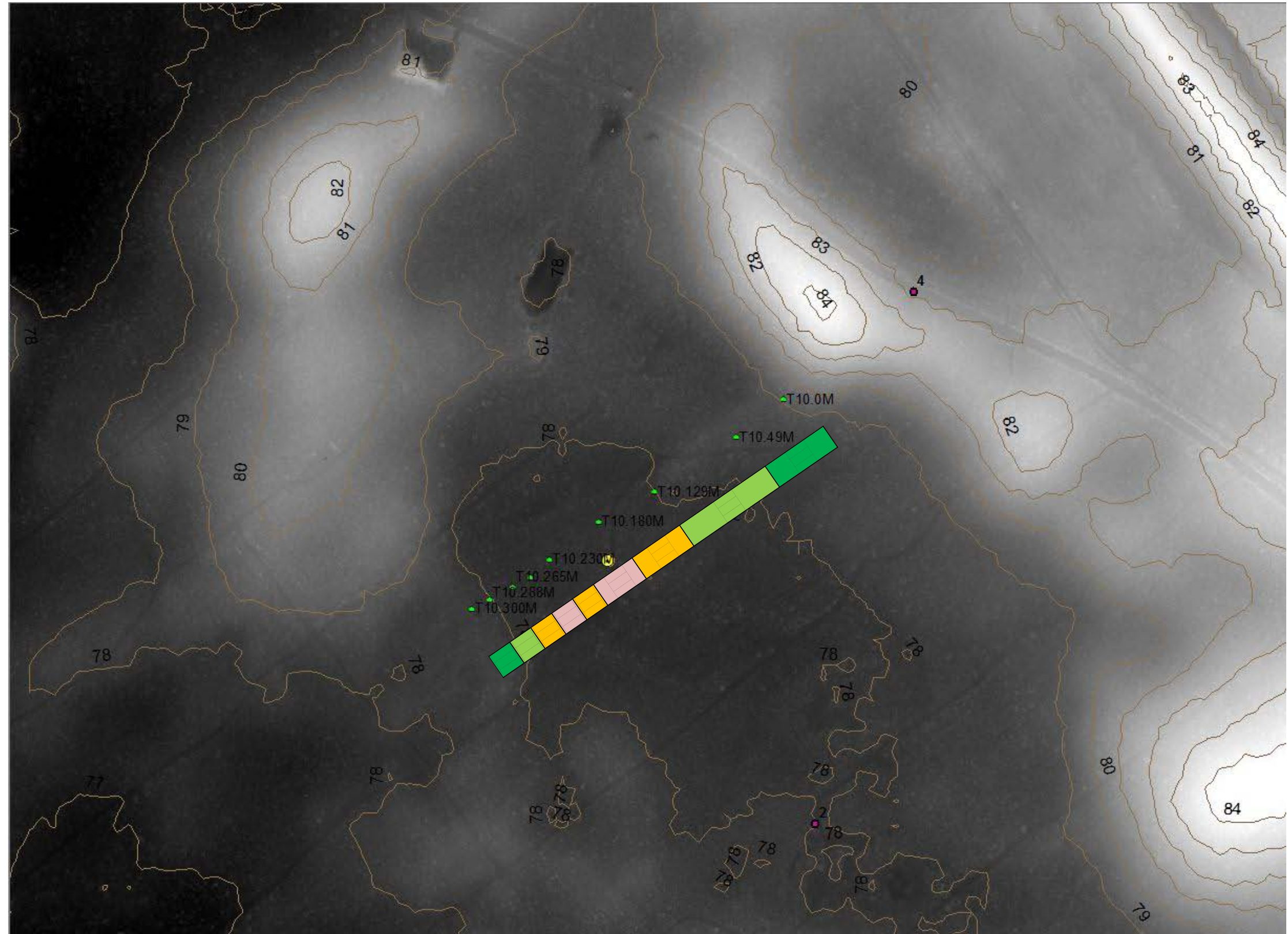
- Average tree height
- Average shrub height
- Base of Bassendean sand (bore data)
- Inferred base of Bassendean sand
- Bassendean sand
- Guildford formation
- Bore hole location
- × Point of vegetation community change

COMMUNITY 1	
Family	Species
Casuarinaceae	<i>Allocasuarina humilis</i>
Proteaceae	<i>Banksia attenuata</i>
Proteaceae	<i>Conospermum stoechadis</i>
Fabaceae	<i>Daviesia incrassata</i>
Myrtaceae	<i>Eremaea pauciflora</i> var. ? <i>pauciflora</i>
Myrtaceae	<i>Eucalyptus todtiana</i>
Iridaceae	<i>Patersonia occidentalis</i>
Myrtaceae	<i>Scholtzia ?laxiflora</i>
Proteaceae	<i>Stirlingia latifolia</i>
Xanthorrhoeaceae	<i>Xanthorrhoea preissii</i>

COMMUNITY 2	
Family	Species
Proteaceae	<i>Banksia telmatiaea</i>
Restionaceae	<i>Chordifex sinuosus</i>
Cyperaceae	<i>Lepidosperma longitudinale</i>
Anarthriaceae	<i>Lyginia imberbis</i>
Myrtaceae	<i>Melaleuca seriata</i>
Xanthorrhoeaceae	<i>Xanthorrhoea preissii</i>

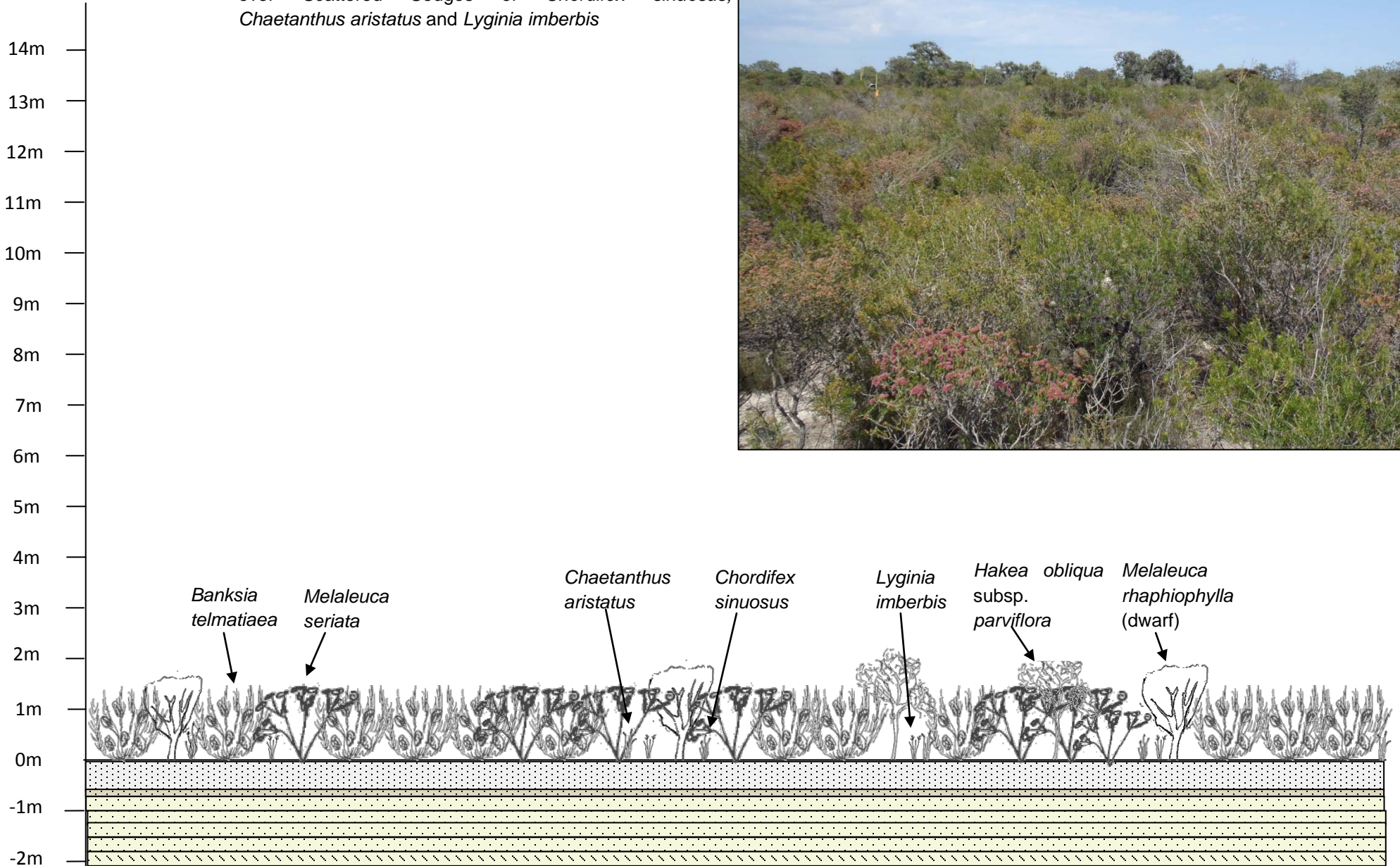
COMMUNITY 3	
Family	Species
Proteaceae	<i>Banksia telmatiaea</i>
Restionaceae	<i>Chordifex sinuosus</i>
Myrtaceae	<i>Melaleuca seriata</i>

COMMUNITY 4	
Family	Species
Proteaceae	<i>Banksia telmatiaea</i>
Restionaceae	<i>Chordifex sinuosus</i>
Myrtaceae	<i>Regelia ciliata</i>



**A02 Transect 10**

**T10 230m** - Scattered Shrubs of *Melaleuca raphiophylla* (dwarf) over Open Low Heath of *Banksia telmatiaea*, *Melaleuca seriata* and *Hakea obliqua* subsp. *parviflora* over Scattered Sedges of *Chordifex sinuosus*, *Chaetanthus aristatus* and *Lyginia imberbis*



Depth (m)	Graphic Log	Classification Symbol	Material Description	Samples Tests Remarks	PID (ppm)	Additional Observations
0.0 - 0.1	[Dotted pattern]	SP	SAND, fine, uniform, white-pale grey, dry.			Contains fine roots in the top 0.1m; fibrous
0.1 - 0.2	[Dotted pattern]	SP	SAND, fine to medium, poorly graded, pale brown, dry.			Contains some Organic Matte throughout the layer; also contains some fine root material. Contains some small fragments (approximately 1cm <sup>3</sup> in size) of well-cemented silty/sand (fragments were red in colour due to extensive ferruginisation). Contains small fragments of well-cemented gravelly material.
0.2 - 0.3	[Dotted pattern]	SP	SAND, fine to medium, poorly graded, yellow-grey, slightly moist to dry.			
0.3 - 0.4	[Dotted pattern]	SP	SAND, fine to medium, poorly graded, yellow-grey, slightly moist.			
0.4 - 0.5	[Dotted pattern]	SP	SAND, medium, poorly graded, yellow-grey, slightly moist.			
0.5 - 0.6	[Dotted pattern]	SP	SAND, medium, poorly graded, yellow-grey, slightly moist.			
0.6 - 1.8	[Dotted pattern]	SP-SC	SAND WITH CLAY, medium plasticity, fine to medium, poorly graded, yellow-grey, slightly moist.			
1.8 - 2.0	[Dotted pattern]		Borehole A02 terminated at 1.8m			Contains small fragments of well-cemented gravelly material. Contains some clays throughout the layer; also contains small fragments of well-cemented Silty Sand (red in colour due to extensive ferruginisation).
2.0 - 3.0	[Dotted pattern]					
3.0 - 4.0	[Dotted pattern]					

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TRANSECT 11



Community 1: Open Low Heath of *Eremaea pauciflora* var. ? *Pauciflora*, *Hibbertia hypericoides* and *Acacia pulchella*

Community 2 Scattered *Xanthorrhoea preissii* over *Banksia telmatiaea* and *Calothamnus quadrifidus* subsp. *angustifolius* Open Low Heath

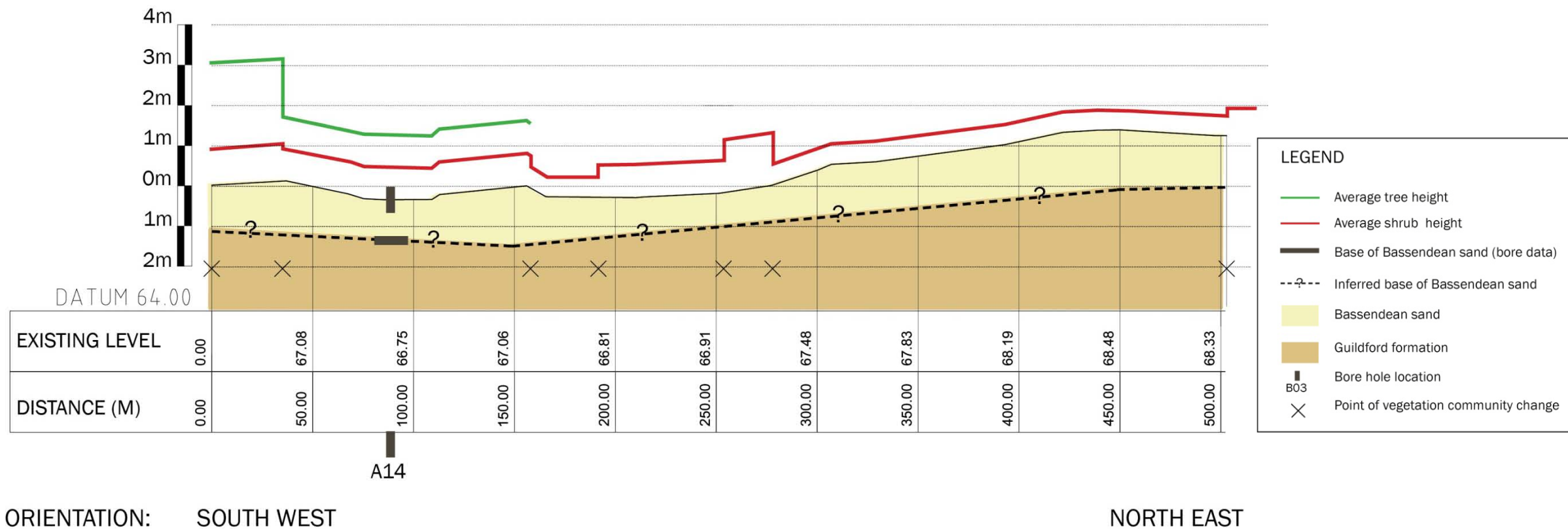
Community 3: Low Shrubland of *Petrophile seminuda*, *Verticordia densiflora* var. *densiflora* and *Petrophile brevifolia*

Community 4: Closed Heath of *Banksia telmatiaea*, *Hakea obliqua* subsp. *parviflora* and *Calothamnus quadrifidus* subsp. *angustifolius*

Community 5: Closed Low Heath of *Banksia armata*, *Calothamnus hirsutus* and *Banksia telmatiaea* over Very Open Sedgeland of *Schoenus clandestinus*



TRANSECT 11



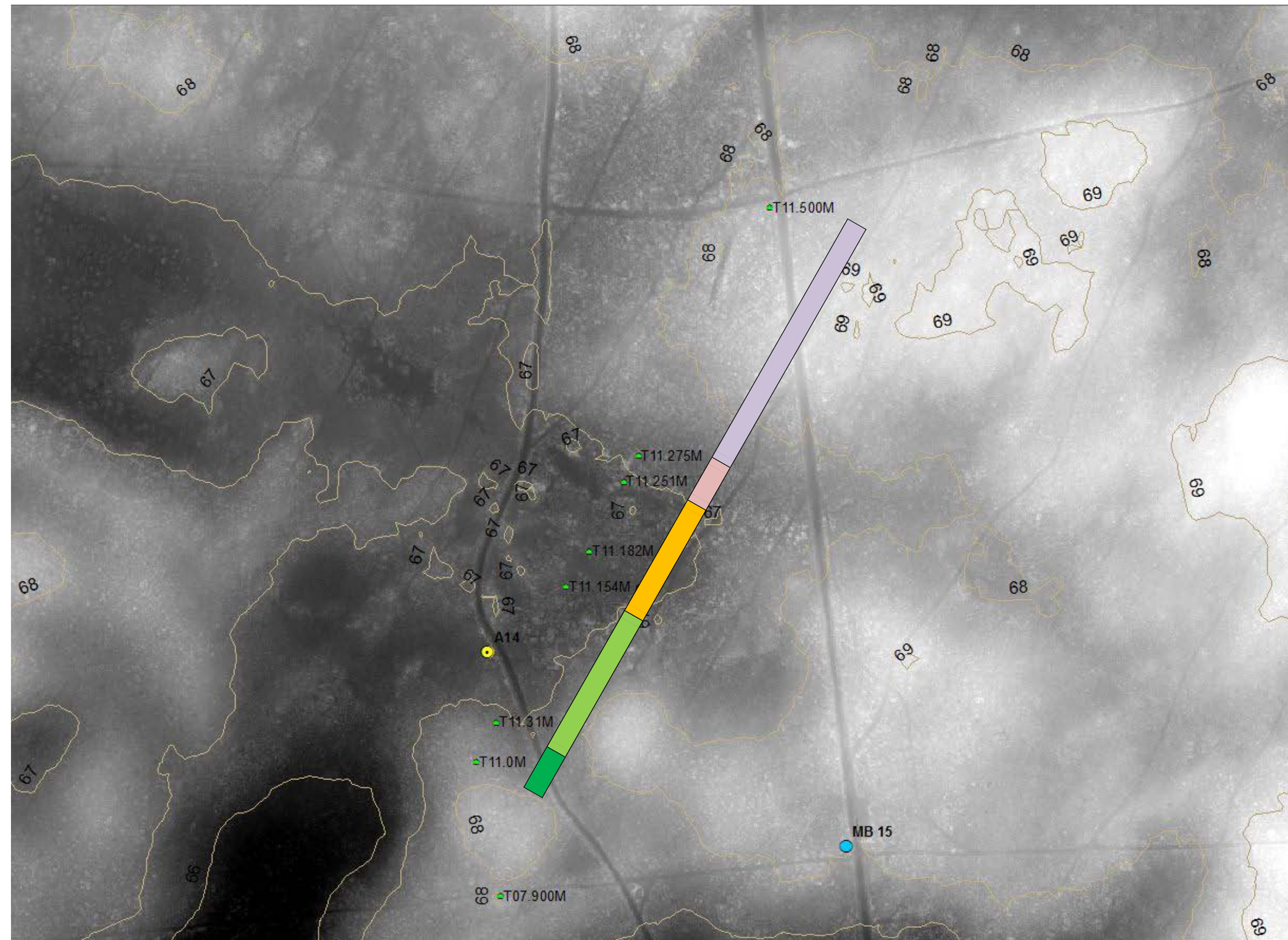
COMMUNITY 1	
Family	Species
Fabaceae	<i>Acacia pulchella</i>
Myrtaceae	<i>Eremaea pauciflora</i> var. ? <i>pauciflora</i>
Dilleniaceae	<i>Hibbertia hypericoides</i>

COMMUNITY 2	
Family	Species
Proteaceae	<i>Banksia telmatiaea</i>
Fabaceae	<i>Acacia pulchella</i>
Myrtaceae	<i>Calothamnus quadrifidus</i> subsp. <i>angustifolius</i>
Restionaceae	<i>Chordifex sinuosus</i>
Myrtaceae	<i>Melaleuca seriata</i>
Haemodoraceae	<i>Phlebocarya ciliata</i>
Xanthorrhoeaceae	<i>Xanthorrhoea preissii</i>

COMMUNITY 3	
Family	Species
Proteaceae	<i>Petrophile seminuda</i>
Myrtaceae	<i>Verticordia densiflora</i> var. <i>densiflora</i>

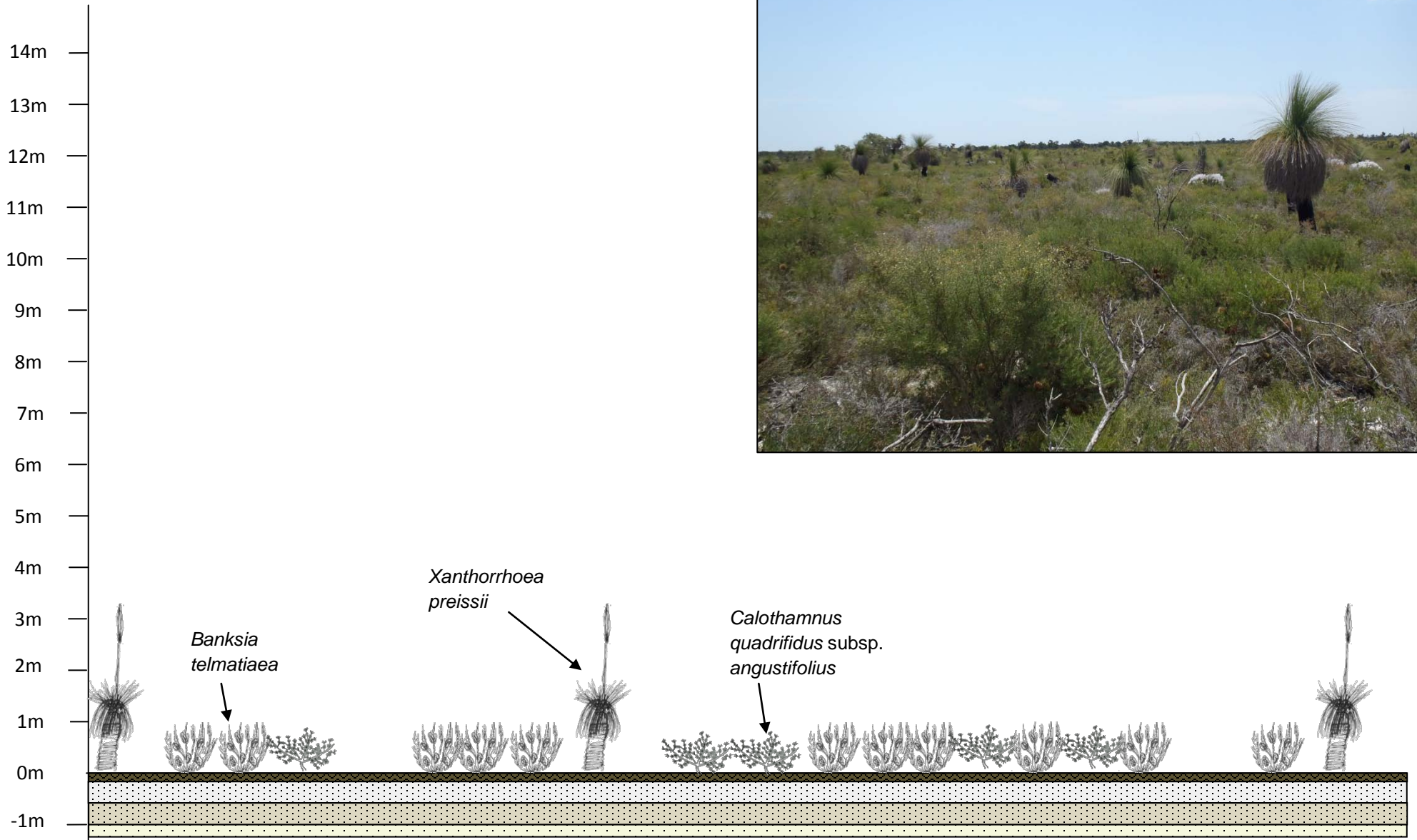
COMMUNITY 4	
Family	Species
Proteaceae	<i>Banksia telmatiaea</i>
Myrtaceae	<i>Calothamnus quadrifidus</i> subsp. <i>angustifolius</i>
Proteaceae	<i>Hakea obliqua</i> subsp. <i>parviflora</i>
Myrtaceae	<i>Hypocalymma angustifolium</i>
Xanthorrhoeaceae	<i>Xanthorrhoea preissii</i>

COMMUNITY 5	
Family	Species
Proteaceae	<i>Banksia armata</i>
Proteaceae	<i>Banksia telmatiaea</i>
Myrtaceae	<i>Calothamnus hirstus</i>
Fabaceae	<i>Gastrolobium oxylobioides</i>
Proteaceae	<i>Hakea obliqua</i> subsp. <i>parviflora</i>
Cyperaceae	<i>Schoenus clandestinus</i>



**A14 Transect 11**

**T11 31m** – Scattered *Xanthorrhoea preissii* over *Banksia telmatiaea* and *Calothamnus quadrifidus* subsp. *angustifolius* Open Low Heath



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Depth (m)	Graphic Log	Classification Symbol	Material Description	Samples Tests Remarks	PID (ppm)	Additional Observations
0.0 - 0.5	[Dotted pattern]	SP	TOPSOIL, fine to medium, poorly graded, brown, dry. SAND, fine, uniform, white-pale grey, dry.			Contains fine roots throughout the layer Very friable; contains fine root material throughout the layer
0.5 - 0.8	[Dotted pattern]	SW	SAND, fine, poorly graded, pale brown-grey, dry.			Contains large fragments of well-cemented ferruginised coarse sand.
0.8 - 1.1	[Dotted pattern]	SP	SAND, fine to medium, well graded, grey-yellow, dry.			Contains fragments of moderately-cemented Silty Sand (extensively-ferruginised).
1.1 - 1.1			Borehole A14 terminated at 1.1m			



COMMUNITY 1	
Family	Species
Cyperaceae	<i>Lepidosperma longitudinale</i>
Restionaceae	<i>Meeboldina coangustata</i>
Myrtaceae	<i>Melaleuca lateritia</i>
Myrtaceae	<i>Melaleuca raphiophylla</i>
Myrtaceae	<i>Melaleuca teretifolia</i>

COMMUNITY 2	
Family	Species
Myrtaceae	<i>Melaleuca raphiophylla</i>
Myrtaceae	<i>Regelia ciliata</i>

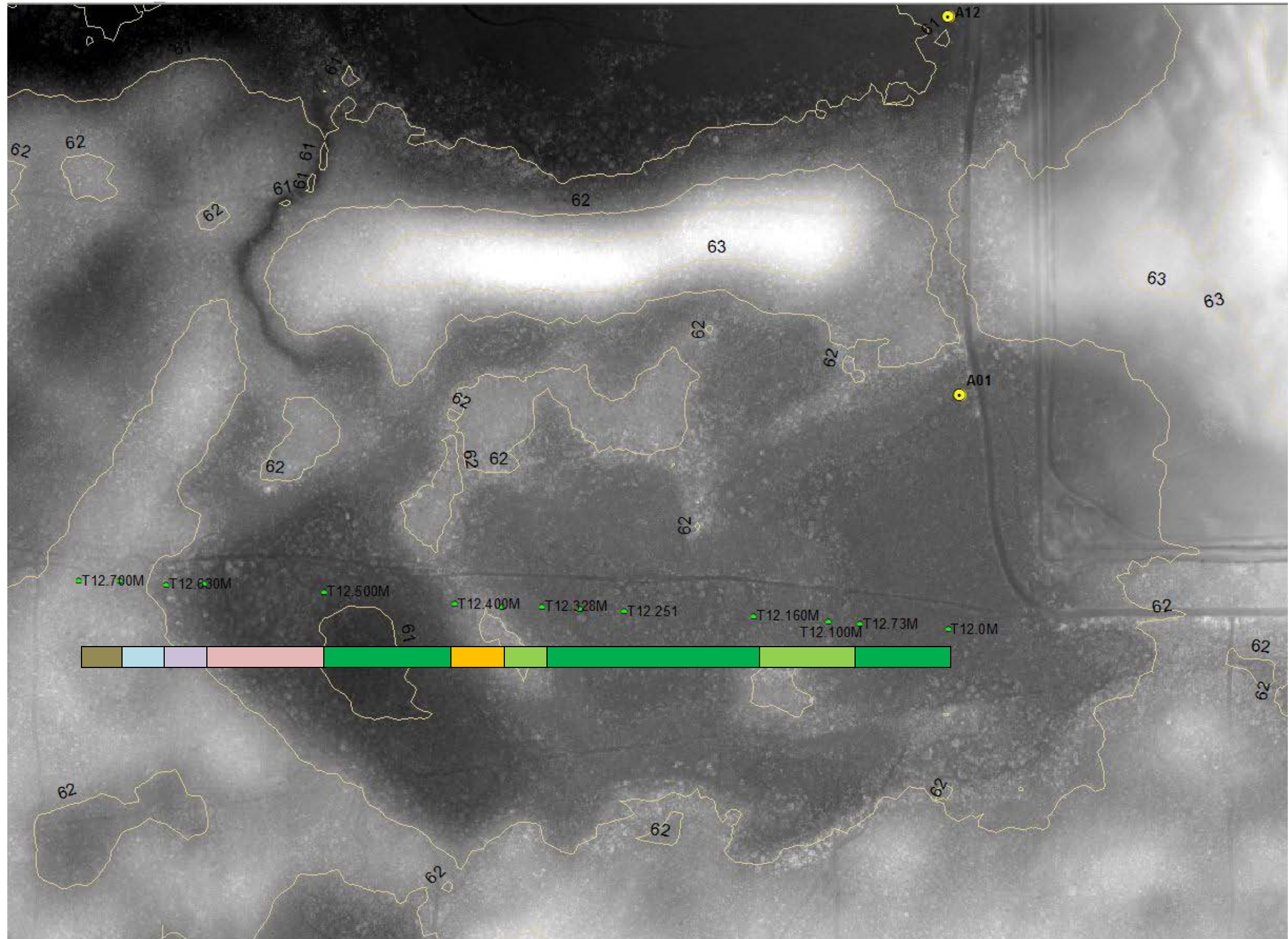
COMMUNITY 3	
Family	Species
Myrtaceae	<i>Astartea ?scoparia</i>
Proteaceae	<i>Banksia telmatiaea</i>
Haemodoraceae	<i>Phlebocarya ciliata</i>
Xanthorrhoeaceae	<i>Xanthorrhoea preissii</i>

COMMUNITY 4	
Family	Species
Myrtaceae	<i>Melaleuca lateritia</i>
Myrtaceae	<i>Melaleuca teretifolia</i>
Myrtaceae	<i>Melaleuca raphiophylla</i>

COMMUNITY 5	
Family	Species
Proteaceae	<i>Banksia telmatiaea</i>
Myrtaceae	<i>Regelia ciliata</i>
Myrtaceae	<i>Verticordia densiflora</i> var. <i>densiflora</i>

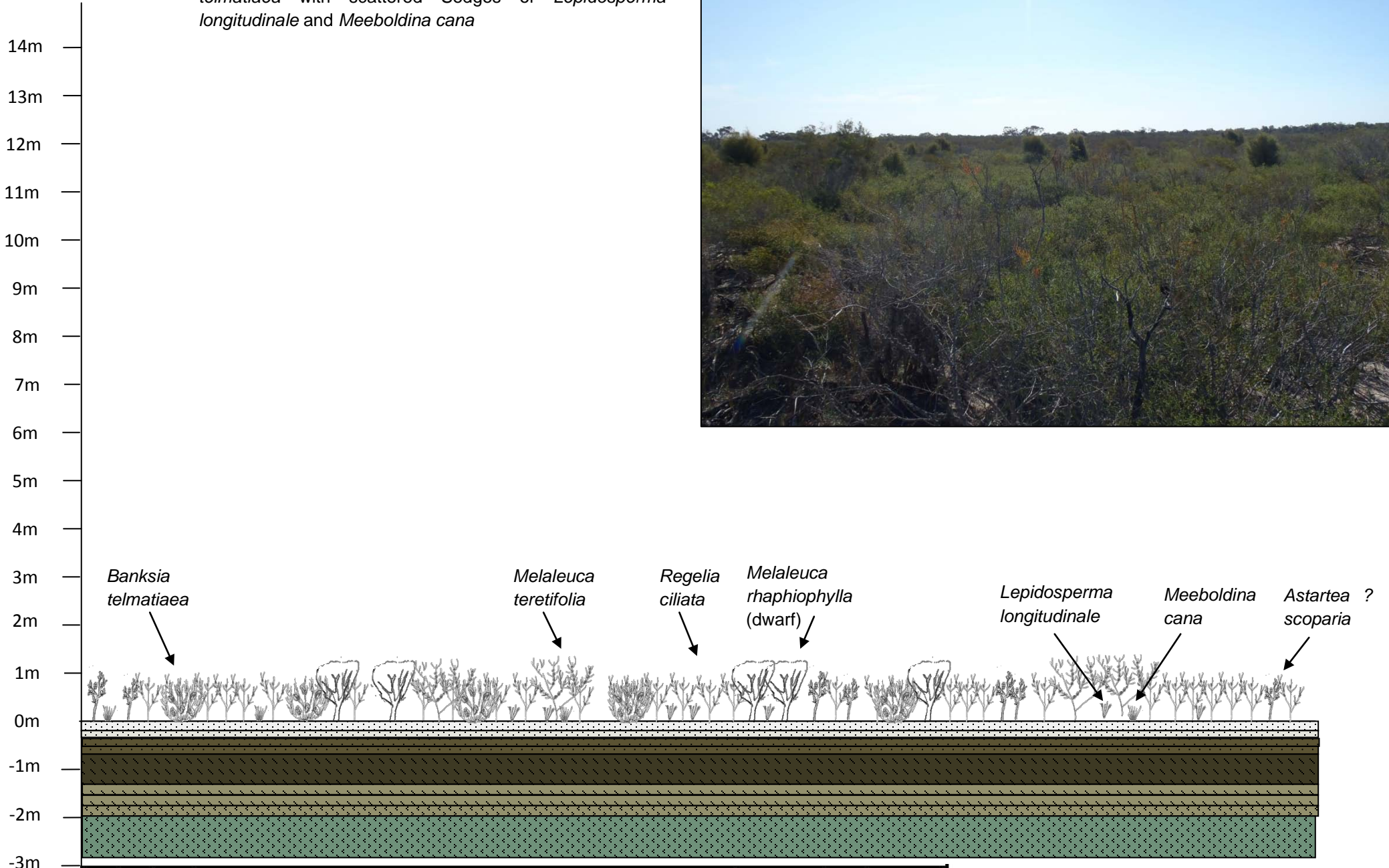
COMMUNITY 6	
Family	Species
Myrtaceae	<i>Eucalyptus rudis</i> subsp. <i>rudis</i>
Fabaceae	<i>Jacksonia stembergiana</i>

COMMUNITY 7	
Family	Species
Proteaceae	<i>Banksia attenuata</i>
Proteaceae	<i>Conospermum stoechadis</i>
Dasypogonaceae	<i>Dasypogon bromeliifolius</i>
Myrtaceae	<i>Eremaea pauciflora</i> var. ? <i>pauciflora</i>
Myrtaceae	<i>Eucalyptus todiana</i>
Dilleniaceae	<i>Hibbertia hypericoides</i>
Proteaceae	<i>Stirlingia latifolia</i>
Xanthorrhoeaceae	<i>Xanthorrhoea preissii</i>



**A1 Transect 12**

**T12 100m** Open Shrubland of *Melaleuca raphiophylla* (dwarf) over Closed Low Heath of *Regelia ciliata*, *Melaleuca teretifolia*, *Astartea ? scoparia* and *Banksia telmatiaea* with scattered Sedges of *Lepidosperma longitudinale* and *Meeboldina cana*



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Depth (m)	Graphic Log	Classification Symbol	Material Description	Samples Tests Remarks	PID (ppm)	Additional Observations
0.0 - 0.1	[Dotted pattern]	SP	SAND, fine, uniform, white-pale grey, dry.			Contains fine roots in the top 0.1m; fibrous
0.1 - 0.2	[Dotted pattern]	SP	SAND, fine, uniform, white-yellow, dry.			
0.2 - 0.3	[Dark brown diagonal lines]	SP	SAND, fine to medium, poorly graded, dark brown-pale brown, dry.			Contains some well-cemented fragments of Silty Sand (brown in colour) which are fibrous under lightly-applied pressure; white crystalline structures also present sporadically across the layer
0.3 - 0.4	[Dark brown diagonal lines]	SP	SAND, fine to medium, poorly graded, dark brown, dry.			
0.4 - 0.5	[Dark brown diagonal lines]	SP-SC	SAND WITH CLAY, medium plasticity, fine to medium, poorly graded, pale brown-yellow, dry.			
0.5 - 0.6	[Dark brown diagonal lines]	SP-SC	SAND WITH CLAY, high plasticity, fine to medium, poorly graded, pale brown-green, moist.			
0.6 - 0.7	[Dark brown diagonal lines]	SC	SAND WITH CLAY, high plasticity, fine to medium, poorly graded, pale brown-green, moist.			
0.7 - 0.8	[Dark brown diagonal lines]	CL	CLAYEY SAND, high plasticity, fine to medium, poorly graded, brown-green, moist to slightly moist.			Contains some well-cemented fragments of Silty Sand (brown in colour) which are fibrous under lightly-applied pressure
0.8 - 0.9	[Dark brown diagonal lines]	CL	CLAYEY SAND, medium plasticity, fine to medium, poorly graded, dark green, moist.			Some clays present within the layer
0.9 - 1.0	[Dark brown diagonal lines]					Contains smaller fragments of well-cemented fine-grained sand (extensively ferruginised)
1.0 - 1.1	[Dark brown diagonal lines]					Contains smaller fragments of well-cemented fine-grained sand (extensively ferruginised)
1.1 - 1.2	[Dark brown diagonal lines]					Contains some small roots (found within the green areas of the material, also surrounded by white material); some small areas of ferruginised material found within the layer
1.2 - 1.3	[Dark brown diagonal lines]					Contains some fragments of well-cemented Silty Sands
1.3 - 1.4	[Dark brown diagonal lines]					
1.4 - 1.5	[Dark brown diagonal lines]					
1.5 - 1.6	[Dark brown diagonal lines]					
1.6 - 1.7	[Dark brown diagonal lines]					
1.7 - 1.8	[Dark brown diagonal lines]					
1.8 - 1.9	[Dark brown diagonal lines]					
1.9 - 2.0	[Dark brown diagonal lines]					
2.0 - 2.1	[Dark brown diagonal lines]					
2.1 - 2.2	[Dark brown diagonal lines]					
2.2 - 2.3	[Dark brown diagonal lines]					
2.3 - 2.4	[Dark brown diagonal lines]					
2.4 - 2.5	[Dark brown diagonal lines]					
2.5 - 2.6	[Dark brown diagonal lines]					
2.6 - 2.7	[Dark brown diagonal lines]					
2.7 - 2.8	[Dark brown diagonal lines]					
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2.9 - 3.0	[Dark brown diagonal lines]					
3.0 - 3.1	[Dark brown diagonal lines]					
3.1 - 3.2	[Dark brown diagonal lines]					
3.2 - 3.3	[Dark brown diagonal lines]					
3.3 - 3.4	[Dark brown diagonal lines]					
3.4 - 3.5	[Dark brown diagonal lines]					
3.5 - 3.6	[Dark brown diagonal lines]					
3.6 - 3.7	[Dark brown diagonal lines]					
3.7 - 3.8	[Dark brown diagonal lines]					
3.8 - 3.9	[Dark brown diagonal lines]					
3.9 - 4.0	[Dark brown diagonal lines]					
4.0 - 4.1	[Dark brown diagonal lines]					
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4.9 - 5.0	[Dark brown diagonal lines]					
5.0 - 5.1	[Dark brown diagonal lines]					
5.1 - 5.2	[Dark brown diagonal lines]					
5.2 - 5.3	[Dark brown diagonal lines]					
5.3 - 5.4	[Dark brown diagonal lines]					
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5.6 - 5.7	[Dark brown diagonal lines]					
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6.9 - 7.0	[Dark brown diagonal lines]					
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7.8 - 7.9	[Dark brown diagonal lines]					
7.9 - 8.0	[Dark brown diagonal lines]					
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8.3 - 8.4	[Dark brown diagonal lines]					
8.4 - 8.5	[Dark brown diagonal lines]					
8.5 - 8.6	[Dark brown diagonal lines]					
8.6 - 8.7	[Dark brown diagonal lines]					
8.7 - 8.8	[Dark brown diagonal lines]					
8.8 - 8.9	[Dark brown diagonal lines]					
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9.3 - 9.4	[Dark brown diagonal lines]					
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10.9 - 11.0	[Dark brown diagonal lines]					
11.0 - 11.1	[Dark brown diagonal lines]					
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11.4 - 11.5	[Dark brown diagonal lines]					
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11.9 - 12.0	[Dark brown diagonal lines]					
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14.9 - 15.0	[Dark brown diagonal lines]					
15.0 - 15.1	[Dark brown diagonal lines]					
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15.2 - 15.3	[Dark brown diagonal lines]					
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15.6 - 15.7	[Dark brown diagonal lines]					
15.7 - 15.8	[Dark brown diagonal lines]					
15.8 - 15.9	[Dark brown diagonal lines]					
15.9 - 16.0	[Dark brown diagonal lines]					
16.0 - 16.1	[Dark brown diagonal lines]					
16.1 - 16.2	[Dark brown diagonal lines]					
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16.4 - 16.5	[Dark brown diagonal lines]					
16.5 - 16.6	[Dark brown diagonal lines]					
16.6 - 16.7	[Dark brown diagonal lines]					
16.7 - 16.8	[Dark brown diagonal lines]					
16.8 - 16.9	[Dark brown diagonal lines]					
16.9 - 17.0	[Dark brown diagonal lines]					
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17.1 - 17.2	[Dark brown diagonal lines]					
17.2 - 17.3	[Dark brown diagonal lines]					
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18.1 - 18.2	[Dark brown diagonal lines]					
18.2 - 18.3	[Dark brown diagonal lines]					
18.3 - 18.4	[Dark brown diagonal lines]					
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18.8 - 18.9	[Dark brown diagonal lines]					
18.9 - 19.0	[Dark brown diagonal lines]					
19.0 - 19.1	[Dark brown diagonal lines]					
19.1 - 19.2	[Dark brown diagonal lines]					
19.2 - 19.3	[Dark brown diagonal lines]					
19.3 - 19.4	[Dark brown diagonal lines]					
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19.5 - 19.6	[Dark brown diagonal lines]					
19.6 - 19.7	[Dark brown diagonal lines]					
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19.8 - 19.9	[Dark brown diagonal lines]					
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TRANSECT 13



Community 1: Scattered *Banksia attenuata* and *Banksia menziesii* over Open Low Heath of *Eremaea pauciflora* var. ? *Pauciflora*, *Conospermum stoechadis* and *Hibbertia hypericoides* over Herbland of *Dasypogon bromeliifolius*, *Patersonia occidentalis* and *Phlebocarya ciliata*

Community 2: Closed Low Heath of *Banksia telmatiaea*, *Calothamnus quadrifidus* subsp. *angustifolius* and *Melaleuca seriata* over Open Sedgeland of *Chaetanthus aristatus* and *Lepidobolus preissianus*

Community 3: Closed Low Heath of *Banksia telmatiaea*, *Verticordia densiflora* var. *densiflora* and *Astartea ? scoparia* over Open Sedgeland of *Chaetanthus aristatus* and *Chordifex sinuosus*

Community 4: Closed Low Heath of *Petrophile seminuda*, *Banksia telmatiaea* and *Calytrix ? aurea*

Community 5: Closed Low Heath of *Regelia ciliata*, *Banksia telmatiaea* and *Melaleuca brevifolia* over Very Open Sedgeland of *Chaetanthus aristatus*

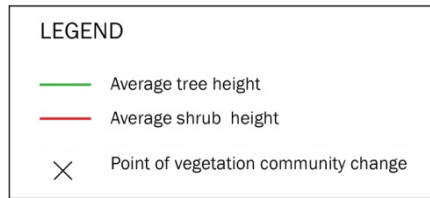
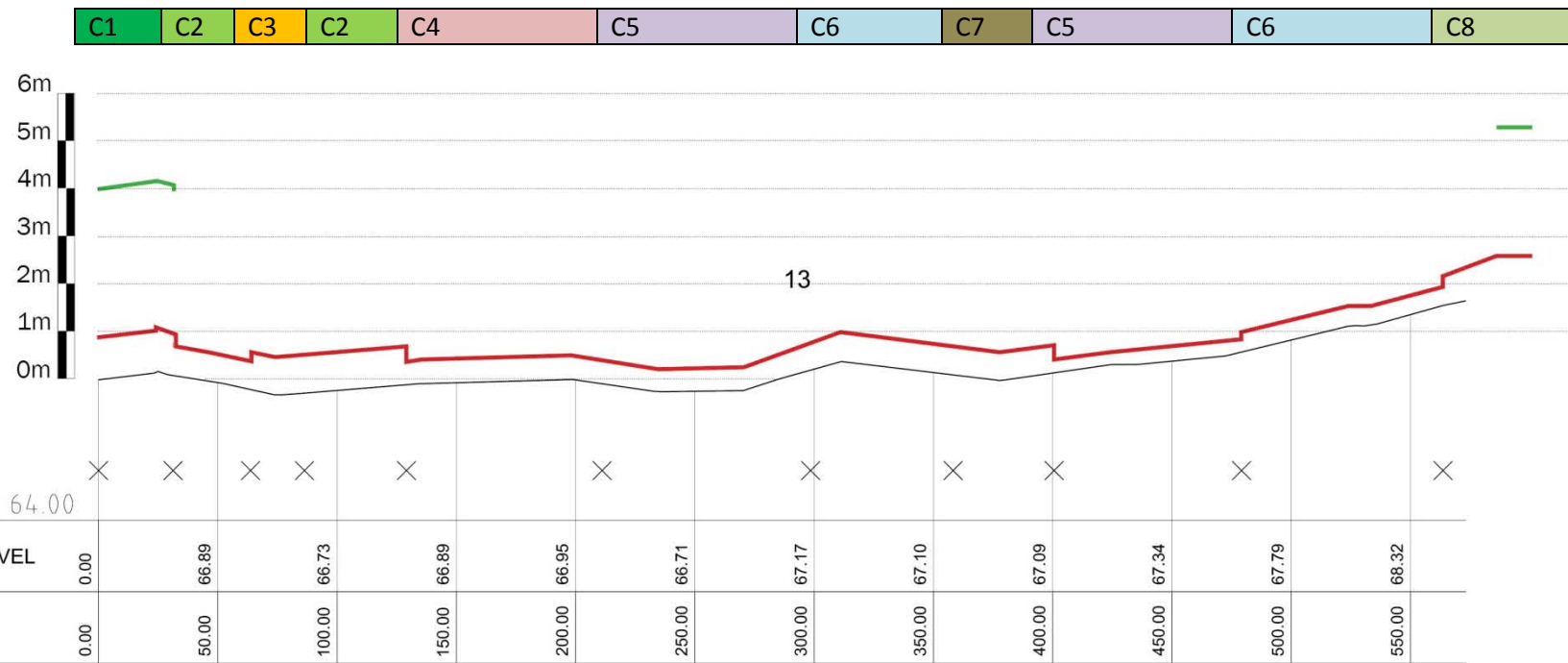


Community 6: Closed Low Heath of *Beaufortia squarrosa*, *Banksia telmatiaea* and *Calytrix ? aurea*

Community 7: Closed Low Heath of *Banksia telmatiaea*, *Calothamnus quadrifidus* subsp. *angustifolius* and *Verticordia densiflora* var. *densiflora* over Very Open Sedgeland of *Anarthria laevis*



Community 8: Low Open Woodland of *Banksia attenuata* and *Banksia littoralis* over Shrubland of *Hibbertia hypericoides* and *Eremaea pauciflora* var. ? *pauciflora* over Very Open Herbland of *Stirlingia latifolia* and *Dasypogon bromeliifolius*



COMMUNITY 1	
Family	Species
Proteaceae	<i>Banksia attenuata</i>
Proteaceae	<i>Banksia menziesii</i>
Dasypogonaceae	<i>Dasypogon bromeliifolius</i>
Myrtaceae	<i>Eremaea pauciflora</i> var. ? <i>pauciflora</i>
Dilleniaceae	<i>Hibbertia hypericoides</i>
Restionaceae	<i>Onychosepalum nodatum</i>
Iridaceae	<i>Patersonia occidentalis</i>
Haemodoraceae	<i>Phlebocarya ciliata</i>

COMMUNITY 2	
Family	Species
Proteaceae	<i>Banksia telmatiaea</i>
Myrtaceae	<i>Calothamnus quadrifidus</i> subsp. <i>angustifolius</i>
Myrtaceae	<i>Calytrix ?aurea</i>
Restionaceae	<i>Lepidobolus preissianus</i>
Myrtaceae	<i>Melaleuca seriata</i>
Myrtaceae	<i>Verticordia densiflora</i> var. <i>densiflora</i>

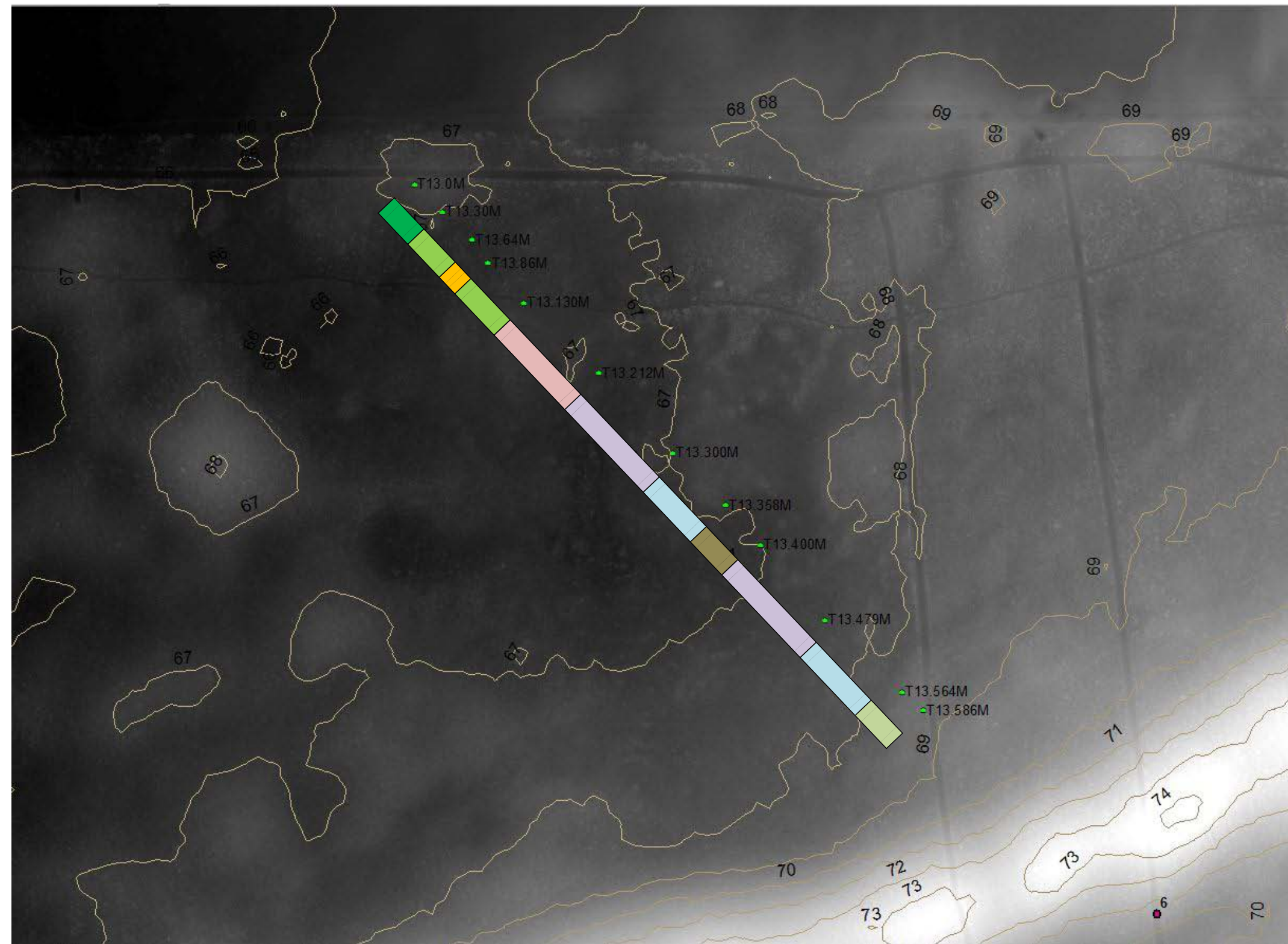
COMMUNITY 3	
Family	Species
Myrtaceae	<i>Astartea ?scoparia</i>
Proteaceae	<i>Banksia telmatiaea</i>
Restionaceae	<i>Chaetanthus aristatus</i>
Myrtaceae	<i>Verticordia densiflora</i> var. <i>densiflora</i>

COMMUNITY 4	
Family	Species
Proteaceae	<i>Banksia telmatiaea</i>
Myrtaceae	<i>Calytrix ?aurea</i>
Proteaceae	<i>Petrophile seminuda</i>

COMMUNITY 5	
Family	Species
Restionaceae	<i>Chaetanthus aristatus</i>
Myrtaceae	<i>Regelia ciliata</i>

COMMUNITY 6	
Family	Species
Proteaceae	<i>Banksia telmatiaea</i>
Myrtaceae	<i>Beaufortia squarrosa</i>
Myrtaceae	<i>Calytrix ?aurea</i>

COMMUNITY 7	
Family	Species
Anarthriaceae	<i>Anarthria laevis</i>
Proteaceae	<i>Banksia nivea</i> subsp. <i>nivea</i>
Proteaceae	<i>Banksia telmatiaea</i>
Myrtaceae	<i>Calothamnus quadrifidus</i> subsp. <i>angustifolius</i>
Myrtaceae	<i>Melaleuca brevifolia</i>
Myrtaceae	<i>Verticordia densiflora</i> var. <i>densiflora</i>



COMMUNITY 8	
Family	Species
Proteaceae	<i>Banksia attenuata</i>
Proteaceae	<i>Banksia littoralis</i>
Dasypogonaceae	<i>Dasypogon bromeliifolius</i>
Dilleniaceae	<i>Hibbertia hypericoides</i>
Proteaceae	<i>Stirlingia latifolia</i>

**APPENDIX 2 Bore logs from direct push and hand auger drilling programmes.**

CLIENT Tronox Limited PROJECT NAME Tronox

PROJECT NUMBER 1221 PROJECT LOCATION Tronox Cooljarloo Site

DATE STARTED 25/10/12 COMPLETED 25/10/12 R.L. SURFACE (m) \_\_\_\_\_ DATUM \_\_\_\_\_

DRILLING CONTRACTOR Ecoprobe NORTHING (m) 6605555.698 CO-ORDINATE SYSTEM GDA94

EQUIPMENT Direct Push Probe EASTING (m) 342641.996 HOLE LOCATION \_\_\_\_\_

HOLE SIZE (mm) 50 LOGGED BY AR CHECKED BY EO

NOTES

Method	Water	RL (m)	Depth (m)	Graphic Log	Classification Symbol	Material Description	Samples Tests Remarks	PID (ppm)	Additional Observations
						TOPSOIL, fine to medium, poorly graded, brown, dry.			
			1		SP	SAND, fine, uniform, white-pale grey, dry.			
			2		SP	SAND, fine, uniform, white-pale grey, slightly moist to dry.			
			2		SP	SAND, fine, poorly graded, white-yellow, slightly moist.			Contains some small pisolites.
			3		SP	SAND, fine, poorly graded, pale brown-dark brown, dry to slightly moist.			Contains small fragments (~2-3m^3) varying in colour.
			4		SM	CLAYEY SAND, low plasticity, fine to medium, poorly graded, pale brown-mottled red, slightly moist.			Ferruginised material present throughout.
			5			Borehole B01 terminated at 5m			
			6						

CLIENT Tronox Limited PROJECT NAME Tronox

PROJECT NUMBER 1221 PROJECT LOCATION Tronox Cooljarloo Site

DATE STARTED 25/10/12 COMPLETED 25/10/12 R.L. SURFACE (m) \_\_\_\_\_ DATUM \_\_\_\_\_

DRILLING CONTRACTOR Ecoprobe NORTHING (m) 6604704.953 CO-ORDINATE SYSTEM GDA94

EQUIPMENT Direct Push Probe EASTING (m) 342134.562 HOLE LOCATION \_\_\_\_\_

HOLE SIZE (mm) 50 LOGGED BY AR CHECKED BY EO






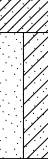




**NOTES**

Method	Water	RL (m)	Depth (m)	Graphic Log	Classification Symbol	Material Description	Samples Tests Remarks	PID (ppm)	Additional Observations
					SP	SAND, medium, well graded, rounded, dark grey-brown, dry.			
			1		SP	SAND, fine to medium, well graded, sub-rounded, white-pale grey, dry.			
			2		SP	SAND, fine to medium, well graded, pale grey-brown, slightly moist to dry.			
					SM	SAND, fine to medium, grey-mottled orange, slightly moist.			
			3			Borehole B02 terminated at 2.6m			Contains smaller fragments of varying colours (approximately 2mm <sup>3</sup> in size). Some ferruginised sediment spread throughout the material.
			4						
			5						
			6						

CLIENT Tronox Limited PROJECT NAME Tronox  
 PROJECT NUMBER 1221 PROJECT LOCATION Tronox Cooljarloo Site

DATE STARTED 24/10/12 COMPLETED 24/10/12 R.L. SURFACE (m) \_\_\_\_\_ DATUM \_\_\_\_\_  
 DRILLING CONTRACTOR Ecoprobe NORTHING (m) 6606156.965 CO-ORDINATE SYSTEM GDA94  
 EQUIPMENT Direct Push Probe EASTING (m) 340554.297 HOLE LOCATION \_\_\_\_\_  
 HOLE SIZE (mm) 50 LOGGED BY AR CHECKED BY EO

NOTES

Method	Water	RL (m)	Depth (m)	Graphic Log	Classification Symbol	Material Description	Samples Tests Remarks	PID (ppm)	Additional Observations
					SP	SAND, fine, uniform, rounded, pale white-pale grey, dry.			
			1		SP	SAND, medium, yellow-mottled dark red, slightly moist.			
					SP-SC	SAND WITH CLAY, medium plasticity, medium, red-grey, slightly moist.			
			2		SP	SAND, fine to medium, pale white-pale grey, slightly moist.			
					CL	CLAY WITH SAND, medium plasticity, fine to medium, grey, slightly moist.			
			3		CL	CLAY WITH SAND, medium plasticity, fine to medium, grey-mottled red, slightly moist.			
			4		SP-SC	SANDY CLAY, high plasticity, fine to medium, dark brown-mottled red, slightly moist.			Highly ferruginised layer.
					CH	CLAY, high plasticity, fine to medium, grey, slightly moist.			
					SP-SC	SANDY CLAY, high plasticity, fine to medium, dark brown-mottled red, slightly moist.			Highly ferruginised layer.
					CH	CLAY, high plasticity, fine to medium, grey, slightly moist.			
			5			Borehole B03 terminated at 5m			
			6						

CLIENT Tronox Limited PROJECT NAME Tronox

PROJECT NUMBER 1221 PROJECT LOCATION Tronox Cooljarloo Site

DATE STARTED 25/10/12 COMPLETED 25/10/12 R.L. SURFACE (m) \_\_\_\_\_ DATUM \_\_\_\_\_

DRILLING CONTRACTOR Ecoprobe NORTHING (m) 6604215.825 CO-ORDINATE SYSTEM GDA94

EQUIPMENT Direct Push Probe EASTING (m) 341098.121 HOLE LOCATION \_\_\_\_\_

HOLE SIZE (mm) 50 LOGGED BY AR CHECKED BY EO

NOTES

Method	Water	RL (m)	Depth (m)	Graphic Log	Classification Symbol	Material Description	Samples Tests Remarks	PID (ppm)	Additional Observations
					SP	TOPSOIL, fine, uniform, brown, dry.			
					SP	SAND, fine, grey-white, dry.			
			1		SP	SAND, fine, grey-yellow, moist to slightly moist.			
			2		SW-SC	SANDY CLAY, medium plasticity, medium to coarse, poorly graded, brown-yellow, moist.			Contains some root material (of varying sizes)
					SW-SC	SANDY CLAY, medium plasticity, medium to coarse, poorly graded, orange-mottled red, moist.			Strongly ferruginised sediment.
			3		SM	SANDY CLAY, medium plasticity, medium, poorly graded, brown-yellow, moist.			Contains some root material (of varying sizes)
					SP-SM	SAND, high plasticity, medium, yellow-brown, slightly moist.			
					SP-SM	SAND, fine to medium, orange-mottled red, moist.			Strongly ferruginised sediment.
			4		SP-SM	SAND, fine, yellow-brown, slightly moist to dry.			Some ferruginised bands present within the material.
			5		SP-SM	SAND, fine, red-brown, slightly moist.			Strongly ferruginised throughout.
						Borehole B04 terminated at 5m			
			6						

CLIENT Tronox Limited PROJECT NAME Tronox

PROJECT NUMBER 1221 PROJECT LOCATION Tronox Cooljarloo Site

DATE STARTED 25/10/12 COMPLETED 25/10/12 R.L. SURFACE (m) \_\_\_\_\_ DATUM \_\_\_\_\_

DRILLING CONTRACTOR Ecoprobe NORTHING (m) 6604927.31 CO-ORDINATE SYSTEM GDA94

EQUIPMENT Direct Push Probe EASTING (m) 344798.355 HOLE LOCATION \_\_\_\_\_

HOLE SIZE (mm) 50 LOGGED BY AR CHECKED BY EO

NOTES

Method	Water	RL (m)	Depth (m)	Graphic Log	Classification Symbol	Material Description	Samples Tests Remarks	PID (ppm)	Additional Observations
						TOPSOIL, fine to medium, dark brown-brown, dry.			
			1		SP	SAND, fine, uniform, white-pale grey, dry.			
					SP	SAND, fine to medium, pale grey-pale yellow, dry.			Contains some small fragments (Approximately 2mm^3, red or black in colour).
					SM	SAND, fine to medium, grey-mottled yellow, slightly moist to dry.			Extensive ferruginisation in parts.
			2		SM	SANDY CLAY, low plasticity, fine, grey-mottled dark yellow, moist to slightly moist.			
					SP	SAND, fine, white-pale grey, dry.			Highly friable sediment.
					SP-SM	SANDY CLAY, low plasticity, fine to medium, poorly graded, orange-white, slightly moist.			
					SM	SANDY CLAY, low plasticity, fine, yellow-mottled red, slightly moist.			Highly ferruginised sediment.
			3			Borehole B05 terminated at 2.8m			
			4						
			5						
			6						

CLIENT Tronox Limited PROJECT NAME Tronox

PROJECT NUMBER 1221 PROJECT LOCATION Tronox Cooljarloo Site







DATE STARTED 25/10/12 COMPLETED 25/10/12 R.L. SURFACE (m) \_\_\_\_\_ DATUM \_\_\_\_\_

DRILLING CONTRACTOR Ecoprobe NORTHING (m) 6604510.592 CO-ORDINATE SYSTEM GDA94

EQUIPMENT Direct Push Probe EASTING (m) 344732.209 HOLE LOCATION \_\_\_\_\_

HOLE SIZE (mm) 50 LOGGED BY AR CHECKED BY EO

NOTES

Method	Water	RL (m)	Depth (m)	Graphic Log	Classification Symbol	Material Description	Samples Tests Remarks	PID (ppm)	Additional Observations
			1		SP	SAND, fine, uniform, white-pale grey, dry.			Contains some fine roots (~1mm width)
					SP	SAND, fine to medium, poorly graded, brown-pale grey, dry.			Contains dark brown & red fragments of varying sizes.
					SP	SAND, fine to medium, grey-yellow, slightly moist.			
			2		SC-SM	CLAYEY SAND, medium plasticity, medium, yellow-grey, dry to slightly moist.			Extremely friable material.
					SC-SM	CLAYEY SAND, low plasticity, fine, grey, dry.			
			3		SP-SC	SAND WITH CLAY, medium plasticity, fine to medium, grey-yellow, slightly moist to dry.			Contains small white crystalline structures (approximately 2mm^3 in size) throughout the material.
						Borehole B06 terminated at 3.5m			
			4						
			5						
			6						

CLIENT Tronox Limited PROJECT NAME Tronox

PROJECT NUMBER 1221 PROJECT LOCATION Tronox Cooljarloo Site

DATE STARTED 26/10/12 COMPLETED 26/10/12 R.L. SURFACE (m) \_\_\_\_\_ DATUM \_\_\_\_\_

DRILLING CONTRACTOR Ecoprobe NORTHING (m) 6603303.428 CO-ORDINATE SYSTEM GDA94

EQUIPMENT Direct Push Probe EASTING (m) 345618.564 HOLE LOCATION \_\_\_\_\_

HOLE SIZE (mm) 50 LOGGED BY AR CHECKED BY EO

NOTES

Method	Water	RL (m)	Depth (m)	Graphic Log	Classification Symbol	Material Description	Samples Tests Remarks	PID (ppm)	Additional Observations
					SP-SM	SAND, fine, uniform, pale grey-brown, dry.			Contains some fine roots (~1mm width)
					SC	SANDY CLAY, high plasticity, fine to medium, poorly graded, dark yellow-brown, slightly moist.			
					SM	SAND, medium, yellow, slightly moist.			
			1		SM	SANDY CLAY, low plasticity, fine to medium, poorly graded, pale grey-yellow, slightly moist.			Extensive ferruginisation throughout.
			2		SM	SANDY CLAY, low plasticity, fine to medium, poorly graded, pale grey-yellow, slightly moist.			
			3		GM	SANDY CLAY, low plasticity, medium, yellow-dark grey, dry.			
					SP-SC	SAND WITH CLAY, low plasticity, medium, poorly graded, pale grey-yellow, slightly moist.			Contains small white crystalline structures (approximately 2mm^3 in size) throughout the material. Extensive ferruginisation throughout.
						Borehole B07 terminated at 3.5m			
			4						
			5						
			6						

CLIENT Tronox Limited PROJECT NAME Tronox

PROJECT NUMBER 1221 PROJECT LOCATION Tronox Cooljarloo Site








DATE STARTED 25/10/12 COMPLETED 25/10/12 R.L. SURFACE (m) \_\_\_\_\_ DATUM \_\_\_\_\_

DRILLING CONTRACTOR Ecoprobe NORTHING (m) 6602879.658 CO-ORDINATE SYSTEM GDA94

EQUIPMENT Direct Push Probe EASTING (m) 342800.61 HOLE LOCATION \_\_\_\_\_

HOLE SIZE (mm) 50 LOGGED BY AR CHECKED BY EO

NOTES

Method	Water	RL (m)	Depth (m)	Graphic Log	Classification Symbol	Material Description	Samples Tests Remarks	PID (ppm)	Additional Observations
			1		SP	SAND, fine, uniform, pale yellow-pale grey, dry.			
					SP	SAND, fine to medium, poorly graded, rounded, yellow-pale grey, dry.			
					SP	SAND, fine, uniform, yellow-pale grey, slightly moist to dry.			Contains small roots (~1mm width); friable when broken under pressure.
					SP	SAND, fine to medium, dark yellow-yellow, dry.			
			2		SP	SAND, fine, yellow-grey, slightly moist.			Allochthonous pisolites are present within the material.
					SP-SC	SAND WITH CLAY, medium plasticity, fine to medium, yellow-mottled dark red, moist to slightly moist.			Increasingly widespread ferruginisation throughout the material, leading to increasing nodulisation; some clays contained within the sediment.
					SP-SC	SAND WITH CLAY, medium plasticity, fine to medium, well graded, grey-mottled dark red, slightly moist.			Extensive mottling & some nodulisation (ferruginous); contains small white crystalline structures throughout.
			4			Borehole B08 terminated at 3.5m			
			5						
			6						

CLIENT Tronox Limited PROJECT NAME Tronox

PROJECT NUMBER 1221 PROJECT LOCATION Tronox Cooljarloo Site

DATE STARTED 26/10/12 COMPLETED 26/10/12 R.L. SURFACE (m) \_\_\_\_\_ DATUM \_\_\_\_\_

DRILLING CONTRACTOR Ecoprobe NORTHING (m) 6608664.233 CO-ORDINATE SYSTEM GDA94

EQUIPMENT Direct Push Probe EASTING (m) 343098.634 HOLE LOCATION \_\_\_\_\_

HOLE SIZE (mm) 50 LOGGED BY AR CHECKED BY EO

**NOTES**

Method	Water	RL (m)	Depth (m)	Graphic Log	Classification Symbol	Material Description	Samples Tests Remarks	PID (ppm)	Additional Observations
					SP	SAND, fine, uniform, dark red-grey, dry.			Very fibrous material.
			1		SC-SM	CLAYEY SAND, medium plasticity, fine to medium, yellow-grey, slightly moist to dry.			Extensive mottling and ferruginisation found in the upper 0.5m; moisture content gradually increases with depth.
			2		SP-SC	SANDY CLAY, high plasticity, fine to medium, well graded, pale red-yellow, slightly moist.			
			3		SP-SC	SANDY CLAY, high plasticity, fine to medium, well graded, pale red-yellow, slightly moist.			Some ferruginisation throughout the material; contains small white crystals throughout.
			4		SP-SC	SANDY CLAY, high plasticity, fine to medium, well graded, red-green, slightly moist.			Ferruginised material present throughout; contains small white crystalline structures; increased amounts of green clay material throughout.
			5		SP-SC	SANDY CLAY, high plasticity, fine to medium, well graded, red-green, slightly moist.			
			6			Borehole MB01 terminated at 5.5m			



CLIENT Tronox Limited PROJECT NAME Tronox

PROJECT NUMBER 1221 PROJECT LOCATION Tronox Cooljarloo Site

DATE STARTED 24/10/12 COMPLETED 24/10/12 R.L. SURFACE (m) \_\_\_\_\_ DATUM \_\_\_\_\_

DRILLING CONTRACTOR Ecoprobe NORTHING (m) 6605270.029 CO-ORDINATE SYSTEM GDA94

EQUIPMENT Direct Push Probe EASTING (m) 340821.661 HOLE LOCATION \_\_\_\_\_

HOLE SIZE (mm) 50 LOGGED BY AR CHECKED BY EO

**NOTES**

Method	Water	RL (m)	Depth (m)	Graphic Log	Classification Symbol	Material Description	Samples Tests Remarks	PID (ppm)	Additional Observations
			1		SP	SAND, fine, uniform, grey-white, dry to slightly moist.			<p>Contains small fragments (0.4-0.8mm<sup>3</sup> in size, brown in colour).</p> <p>Some ferruginisation throughout the material.</p>
					SP	SAND, fine, poorly graded, yellow-pale brown, dry.			
					SP	SAND, fine to medium, grey-pale brown, slightly moist.			
			2		SP	SAND, fine to medium, poorly graded, yellow-mottled red, slightly moist.			
					SP	SAND, fine to medium, mottled dark red-brown, slightly moist.			
			3			Borehole MB03 terminated at 2.7m			
			4						
			5						
			6						

BOREHOLE / TEST PIT / OCTOBER BORELOGS - AMMENDED\_25072013.GPJ SYRINX AUSTRALIAN STANDARD.GDT 25/7/13

CLIENT Tronox Limited PROJECT NAME Tronox

PROJECT NUMBER 1221 PROJECT LOCATION Tronox Cooljarloo Site

DATE STARTED 26/10/12 COMPLETED 26/10/12 R.L. SURFACE (m) \_\_\_\_\_ DATUM \_\_\_\_\_

DRILLING CONTRACTOR Ecoprobe NORTHING (m) 6607083.487 CO-ORDINATE SYSTEM GDA94

EQUIPMENT Direct Push Probe EASTING (m) 343116.132 HOLE LOCATION \_\_\_\_\_

HOLE SIZE (mm) 50 LOGGED BY AR CHECKED BY EO

**NOTES**

Method	Water	RL (m)	Depth (m)	Graphic Log	Classification Symbol	Material Description	Samples Tests Remarks	PID (ppm)	Additional Observations
					SP	SAND, fine, uniform, dark grey-white, dry to slightly moist.			
					SP	SAND, fine, uniform, dark grey-white, wet to saturated.			
					SC-SM	CLAYEY SAND, medium plasticity, fine to medium, dark brown-grey, wet to very wet.			
			1		SC-SM	CLAYEY SAND, medium plasticity, fine to medium, yellow-grey, slightly moist.			
			2						Some ferruginisation throughout the material.
			3		SC-SM	CLAYEY SAND, high plasticity, fine, green-pale grey, very moist to moist.			White crystals are abundant throughout the material.
					SC-SM	CLAYEY SAND, high plasticity, fine, black-dark green, very moist to moist.			Contains several small fragments (approximately 10mm^3 in size), which are dark in colour with a white crystalline structure.
			4			Borehole MB04 terminated at 3.5m			
			5						
			6						

BOREHOLE / TEST PIT / OCTOBER BORELOGS - AMMENDED\_25072013.GPJ SYRINX AUSTRALIAN STANDARD.GDT 25/7/13

Groundwater Level ▼

CLIENT Tronox Limited PROJECT NAME Tronox

PROJECT NUMBER 1221 PROJECT LOCATION Tronox Cooljarloo Site

DATE STARTED 25/10/12 COMPLETED 25/10/12 R.L. SURFACE (m) \_\_\_\_\_ DATUM \_\_\_\_\_

DRILLING CONTRACTOR Ecoprobe NORTHING (m) 6605036.052 CO-ORDINATE SYSTEM GDA94

EQUIPMENT Direct Push Probe EASTING (m) 344105.905 HOLE LOCATION \_\_\_\_\_

HOLE SIZE (mm) 50 LOGGED BY AR CHECKED BY EO

NOTES

Method	Water	RL (m)	Depth (m)	Graphic Log	Classification Symbol	Material Description	Samples Tests Remarks	PID (ppm)	Additional Observations
					SP	SAND, fine, uniform, dark brown-brown, dry.			
					SP	SAND, fine to medium, poorly graded, brown, dry.			
			1		SP	SAND, fine to medium, poorly graded, white-yellow, dry.			Becomes more ferruginous with depth; also contains small fragments (approximately 2mm <sup>2</sup> in size and black & yellow in colour) spread throughout the material.
			2		SM	SAND, fine, yellow, slightly moist.			
					SC	CLAYEY SAND, medium plasticity, fine to medium, pale grey-mottled yellow, moist to slightly moist.			Some ferruginised material present throughout.
			3		SC-SM	SANDY CLAY, low plasticity, fine to medium, grey-mottled yellow, moist to slightly moist.			Some sparse nodulisation present in the material.
			4			Borehole MB08 terminated at 3.5m			
			5						
			6						

CLIENT Tronox Limited PROJECT NAME Tronox

PROJECT NUMBER 1221 PROJECT LOCATION Tronox Cooljarloo Site

DATE STARTED 25/10/12 COMPLETED 25/10/12 R.L. SURFACE (m) \_\_\_\_\_ DATUM \_\_\_\_\_

DRILLING CONTRACTOR Ecoprobe NORTHING (m) 6604373.419 CO-ORDINATE SYSTEM GDA94

EQUIPMENT Direct Push Probe EASTING (m) 340592.452 HOLE LOCATION \_\_\_\_\_

HOLE SIZE (mm) 50 LOGGED BY AR CHECKED BY EO

NOTES

Method	Water	RL (m)	Depth (m)	Graphic Log	Classification Symbol	Material Description	Samples Tests Remarks	PID (ppm)	Additional Observations
			1		SP	SAND, fine, grey-pale white, dry.			
			2		SP	SAND, medium, yellow-pale brown, slightly moist to dry.			
			3		SP	SAND, medium to coarse, grey-dark orange, slightly moist.			Some ferruginisation throughout the material.
					SP	SAND, medium, red-brown, slightly moist.			Highly ferruginised material.
					SP	SAND, fine to medium, red-brown, slightly moist.			Sand
					SP	SAND, coarse, grey-brown, slightly moist.			Some ferruginised material present, (however less widespread than in other layers).
			4			Borehole MB10 terminated at 3.5m			
			5						
			6						

CLIENT Tronox Limited PROJECT NAME Tronox

PROJECT NUMBER 1221 PROJECT LOCATION Tronox Cooljarloo Site

DATE STARTED 25/10/12 COMPLETED 25/10/12 R.L. SURFACE (m) \_\_\_\_\_ DATUM \_\_\_\_\_

DRILLING CONTRACTOR Ecoprobe NORTHING (m) 6604086.73 CO-ORDINATE SYSTEM GDA94

EQUIPMENT Direct Push Probe EASTING (m) 344208.44 HOLE LOCATION \_\_\_\_\_

HOLE SIZE (mm) 50 LOGGED BY AR CHECKED BY EO

NOTES

Method	Water	RL (m)	Depth (m)	Graphic Log	Classification Symbol	Material Description	Samples Tests Remarks	PID (ppm)	Additional Observations
			1		SP	SAND, fine, uniform, pale grey-pale brown, moist to slightly moist.			Contains some small roots (~1-2mm wide). Contains some small roots (~1-2mm wide). Some variable clay content. Dark red colouration caused by high amounts of ferruginisation within the material. Friable once broken.
					SP	SAND, fine to medium, pale brown-yellow, slightly moist.			
					SP	SAND, fine to medium, rounded, yellow-mottled dark red, slightly moist to moist.			
					SP	SAND, fine to medium, grey-yellow, slightly moist.			
			2			Borehole MB12 terminated at 1.5m			
			3						
			4						
			5						
			6						

CLIENT Tronox Limited PROJECT NAME Tronox

PROJECT NUMBER 1221 PROJECT LOCATION Tronox Cooljarloo Site

DATE STARTED 25/10/12 COMPLETED 25/10/12 R.L. SURFACE (m) \_\_\_\_\_ DATUM \_\_\_\_\_

DRILLING CONTRACTOR Ecoprobe NORTHING (m) 6602900.406 CO-ORDINATE SYSTEM GDA94

EQUIPMENT Direct Push Probe EASTING (m) 343314.111 HOLE LOCATION \_\_\_\_\_

HOLE SIZE (mm) 50 LOGGED BY AR CHECKED BY EO

NOTES

Method	Water	RL (m)	Depth (m)	Graphic Log	Classification Symbol	Material Description	Samples Tests Remarks	PID (ppm)	Additional Observations
						SAND, fine, uniform, dark brown, dry.			Contains small roots (~1mm width) and some organic matter.
					SP	SAND, fine, uniform, pale white-pale grey, dry.			
			1		SP	SAND, fine, uniform, pale grey, dry.			
			2						
					SP	SAND, fine, yellow-pale white, slightly moist to dry.			
			3						
					SP	SAND, fine to medium, white-yellow, wet to very moist.			
			4		SP	SAND, fine to medium, yellow-mottled red, slightly moist to dry.			Highly ferruginised sands; friable under pressure.
					SP	SAND, fine to medium, yellow-mottled red, moist.			
			5		SC-SM	SANDY CLAY, medium plasticity, fine to medium, grey-mottled red, slightly moist.			Highly ferruginised; 'Coffee Rock' formed.
						Borehole MB14 terminated at 5m			
			6						

BOREHOLE / TEST PIT / OCTOBER BORELOGS - AMMENDED\_25072013.GPJ SYRINX AUSTRALIAN STANDARD.GDT 25/7/13

CLIENT Tronox Limited PROJECT NAME Tronox

PROJECT NUMBER 1221 PROJECT LOCATION Tronox Cooljarloo Site





DATE STARTED 26/10/12 COMPLETED 26/10/12 R.L. SURFACE (m) \_\_\_\_\_ DATUM \_\_\_\_\_

DRILLING CONTRACTOR Ecoprobe NORTHING (m) 6602200 CO-ORDINATE SYSTEM GDA94

EQUIPMENT Direct Push Probe EASTING (m) 345123.997 HOLE LOCATION \_\_\_\_\_

HOLE SIZE (mm) 50 LOGGED BY AR CHECKED BY EO

**NOTES**

Method	Water	RL (m)	Depth (m)	Graphic Log	Classification Symbol	Material Description	Samples Tests Remarks	PID (ppm)	Additional Observations
					SP	SAND, fine to medium, uniform, pale grey-white, dry.			Contains roots in a range of different sizes
			1		SP	SAND, medium to coarse, gap graded, yellow, dry to slightly moist.			Some small roots (~2mm width) present
					SC	SANDY CLAY, high plasticity, fine to medium, dark grey-mottled dark red, slightly moist to moist.			
			2		SC-SM	CLAYEY SAND, low plasticity, fine to medium, yellow-mottled dark red, slightly moist.			Some ferruginisation throughout the material
			3						
			4			Borehole MB15 terminated at 3.5m			
			5						
			6						

CLIENT Tronox Limited PROJECT NAME Tronox

PROJECT NUMBER 1221 PROJECT LOCATION Tronox Cooljarloo Site

DATE STARTED 26/10/12 COMPLETED 26/10/12 R.L. SURFACE (m) \_\_\_\_\_ DATUM \_\_\_\_\_

DRILLING CONTRACTOR Ecoprobe NORTHING (m) 6601292.87 CO-ORDINATE SYSTEM GDA94

EQUIPMENT Direct Push Probe EASTING (m) 345075.235 HOLE LOCATION \_\_\_\_\_

HOLE SIZE (mm) 50 LOGGED BY AR CHECKED BY EO

NOTES

Method	Water	RL (m)	Depth (m)	Graphic Log	Classification Symbol	Material Description	Samples Tests Remarks	PID (ppm)	Additional Observations
			1		SP SP-SC SP-SC	SAND, fine, uniform, pale grey-brown, dry. SANDY CLAY, low plasticity, fine to medium, yellow-pale grey, slightly moist. SANDY CLAY, low plasticity, fine to medium, yellow-mottled dark red, slightly moist to dry.			Contains some Organic Matter and small roots.  Extensive ferruginisation occurring in bands; extremely friable
			2			Borehole MB17 terminated at 1.3m			
			3						
			4						
			5						
			6						

CLIENT Tronox Limited PROJECT NAME Tronox

PROJECT NUMBER 1221 PROJECT LOCATION Tronox Cooljarloo Site

DATE STARTED 26/10/12 COMPLETED 26/10/12 R.L. SURFACE (m) \_\_\_\_\_ DATUM \_\_\_\_\_

DRILLING CONTRACTOR Ecoprobe NORTHING (m) 6603304.78 CO-ORDINATE SYSTEM GDA94

EQUIPMENT Direct Push Probe EASTING (m) 346193.04 HOLE LOCATION \_\_\_\_\_

HOLE SIZE (mm) 50 LOGGED BY AR CHECKED BY EO

**NOTES**

Method	Water	RL (m)	Depth (m)	Graphic Log	Classification Symbol	Material Description	Samples Tests Remarks	PID (ppm)	Additional Observations
			1		SP-SM CL CL	SAND, fine, uniform, pale grey-brown, dry. SANDY CLAY, high plasticity, fine to medium, poorly graded, dark yellow-brown, moist. SANDY CLAY, medium plasticity, fine to medium, poorly graded, grey-mottled dark red, slightly moist to moist.			Contains some small roots (~1mm width) Contains some roots (~3mm wide and 30mm long) Extensively ferruginised and mottled
			2			Borehole MB18 terminated at 1.1m			
			3						
			4						
			5						
			6						

CLIENT Tronox Limited PROJECT NAME Tronox

PROJECT NUMBER 1221 PROJECT LOCATION Tronox Cooljarloo Site

DATE STARTED 26/10/12 COMPLETED 26/10/12 R.L. SURFACE (m) \_\_\_\_\_ DATUM \_\_\_\_\_

DRILLING CONTRACTOR Ecoprobe NORTHING (m) 6601655 CO-ORDINATE SYSTEM GDA94

EQUIPMENT Hand Augur EASTING (m) 348975.907 HOLE LOCATION \_\_\_\_\_

HOLE SIZE (mm) 50 LOGGED BY AR CHECKED BY EO

**NOTES**

Method	Water	RL (m)	Depth (m)	Graphic Log	Classification Symbol	Material Description	Samples Tests Remarks	PID (ppm)	Additional Observations
				SP	SP	SAND, fine, uniform, white-pale grey, dry.			Contains plant roots of varying sizes.
			1	SP	SP	SAND, fine, uniform, yellow-pale grey, dry.			
			2	SP	SP	SAND, medium to coarse, uniform, dark brown-dark red, slightly moist.			
						Borehole R01 terminated at 2m			
			3						
			4						
			5						
			6						

**CLIENT** Tronox Limited **PROJECT NAME** Tronox  
**PROJECT NUMBER** 1221 **PROJECT LOCATION** Tronox Cooljarloo West Site  
**DATE STARTED** 13/12/12 **COMPLETED** 13/12/12 **R.L. SURFACE (m)** - **DATUM**   
**DRILLING CONTRACTOR** Syrinx Personnel **NORTHING (m)** 6607256 **CO-ORDINATE SYSTEM** GDA 94  
**EQUIPMENT** Hand Auger **EASTING (m)** 342764 **HOLE LOCATION**   
**HOLE SIZE (mm)** 85 **LOGGED BY** AR **CHECKED BY** SDo

**NOTES**

Method	Water	RL (m)	Depth (m)	Graphic Log	Classification Symbol	Material Description	Samples Tests Remarks	PID (ppm)	Additional Observations
					SP	SAND, fine, uniform, white-pale grey, dry.			Contains fine roots in the top 0.1m; fibrous  Contains some well-cemented fragments of Silty Sand (brown in colour) which are fibrous under lightly-applied pressure; white crystalline structures also present sporadically across the layer  Contains some well-cemented fragments of Silty Sand (brown in colour) which are fibrous under lightly-applied pressure  Some clays present within the layer  Contains smaller fragments of well-cemented fine-grained sand (extensively ferruginised)  Contains smaller fragments of well-cemented fine-grained sand (extensively ferruginised)  Contains some small roots (found within the green areas of the material, also surrounded by white material); some small areas of ferruginised material found within the layer  Contains some fragments of well-cemented Silty Sands
					SP	SAND, fine, uniform, white-yellow, dry.			
					SP	SAND, fine to medium, poorly graded, dark brown-pale brown, dry.			
					SP	SAND, fine to medium, poorly graded, dark brown, dry.			
			1		SP-SC	SAND WITH CLAY, medium plasticity, fine to medium, poorly graded, pale brown-yellow, dry.			
					SP-SC	SAND WITH CLAY, high plasticity, fine to medium, poorly graded, pale brown-green, moist.			
					SC	SAND WITH CLAY, high plasticity, fine to medium, poorly graded, pale brown-green, moist.			
			2		CL	CLAYEY SAND, high plasticity, fine to medium, poorly graded, brown-green, moist to slightly moist.			
					CL	CLAYEY SAND, medium plasticity, fine to medium, poorly graded, dark green, moist.			
			3			Borehole A01 terminated at 2.8m			
			4						
			5						
			6						

BOREHOLE / TEST PIT HAND AUGERING\_AMMENDED\_250713.GPJ SYRINX AUSTRALIAN STANDARD.GDT 28/7/13

**CLIENT** Tronox Limited **PROJECT NAME** Tronox  
**PROJECT NUMBER** 1221 **PROJECT LOCATION** Tronox Cooljarloo West Site  
**DATE STARTED** 13/12/12 **COMPLETED** 13/12/12 **R.L. SURFACE (m)** - **DATUM** \_\_\_\_\_  
**DRILLING CONTRACTOR** Syrinx Personnel **NORTHING (m)** 6606264 **CO-ORDINATE SYSTEM** GDA 94  
**EQUIPMENT** Hand Auger **EASTING (m)** 347659 **HOLE LOCATION** \_\_\_\_\_  
**HOLE SIZE (mm)** 85 **LOGGED BY** AR **CHECKED BY** SDo

**NOTES**

Method	Water	RL (m)	Depth (m)	Graphic Log	Classification Symbol	Material Description	Samples Tests Remarks	PID (ppm)	Additional Observations
					SP	SAND, fine, uniform, white-pale grey, dry.			Contains fine roots in the top 0.1m; fibrous
			1		SP	SAND, fine to medium, poorly graded, pale brown, dry.			Contains some Organic Matte throughout the layer; also contains some fine root material. Contains some small fragments (approximately 1cm <sup>3</sup> in size) of well-cemented silty/sand (fragments were red in colour due to extensive ferruginisation).
					SP	SAND, fine to medium, poorly graded, yellow-grey, slightly moist to dry.			
					SP	SAND, fine to medium, poorly graded, yellow-grey, slightly moist.			
					SP	SAND, medium, poorly graded, yellow-grey, slightly moist.			
					SP	SAND, medium, poorly graded, yellow-grey, slightly moist.			
					SP-SC	SAND WITH CLAY, medium plasticity, fine to medium, poorly graded, yellow-grey, slightly moist.			
			2			Borehole A02 terminated at 1.8m			
			3						
			4						
			5						
			6						

BOREHOLE / TEST PIT HAND AUGERING\_AMMENDED\_250713.GPJ SYRINX AUSTRALIAN STANDARD.GDT 28/7/13

CLIENT Tronox Limited PROJECT NAME Tronox

PROJECT NUMBER 1221 PROJECT LOCATION Tronox Cooljarloo West Site


DATE STARTED 14/12/12 COMPLETED 14/12/12 R.L. SURFACE (m) - DATUM

DRILLING CONTRACTOR Syrinx Personnel NORTHING (m) 6604766 CO-ORDINATE SYSTEM GDA 94

EQUIPMENT Hand Auger EASTING (m) 344704 HOLE LOCATION

HOLE SIZE (mm) 85 LOGGED BY AR CHECKED BY SDo

NOTES

Method	Water	RL (m)	Depth (m)	Graphic Log	Classification Symbol	Material Description	Samples Tests Remarks	PID (ppm)	Additional Observations
			1		SP	SAND, fine, uniform, white-pale grey, dry.			Contains fine roots in the top 0.1m; fibrous
					SP	SAND, fine, uniform, pale yellow-white, dry.			
					SP	SAND, fine to medium, uniform, yellow-white, dry.			
					SP	SAND, fine to medium, poorly graded, brown-grey, slightly moist.			Contains some small fragments of lightly-cemented, fine-grained sands (grey in colour)
			2			Borehole A03 terminated at 1.6m			
			3						
			4						
			5						
			6						

CLIENT Tronox Limited PROJECT NAME Tronox

PROJECT NUMBER 1221 PROJECT LOCATION Tronox Cooljarloo West Site

DATE STARTED 14/12/12 COMPLETED 14/12/12 R.L. SURFACE (m) - DATUM

DRILLING CONTRACTOR Syrinx Personnel NORTHING (m) 6604490 CO-ORDINATE SYSTEM GDA 94

EQUIPMENT Hand Auger EASTING (m) 342218 HOLE LOCATION

HOLE SIZE (mm) 85 LOGGED BY AR CHECKED BY SDo

**NOTES**

Method	Water	RL (m)	Depth (m)	Graphic Log	Classification Symbol	Material Description	Samples Tests Remarks	PID (ppm)	Additional Observations
			1		SP	SAND, fine to medium, uniform, white-pale grey, slightly moist.			Contains fine roots in the top 0.1m; fibrous Contains larger fragments of well-cemented, fine-grained Silty Sand; fine roots also present throughout Contains large fragments of moderately-consolidated Silty Clay (grey in colour)
					SP	SAND, fine to medium, poorly graded, pale brown-yellow, slightly moist.			
					SP	SAND, fine to medium, poorly graded, pale brown-yellow, moist.			
					SP	SAND, fine to medium, poorly graded, pale grey-white, slightly moist.			
			2		SP	SAND, fine to medium, poorly graded, yellow-pale brown, slightly moist.			
						Borehole A04 terminated at 1.75m			
			3						
			4						
			5						
			6						



CLIENT Tronox Limited PROJECT NAME Tronox

PROJECT NUMBER 1221 PROJECT LOCATION Tronox Cooljarloo West Site

DATE STARTED 13/12/12 COMPLETED 13/12/12 R.L. SURFACE (m) - DATUM

DRILLING CONTRACTOR Syrinx Personnel NORTHING (m) 6605519 CO-ORDINATE SYSTEM GDA 94

EQUIPMENT Hand Auger EASTING (m) 340712 HOLE LOCATION

HOLE SIZE (mm) 85 LOGGED BY AR CHECKED BY SDo

**NOTES**

Method	Water	RL (m)	Depth (m)	Graphic Log	Classification Symbol	Material Description	Samples Tests Remarks	PID (ppm)	Additional Observations
					SP	SAND, fine to medium, poorly graded, pale brown-yellow, slightly moist to dry.			Contains fine roots throughout the material
					SP	SAND, coarse, well graded, yellow, slightly moist.			Contains larger fragments (~1/cm <sup>3</sup> ) of well-cemented coarse sand; dark brown/red in colour (extensively ferruginised). Fragments are widespread throughout the layer.
			1			Borehole A05 terminated at 0.9m			
			2						
			3						
			4						
			5						
			6						

CLIENT Tronox Limited PROJECT NAME Tronox

PROJECT NUMBER 1221 PROJECT LOCATION Tronox Cooljarloo West Site

DATE STARTED 14/12/12 COMPLETED 14/12/12 R.L. SURFACE (m) - DATUM

DRILLING CONTRACTOR Syrinx Personnel NORTHING (m) 6604231 CO-ORDINATE SYSTEM GDA 94

EQUIPMENT Hand Auger EASTING (m) 340967 HOLE LOCATION

HOLE SIZE (mm) 85 LOGGED BY AR CHECKED BY SDo

**NOTES**

Method	Water	RL (m)	Depth (m)	Graphic Log	Classification Symbol	Material Description	Samples Tests Remarks	PID (ppm)	Additional Observations
					SP	SAND, fine, uniform, white-pale yellow, slightly moist.			Contains fine roots in the top 0.1m; fibrous
					PT	FIBROUS PEAT, fine to medium, poorly graded, dark brown, slightly moist.			
					SW-SM	SAND, fine to medium, well graded, dark brown-yellow, slightly moist.			
					PT	FIBROUS PEAT, low plasticity, fine to medium, poorly graded, dark brown, moist.			
					SP	SAND, medium, poorly graded, dark brown-yellow, slightly moist.			Contains fine root material
			1		ML	SAND WITH CLAY, high plasticity, medium to coarse, poorly graded, dark yellow-brown, slightly moist.			Contains clay material within the layer
					SW	SAND, fine to medium, poorly graded, yellow-white, dry to slightly moist.			Contains larger fragments of poorly-cemented, coarse-grained sand (fibrous under a small amount of pressure)
					SM	SAND WITH CLAY, medium plasticity, fine to medium, poorly graded, pale brown-yellow, slightly moist.			Contains some clay material
					SM	SAND WITH CLAY, medium plasticity, fine to medium, poorly graded, brown-yellow, slightly moist.			Contains some clay material; small fragments of well-cemented, ferruginised Silty Sand are also abundant throughout the layer
			2			Borehole A06 terminated at 1.7m			
			3						
			4						
			5						
			6						

CLIENT Tronox Limited PROJECT NAME Tronox

PROJECT NUMBER 1221 PROJECT LOCATION Tronox Cooljarloo West Site



DATE STARTED 14/12/12 COMPLETED 14/12/12 R.L. SURFACE (m) - DATUM

DRILLING CONTRACTOR Syrinx Personnel NORTHING (m) 6602776 CO-ORDINATE SYSTEM GDA 94

EQUIPMENT Hand Auger EASTING (m) 342718 HOLE LOCATION

HOLE SIZE (mm) 85 LOGGED BY AR CHECKED BY SDo

NOTES

Method	Water	RL (m)	Depth (m)	Graphic Log	Classification Symbol	Material Description	Samples Tests Remarks	PID (ppm)	Additional Observations
					SP	SAND, fine, uniform, white-pale grey, dry.			Contains fine roots in the top 0.1m; fibrous Contains some fine root material
					SM	SAND, fine to medium, poorly graded, yellow-grey, slightly moist.			
						Borehole A07 terminated at 0.5m			
			1						
			2						
			3						
			4						
			5						
			6						

CLIENT Tronox Limited PROJECT NAME Tronox

PROJECT NUMBER 1221 PROJECT LOCATION Tronox Cooljarloo West Site

DATE STARTED 14/12/12 COMPLETED 14/12/12 R.L. SURFACE (m) - DATUM

DRILLING CONTRACTOR Syrinx Personnel NORTHING (m) 6601987 CO-ORDINATE SYSTEM GDA 94

EQUIPMENT Hand Auger EASTING (m) 345042 HOLE LOCATION

HOLE SIZE (mm) 85 LOGGED BY AR CHECKED BY SDo

**NOTES**

Method	Water	RL (m)	Depth (m)	Graphic Log	Classification Symbol	Material Description	Samples Tests Remarks	PID (ppm)	Additional Observations
						TOPSOIL, fine to medium, poorly graded, brown, dry.			
					SP	SAND, fine, uniform, white-pale grey, dry.			Contains some fine root material throughout the layer.
					SM	SAND, fine to medium, poorly graded, brown-yellow, dry.			Contains large fragments of well-cemented, ferruginised silty sand.
			1			Borehole A08 terminated at 0.8m			
			2						
			3						
			4						
			5						
			6						

CLIENT Tronox Limited PROJECT NAME Tronox

PROJECT NUMBER 1221 PROJECT LOCATION Tronox Cooljarloo West Site

DATE STARTED 14/12/12 COMPLETED 14/12/12 R.L. SURFACE (m) - DATUM

DRILLING CONTRACTOR Syrinx Personnel NORTHING (m) 6601603 CO-ORDINATE SYSTEM GDA 94

EQUIPMENT Hand Auger EASTING (m) 345103 HOLE LOCATION

HOLE SIZE (mm) 85 LOGGED BY AR CHECKED BY SDo

NOTES

Method	Water	RL (m)	Depth (m)	Graphic Log	Classification Symbol	Material Description	Samples Tests Remarks	PID (ppm)	Additional Observations
						TOPSOIL, fine to medium, poorly graded, brown, slightly moist to dry.			Large amounts of fine-grained root material present throughout the layer
			1		SW	SAND, fine, uniform, white-yellow, dry.			
					SP	SAND, fine to medium, poorly graded, yellow-brown, slightly moist.			
			2		SM	SILTY SAND, fine to medium, poorly graded, brown, slightly moist.			
					SW	SAND, fine to medium, well graded, yellow-grey, slightly moist.			Friable under low levels of applied pressure Contains small fragments of well-cemented coarse sand (yellow/brown in colour)
			2.4			Borehole A09 terminated at 2.4m			
			3						
			4						
			5						
			6						

BOREHOLE / TEST PIT HAND AUGERING\_AMMENDED\_250713.GPJ SYRINX AUSTRALIAN STANDARD.GDT 28/7/13

CLIENT Tronox Limited PROJECT NAME Tronox

PROJECT NUMBER 1221 PROJECT LOCATION Tronox Cooljarloo West Site

DATE STARTED 14/12/12 COMPLETED 14/12/12 R.L. SURFACE (m) - DATUM

DRILLING CONTRACTOR Syrinx Personnel NORTHING (m) 6603301 CO-ORDINATE SYSTEM GDA 94

EQUIPMENT Hand Auger EASTING (m) 345919 HOLE LOCATION

HOLE SIZE (mm) 85 LOGGED BY AR CHECKED BY SDo

NOTES

Method	Water	RL (m)	Depth (m)	Graphic Log	Classification Symbol	Material Description	Samples Tests Remarks	PID (ppm)	Additional Observations
					SP	TOPSOIL, fine to medium, poorly graded, brown, slightly moist to dry. SAND, fine, uniform, pale grey-white, moist.			
					SP-SC	SAND WITH CLAY, high plasticity, fine, poorly graded, pale yellow-brown, moist.			Material is partially ferruginised in places (resulting in a dark-red colouring); also contains fine root material throughout the layer, and small white crystalline structures sparsely across the layer.
			1		SP	SAND, coarse, uniform, yellow, moist.			
					CL	SANDY CLAY, high plasticity, fine, poorly graded, pale yellow-brown, moist.			
					SP	SAND, coarse, uniform, yellow, moist.			
					SP-SC	SAND WITH CLAY, high plasticity, fine, poorly graded, pale yellow-brown, moist.			
					SP-SC	SAND WITH CLAY, medium plasticity, fine, poorly graded, yellow-red, moist to slightly moist.			
					SC	CLAYEY SAND, high plasticity, medium, poorly graded, grey, slightly moist.			
					SP-SC	SAND WITH CLAY, medium plasticity, fine to medium, poorly graded, grey-yellow, slightly moist.			
					SP-SC	SAND WITH CLAY, medium plasticity, fine to medium, poorly graded, grey-yellow, slightly moist.			
			2			Borehole A10 terminated at 2m			
			3						Material is partially ferruginised in places (resulting in a dark-red colouring); also contains fine root material throughout the layer, and small white crystalline structures sparsely across the layer.
			4						Material is partially ferruginised in places (resulting in a dark-red colouring); also contains fine root material throughout the layer, and small white crystalline structures sparsely across the layer.
			5						Contains fine root material throughout the layer, some ferruginisation across the layer.
			6						Contains fine root material throughout the layer Contains some clay within the layer



Syrinx Environmental

CLIENT Tronox Limited PROJECT NAME Tronox

PROJECT NUMBER 1221 PROJECT LOCATION Tronox Cooljarloo West Site

DATE STARTED 14/12/12 COMPLETED 14/12/12 R.L. SURFACE (m) - DATUM

DRILLING CONTRACTOR Syrinx Personnel NORTHING (m) 6603301 CO-ORDINATE SYSTEM GDA 94

EQUIPMENT Hand Auger EASTING (m) 345919 HOLE LOCATION

HOLE SIZE (mm) 85 LOGGED BY AR CHECKED BY SDo

**NOTES**

Method	Water	RL (m)	Depth (m)	Graphic Log	Classification Symbol	Material Description	Samples Tests Remarks	PID (ppm)	Additional Observations
			7						
			8						
			9						
			10						
			11						
			12						Contains some clay within the layer

BOREHOLE / TEST PIT HAND AUGERING\_AMMENDED\_250713.GPJ SYRINX AUSTRALIAN STANDARD.GDT 26/7/13

CLIENT Tronox Limited PROJECT NAME Tronox

PROJECT NUMBER 1221 PROJECT LOCATION Tronox Cooljarloo West Site

DATE STARTED 14/12/12 COMPLETED 14/12/12 R.L. SURFACE (m) - DATUM

DRILLING CONTRACTOR Syrinx Personnel NORTHING (m) 6601741 CO-ORDINATE SYSTEM GDA 94

EQUIPMENT Hand Auger EASTING (m) 348928 HOLE LOCATION

HOLE SIZE (mm) 85 LOGGED BY AR CHECKED BY SDo

NOTES

Method	Water	RL (m)	Depth (m)	Graphic Log	Classification Symbol	Material Description	Samples Tests Remarks	PID (ppm)	Additional Observations
						TOPSOIL, fine to medium, poorly graded, brown-grey, slightly moist to dry.			
					SP	SAND, fine to medium, poorly graded, pale grey-brown, slightly moist to dry.			Large amounts of fine-grained root material present throughout the layer Contains fragments of poorly-cemented fragments of slightly-ferruginised, fine-grained sand. Poorly-sorted layer, contains large fragments of well-cemented, moderately-ferruginised, fine-grained sand. Poorly-sorted, contains fragments of poorly-cemented Silty Clay (yellow/brown in colour), as well as a large amount of fine-grained root material. Moderately/Well-sorted: contains small fragments of well-cemented, fine-grained Silty Sand (brown/black in colour) Moderately-sorted: contains fragments of well-cemented, coarse-grained Silty Sand (grey in colour).
					SP	SAND, fine, uniform, yellow-brown, slightly moist.			
			1		SP-SC	SAND WITH CLAY, medium plasticity, fine to medium, poorly graded, red-yellow, slightly moist.			
					SW	SAND, fine, uniform, dark grey-white, slightly moist.			
					SW	SAND, fine, uniform, yellow-pale brown, moist.			
			2		SP	SAND, medium, poorly graded, yellow-dark brown, wet.			
					SP-SC	SAND WITH CLAY, low plasticity, medium to coarse, poorly graded, green-pale grey, saturated.			
			3						
			4			Borehole A11 terminated at 3.9m			
			5						
			6						

BOREHOLE / TEST PIT HAND AUGERING, AMMENDED, 250713.GPJ SYRINX AUSTRALIAN STANDARD.GDT 26/7/13

CLIENT Tronox Limited PROJECT NAME Tronox

PROJECT NUMBER 1221 PROJECT LOCATION Tronox Cooljarloo West Site






DATE STARTED 13/12/12 COMPLETED 13/12/12 R.L. SURFACE (m) - DATUM

DRILLING CONTRACTOR Syrinx Personnel NORTHING (m) 6607561 CO-ORDINATE SYSTEM GDA 94

EQUIPMENT Hand Auger EASTING (m) 342754 HOLE LOCATION

HOLE SIZE (mm) 85 LOGGED BY AR CHECKED BY SDo

**NOTES**

Method	Water	RL (m)	Depth (m)	Graphic Log	Classification Symbol	Material Description	Samples Tests Remarks	PID (ppm)	Additional Observations
					SP	SAND, fine, uniform, white-pale yellow, slightly moist to dry.			Contains fine root material; extremely friable. Contains some clay within the material; contains fine roots; also contains small fragments of well-cemented fine-grained sands (dark brown in colour). Contains some small fragments of well-cemented, coarse-grained sand (dark brown/black in colour).
					SP-SC	SAND WITH CLAY, medium plasticity, fine to medium, poorly graded, dark brown-grey, slightly moist.			
					SP	SAND, fine to medium, poorly graded, pale brown-yellow, moist.			
					SP	SAND, fine to medium, poorly graded, pale grey, moist.			
			1		SP-SC	SAND WITH CLAY, high plasticity, fine to medium, poorly graded, yellow-grey, moist.			
			2			Borehole A12 terminated at 1.9m			
			3						
			4						
			5						
			6						

BOREHOLE / TEST PIT HAND AUGERING\_AMMENDED\_250713.GPJ SYRINX AUSTRALIAN STANDARD.GDT 28/7/13

**CLIENT** Tronox Limited **PROJECT NAME** Tronox  
**PROJECT NUMBER** 1221 **PROJECT LOCATION** Tronox Cooljarloo West Site  
**DATE STARTED** 13/12/12 **COMPLETED** 13/12/12 **R.L. SURFACE (m)** - **DATUM**   
**DRILLING CONTRACTOR** Syrinx Personnel **NORTHING (m)** 6605835 **CO-ORDINATE SYSTEM** GDA 94  
**EQUIPMENT** Hand Auger **EASTING (m)** 340714 **HOLE LOCATION**   
**HOLE SIZE (mm)** 85 **LOGGED BY** AR **CHECKED BY** SDo

**NOTES**

Method	Water	RL (m)	Depth (m)	Graphic Log	Classification Symbol	Material Description	Samples Tests Remarks	PID (ppm)	Additional Observations
					SW	SAND, fine, uniform, white-pale grey, dry.			Contains fine roots throughout the material; fibrous. Layer contains a lot of Organic Matter and roots
					SP	SAND, fine to medium, poorly graded, dark brown-grey, moist.			
					SW	SAND, fine, uniform, white-pale grey, dry.			
					SW	SAND, fine, poorly graded, grey-red, dry.			
					SP	SAND, fine to medium, poorly graded, yellow, dry.			
			1			Borehole A13 terminated at 0.85m			Contains several small fragments of well-cemented coarse sand (red & dark brown in colour due to extensive ferruginisation) Contains several small fragments of well-cemented coarse sand (red & dark brown in colour due to extensive ferruginisation)
			2						
			3						
			4						
			5						
			6						

CLIENT Tronox Limited PROJECT NAME Tronox

PROJECT NUMBER 1221 PROJECT LOCATION Tronox Cooljarloo West Site




DATE STARTED 14/12/12 COMPLETED 14/12/12 R.L. SURFACE (m) - DATUM

DRILLING CONTRACTOR Syrinx Personnel NORTHING (m) 6602356 CO-ORDINATE SYSTEM GDA 94

EQUIPMENT Hand Auger EASTING (m) 344837 HOLE LOCATION

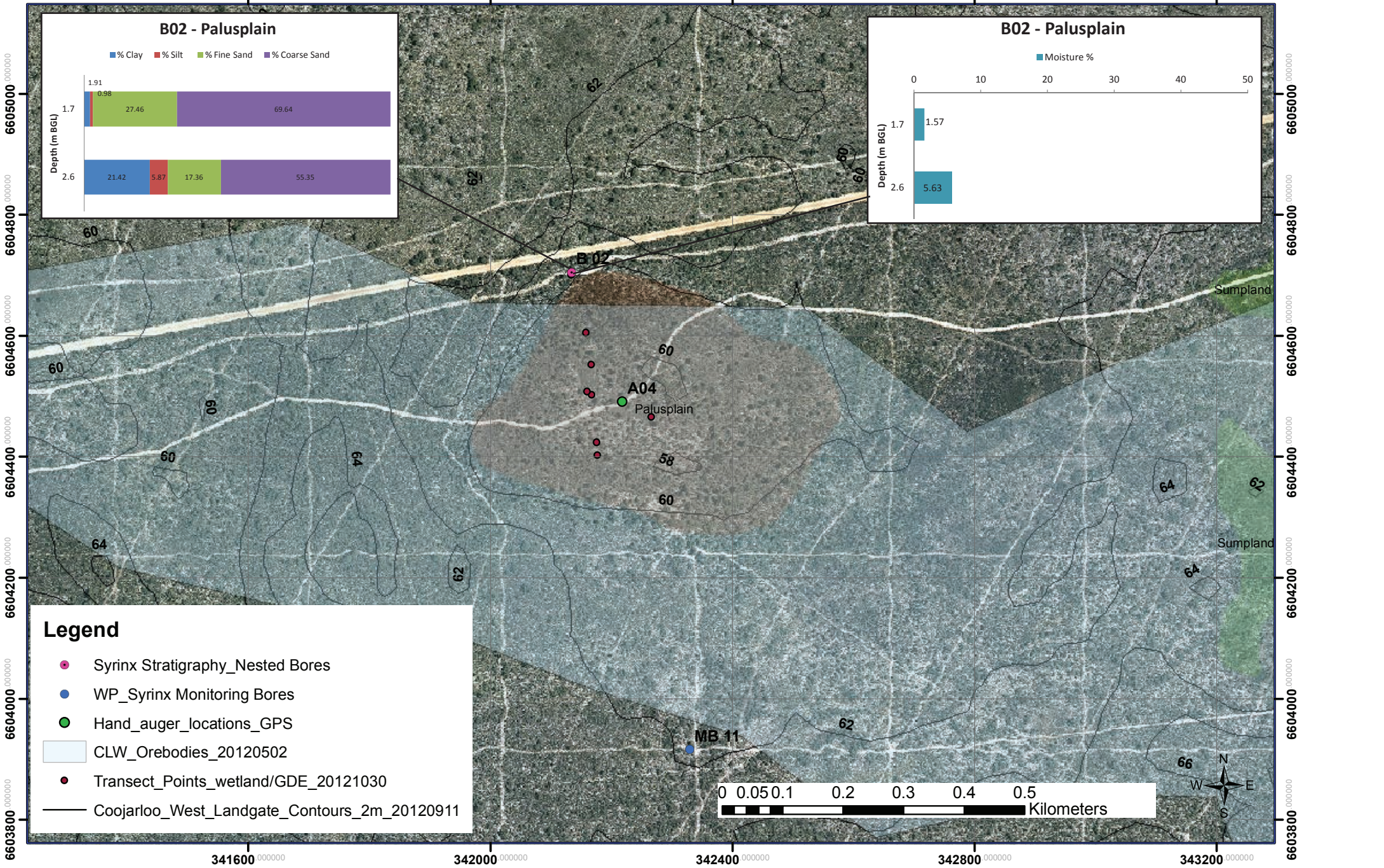
HOLE SIZE (mm) 85 LOGGED BY AR CHECKED BY SDo

NOTES

Method	Water	RL (m)	Depth (m)	Graphic Log	Classification Symbol	Material Description	Samples Tests Remarks	PID (ppm)	Additional Observations
					SP	TOPSOIL, fine to medium, poorly graded, brown, dry. SAND, fine, uniform, white-pale grey, dry.			Contains fine roots throughout the layer Very friable; contains fine root material throughout the layer
			1		SW	SAND, fine, poorly graded, pale brown-grey, dry.			Contains large fragments of well-cemented, ferruginised coarse sand.
					SP	SAND, fine to medium, well graded, grey-yellow, dry.			Contains fragments of moderately-cemented Silty Sand (extensively-ferruginised).
						Borehole A14 terminated at 1.1m			
			2						
			3						
			4						
			5						
			6						

**APPENDIX 3 Soil particle size distribution and soil moisture content (October 2012).**

341600.000000 342000.000000 342400.000000 342800.000000 343200.000000



6605000 6604800 6604600 6604400 6604200 6604000 6603800

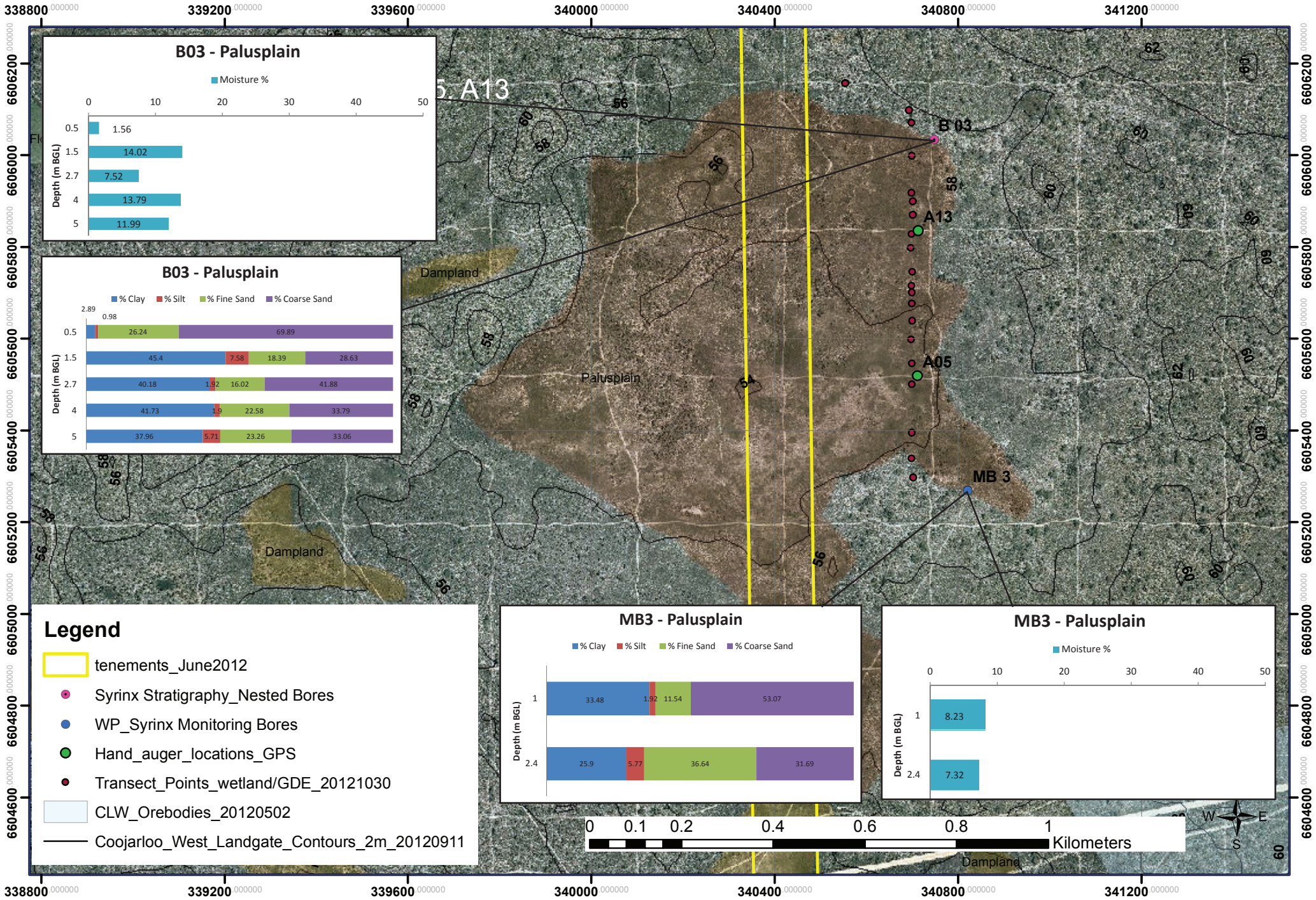
341600.000000 342000.000000 342400.000000 342800.000000 343200.000000

CLIENT : TRONOX  
 PROJECT : COOLJARLOO WEST  
 PROJECT NUMBER : 1221

DRAWING : PALUSPLAIN (ENV 2010) B02, A04  
 DRAWING NUMBER :  
 REPORT:

DATE : 09.08.2013  
 SCALE : SEE SCALE BAR  
 DRAWN BY : JA / SDO



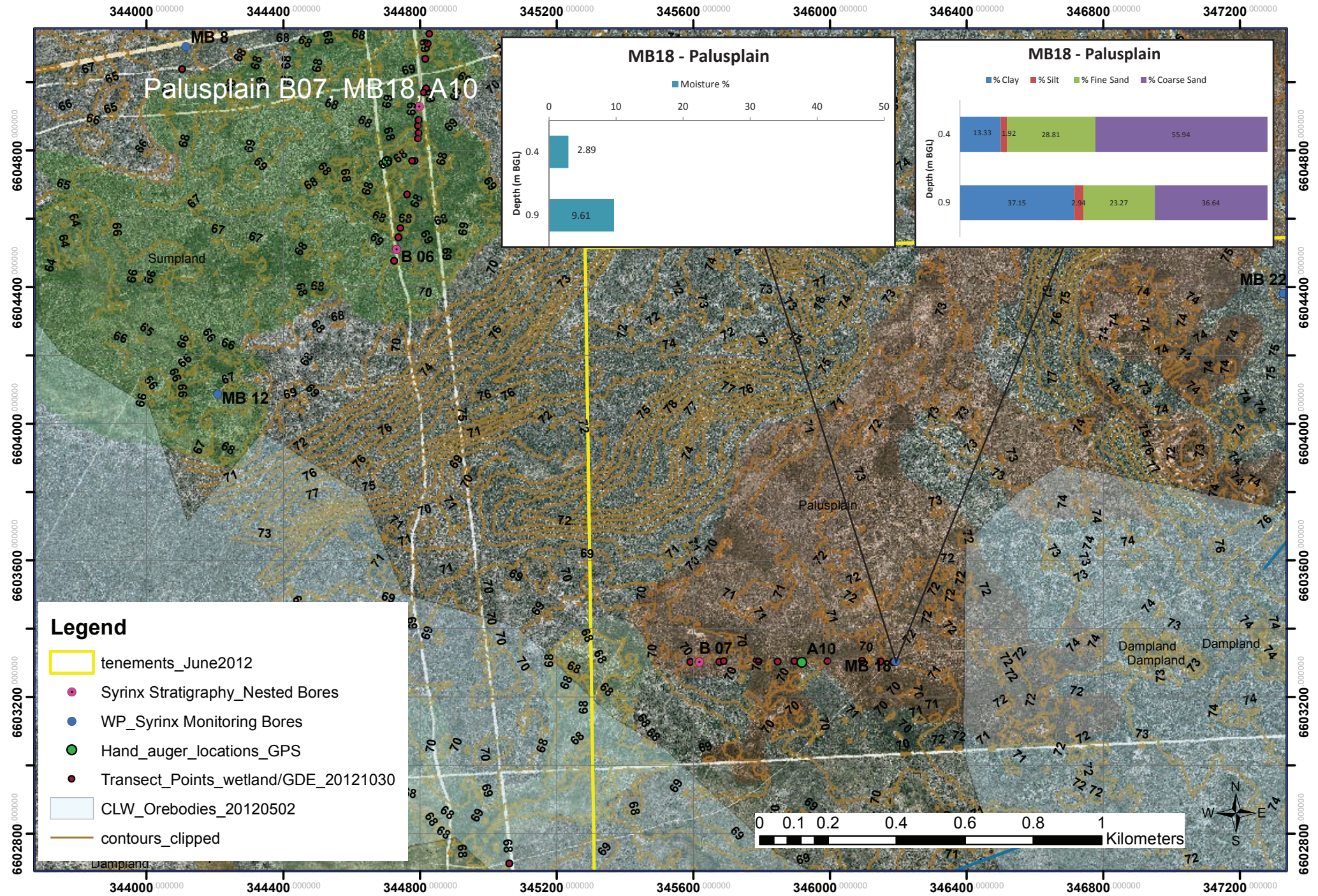


CLIENT : TRONOX  
 PROJECT : COOLJARLOO WEST  
 PROJECT NUMBER : 1221

DRAWING : PALUSPLAIN (ENV 2010) B3, MB3, A05, A13  
 DRAWING NUMBER :  
 REPORT:

DATE : 09.08.2013  
 SCALE : SEE SCALE BAR  
 DRAWN BY : JA / SDO



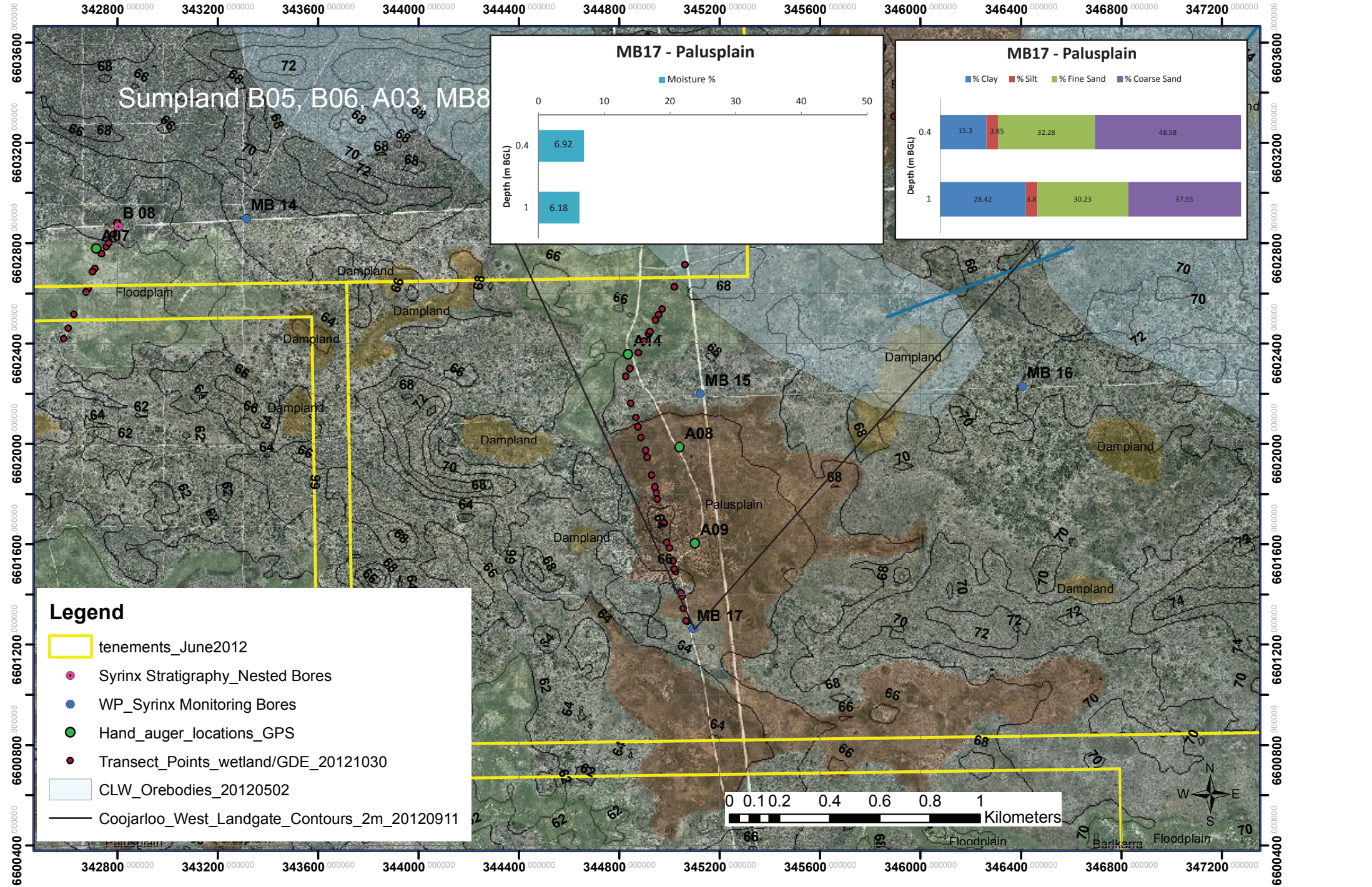


CLIENT : TRONOX  
 PROJECT : COOLJARLOO WEST  
 PROJECT NUMBER : 1221

DRAWING : PALUSPLAIN (ENV 2010) B07, MB18, A10  
 DRAWING NUMBER :  
 REPORT:

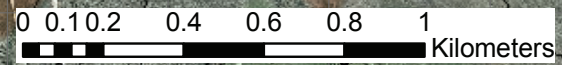
DATE : 09.08.2013  
 SCALE : SEE SCALE BAR  
 DRAWN BY : JA / SDO





**Legend**

- tenements\_June2012
- Syrix Stratigraphy\_Nested Bores
- WP\_Syrix Monitoring Bores
- Hand\_auger\_locations\_GPS
- Transect\_Points\_wetland/GDE\_20121030
- CLW\_Orebodies\_20120502
- Coojarloo\_West\_Landgate\_Contours\_2m\_20120911

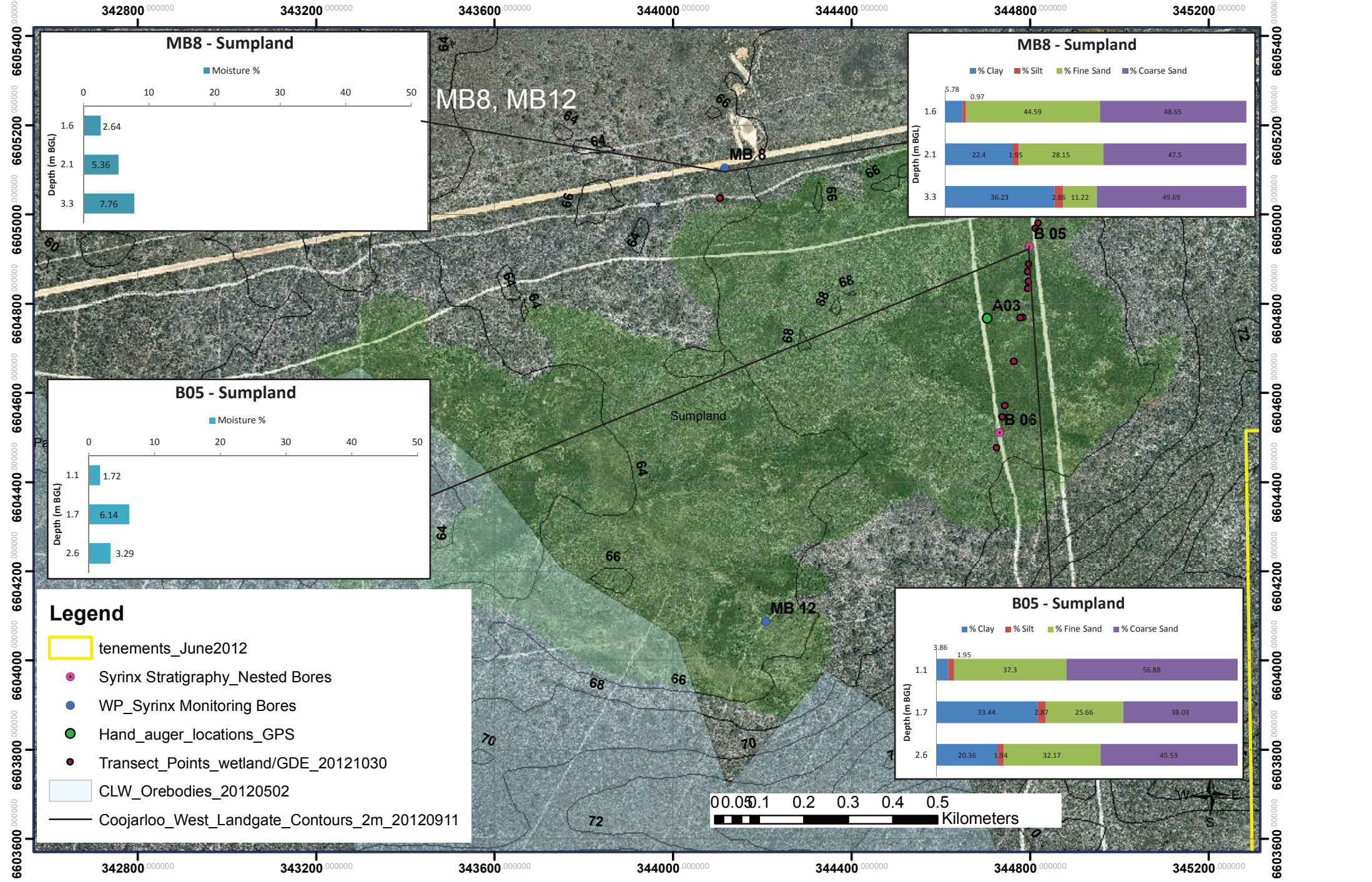


CLIENT : TRONOX  
 PROJECT : COOLJARLOO WEST  
 PROJECT NUMBER : 1221

DRAWING : PALUSPLAIN (ENV 2010) MB 15, MB17, A08, A09, FLOOD-PLAIN A14  
 DRAWING NUMBER :  
 REPORT:

DATE : 09.08.2013  
 SCALE : SEE SCALE BAR  
 DRAWN BY : JA / SDO



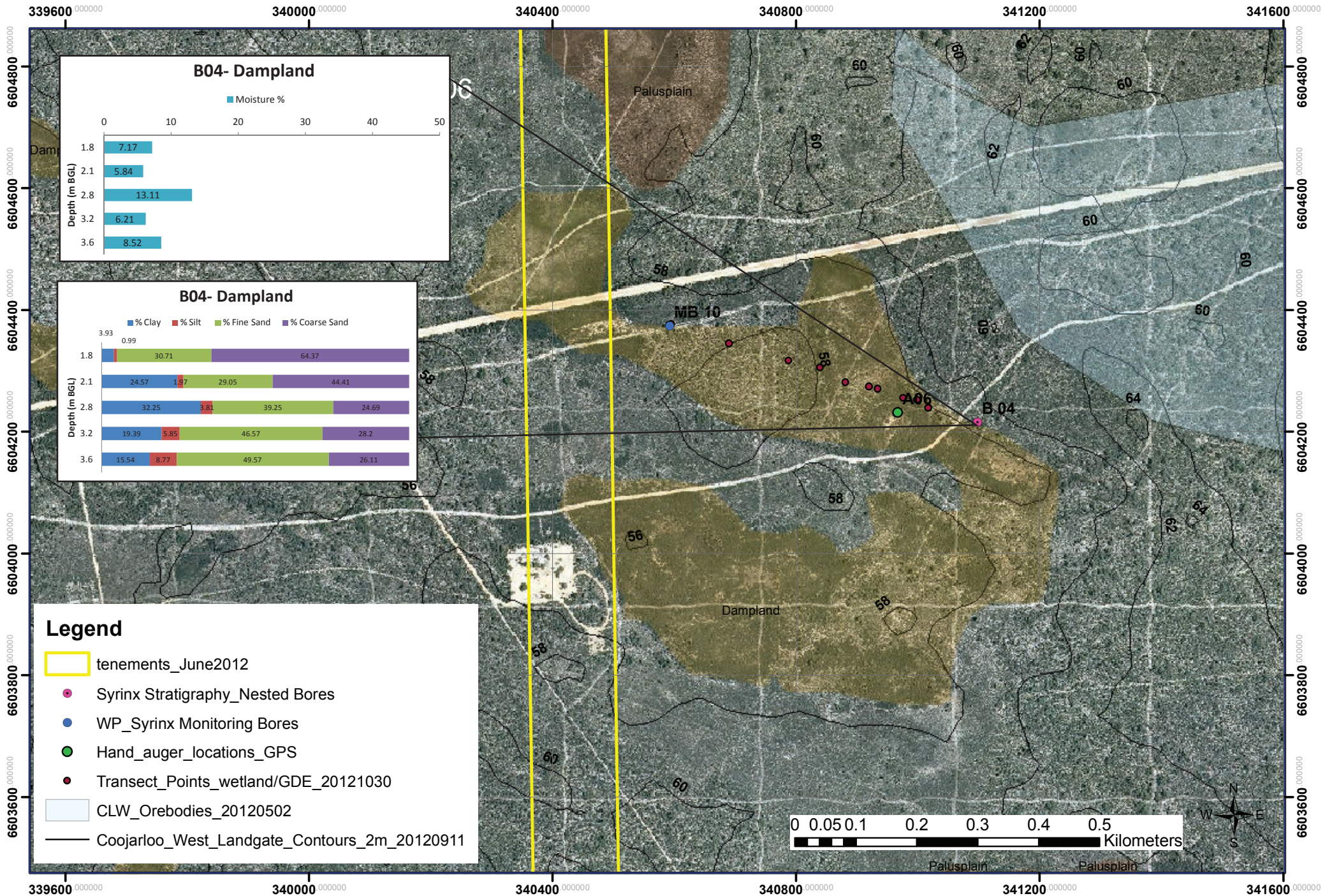


CLIENT : TRONOX  
 PROJECT : COOLJARLOO WEST  
 PROJECT NUMBER : 1221

DRAWING : SUMPLAND (ENV 2011) B05, B06, A03, MB8, MB12  
 DRAWING NUMBER :  
 REPORT:

DATE : 09.08.2013  
 SCALE : SEE SCALE BAR  
 DRAWN BY : JA / SDO



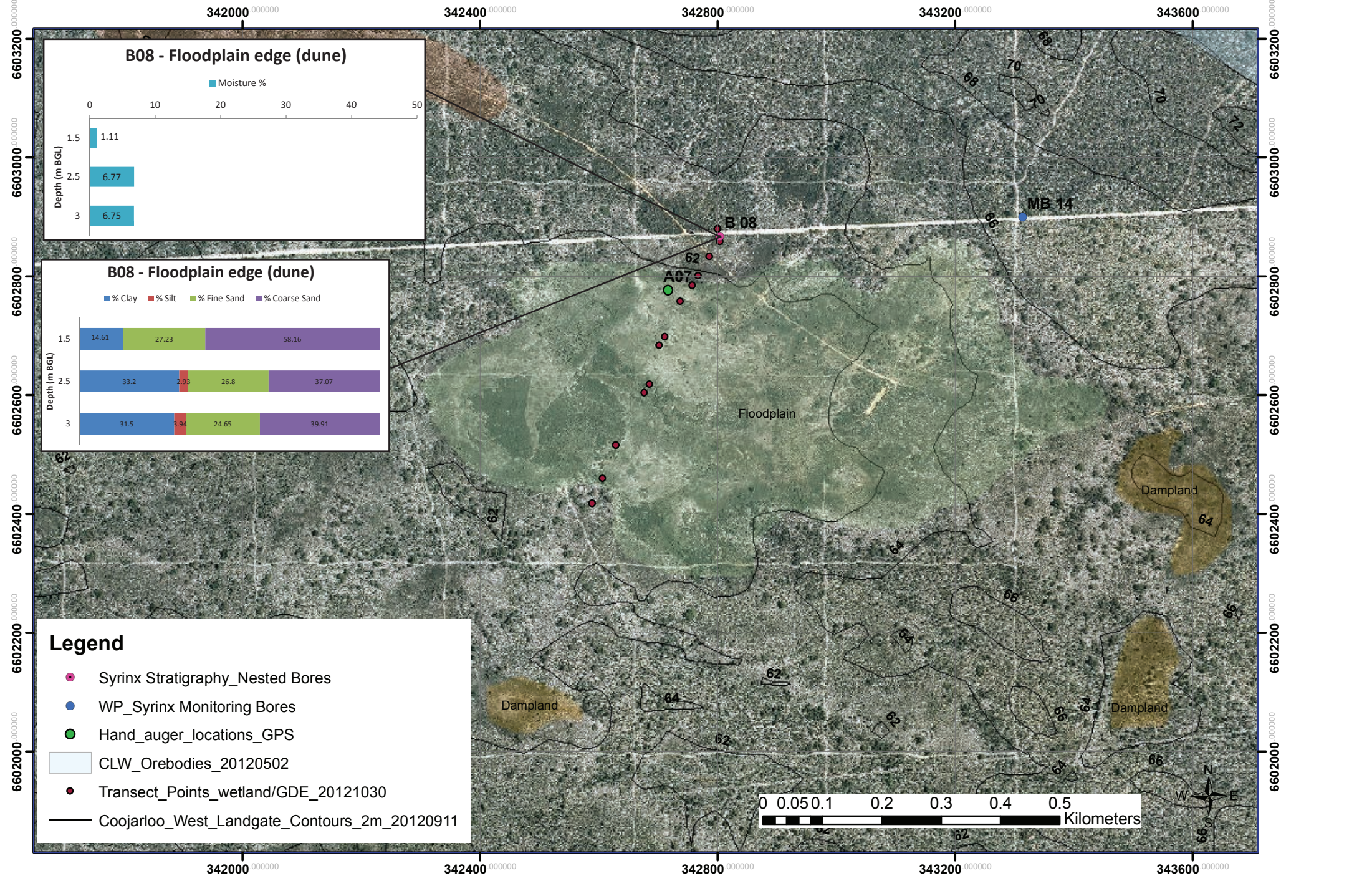


CLIENT : TRONOX  
 PROJECT : COOLJARLOO WEST  
 PROJECT NUMBER : 1221

DRAWING : DAMPLAND (ENV 2010) MB10, B04, A06  
 DRAWING NUMBER :  
 REPORT:

DATE : 09.08.2013  
 SCALE : SEE SCALE BAR  
 DRAWN BY : JA / SDO



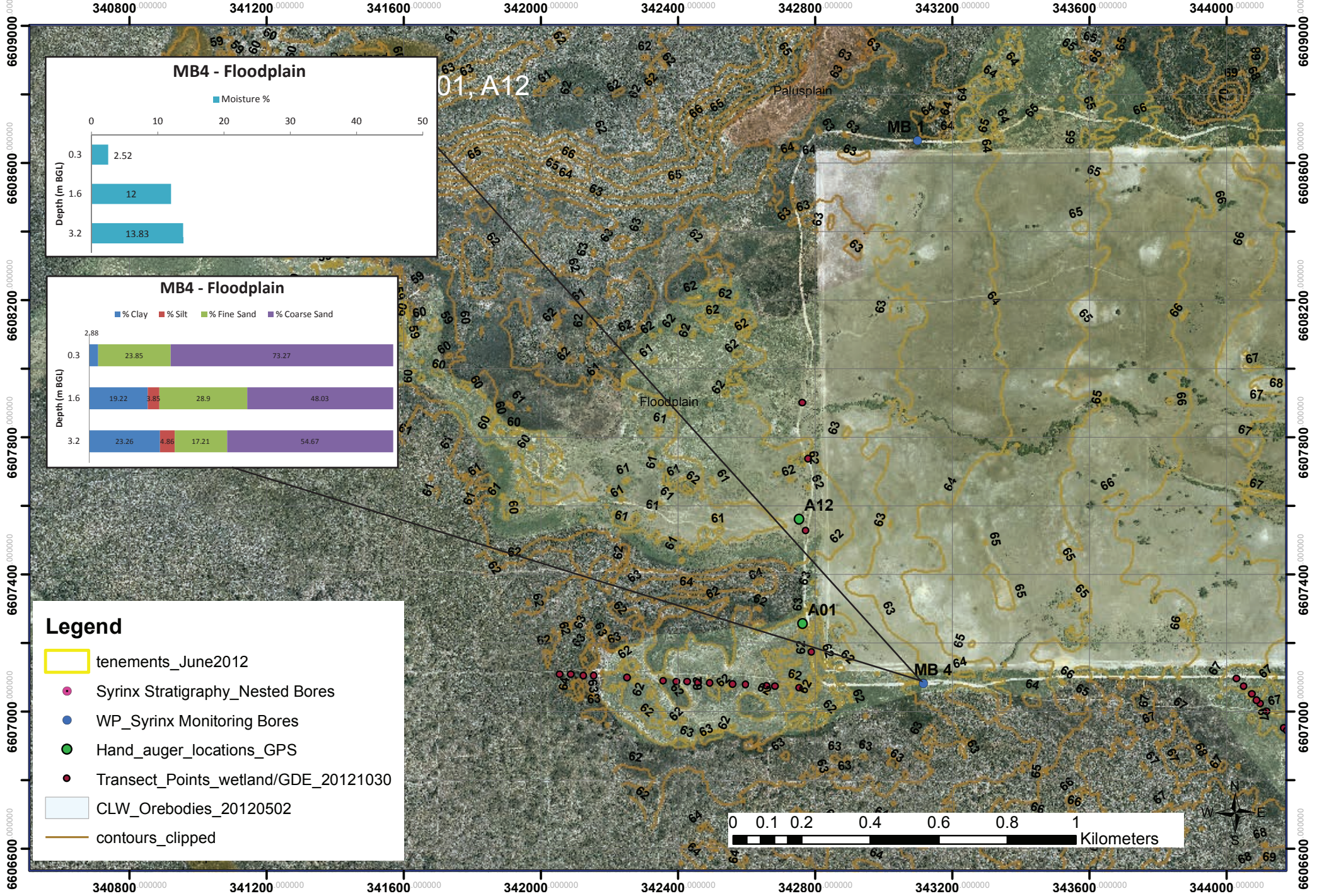


CLIENT : TRONOX  
 PROJECT : COOLJARLOO WEST  
 PROJECT NUMBER : 1221

DRAWING : FLOODPLAIN (ENV 2010) B08, A07  
 DRAWING NUMBER :  
 REPORT:

DATE : 09.08.2013  
 SCALE : SEE SCALE BAR  
 DRAWN BY : JA / SDO





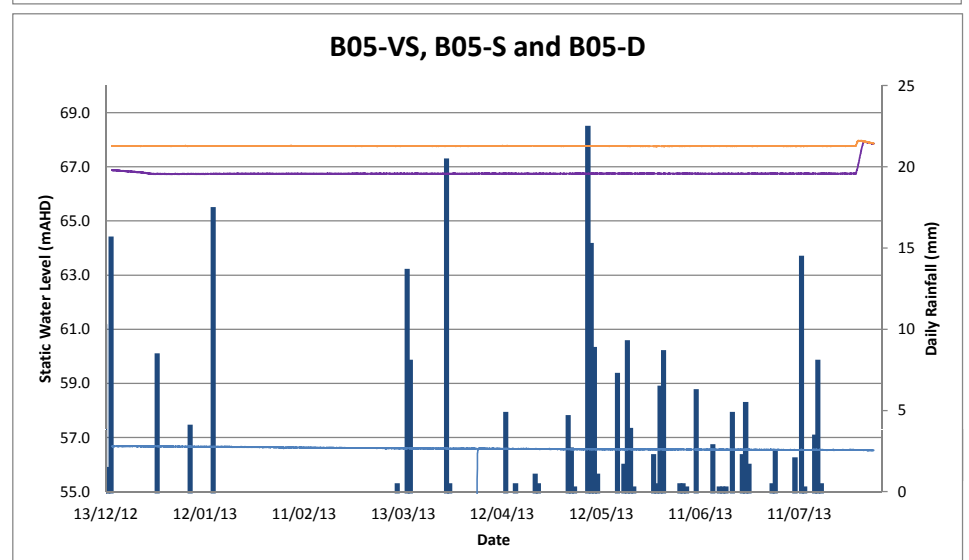
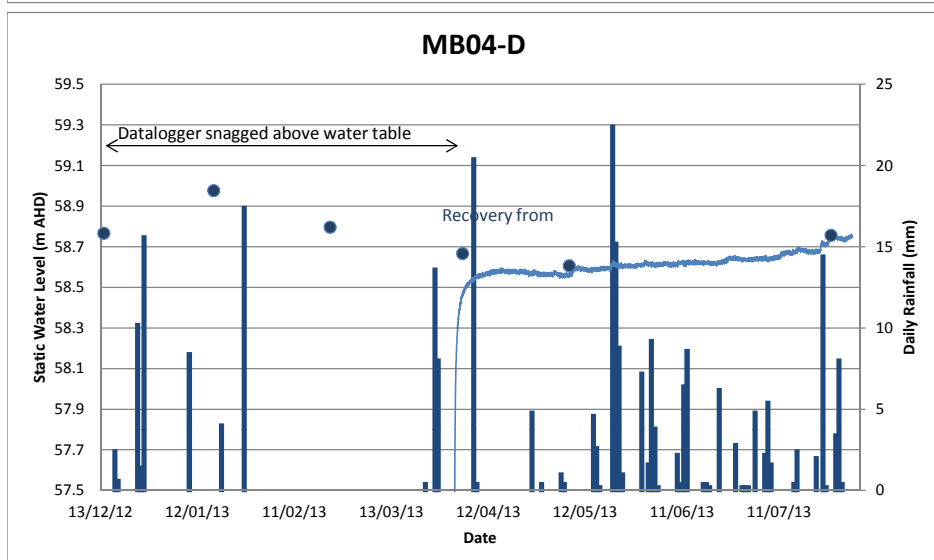
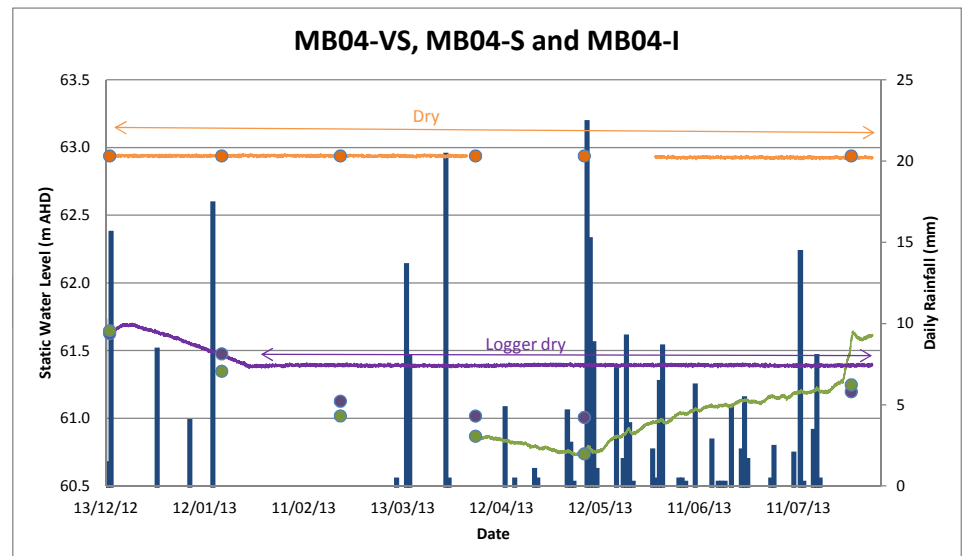
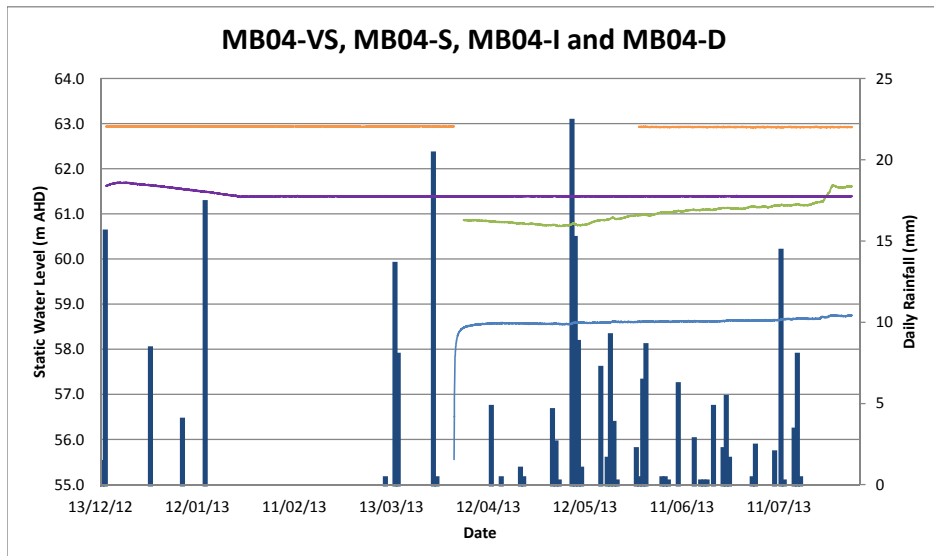
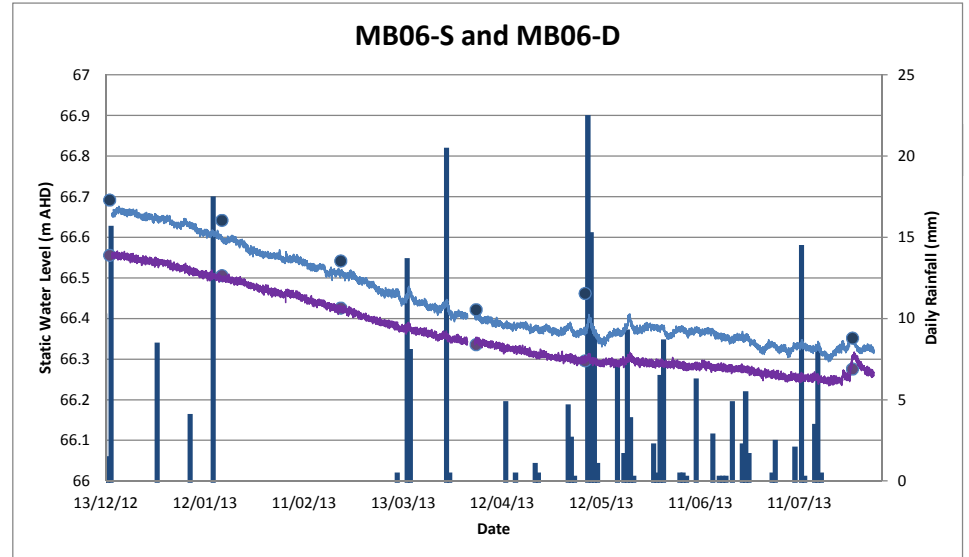
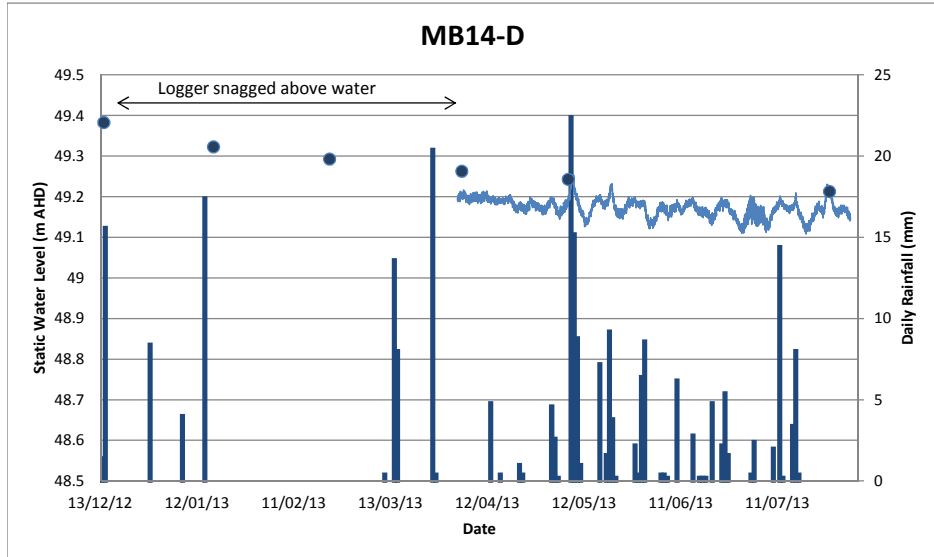
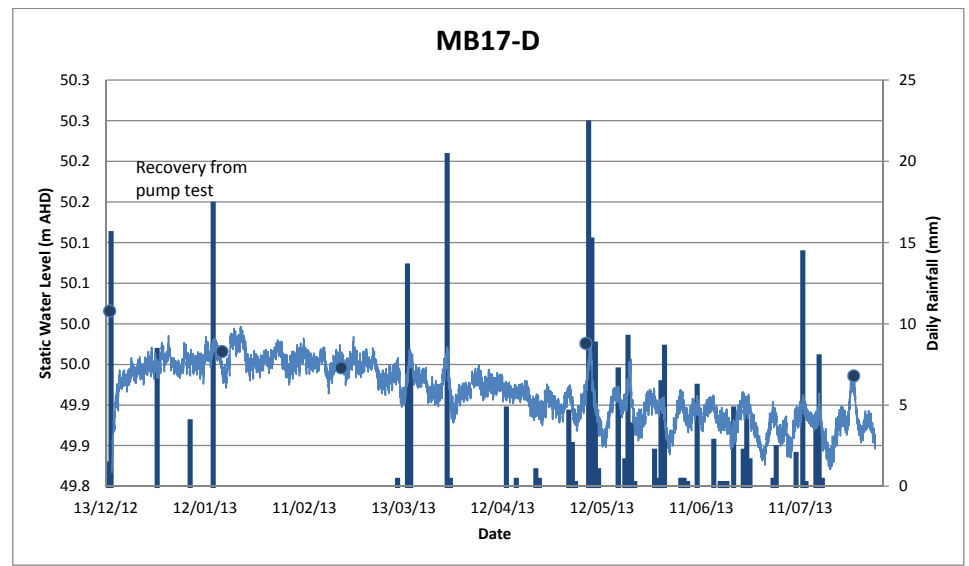
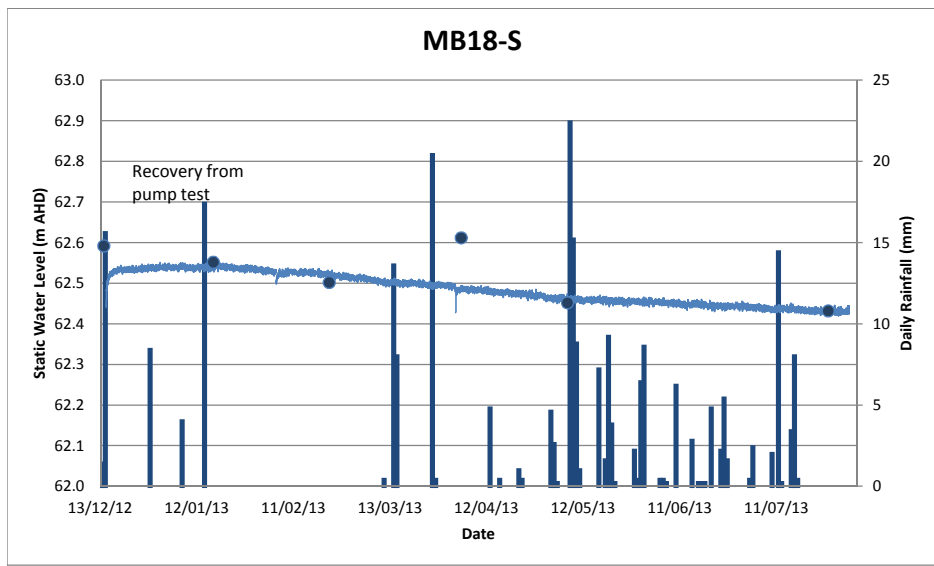
CLIENT : TRONOX  
 PROJECT : COOLJARLOO WEST  
 PROJECT NUMBER : 1221

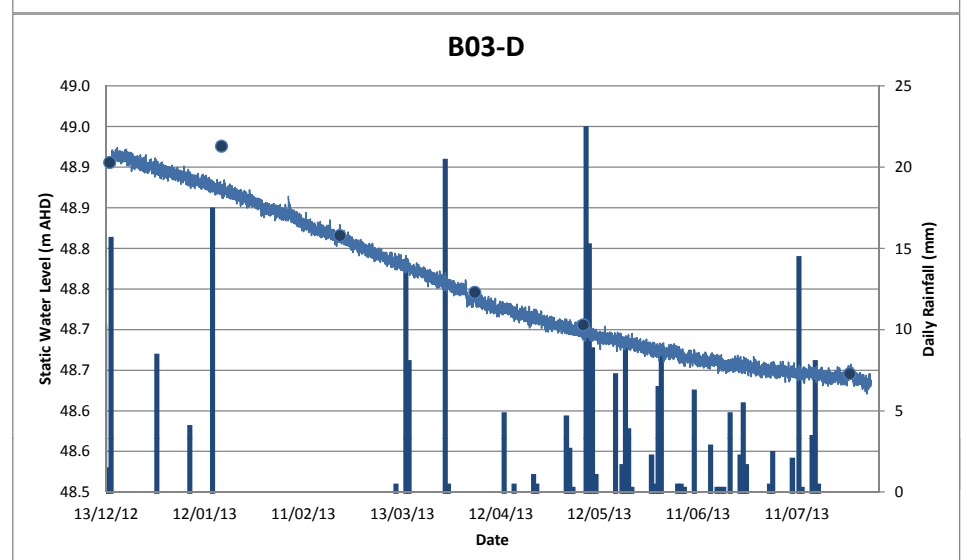
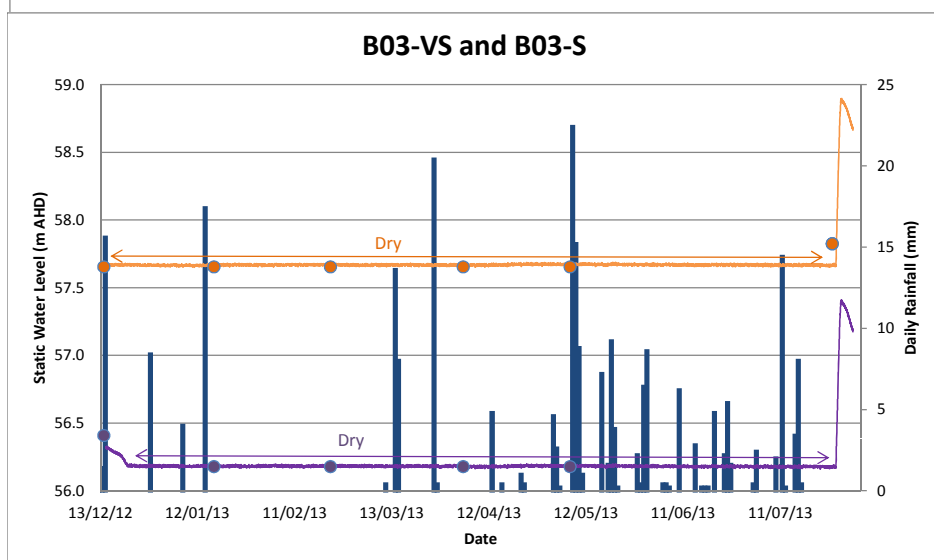
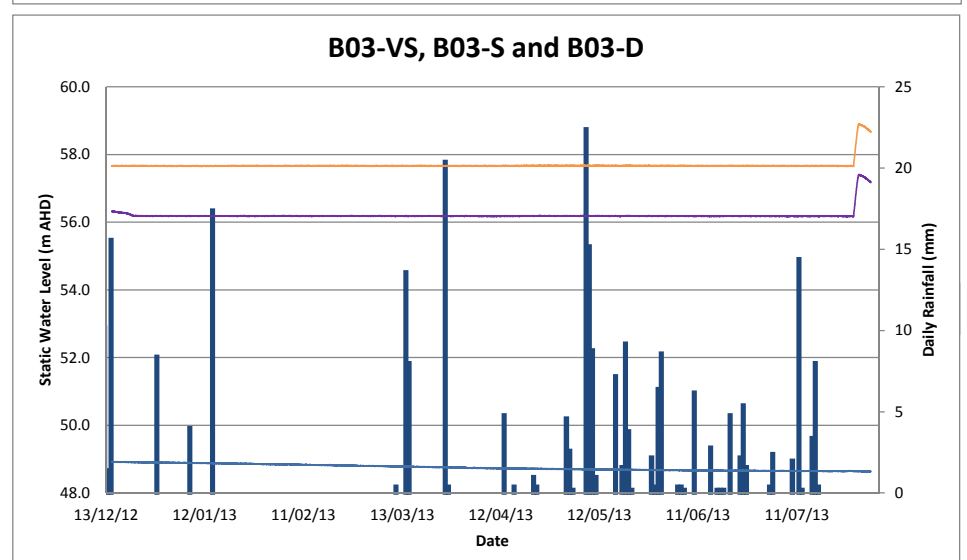
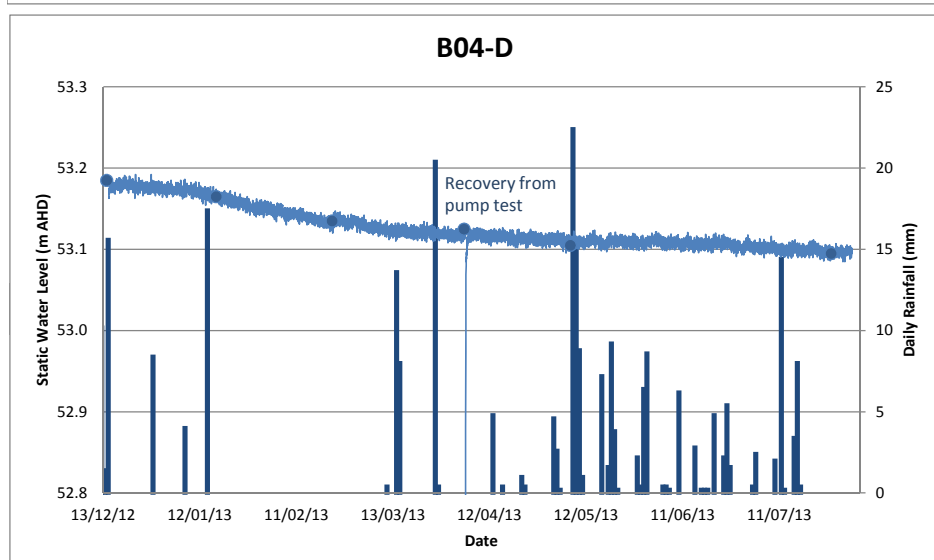
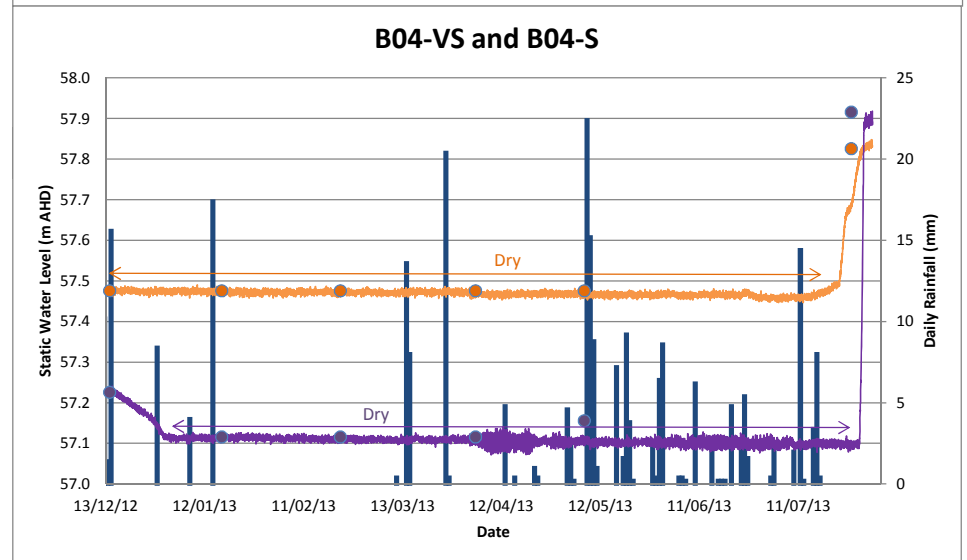
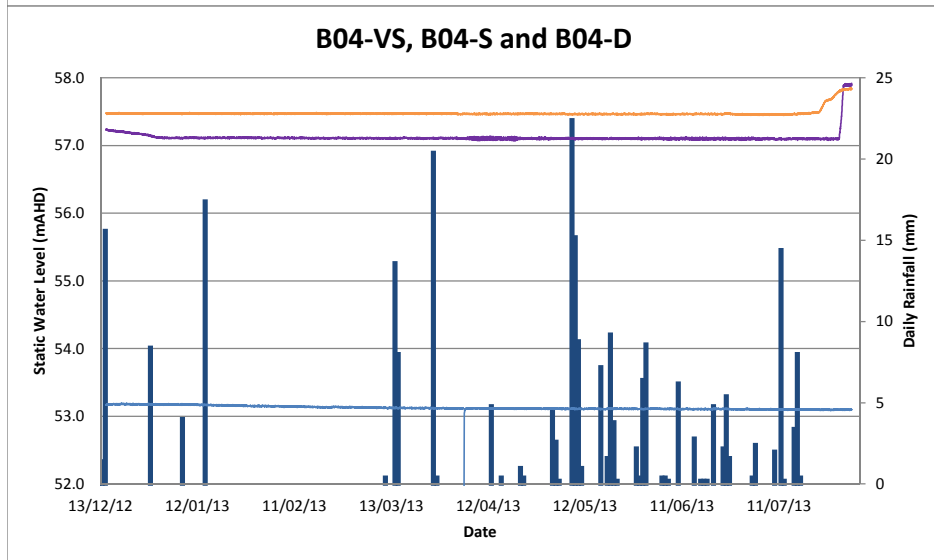
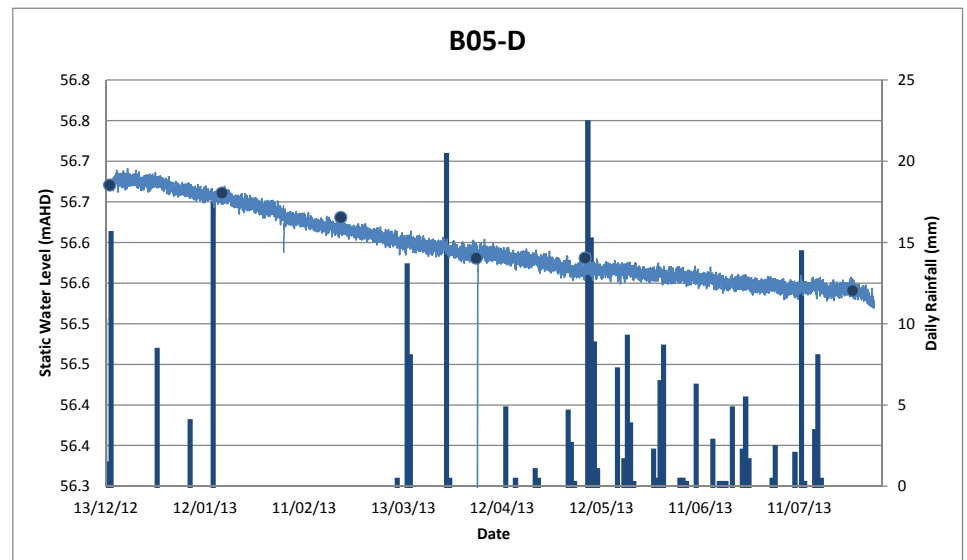
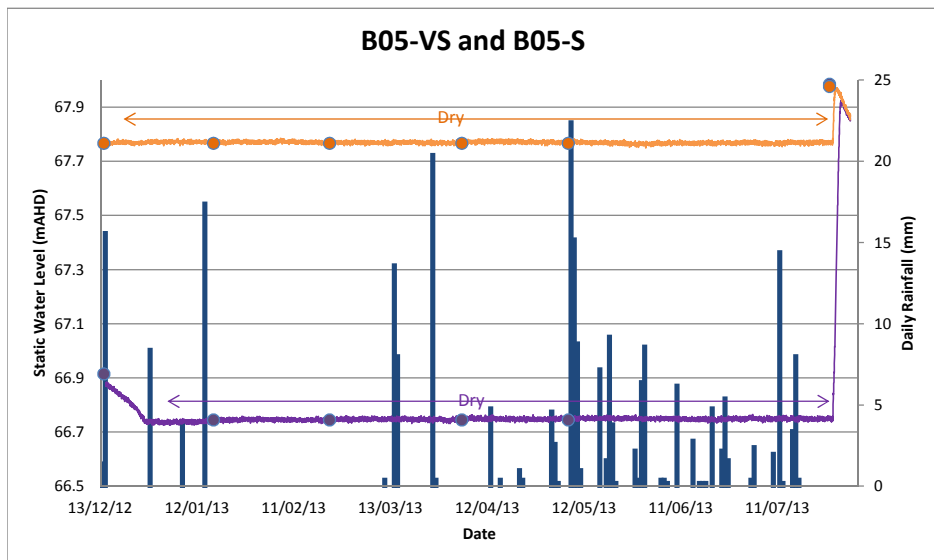
DRAWING : FLOODPLAIN (ENV 2010) MB4, MB1, A01, A12  
 DRAWING NUMBER :  
 REPORT:

DATE : 09.08.2013  
 SCALE : SEE SCALE BAR  
 DRAWN BY : JA / SDO



**APPENDIX 4 Groundwater level logger results**





**APPENDIX 5 Soil analysis results.**

## Soil analysis

Sample Name	Geomorphic Wetland Type (DEC)	Syrinx changes to Geomorphic Wetland Type (DEC)	Site Name	Depth	Colour	Texture	Ammonium Nitrogen	Nitrate Nitrogen	Phosphorus Colwell	Potassium Colwell
				(mBGL)	Munsell		mg/Kg	mg/Kg	mg/Kg	mg/Kg
B02 1.7	PALUSPLAIN	DAMPLAND	B02	1.7	WH	1	0.5	0.5	1	16
B02 2.6	PALUSPLAIN	DAMPLAND	B02	2.6	LTGR	1.5	7	1	1	32
B03 0.5	PALUSPLAIN	PALUSPLAIN	B03	0.5	GRWH	1.5	2	0.5	1	21
B03 1.5	PALUSPLAIN	PALUSPLAIN	B03	1.5	GRBR	3.5	2	0.5	1	70
B03 2.7	PALUSPLAIN	PALUSPLAIN	B03	2.7	LTGR	3.5	2	0.5	1	55
B03 4	PALUSPLAIN	PALUSPLAIN	B03	4	GRBR	3.5	3	1	1	113
B03 5	PALUSPLAIN	PALUSPLAIN	B03	5	GR	3.5	2	0.5	1	111
B04 1.8	DAMPLAND	DAMPLAND	B04	1.8	WH	1.5	1	0.5	2	19
B04 2.1	DAMPLAND	DAMPLAND	B04	2.1	GRWH	1.5	2	0.5	1	49
B04 2.8	DAMPLAND	DAMPLAND	B04	2.8	LTGR	1.5	3	0.5	1	77
B04 3.2	DAMPLAND	DAMPLAND	B04	3.2	BROR	3.5	2	1	1	58
B04 3.6	DAMPLAND	DAMPLAND	B04	3.6	OR	3	2	1	1	49
B05 1.1	SUMLAND	DAMPLAND	B05	1.1	WH	1	0.5	0.5	1	23
B05 1.7	SUMLAND	DAMPLAND	B05	1.7	BROR	3.5	2	0.5	1	76
B05 2.6	SUMLAND	DAMPLAND	B05	2.6	GRPK	1.5	2	0.5	1	70
B08 1.5	FLOODPLAIN	DAMPLAND	B08	1.5	YW	1.5	3	0.5	3	34
B08 2.5	FLOODPLAIN	DAMPLAND	B08	2.5	GR	1.5	4	1	2	53
B08 3	FLOODPLAIN	DAMPLAND	B08	3	GRPK	1.5	2	0.5	1	39
MB03 1	PALUSPLAIN	PALUSPLAIN	MB03	1	BROR	3.5	2	0.5	1	60
MB03 2.4	PALUSPLAIN	PALUSPLAIN	MB03	2.4	GRPK	3	4	0.5	1	35
MB03 2.8	PALUSPLAIN	PALUSPLAIN	MB03	2.8	no data	no data	no data	no data	no data	no data
MB04 0.3	FLOODPLAIN	FLOODPLAIN	MB04	0.3	WH	1	0.5	0.5	3	22
MB04 1.6	FLOODPLAIN	FLOODPLAIN	MB04	1.6	GRYW	3	2	0.5	2	118
MB04 3.2	FLOODPLAIN	FLOODPLAIN	MB04	3.2	GR	3	1	0.5	1	172
MB08 1.6	SUMLAND	DAMPLAND	MB08	1.6	YW	1.5	2	0.5	1	38
MB08 2.1	SUMLAND	DAMPLAND	MB08	2.1	GR	3	3	0.5	1	59
MB08 3.3	SUMLAND	DAMPLAND	MB08	3.3	BROR	3	4	1	1	93
MB14 2.8	FLOODPLAIN	DAMPLAND (dune sampling)	MB14	2.8	WH	1	2	0.5	1	20
MB14 3.4	FLOODPLAIN	DAMPLAND (dune sampling)	MB14	3.4	LTGR	1.5	3	0.5	1	54
MB14 4.9	FLOODPLAIN	DAMPLAND (dune sampling)	MB14	4.9	OR	3.5	2	1	1	90
MB17 0.4	PALUSPLAIN	PALUSPLAIN	MB17	0.4	GRBR	1.5	5	0.5	1	36
MB17 1	PALUSPLAIN	PALUSPLAIN	MB17	1	BRRD	3	6	2	1	61
MB18 0.4	PALUSPLAIN	PALUSPLAIN	MB18	0.4	LTBR	1.5	5	1	1	47
MB18 0.9	PALUSPLAIN	PALUSPLAIN	MB18	0.9	GRPK	3.5	3	2	3	110

## Soil analysis

Sample Name	Organic Carbon	Conductivity (CSBP)	pH Level (CaCl <sub>2</sub> ) CSBP	pH Level (H <sub>2</sub> O) CSBP	Total Nitrogen	Clay	Coarse Sand	Fine Sand	Sand	Silt	Moisture	Carbon (Curtin)	Carbonate
	%	dS/m	pH	pH	%	%	%	%	%	%	%	mg/kg	%
B02 1.7	0.13	0.01	5.5	6.2	0.005	1.91	69.64	27.46	97.11	0.98	1.57	154.1	BDL
B02 2.6	0.22	0.268	7.3	7.9	0.01	21.42	55.35	17.36	72.71	5.87	5.63	1686	BDL
B03 0.5	0.35	0.015	5.5	6.4	0.01	2.89	69.89	26.24	96.13	0.98	1.56	841.7	BDL
B03 1.5	0.21	0.151	7	7.7	0.005	45.4	28.63	18.39	47.01	7.58	14.02	703.4	BDL
B03 2.7	0.38	0.185	6.9	7.8	0.005	40.18	41.88	16.02	57.9	1.92	7.52	507.7	BDL
B03 4	0.55	0.369	6.6	7.4	0.005	41.73	33.79	22.58	56.37	1.9	13.79	184.3	BDL
B03 5	0.15	0.254	6.9	7.5	0.005	37.96	33.06	23.26	56.33	5.71	11.99	135.9	BDL
B04 1.8	0.28	0.014	5.4	6.3	0.005	3.93	64.37	30.71	95.08	0.99	7.17	598.3	BDL
B04 2.1	0.22	0.09	6	6.8	0.005	24.57	44.41	29.05	73.46	1.97	5.84	800.1	BDL
B04 2.8	0.26	0.335	5.8	6.8	0.005	32.25	24.69	39.25	63.94	3.81	13.11	887.1	BDL
B04 3.2	0.24	0.679	5.8	6.3	0.005	19.39	28.2	46.57	74.77	5.85	6.21	720.5	BDL
B04 3.6	0.25	0.707	6	6.4	0.005	15.54	26.11	49.57	75.69	8.77	8.52	498	BDL
B05 1.1	0.2	0.023	5.6	6	0.005	3.86	56.88	37.3	94.19	1.95	1.72	634.6	BDL
B05 1.7	0.17	0.112	7	7.7	0.005	33.44	38.03	25.66	63.69	2.87	6.14	421.1	BDL
B05 2.6	0.17	0.04	6	6.7	0.005	20.36	45.53	32.17	77.7	1.94	3.29	358.3	BDL
B08 1.5	0.17	0.023	6.2	6.7	0.01	14.61	58.16	27.23	85.39	0.005	1.11	593.8	BDL
B08 2.5	0.24	0.145	7.1	7.8	0.01	33.2	37.07	26.8	63.86	2.93	6.77	279.6	BDL
B08 3	0.41	0.151	7.1	7.9	0.005	31.5	39.91	24.65	64.55	3.94	6.75	554.2	BDL
MB03 1	0.6	0.094	6.8	7.3	0.01	33.48	53.07	11.54	64.61	1.92	8.23	581	BDL
MB03 2.4	0.16	0.144	6.8	7.5	0.005	25.9	31.69	36.64	68.33	5.77	7.32	702.5	BDL
MB03 2.8	no data	no data	no data	no data	no data	no data	no data	no data	no data	no data	no data	400.5	BDL
MB04 0.3	0.14	0.005	6	6.5	0.005	2.88	73.27	23.85	97.12	0.005	2.52	203.4	BDL
MB04 1.6	0.17	0.723	7.1	7.9	0.005	19.22	48.03	28.9	76.93	3.85	12	134.8	BDL
MB04 3.2	0.19	0.644	7.5	8.5	0.005	23.26	54.67	17.21	71.89	4.86	13.83	1024	BDL
MB08 1.6	0.19	0.013	5.6	6.4	0.005	5.78	48.65	44.59	93.24	0.97	2.64	384.1	BDL
MB08 2.1	0.22	0.056	6.8	7.3	0.01	22.4	47.5	28.15	75.65	1.95	5.36	1006	BDL
MB08 3.3	0.14	0.067	6.4	7.1	0.005	36.23	49.69	11.22	60.91	2.86	7.76	207.3	BDL
MB14 2.8	0.2	0.014	5.8	6.4	0.005	2.89	69.63	26.51	96.14	0.98	2.87	848.3	BDL
MB14 3.4	0.18	0.156	7.4	7.9	0.005	19.49	49.76	27.82	77.58	2.93	9.19	423.5	BDL
MB14 4.9	0.18	0.372	7.5	8.2	0.01	44.48	24.42	26.26	50.68	4.84	25.14	235.3	BDL
MB17 0.4	0.62	0.04	6.5	6.9	0.03	15.3	48.58	32.28	80.86	3.85	6.92	3958	BDL
MB17 1	0.31	0.134	7.2	7.8	0.02	28.42	37.55	30.23	67.78	3.8	6.18	366.6	BDL
MB18 0.4	0.32	0.112	7.3	7.7	0.02	13.33	55.94	28.81	84.76	1.92	2.89	2806	BDL
MB18 0.9	0.24	0.243	7.6	8.3	0.02	37.15	36.64	23.27	59.91	2.94	9.61	540.4	BDL

## Soil analysis

Sample Name	Sodium	Magnesium	Aluminium	Silicon	Phosphorous	Sulfur	Potassium	Calcium	Manganese	Iron
	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg
B02 1.7	26.1	5	217.5	75.5	2.65	3.6	22.05	13.45	7.05	223.5
B02 2.6	431	565	27500	1315	12	74	293	33.4	6.6	23700
B03 0.5	10.85	16.45	468.5	84	6.75	8.85	20.2	38.85	16	488.5
B03 1.5	304	795	57000	1185	28.6	25.75	1200	279.5	14.2	36700
B03 2.7	650	860	59500	1285	18.35	13	890	335.5	11.55	21900
B03 4	1445	2660	60000	1235	27.2	16.2	1370	1075	24.55	28550
B03 5	1065	2370	48850	1340	29.75	27.95	1085	680	17.1	7750
B04 1.8	15.65	28.25	2840	185	5.05	9.3	44.05	27.45	7.35	493
B04 2.1	272.5	494	42750	1075	12.5	46.1	555	186	8.9	4045
B04 2.8	1280	2025	45800	1160	23.35	55	1590	379	16	21950
B04 3.2	630	640	22850	805	27.05	59	690	93	15.25	4345
B04 3.6	940	875	30250	930	43.4	102	960	122.5	21	24750
B05 1.1	23.8	24.65	1095	125.5	3.9	8.7	26.35	39.65	14.6	550
B05 1.7	268.5	620	55000	1180	26.9	35.95	895	283.5	11.2	22000
B05 2.6	316	700	31350	995	17.95	9.8	780	179.5	14.15	7400
B08 1.5	79	171	18250	695	9.35	10.75	205.5	102.5	7.75	5300
B08 2.5	437.5	870	75000	1365	26.25	24.25	1195	335.5	17.3	16450
B08 3	810	1085	48100	1195	33.3	18.75	1175	378	12.55	24450
MB03 1	248.5	630	59500	1595	22.65	27	990	320.5	12.15	10350
MB03 2.4	650	945	58000	1370	32.4	19.5	1340	285.5	22.05	14350
MB03 2.8	645	710	37600	1330	25.55	20.8	885	209	16.35	18550
MB04 0.3	15	17.05	620	109.5	3.1	4.2	22	17.95	16	565
MB04 1.6	1630	1105	22700	1060	13.9	97	565	216	7.1	29450
MB04 3.2	2725	1680	19750	965	19.15	134.5	715	398	40.25	55500
MB08 1.6	23.8	44.95	4400	215.5	5.1	7.5	67.5	52.5	9.75	2160
MB08 2.1	139.5	395	35550	990	15.35	15.95	590	231.5	9.45	5400
MB08 3.3	352	650	61500	1510	18.9	15.75	835	280	8.15	19750
MB14 2.8	16.95	34.3	3360	145.5	2.25	18.15	37.9	48.55	2.95	535
MB14 3.4	457	605	68000	1380	22.45	32.95	995	221.5	10.45	4920
MB14 4.9	494	835	57000	1515	31.2	33.6	1355	262	14.95	25600
MB17 0.4	140.5	429	62000	1410	29.1	48.75	815	418.5	11.3	20850
MB17 1	140	383	47550	1640	23.25	59.5	560	266	7.85	37150
MB18 0.4	303	685	78000	1430	26.75	45.2	1210	319	10.7	24850
MB18 0.9	421.5	845	56000	1435	18.9	37.3	875	241	12.75	15150

**APPENDIX 6 Groundwater field sampling information and analysis results.**

Groundwater sampling field information- December 2012 (data provided by Worley Parsons)

Bore ID	Date and time	Water level (m bTOC)		Purging information					Field parameters						Comments
		Initial	Final	Total depth (m bTOC)	Volume purged (l)	Time taken	Method	Sample collected	Temp. (°C)	EC (mS/cm)	pH	Colour	Clarity	Sediment	
B03-VS	13/12/2012 15:40	DRY	-	1.70	0	N/A	N/A	No	-	-	-	-	-	-	
B03-S	13/12/2012 15:40	2.87	-	3.35	3	~20min	Bailer	Yes	22.2	13.78	5.13	Brown	Turbid	Fines	
B03-D	13/12/2012 15:40	10.40	10.82	17.88	80	12min	Pump	Yes	21.4	2.45	6.22	Brown	Turbid	Fines	
B04-VS	13/12/2012 14:15	DRY	-	2.60	0	N/A	N/A	No	-	-	-	-	-	-	
B04-S	13/12/2012 15:40	2.77	3.13	3.13	1.5	~15min	Bailer	Yes - from purged water	25.1	17.36	4.74	Brown	V. turbid	Fines and some f-m sand	Purged dry.
B04-D	13/12/2012 13:30	7.20	>17.88	18.98	60	25min	Pump	Yes	25.1	11.13	5.08	Brown	V. turbid	Fines and occn f-m sand	Purged dry.
B05-VS	13/12/2012 6:30	DRY	-	2.13	0	N/A	N/A	No	-	-	-	-	-	-	
B05-S	13/12/2012 6:30	2.42	3.11	3.11	3	~20min	Bailer	Yes - from purged water	22.3	9.37	4.91	Brown	V turbid	Fines	Purged dry.
B05-D	13/12/2012 6:30	13.03	17.38	19.12	40	1 hour	Bailer	Yes	21.9	5.62	5.48	Brown	V turbid	Fines	
MB01	12/12/2012 15:00	3.74	3.90	20.89	200	42min	Pump	Yes	21.7	2.67	6.74	Yellow	Clear to sl opaque	None	
MB03-S	14/12/2012 7:00	DRY	-	4.79	0	N/A	N/A	No	-	-	-	-	-	-	
MB03-D	14/12/2012 7:00	10.94	11.23	32.85	180	25min	Pump	Yes	20.8	3.62	6.73	Brown	Clear	Minor	
MB04-VS	12/12/2012 13:00	DRY	-	1.65	0	N/A	N/A	No	-	-	-	-	-	-	
MB04-S	12/12/2012 13:00	2.52	3.20	3.30	4	~25min	Bailer	Yes - from purged water	21.7	4.32	7.08	Grey	V. turbid	Silt + f-m sand	Purged dry.
MB04-I (MBD1_MB04I Dup)	12/12/2012 16:40	2.85	17.08	18.75	100	1.5hours	Pump	Yes	21.6	16.8	4.97	Brown	V. turbid	Fines	No reaction to pumping in MB04-D
MB04-D	12/12/2012 13:00	5.52	11.64	22.02	130	55min	Pump	Yes	22.5	>20	5.56	Clear	Clear	None	
MB06-S	13/12/2012 9:30	9.86	13.93	14.62	30	~40min	Pump/Bailer	Yes	20.8	8.2	5.43	Brown	Turbid	Very silty	Strong chlorine odour. Pumped dry, bailer used for remaining purging.
MB06-D	13/12/2012 8:30	9.70	10.00	38.27	200	30min	Pump	Yes	20.6	1.04	6.24	Clear	Clear	None	
MB07	12/12/2012 17:00	14.61	-	19.04	25	42min	Bailer	Yes	20.5	3.21	6.64	Brown	V turbid	Fines	No time for recovery monitoring.
MB08-S	13/12/2012 11:00	DRY	DRY	4.28	0	N/A	N/A	No	-	-	-	-	-	-	
MB08-I	13/12/2012 11:00	DRY	DRY	11.05	0	N/A	N/A	No	-	-	-	-	-	-	
MB08-D	13/12/2012 11:00	15.62	16.09	25.9	100	20min	Pump	Yes	20.7	2.41	6.9	Green	Clear	Minimal fine	Slight sulphur odour, decreased with purging.
MB09	13/12/2012 11:50	11.41	11.46	20.61	100	55min	Pump	Yes	22.5	0.42	6.01	Tan	Turbid	Minor fines	Minimal drawdown
MB10	13/12/2012 14:15	11.88	12.01	37.99	200	40min	Pump	Yes	21.1	2.95	7.02	Clear	Clear	Occn v. fine black mineral sand	Mineral fines decreased with purging
MB11-S	14/12/2012 9:00	13.41	17.8	19.06	35	20min	Pump	Yes	21.1	3.44	5.19	Brown	Turbid	Fine qz sand	Ran dry, surged pump to obtain samples. Slight sulphur odour

Groundwater sampling field information- December 2012 (data provided by Worley Parsons)

Bore ID	Date and time	Water level (m bTOC)		Purging information					Field parameters					Comments	
		Initial	Final	Total depth (m bTOC)	Volume purged (l)	Time taken	Method	Sample collected	Temp. (°C)	EC (mS/cm)	pH	Colour	Clarity		Sediment
MB11-D	14/12/2012 8:00	13.13	16.14	41.64	200	30min	Pump	Yes	20.5	1.76	5.54	Dark brown	Turbid	Fines, occn fine black sand	Sulphurous odour. No drawdown in MB11-S
MB12	12/12/2012 16:00	10.84	17.32	23.2	80	14min	Pump	Yes	21.5	1.12	6.27	Brown	Sl turbid	Slight silt	
MB14-S	12/12/2012 14:20	14.64	16.7	16.7	15	1hour	Bailer	No	20.9	11.04	4.99	Brown	Turbid	Silty	Ran dry, no sample. Attempted again on 13/12/2012 but no sig. recharge.
MB14-I	12/12/2012 14:40	18.94	21.57	28.7	100	35min	Pump	Yes	20.6	1.67	6.17	Brown	Sl turbid	Minor fines	
MB14-D	12/12/2012 14:40	18.96	19.09	35.45	200	45min	Pump	Yes	23	2.5	7.02	Sl white	Clear	None	Ran clear quickly
MB15-VS	11/12/2012 8:30	DRY	-	2.50	0	N/A	N/A	No	-	-	-	-	-	-	
MB15-S	11/12/2012 8:30	10.79	14.14	18.7	20	-	Pump	Yes	29.9	6.16	5.37	Brown	V. turbid	Silt	V low flow
MB15-I	11/12/2012 8:30	19.22	20.27	27.75	60	-	Pump	Yes - taken with bailer after 1:45hr recovery	22.4	5.52	5.68	Brown	V. turbid	Silt	Purged dry repeatedly.
MB15-D	12/12/2012 8:00	19.44	20.61	41.91	210	50min	Pump	Yes	22.3	2.55	6.57	Sl. White	Clear	Minimal fine	Pump not working on 11/12/2012 so sampled on 12/12/2012
MB16-VS	10/12/2012 15:00	DRY	-	3.61	0	N/A	N/A	No	-	-	-	-	-	-	
MB16-S	10/12/2012 15:00	13.68	-	16.99	20	~40min	Bailer	Yes	24.2	10.65	6.15	Brown	Turbid	Silt	
MB16-D	10/12/2012 14:40	13.66	17.50	37.8	120	25min	Pump	Yes		1.31	6.37	Clear	Clear	None	
MB17-S	11/12/2012 6:50	12.89	15.54	15.86	20	-	Bailer	Yes	21.4	13.47	5.05	Brown	V. turbid	Silt	Chlorine odour
MB17-D	11/12/2012 6:45	18.36	18.38	34.41	100	-	Bailer	Yes	25.5	2.1	6.93	Clear	Clear	Minor fines	
MB18-S (MBD3_MB 18S Dup)	12/12/2012 10:00	9.07	11.71	16.83	220	50min	Pump	Yes	21.4	0.51	5.87	Clear	Clear	None	
MB18-D	12/12/2012 10:00	8.96	25.79	39.03	200	1hour	Pump	Yes	21.3	2.63	5.88	Clear	Clear	Very minimal	
MB19	10/12/2012 16:50	10.57	17.21	23.94	100	20min	Pump	Yes	22.8	0.93	6.95	Clear	Clear	None	
MB21-VS	10/12/2012 9:45	2.74	2.94	2.94	1.5	~15min	Bailer	Yes	-	-	-	Brown	Turbid	Silt	
MB21-S	10/12/2012 9:45	9.15	14.09	17.9	60	1:15hour	Pump	Yes	26.4	7.2	6.26	Brown	Turbid	Silt	
MB21-D	10/12/2012 9:45	9.69	14.44	38.9	140	13 min	Pump	Yes	21.6	2.66	6.13	Clear	Clear	None	
MB22	12/12/2012 11:36	11.04	13.92	23.05	100	25min	Pump	Yes	21.3	2.75	6.08	Sl brown	Sl turbid	Sl silt	

Groundwater results - December 2012		Date	13/12/2012	13/12/2012	13/12/2012	12/12/2012	13/12/2012	13/12/2012	13/12/2012	12/12/2012	12/12/2012	11/12/2012	11/12/2012	11/12/2012	12/12/2012	12/12/2012	14/12/2012
Cooljarloo West		Aquifer	Perch. Bass/UG	Perch. Bass/UG	Perch. Bass/UG	Perch. Bass/UG	UG	UG	UG	UG	UG	UG	UG	UG	UG	UG	UG
		BH ID	B03-S	B04-S	B05-S	MB04_S	B03-D	B04-D	B05-D	MB04_I	MB04_D	MB12	MB15-S	MB17-S	MB18_S	MB01	MB03-D
Analyte grouping/Analyte	Units	LOR															
pH Value	pH Unit	0.01	5.66	5.16	5.41	7.49	6.64	5.53	6.01	5.45	6.37	6.52	6.08	5.48	6.48	7.33	7.37
Sodium Adsorption Ratio	-	0.01	56.3	72.5	40.2	19.1	17.1	37.4	22.1	28.3	26.6	10.6	25	45.4	5.24	8.31	21.5
Electrical Conductivity @ 25°C	µS/cm	1	13200	16100	8600	3350	2290	10600	5110	15800	21100	1050	5670	12100	495	2510	3290
Total Dissolved Solids @180°C	mg/L	10															
Total Dissolved Solids (Calc.)	mg/L	1	8580	10500	5590	2180	1490	6890	3320	10300	13700	682	3680	7860	322	1630	2140
Total Hardness as CaCO3	mg/L	1	533	836	710	151	115	656	404	1780	3430	64	381	900	43	326	183
Hydroxide Alkalinity as CaCO3	mg/L	1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Carbonate Alkalinity as CaCO3	mg/L	1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Bicarbonate Alkalinity as CaCO3	mg/L	1	610	820	629	335	225	269	330	243	37	78	191	585	35	139	518
Total Alkalinity as CaCO3	mg/L	1	610	820	629	335	225	269	330	243	37	78	191	585	35	139	518
Sulfate as SO4 - Turbidimetric	mg/L	1	<1	<1	126	122	38	482	<5	677	900	54	169	137	19	71	132
Chloride	mg/L	1	3120	1820	810	536	3250	1530	5640	7660	254	1560	2170	117	697	716	
Calcium	mg/L	1	52	140	83	21	18	35	30	90	133	6	47	52	4	53	42
Magnesium	mg/L	1	98	118	122	24	17	138	80	379	753	12	64	187	8	47	19
Sodium	mg/L	1	2990	4820	2460	541	422	2200	1020	2750	3590	196	1120	3130	79	345	669
Potassium	mg/L	1	45	24	95	86	49	25	44	85	91	14	25	25	4	11	9
Aluminium	mg/L	0.01	33.8	71.2	51	0.08	5.65	10.8	21.6	2.8	0.02	2.01	1.55	42	0.18	0.02	0.39
Arsenic	mg/L	0.001	0.264	0.438	0.328	0.018	0.045	0.132	0.158	0.044	0.001	0.012	0.066	0.311	0.002	0.002	0.724
Boron	mg/L	0.05	0.23	0.06	0.12	0.09	0.08	0.11	0.19	0.12	0.11	<0.05	0.08	0.11	<0.05	<0.05	0.14
Strontium	mg/L	0.001	0.201	0.669	0.413	0.221	0.096	0.164	0.142	0.907	2.24	0.046	0.174	0.166	0.052	0.348	0.27
Barium	mg/L	0.001	0.11	0.858	0.204	0.072	0.05	0.02	0.031	0.06	0.068	0.004	0.002	0.034	0.024	0.087	0.013
Titanium	mg/L	0.01	0.26	0.52	0.33	0.03	0.04	0.12	0.18	0.15	0.02	0.07	0.05	0.27	<0.01	<0.01	0.05
Beryllium	mg/L	0.001	0.021	0.028	0.022	<0.001	0.011	0.012	0.017	0.006	0.001	0.004	0.01	0.048	<0.001	<0.001	0.011
Gallium	mg/L	0.001	0.009	0.03	0.014	<0.001	<0.001	0.002	0.002	<0.001	<0.001	<0.001	<0.001	0.009	<0.001	<0.001	<0.001
Cadmium	mg/L	0.0001	0.0008	0.0013	0.0008	<0.0001	0.0001	0.0002	0.0003	0.0002	<0.0001	0.0001	<0.0001	0.0004	<0.0001	<0.0001	<0.0001
Cobalt	mg/L	0.001	0.003	0.011	0.005	0.004	0.008	0.003	0.002	0.009	0.021	0.002	0.001	0.014	0.003	<0.001	0.004
Uranium	mg/L	0.001	0.072	0.159	0.093	0.001	0.085	0.046	0.103	0.014	<0.001	0.011	0.006	0.123	<0.001	<0.001	0.006
Chromium	mg/L	0.001	2	0.674	0.4	<0.001	0.055	0.102	0.118	0.025	<0.001	0.006	0.066	2.43	<0.001	<0.001	0.054
Copper	mg/L	0.001	0.805	0.335	0.112	0.001	0.013	0.036	0.027	0.026	0.002	0.004	0.03	0.253	<0.001	<0.001	0.002
Lanthanum	mg/L	0.001	0.003	0.035	0.007	<0.001	0.004	<0.001	<0.001	<0.001	0.022	0.003	<0.001	<0.001	0.003	<0.001	<0.001
Rubidium	mg/L	0.001	0.021	0.022	0.03	0.026	0.012	0.017	0.022	0.051	0.08	0.01	0.018	0.023	0.006	0.014	0.01
Lithium	mg/L	0.001	0.018	0.03	0.02	0.021	0.004	0.019	0.015	0.02	0.023	0.003	0.013	0.045	0.003	0.005	0.011
Thorium	mg/L	0.001	0.01	0.107	0.012	<0.001	0.001	<0.001	0.001	0.005	<0.001	0.004	0.005	0.006	<0.001	<0.001	<0.001
Cerium	mg/L	0.001	0.038	0.329	0.063	<0.001	0.026	0.003	0.007	<0.001	0.056	0.018	<0.001	0.014	0.017	<0.001	<0.001
Manganese	mg/L	0.001	1.42	8.87	9.04	0.416	0.658	2.41	4.37	1.16	0.14	0.078	0.543	1.5	0.083	0.107	0.102
Neodymium	mg/L	0.001	0.006	0.068	0.015	<0.001	0.008	<0.001	0.002	<0.001	0.01	0.005	<0.001	0.001	0.005	<0.001	<0.001
Molybdenum	mg/L	0.001	0.006	0.018	0.01	0.012	0.007	0.005	0.007	0.004	<0.001	0.003	0.004	0.005	<0.001	<0.001	0.026
Nickel	mg/L	0.001	0.028	0.077	0.034	0.008	0.018	0.015	0.012	0.024	0.018	0.004	0.012	0.036	0.002	<0.001	0.012
Lead	mg/L	0.001	0.008	0.021	0.011	<0.001	0.006	0.002	0.002	<0.001	<0.001	<0.001	<0.001	0.003	<0.001	<0.001	<0.001
Antimony	mg/L	0.001	0.036	0.103	0.051	0.001	0.006	0.009	0.011	0.002	<0.001	<0.001	0.004	0.031	<0.001	<0.001	0.002
Selenium	mg/L	0.01	0.72	0.03	0.02	<0.01	0.05	0.03	<0.01	0.02	<0.01	<0.01	0.02	<0.01	<0.01	<0.01	<0.01
Tin	mg/L	0.001	0.016	0.012	0.007	<0.001	<0.001	0.002	0.001	<0.001	<0.001	<0.001	<0.001	0.014	<0.001	<0.001	<0.001
Yttrium	mg/L	0.001	0.012	0.085	0.025	<0.001	0.005	0.001	0.003	<0.001	0.007	0.004	<0.001	0.004	0.002	<0.001	<0.001
Zirconium	mg/L	0.005	0.225	0.317	0.235	<0.005	0.019	0.039	0.066	0.014	<0.005	0.006	0.008	0.107	<0.005	<0.005	<0.005
Vanadium	mg/L	0.01	0.62	1.19	0.84	0.01	0.56	0.27	0.34	0.06	<0.01	0.06	0.1	0.77	<0.01	<0.01	0.05
Zinc	mg/L	0.005	0.301	0.148	0.079	0.008	0.007	0.028	0.029	0.03	0.013	0.024	0.01	0.11	<0.005	<0.005	0.007
Iron (Dissolved)	mg/L	0.05	31.7	83.2	54.1	0.76	2.8	6.6	10.8	3.43	4.73	3.51	0.36	21.5	0.69	3.87	2.79
Aluminium	mg/L	0.01															
Iron (Total)	mg/L	0.05															
Ferrous Iron (Fe II)	mg/L	0.05	0.39	<0.05		0.21	1.29	0.08	0.09	0.12	4.29			0.27		1.62	
Ferric Iron (Fe III)	mg/L	0.05	31.3	83.2		0.55	1.51	6.52	10.7	3.31	0.44			0.42		2.25	1.91
Fluoride	mg/L	0.1	0.2	0.6	0.2	0.6	0.6	0.3	0.3	0.1	0.2	0.8	0.2	0.4	0.2	0.2	0.2
Ammonia as N	mg/L	0.01	0.09	0.11	0.12	0.01	0.05	0.08	0.08	0.31		0.06	0.39	<0.10	0.16	0.08	
Nitrite as N	mg/L	0.01	<0.01	0.04	0.08	<0.01	<0.01	0.02	0.03	0.01		<0.01	<0.01	0.42	<0.01	<0.01	
Nitrate as N	mg/L	0.01	<0.01	2.11	1.15	0.01	<0.05	0.06	<0.01	<0.01		0.01	0.03	0.47	0.01	<0.01	
Nitrite + Nitrate as N	mg/L	0.01	<0.01	2.15	1.23	0.01	<0.05	0.08	0.03	<0.01		0.01	0.03	0.89	0.01	<0.01	
Total Kjeldahl Nitrogen as N	mg/L	0.1	9.7	5.2	13.6		2.9	4.1	1.9	2.1		1	2.6	9.5	0.8	0.1	
Total Nitrogen as N	mg/L	0.1	9.7	7.4	14.8		2.9	4.2	1.9	2.1		1	2.6	10.4	0.8	0.1	
Total Phosphorus as P	mg/L	0.01	3510	4710	2410		66.5	735	398	113		45.1	163	1220	1.24	1.15	
Reactive Phosphorus as P	mg/L	0.01	158	521	388	10.1	22	90.9	137	36.6		16.4	66	238	0.67	0.12	
Sulfide as S2-	mg/L	0.1															
Total Anions	meq/L	0.01	100	67.7	18.1	32.1	20.4	107	49.8	178	236	9.85	51.3	75.8	4.4	23.9	33.3
Total Cations	meq/L	0.01	142	227	124	28.8	21.9	109	53.6	157	227	10.2	57	155	4.4	21.8	33
Ionic Balance	%	0.01	17.2	54	51.2	5.49	3.52	1.06	3.68	6.15	1.84	1.59	5.18	34.2	&		

Groundwater results - December 2012		Date	13/12/2012	13/12/2012	11/12/2012	11/12/2012	11/12/2012	12/12/2012	11/12/2012	12/12/2012
Cooljarloo West		Aquifer	Yoga	LG/ Yoga	LG/ Yoga	Yoga	LG/ Yoga	Yoga	Yoga	Yoga
		BH ID	MB08-D	MB10	MW14-I	MB14-D	MB15-I	MB15_D	MB17-D	MB18_D
Analyte grouping/Analyte	Units	LOR								
pH Value	pH Unit	0.01	7.44	7.53	6.65	7.6	6.42		7.61	6.56
Sodium Adsorption Ratio	-	0.01	8.47		11.8	7.54	21.5		10.6	14
Electrical Conductivity @ 25°C	µS/cm	1	2260	2780	1660	2250	4740		2270	2600
Total Dissolved Solids @180°C	mg/L	10		1660						
Total Dissolved Solids (Calc.)	mg/L	1	1470		1080	1460	3080		1480	1690
Total Hardness as CaCO3	mg/L	1	300		134	349	366		261	185
Hydroxide Alkalinity as CaCO3	mg/L	1	<1	<1	<1	<1	<1		<1	<1
Carbonate Alkalinity as CaCO3	mg/L	1	<1	<1	<1	<1	<1		<1	<1
Bicarbonate Alkalinity as CaCO3	mg/L	1	239	211	125	248	151		319	64
Total Alkalinity as CaCO3	mg/L	1	239	211	125	248	151		319	64
Sulfate as SO4 - Turbidimetric	mg/L	1	60	79	55	66	107		76	76
Chloride	mg/L	1	558	782	441	573	1360		553	754
Calcium	mg/L	1	64	76	19	82	56		60	18
Magnesium	mg/L	1	34	60	21	35	55		27	34
Sodium	mg/L	1	337	372	313	324	945		395	438
Potassium	mg/L	1	11	15	16	14	22		14	10
Aluminium	mg/L	0.01	0.06	0.02	1.86	0.06	1.08	0.03	22.3	0.06
Arsenic	mg/L	0.001	0.003	0.055	0.016	0.004	0.034	<0.001	0.159	0.002
Boron	mg/L	0.05	0.16	0.05	0.06	0.06	<0.05	0.05	0.08	0.05
Strontium	mg/L	0.001	0.439	0.638	0.117	0.587	0.34	0.749	0.097	0.279
Barium	mg/L	0.001	0.052	0.122	0.024	0.058	0.009	0.144	0.011	0.102
Titanium	mg/L	0.01	0.06	<0.01	0.02	0.01	0.06	<0.01	0.14	<0.01
Beryllium	mg/L	0.001	<0.001	<0.001	0.024	<0.001	0.015	<0.001	0.027	<0.001
Gallium	mg/L	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.004	<0.001
Cadmium	mg/L	0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	0.0002	<0.0001
Cobalt	mg/L	0.001	0.002	<0.001	0.002	0.002	0.001	<0.001	0.007	0.002
Uranium	mg/L	0.001	<0.001	0.002	0.007	<0.001	0.003	<0.001	0.061	<0.001
Chromium	mg/L	0.001	0.002	<0.001	0.026	<0.001	0.016	<0.001	1.19	<0.001
Copper	mg/L	0.001	<0.001	<0.001	0.007	<0.001	0.023	<0.001	0.135	0.001
Lanthanum	mg/L	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Rubidium	mg/L	0.001	0.018	0.018	0.011	0.012	0.019	0.015	0.017	0.012
Lithium	mg/L	0.001	0.01	0.008	0.007	0.008	0.018	0.008	0.028	0.003
Thorium	mg/L	0.001	<0.001	<0.001	0.002	<0.001	0.001	<0.001	0.004	<0.001
Cerium	mg/L	0.001	<0.001	<0.001	0.003	<0.001	<0.001	<0.001	0.005	<0.001
Manganese	mg/L	0.001	0.262	0.126	0.124	0.254	0.145	0.198	0.865	0.236
Neodymium	mg/L	0.001	<0.001	<0.001	0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Molybdenum	mg/L	0.001	0.001	0.002	<0.001	<0.001	0.001	<0.001	0.006	<0.001
Nickel	mg/L	0.001	0.002	<0.001	0.007	0.002	0.01	<0.001	0.018	0.002
Lead	mg/L	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.002	<0.001
Antimony	mg/L	0.001	<0.001	<0.001	<0.001	<0.001	0.002	<0.001	0.017	<0.001
Selenium	mg/L	0.01	<0.01	<0.01	0.02	<0.01	0.01	<0.01	0.01	<0.01
Tin	mg/L	0.001	<0.001	<0.001	<0.001	<0.001	0.002	<0.001	0.007	<0.001
Yttrium	mg/L	0.001	<0.001	<0.001	0.005	<0.001	<0.001	<0.001	0.001	<0.001
Zirconium	mg/L	0.005	<0.005	<0.005	0.006	<0.005	<0.005	<0.005	0.058	<0.005
Vanadium	mg/L	0.01	<0.01	<0.01	0.02	<0.01	0.04	<0.01	0.41	<0.01
Zinc	mg/L	0.005	<0.005	<0.005	<0.005	<0.005	0.047	<0.005	0.056	<0.005
Iron (Dissolved)	mg/L	0.05	2.69	0.38	0.88	1.22	0.25	5.05	10.9	3.3
Aluminium	mg/L	0.01		0.28						
Iron (Total)	mg/L	0.05		0.87						
Ferrous Iron (Fe II)	mg/L	0.05	<0.05	<0.05				0.12		2.2
Ferric Iron (Fe III)	mg/L	0.05	2.69	0.38				4.93		1.1
Fluoride	mg/L	0.1	<0.1		0.4	0.2	0.2		0.3	0.1
Ammonia as N	mg/L	0.01		0.23	0.01		0.25			
Nitrite as N	mg/L	0.01			<0.01		<0.01			
Nitrate as N	mg/L	0.01			<0.01		0.09			
Nitrite + Nitrate as N	mg/L	0.01		<0.01	<0.01		0.09			
Total Kjeldahl Nitrogen as N	mg/L	0.1		0.2						
Total Nitrogen as N	mg/L	0.1		0.2						
Total Phosphorus as P	mg/L	0.01		0.03						
Reactive Phosphorus as P	mg/L	0.01		<0.01	13.1		30.9			
Sulfide as S2-	mg/L	0.1		<0.1						
Total Anions	meq/L	0.01	21.8	27.9	16.1	22.5	43.6		23.6	24.1
Total Cations	meq/L	0.01	20.9	25.3	16.7	21.4	49		22.8	23
Ionic Balance	%	0.01	1.96	4.94	1.86	2.44	5.79		1.74	2.41

Groundwater sampling field information- April 2013 (data provided by Worley Parsons)

Bore ID	Date and time	Water level (m bTOC)		Purging information					Field parameters						Comments
		Initial	Final	Total depth (m bTOC)	Volume purged (l)	Time taken (min)	Method	Sample collected	Temp. (°C)	EC (mS/cm)	pH	Colour	Clarity	Sediment	
B03-VS	3/04/2013 16:00	DRY	DRY	1.64	0	N/A	N/A	No	-	-	-	-	-	-	Rugged TROLL SN 323580 OK
B03-S	3/04/2013 16:00	DRY	DRY	3.35	0	N/A	N/A	No	-	-	-	-	-	-	Rugged TROLL SN 312987 OK
B03-D	3/04/2013 16:00	10.56	11.08	17.56	60	15	Pump	Yes	20.8	0.76	6.38	C'less	Clear	Minor	Rugged TROLL SN 324263 OK
B04-VS	4/04/2013 7:15	DRY	DRY	2.60	0	N/A	N/A	No	-	-	-	-	-	-	Rugged TROLL SN 323583 OK
B04-S	4/04/2013 7:15	DRY	DRY	3.10	1.5	N/A	N/a	No	-	-	-	-	-	-	Rugged TROLL SN 325467 OK
B04-D	4/04/2013 7:15	7.23	DRY	18.67	60	75	Pump	Yes	21.4	7.96	6.47	Brown	Turbid	Minor Silt	Rugged TROLL SN 323540 OK
B05-VS	4/04/2013 6:30	DRY	DRY	2.13	0	N/A	N/A	No	-	-	-	-	-	-	Rugged TROLL SN 325829 OK
B05-S	4/04/2013 6:30	DRY	DRY	3.08	0	N/A	N/a	No	-	-	-	-	-	-	Rugged TROLL SN 312922 OK
B05-D	4/04/2013 6:30	13.13	17.65	19.12	40	30	Pump	Yes	20.2	4.64	6.33	Brown	Turbid	Minor	Rugged TROLL SN 325828 OK
MB01	1/04/2013 12:10	4.04	4.24	29.80	160	21	Pump	Yes	21.4	2.79	6.65	White	Clear	None	
MB03-S	3/04/2013 15:30	DRY	DRY	4.76	0	N/A	N/A	No	-	-	-	-	-	-	
MB03-D	3/04/2013 15:30	11.07	11.17	32.30	140	71	Pump	Yes	23.3	2.1	6.94	C'less	Clear	Minor	
MB04-VS	1/04/2013 9:25	DRY	DRY	1.65	0	N/A	N/A	No	-	-	-	-	-	-	Rugged TROLL SN 323541 OK
MB04-S	1/04/2013 9:25	3.46	DRY	3.47	0	N/A	N/A	No	-	-	-	-	-	-	Rugged TROLL SN 312985 OK
MB04-I	1/04/2013 9:25	3.69	17.90	18.37	85	105	Pump	Yes	28.4	19.24	5.66	Brown	Turbid	Some Silt	Rugged TROLL SN 313049 FAULTY returned to manufacturer. Running dry at 85L, surged pump to retrieve samples
MB04-D	1/04/2013 9:25	5.80	15.89	26.39	140	34	Pump	Yes	22	>20	5.46	C'less	Clear	None	Rugged TROLL SN 325826 RESET due to erroneous run
MB06-S	3/04/2013 6:30	10.07	13.50	14.60	20	20	Pump	Yes	19.1	3.5	5.99	Brown	Turbid	Silt	Rugged TROLL SN 324268 OK
MB06-D	3/04/2013 6:30	10.01	10.12	38.05	180	45	Pump	Yes	21.1	1.03	6.19	C'less	Clear	None	Rugged TROLL SN 324254 OK
MB07	2/04/2013 17:15	14.70	DRY	18.52	24	35	Bailer	Yes	21.1	3.31	6.57	Brown	Turbid	Minor	Purged dry due to slow recovery
MB08-S	3/04/2013 11:15	DRY	DRY	4.28	0	N/A	N/A	No	-	-	-	-	-	-	
MB08-I	3/04/2013 11:15	DRY	DRY	11.12	0	N/A	N/A	No	-	-	-	-	-	-	
MB08-D	3/04/2013 11:15	15.8	16.33	26.01	60	18	Pump	Yes	21.9	2.48	6.69	C'less	Clear	None	
MB09	3/04/2013 11:00	11.54	11.66	20.68	80	28	Pump	Yes	26.1	0.26	5.96	Brown	Clear	None	
MB10	3/04/2013 12:20	12.13	12.28	37.18	160	41	Pump	Yes	21.1	3.4	6.95	C'less	Clear	Minor Mineral	
MB11-S	3/04/2013 13:30	13.6	17.3	18.66	30	12	Pump	Yes	21.5	3.85	5.76	Brown	Turbid	Minor	
MB11-D	3/04/2013 13:30	13.41	14.22	41.1	180	102	Pump	Yes	24	1.78	5.44	Brown	SI Turbid	Some Mineral	Strong Sulfurous odour
MB12	2/04/2013 14:30	10.94	21.56	23.52	80	14	Pump	Yes	20.9	0.9	6.19	Brown	SI turbid	Minor Fines	
MB14-S	2/04/2013 16:00	DRY	DRY	16.53	0	N/A	N/A	No	-	-	-	-	-	-	
MB14-I	2/04/2013 16:00	19.03	21.34	28.93	60	16	Pump	Yes	21.3	1.78	6.18	White	Clear	None	
MB14-D	2/04/2013 17:15	19.07	19.17	35.99	180	72	Pump	Yes	22.8	2.28	7.46	C'less	Clear	None	Rugged TROLL SN 325832 SNAGGED above water table. Slight sulfurous odour and grey tinge for first 10L
Bore ID	Date and time	Water level (m)		Purging information					Field parameters						Comments
		Initial	Final	Total depth (m bTOC)	Volume purged (l)	Time taken (min)	Method	Sample collected	Temp. (°C)	EC (mS/cm)	pH	Colour	Clarity	Sediment	
MB15-VS	2/04/2013 11:30	DRY	DRY	2.51	0	N/A	N/A	No	-	-	-	-	-	-	
MB15-S	2/04/2013 11:30	10.56	DRY	19.9	60	60	Pump/Bailer	Yes	21.4	5.77	6.16	Brown	Turbid	Silt	Purged dry at 30L
MB15-I	2/04/2013 11:30	19.15	25.02	27.5	60	56	Pump	Yes	26.9	4.98	6.03	Brown	Clear	Some Silt	
MB15-D	2/04/2013 11:30	19.58	20.08	41.7	140	65	Pump	Yes	22.6	2.61	7.32	C'less	Clear	None	
MB16-VS	1/04/2013 16:25	DRY	DRY	3.61	0	N/A	N/A	No	-	-	-	-	-	-	
MB16-S	1/04/2013 16:25	13.86	DRY	16.99	30	25	Bailer	Yes	21.1	5.22	6.29	Brown	Turbid	Silt	
MB16-D	1/04/2013 16:25	13.82	18.18	38.44	160	35	Pump	Yes	20.8	1.25	6.21	C'less	Clear	None	
MB17-S	2/04/2013 13:00	15.4	DRY	15.78	0.5	5	Bailer	Yes - Purge	23.9	9.53	5.57	Brown	V. turbid	Silt	Sampled for routine parameters only - not enough purge water
MB17-D	2/04/2013 13:00	15.44	18.68	33.8	160	37	Pump	Yes	21.8	2.53	7.19	C'less	Clear	None	Rugged TROLL 313124 OK
MB18-S	2/04/2013 7:30	9.05	10.9	16.64	60	18	Pump	Yes	19.9	0.55	6.16	White	SI Turbid	None	Rugged TROLL 325838 OK; BaroTROLL 318637 OK
MB18-D	2/04/2013 7:30	9.19	17.38	38.64	180	97	Pump	Yes	22.6	2.66	5.91	C'less	Clear	None	
MB19	2/04/2013 9:00	10.76	16.79	23.51	80	27	Pump	Yes	21	1.08	6.61	C'less	Clear	None	
MB21-VS	1/04/2013 14:15	DRY	DRY	2.93	0	N/A	N/A	No	-	-	-	-	-	-	
MB21-S	1/04/2013 14:15	9.24	15.88	17.56	60	20	Pump	Yes	25.9	6.08	6.77	Brown	Clear	None	
MB21-D	1/04/2013 14:15	9.82	12.54	39.56	180	73	Pump	Yes	22.3	3.7	6.34	Brown	Clear	Minor Mineral	
MB22	2/04/2013 6:00	11.2	14.22	22.89	80	17	Pump	Yes	19.6	2.88	5.78	C'less	Clear	Minor	

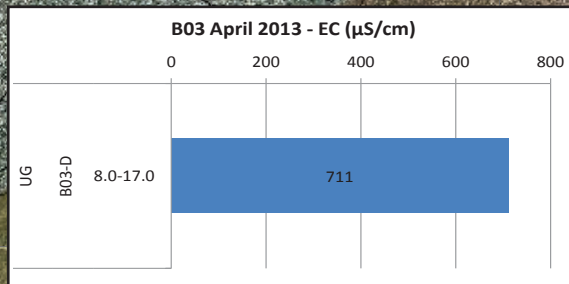
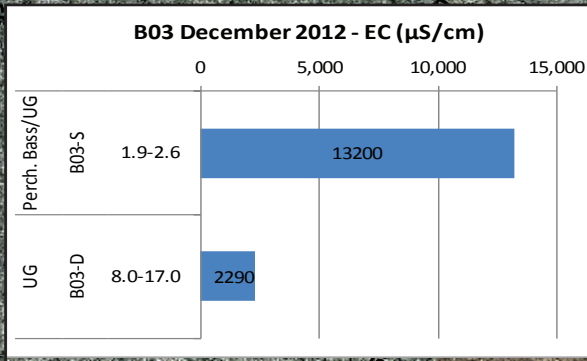
Groundwater results - April 2013 Cooljarloo West		Aquifer	UG	UG	UG	UG	UG	UG	UG	UG	UG	UG	UG
		Date	1/04/2013	1/04/2013	3/04/2013	2/04/2013	3/04/2013	2/04/2013	2/04/2013	1/04/2013	2/04/2013	2/04/2013	2/04/2013
		Bore ID	MB04_I	MB04_D	MB06-S	MB07	MB11S	MB12	MB15-S	MB16_S	MB17-S	MB18_S	MB19_D1
Analyte grouping/Analyte	Units	LOR											
pH Value	pH Unit	0.01	6.12	6.12	6.35	7.22	6.09	6.82	7.06	6.51	5.86	6.74	7.33
Sodium Adsorption Ratio	-	0.01	31.8	30.4	28.4	14.4	15.9	9.58	14	41.2	48	4.99	9.42
Electrical Conductivity @ 25°C	µS/cm	1	19000	22200	3440	3230	3730	890	5780	5340	10100	501	995
Total Dissolved Solids (Calc.)	mg/L	1	12400	14400	2240	2100	2420	578	3760	3470	6560	326	647
Total Hardness as CaCO3	mg/L	1	2900	3780	143	296	342	60	778	219	539	56	82
Hydroxide Alkalinity as CaCO3	mg/L	1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Carbonate Alkalinity as CaCO3	mg/L	1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Bicarbonate Alkalinity as CaCO3	mg/L	1	62	26	131	95	29	121	189	545	590	46	118
Total Alkalinity as CaCO3	mg/L	1	62	26	131	95	29	121	189	545	590	46	118
Sulfate as SO4 - Turbidimetric	mg/L	1	783	935	89	106	136	44	166	3	1	29	22
Chloride	mg/L	1	6800	7880	814	906	1020	175	1550	1120	2610	104	226
Calcium	mg/L	1	141	147	11	36	15	6	137	20	31	6	18
Magnesium	mg/L	1	620	828	28	50	74	11	106	41	112	10	9
Sodium	mg/L	1	3940	4300	780	571	678	171	898	1400	2560	86	196
Potassium	mg/L	1	68	68	10	14	10	10	24	28	57	5	6
Silicon	mg/L	0.05	57.1	39.5	58.8	21.5	36.8	24.7	22.5	73.3	78.2	13.6	12.9
Aluminium	mg/L	0.01	0.06	0.02	2.88	<0.01	<0.01	0.13	0.07	28.2		0.03	<0.01
Arsenic	mg/L	0.001	0.018	<0.001	0.114	<0.001	<0.001	0.011	0.01	0.262		0.002	0.013
Beryllium	mg/L	0.001	<0.001	<0.001	0.006	<0.001	<0.001	<0.001	<0.001	0.014		<0.001	<0.001
Barium	mg/L	0.001	0.402	0.053	0.036	0.176	0.096	0.006	0.079	0.035		0.044	0.045
Cadmium	mg/L	0.0001	0.0005	<0.0001	<0.0001	0.0004	<0.0001	<0.0001	0.0006	0.0008		<0.0001	<0.0001
Chromium	mg/L	0.001	0.011	<0.001	0.416	<0.001	<0.001	<0.001	0.006	0.617		<0.001	<0.001
Copper	mg/L	0.001	0.041	0.047	0.005	0.001	<0.001	<0.001	0.005	0.056		<0.001	<0.001
Nickel	mg/L	0.001	0.084	0.02	0.003	0.003	0.006	0.002	0.009	0.014		0.001	<0.001
Lead	mg/L	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.002		<0.001	<0.001
Zinc	mg/L	0.005	0.02	0.016	0.009	0.015	0.005	<0.005	0.013	0.046		<0.005	<0.005
Manganese	mg/L	0.001	2.05	0.086	0.104	0.563	0.315	0.052	0.777	3.15		0.153	0.195
Selenium	mg/L	0.01	<0.01	<0.01	0.02	<0.01	<0.01	<0.01	<0.01	0.05		<0.01	<0.01
Thorium	mg/L	0.001	<0.001	<0.001	0.004	<0.001	<0.001	<0.001	<0.001	0.008		<0.001	<0.001
Iron	mg/L	0.05	0.76	3.08	1.9	0.78	0.07	2.95	0.13	19		0.81	0.06
Ferrous Iron	mg/L	0.05	0.79	4.24	<0.05	1	0.08	3.25	0.54	0.84		1.02	0.09
Ferric Iron	mg/L	0.05	<0.05	<0.05	1.9	<0.05	<0.05	<0.05	<0.05	18.2		<0.05	<0.05
Fluoride	mg/L	0.1	0.2	0.1	0.5	0.2	<0.1	0.6	0.2	0.8	0.3	0.2	0.3
Ammonia as N	mg/L	0.01	0.72	0.97	0.04	0.07	0.14	0.1	0.42	0.07	<0.01	0.15	0.11
Nitrite as N	mg/L	0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.01	0.06	<0.01	<0.01
Nitrate as N	mg/L	0.01	<0.01	<0.01	0.13	<0.01	0.02	<0.01	0.03	<0.05	0.55	<0.01	<0.01
Nitrite + Nitrate as N	mg/L	0.01	<0.01	<0.01	0.13	<0.01	0.02	<0.01	0.03	<0.05	0.61	<0.01	<0.01
Total Kjeldahl Nitrogen as N	mg/L	0.1	4	1	1.7	0.8	3.2	4.2	3.3	6.7	4.9	0.3	0.1
Total Nitrogen as N	mg/L	0.1	4	1	1.8	0.8	3.2	4.2	3.3	6.7	5.5	0.3	0.1
Total Phosphorus as P	mg/L	0.01	76.5	0.13	164	0.33	1.07	39.1	23.8	574	1350	0.99	3.79
Reactive Phosphorus as P	mg/L	0.01	58.7	<0.01	141	0.07	0.02	19.4	18.4	277	390	0.83	3.88
Sulfide as S2-	mg/L	0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1		<0.1	<0.1
Total Anions	meq/L	0.01	209	242	41.1	29.7	32.2	8.27	51	70.2	124	4.46	9.19
Total Cations	meq/L	0.01	231	264	37	31.1	36.6	8.9	55.2	66	124	4.99	10.3
Ionic Balance	%	0.01	4.94	4.33	5.24	2.36	6.38	3.63	4.02	3.11	0.4	5.64	5.76

Groundwater results - April 2013 Cooljarloo West		Aquifer	UG	UG	UG	UG	UG	UG	UG	LG	LG	LG
		Date	2/04/2013	1/04/2013	2/04/2013	3/04/2013	4/04/2013	4/04/2013	4/04/2013	1/04/2013	3/04/2013	3/04/2013
		Bore ID	MB19	MB21_S	MB22	B03D	B04D	B04D3	B05D	MB01	MB03D	MB06-D
Analyte grouping/Analyte	Units	LOR										
pH Value	pH Unit	0.01	7.36	7.03	6.67	7.06	7.01	6.95	7.02	7.43	7.63	6.87
Sodium Adsorption Ratio	-	0.01	9.37	26	12.8	10.8	20.5	21.8	25.7	10.3	6.99	7.46
Electrical Conductivity @ 25°C	µS/cm	1	994	5880	2760	711	8220	8220	10200	2580	2060	980
Total Dissolved Solids (Calc.)	mg/L	1	646	3820	1790	462	5340	5340	6630	1680	1340	637
Total Hardness as CaCO3	mg/L	1	82	362	260	33	956	970	1120	351	350	96
Hydroxide Alkalinity as CaCO3	mg/L	1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Carbonate Alkalinity as CaCO3	mg/L	1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Bicarbonate Alkalinity as CaCO3	mg/L	1	121	271	45	112	132	136	193	122	279	58
Total Alkalinity as CaCO3	mg/L	1	121	271	45	112	132	136	193	122	279	58
Sulfate as SO4 - Turbidimetric	mg/L	1	22	345	92	20	184	179	322	76	38	38
Chloride	mg/L	1	226	1470	768	127	2470	2470	3100	679	474	249
Calcium	mg/L	1	18	38	12	5	71	75	81	55	81	12
Magnesium	mg/L	1	9	65	56	5	189	190	224	52	36	16
Sodium	mg/L	1	195	1140	474	143	1460	1560	1980	446	301	168
Potassium	mg/L	1	6	28	13	13	16	16	36	11	7	7
Silicon	mg/L	0.05	13	35	23.7	14.4	28.7	27.4	43.8	11.8	13.2	23.4
Aluminium	mg/L	0.01	<0.01	0.3	<0.01	0.08	0.02	0.03	<0.01	<0.01	0.01	<0.01
Arsenic	mg/L	0.001	0.013	0.028	<0.001	0.004	0.017	0.017	0.018	0.002	0.1	0.004
Beryllium	mg/L	0.001	<0.001	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Barium	mg/L	0.001	0.044	0.072	0.126	0.039	0.223	0.229	0.346	0.081	0.026	0.054
Cadmium	mg/L	0.0001	<0.0001	0.0005	<0.0001	<0.0001	<0.0001	<0.0001	0.0001	<0.0001	<0.0001	<0.0001
Chromium	mg/L	0.001	<0.001	0.02	<0.001	0.003	0.003	0.003	<0.001	<0.001	0.001	0.006
Copper	mg/L	0.001	<0.001	0.012	<0.001	<0.001	0.002	0.002	0.002	<0.001	<0.001	<0.001
Nickel	mg/L	0.001	<0.001	0.025	0.003	0.004	0.009	0.009	0.014	<0.001	0.002	<0.001
Lead	mg/L	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Zinc	mg/L	0.005	<0.005	0.016	0.027	0.011	<0.005	<0.005	<0.005	<0.005	0.01	<0.005
Manganese	mg/L	0.001	0.183	0.674	0.377	0.474	0.354	0.362	2.38	0.067	0.055	0.034
Selenium	mg/L	0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Thorium	mg/L	0.001	<0.001	0.007	<0.001	0.002	0.004	0.002	<0.001	<0.001	<0.001	<0.001
Iron	mg/L	0.05	0.05	0.57	0.22	3.71	0.08	<0.05	0.33	4.64	2.9	<0.05
Ferrous Iron	mg/L	0.05	0.08	0.48	0.26	4.37	<0.05	<0.05	0.39	4.98	3.35	<0.05
Ferric Iron	mg/L	0.05	<0.05	0.09	<0.05	<0.05	0.08	<0.05	<0.05	<0.05	<0.05	0.05
Fluoride	mg/L	0.1	0.3	0.3	<0.1	0.6	0.2	0.2	0.3	0.1	0.2	0.2
Ammonia as N	mg/L	0.01	0.12	0.53	0.06	0.07	0.15	0.15	0.05	0.08	0.29	0.02
Nitrite as N	mg/L	0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Nitrate as N	mg/L	0.01	<0.01	<0.02	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.05
Nitrite + Nitrate as N	mg/L	0.01	<0.01	<0.02	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.05
Total Kjeldahl Nitrogen as N	mg/L	0.1	0.2	3.2	0.1	1.1	1.8	1.1	2.5	0.1	0.4	<0.1
Total Nitrogen as N	mg/L	0.1	0.2	3.2	0.1	1.1	1.8	1.1	2.5	0.1	0.4	<0.1
Total Phosphorus as P	mg/L	0.01	3.8	44.8	0.02	23	77.2	43.2	93.7	0.18	11.9	5.47
Reactive Phosphorus as P	mg/L	0.01	3.81	47	0.01	19.2	13.4	14.2	15.1	<0.01	8.63	5.78
Sulfide as S2-	mg/L	0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Total Anions	meq/L	0.01	9.25	58.8	24.5	6.24	76.1	76.1	98	23.2	19.7	8.97
Total Cations	meq/L	0.01	10.3	57.6	26.2	7.21	83	87.6	110	26.7	20.3	9.4
Ionic Balance	%	0.01	5.22	1.03	3.3	7.23	4.3	7.02	5.53	7.07	1.34	2.31

Groundwater results - April 2013 Cooljarloo West		Aquifer	LG	LG	LG	LG	LG	LG	LG	LG	LG	LG	LG	LG	
		Date	3/04/2013	3/04/2013	3/04/2013	3/04/2013	3/04/2013	2/04/2013	2/04/2013	2/04/2013	2/04/2013	1/04/2013	2/04/2013	2/04/2013	1/04/2013
		Bore ID	MB06-D2	MB08D	MB09	MB10	MB11D	MB14-D	MB14-I	MB15-D	MB15-I	MB16_D	MB17-D	MB18_D	MB21_D
Analyte grouping/Analyte	Units	LOR													
pH Value	pH Unit	0.01	6.96	7.67	6.78	7.53	6.17	7.89	6.85	7.78	6.86	6.68	7.86	6.79	6.77
Sodium Adsorption Ratio	-	0.01	7.59	8.54	3.15	9.52	13.9	7.45	13.1	8.37	10.6	7.88	9.57	15	15.4
Electrical Conductivity @ 25°C	µS/cm	1	991	2330	244	3270	1670	2270	1650	2620	5250	1190	2360	2600	3510
Total Dissolved Solids (Calc.)	mg/L	1	644	1510	159	2120	1080	1480	1070	1700	3410	774	1530	1690	2280
Total Hardness as CaCO3	mg/L	1	98	351	29	515	105	406	122	426	906	134	327	192	310
Hydroxide Alkalinity as CaCO3	mg/L	1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Carbonate Alkalinity as CaCO3	mg/L	1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Bicarbonate Alkalinity as CaCO3	mg/L	1	59	221	30	198	38	225	120	246	182	64	262	58	95
Total Alkalinity as CaCO3	mg/L	1	59	221	30	198	38	225	120	246	182	64	262	58	95
Sulfate as SO4 - Turbidimetric	mg/L	1	37	50	5	93	43	53	55	56	104	45	60	76	94
Chloride	mg/L	1	245	566	46	831	485	540	390	619	1410	308	554	722	1010
Calcium	mg/L	1	13	73	5	86	4	95	19	98	183	11	75	19	25
Magnesium	mg/L	1	16	41	4	73	23	41	18	44	109	26	34	35	60
Sodium	mg/L	1	173	368	39	497	327	345	331	397	735	210	398	477	623
Potassium	mg/L	1	7	11	3	15	6	10	13	10	22	8	10	9	15
Silicon	mg/L	0.05	23.6	16.5	6.04	11.5	20.7	16.5	46.1	11.7	33.3	13.5	14.8	11.1	15
Aluminium	mg/L	0.01	<0.01	<0.01	0.07	<0.01	0.02	<0.01	0.44	<0.01	0.14	0.04	0.02	<0.01	0.02
Arsenic	mg/L	0.001	0.003	0.002	0.002	0.04	0.004	0.002	0.023	<0.001	0.016	0.006	0.004	0.002	0.007
Beryllium	mg/L	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.01	<0.001	0.002	<0.001	<0.001	<0.001	<0.001
Barium	mg/L	0.001	0.054	0.07	0.088	0.116	0.033	0.083	0.036	0.161	0.452	0.063	0.064	0.141	0.055
Cadmium	mg/L	0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Chromium	mg/L	0.001	<0.001	<0.001	0.001	<0.001	<0.001	<0.001	0.007	<0.001	0.003	0.001	<0.001	<0.001	<0.001
Copper	mg/L	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.003	0.001	<0.001	<0.001	<0.001
Nickel	mg/L	0.001	<0.001	<0.001	0.004	<0.001	<0.001	<0.001	0.005	<0.001	0.008	0.002	0.001	0.003	0.008
Lead	mg/L	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Zinc	mg/L	0.005	<0.005	<0.005	0.013	0.006	<0.005	<0.005	<0.005	<0.005	0.012	<0.005	<0.005	0.006	0.009
Manganese	mg/L	0.001	0.04	0.094	0.438	0.122	0.008	0.45	0.298	0.348	0.749	0.179	0.502	0.57	0.732
Selenium	mg/L	0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Thorium	mg/L	0.001	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.005	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Iron	mg/L	0.05	<0.05	2.86	0.42	1.06	0.94	0.97	0.56	3.26	0.55	0.61	1.19	3.64	6.74
Ferrous Iron	mg/L	0.05	<0.05	3.35	0.5	1.15	1	1.24	0.34	4.05	0.06	0.75	1.35	4.15	7.6
Ferric Iron	mg/L	0.05	<0.05	<0.05	0.07	<0.05	<0.05	<0.05	0.22	<0.05	0.49	<0.05	<0.05	<0.05	<0.05
Fluoride	mg/L	0.1	0.2	0.2	<0.1	0.2	0.1	0.2	0.3	0.2	0.2	0.1	0.2	<0.1	0.2
Ammonia as N	mg/L	0.01	0.02	0.08	0.14	0.2	0.17	0.13	0.05	0.24	0.46	0.17	0.04	0.32	0.54
Nitrite as N	mg/L	0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Nitrate as N	mg/L	0.01	0.05	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Nitrite + Nitrate as N	mg/L	0.01	0.05	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Total Kjeldahl Nitrogen as N	mg/L	0.1	<0.1	0.1	0.4	0.4	0.7	0.3	0.3	0.4	1.1	0.5	0.2	0.4	0.6
Total Nitrogen as N	mg/L	0.1	<0.1	0.1	0.4	0.4	0.7	0.3	0.3	0.4	1.1	0.5	0.2	0.4	0.6
Total Phosphorus as P	mg/L	0.01	6.21	4.02	1.14	0.04	0.02	3.23	42.4	0.08	23.6	8.38	7.49	0.26	3.36
Reactive Phosphorus as P	mg/L	0.01	5.63	2.31	1	0.01	0.02	2.6	39	<0.01	19.7	8.92	7.15	<0.01	2.07
Sulfide as S2-	mg/L	0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Total Anions	meq/L	0.01	8.86	21.4	2	29.3	15.3	20.8	18.8	23.5	45.6	10.9	22.1	23.1	32.4
Total Cations	meq/L	0.01	9.67	23.3	2.35	32.3	16.5	23.4	17.2	26	50.6	12	24.1	24.8	33.7
Ionic Balance	%	0.01	4.35	4.2		4.81	3.54	5.75	4.39	5.02	5.26	4.88	4.31	3.53	1.98

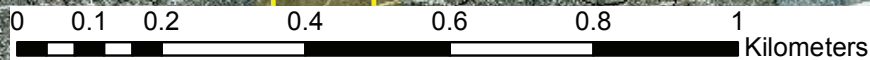
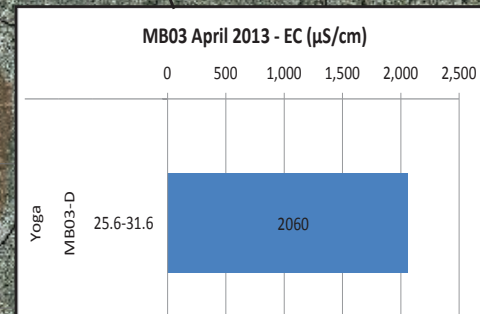
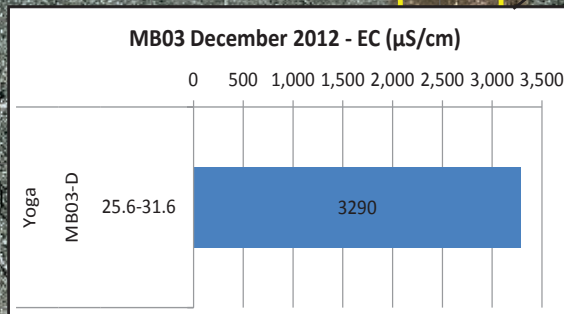
**APPENDIX 7 Groundwater electrical conductivity maps.**

# Palusplain B3, MB3, A05, A13



## Legend

- tenements\_June2012
- Syrix Stratigraphy\_Nested Bores
- WP\_Syrix Monitoring Bores
- Hand\_auger\_locations\_GPS
- Transect\_Points\_wetland/GDE\_20121030
- CLW\_Orebodies\_20120502
- Coojarloo\_West\_Landgate\_Contours\_2m\_20120911

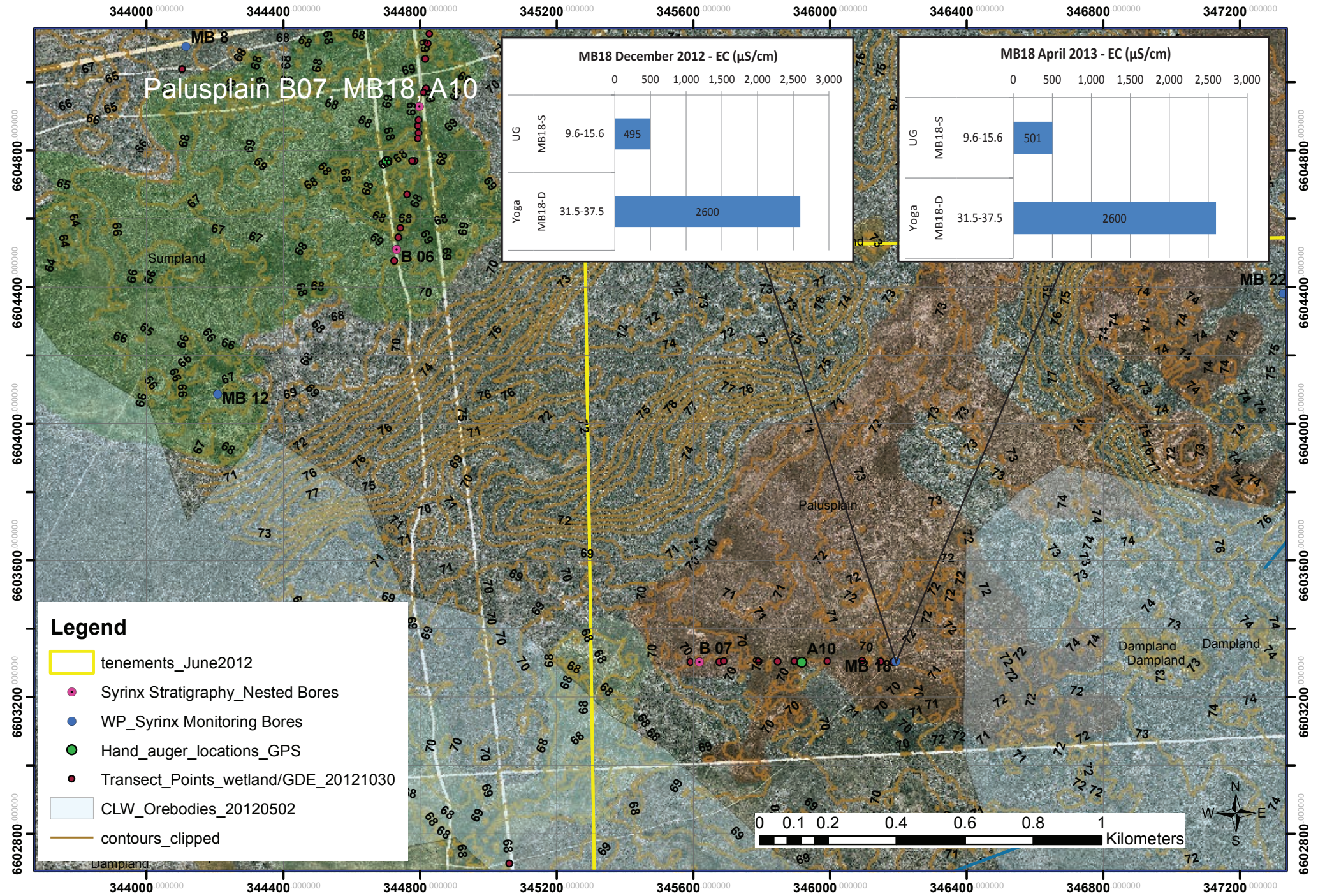


CLIENT : TRONOX  
 PROJECT : COOLJARLOO WEST  
 PROJECT NUMBER : 1221

DRAWING : PALUSPLAIN (ENV 2010) B3, MB3, A05, A13  
 DRAWING NUMBER :  
 REPORT:

DATE : 09.08.2013  
 SCALE : SEE SCALE BAR  
 DRAWN BY : SDo



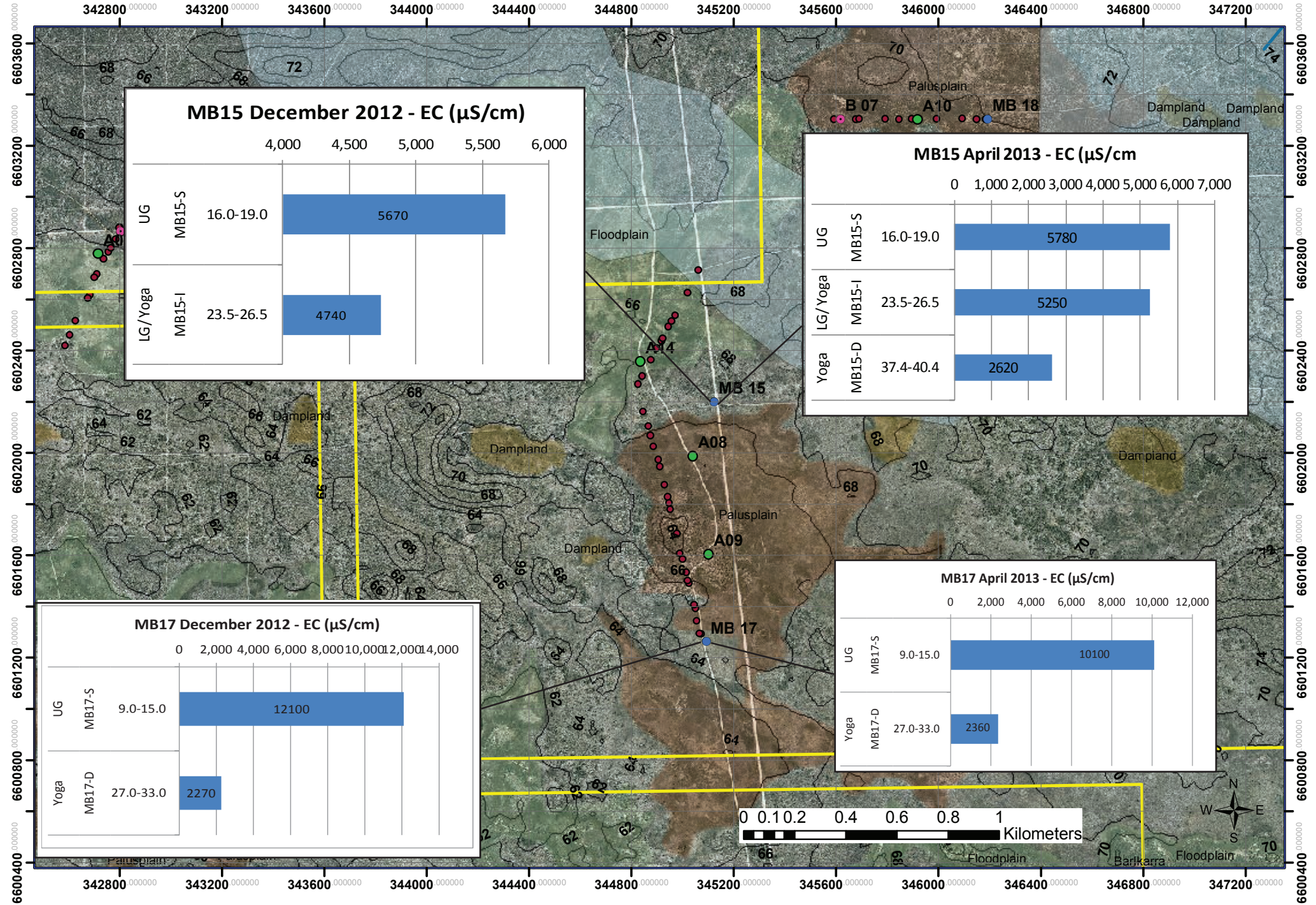


CLIENT : TRONOX  
 PROJECT : COOLJARLOO WEST  
 PROJECT NUMBER : 1221

DRAWING : PALUSPLAIN (ENV 2010) B07, MB18, A10  
 DRAWING NUMBER :  
 REPORT :

DATE : 09.08.2013  
 SCALE : SEE SCALE BAR  
 DRAWN BY : SDo





CLIENT : TRONOX  
 PROJECT : COOLJARLOO WEST  
 PROJECT NUMBER : 1221

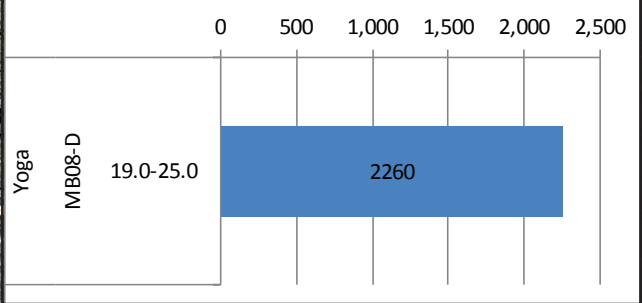
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 DRAWING NUMBER :  
 REPORT:

DATE : 09.08.2013  
 SCALE : SEE SCALE BAR  
 DRAWN BY : SDo

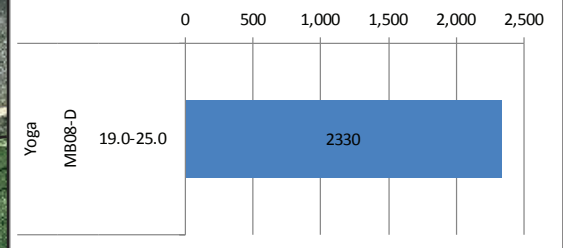


# Sumpland B05, B06, A03, MB8, MB12

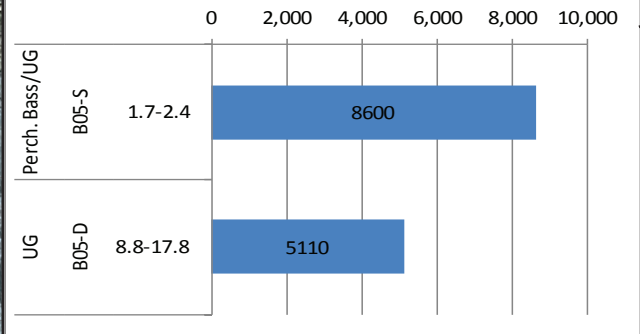
**MB08 December 2012 - EC ( $\mu\text{S}/\text{cm}$ )**



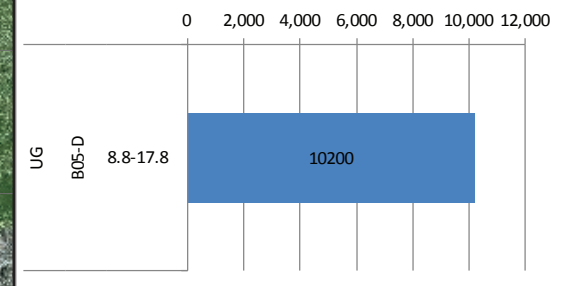
**MB08 April 2013 - EC ( $\mu\text{S}/\text{cm}$ )**



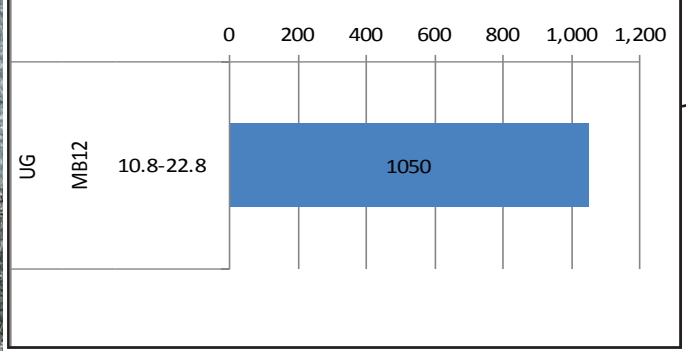
**B05 December 2012 - EC ( $\mu\text{S}/\text{cm}$ )**



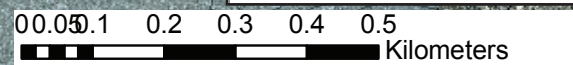
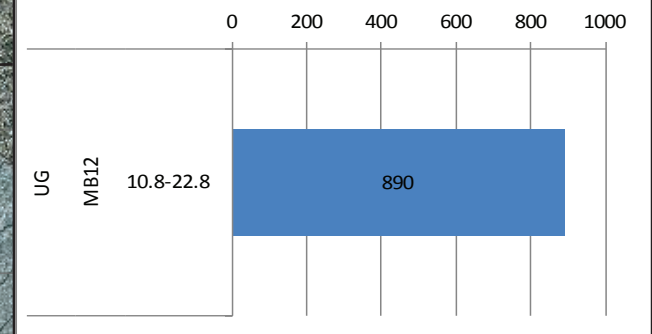
**B05 April 2013 - EC ( $\mu\text{S}/\text{cm}$ )**



**MB12 December 2012 - EC ( $\mu\text{S}/\text{cm}$ )**



**MB12 April 2013 - EC ( $\mu\text{S}/\text{cm}$ )**



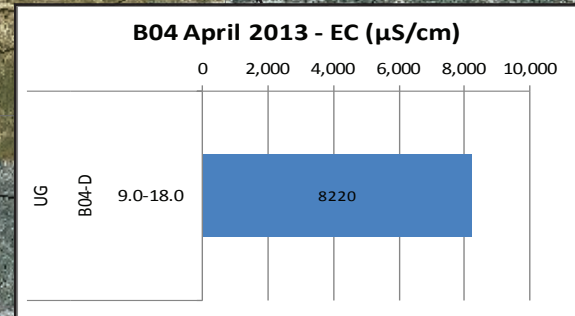
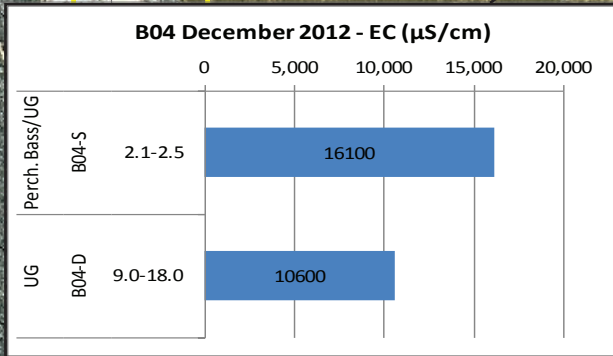
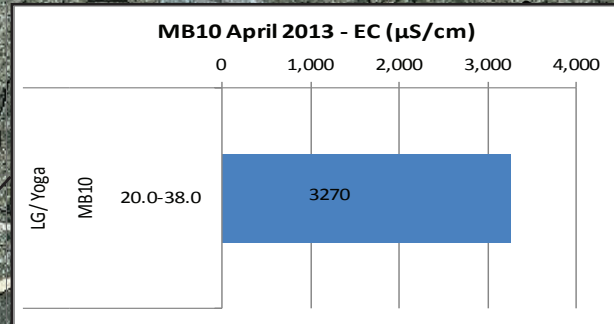
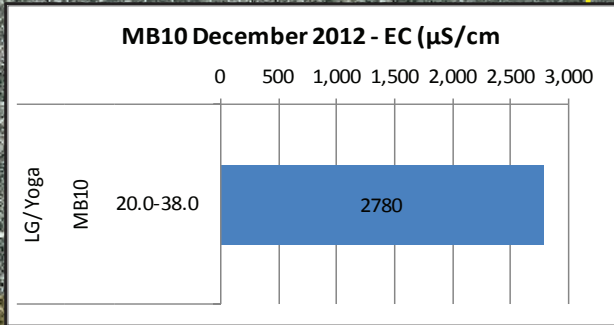
CLIENT : TRONOX  
 PROJECT : COOLJARLOO WEST  
 PROJECT NUMBER : 1221

DRAWING : SUMPLAND (ENV 2010) B05, B06, A03, MB8, MB12  
 DRAWING NUMBER :  
 REPORT:

DATE : 09.08.2013  
 SCALE : SEE SCALE BAR  
 DRAWN BY : SDo

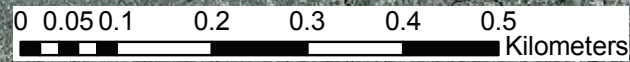


# Dampland MB10, B04, A06



## Legend

- tenements\_June2012
- Syrix Stratigraphy\_Nested Bores
- WP\_Syrix Monitoring Bores
- Hand\_auger\_locations\_GPS
- Transect\_Points\_wetland/GDE\_20121030
- CLW\_Orebodies\_20120502
- Coojarloo\_West\_Landgate\_Contours\_2m\_20120911

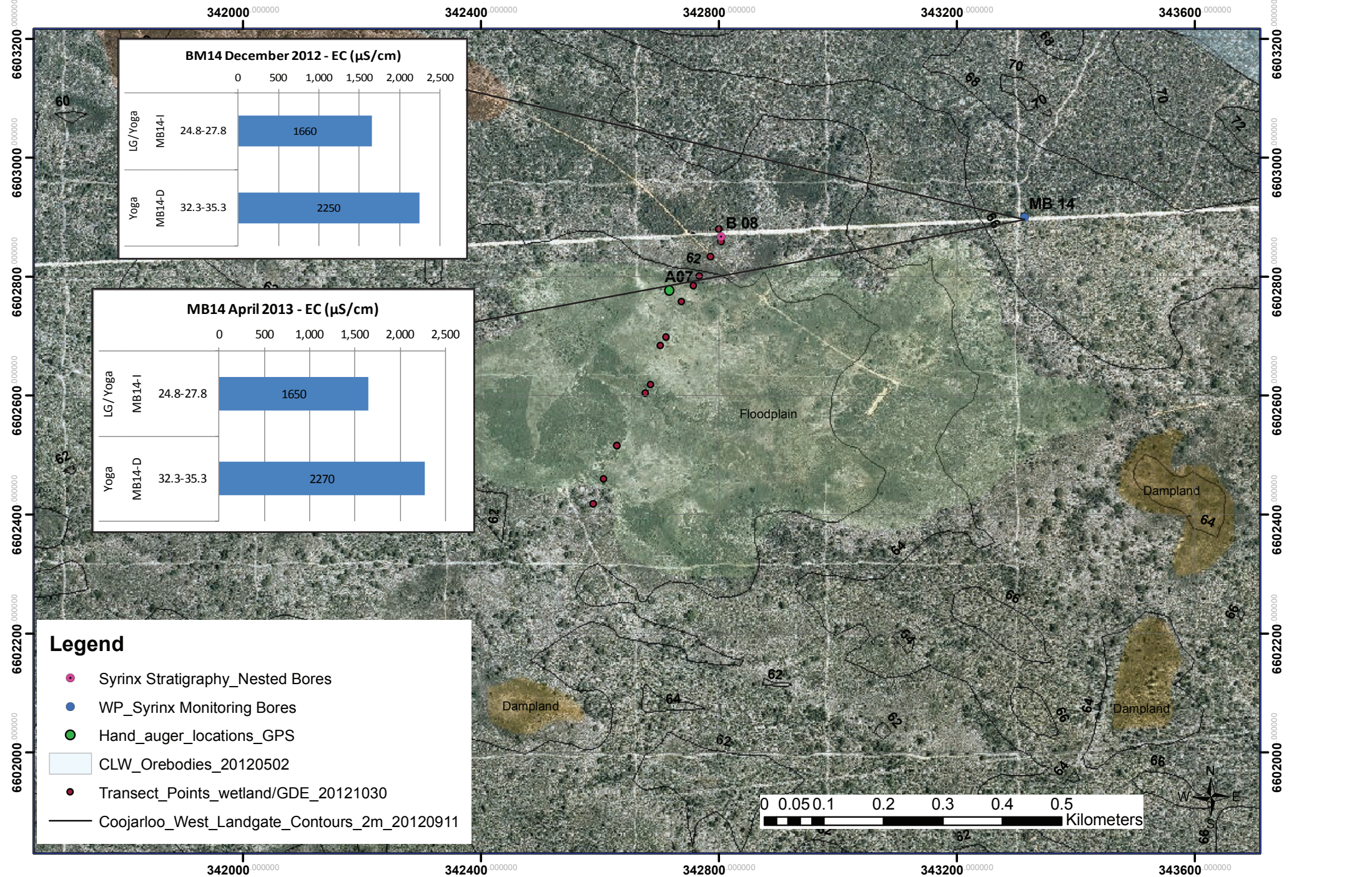


CLIENT : TRONOX  
 PROJECT : COOLJARLOO WEST  
 PROJECT NUMBER : 1221

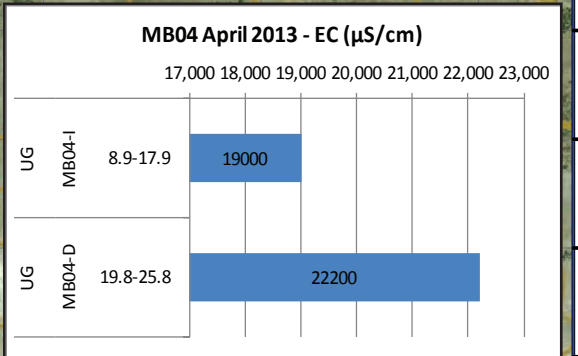
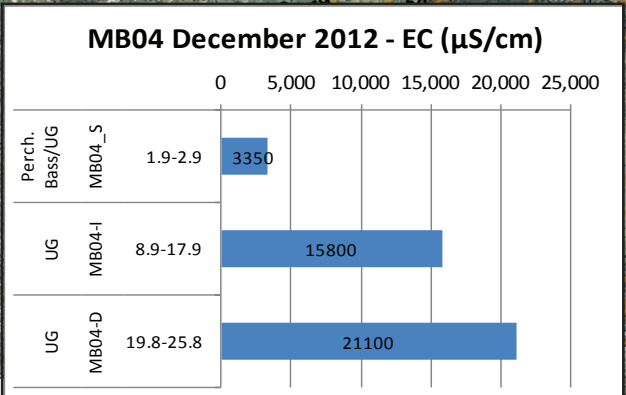
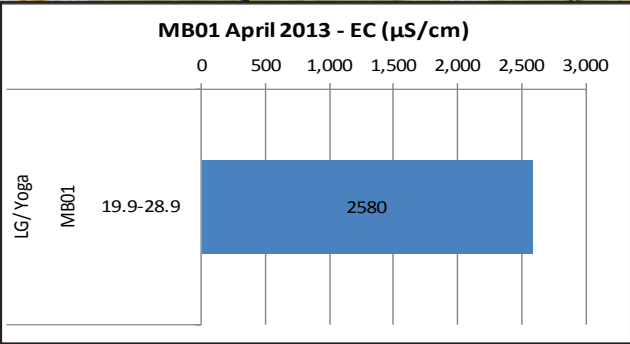
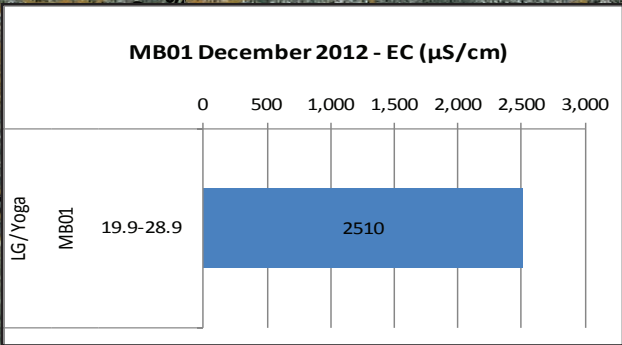
DRAWING : DAMPLAND (ENV 2010) MB10, B04, A06  
 DRAWING NUMBER :  
 REPORT:

DATE : 09.08.2013  
 SCALE : SEE SCALE BAR  
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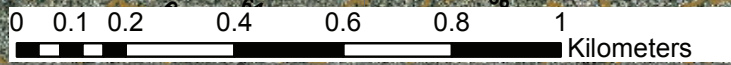


# Floodplain MB4, MB1, A01, A12



## Legend

- tenements\_June2012
- Syrinx Stratigraphy\_Nested Bores
- WP\_Syrinx Monitoring Bores
- Hand\_auger\_locations\_GPS
- Transect\_Points\_wetland/GDE\_20121030
- CLW\_Orebodies\_20120502
- contours\_clipped



CLIENT : TRONOX  
 PROJECT : COOLJARLOO WEST  
 PROJECT NUMBER : 1221

DRAWING : FLOODPLAIN (ENV 2010) MB4, MB1, A01, A12  
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**APPENDIX 8 Root Study.**

## APPENDIX 8: ROOT STUDY

### 1.0 INTRODUCTION

The objective of this study was to assess the relative dependency of selected species on the different aquifers (perched water and soil moisture in the Bassendean Unit vs the Yoganup aquifer) via assessment of root architecture, root mass in each lithological unit, and evidence of root penetration/structuring through the clayey sands and sandy clays of the Guildford Unit.

The root architecture (i.e. spatial configuration of the root system) investigations were undertaken as a supplementary study to support the formulated understanding of the mechanisms underpinning wetland and GDE functioning, as outlined in the Conceptual Site Model for the Proposal area (Section 11).

In order to understand the water usage of plants, particularly those described as ground or surface water dependant, the root architecture and particularly the root abundance and spread through each soil horizon were assessed and correlated to hydrogeological data to interpret and better understand the use of groundwater for a particular species or vegetation community.

### 2.0 METHODS

#### 2.1 EXCAVATION

Root systems were exposed by digging a series of deep and shallow trenches of 2.5 – 4.8 m depth by means of excavator. Only entire root system or a large subset of the root system of an individual plant was investigated. Where possible the plants were excavated whole or if fragmented were pieced together in order to take photographs. Notes relating to the depth, dimension and general morphology of roots were taken as well as the height and width of the particular plants investigated.

As the root architecture study was limited in time and resources, detailed studies of large specimens on site were not possible beyond those which had obvious presence on the excavated trench face.

Therefore, where available, seedlings of dominant species within a particular vegetation community were collected. Given the lack of recent fires and a relatively dry season the collection of seedlings was limited to disturbance areas mostly along the roadside tracks as no seedlings were observed in the mature vegetation communities surveyed. When collecting seedlings, impacts of ground compaction were taken into consideration and only seedlings that appeared to have grown in a non compacted area of the track clearing were collected and analysed.

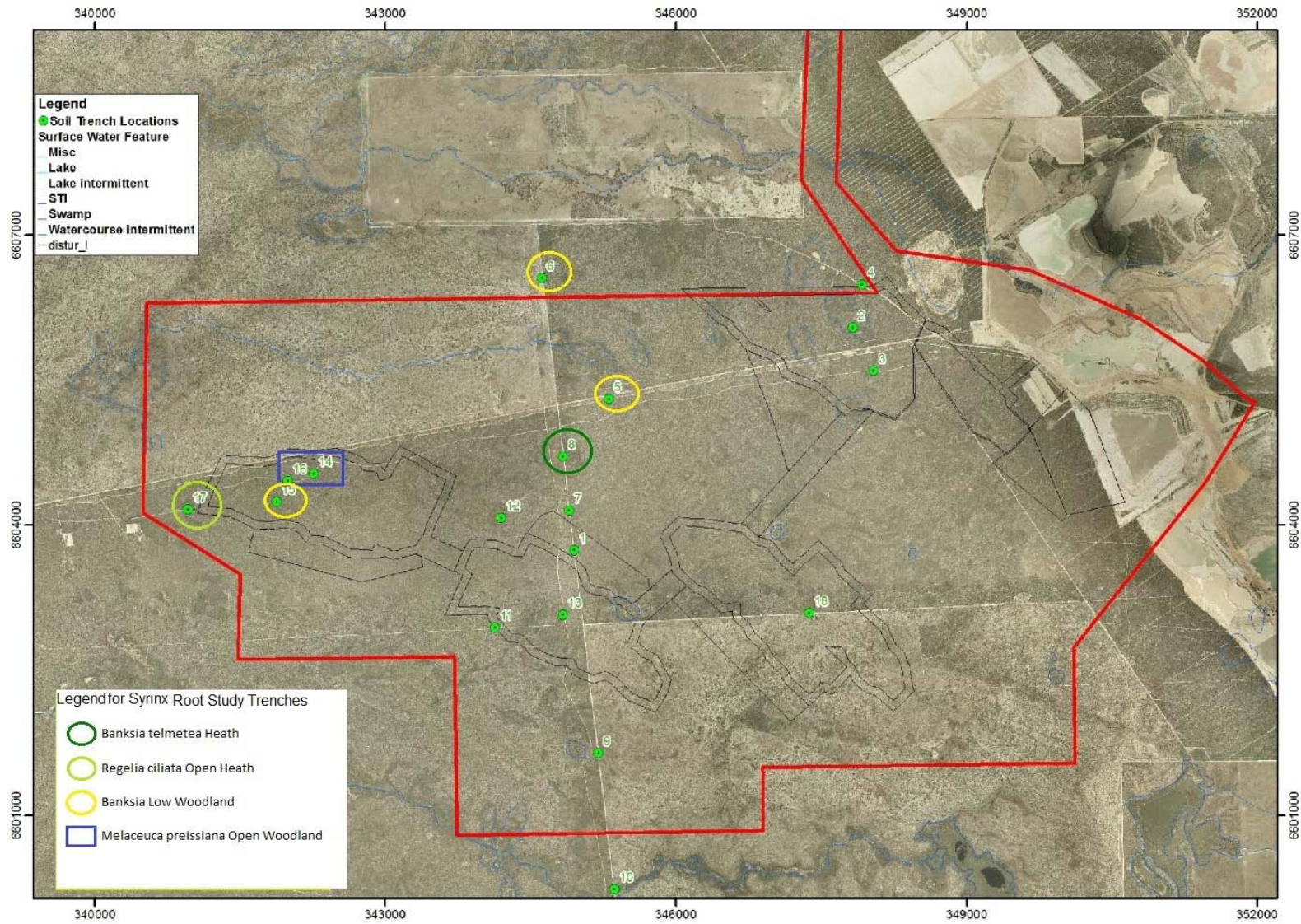


Figure 1 Location of trenches for stratigraphy and root architecture studies (figure modified from SWC, 2013).

### 2.1.1 Classification

The root architecture of key indicator species present at excavation trenches was classified in accordance with the morphotypes described by Dodd *et al.*, (1984) and correlated to observed stratigraphy to determine the most probable method of water uptake and / or groundwater dependency.

A limited root architecture study was conducted on GDE indicator species for four vegetation types and landforms:

- Banksia* Low Woodland (3 sites);
- Banksia telmatiaea* Heath (1 site);
- Regelia ciliata* Open Heath (1 site);
- Melaleuca preissiana* Open Woodland (2 sites).

Whilst detailed soil profiles are described in a separate soil report (SWC, 2013), typical profiles for four vegetation groups listed above are presented briefly in this report to provide context to the root patterns observed.

## 3.0 RESULTS

### 3.1 ROOT TYPES

Overall, the root architecture was dominated by extensive lateral roots. Whilst root types were similar to the Type 4 root system described by Dodd *et al.* (1984) (Figure 2), tap roots were variably deformed extending vertically to the top of the clayey sand layer then laterally with extensive branching. Almost all indicator species exhibited a wide and well developed lateral root system in the upper 20cm of the soil profile. Indicator species associated with deep sands on dunal slopes, crests and rises in general had larger diameter tap roots than those associated with depressions and flats where sands were usually less than 1m deep.

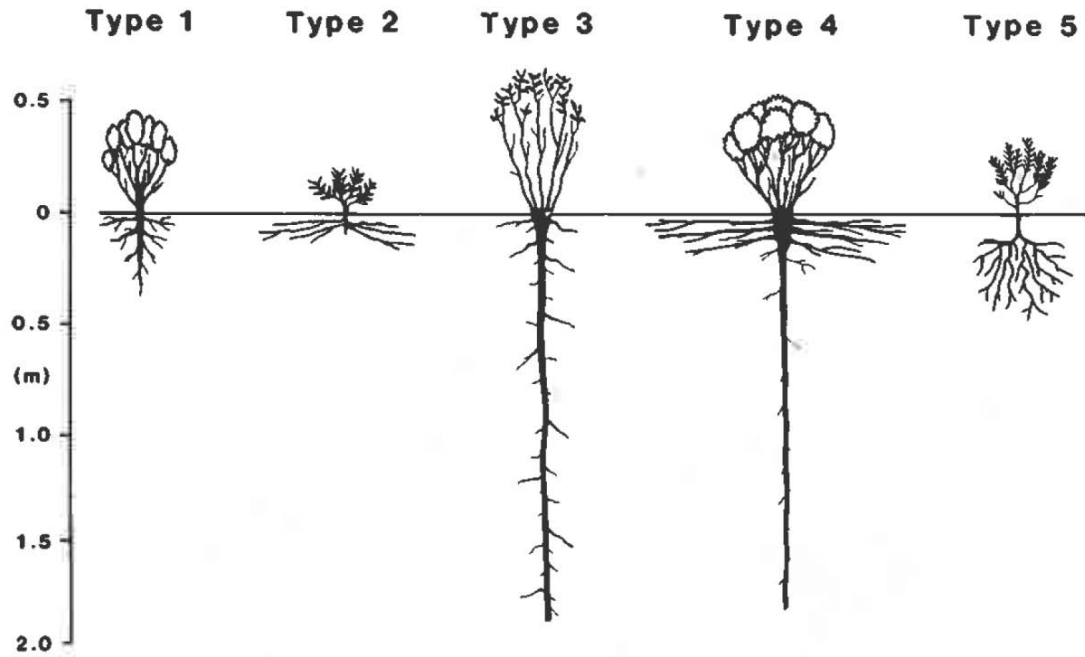


Figure 2 Examples of different root systems amongst Swan Coastal Plain shrubs (Dodd et al., 1984).

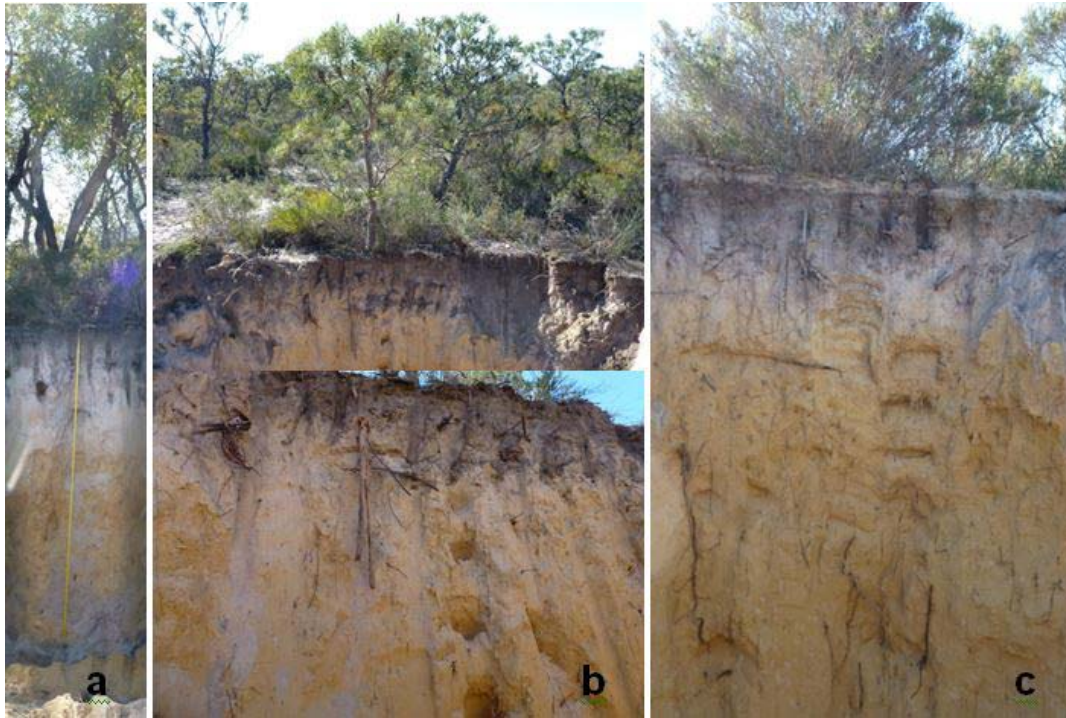
### 3.2 TYPICAL ROOTING PATTERNS WITHIN VEGETATION COMMUNITIES

#### 3.2.1 *Banksia* Low Woodland

Typical soil profiles and root structuring within the *Banksia* Low Woodland taken at three different sites on the dune are shown in Figure 3.

The thickness of sands for the trenches presented in Figure 3 was 3 m and deeper, with the depth decreasing with the slope of the dune (i.e. lower slope had lower sand profile). The sites investigated were located mostly on the lower (Figure 3a), upper (Figure 3b) and mid (Figure 3c) dune slopes and the thickness of sand is likely to be much higher on crests of dunes.

Soil colour varied from grey topsoils to underlying white – grey sands in the A horizon, then yellow sands with increasing clay content as the depth increased. The sands closer to open depressions and swales were more bleached in the top profile than those of the upper slopes and crests.



**Figure 3 Typical Banksia Low Woodland Soil profiles showing root abundance at three sites: a) lower slope b) upper and c) mid slope of the dune.**

The surface soils were densely packed with roots, particularly within the top 10cm of the profile where proteoid roots of Banksias were most prominent together with the horizontal sinker and finer lateral roots of larger shrubs such as *Eremaea pauciflora* and *Hibbertia hypericoides*. Lateral roots of *Eucalyptus todtiana* extended throughout the 20 – 30 cm soil horizon. The root architecture of Banksia Low Woodland species shows that most shrub and tree species exhibit Type 4 roots (Dodd et al 1984) with extensive lateral root systems and tap and sinker roots that penetrate deep through the sandy profile. Some examples of root architecture of plants found in the Banksia woodland community are shown in Figure 4. Note the deformation of the tap roots at the start of the clayey sand Guildford sands, where tap roots then extend laterally to seek more permeable layers.

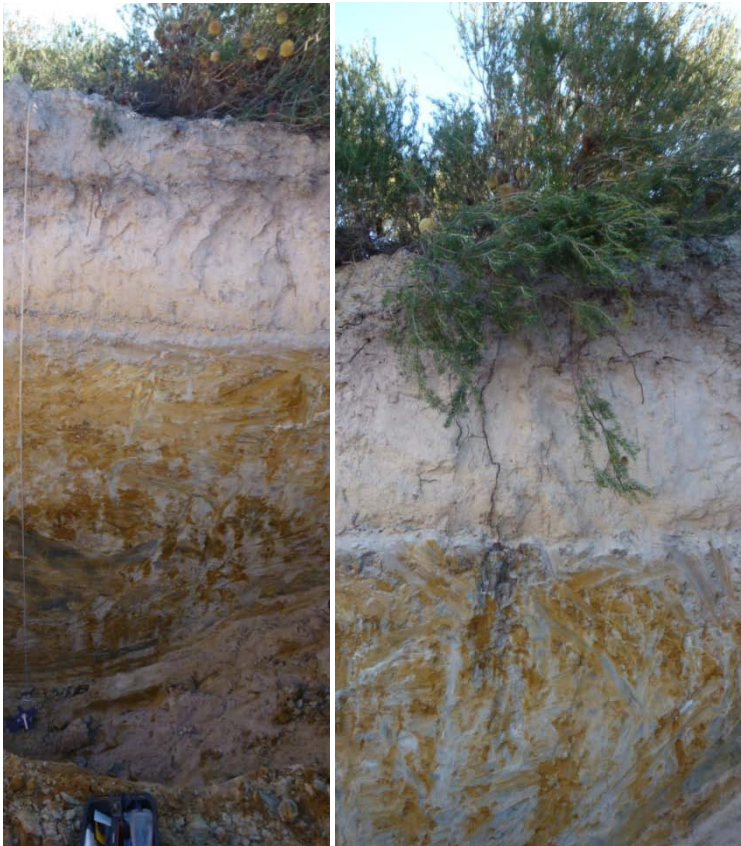


**Figure 4** Examples of root architecture and root distribution in *Banksia* Low Woodland.

*Eucalyptus todtiana* had the largest and longest (12 m and longer) observable lateral and sinker roots. *Banksia* spp. roots were present throughout the profile and were finer in structure than those of *Eucalyptus todtiana*. The longest observable lateral root for a shrub species was recorded for *Eremaea pauciflora* which had laterals extending for more than 3 m from the tap root.

### 3.2.2 *Banksia telmatiaea* Heath

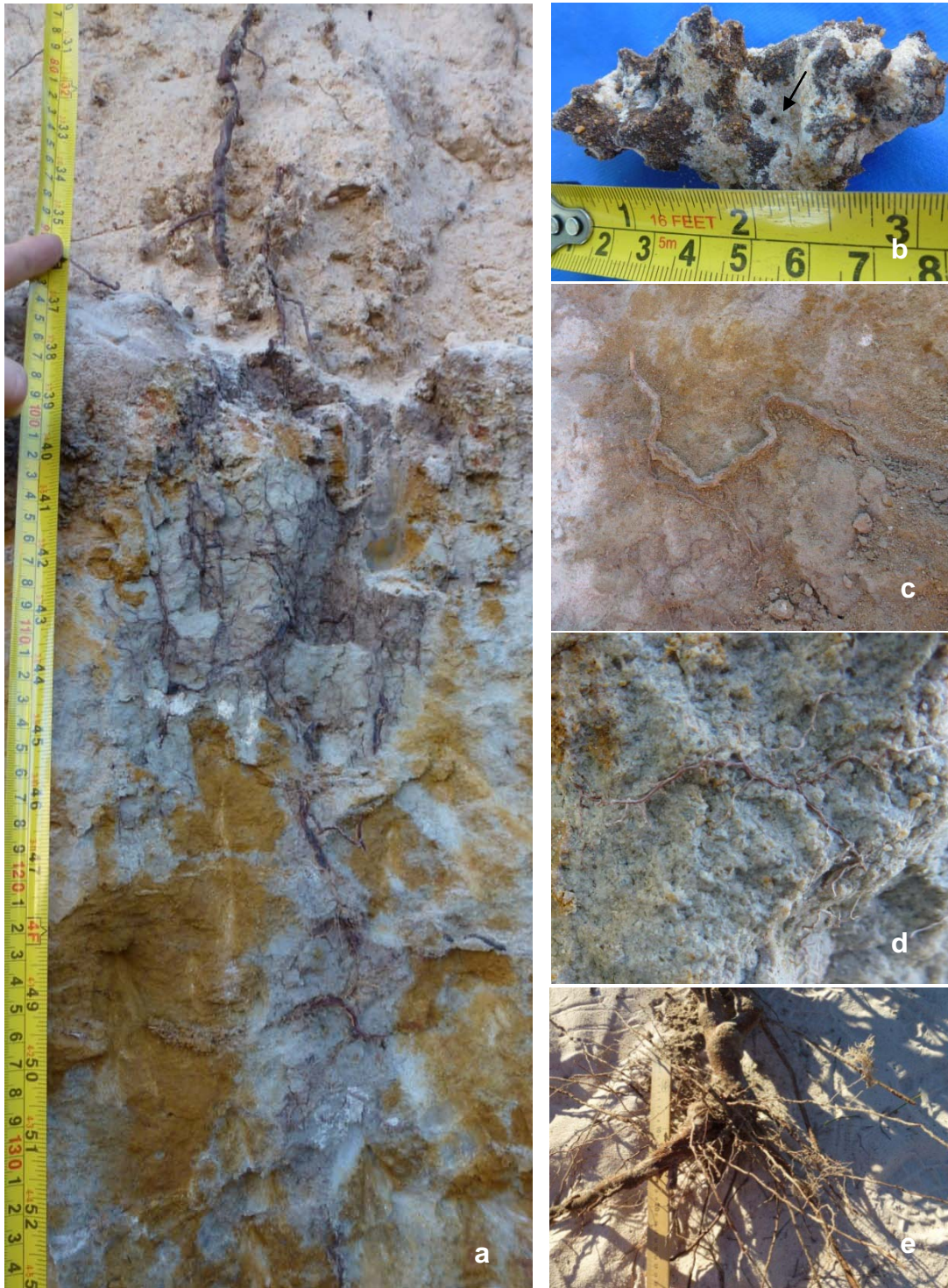
The soil profiles for the typical *Banksia telmatiaea* Heath are presented in Figure 5 followed by the root architecture through those profiles in Figure 6.



**Figure 5 The soil profile (4 m deep trench) of a typical *Banksia telmatiaea* Heath.**

The vegetation of the *Banksia telmatiaea* heath exhibited similarities in root architecture to the Banksia Low Woodland and this was correlated with the depth of Bassendean sands to the Guilford Formation. The depth of sands was up to 90cm beneath which a 10 cm thick layer of ferruginised pebbles occurred overlaying the sandy clays of the Guilford Formation.

Typically, almost all of the major root system for this vegetation type was confined to the top 25 cm of soil with only minor lateral roots extending to 30cm. Tap and some sinker roots were extending to the Guilford Layer through the ferruginous pebble layer where only fine roots could be seen through the sandy clay ferruginised mottled profile.



**Figure 6** *Banksia telmatiaea* root system and soil characteristics a) transition to Guilford formation; b) ferricrete pebble with biopore, c) roots at the interface with Guilford formation (clay layer) d) roots at 4m; and e, f) *B. telmatiaea* roots showing tap root extending laterally at Guildford clay layer.

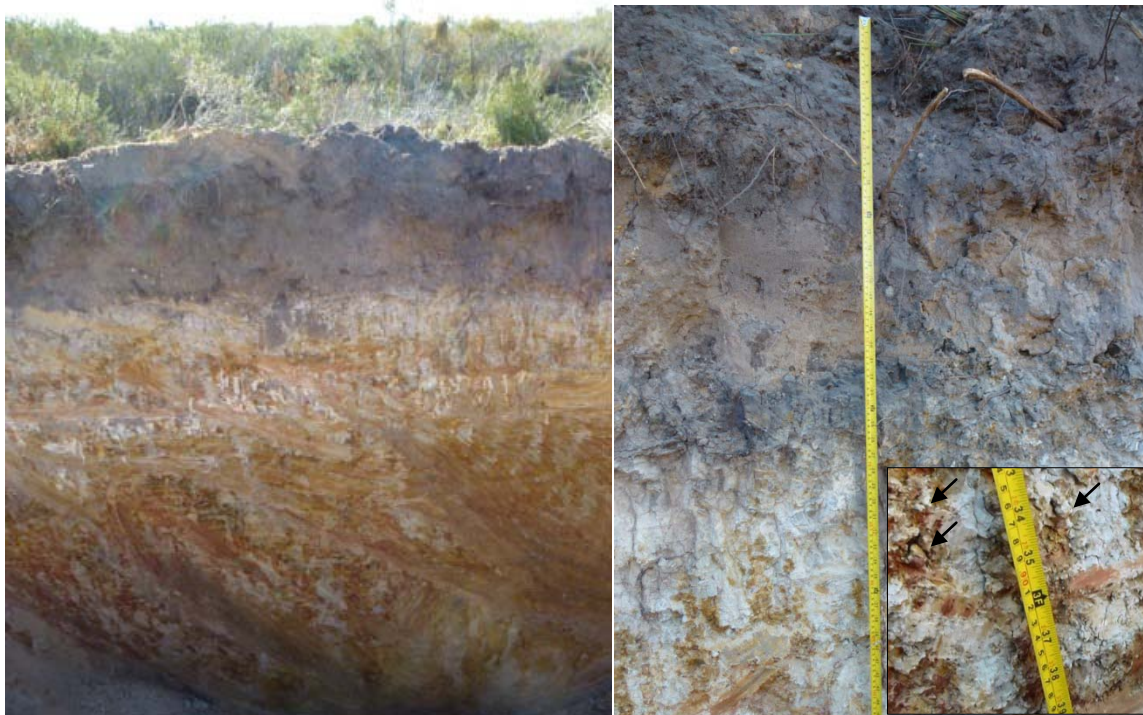
The roots penetrated the sandy layer without being impacted and appeared mostly vertical, until the interface with the ferruginised pebble layer. The penetration through this layer was two fold between the pebble spaces and through biopores (Figure 6b) causing kinks in the root system. Once in contact

with the sandy clays roots often extended laterally (Figure 6c) until the root could extend through gaps in the clay or through mottled sandy pockets in the clay, deeper into the profile.

From the entry into the Guilford layer the root diameter was small and remained mostly consistent 1mm or less beyond 1.5m.

### 3.2.3 *Regelia ciliata* Heath

The root architecture and soil profile of this community was very similar to *Banksia telmatiaea* heath however the thickness of sand was less and the upper Guilford Formation layer appeared to be more friable and calcareous. The sand appeared to be darker than in the *B. telmatiaea* Heath possibly due to higher organic content, and presence of clays and ferruginised laterite. The soil profile of the trench dug to 4.8m and the detail of the transition between the sandy and clay layers is shown in Figure 7 below.



**Figure 7 Typical soil profile found in the *Regelia ciliata* Heath (left) and detail of transition between the sand and upper Guilford Formation and laterite pebbles (right).**

The sands extended to 50cm depth beneath which was a grey clay layer band approximately 10 cm thick prior to the interface with the Guilford Formation layer which extended beyond the excavation (4.8m). The upper section of the Guilford clay layer contained large (up to 2cm diameter) lateritic pebbles and was relatively friable.

As with the *B. telmatiaea* community the lateral roots of most shrubs were well developed and the tap roots were penetrating into the upper clay layer. The first 10 cm of the soil were densely packed with fine roots of sedges and large lateral roots of shrubs. Many shrubs showed a kink in the tap root at the

clay interface, however many were able to penetrate much further through this layer than in the *Banksia telmatiaea* heath, perhaps due to higher extent of fracturing in these clays. Hence, many roots found throughout the clay profile were larger in size than those noted for the *B. telmatiaea* community as shown in Figure 8.

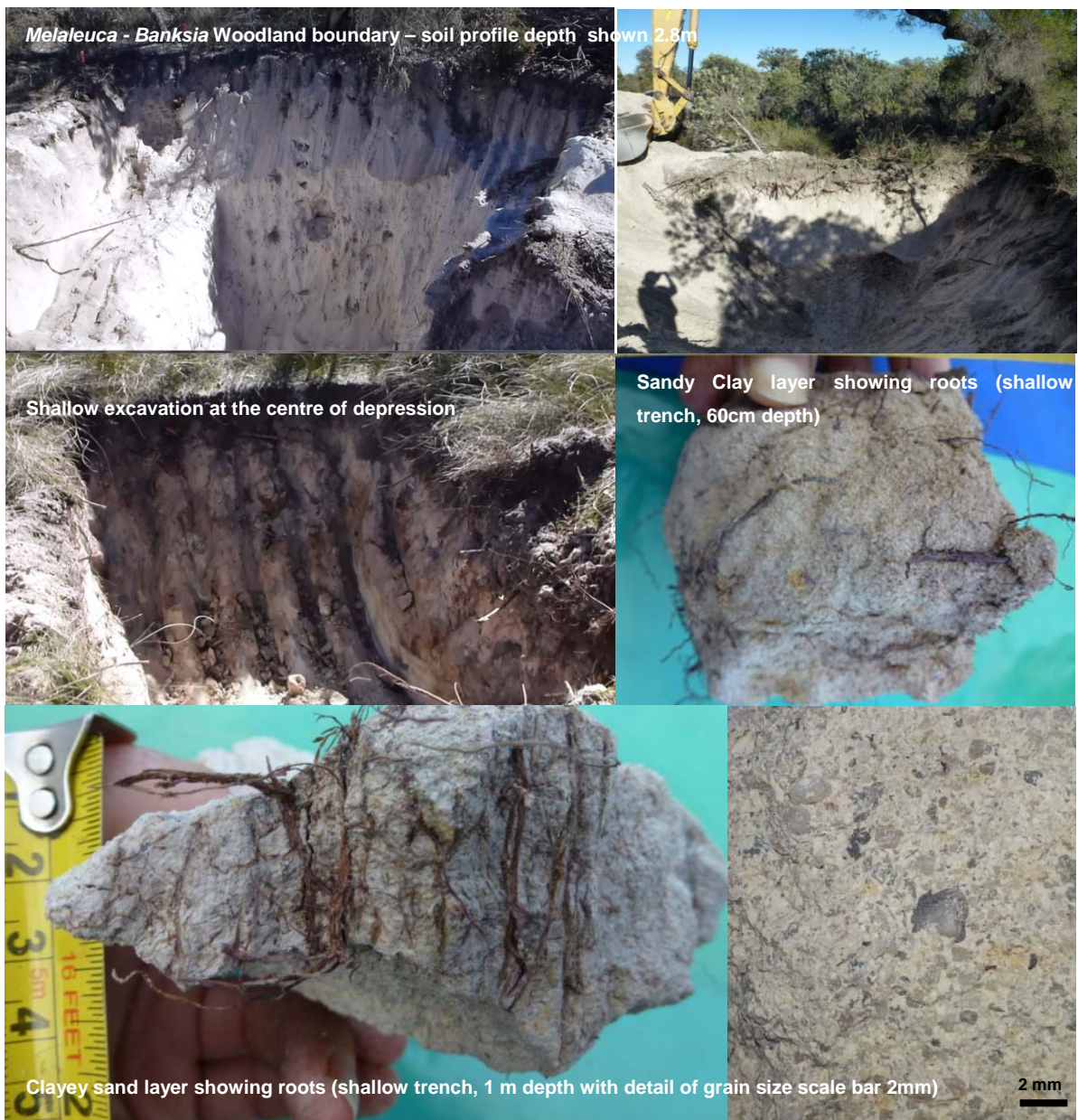


Figure 8 a) Roots penetrating the Guildford clays in the *Regelia ciliata* Heath (roots shown are *Melaleuca* spp.); b) *Melaleuca raphiophylla* (dwarf) and c) root detail; d) *Hypocalymma angustifolium*.

### 3.2.4 *Melaleuca preissiana* Open Woodland

The root architecture of this community was of particular interest for the studies as it incorporated some of the largest GDE and wetland species within the Proposal area (*Melaleuca preissiana*, *Melaleuca raphiophylla*, *Eucalyptus rudis* and *Banksia* spp.). The investigations covered a deep trench on a small sandy rise within a wetland depression, a shallow trench at the edge of the depression (3.3 m) and a very shallow (1.3 m) trench at the low point in the depression covered with a dense sward of *Schoenus subfascicularis* sedgeland and isolated *Eucalyptus rudis* trees.

The soil profiles of the deep and shallow trenches are shown in Figure 9. Whilst the profiles of the deep and shallow trenches were similar to those of the *Banksia* community, the sands were heavily bleached in the lower profile and the topsoils were darker as they contained more organic matter.



**Figure 9 Soil profile of the deep (top) and shallow (centre and bottom) trenches of the *Melaleuca preissiana* Open Woodland.**

The deep excavation trench showed the presence of Bassendean sands to 3.3 m after which the hard clay layer of the Guldford formation was encountered. As with the *Banksia* woodlands, the deep sandy profile showed even, unhindered distribution of roots through to the clay layer. The large lateral roots were observable for both *Banksia attenuata* and *Melaleuca preissiana* at 20 – 30 cm from the surface in the grey sands, as was the case with the shallow trench located in the wetland depression.

In the shallow trench, sands were observed in the top 0.6 m and a sandy clay band was present between 0.6 and 0.9 mbgl. From 0.9 to 1.32 mbgl (extent of excavation) coarse, well cemented, white clayey sands were encountered and these sediments were dry and friable.

The roots were found throughout the profile with many fine roots penetrating the clay layer into the coarse sandy clay layer. It was noted that the water retention in the coarse sandy clay layer is likely to be low and water drained freely when poured onto the broken off 'rock', unlike the clay layer (or fine, sandy clay). Examples of root morphology found for the deep and the shallow trench are given in Figure 10.



**Figure 10 Root architecture of species within *Melaleuca preissiana* - *Banksia* Open Woodland (2 m from surface).**

## 4.0 SUMMARY

The root excavation and examination of root architecture indicate that there in general, roots are predominantly characterised by a short vertical tap root that penetrates through the Bassendean Sands to the Guildford clays, and by extensive lateral roots within the Bassendean Sands. In general, the majority of roots are confined to the upper 2 – 3 m, with finer roots preferentially radiating along well-structured surfaces, old root channels and within the sand lenses of heterogeneous subsoil materials. As noted by SWC (2013), this preferential exploitation results in low root density below 2 m ( $< 2 \text{ cm/cm}^3$ ).

The SWC report shows detailed root density data vertically throughout root excavation trenches, which quantifies this pattern.

Significantly, no evidence of significant root penetration through the full Guildford Formation was apparent in any excavation trenches (refer also to SWC, 2013). That is, while penetration of some roots into the Yoganup and deep aquifer cannot be discounted, this would only account for a very small fraction of a plant's root system and is unlikely to be vital to the water supply of these plants. Hence, the root study supplements the view that the ecosystems within the Cooljarloo West study proposal area are supported by perched water, largely at the interface of the Bassendean and Guildford Units. The importance of surface and near-surface water runoff to wetlands (via drainage lines and run-off) as discussed in Sections 8.3 and 11.2 of this report and in SWC (2013), suggests this to be the key factor in terms of supporting these systems and hence the major risk management challenge.

13 pages in pdf