Barwon Downs Vegetation Survey 2016

Barwon Water

Barwon Downs Vegetation Survey

| FINAL REPORT

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Background

Barwon Water uses the Barwon Downs Borefield to augment Geelong's potable supplies during dry times. The groundwater extraction licence for Barwon Downs is due for renewal in 2019 and to help prepare for this, Jacobs has undertaken a range studies under the Technical Works Monitoring Program. The focus of this study is to assess the vegetation condition across the catchment to ensure there is adequate baseline information prior to Barwon Downs borefield being turned on in 2016.

The vegetation condition across the catchment has been monitored regularly since the mid 1990s. A review completed in 2009 recommended that a more comprehensive monitoring program be established as the results of the 2009 vegetation study were inconclusive (SKM, 2009). A revised monitoring network was established in 2014/15 and comprises 14 sites located in potential groundwater dependent ecosystems throughout the Otway Forest. Reference and impact sites were selected in areas where the Lower Tertiary Aquifer (LTA) is unconfined and confined, to attempt to compare and contrast the likely causes of potential changes in vegetation condition.

Objective of this study

The objective of this vegetation survey is to monitor the vegetation condition at each of the (recently revised) 14 monitoring sites to ensure there is adequate baseline information prior to Barwon Downs borefield being pumped, which was considered likely in early 2016. The survey was timed to provide information on the vegetation's response and resilience to the recent below average rainfall conditions, without the influence of groundwater extraction from the Barwon Downs borefield. The borefield was last used in 2010 and was most recently pumped in late April 2016.

This study assesses the change in vegetation at the vegetation monitoring sites only and does not report on the condition and health of vegetation in other areas of the catchment.

Approach

The location of the 14 vegetation monitoring sites is shown in Figure 1-1. This shows the impact and reference sites and whether the LTA is confined or unconfined.

Each vegetation transect is 40 m long, with the exception of T1 which is 70 m long. The transects are assessed using eight 5 x 5 m quadrats and the cover of each species within the quadrat is estimated to the nearest 5%.

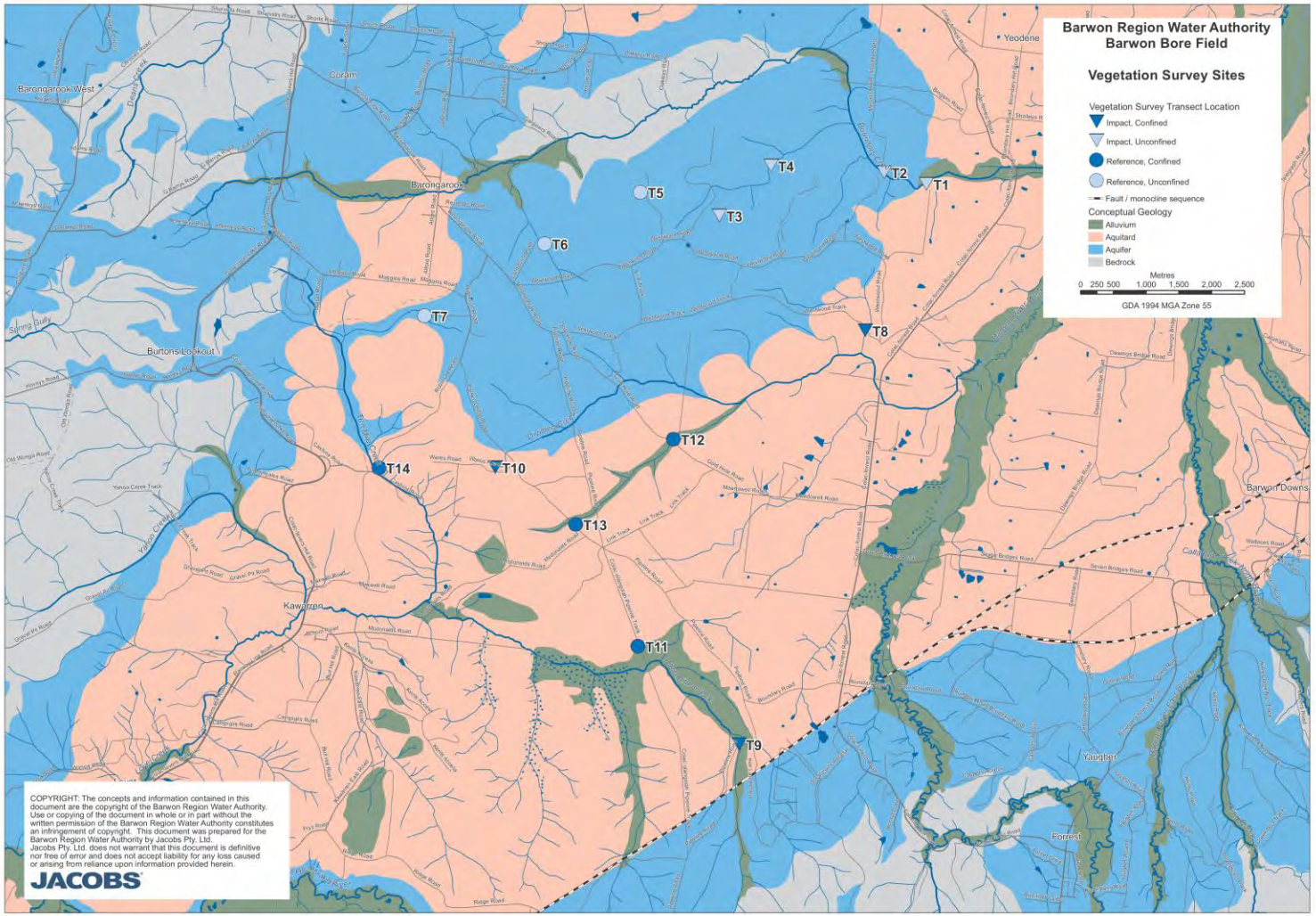
Vegetation types are categorised into functional groups with similar water requirements, for example:

- Functional group 0 – vegetation is most unlikely to use groundwater.
- Functional groups 1 and 2 – vegetation may use groundwater opportunistically, in particular species with shallow root systems.
- Function groups 3 to 6 – vegetation is highly likely to use groundwater and may be dependent on groundwater.

The functional groups along each transect have been described as well as any changes noted since the last vegetation survey in 2015. Statistical analysis was undertaken using the data analysis pack of Microsoft Excel. One way and Two-way ANOVA tests were undertaken with variables being local hydrogeology (confined versus unconfined aquifer) and impact (reference/control versus impact sites).

The vegetation condition was also considered in the context of the local hydrogeology and depth to watertable to determine the likelihood of vegetation being groundwater dependent.

Figure 1-1 Location of vegetation monitoring sites



Refer to Jacobs document: J:\IE\Projects\03_Southern\IS129200\Spatial\Working\ArcGIS\Vegetation_monitoring_A3.mxd

Key Findings

South west Victoria has experienced below average rainfall conditions over the last 12 to 18 months and the vegetation condition across the catchment showed signs of decline. Given the borefield has not operated since 2010 the results of the study highlight ecosystems response to natural climate variability.

Vegetation changes

Decline in vegetation condition was consistent across the monitored sites. There were no noticeable differences between impact/reference sites and confined/unconfined sites. This result is not surprising, given the borefield has not be used since 2010. The changes were also not statistically significant across the catchment. Overall vegetation species abundance has not changed markedly since the last vegetation survey. However, two sites (T5 and T13) had been burnt by controlled burns since the last survey. Vegetation is regenerating at both sites with almost all species previously detected re-recorded.

At Site T3 there was a loss of surface water and a decline in vegetation condition. The surface water in the wetland is dependent on rainfall and a local perched aquifer in the alluvium that is not connected to the regional groundwater system.

Localised responses are apparent at sites T7, T8 and T9 where there has been a noticeable decline in fern species. These sites are in a range of hydrogeological settings and we conclude that groundwater conditions attributable to the borefield do not explain the observed changes.

Link between vegetation changes and groundwater changes

The majority of monitoring bores show declining groundwater trends, with seasonal fluctuations, in response to below average rainfall conditions. This is natural response to less rainfall, especially as the borefield has not operated since 2010.

Two sites have localised perched aquifers (T3 and T4) where groundwater levels are at or close to the surface. These perched systems are not connected to the regional groundwater system, which is the Lower Tertiary Aquifer, at both locations.

At all sites, groundwater is relatively close to the surface and accessible by some vegetation. Although groundwater levels have declined across the catchment, in most cases the watertable remains accessible to at least the deep-rooted vegetation. Consequently, there was little change in the condition of larger woody species that will have access to water at deeper levels compared with other vegetation types. In contrast, there were significant changes in shallow rooted species (such as ferns) at sites T7 and T8, which is attributed to decline in available soil moisture and declines in the watertable.

Although the link between groundwater and vegetation present is highly variable and localised, all sites are considered to be groundwater dependent to some extent and vegetation condition is likely to continue to decline if rainfall remains below average as groundwater levels will decline (naturally) in low rainfall periods.

Recommendations

The optimal frequency of future monitoring has been considered using a risk-based approach. To reduce the risk and provide confidence in the results and improved understanding of key drivers of potential changes in vegetation condition, we recommend the following:

- Vegetation surveys to be conducted every 1 – 2 years, whilst the borefield is operating.
- Vegetation monitoring should be conducted in mid to late autumn as this is the period when stress in groundwater dependent ecosystems is most likely to be evident (as it is typically the period of lowest seasonal groundwater level).

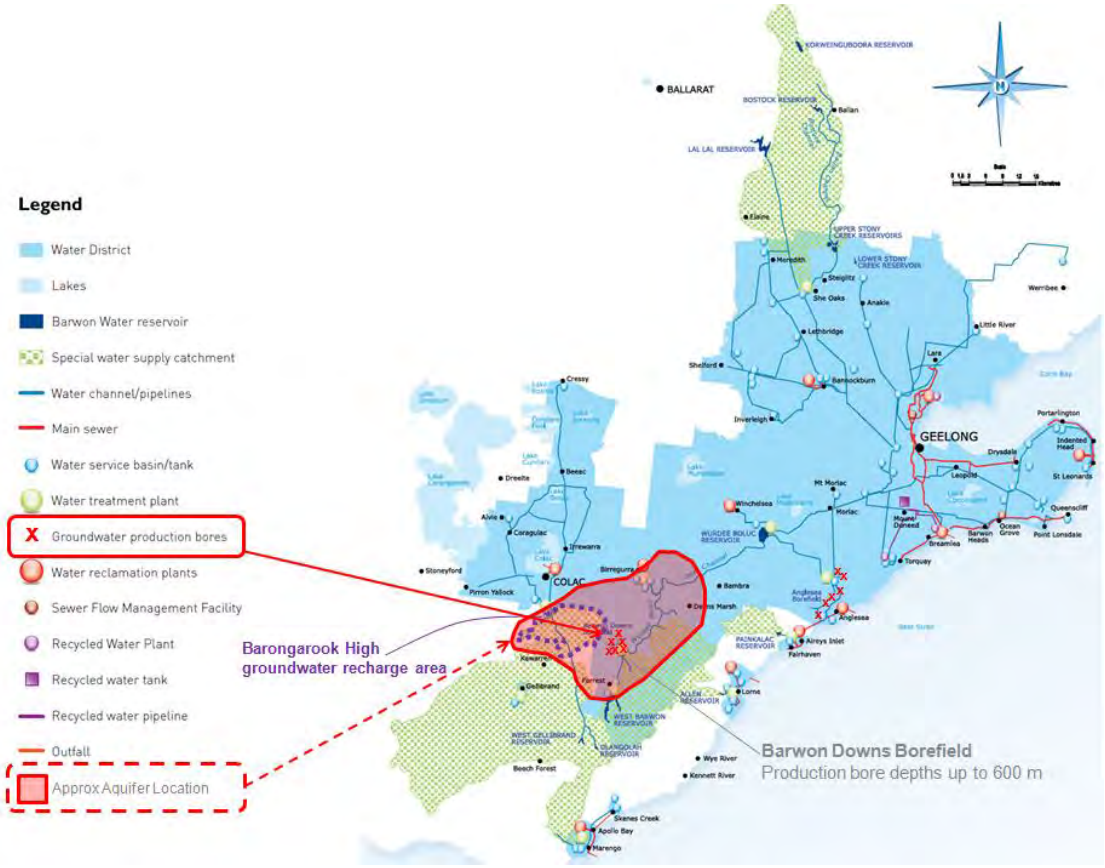
- No targeted fauna monitoring is recommended at this time. Burrowing-cray holes were still evident at site T2. This recommendation should be revisited following future monitoring events should the situation change.
- Relocate transect at site T11 to better connect with the groundwater dependent ecosystems in the area.

1. Introduction

1.1 Barwon Downs region

The Barwon Downs bore field is located approximately 70 km south west of Geelong and 30 km south east of Colac (refer to Figure 1-1). The surrounding land is a mixture of agriculture and state forest. A substantial proportion of the catchment area has been farmed for over a century which has resulted in some parts of the landscape being highly modified compared to the surrounding natural environment.

Figure 1-1 Map of the Barwon Downs region including the aquifer extent and the groundwater recharge area



The regional groundwater system extends beneath two surface water catchments, the Barwon River catchment and the Otways Coast catchment.

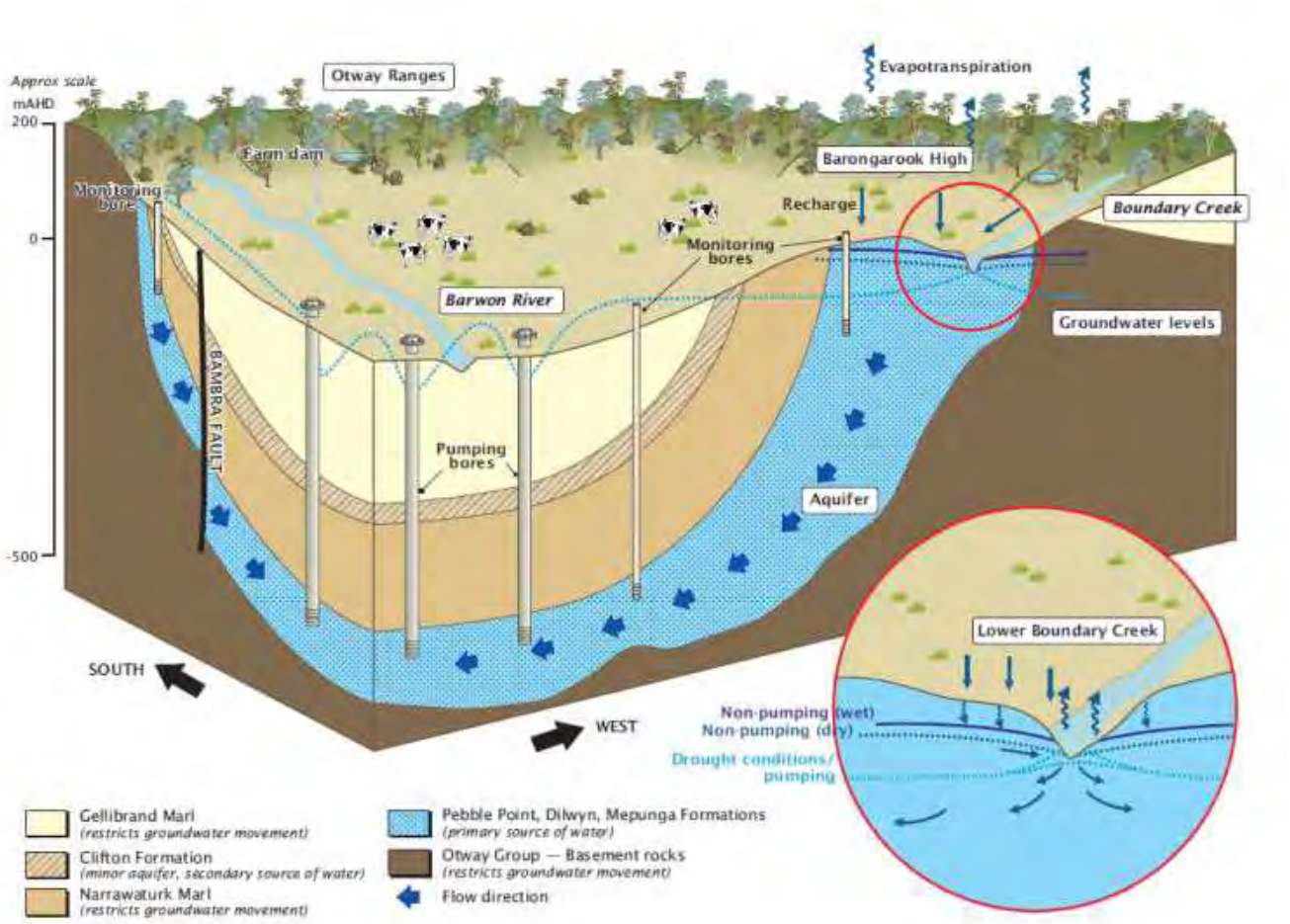
The Barwon River and its tributaries rise in the Otway Ranges and flow north through Forrest and Birregurra. The Barwon River West Branch and East Branch drain the southern half of the catchment and come together just upstream of the confluence with Boundary Creek. Boundary Creek flows east across the Barongarook High and joins the Barwon River around Yeodene.

The Otways Coast catchment is a large catchment with many rivers that flow towards the coast. The Gellibrand River is in the Otways Coast catchment and rises near Upper Gellibrand and flows in a westerly direction towards Gellibrand. The Gellibrand River discharges to the ocean at Princetown.

The borefield taps into an underground source of water, known as the Lower Tertiary Aquifer, with depths of to 600 metres at the borefield. The aquifer covers an area of approximately 500 km^2 below the surface and is connected to the surface in both the Barwon River catchment (Barongarook High) and the Otways Coast

catchment near Gellibrand. Barongarook High is the main recharge area of the aquifer because of its unconfined nature.

Figure 1-2 Schematic of the Lower Tertiary Aquifer and where it outcrops at the surface



1.2 History of the Barwon Downs borefield

1.2.1 Borefield history

In response to the 1967-68 drought, when water supplies reached critical levels, the Geelong Waterworks and Sewerage Trust (now Barwon Water) began investigating groundwater resources as a means of supplementing surface water supplies used for the Geelong region. Investigations conducted in the Barwon Downs region revealed a significant groundwater resource to meet this need.

In 1969 a trial production bore was built and tested close to the Wurdee Boluc inlet channel at Barwon Downs. With knowledge gained from these results another bore was built at nearby Gerangamete in 1977. A long term pump testing programme from 1987-1990 confirmed that the borefield should be centred on Gerangamete.

There are now six production bores in the borefield each between 500 and 600 metres deep. Pumps in each bore are capable of providing daily flows of up to 12 megalitres (ML) per day per bore. The pumped water is treated by an iron removal plant prior to transfer to Wurdee Buloc Reservoir. Total borefield production capacity is 55 ML per day.

1.2.2 Groundwater extraction

Barwon Water operates the borefield in times of extended dry periods. This has occurred only five times in the last 30 years. The borefield is a critical back up source for Barwon Water because it is buffered from climate variability due to the depth of the aquifer, whereas surface water catchments are susceptible to seasonal fill patterns mostly driven by rainfall.

Although extraction occurs infrequently, large amounts of groundwater are drawn when needed to supplement surface water storages during drought. This is completed in compliance with the groundwater licence (refer to Section 1.3). This operational philosophy of intermittent pumping has been an effective way to provide customers with security of supply, especially in times of prolonged dry conditions.

To date, Barwon Water has extracted the following volumes from the aquifer:

- 3,652 ML from February to April in 1983 due to drought,
- 19,074 ML during a long term pump test in the late 1980s,
- 36,817 ML during the 1997 - 2001 drought,
- 52,684 ML during the 2006 – 2010 millennium drought, and
- 2,383 ML in 2016 to boost storages after a record dry summer.

Groundwater extraction has supplemented surface water supply by a total of 114,610 ML, equating to approximately 10 per cent of total water consumed over a 30 year period.

1.2.3 Licence history

The first licence was issued in 1975 but did not come into effect until 1982, as the bores were not brought into operation until the 1982-83 drought. This was the first time the borefield was used to supply water to Geelong. The licence issued by the State Rivers and Water Supply Commission (now Southern Rural Water) was to allow Barwon Water to operate four production bores based on the following conditions:

- Extraction for the purpose of urban water supply;
- Maximum daily extraction rate of 42.5 ML;
- Maximum annual extraction rate of 12,600 ML;
- Maximum ten-year extraction rate of 80,000 ML; and
- Periods of licence renewal of 15 years (1975 – 1990).

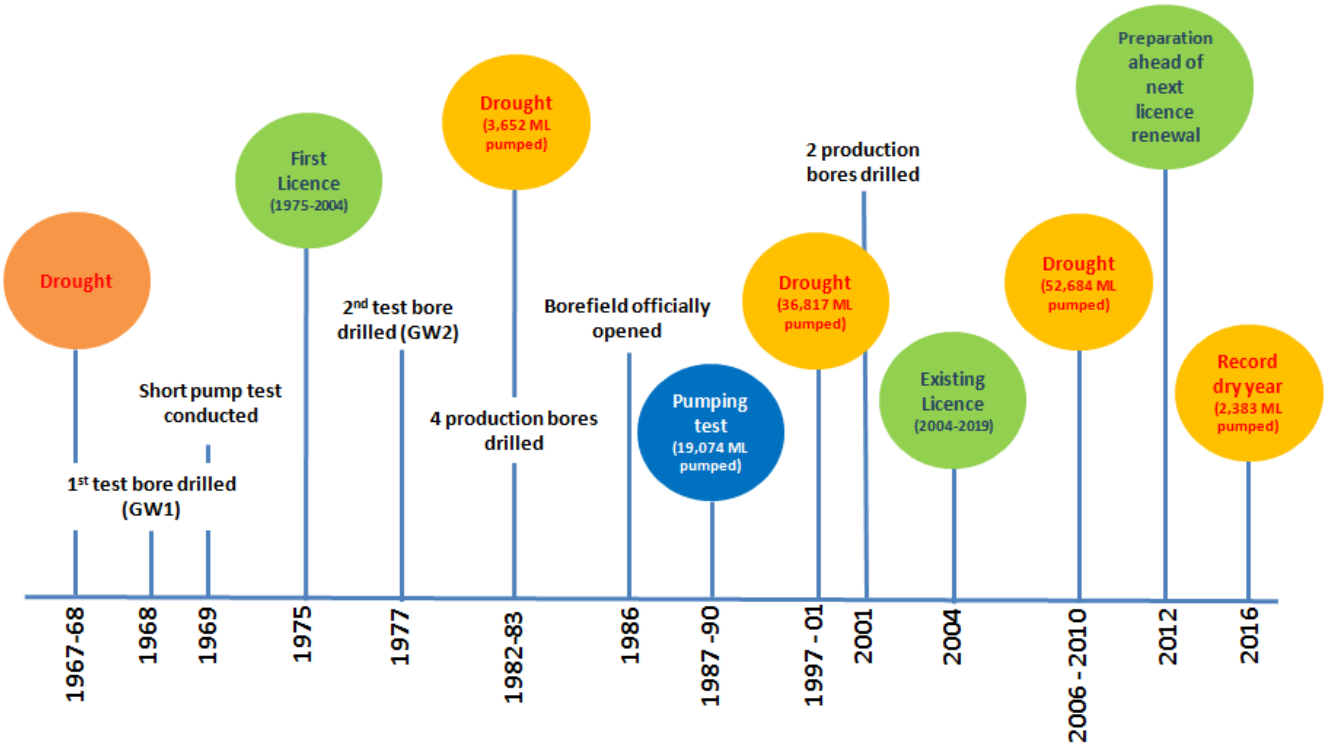
The licence was subsequently renewed for two periods of five years up to 2000. From 2000, the licence was temporarily extended three times for a total of four years to allow the licence renewal to take place through to 31 August 2004.

In 2002[1], Barwon Region Water Authority (now Barwon Water) applied to renew the Barwon Downs borefield licence for extraction of groundwater to meet urban water supply needs. The application proposed the following:

- Maximum daily extraction rate of 55 ML;
- Maximum annual extraction rate of 20,000 ML;
- Maximum ten-year extraction rate of 80,000 ML;
- Long term (100 year period) average extraction rate of 4,000 ML/year; and
- Renewal period of 15 years.

From 2004 to 2006, the licence was temporarily extended to allow for the licence renewal to take place. Licence conditions were drafted by the panel taking into consideration the findings of the technical groups and the submissions received. This licence is valid to 30 June 2019.

Figure 1-3 Timeline of events that surround the development and use of the Borefield



[1] *Note: Bulk Entitlement was considered in 2002 so that the Upper Barwon System could be managed conjunctively. This was put aside as the view at the time was that the rights to groundwater should continue to be contained in a licence and subject to regular review.*

1.3 Current groundwater licence

The Barwon Downs borefield is operated under licence from Southern Rural Water. This licence was granted in 2004 and is due for renewal by June, 2019.

This licence makes provision for extraction limits on a volumetric basis over a range of time scales. As part of the licence conditions, Barwon Water monitor groundwater levels and quality, subsidence, flow in Boundary Creek as well as the protection of riparian vegetation, protection of stock and domestic use and the protection of flows in the Barwon River tributaries.

Reporting against these licence conditions is provided in an annual report to Southern Rural Water who administers and regulates groundwater licences on behalf of the Water Minister. Barwon Water has and will continue to operate the borefield in accordance with current licence conditions.

1.4 Strategic drivers for the Barwon Downs technical works monitoring program

Ahead of the upcoming 2019 licence renewal process, Barwon Water instigated a technical works monitoring program to improve the comprehensiveness of the current monitoring program to ensure the submission of a technically sound licence application.

Driving the need for this monitoring program is the reliance on the borefield to provide water security for Barwon Water customers, to address outstanding community issues particularly where the relationship between cause and effect is not yet fully understood, and to close out any known technical knowledge gaps.

1.4.1 Water security

The Barwon Downs borefield provides water for the regional communities of Geelong, the Surf Coast, the Bellarine Peninsula and part of the Golden Plains Shire.

A prolonged period of unprecedented drought (known as the Millennium drought) saw a sustained dry climate average from 1997 to 2011. In 1997, many of the region's water storages were close to capacity, however by January 1998, after high consumption and low catchment inflows, water restrictions were necessary to balance supply and demand in the Geelong area. This clearly highlighted that even by having large storages our region was susceptible to rapid changes.

In 2001, strong catchment inflows from healthy rainfall refilled storages, ending water restrictions in Geelong. Five years later, after a very dry year, strict water restrictions were again required with climate extremes exceeding the historical record. At the height of the Millennium drought, Geelong's water storages dropped to 14 per cent when catchment inflows were severely reduced. To meet demand during this time 52,684 ML was extracted from the borefield providing up to 70 per cent of Geelong's drinking water.

In 2010, improved rainfall restored storages and restrictions were again slowly lifted in the Geelong area. This allowed the Barwon Downs borefield to be switched off and to begin recharging. Without the use of the borefield during this time, Geelong residents would have run out of water.

The township of Colac will soon be connected to the Geelong system through construction of a pipeline between Colac and Geelong. This interconnection will also allow the borefield to supply Colac residents and will provide additional water security for the water supply system which is currently susceptible to seasonal fill patterns.

1.4.2 Community issues

Although Barwon Water is compliant with the monitoring program associated with the 2004 licence, it is accepted that this program is not comprehensive enough to address community interest about specific issues centered on potential environmental impacts in the local catchment.

Areas of community interest recently have included the:

- extent of stream flow reduction and any ecological impacts at various points along Boundary Creek,
- potential to increase existing acid sulphate soil risks in the Yeodene peat swamp,
- potential to increase the existing fire risk at the Yeodene peat swamp, and
- extraction limits and the current operational regime of the borefield, and whether they are sustainable under climate change projections.

A Community Reference Group was established in 2013 to provide community feedback and input into the technical works monitoring program.

1.4.3 Informing the licence renewal

To address community interest adequately and inform the licence renewal in 2019, Barwon Water commissioned a review of the existing monitoring program associated with the 2004 licence. This technical review recommended that a revised technical works monitoring program be developed with the following objectives:

- Better understand the environmental impacts of groundwater extraction;
- Determine the cause and relative contribution of groundwater variability (for example, groundwater extraction, drought and land use changes) in contributing to environmental impacts; and
- Provide additional monitoring data and subsequent analysis required to support the licence renewal process.

1.5 Overview of the technical works monitoring program

1.5.1 Monitoring program development

The development of the technical works monitoring program is shown in Figure 1-4 and can be broken down into the following stages.

Stage 1: Review of the existing monitoring program

In 2012, Barwon Water initiated a review of the Barwon Downs monitoring program. The technical works monitoring program was developed in response to the:

- desire to address key community issues (see section 1.4.2), and
- 2008-09 flora study which recommended a long term vegetation and hydrogeological monitoring program be designed and implemented to better understand a range of factors such as groundwater extraction, drought and land use changes that were contributing to the drying of the catchment.

This review took into account both the social and technical issues that needed to be addressed to ensure a successful licence renewal in 2019 and was initiated early to allow sufficient time to establish a comprehensive monitoring program. A risk based approach was used to rank these issues, and control measures were developed to downgrade the residual risk ranking, which included activities such as additional monitoring and technical studies.

Stage 2: Technical works monitoring program scope refinement

In 2013, the scope of the technical works monitoring program was developed based on the recommendations of Stage 1. The technical works program was designed to improve the capacity to differentiate between groundwater extraction and climate effects on the groundwater system, predict water table and stream flow changes, and increase understanding of potential ecological impacts. Key improvement areas include:

- differentiating between groundwater extraction and climate effects on the regional groundwater system,
- understanding the potential risks of acid sulphate soils and whether that could change future extraction practices,
- assessing whether vegetation in areas dependent on groundwater will be at risk from water table decline, which could change future extraction practices,
- assessing flow requirements in Boundary Creek to determine if the current compensatory flow is effective,
- characterising groundwater dynamics in the aquitard to improve hydrogeological understanding of groundwater flow and quantity, and
- better understanding of groundwater and surface water interaction, particularly along Boundary Creek where groundwater contributes to base flow.

In the same year, the Barwon Downs Groundwater Community Reference Group was also formed by Barwon Water to ensure where possible, the monitoring program was adjusted and the scope refined, to take into consideration community issues and views. This was a critical contribution towards the broader licence renewal strategy as it raised confidence that the right monitoring data would be captured to specifically target key areas of community concern.

Stage 3: Construction of additional monitoring assets

During 2014-15, the following construction works were completed:

- 33 new groundwater monitoring bores drilled, including the replacement of one existing bore,
- refurbishment of three existing bores,
- Four new potential acid sulphate soils monitoring bores,
- 32 data loggers and two barometric loggers installed in new and existing bores,
- two new stream flow gauges installed, and
- two existing stream flow gauges replaced.

Stage 4: Ongoing monitoring

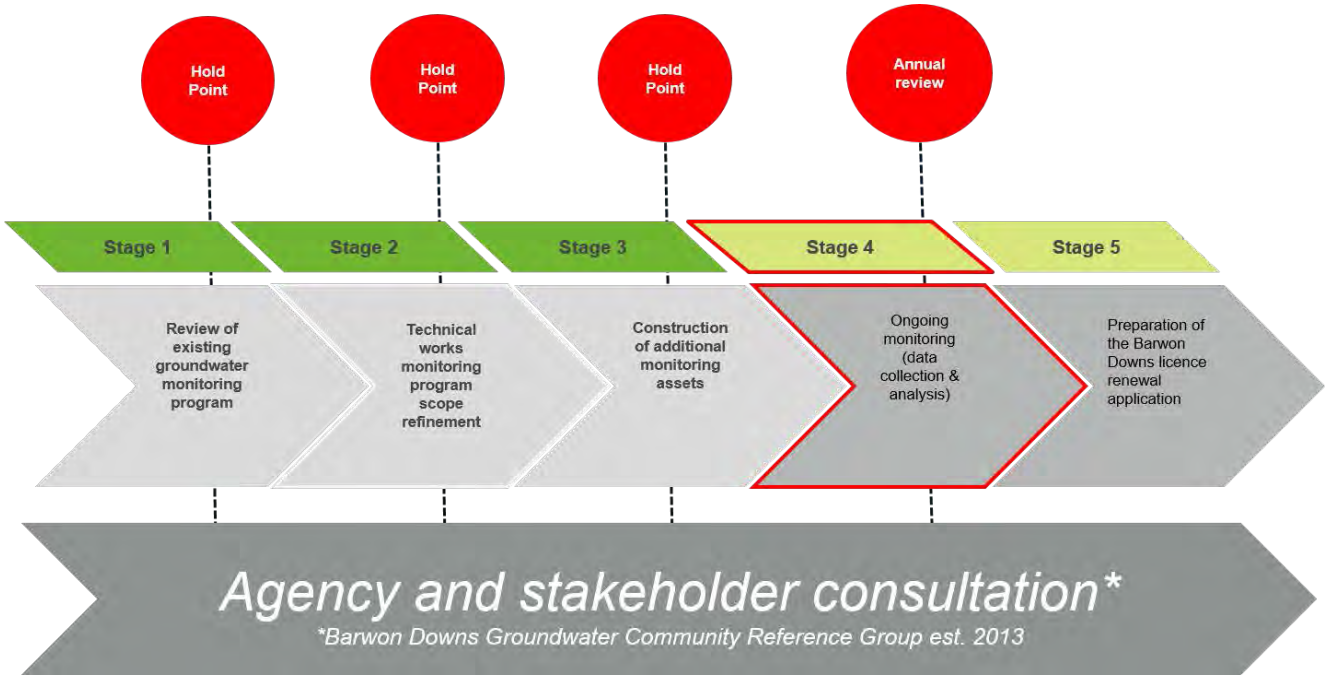
The technical works monitoring program is now in a phase of data collection and preliminary analysis. The intention of this stage is to update the conceptual understanding of the hydrogeology in the Barwon Downs region. This will be based on data collected from additional and existing monitoring assets and the outcomes of a range of investigative technical studies, all of which will be used to update and calibrate the groundwater model.

Preparation will also begin at this stage to form a comprehensive licence application.

Stage 5: Preparation for licence renewal submission

During 2018, Barwon Water will need to formally submit a licence renewal application to be to Southern Rural Water. This will initiate a groundwater resource assessment process as set out under the Water Act.

Figure 1-4 Development of the technical works monitoring program



1.5.2 The inter-relationships of the technical works monitoring program

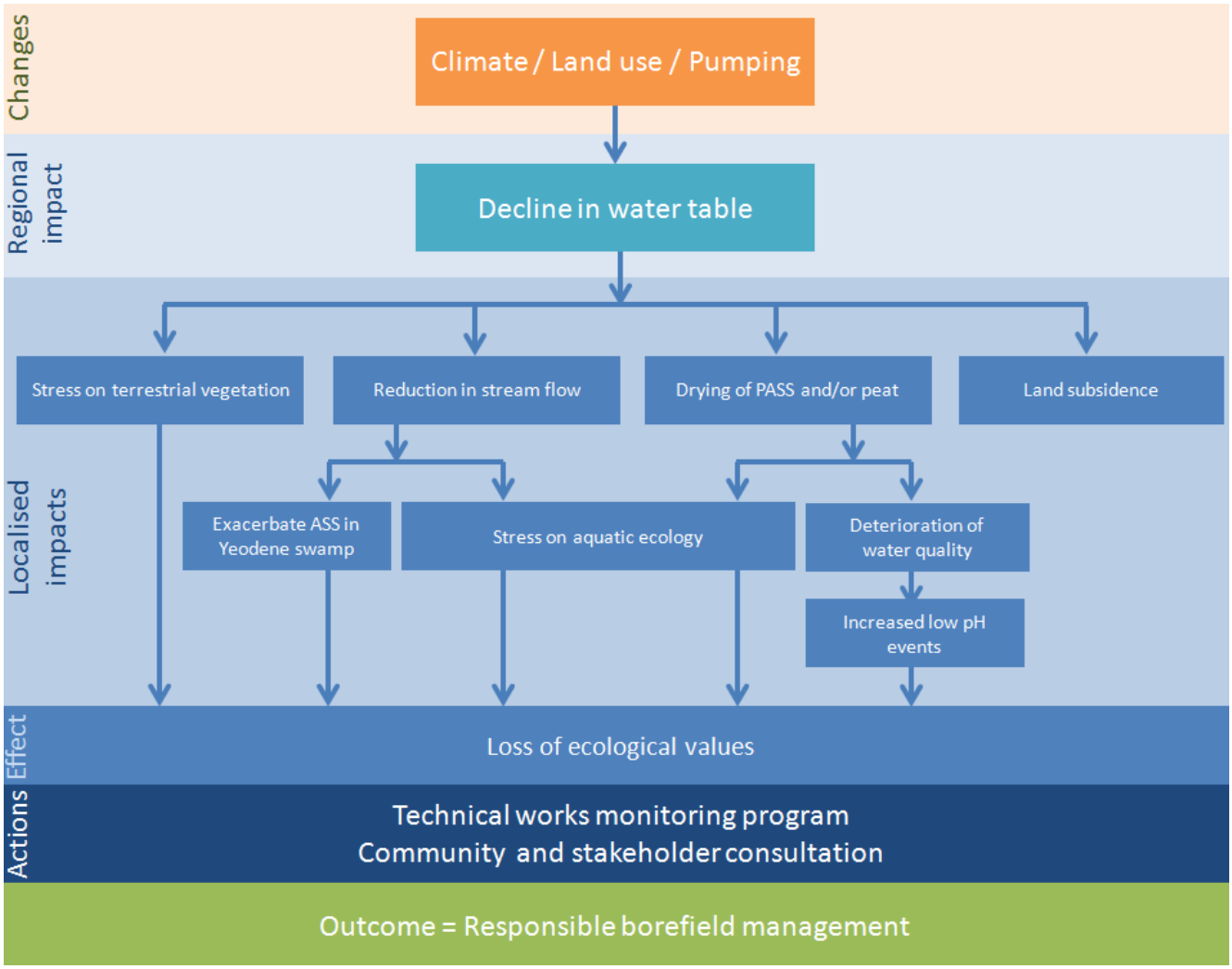
The technical works monitoring program is a complex, multi-disciplinary project due to the overlapping nature of the various components of the program as shown in Figure 1-5.

Changes in climate, land use practices and groundwater pumping will alter water availability throughout the catchment, including stream flow and groundwater levels. Many receptors are sensitive to changes in groundwater levels and stream flows, particularly those that are dependent on groundwater. Ultimately this can lead to the loss of ecological values (refer to Figure 1-5).

For example, a decline in groundwater level beneath a stream can cause a reduction in stream flow, which in turn can impact the habitat of aquatic ecology in the stream. Declining groundwater levels or reduced stream flow also has the potential to activate potential acid sulphate soils and cause water quality impacts.

The technical works monitoring program is designed to address knowledge gaps to better understand potential impacts from the borefield. The program is underpinned by scientific rigor using multiple lines of evidence-based techniques to establish the relationship between cause and effect for potential impacts caused by groundwater extraction.

Figure 1-5 Potential impacts in the catchment from changes in the catchment



1.6 This report

1.6.1 Background

Due to record dry conditions in south west Victoria, Barwon Water reactivated the Barwon Downs borefield to supplement low surface water inflows. Groundwater extraction commenced in late April 2016. Prior to extraction commencing, an additional flora survey was completed to collect more data to ensure that there is an adequate baseline description of vegetation prior to any groundwater extraction.

1.6.2 Objective

The objective of this vegetation survey is to monitor the vegetation condition at each of the 14 monitoring sites to ensure there is adequate baseline information prior to use of the Barwon Downs borefield in 2016. The survey was timed to provide information on the vegetation's response and resilience to the recent below average rainfall conditions, without the influence of groundwater extraction from the Barwon Downs borefield. The borefield was last used in 2010 and was recently turned on in late April 2016.

This study assesses the change in vegetation at the vegetation monitoring sites only and does not report on the condition and health of vegetation in other areas of the catchment.

1.7 Previous vegetation studies

Vegetation across the Otway region was first described in the 1980s and vegetation monitoring has occurred regularly since 1994 (e.g. 1994, 2002, 2008/09 and 2014/15). A description of the past vegetation studies in the region is provided below.

Farmar-Bowers 1986

Farmar-Bowers (1986) reviewed the potential environmental issues associated with Barwon Downs borefield, including the potential impact on the native vegetation. Farmar-Bowers noted that the flora (and fauna) of the area was not well understood at the time of the study, as only broad scale information was available. He noted that the principle types of trees were Peppermints, Messmate Stringybark and Manna Gum. The latter two species are most likely to be impacted by declining groundwater levels as they are located on the break of slope, where the topography starts to rise out the valley (Farmar-Bowers 1986).

Farmar-Bowers (1986) also collated information from previous studies that included the Barwon Downs region and these are summarised below. These studies were completed in the early 1980s.

- Beauglehole (1980) divided the Corangamite-Otway area into sectors, blocks and sub-blocks and summarised the vegetation in each area. The vegetation survey of the block in the Barwon Downs study area was found to be inadequate for the purposes of defining the vegetation and further investigation was recommended.
- Pitt (1981) described the vegetation across the Otway region in different land systems, of which the most relevant land systems to the Barwon Downs study area are open forest and woodland. Pitt noted that in open forest areas, Swamp Gum (Eucalptus ovata) was widespread and found in waterlogged and sometimes acidic soils outside the study area (e.g. Paraparap). In areas classified as woodland, Narrow Leaf Peppermint (Eucalyptus radiata) were common in well drained soils and also found in open forest associations, particularly those dominated by Messmate.
- Hook (1982) reviewed the information available at the time on vegetation in the Otways and highlighted that areas around the Barongarook area were not well understood and there was little information on community types or maps of communities, even at the broadest scale.

Carr and Muir 1994

Following from the work of Farmar-Bowers, Carr and Muir (1994) were commissioned by Barwon Water to complete a vegetation survey involving 82 quadrats across three catchments in the Barwon Downs study area including Boundary Creek, Dividing Creek and Porcupine Creek. The location of the quadrats is described, although a location map was not provided in the report. The vegetation information and location of the quadrats report has however been recorded within the Victorian Biodiversity Atlas database maintained by the Department of Environment, Land, Water and Planning. This study focussed on aquatic environments (in-stream, riparian, wetland) in hydraulically sensitive areas, such as drainage lines and swamps.

Carr 2002

The vegetation was re-surveyed in 2002 at 24 of the quadrats surveyed in 1994 (Carr 2002). The quadrats that were re-surveyed comprised targeted swampy areas with Manna Gum Riparian Forest, Swamp Gum Forest, Scented Paperbark–Woolly Tea-tree Forest or Scrub, Swamp Gum Grassy Wetland, Pith Saw-sedge Sedgeland and Fine Twig-sedge Sedgeland. The survey was conducted during the early stages of the Millenium Drought (2000-2010), when rainfall was below average and the Barwon Downs borefield was also being used. Vegetation was found to have declined in health at several swamp sites as a result of declines in water availability. Carr (2002) concluded that the observed decline in vegetation health was likely the result of the combined influence of below average rainfall conditions and declining groundwater levels from groundwater extraction.

SKM and EA 2008

In 2008, SKM and EA (including Geoff Carr who undertook the vegetation surveys in 2002 and 1994) resurveyed the vegetation at eight quadrats, of which three were surveyed in 1994 and 2002 (Site 1, 2 and 6)

(SKM and EA, 2008). The eight quadrats were targeted in areas where the aquifer and aquitard outcrops. This study also considered the depth to watertable at the sites to understand how changes in groundwater levels could have influenced changes in vegetation. The study found evidence of vegetation stress across the catchment, as expected after 11 years of below average rainfall conditions experienced during the Millennium Drought.

The study concluded that drought, groundwater extraction and provision of supplementary watering had a significant effect on riparian vegetation. However, given the complex interaction of these factors, the study was unable to determine the ultimate cause of drying of the vegetation (e.g. groundwater extraction, drought, climate change and other catchment and hydrological factors). The study was inconclusive and recommended that a more comprehensive monitoring program be established. This aligned with community interest in improving the understanding of potential borefield impacts in the local catchment.

Three sites surveyed in 2008 are included in the current vegetation monitoring network – Sites 1, 3 and 5. Site 1 is located close to T2, Site 3 is located close to T7 and Site 5 is located close to T11.

At Site 1, the watertable was about 1 metre below the surface in 1986 and had declined 9-10 metres in 2008 as a result of below average rainfall and groundwater extraction from the Barwon Downs borefield (SKM and EA, 2008). While vegetation species had reduced since the 1994 survey, the site now has an additional water source from the supplementary flow in Boundary Creek which has operated since around 2002. This additional water has replenished the watertable and maintained the hydrologically sensitive vegetation (SKM and EA, 2008).

The watertable at Site 3, a new site for the 2008 survey located on Ten Mile Creek, was also within 1 metre of the surface and had declined less than a metre in 2008. Water was still present in the creek during 2008 and is expected to be supported by groundwater (SKM and EA, 2008).

Site 5 is another new site located away from the Barongarook area and is situated on the aquitard. This site is one of the control sites within the current assessment framework, and vegetation stress was also found at this site (SKM and EA, 2008).

Jacobs 2015

In 2014/15, 14 new vegetation monitoring sites were assessed at sites chosen in potential groundwater-dependent ecosystems throughout the Otway Forest. Reference and impact sites were selected in an attempt to determine the likely cause of potential changes in vegetation condition. The study was a baseline assessment of vegetation condition at the selected sites which are to form the basis of an ongoing monitoring program.

In summary, the historical studies undertaken have improved the understanding of the vegetation communities present within the Barwon Downs region. Those undertaken during the 1980s outlined only broad descriptions of the vegetation across the Corangamite and Otway region. All studies during this time noted that there was very limited information available across the northern Otways, including around the Barwon Downs study area. Given the lack of information available, is it not possible to understand the vegetation communities and their condition prior to the 1994 vegetation survey conducted by Carr and Muir which provided a base understanding of vegetation across the region and has under-pinned all subsequent assessments. Site 1 is the only site that has been monitoring since 1994 and while the watertable has declined in the area, the vegetation at this site has been maintained by the supplementary flow in Boundary Creek since 2002.

2. Methods

2.1 Site location

Fourteen sites have been selected to monitor the health of vegetation across the catchment. The sites are called T1 to T14 and are located in topographic depressions associated with drainage lines and creeks. The sites were last monitored in 2014 (Jacobs, 2015).

The sites were selected based on a binomial design to monitor changes to potential Groundwater Dependent Ecosystems (GDE) located in both confined and un-confined areas of the Lower Tertiary Aquifer and in areas that could be impacted by pumping at Barwon Downs borefield and areas that are not impacted. The location of the sites is shown in Figure 2-1.

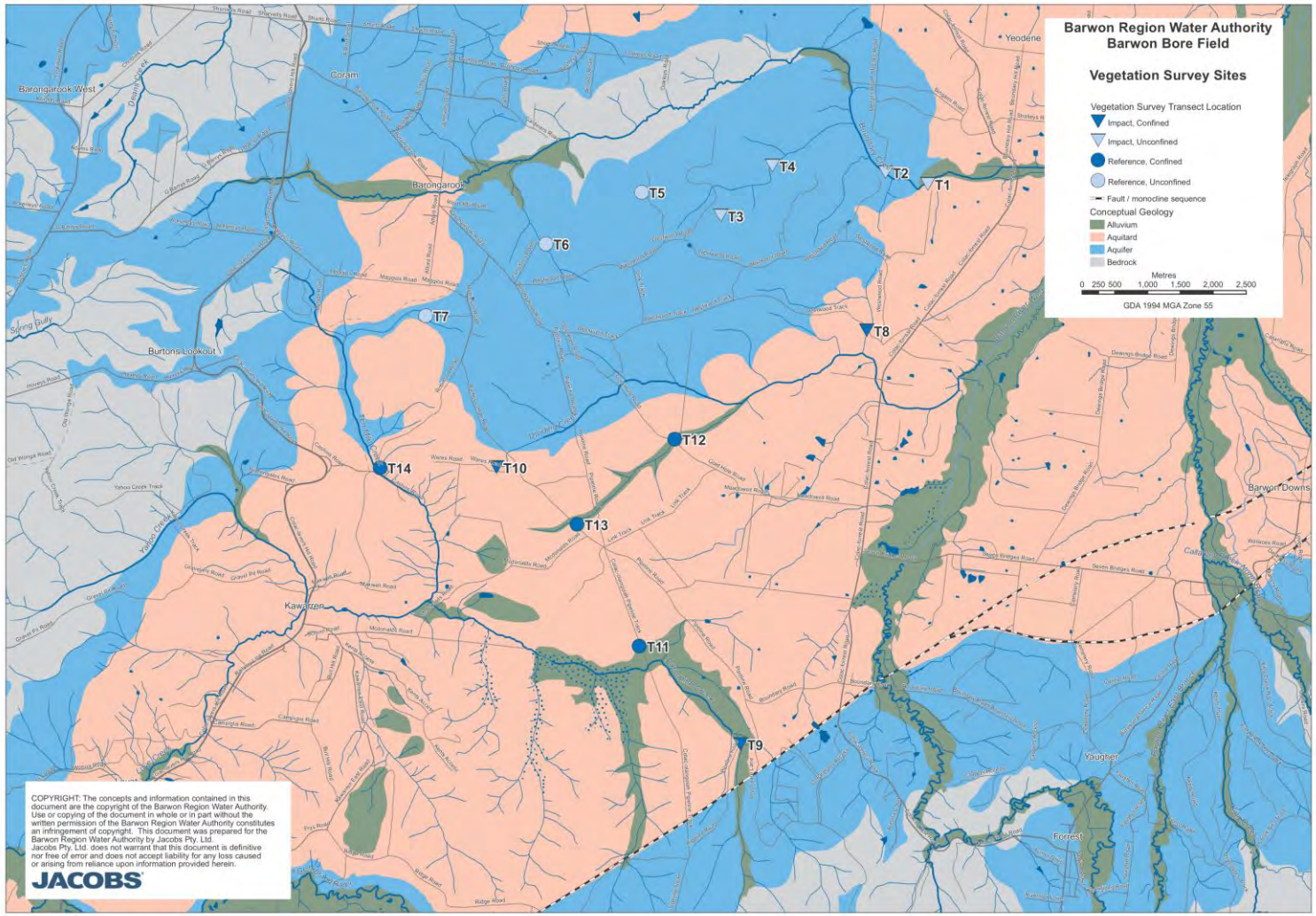
The two variables tested were the hydrogeological nature of the aquifer:

- whether the aquifer was confined or unconfined, and
- whether sites would be impacted by the removal of water at Barwon Downs.

Impact sites were located in areas of the aquifer where the watertable was either known to have been affected from past pumping or potentially affected by the Barwon Downs borefield. Reference sites were located in parts of the aquifers where no impact on water levels from the Barwon Downs borefield has been observed (or is expected to be observed under future pumping).

Groundwater monitoring bores were constructed at each site to monitor depth to watertable at each site. Soil bores were also installed during a parallel study (Jacobs 2016a) that assessed the depth at which trees at each site were drawing their water.

Figure 2-1 Location of vegetation monitoring sites



Refer to Jacobs document; J:\IE\Projects\03_Southern\IS129200\Spatial\Working\ArcGIS\Vegetation_monitoring_A3.mxd

2.2 Vegetation assessment including monitoring design rationale

2.2.1 Transect vegetation survey

Transects of 40 m were assessed at each location with the exception of site T1 (70m). Site T1, as described below was subject to a fire in the recent past. The transect began in relatively unburnt vegetation and a total of 70 m was assessed to account for a change between unburnt and burnt vegetation.

Transects were located at the edges of the potential GDEs and extended 40 m into the potential GDE. The location at the edge of the ecosystem is to maximise the potential for the monitoring to detect change over time. Any detectable change will be more noticeable in the zone where changes in groundwater level or inundation frequency are most likely to cause impact (i.e. wetlands generally dry out from the edges). Other concerns were locating transects close to groundwater monitoring bores.

Transects were marked with short yellow topped posts in areas outside the Greater Otway National Park (T1-8). Sites within the Greater Otway National Park (T9-14) were not marked as this was not permitted.

The start and end of each transect was recorded with GPS (see results for each transect location).

Sites T1-8 and T12 were assessed between 29-31 March 2016 and Sites T9 and T11-14 were assessed between on 26 and 27 April 2016. Sites T9 and T11-14 are located in Greater Otway National Park and required research permits from Park Victoria. There was a significant delay in receiving these permits, which meant that all the sites could not be surveyed at the same time.

2.2.2 Analysis of vegetation transects

Similar to the previous vegetation survey, each vegetation transect was assessed using eight 5 x 5 m quadrats located along the transect (Jacobs 2016). For site T1 which is 70 m long, 14 quadrats were assessed although only 8 quadrants from 30-70 m are reported and analysed here.

The quadrats were located alternatively on the right then left of the transect looking from start to finish. In each quadrat the cover of each species located within the quadrat was estimated to the nearest 5 per cent, including any dead material still attached to plants. Although cover estimates are known to introduce observer error, the analysis of absolute cover estimates is more statistically robust and adaptable to data analysis such as functional groups where sums of cover are used, and therefore preferred for this monitoring regime, compared to categorical measures (such as Braun-Blanquet measures),. Where a species represented less than 2.5 per cent of the total cover (i.e. did not round to 5 per cent) a nominal 1 per cent cover was assigned. Cover of litter, bare ground, moss, and water was also recorded. Due to many strata overhanging each other (i.e. trees over shrubs over ferns etc.), totals generally added up to more than 100 per cent. This is common in ecological surveys and has been accounted for when comparing sites by considering the proportion of vegetation cover (i.e. excluding litter and bare ground) that is attributable to any species or functional group.

The eight quadrats allow for sufficient replication to account for variation in the vegetation characteristics within each site, thus providing a representative average cover for each species across the transect (i.e. a site-based value), as well as sufficient replication to allow for statistical analysis for changes over time at each site.

2.2.3 Functional Group selection

As the reliance on ground water differs between species and species differed between sites, each species was assigned a functional group depending on its assumed reliance on groundwater availability. Although various functional groups have been defined for groundwater dependent species, (refer to Cassanova, 2011 and Daly et al. 2012) these generally focus on wetland ecosystems rather than forest and scrub ecosystems encountered in

this project. A hybrid system based on previous analyses and Orrelana et al. (2012) has been used in this assessment to focus on terrestrial species that rely on groundwater as outlined in Table 2-1.

Assigning plant species to functional groups was based on descriptions of habitat in literature, primarily in the Flora of Victoria (Walsh and Entwistle, 1994-1999), observer knowledge, past flora reports (Carr and Muir 1994, Carr 2002, SKM and Ecology Australia 2008), and observations taken during the survey described in this report.

The distinction between groundwater and surface water dependency is difficult to discern as plants do not make a distinction as to the source of water available unless other variables such as pH or salinity are limiting factors. For the purposes of this assessment, a species reliance on groundwater or surface water depends on the hydrology at each site and the degree to which the water available at the site is derived from groundwater or surface water.

Moss was assigned to category 3 for all cases. This is updated from the 2014/15 assessments where moss was excluded at all sites with the exception T1 where sphagnum was assigned to category 3. Previous data was updated for the purposes of comparisons presented in this report to ensure like for like data was compared.

For analysis of sites, all species within each category were grouped at each site. The cover recorded in the eight quadrats assessed was then averaged to provide a site estimate of cover. To account for differences in total cover recorded between sites (which could add to >100 per cent as outlined above) this was also expressed as a proportion of total vegetation cover.

Functional Group analysis within each site compared average cover in each functional group and other supporting categories of litter, bare ground and water in graphical form.

Table 2-1 : Functional Group descriptions.

Category	Description	Groundwater Dependency
0	Not connected to ground and therefore not linked to groundwater e.g. epiphytes and certain saprophytic and parasitic plants.	None
1	Obligate terrestrial species requiring well aerated soils and not tolerant of saturating conditions in root zone. Can include shallow rooted and annual weed species making opportunistic use of seasonal water availability.	Opportunistic
2	Terrestrial species sometimes found in GDEs as an opportunistic user of available water. Common in ecosystems outside the GDEs assessed where availability of groundwater is low or non-existent. Includes ferns such as Bracken, shrubs such as Prickly Moses and trees such as Messmate.	
3	Terrestrial species only found in riparian ecosystems or GDEs. Species require readily available water but are not tolerant of regular inundation.	Groundwater Dependent
4	Species requiring at least periodic inundation of root zone for continuing survival	
5	Species requiring regular inundation of root zone for continuing survival.	
6	Obligate aquatic species reliant on inundation for continuing survival.	

2.3 Statistical Analysis

Statistical analyses were undertaken using the data analysis pack of Microsoft Excel. One way and Two-way ANOVA tests were undertaken with variables being local hydrogeology (confined versus unconfined aquifer) and impact (reference/control versus impact sites). These tests examine whether any difference between the average cover of groundwater dependent species is detected between groups. A standard alpha value of 0.05 was used for all tests – that is, a positive result states there is a 95 per cent probability that there is a difference between the averages of the groups tested. For these tests, average cover values for each site were used, therefore accounting for variation in the cover of individual species along each transect.

To maintain equal sample sizes between groups, and therefore the assumptions of the test, sites T3 and T14 were excluded from Two-way ANOVA tests. These specific sites were excluded as Site T3 was found to be overlying a perched aquifer (not connected to the regional groundwater system) and Site T14 is a "spare site" to be included should any one site not be available. One-way ANOVA tests were conducted, both including and excluding sites T3 and T14.

2.4 Local Hydrogeology

Each vegetation survey site has a nearby groundwater monitoring bore that was used to measure the depth to watertable at the site. The depth to watertable provides an indication of whether vegetation at the site has access to groundwater and how depth to watertable varies throughout the year.

3. Results

The results of the vegetation survey are discussed in the following sections. The vegetation condition is assessed by describing the following:

- Vegetation species found along the transect
- Changes in the vegetation type and cover since the last vegetation survey in 2014
- Local hydrogeology along the transect and potential for groundwater use by vegetation
- Recommendations for future vegetation surveys.

The changes since the last vegetation survey are presented as a graph showing the changes in vegetation cover in each functional group. Vegetation is classified according to the potential for groundwater dependency as outlined in Table 2-1 and summarised below:

- Functional group 0 – vegetation does not use groundwater.
- Functional groups 1 and 2 – vegetation may use groundwater opportunistically, in particular species with shallow root systems.
- Function groups 3 to 6 – vegetation is highly likely to be groundwater dependent.

During wet conditions when rainfall is above average and groundwater levels rise as a result of greater recharge, vegetation at these sites are expected to comprise species categorised as functional groups 3 to 6. The condition and health of the vegetation is also expected to be good.

During drier climate conditions when rainfall is below average, groundwater levels may decline and vegetation cover will include more species in functional groups 1 and 2 and the condition and health of the vegetation may decline as there is less water available.

The percentage of vegetation cover in each functional group is shown on a graph for each transect. The graph also shows the results of the previous survey, so changes at each site can be discussed.

3.1 Site T1

The location of site T1 is shown in Figure 3-1. This site is located within Big Swamp into which Boundary Creek flows and dissipates before reverting to a channel west of Colac-Forrest Road. Big Swamp is a peat swamp and the majority of peat was burnt intermittently between 1998 and 2010, primarily as a subterranean peat fire. A large (2m wide x 2m deep) trench runs along the southern edge of Peat Swamp which was constructed in 2010 to prevent fire escaping to surrounding areas.

The transect is located 5 m north of the trench and extends for 70m north east into the swamp. The transect comprised 14 quadrats encompassing six quadrats in an unburnt state at the beginning and eight quadrats burnt from the 30m mark onward. Only the latter eight in the burnt areas have been included in the vegetation analysis. The pegs associated with this transect, installed in 2014, were relocated for this assessment.

The transect is located approximately 550 m west of the ground water monitoring site (TB1). Site T1 represents a site located within the potential impact zone of the borefield and on an unconfined aquifer.

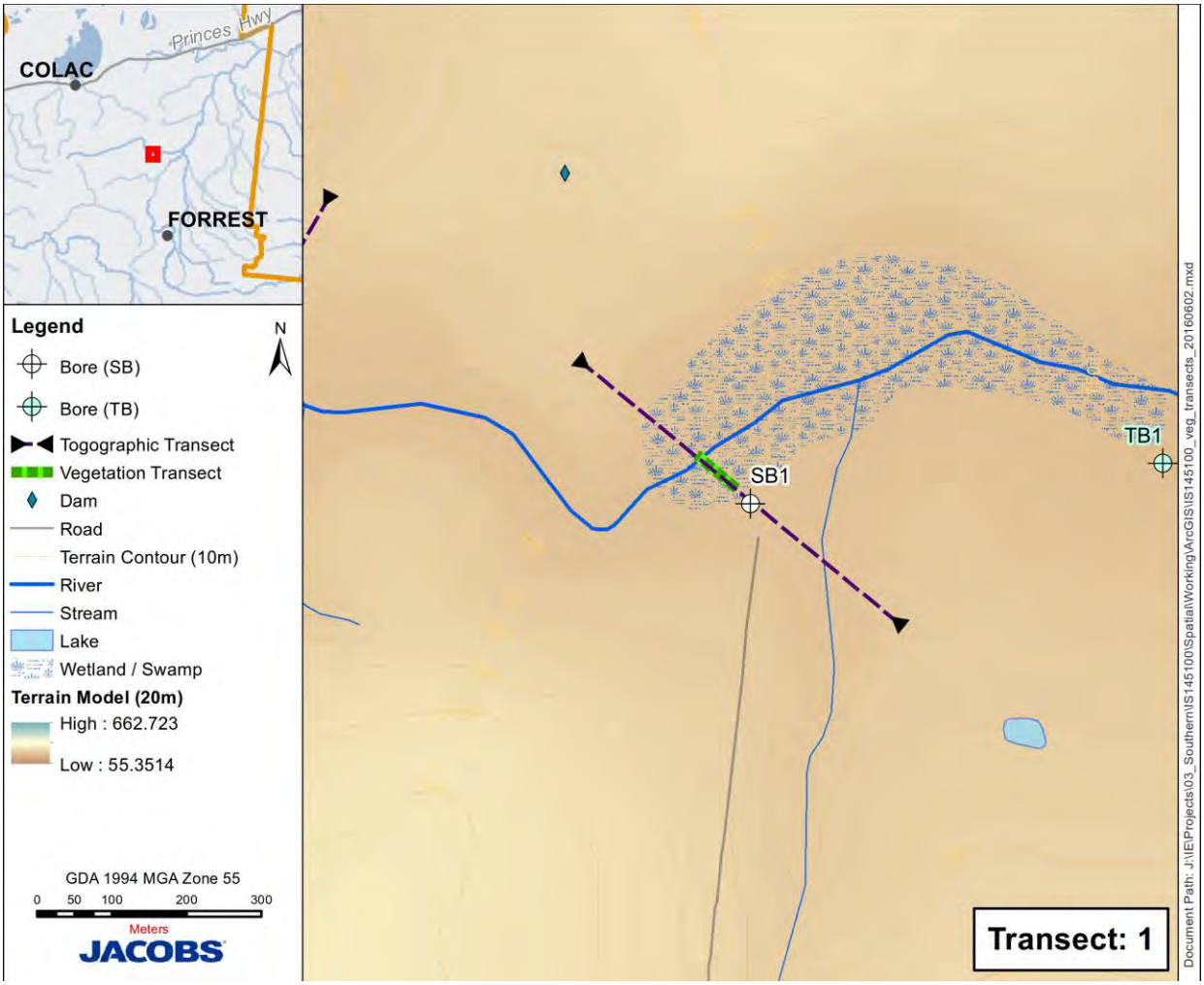


Figure 3-1 : Location of site T1

3.1.1 Vegetation description

The vegetation at the beginning of the transect (0-30m) comprises a dense Bracken (*Pteridium esculentum*) layer with occasional regenerating Swamp Gums (*Eucalyptus ovata*) that are evident around the edges of the entire Big Swamp but do not encroach more than 50 m into the swamp from the surrounding forest. As Bracken is a primary colonising species, the dense layer of this fern would indicate that there was recent disturbance in this zone, probably as a result of land disturbance resulting from efforts to control the aforementioned peat fire in Big Swamp.

From the 30 m mark of the transect to the 70 m finish, the vegetation changes markedly to a sphagnum dominated swamp recovering from recent fire, evident as bare red areas of burnt peat with embedded charcoal. Whilst Sphagnum dominates the ground layer (average cover of 36%), the overstorey (though only 1-2 m tall), shifts from Bracken that is still dominant in quadrats 1-3, to dense Prickly Tea-tree (*Leptospermum continentale*) which comprises a dense scrub in quadrats 4-8. The ground layer comprises almost exclusively litter and/or moss layers. Herbs and grasses are almost entirely absent although the weed Sheep Sorrel (*Acetosella vulgaris*) is locally common at quadrat 2.

3.1.2 Evidence of change from 2014

The vegetation cover from the two surveys is shown in Figure 3-2 where species have been categorised into the functional groups based on their reliance on water availability. This shows there is little change in the type of vegetation present at the site. There is a general drop in the vegetation cover recorded across the site in all functional groups (total cover of 93% in 2016 versus 109% in 2014). While this difference is not statistically significant, it is supported by a similar increase in the cover estimates of bare ground and litter at the sites. This suggests that the vegetation cover is potentially decreasing at the site. This is supported by photographs taken which show in particular that the Bracken is less dense and showing signs of water stress (drying out of frond tips).

The previous report noted that particular attention be given to the moss category at this site given that the Sphagnum moss present is a major component of the vegetation. The cover assessed has declined from 45% to 36% though the difference is not significant and is supported by the general decrease noted across the site in vegetation cover.

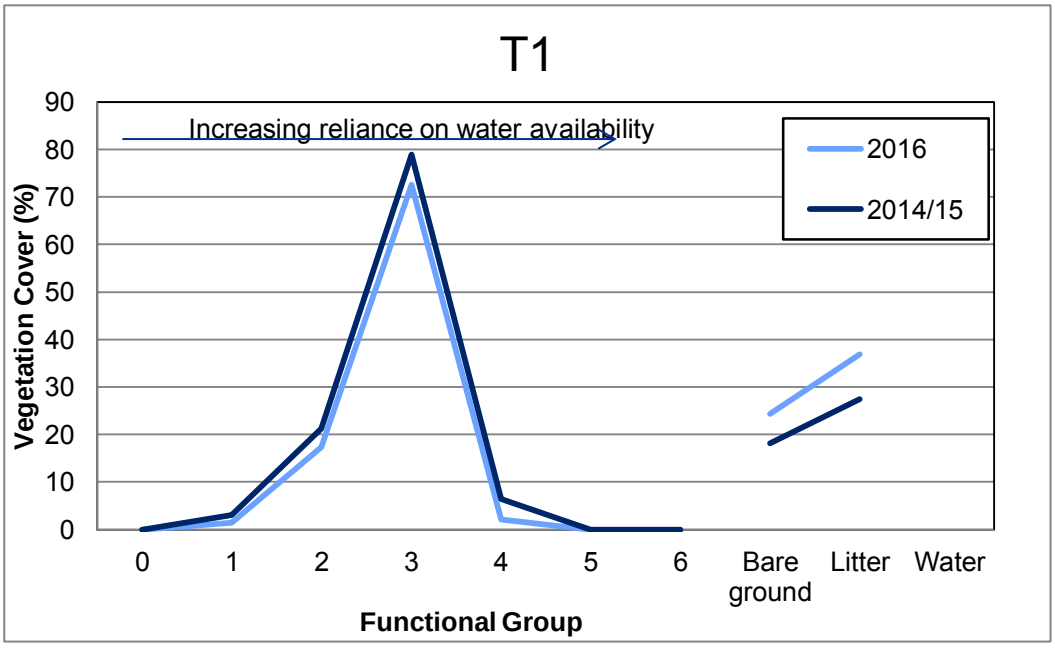


Figure 3-2 : Vegetation cover at site T1 according to functional grouping based on species reliance on water availability.

3.1.3 Link between vegetation changes and hydrogeology

A conceptual cross section of the transect is shown in Figure 3-3. The closest groundwater monitoring bores are 0.5 km to the east (downstream along Boundary Creek) and are not shown on the transect. There are three nested bores at this location – TB1a, TB1b, TB1c. TB1a monitors groundwater levels in the shallow alluvial aquifer, TB1b monitors the underlying aquitard and TB1c monitors the Lower Tertiary Aquifer.

The watertable at the vegetation survey site lies within the shallow alluvial aquifer and based on the results of the soil bore at the site and groundwater bores TB1a, is likely to be within 2 m of the ground surface all year round. Most vegetation is likely to have access to the groundwater in the alluvium. The alluvial aquifer overlies the Middle Tertiary Aquitard (MTD). This site represents a potential impact site in unconfined conditions because the site is located at the edge of the MTD where the formation is thin.

The groundwater level shown in Figure 3-3 is an estimate for illustrative purposes only as there is no monitoring at this exact location. Groundwater levels have declined 1.5 metres in the shallow aquifer since September 2015 at the downstream groundwater monitoring site, from a depth of 0.2 m to 2.5 m below the surface (refer Appendix B for more information). This is consistent with below average rainfall conditions. The general decline in water availability has manifested in a slight decline in vegetation cover however this does not represent an ongoing risk to the site at this stage given the availability of water close to the surface.

More detail on the local hydrogeology at this site is provided in Appendix B.

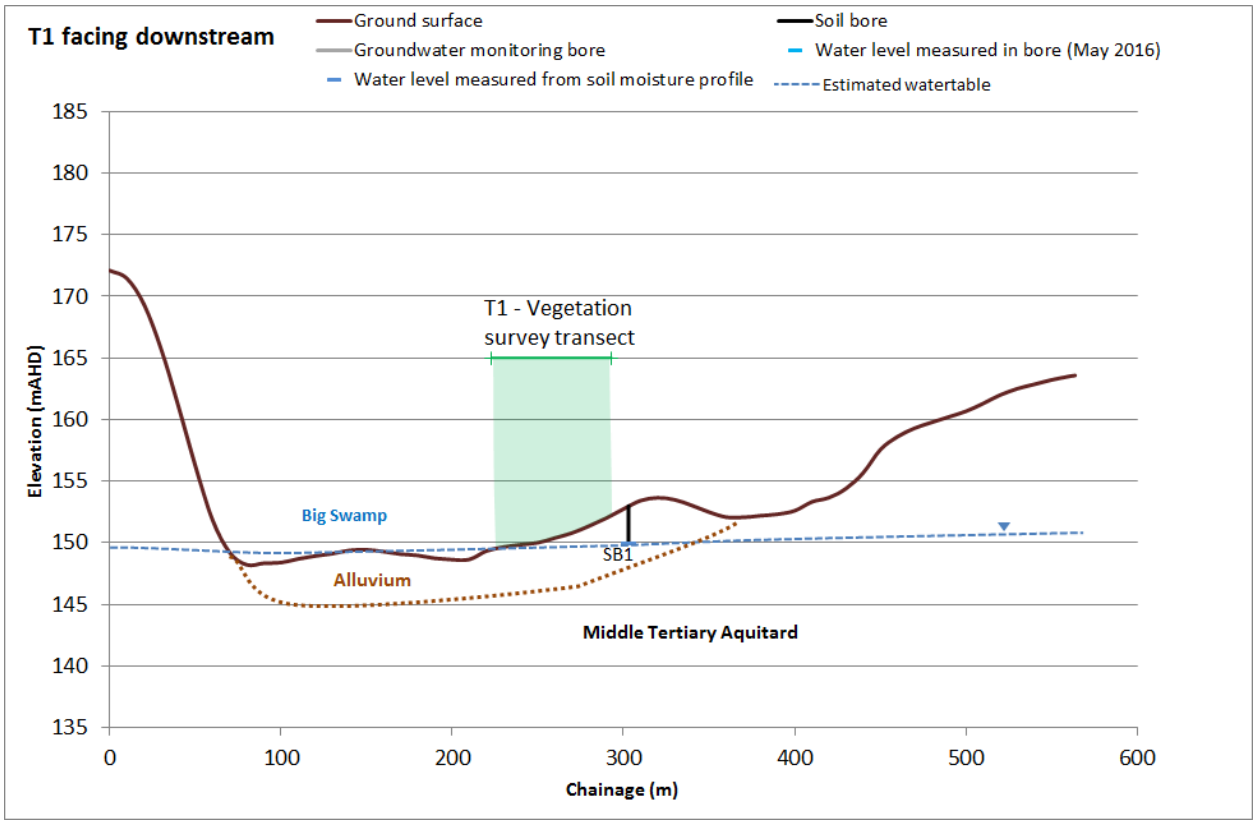


Figure 3-3 : Conceptual cross section of site T1

3.1.4 Recommendations for future vegetation surveys

Given that changes were recorded in vegetation cover across all classes at this site, the trajectory of the vegetation cover, should be noted in the next monitoring event. In particular, whether any notable signs of water stress such as the burning tips of the Bracken are evident in the future would be of interest.

3.2 Site T2

The location of site T2 is shown in Figure 3-4. Site T2 is located at Boundary Creek west of the crossing of an un-named private road and upstream from the western end of Big Swamp.

Access was achieved from the south side of the creek along an unmarked but well-made access track to the east of the bore location located approximately 100 m south of the transect. The transect covers 40 m from the edge of the track due north and crosses Boundary Creek which has multiple meandering channels at the site. The start and end of the transect is marked with a yellow-capped post, with the starting post within 3 m of the edge of the access track.

The site is located in a potential impact zone from the borefield where the LTA is unconfined.

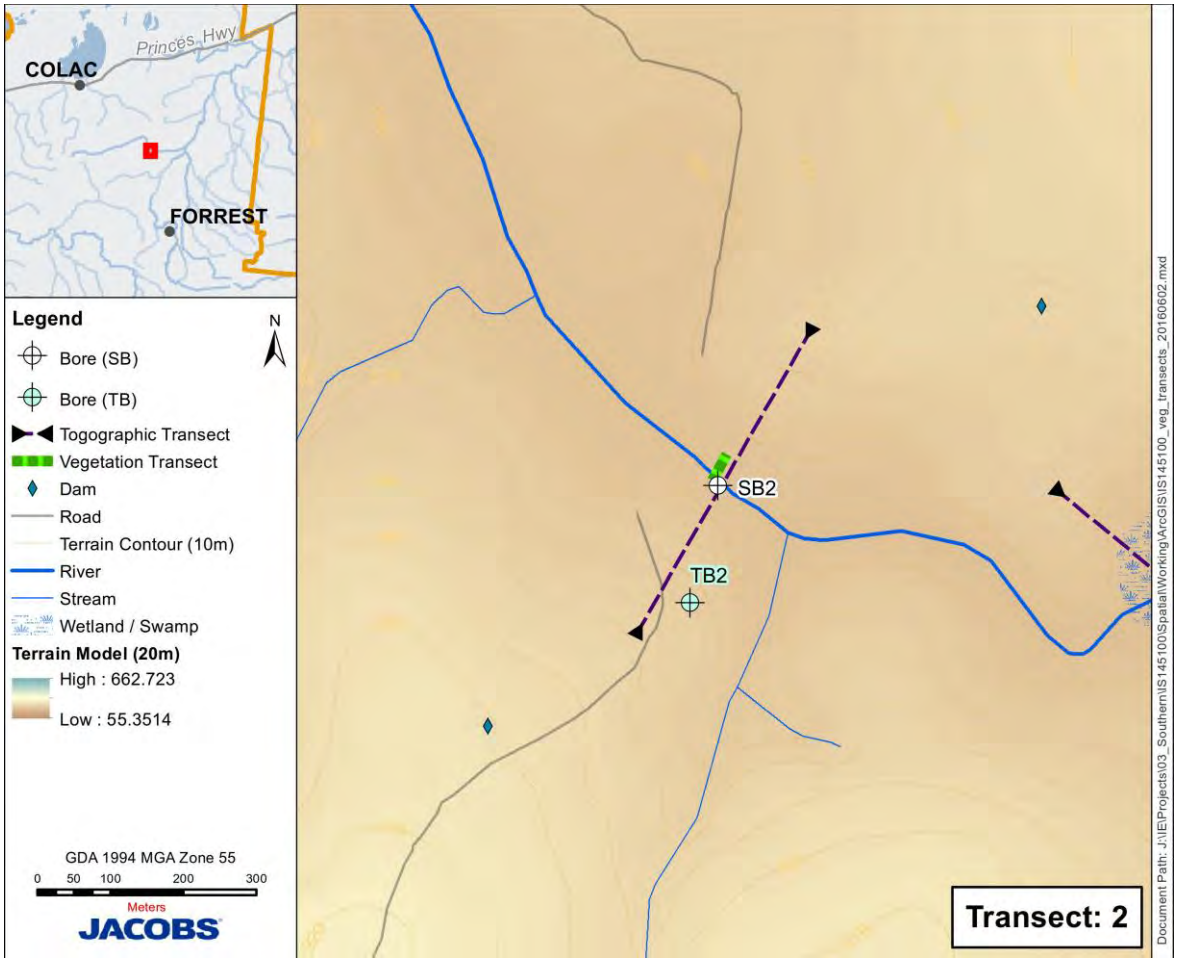


Figure 3-4 : Location of site T2

3.2.1 Vegetation description

The site at T2 across Boundary Creek supports swampy vegetation with overhanging Swamp Gums (*Eucalyptus ovata*), many with a noticeable lean, over a dense layer of shrubs including Wooly Tea-tree (*Leptospermum lanigerum*) and Scented Paperbark (*Melaleuca squarrosa*). The ground layer comprised predominantly a diverse range of sedges and ferns with occasional hydro-phyllic herbs. The sedges ranged from Red-fruit Saw-sedge (*Gahnia sieberiana*) and Tall Sword-sedge (Lepidosperma elatius) on the exposed areas of the swamp to Tall Sedge (*Carex appressa*) and Swamp Club-sedge (*Isolepis inundata*) within the channels and low-lying pools across the site. Ferns were common with six species recorded and dominated by Scrambling Coral-fern (*Gleichenia microphylla*) which can form dense thickets on the margins of swamps and wetter forests.

3.2.2 Evidence of change from 2014

The previous report included a note that there were numerous recruits in the section between quadrats 3 and 7 and that these had capacity to result in significant cover changes in the next (i.e. this) survey. There was no evidence of increased cover in the quadrats in question as a result of recruitment evident in these quadrats – rather an increase in the amount of bare ground and litter.

The vegetation cover from two surveys is shown in Figure 3-5, where species have been categorised based on their reliance on water availability. The pattern of the functional groups at this site is largely unchanged from November 2014 to March 2016 with the exception of the notable decrease in cover in species within functional group 4 (species requiring at least periodic inundation of root zone for continuing survival). Otherwise, the species mix and site descriptions are largely unchanged. The change in cover in functional group 4 species is interpreted primarily as a response to a decrease in the surface water present at the surface during the assessment.

Within the site, Boundary Creek is a meandering waterway with two channels (Q2-Q3 and Q6) and a saturated zone between these two channels. For this survey, the channel in Q2-Q3 was dry and the channel in Q6 held less water (cover reduced from 35% to 20%). There were much higher levels of litter recorded across the site which appears to be closely related to a drop in the cover of water and bare ground recorded at the site compared to 2014/15.

The reduction in surface water is supported by the reduction in the cover of species within category 4 (57% to 43%), primarily driven by decreases in the cover of Swamp Gums and Scented Paperbark. This change did not appear to be a result of tree fall but rather a general thinning of the canopy across the site. These larger woody species can reduce the degree to which they hold leaves in their canopy in response to drying conditions (including seasonally) and the result is supported by a rise in the cover of litter across the site (24% to 36%).

The previous report noted that future surveys should look for increased cover in quadrats 3-7, which had significant numbers of recruits emerging at the time of assessment and would result in changes should conditions remain static. Conditions have not remained static as outlined below and subsequent sections and these recruits have largely died off. The species within category 5 which rely on semi-permanent surface water were also noted as being worthy of specific attention in 2015 and were still evident within the channels in this assessment although the Water Ribbons (*Cycnogeton procerum*) were not seen. As this species retains large subterranean tubers from which leaves sprout in suitable conditions, this absence is unlikely to be permanent but does support a general reduction in water availability at the site.

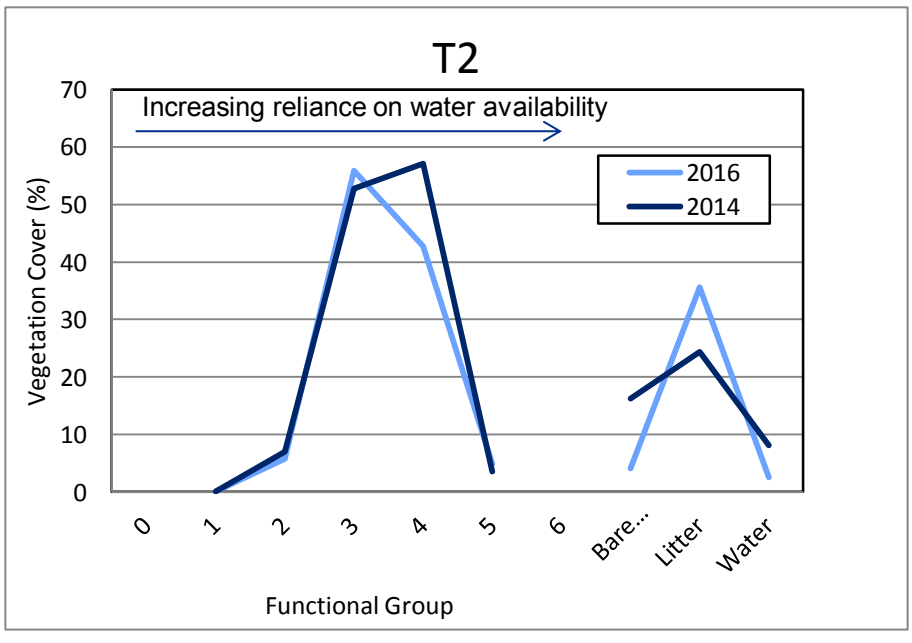


Figure 3-5: Vegetation cover at site T2 according to functional grouping based on species reliance on water availability.

3.2.3 Link between vegetation changes and hydrogeology

The conceptual cross section of site T2 is shown in Figure 3-6. This shows there are thin alluvial sediments that contain groundwater in the valley floor. The alluvial aquifer overlies the Lower Tertiary Aquifer. At the transect groundwater levels have declined since TB2c was installed and are now greater than 3 m depth. The major changes in vegetation cover noted relate to those species more reliant on the presence of surface water (e.g. Water Ribbons). These species had declined at the time of assessment due to a notable decline in surface water being present.

The topography rises away from the valley and TB2a is located on higher ground and is not deep enough to intersect the watertable. Groundwater levels in the Lower Tertiary Aquifer have been influenced by pumping from Barwon Downs at this location and have declined up to 20 m (refer to Appendix B for more information).

Groundwater levels have declined since 2014 when the soil bore was drilled and are greater than 3 m depth. Based on the available information, some vegetation located along the transect could access groundwater. Away from the transect site the depth to water table is likely to be too deep for most vegetation.

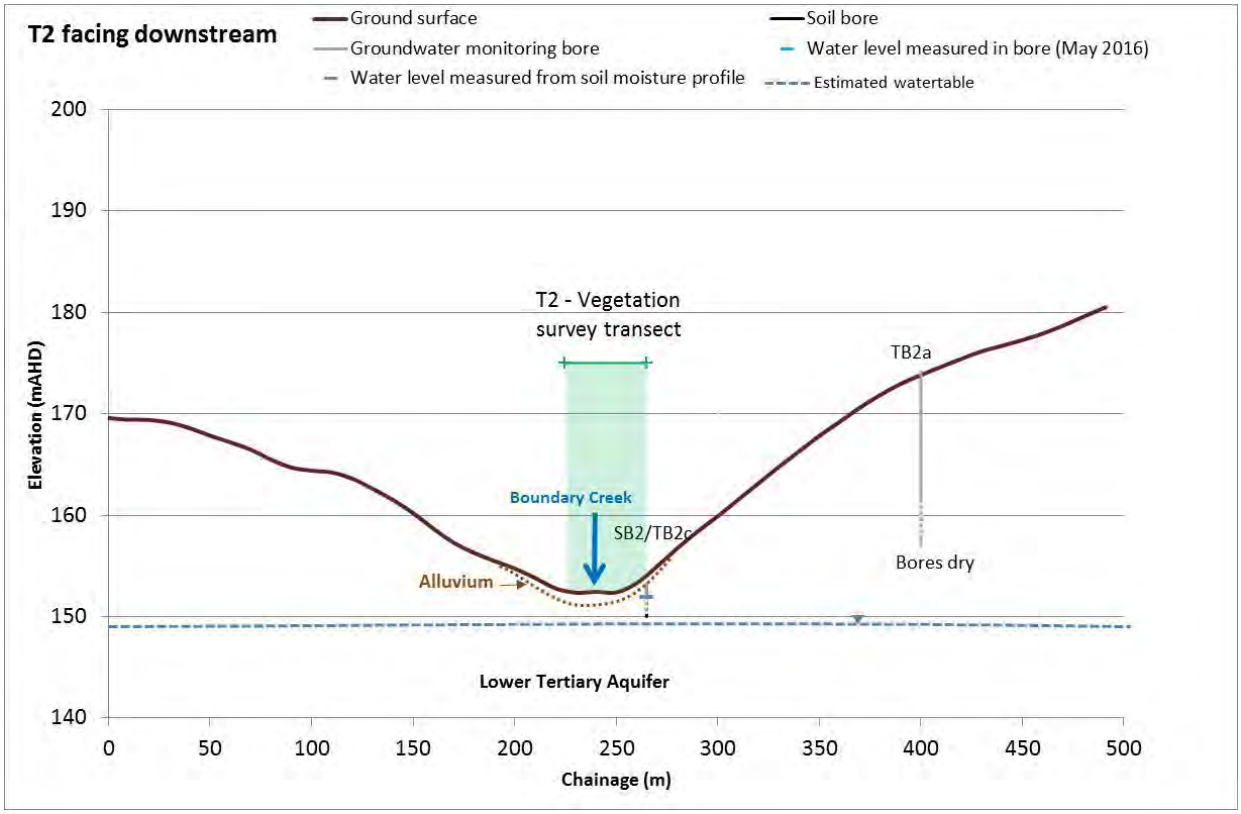


Figure 3-6: Conceptual cross section of site T2

3.2.4 Recommendations for future vegetation surveys

The presence of water within the two channels across this transect should be noted in future reports as this will provide an indication of the current water levels at the site. The litter levels and canopies of the major trees and shrub layers should be examined noting if there is any evidence of die-back, coppice growth or other evidence of water stress given the changes noted in this report. The presence or absence of holes made by Burrowing Crays should be noted in future reports. The presence of absence of Water Ribbons is also of interest for future reports and may be indicative of recent hydrological conditions at the site.

3.3 Site T3

Site T3 is located at an unnamed swampy wetland with standing water across a 1.2 ha area east of an un-named maintenance track running north off Westwood Track and west of crossing of an un-named private road (see Figure 3-7). Access to the site is from the south side of the creek along an unmarked but well-made access track, located 20 m uphill from the transect. The transect covers 40 m from the edge of the track and crosses Boundary Creek which has multiple meandering channels at the site (not shown in Figure 3-7).

The transect was located at the western end of the swamp as it appeared to drain to the north east and any potential changes are more likely to be detectable at the upper end and at the edge of the swamp. The site is located in a potential impact area from the borefield and where the Lower Tertiary Aquifer is unconfined.

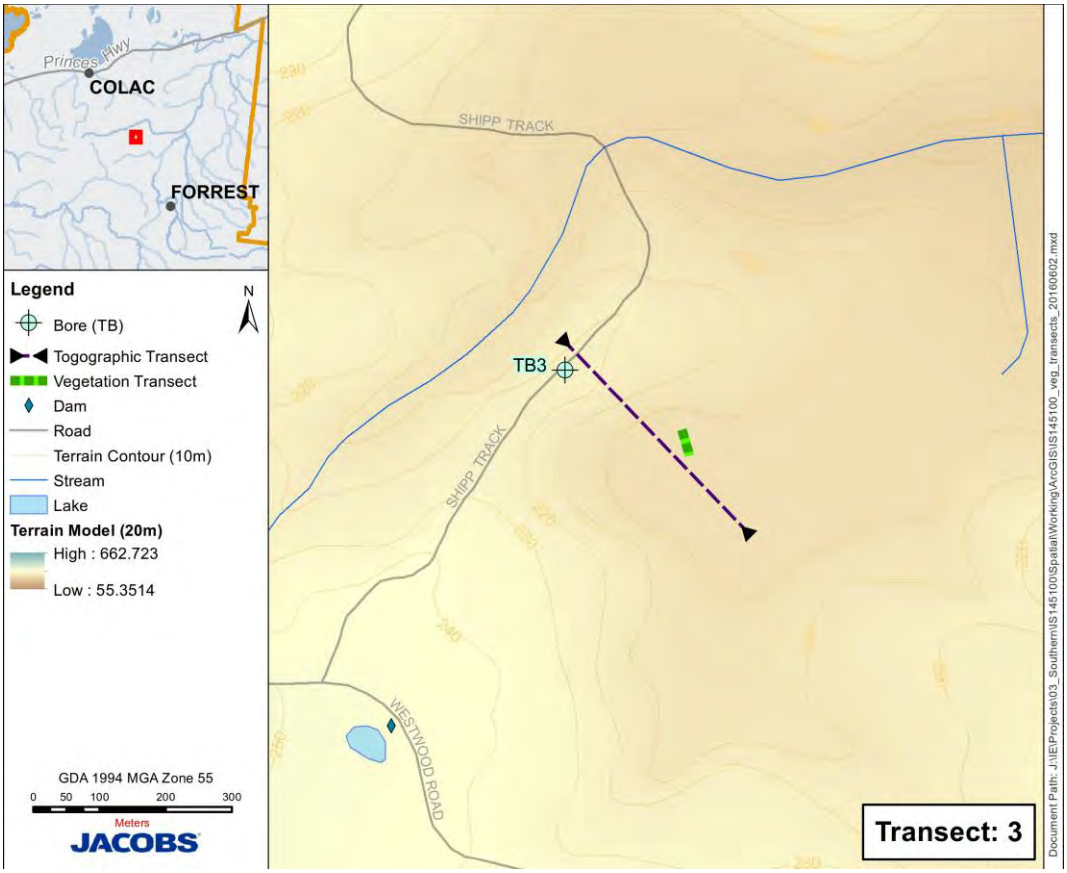


Figure 3-7 : Location of site T3

3.3.1 Vegetation description

At the edge of the swamp, the vegetation comprises an overhanging canopy of Swamp Gums (*Eucalyptus ovata*) over a ground layer of obligate wetland rushes, sedges and grasses. The Swamp Gums grow to full height only at the edges of the swamp at the invert from the flat swamp section to the rising slopes which ring this area. Within the swamp, there are a few small trees (to 5m) and many fallen logs. This would suggest the wetland goes through wetting and drying events with trees establishing during comparatively dry conditions and falling when the soil saturates and resulting root rot reduces the stability of the trees.

The ground layer during the assessment comprised dead or dying sedges and rushes, mainly Jointed Twig-sedge (*Baumea articulata*) and Tall Rush (*Juncus procerus*) with a layer of grass, predominantly Common Blown-grass (*Lachnogrostis filiformis*) and Dark Swamp Wallaby-grass (*Amphibromus recurvatus*) in areas that previously were covered by standing water. It should be noted that dead material still attached to the plant was included in cover estimates rather than litter. Opportunistic weed species (Yorkshire Fog – *Holcus lanatus,* Flatweed – *Hypochaeris radicata*) were also detected in low abundance throughout the transect.

3.3.2 Evidence of change from 2014

The previous report included a note that it was considered that this site was most likely linked to a perched aquifer and as noted below and in the hydrogeological summary, this has been confirmed given the drastic changes noted. This site demonstrates the rapid changes that can occur in a GDE with the loss of available water.

The vegetation cover from two surveys is shown in Figure 3-5; species have been categorised based on their reliance on water availability. The major change at the site was the complete absence of standing water at the site compared to the previous assessment in November 2014. The water cover previously recorded at 38%, has receded completely and the soil has dried and deep cracks have developed in the soil. The sedges and rushes present are reliant on near constant surface water and have largely died with little evidence of new growth. The remaining live vegetation in poor health. However, this has not translated in a large drop in cover, as whilst there has been some loss of vegetation, previously upright leaves and culms on the sedges and rushes have broken and fallen to keep the cover in functional group 5 largely the same (52% to 57 %). As the vegetation breaks down and decays, this cover estimate will fall should the conditions persist with a rise in litter also occurring. Obligate wetland species such as Running Marsh-flower (*Ornduffia reniformis*), and Spotted Knotweed (*Persicaria praetermissa*) previously detected were absent in this survey.

There is an increase in the cover of functional group 4 (7% to 23%) which has arisen due to the growth of Common Blown-grass and Dark Swamp Wallaby-grass in areas that were previously covered in water. These are grasses commonly found in or on the margins of wetlands and waterways, and likely took advantage of the increased areas for germination whilst soils were still wet. The receding water has resulted in many of these grasses also dying off though. This could also be a result of seasonal changes.

The marked change in the hydrology and vegetation at this site will continue to result in changes at this site.

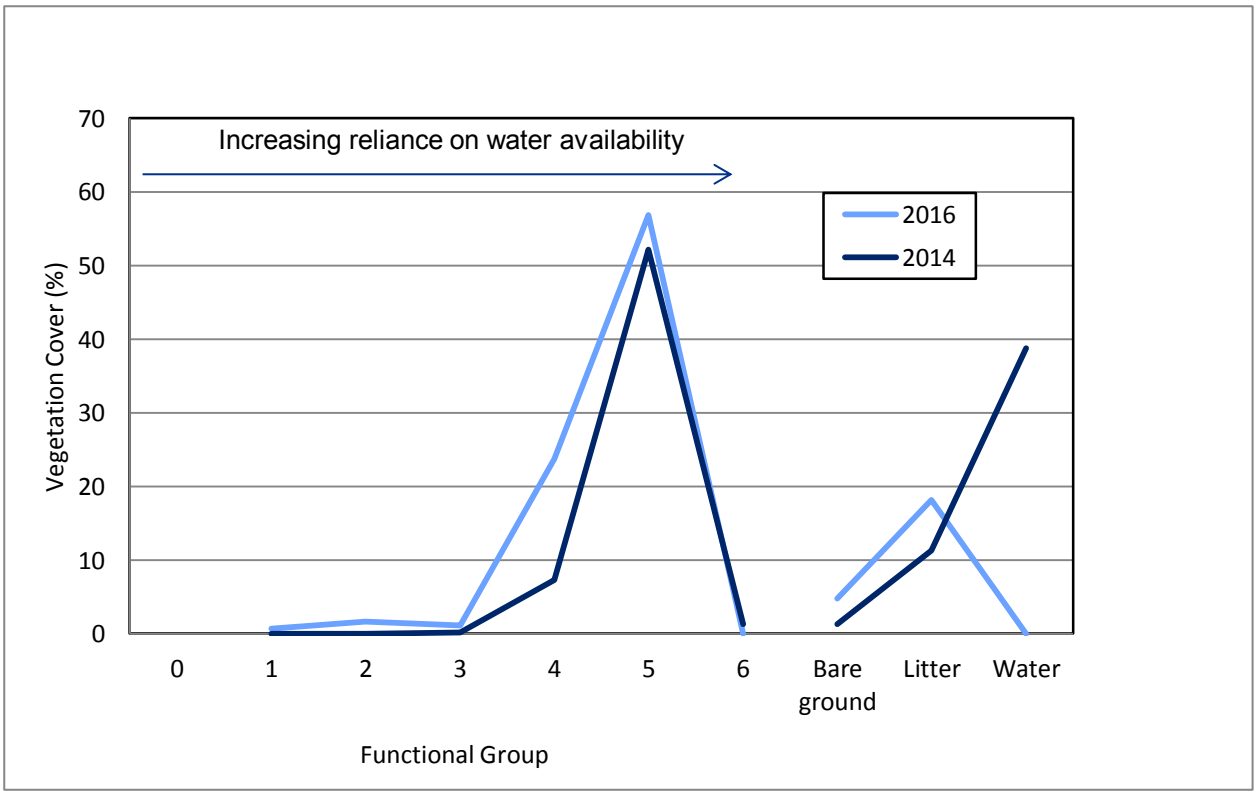


Figure 3-8 : Vegetation cover at site T3 according to functional grouping based on species reliance on water availability.

3.3.3 Link between vegetation changes and hydrogeology

The groundwater lies within the Lower Tertiary Aquifer at this location. Thin alluvial sediments are present in the valley floor, but are not extensive. The alluvial sediments are saturated when there is sufficient rainfall and surface water.

A conceptual cross section across the site is shown in Figure 3-9. Based on groundwater levels in TB3 which is located on higher topography, the depth to groundwater at the transect site is approximately 15 m below the surface (refer to Appendix B for more information). Vegetation at the transect site is unlikely to rely on the regional groundwater system.

The surface water within the wetland is likely to be a derived from rainfall with the potential for a local perched aquifer in the alluvium. This resource will be more susceptible to changes in local rainfall. As the rainfall has declined in the surrounding area over the preceding year, the inflows to the wetland have declined and water levels within the wetland decreased, to the point that there was no apparent surface water and large changes in vegetation composition and health. Changes measured at this site will reflect changes in local rainfall rather than changes in the regional groundwater system (Lower Tertiary Aquifer).

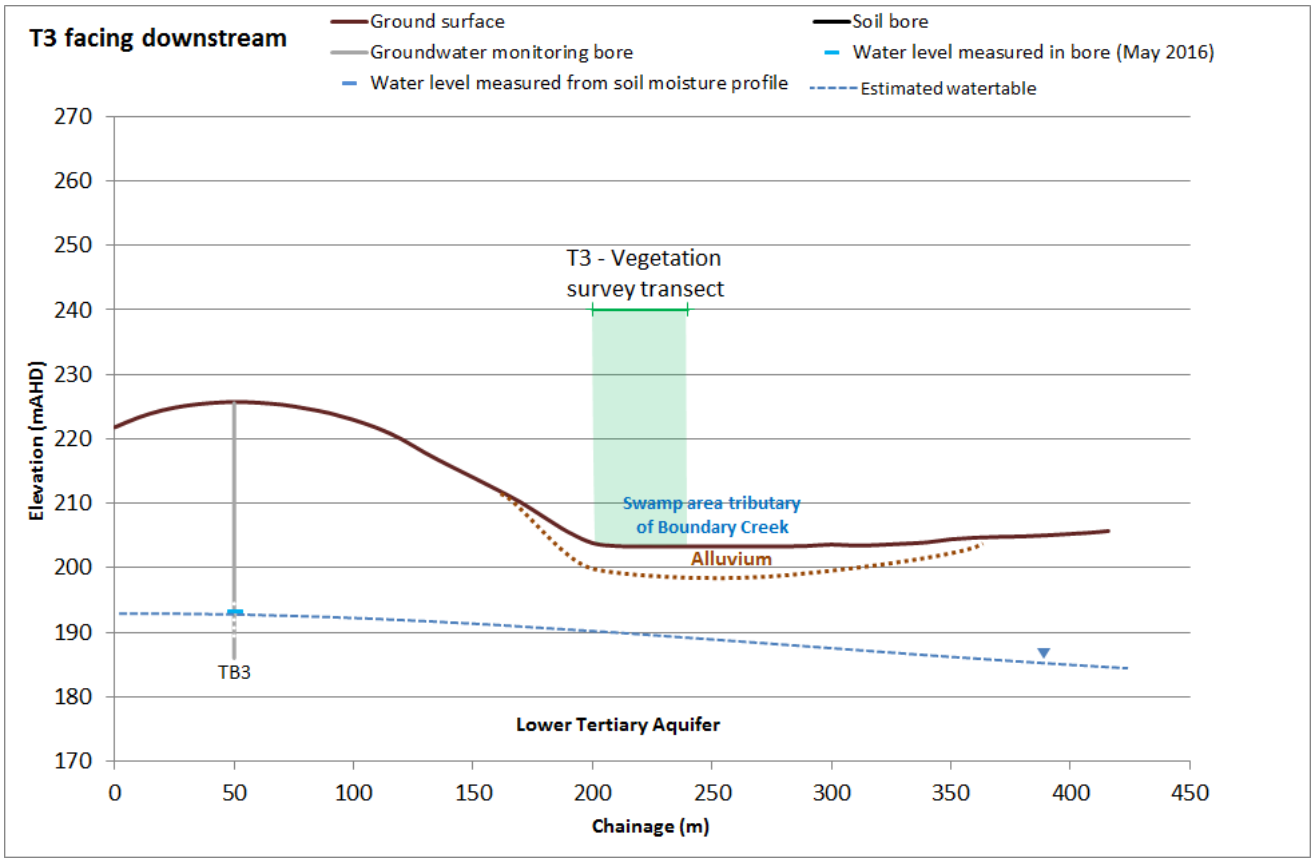


Figure 3-9 Conceptual cross section of site T3

3.3.4 Recommendations for future vegetation surveys

It is recommended that this site be included in future vegetation surveys as it provides information on potential impacts of the borefield and has a shallow aquifer reliant on a small catchment.

3.4 Site T4

The location of site T4 is presented in Figure 3-11. Site T4 is located at the valley of an un-named tributary of Boundary Creek on the north side of un-named and un-marked access track running east-west along the northern border of the Otway Forest Park. Site access is from the west by taking the marked maintenance track running north from Westwood Road 1 km east of the intersection with Link Track. The tributary does not have a defined channel at the assessed area and is comprises a swampy low-lying area.

The transect covers 40 m from the base of the large tree located 5 m north of TB4 The area south of the access track has been significantly disturbed including reconstruction of culverts upstream of the site, apparently as part of controlled burns conducted in early 2016 but these works do not appear to have affected the transect. A photo of the works as assessed during the vegetation survey is shown below

Figure 3-10 :Disturbance upstream of site T4. The transect is located entirely within undisturbed forest to the left of this location.

The site is located in an area of potential impact from the borefield where the Lower Tertiary Aquifer is unconfined.

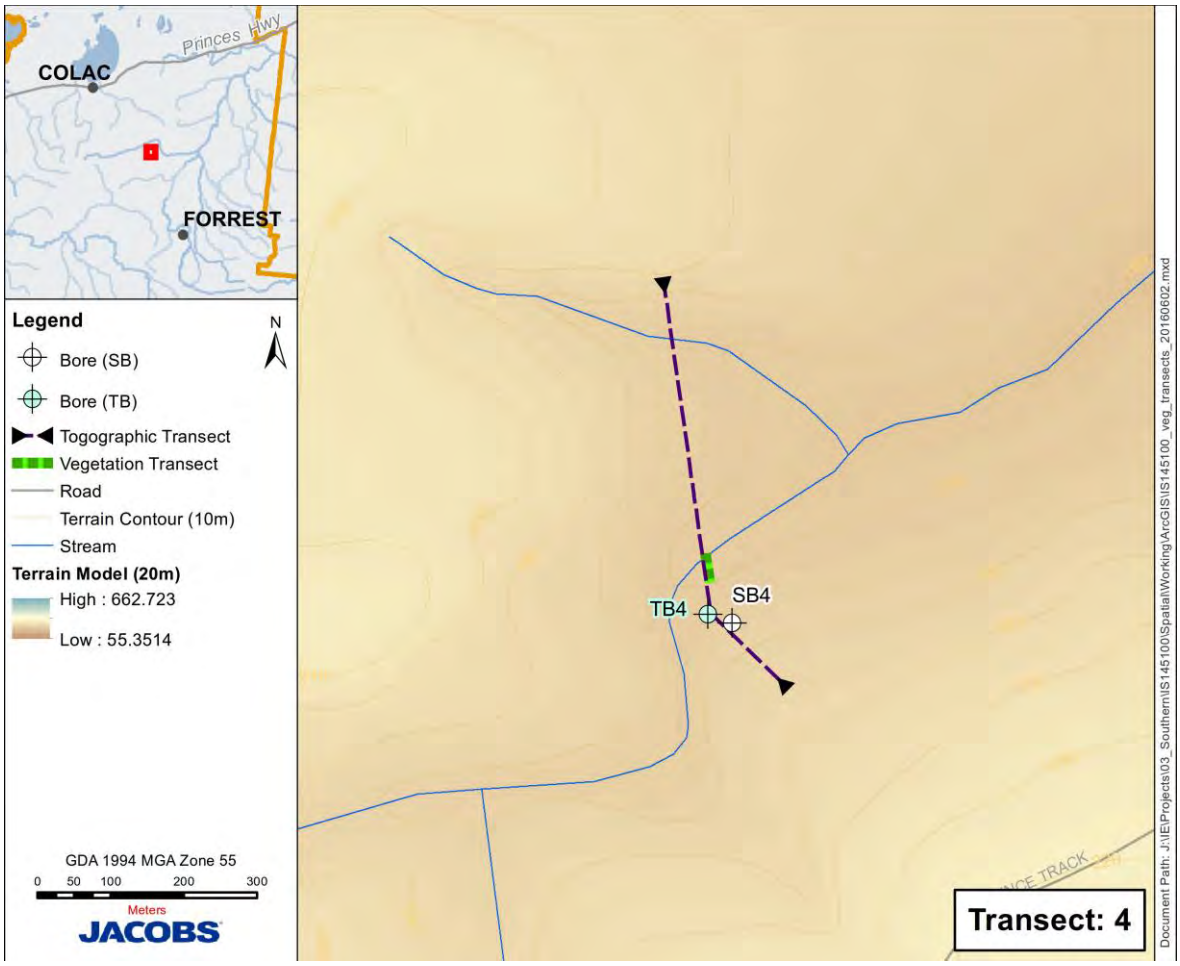


Figure 3-11 : Location of site T4.

3.4.1 Vegetation description

The transect is aligned across the waterway with the vegetation comprising a constant overstorey of Swamp Gum (*Eucalyptus ovata*) and occasional Messmate (*Eucalyptus obliqua*) to 20 m over dense cover of Scented Paperbark (*Melaleuca squarrosa*) and Wooly Tea-tree (*Leptospermum lanigerum*) at 4-5 m. The lower strata is dominated by large sedges, predominantly Tall Sword-sedge (*Lepidosperma elatius*) which averaged at 21% cover across the transect. The ground layer was dominated by ferns (*Blechnum nudum* and *Pteridium esculentum)* and scrambling grasses (*Tetrarrhena juncea* and *Poa tenera*) with very few herbs. The ground layer is largely a dense and deep litter layer particularly in the lowest elevation quadrats (Q6-7) where surface water is most likely to occur. No surface water was observed during the assessment.

3.4.2 Evidence of change from 2014

The previous report noted that there was potential for significant recruitment in quadrats 5-8 with many recruits previously noted. These recruits were not noted in this assessment and no significant recruitment of ferns or sedges was noted.

The vegetation cover from two surveys, conducted in 2014 and 2016, is shown in Figure 3-12 where species have been categorised based on their reliance on water availability. The species mix and the overall structure of the vegetation is largely unchanged from this assessment in March 2016 compared to the previous assessment in November 2014. However, the cover estimates recorded show a marked decline in the cover of vegetation in functional groups 3 (59% to 44%) and 4 (33% to 22%), both of which have been defined as being groundwater dependent. The reason for these reductions is largely a result of lower estimates particularly for Tall Sword-

sedge (35% to 21%) and the tree and shrub canopies (53% to 37%). No discernible change in the cover of species in functional group 2 (opportunistic species) was observed (19% to 18%).

Whilst some of this can be attributed to Scented Paperbark shrubs falling over and dying in Quadrats 2 and 3, this would not explain the overall changes. It is likely that this change is a reduction in the leaf cover of the constituent species, which being large perennial species, are more able to adapt to changing environmental drivers. This is likely driven by changes in the availability of water at the site, driven either by the significant disturbance to the area immediately upstream of the site (construction works associated with planned burns) which could have altered the drainage patterns in the short term, or environmental drivers in the supply of water.

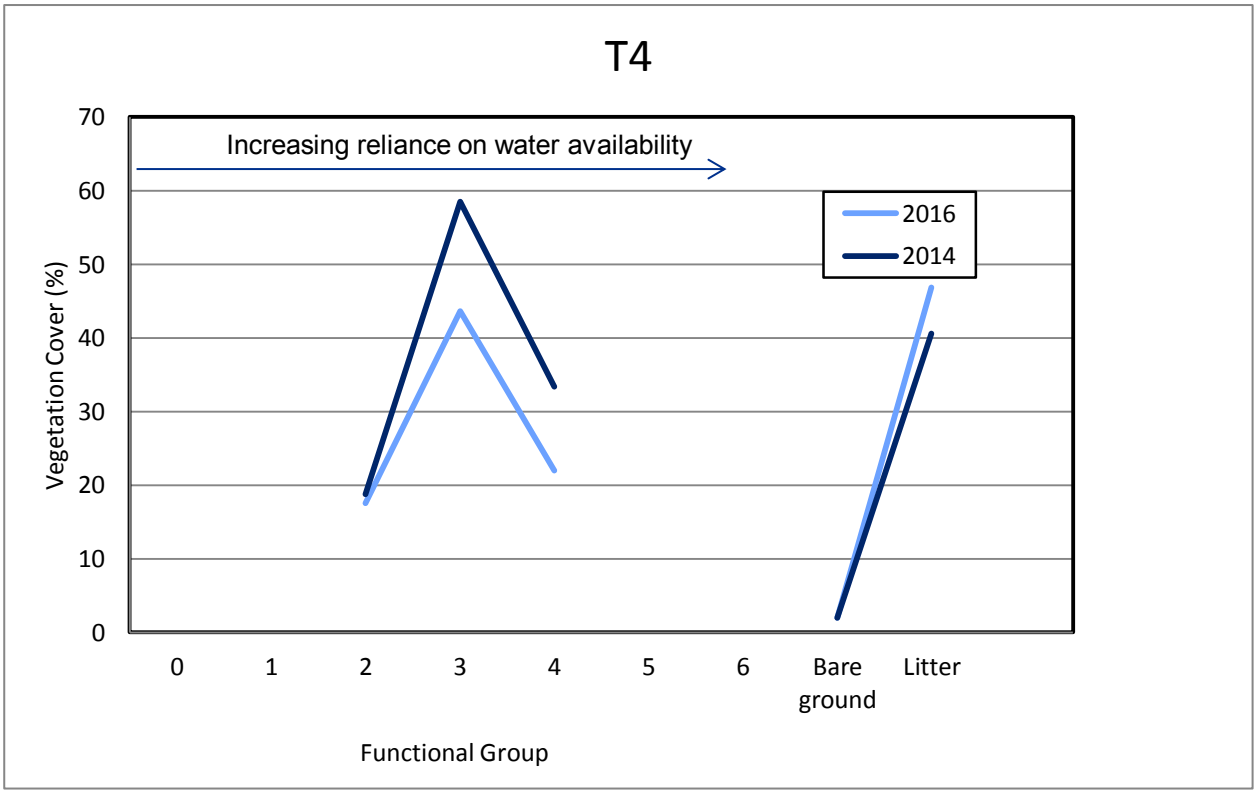


Figure 3-12 : Vegetation cover at site T4 according to functional grouping based on species reliance on water availability.

3.4.3 Link between vegetation changes and hydrogeology

The closest groundwater monitoring bores are approximately 50 m to the south. There are three monitoring bores at this location – TB4a, TB4b and TB4c. TB4b monitors the shallow sandy alluvial perched aquifer and TB4a and TB4c monitors the Lower Tertiary Aquifer at different depths. A conceptual cross section across site T4 shown in Figure 3-13.

The local water table at this vegetation survey site lies within the shallow perched aquifer and is likely to exist only at a local scale when recharge from rainfall and surface water occurs. When the perched aquifer is saturated, the watertable can be within 1 m of the ground surface along parts of the vegetation transect. Vegetation has access to the shallow perched groundwater, however the regional watertable lies 30 metres below the surface in the Lower Tertiary Aquifer (refer Appendix B for more information).

Given the vegetation only has access to the perched water table which is dependent on rainfall, the general decline in the vegetation cover is likely to be related to the below average rainfall conditions. However the influence of the nearby works upstream of the site cannot be quantified or discounted. It is likely that any changes in vegetation condition measured at this site will be related to changes in rainfall within the catchment.

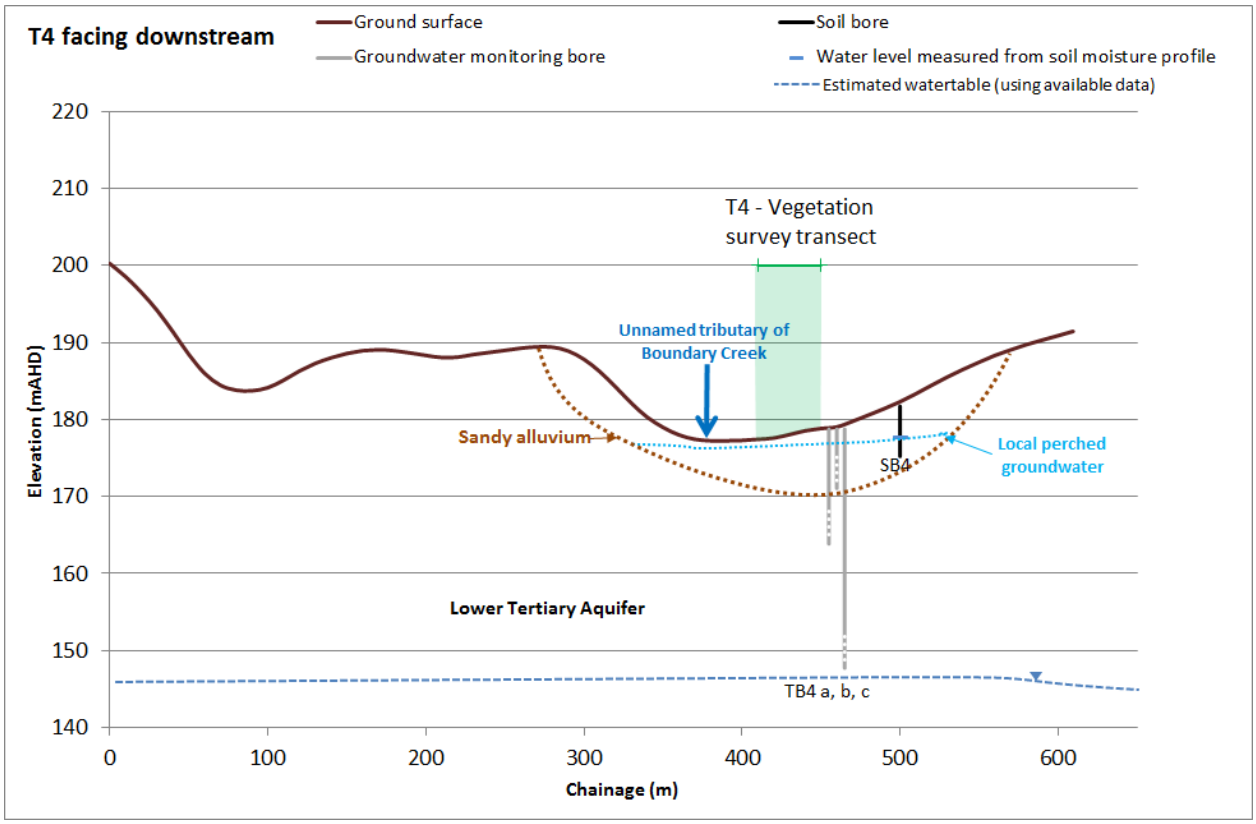


Figure 3-13 : Conceptual cross section of site T4.

3.4.4 Recommendations for future vegetation surveys

The trajectory of vegetation will be important to note at this site in future vegetation surveys. A decrease has across most vegetation classes has been noted and it should be noted if this continues or not and to identify any potential causes.

3.5 Site T5

The location of Site T5 is shown in Figure 3-14. Site T5 is located across the valley of an un-named tributary of Boundary Creek due west of Field and Game Track where sign is located on the west side of the road. The tributary does not have a defined channel and operates largely as a drainage line with vegetation (Swamp Riparian Forest) markedly different from the surrounding slopes (Heathy Dry Forest).

The entire waterway was burnt in controlled burns in 2015 and therefore markedly changed from the previous assessment. Alternative areas to relocate the transect were investigated by following the tributary, however, no suitable un-burnt areas could be located. It is recommended that this site be maintained as a long term monitoring site.

The transect covers 40 m from the base of the large tree located some 250 m west of the track and approximately 300m from TB5. The start and end points of the transect are marked by steel posts with melted yellow caps.

The site is a reference site, located outside the zone of influence from the borefield, where the Lower Tertiary Aquifer is unconfined.

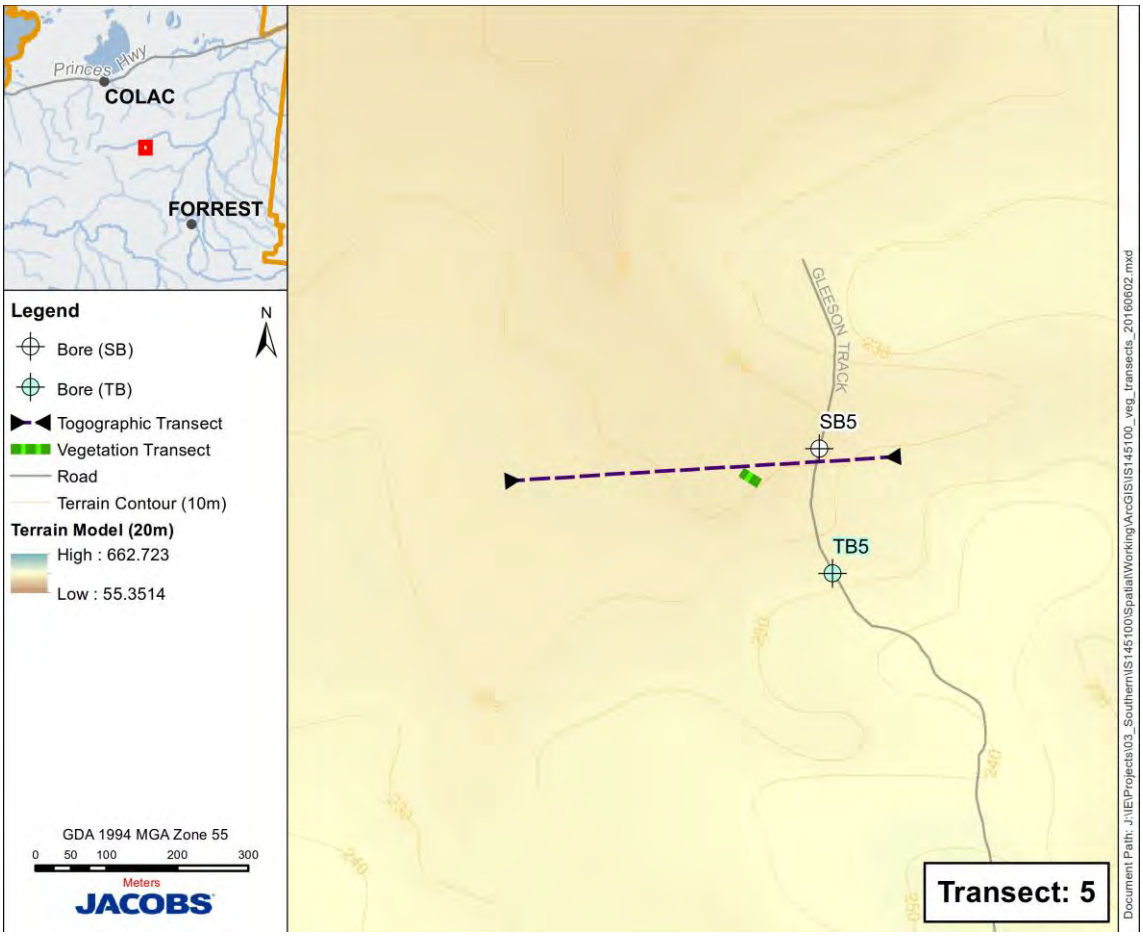


Figure 3-14 : Location of site T5

3.5.1 Vegetation description

The site comprises an overstorey of relatively young Swamp Gum (*Eucalyptus ovata*) and occasional Narrow-leaf Peppermint (*Eucalyptus radiata*) trees to 12 m which were scorched in the control burn and largely survived although the canopies were largely killed and falling as litter. The mid and ground layers are now very open with Scented Paperbark (*Melaleuca squarrosa*) now regenerating from the lower stems of what were once large

shrubs to 5 m tall. The large sedges (Tall Sword-sedge - *Lepidosperma elatius* and Red-fruit Saw-sedge - *Gahnia sieberii*) present also are regenerating from established plants, however a number of these are also dead and unlikely to regenerate. The ground layer at the time of assessment was dominated by rapidly regenerating species, mostly grasses (*Tetrarrhena juncea* and *Poa tenera*) and Spreading Rope-rush (*Empodisma minus*) and many seedlings of a diverse range of species establishing in the ash.

The site is regenerating well given the short time following the burn and should be expected to return to the pre-burnt conditions of 2014 in time. Any results gathered from future monitoring should be interpreted in the context of regeneration.

3.5.2 Evidence of change from 2014

It was noted in the previous report that attention should be given to the presence and performance of Functional Group 1 species. As the site has been extensively burnt, this recommendation is largely moot, however, all species within Functional Group 1 were again detected although all were burnt and recovering along with all other species.

The vegetation cover from two surveys conducted in 2014 and 2016 is shown in Figure 3-15; species have been categorised based on their reliance on water availability. The change from the previous assessment is most evident in a reduction in cover in the groundwater dependant functional groups 3 (41% to 16%) and 4 (42% to 12%). The major species contributing to the change are those which dominated the site in 2014, namely the overstorey of Swamp Gums (27% to 9%), the midstorey of Scented Paperbark (14% to 2%) and the ground layer dominated by Tall Sword-sedge (15% to 4%) and Red-fruit Saw-sedge (8 to 4%). These species are perennial and regenerating from the existing plants so cover will be expected to recover with time (3-10 years). The burn also resulted in litter cover jumping from 49% to 64% and bare ground also increasing from 1% to 9%. As species regenerate and recover, these values are expected to drop.

Only three species were not detected in 2016 following the fires, namely Tall Sundew (*Drosera auriculata*), Milkmaids (*Burchardia umbellata*) and Moth Daisy-bush (*Olearia erubescens*). All were minor components of the vegetation previously (collectively less than 1%) and therefore their absence within the small area assessed may not represent their loss from the wider area, however, future monitoring should assess whether these species return.

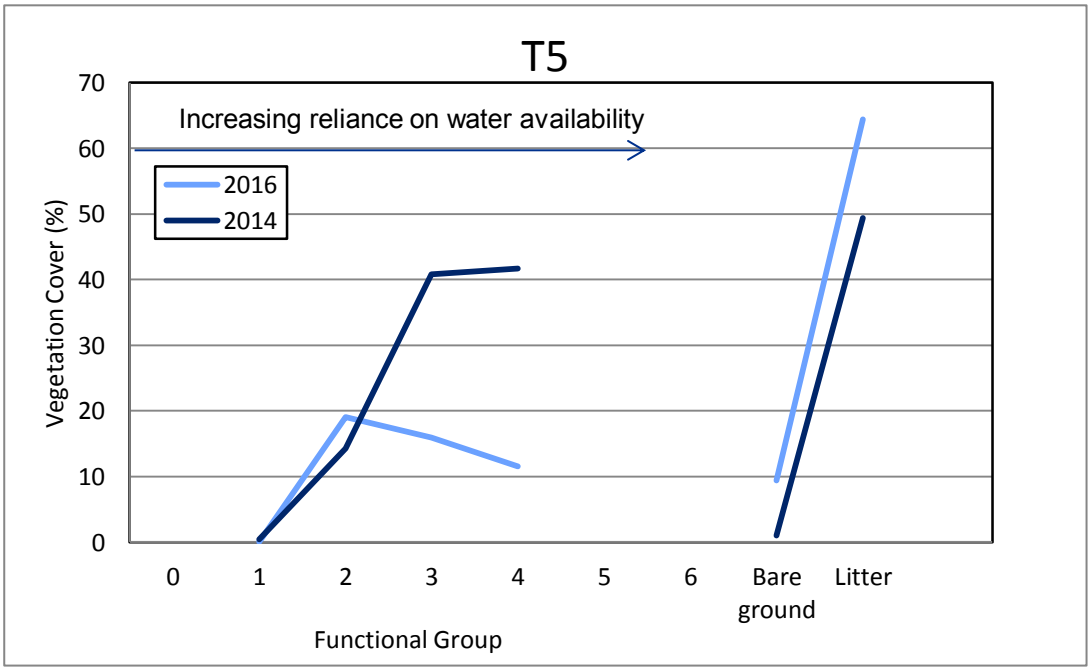


Figure 3-15 : Vegetation cover at site T5 according to functional grouping based on species reliance on water availability.

3.5.3 Link between vegetation changes and hydrogeology

A conceptual cross section across the site of T5 is shown in Figure 3-16. This shows thin alluvial sediments are present near the tributary of Boundary Creek. The groundwater lies within the Lower Tertiary Aquifer at this location. Based on groundwater levels in TB5 which is located on higher topography, the depth to groundwater at the transect site is approximately 5 m below the ground surface all year round. The groundwater level in TB5 was stable over the monitoring period with a slight increase of 0.5 m in December 2015/January 2016 (refer Appendix B for more information).

It is likely that the deeper rooted trees and shrubs at the site have access to groundwater, however, the majority of vegetation will more likely be dependent on soil moisture derived from rainfall. The lower than average rainfall in the past year may have led to changes in the vegetation cover of the various functional groups, however, the recent fire has had more influence than any other environmental factor as the agent of change.

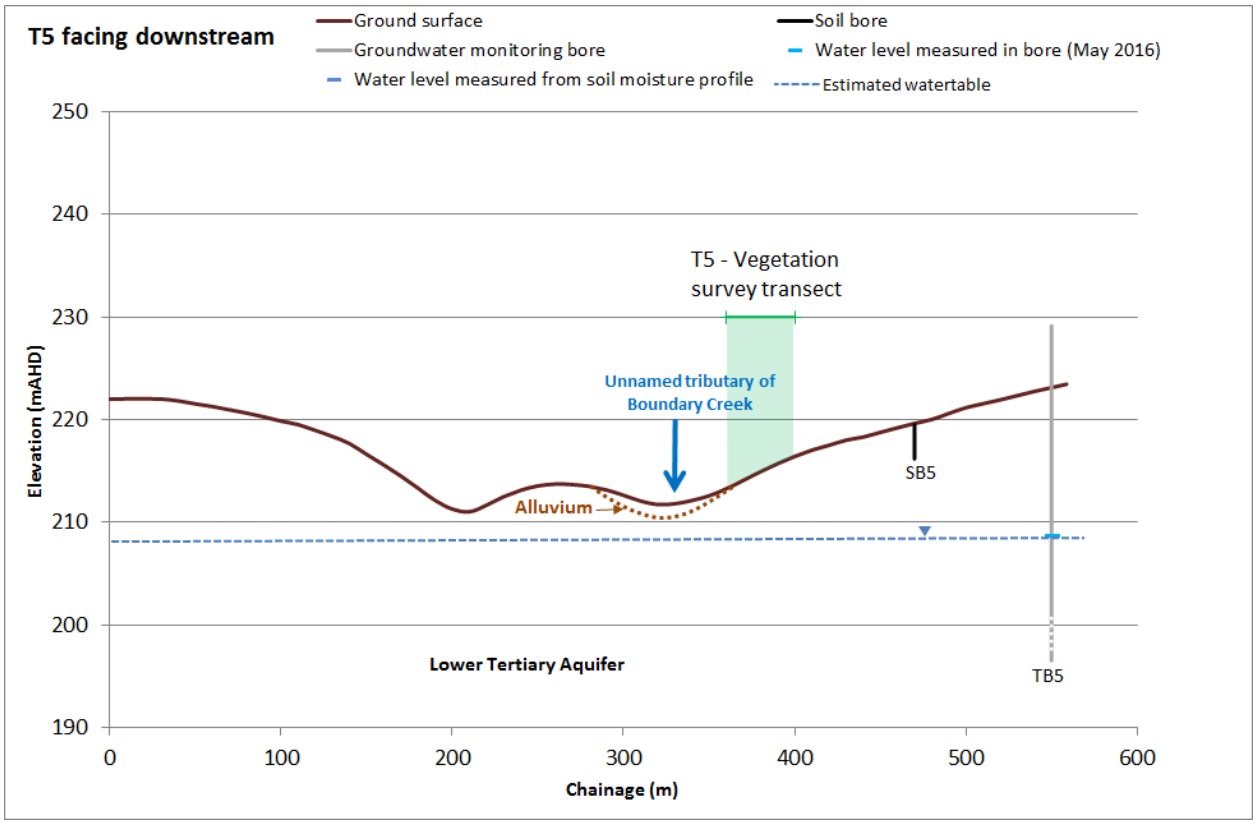


Figure 3-16 : Conceptual cross section of site T5.

3.5.4 Recommendations for future vegetation surveys

During the assessment it was investigated if there was a nearby location in un-burnt vegetation that would be a better location for monitoring in the future but none could be located – the entire drainage line for ~600 m downstream had been burnt and further than this was in very close proximity to a nearby shooting range. The same site should be monitored in the future but future vegetation surveys will need to interpret change in the context of a site recovering from fire. Particular attention should be given to the occurrence of species and their individual recovery response (i.e. do some perform better than others following fire) and also if additional species are detected that have not been described in this or previous reports.

3.6 Site T6

The location of site T6 is presented in Figure 3-17. Site T6 is located at valley of an un-named tributary of Boundary Creek north west and down-stream from an un-named access track off Langdons Road. The tributary does not have a defined channel within the transect and no surface water was observed.

The transect covers 40 m from the base of the large tree located 5 m north of the road on the east side of the tributary. The bore is located ~200 m west of the site at the end of Langdons Road. The area upstream of the site, on the southern side of the access track had been recently burnt as part of the controlled burns carried out in late 2015, however, this did reach the vegetation within the transect.

The site is a reference site, located outside the zone of influence from the borefield, where the Lower Tertiary Aquifer is unconfined.

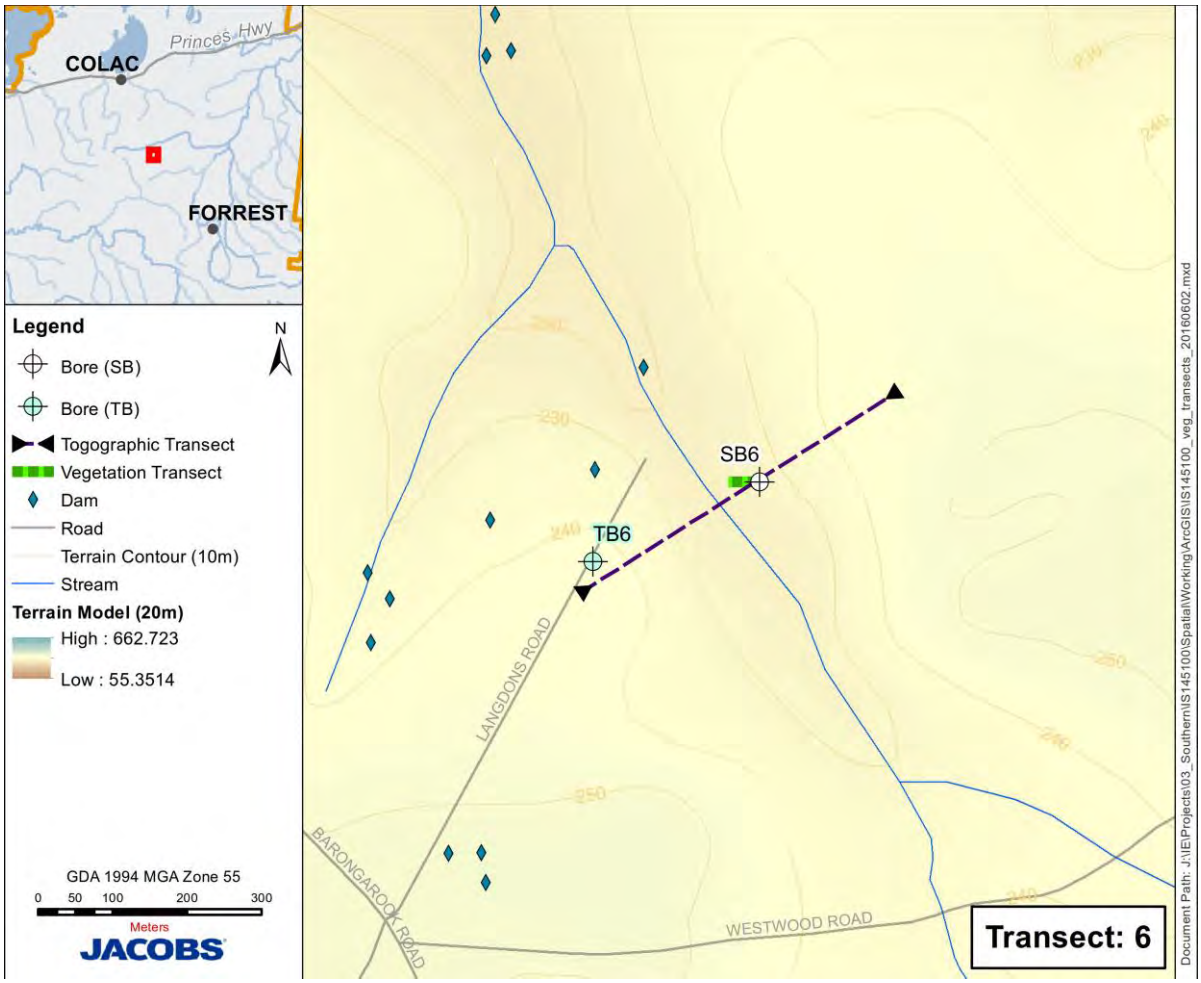


Figure 3-17 : Location of site T6.

3.6.1 Vegetation description

The vegetation within the transect is largely consistent as the valley of the tributary is wide with little change in topography across the transect. It comprises a mixed overstorey of Swamp Gum (*Eucalyptus ovata*) and occasional Messmate (*Eucalyptus obliqua*) to 15 m over a moderate cover of shrubs comprising Woody Tea-tree (*Leptospermum lanigerum*), the rare Currant-wood (*Monotoca glauca*) and Scented Paperbark (*Melaleuca squarrosa*). The understorey dominated by large sedges, predominantly Tall Sword-sedge (*Lepidosperma*

elatius) with some Red-fruit Saw-sedge (*Gahnia sieberii*) and scrambling grasses (*Tetrarrhena juncea* and *Poa tenera*). In contrast to other sites assessed, ferns were only a minor component of the vegetation at this site.

There are a number of fallen trees throughout the swampy area, some showing evidence of having fallen recently. As well, a number of shrubs were noticed to recently have fallen or broken. The cause of the shrub and trees falling was not evident from the field assessment, though the fact many trees had a distinct lean to them could be interpreted as evidence that the soil substrate is relatively unstable.

3.6.2 Evidence of change from 2014

The previous report noted that the canopy was open in setions of this site and attention should be given to whether increases in canopy cover were detected. The tree canopy estimates (29% to 26%) were largely unchanged.

The vegetation cover from two surveys, conducted in 2014 and 2016, is shown in Figure 3-18; species have been categorised based on their reliance on water availability. The pattern of vegetation cover across the transect is largely unchanged from November 2014 to March 2016, with most vegetation falling into functional group 3. However, there was a measured reduction in the cover of all functional groups with estimated vegetation cover declining from 140% to 97%. Most change appears to be related to changes in the grasses (23% to 4%) shrub layer (20% to 13%) as the tree canopy estimates (29% to 26%) and sedge cover estimates (45% to 43%) are largely unchanged.

Whilst the change in cover of shrubs can at least be partially attributed to noted breakages particularly of Scented Paperbark, there is no discernible reason for the change in cover of the grasses. The potential for this to represent seasonal change is not supported when similar changes were not noted at other sites assessed in Spring and Autumn. Nor is the possibility of water availability driven changes relevant given little change was observed in the sedge cover which comprises more water dependent species. It is possible that this change is more likely related to observer error given this is the only site not assessed in 2014/15 by the 2016 assessor as well. Future monitoring should pay particular attention to assessing grass cover in the future.

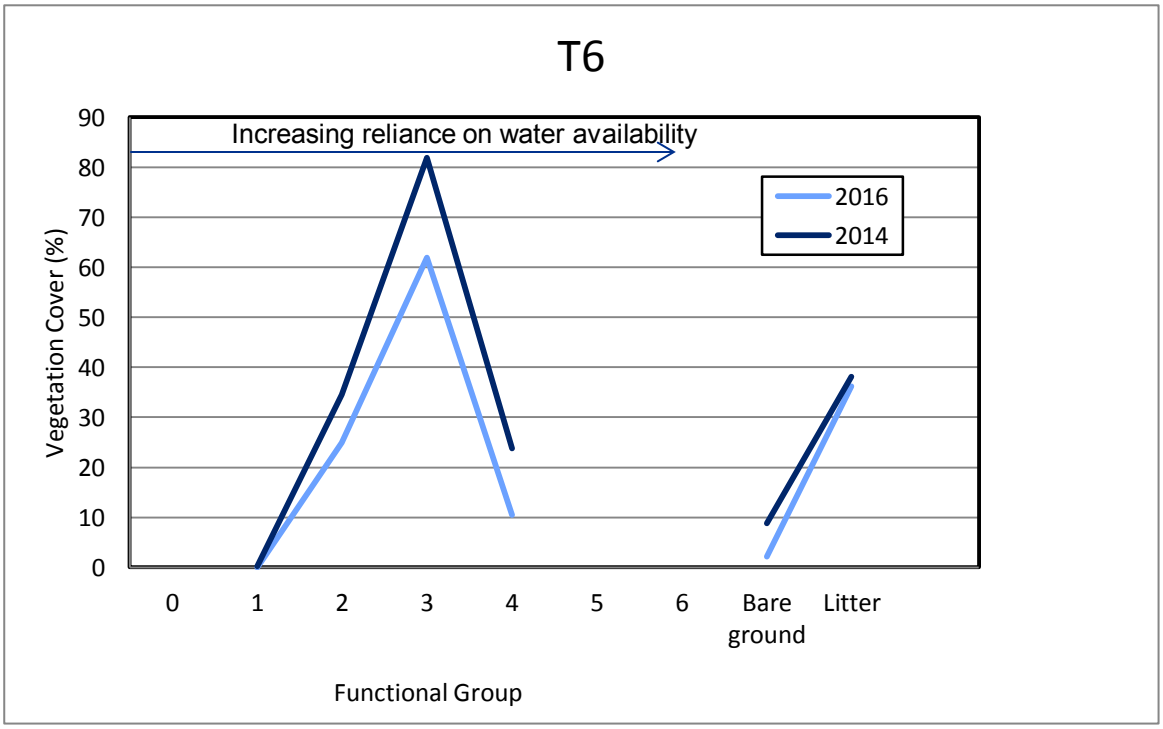


Figure 3-18 : Vegetation cover at site T6 according to functional grouping based on species reliance on water availability.

3.6.3 Link between vegetation changes and hydrogeology

A conceptual cross section across the site is shown in Figure 3-16. Thin alluvial sediments are present in the valley floor but not extensive. The topography rises away from the valley and the monitoring bore TB6 is located on higher ground. The watertable at the vegetation survey site lies within the shallow alluvial sediments and is likely to be within 2 m of the ground surface all year round. Most vegetation, particularly in the valley floor, is likely to have access to the groundwater. Groundwater levels have only decreased marginally by ~0.5m since February 2015 (refer to Appendix B for more information).

The vegetation at this site is highly likely to be dependent on the groundwater given its close proximity to the surface. Given that the observed changes in vegetation noted are unlikely to be related to changes in groundwater level, the changes could be a result of natural variation or observer error as previously noted.

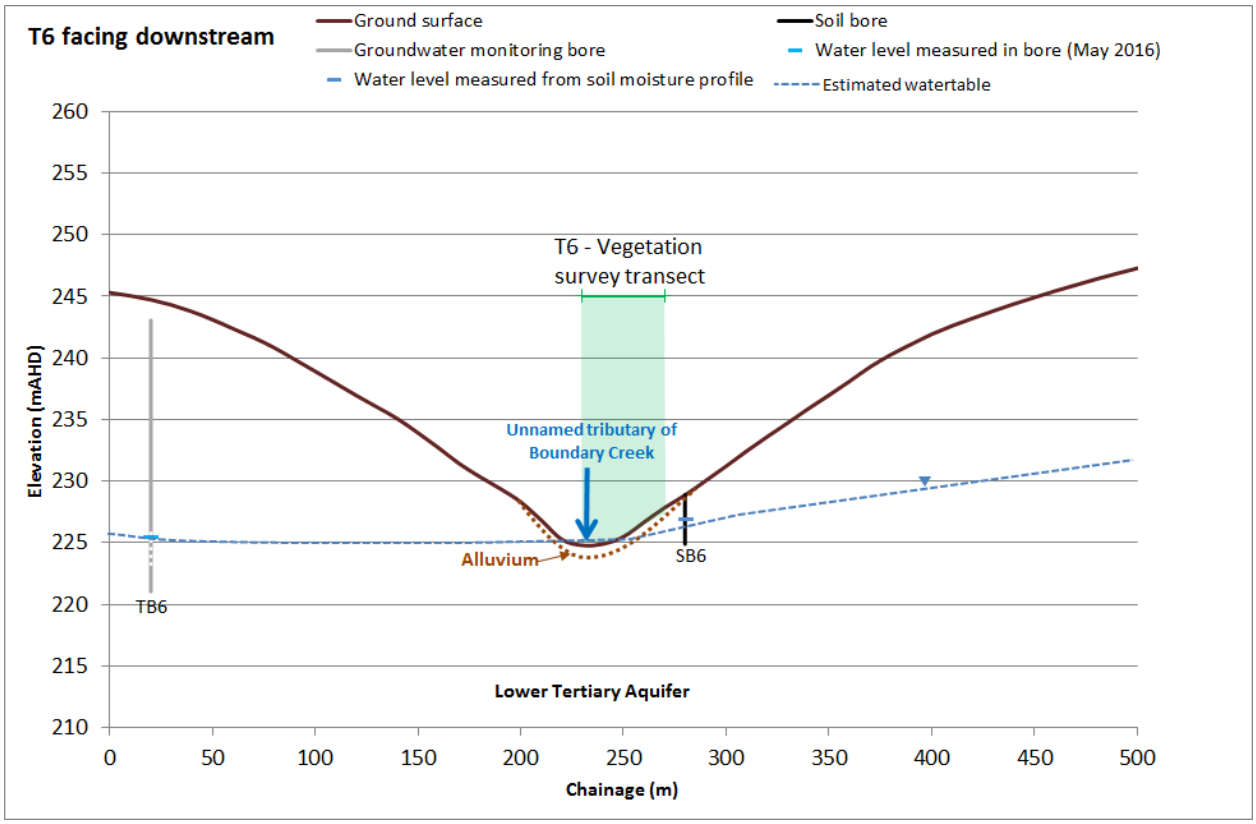


Figure 3-19 : Conceptual cross section of site T6.

3.6.4 Recommendations for future vegetation surveys

Future monitoring should pay particular attention to assessing grass cover in the future as this varied most widelty between this and the previous report.

3.7 Site T7

The location of site T7 is shown in Figure 3-20. Site T7 is located across the valley of an un-named tributary of Ten Mile Creek on an access track running off Robinson Road. The site is located on the western side of the track heading due west from the start location. The tributary at the site does not have a defined channel and operates as a drainage line that is heavily vegetated although the species composition changes markedly as described below. The surrounding slopes support Heathy Dry Forest

The start of the transect is located ~ 25 north west of the monitoring bore TB7 and is close to the Old Beechy Trail which is located approximately 50 m to the north. The site is a reference site, located outside the zone of influence from the borefield, where the Lower Tertiary Aquifer is unconfined.

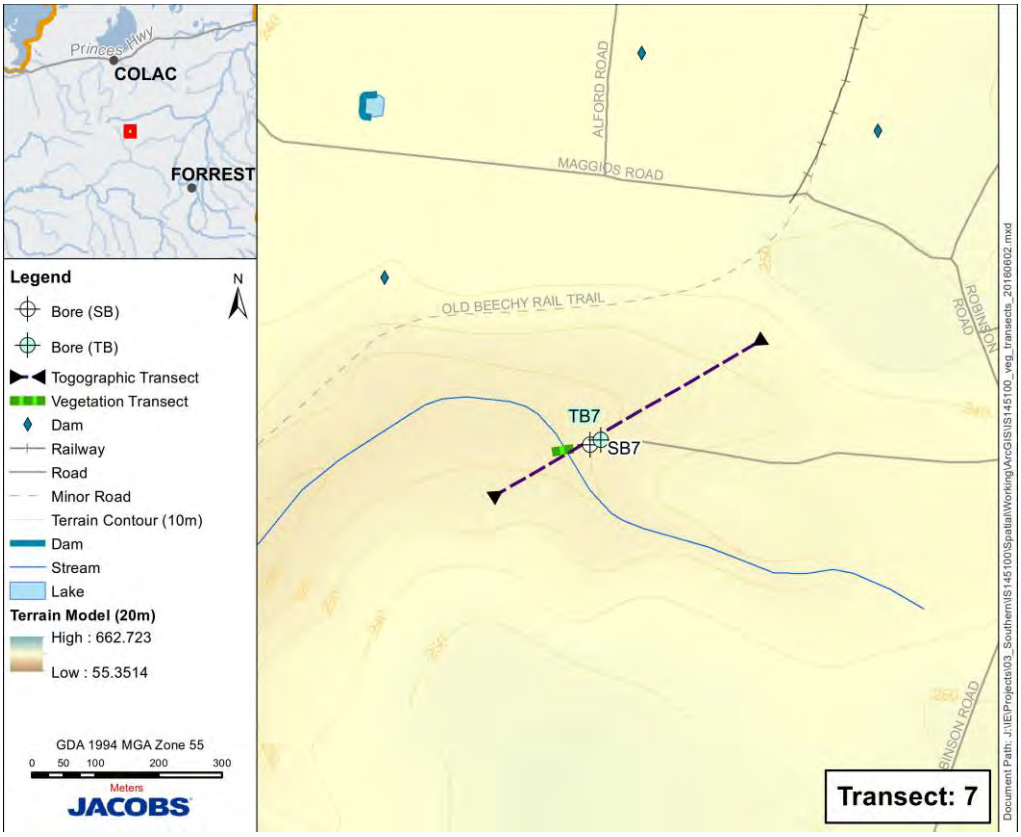


Figure 3-20 : Location of site T7

3.7.1 Vegetation description

The vegetation within the valley of the un-named tributary is distinctly different from the surrounding Heathy Dry Forest. Although surrounded by forested areas, the tributary supports dense vegetation with most species not detectable outside the narrow valley bottom. A tree layer is largely absent with Narrow-leaf Peppermint (*Eucalyptus radiata subsp. radiata*) and Messmate (*Eucalyptus obliqua*) to 15 m present only at the end of the transect in the transition zone to Heathy Dry Forest. There is a moderate cover of Scented Paperbark (*Melaleuca squarrosa*), Woolly Tea-tree (*Leptospermum lanigerum*) and the rare Currant-wood (*Monotoca glauca*) though each species tended to be dominant in different areas of the transect. Overall no species was detected in all quadrats across the transect which is a marked difference from other sites. Six fern species were present, dominated by Pouched Coral-fern (*Gleichenia dicarpa*) which formed dense thickets through many quadrats and Soft Tree-ferns (*Dicksonia antartica*) growing to 2.5 m, dominating quadrats 3 and 4. Sedges common at other sites were absent with the only sedge observed, Square Twig–sedge (*Baumea tetragona*), occurring only at this site and no others and then only at low abundance in 3 quadrats.

Two weed species of concern were detected, namely Yorkshire Fog (*Holcus lanatus*) and Blackberry (*Rubus anglocandicans*) in low abundance. These were removed when observed but should be checked in any future monitoring. Blackberry in particular has the capacity to become dominant in the damp conditions observed at this site.

3.7.2 Evidence of change from 2014

The previous report noted that particular attention should be given to the persistence of ground ferns and herbs at this site. In general, ground fern cover decreased across the site with Annual Fern not detected at all in this assessment. Herbs detected previously were identified again although not in all quadrats or different quadrats in which they were identified in 2014.

The vegetation cover from two surveys, conducted in 2014 and 2016, is shown in Figure 3-21; species have been categorised based on their reliance on water availability. The pattern of cover amongst the function groups is largely similar between the assessments in November 2014 and March 2016. The majority of cover comprises species in functional group 3, namely species reliant on readily available water but are not tolerant of regular inundation of the root zone. The only notable difference observed, either through comparison with previous photographs or numerically as shown in Figure 3-21, is the decline in cover in functional group 3 from 79% to 64%. This is almost entirely driven by a drop in cover in Pouched Coral-fern (40% to 29%) cover across most quadrats, mostly as a result of fronds being "burnt-off", i.e. drying out and dying from the outer extents. Pouched Coral-fern, is rarely as exposed as it is at this site, normally being protected by a tree and shrub canopy. Where it is protected by the overhanging Soft Tree-ferns in quadrats 3 and 4, there is no recorded decline in cover. As such, it is likely that changes in water availability, or increased exposure to light (i.e. lack of clouds), could drive the observed reduction in cover whilst other species better able to regulate water loss, or having deeper roots such as the shrubs and tree-ferns do not show a commensurate loss of cover.

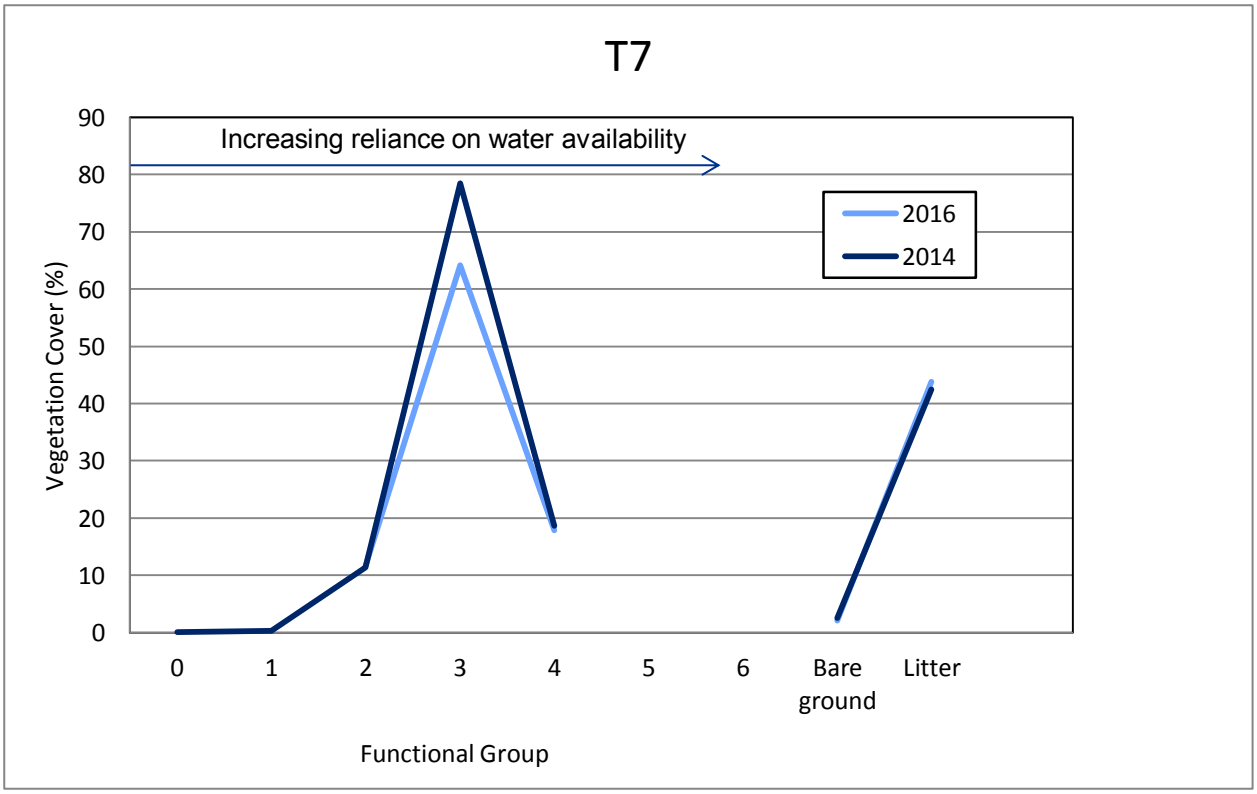


Figure 3-21 : Vegetation cover at site T7 according to functional grouping based on species reliance on water availability.

3.7.3 Link between vegetation changes and hydrogeology

A conceptual cross section across site T7 is shown in Figure 3-22. This shows there are thin alluvial sediments that contain groundwater in the valley floor overlying the Lower Tertiary Aquifer. Based on the water level in TB7 which is located on higher topography, the depth to groundwater at the transect site is approximately within 2m of the ground surface. Most vegetation is likely to have access to the groundwater.

Overall there has been a slight decline in groundwater levels at TB7 over the monitoring period, however, levels typically remain within 2 m of the ground surface at the vegetation transect (refer to Appendix B for further information).

The observed decline in cover of Pouched Coral-fern is likely to be the result of below average rainfall conditions and could be more sensitive to the seasonal decline in groundwater levels. It is likely that the vegetation will recover over the cooler winter months given the proximity of the watertable.

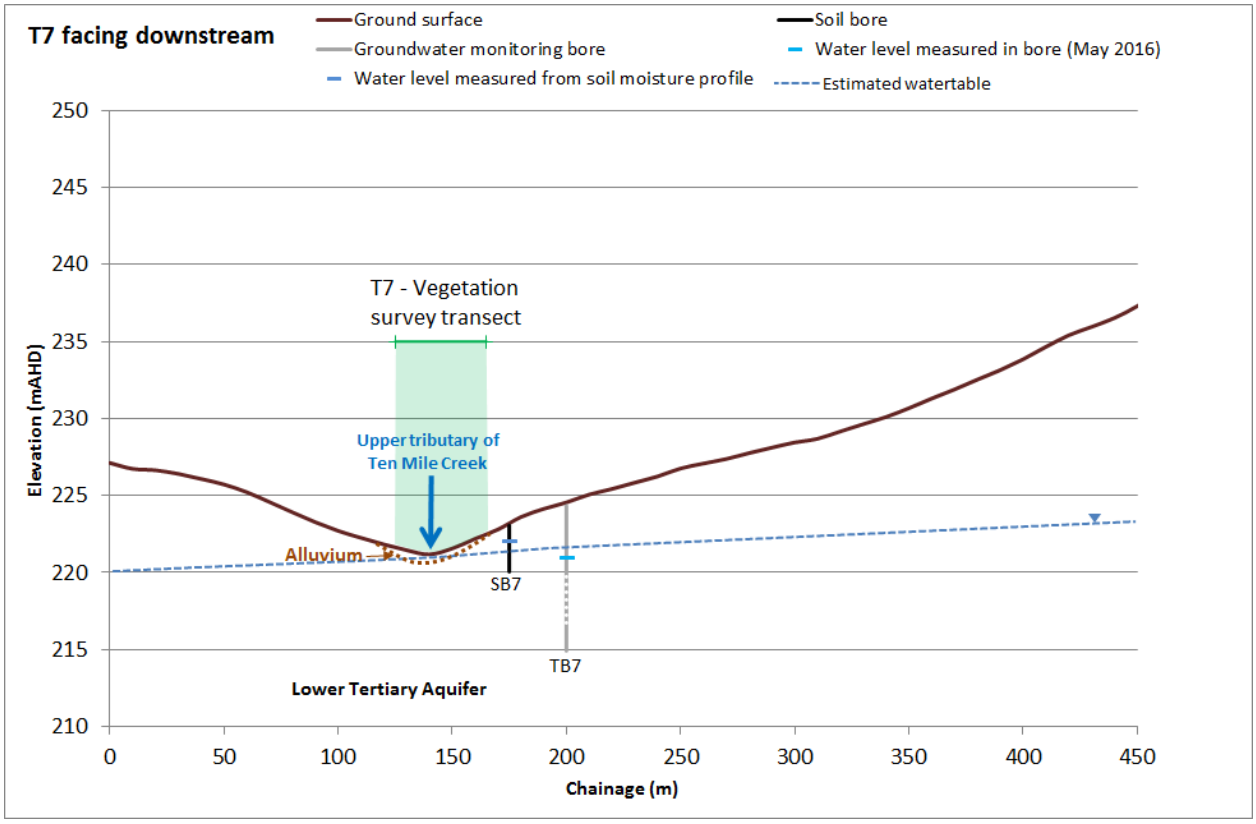


Figure 3-22 : Conceptual cross section of site T7.

3.7.4 Recommendations for future vegetation surveys

Particular attention should be paid to the cover of ferns and herbs at this site, similar to the recommendation in the previous report. A decline in the cover and abundance of these life forms has been noted and whether this trajectory continues or recovers will be important to understand.

3.8 Site T8

The location of site T8 is shown in Figure 3-23. Site T8 is located at a valley of an un-named tributary of Dividing Creek immediately south and downstream of Westwood Track ~250 m west of the intersection with Westwood Road. There is no defined channel at this location with the valley floor being relatively wide (~40 m) and with little change in topography across the transect compared to the surrounding slopes. No standing or running water was observed at the time of assessment.

The start of the transect is located ~ 30m west of the monitoring bore TB8 and 5 m south of the road heading at a bearing of 265, and ends at the edge of the valley floor at the base of a fallen tree and ~2 m from the invert of the valley floor to the surrounding slope. A steel post with a yellow plastic cap marks both ends. The transect covers the entire width of the valley floor with the vegetation at either end rapidly transitioning to Lowland Forest as is common on the surrounding slopes.

The site is located in area of potential impact from the borefield where the Lower Tertiary Aquifer is confined.

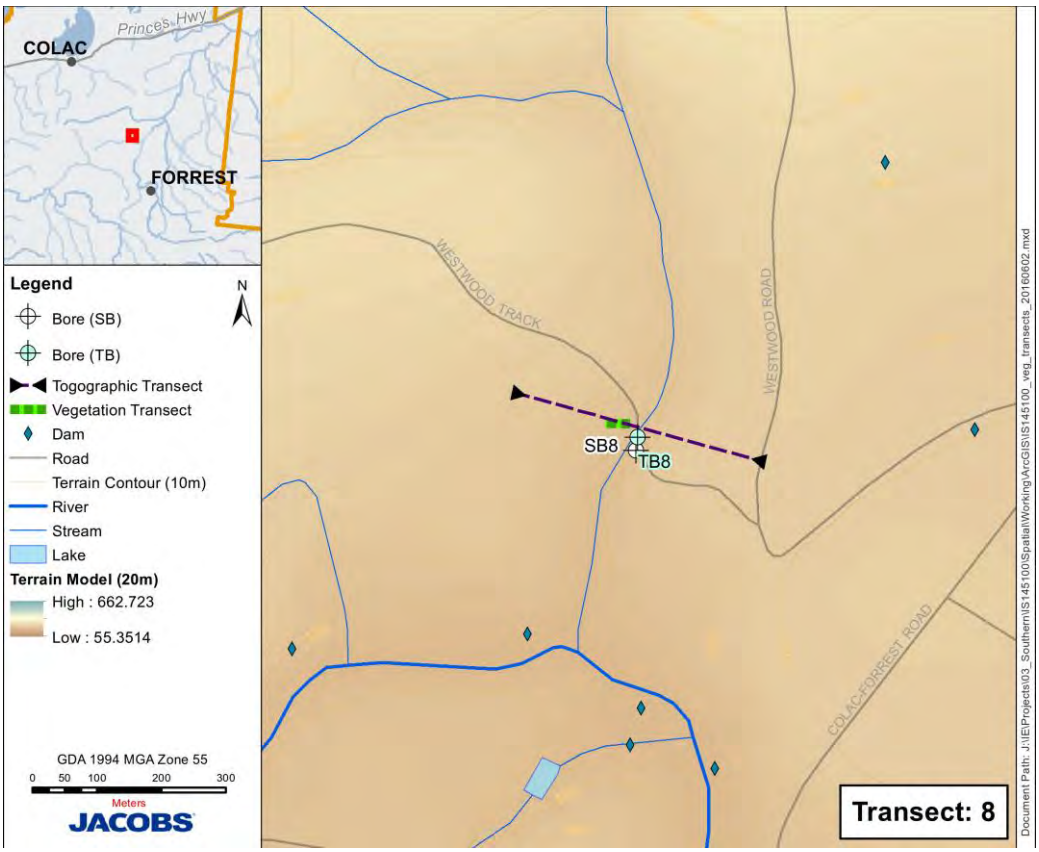


Figure 3-23 : Location of site T8

3.8.1 Vegetation description

The vegetation within the valley was defined by an overstorey of large Brooker's Gum (*E. brookeriana* and closely related to Swamp Gums) and Messmate (*Eucalyptus ovata).* There were a number of fallen trees within the community with two present at quadrats 4 and 7, and evidence of recently broken or fallen Scented Paperbark (*Melaleuca squarrosa*) which was present at the start of the transect and thinned out over quadrats 2-6. The vegetation was dominated by a dense ground layer of Water ferns (*Blechnum nudum* and *B. wattsii*), scrambling grasses (*Poa tenera and Tetrarhena juncea*) and large sedges (*Lepidosperma elatius* and *Gahnia sieberii*). The ground layer was diverse with a range of herbs and ferns, many present in disturbed ground on the edges of small animal tracks through the dense ground layer, or in the disturbed ground at the base of fallen trees. Many of the ferns present showed signs of recent "burning-off", whereby the fronds become dry and brittle from the ends. This is typically a response of ferns to water stress which can occur through lack of

available water and/or exposure to conditions resulting in high rates of evapotranspiration (e.g. hot and dry atmosphere, high winds, direct sun).

3.8.2 Evidence of change from 2014

The previous report suggesting noting the ongoing persistence of ground ferns and ground water dependent herbs at this site. Whilst ground ferns were still present, these appeared to be under stress and of lower cover compared to 2014. Ground water dependent herbs (e.g. *Senecio velloides*) was still present but in fewer quadrats than 2014.

The vegetation cover from two surveys, conducted in 2014 and 2016, is shown in Figure 3-24; species have been categorised based on their reliance on water availability. The distribution of the vegetation cover within site T8 is largely unchanged from November 2014 to March 2016 with the majority of cover attributable to functional group 3 (Figure 3-24). As with site T7, the cover attributed to functional group 3 has declined over time (54% to 48%) though to a lesser degree, and similar to site T7 this is mainly attributable to the decline in cover of fern species, at this site almost entirely due to burning off of the Water-ferns as noted above (20% to 13%). This is supported by a commensurate rise in the recorded litter levels.

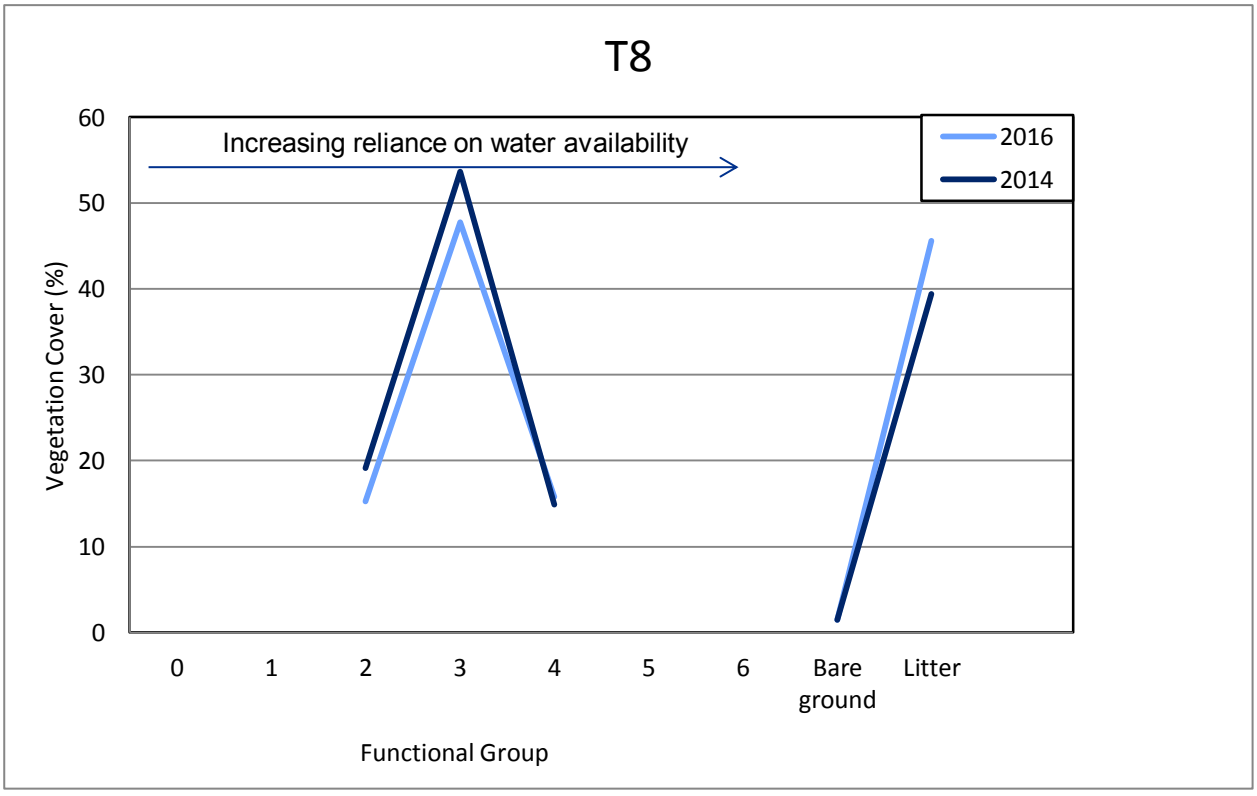


Figure 3-24 : Vegetation cover at site T8 according to functional grouping based on species reliance on water availability.

3.8.3 Link between vegetation changes and hydrogeology

A conceptual cross section across the site is shown in Figure 3-25. This shows that there are thin alluvial sediments that contain groundwater in the valley floor overlying the Lower Tertiary Aquifer. At the transect site groundwater is likely to be within 2 m of the ground surface. Most vegetation is likely to have access to the groundwater.

The groundwater levels at TB8 have varied by less than 1 m over the monitoring period; however, there was a decline of ~0.5 m over the last 7 months and water levels fell to ~2m below ground surface (refer to Appendix B for further information).

The decline in groundwater levels, particularly over the hotter summer months when evaporative stress is highest, correlates well with the drying of the ferns. The Water-ferns were particularly impacted, and are unlikely to be drawing significant water from 2 m or greater depth. It is possible that the groundwater level is now too deep for these plants to access. This impact would have been exacerbated by the relative lack of rainfall which will have contributed to a decline in soil moisture over the past year.

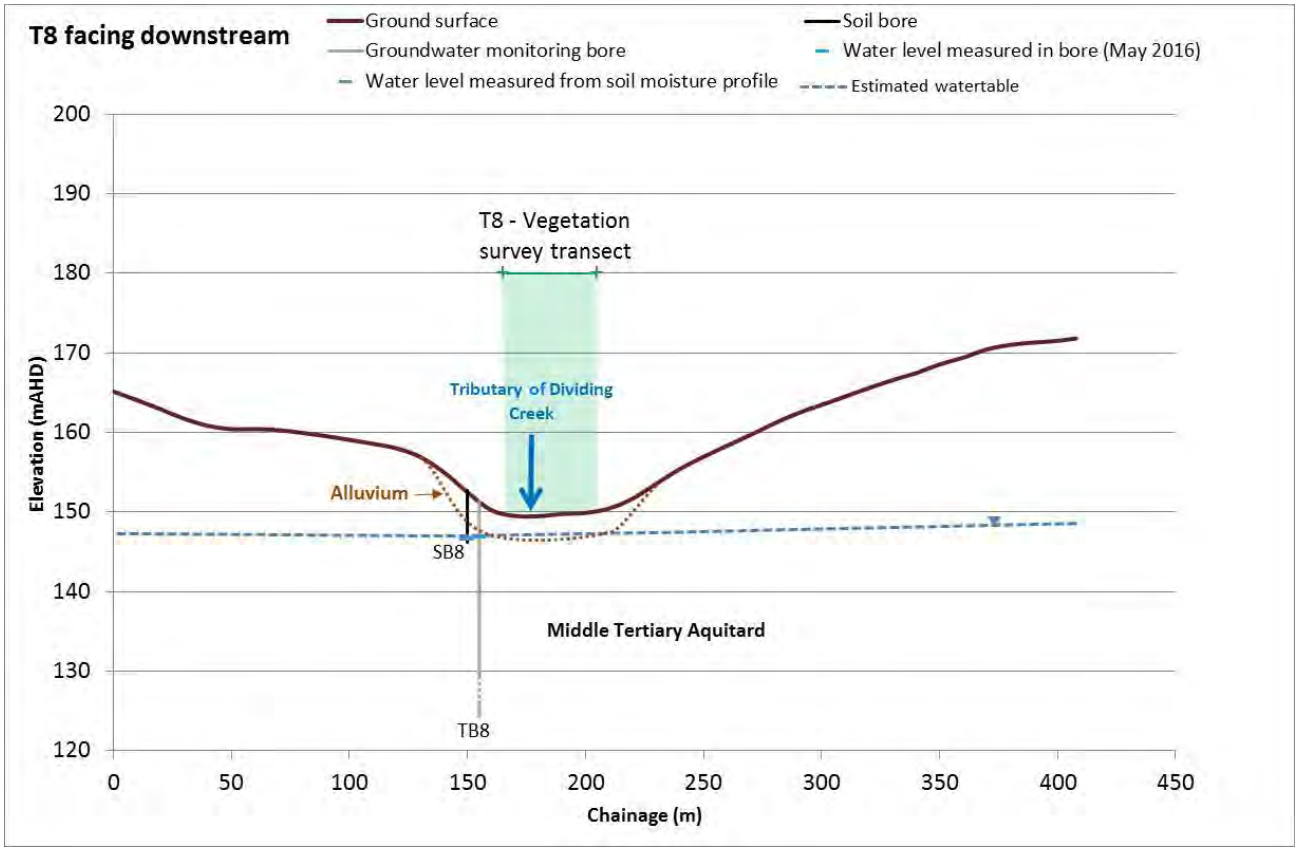


Figure 3-25 : Conceptual cross section of site T8

3.8.4 Recommendations for future vegetation surveys

The recovery of ferns from stress, or continued drying off, should be checked in future surveys along with the continued presence of ground herbs as these appear to be most sensitive to change in the water availability at this site.

3.9 Site T9

The location of site T9 is presented in Figure 3-26. Site T9 is located within Greater Otway National Park and is located on Porcupine Creek immediately north of Pipeline Road ~ 2km north of the intersection with Colac-Olangolah Pipeline Track. Porcupine Creek at this location flows in a narrow channel (2-3 m wide) and the valley is relatively narrow with the valley floor 15 to 20m wide. The creek at the time was of assessment flowing at low volumes. There is cleared farming land immediately to the north of the site.

The start of the transect is located ~ 30m north and on the opposite site of the road from the monitoring bore TB9 and 5 m north of the road on the eastern side of Porcupine creek heading at a bearing of 305 °.

The site is located in area of potential impact from the borefield where the Lower Tertiary Aquifer is confined.

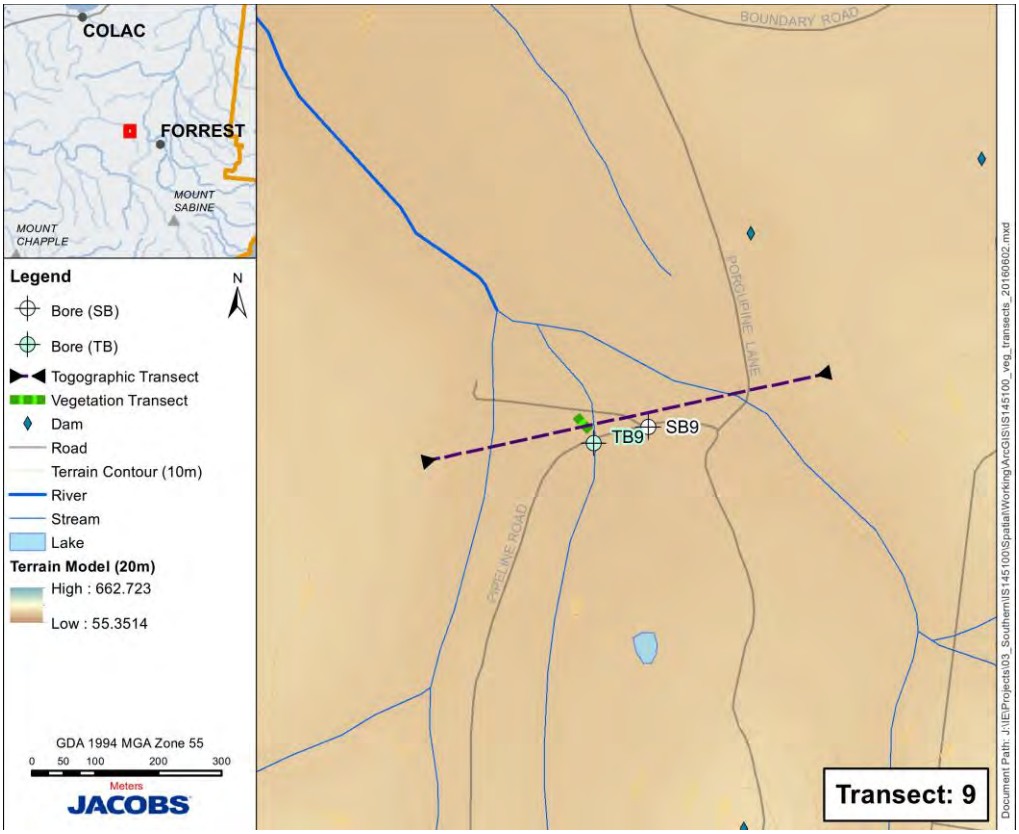


Figure 3-26 : Location of site T9.

3.9.1 Vegetation description

The vegetation along Porcupine Creek at the site comprises predominantly riparian species common in wetter forests throughout the Otway Range though not at other sites assessed; 10 species were recorded only at this site and no other. This included a dense mixed eucalypt overstorey (*Eucalyptus obliqua, E. radiata, E. brookeriana*) at over 30% cover and to 25 m tall, over a dense and diverse shrub layer (e.g. Prickly Currant-bush - *Coprosma quadrifida,* Privet Mock-olive - *Notelaea ligustrina*, Hazel Pomaderris - *Pomaderris aspera*). The site also has a diverse but sparse ground layer of sedges, ferns, grasses, herbs and scramblers in marked contrast to other sites.

3.9.2 Evidence of change from 2015

The previous report noted that there was room for ground ferns to expand at this site with a lot of bare ground and litter present. The combined cover of litter and bare ground has increased since 2014 and there has not been extra colonisation by ferns or other species at this site.

The vegetation cover from two surveys, conducted in 2014 and 2016, is shown in Figure 3-27; species have been categorised based on their reliance on water availability. Changes in the vegetation at site T9 are an increase in the cover of species assigned to functional groups defined as being ground water dependant, with those in functional group 3 increasing in cover from 28% to 37% and a small drop in cover in those assigned to functional group 4 (28% to 24%). It should be noted that the observed changes are relatively small compared to differences at other sites. The change in cover of the functional groups is due to changes in the covers of many species although none by more than 5% and typically less than 1%.

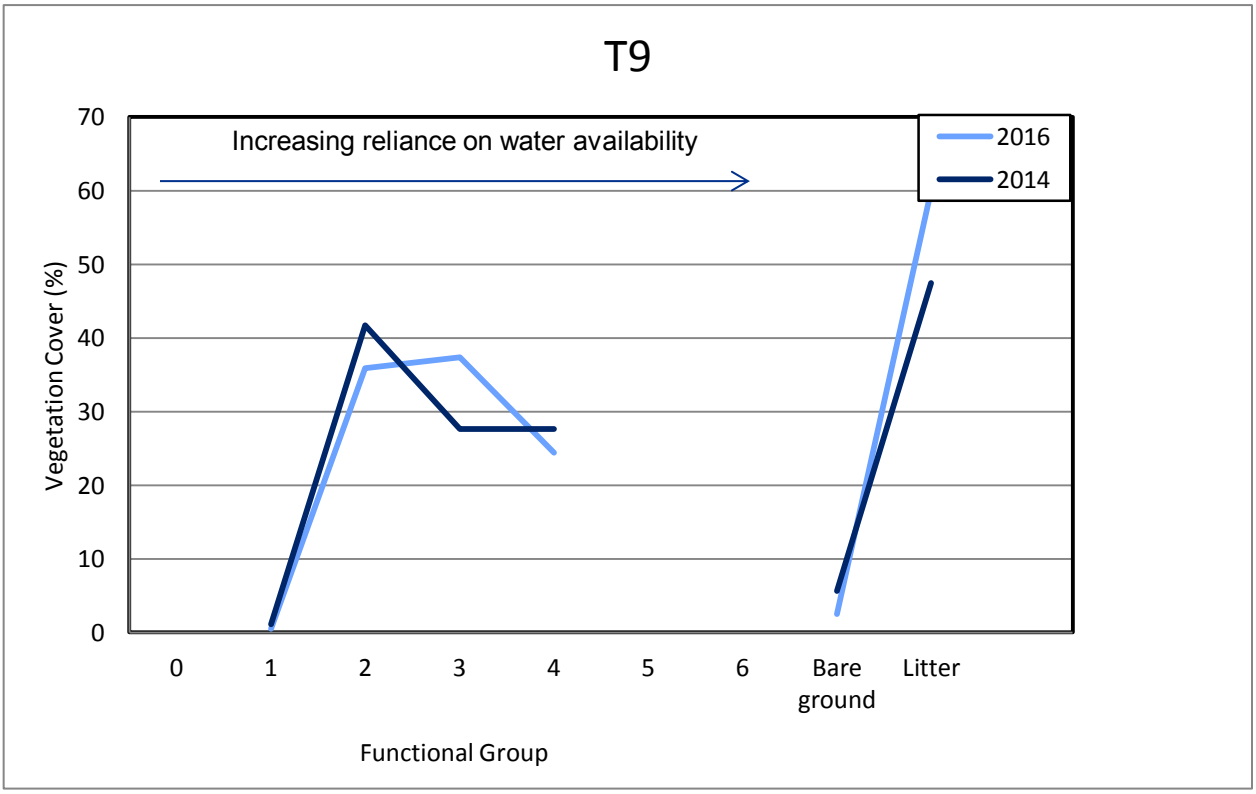


Figure 3-27 : Vegetation cover at site T9 according to functional grouping based on species reliance on water availability.

3.9.3 Link between vegetation changes and hydrogeology

A conceptual cross section across site T9 is shown in Figure 3-28. This shows there are alluvial sediments that contain groundwater in the valley floor. The watertable at the vegetation survey site lies within the shallow alluvial aquifer and is likely to be around 5 m below the ground surface. Most deeper rooted vegetation (i.e. trees and shrubs) can access to the groundwater, although is unlikely to be normally reliant on this water source given Porcupine Creek is more or less constantly flowing at this location.

Groundwater levels in TB9 have slightly declined over the monitoring period, dropping ~ 2m in the last 7 months (refer to Appendix B for further information). This is consistent with seasonal trends and below average rainfall conditions.

As noted above, the vegetation changes at this site are relatively small compared to a number of other sites and could not readily be attributed to one species or group. Given the depth to the groundwater is more than 3 m, and that the decline corresponds with a relative lack of rainfall, the changes noted is more likely attributable to a reduction in flow in Porcupine Creek as a result of less rainfall in the catchment rather than changes in the depth to groundwater.

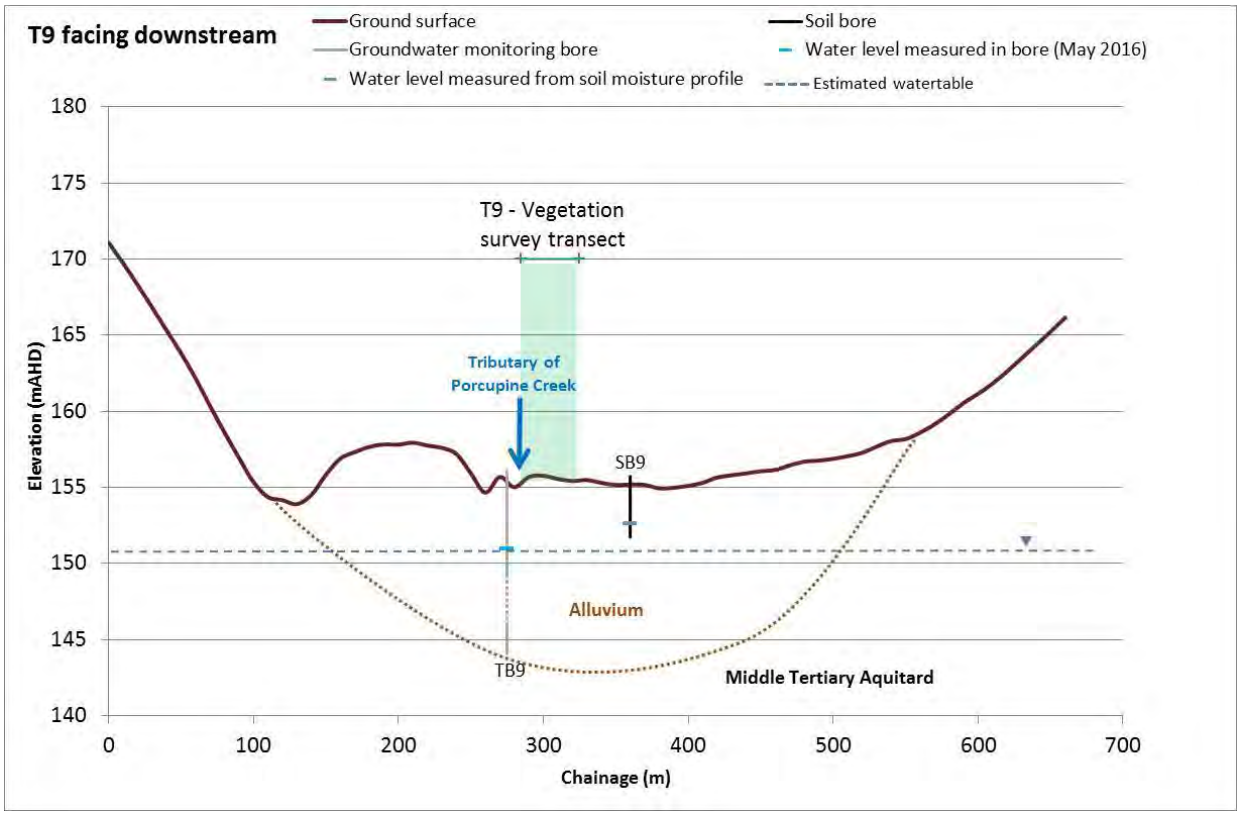


Figure 3-28 : Conceptual cross section of site T9.

3.9.4 Recommendations for future vegetation surveys

There are no specific recommendations for future surveys at this site.

3.10 Site T10

The location of site T10 is shown in Figure 3-29. Site T10 is located immediately south of Wares Road in Greater Otway National Park. The start of the transect is located ~ 5 m south of Wares road in thick scrub and west of the opposite site of the road from the monitoring bore TB9 and 5 m north of the road on the eastern side of Porcupine creek heading at a bearing of 305° and is marked by steel posts.

The location is the headwater of Dividing Creek though at this location there is no defined channel but rather a large wide valley. The site is located in area of potential impact from the borefield where the Lower Tertiary Aquifer is confined.

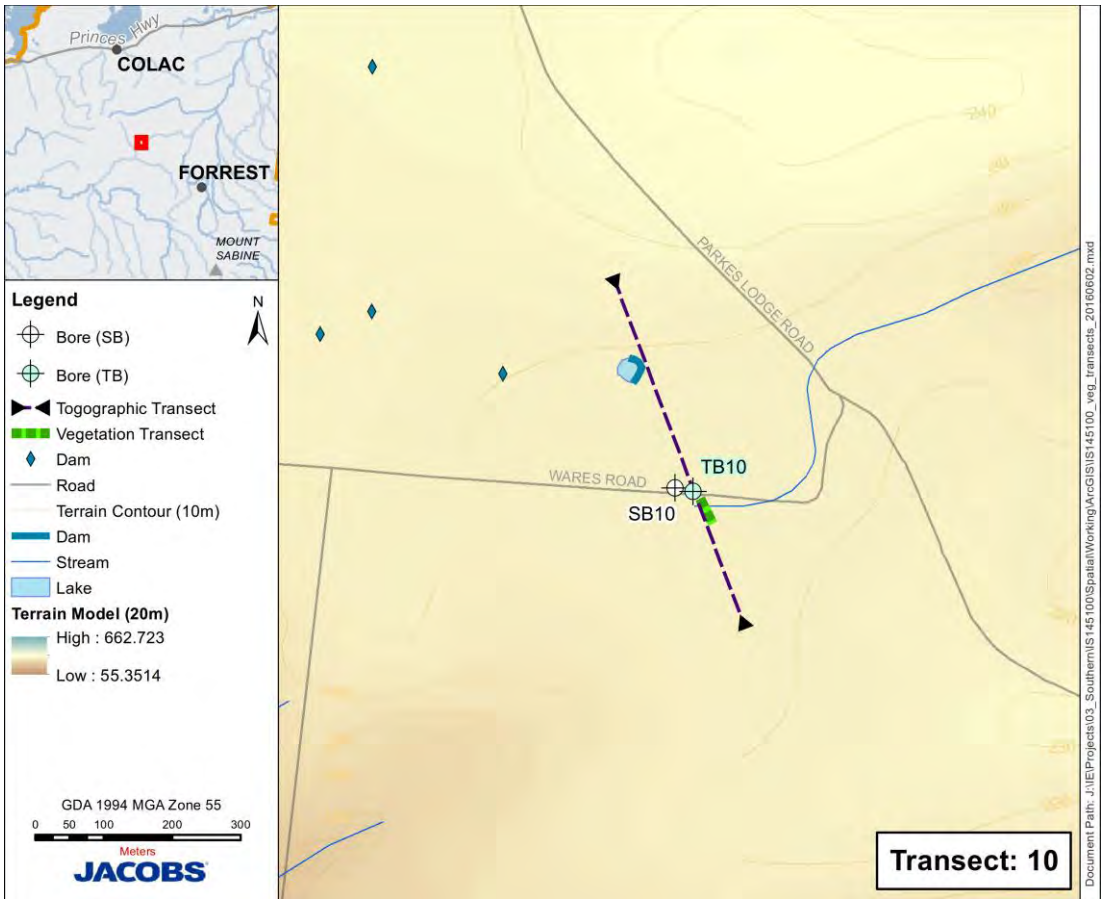


Figure 3-29 : Location of site T10.

3.10.1 Vegetation description

The vegetation at the site comprised Swamp Scrub with a dominant shrub layer of Woolly Tea-tree (*Leptospermum lanigerum*) with some Scented Paperbark (*Melaleuca squarrosa*) which together comprised over 40% cover across the site. A sparse overstorey of Swamp Gum (*Eucalyptus ovata*) and occasional Narrow-leaf Peppermint (*Eucalyptus radiata subsp. radiata*) was present throughout but the ground layer was sparse, dominated by a thick and spongy litter layer (average of over 50% across the transect) and large sedges sedges (*Lepidosperma elatius* and *Gahnia sieberii*). A range of grasses and ferns were also present though none comprised more than 5% of any quadrat.

3.10.2 Evidence of change from 2014

The previous survey made note that there were few ferns present at this site, in stark contrast to most other sites with similar vegetation. This was continued in this assessment with no new fern species detected or major changes in the cover of those present.

The vegetation cover from two surveys, conducted in 2014 and 2016, is shown in Figure 3-18; species have been categorised based on their reliance on water availability. There was little evidence observed in the functional group analysis across site T10 as shown in Figure 3-30; no category changed by more than 5% which can be considered well within the margin of error for cover estimates. There were changes in the cover of individual species with a drop in the cover of Woolly Tea-tree (48% to 38%, likely the result of some shrubs falling) offset by increased cover of other species including the large sedges (34% to 38%).

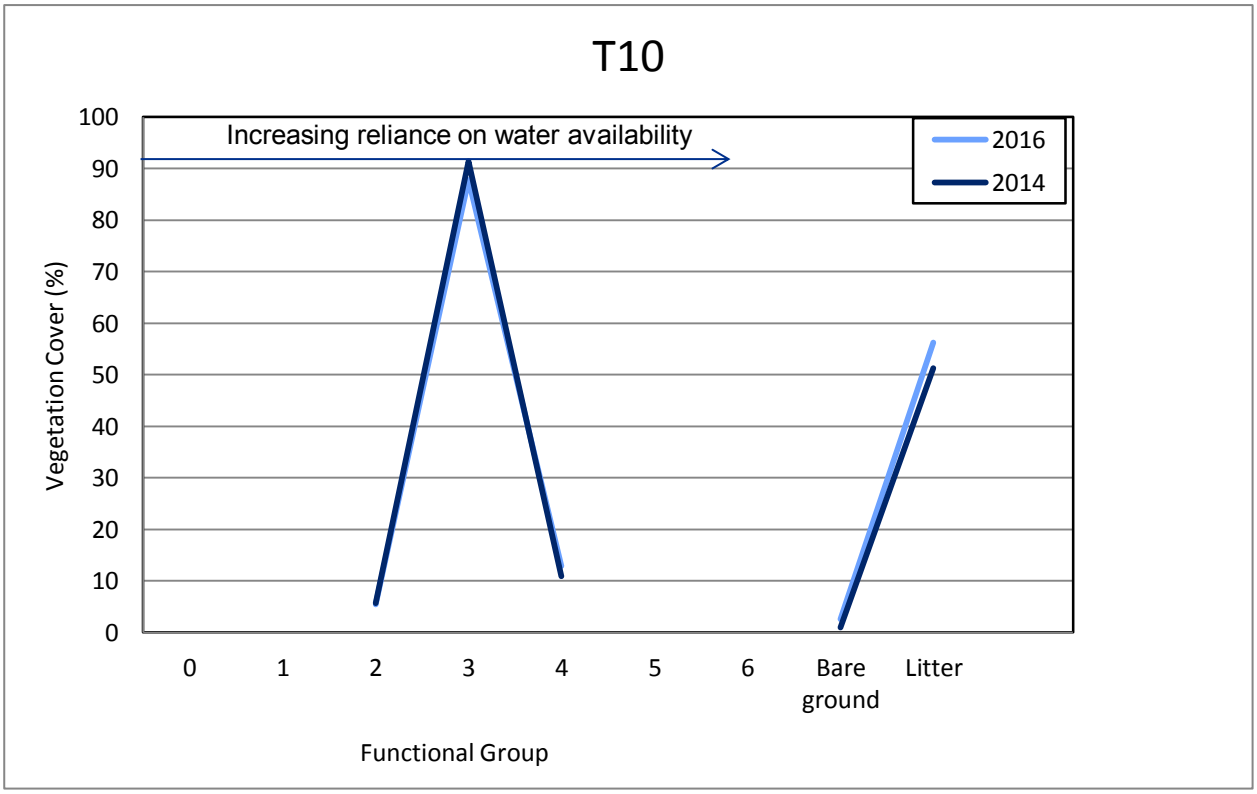


Figure 3-30 : Vegetation cover at site T10 according to functional grouping based on species reliance on water availability.

3.10.3 Link between vegetation changes and hydrogeology

A conceptual cross section across the site is shown in Figure 3-31. This shows there are alluvial sediments that contain groundwater in the valley floor which is underlain by Mid Tertiary Aquitard. The watertable at the vegetation survey site lies within the shallow alluvial aquifer and is likely to be within 5 -10 m of the ground surface. Most larger woody vegetation is likely to have access to groundwater, although ferns and sedges are unlikely to be able to draw on this water source. Groundwater levels in TB10 have declined by ~ 2.5 m over the monitoring period, falling to ~7m below ground surface at the vegetation transect location (refer to Appendix B for further information).

The vegetation at this site is most likely drawing on soil moisture within the un-saturated zone of the alluvial layer, which was still moist at the time of assessment. The presence of the aquitard may assist in maintaining soil moisture within the alluvium. The relatively deep groundwater is likely to be reason there are relatively few ferns at this site compared to other locations.

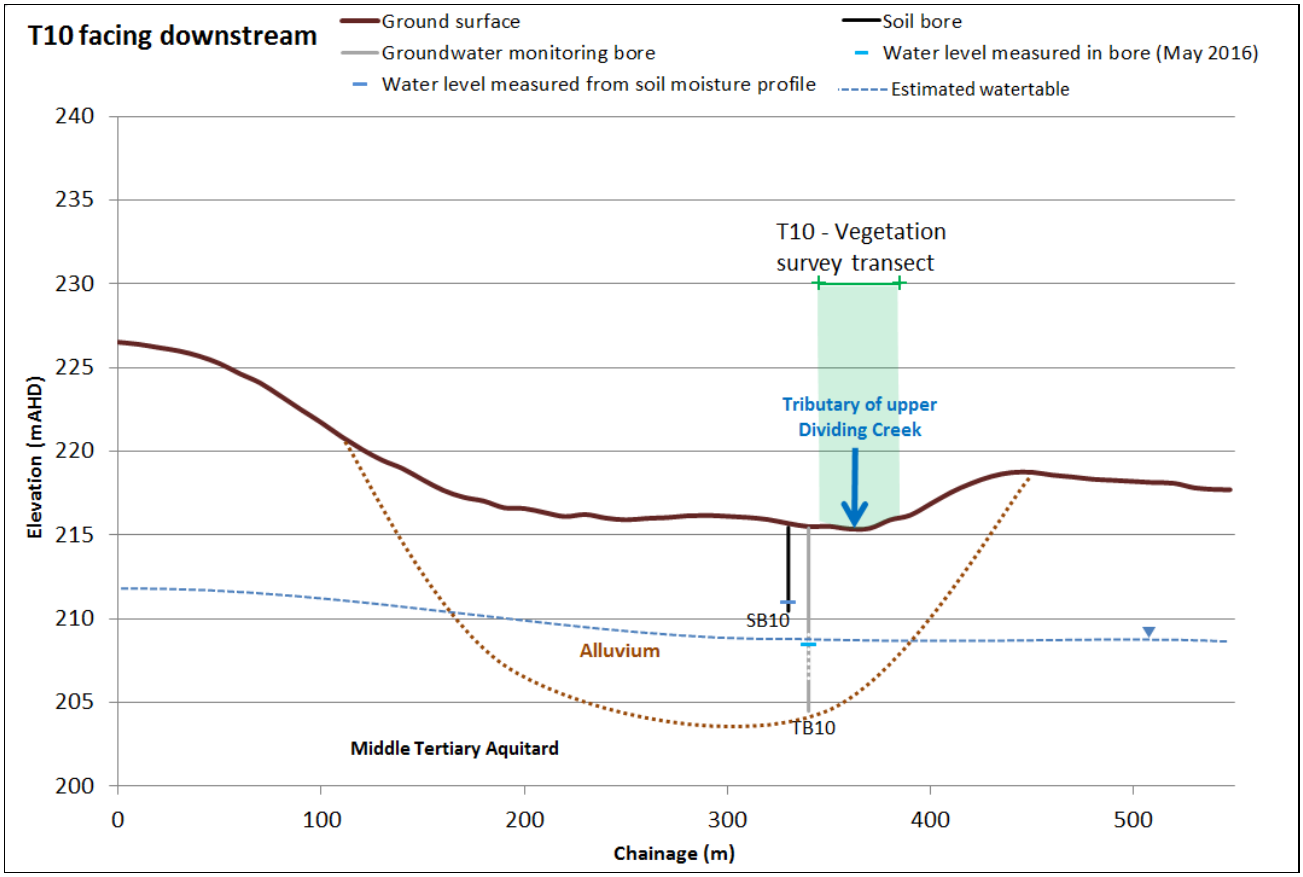


Figure 3-31 : Conceptual cross section of site T10.

3.10.4 Recommendations for future vegetation surveys

There was change in the suite of herbs and ground cover species present at this site. Whilst this is not particularly meaningful based on the surveys to date given the ephemeral nature of most of these species a comparison of the suite of species present at ground level and whether this is still changeable should be included in future surveys

3.11 Site T11

The location of site T11 is presented in Figure 3-32. Site T11 is located on the west side of Colac –Olangolah Pipeline Road north at Porcupine Creek. At this location Porcupine Creek occurs in a wide valley with the transect located on the northern margin of the valley to better enable monitoring of potential change.

The start of the transect is located ~ 10 m west of Colac –Olangolah Pipeline Road ~200 m north of bore TB11 in thick understorey vegetation, north and slightly uphill from the valley floor and continues at a bearing of 192°. The transect was relocated by GPS and comparison with photographs from the previous report.

The site is a reference site, located outside the zone of influence from the bore where the Lower Tertiary Aquifer is confined.

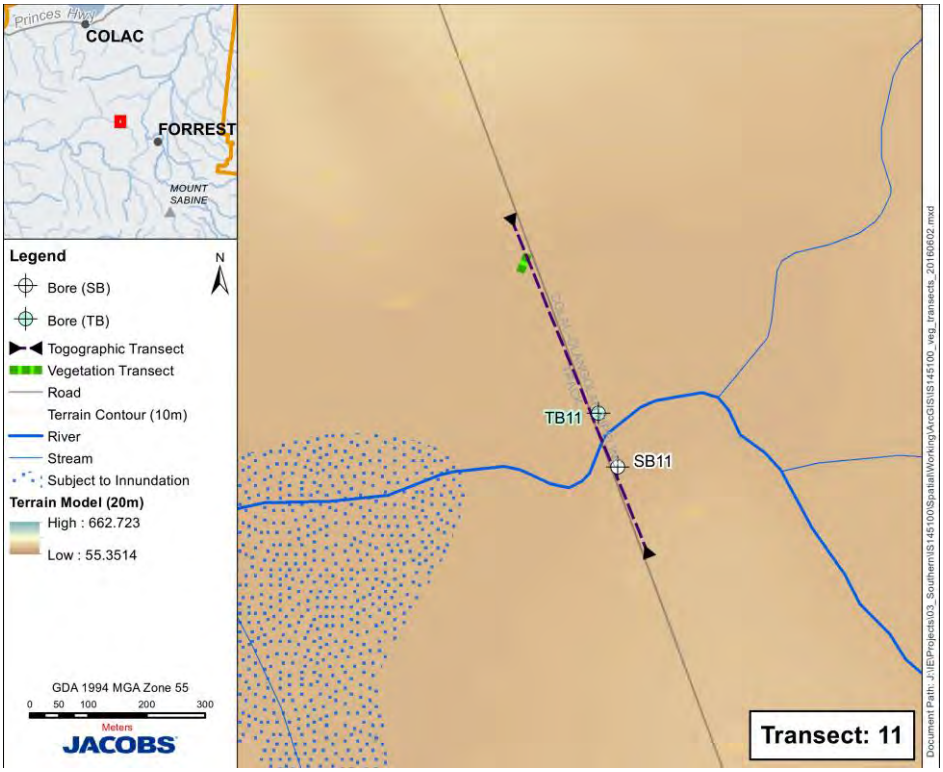


Figure 3-32 : Location of site T11

3.11.1 Vegetation description

This forest ecosystem had a mixed eucalyptus overstorey dominated by a mixed overstorey of Messmate (*Eucalyptus obliqua*) and the rare Brooker's Gum (*Eucalyptus brookeriana*) growing to 25 m. There was a sparse but relatively diverse shrub layer with the ground layer dominated by large sedges (*Lepidosperma elatius and Gahnia sieberii* to an average of 38%) as is common at a number of other sites. Shrubs were sparse and a range of ferns (*Pteridium esculentum, Cyathea australis, Blechnum wattsii*) scrambling grasses (*Poa tenera and Tetrarhena juncea*) and diverse but sparse herb layer was present although very open with litter dominant at ground level (average of 53%).

3.11.2 Evidence of change from 2015

The persistence of herb species at this site was noted as being of interest in the previous report; although remaining at low cover, certain species were not re-detected during this assessment (e.g. *Dichondra repens, Geranium sp. Hydrocotyle sp.*) though these were each previously detected in only one quadrat for each species.

The vegetation cover from two surveys, conducted in 2014 and 2016, is shown in Figure 3-33; species have been categorised based on their reliance on water availability. Although there were few changes from March 2015 to April 2016 in the functional group analysis shown in Figure 3-33, with the greatest change being in category 4 (39% to 32%), these figures mask a marked change in certain plant groups. Ferns, particularly Water-ferns, were markedly reduced in cover and declined from 20% to 3% average cover. These ferns have largely died back and the breakdown of old fronds could explain the large increase in recorded litter (35% to 53%). The decline in fern cover has been offset by an increase in the cover of large sedges which increased from 18% to 38% average cover. This is a dramatic change in one year and future monitoring should pay close attention to the trajectory of these two plant classes.

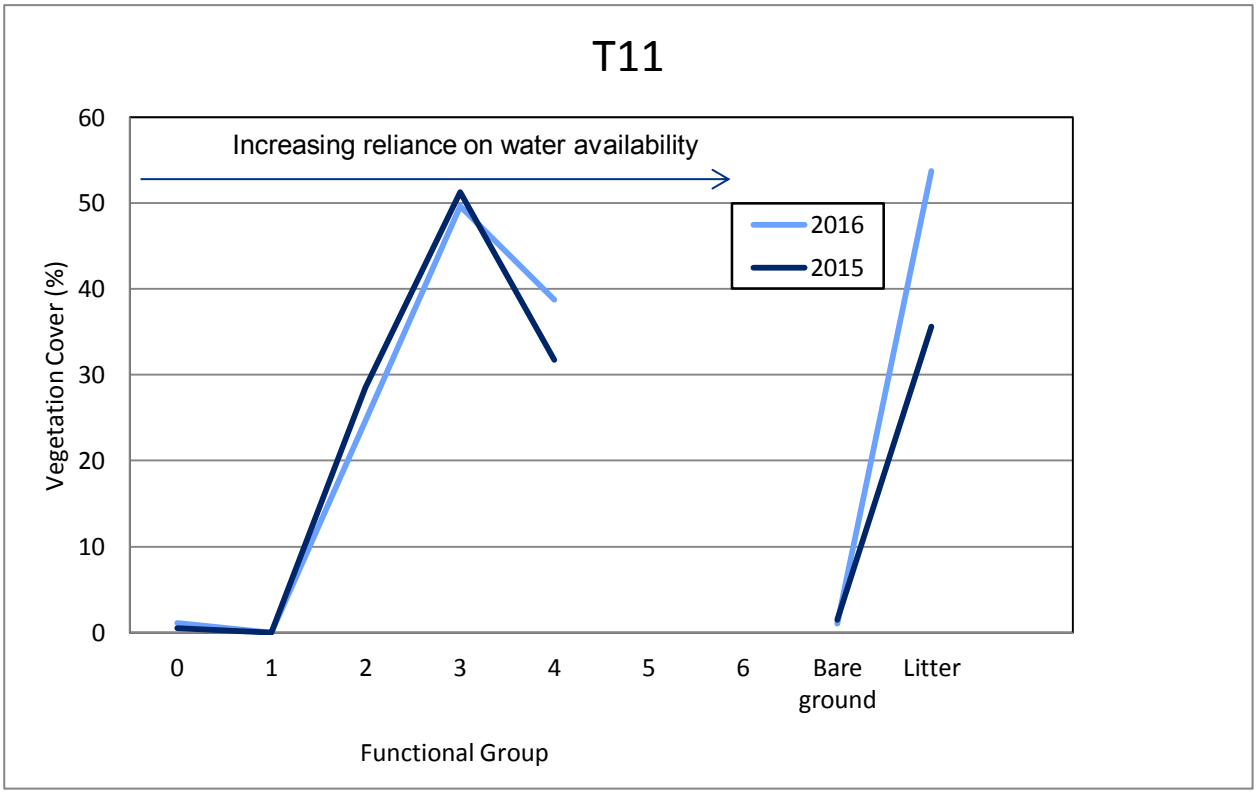


Figure 3-33 : Vegetation cover at site T11 according to functional grouping based on species reliance on water availability.

3.11.3 Link between vegetation changes and hydrogeology

A conceptual cross section across site T11 is shown in Figure 3-34. This shows there are thick alluvial sediments (~10m) that contain groundwater in the valley floor. The watertable at the vegetation survey site, which is located on higher topography, lies within the Middle Tertiary Aquifer and is likely to be within 10 m of the ground surface all year round. Groundwater levels in TB11 have remained around ~8m below ground surface at the vegetation survey site and have fluctuated seasonally by ~3 m (refer to Appendix B for further information). Woody vegetation is likely to have access to groundwater.

The relatively deep groundwater at this location means the decrease in fern cover is related to the relatively low rainfall over the most recent summer rather than changes in groundwater level. Other vegetation groups did not appear to be stressed during recent monitoring period but could decline if the current dry conditions persist.

It should be noted that this transect is not located in the optimal location for monitoring changes in the vegetation. The groundwater levels are greater than 3 m, which means only some vegetation can access the groundwater. The remainder of the vegetation is reliant of rainfall and surface water. The location was originally selected to due its proximity to the trees sampled for the tree water use study (Jacobs, 2015). However, this transect could be relocated closer to Porcupine Creek, where there is available surface water and potential changes in vegetation health will be easier to detect. This is discussed further in Section 5.2.

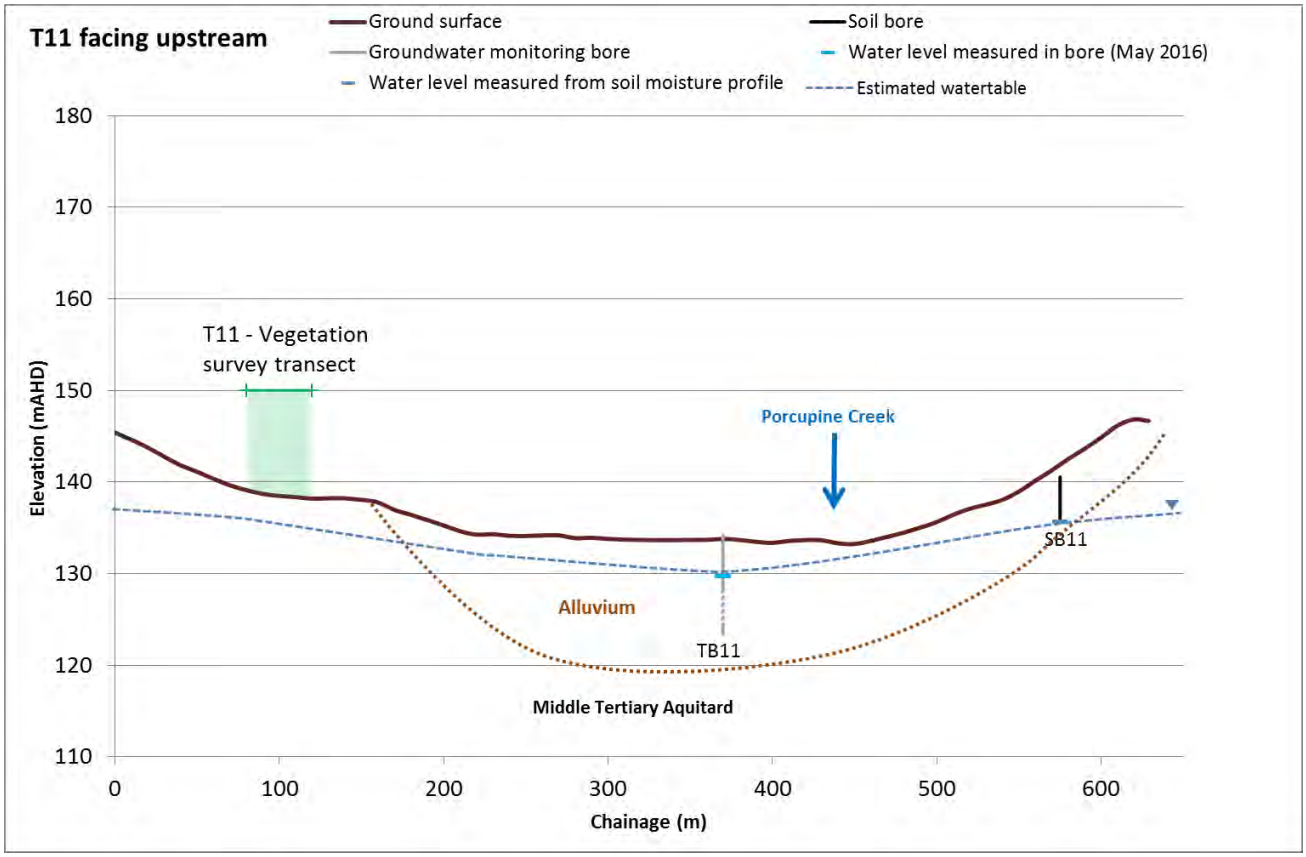


Figure 3-34 : Conceptual cross section of site T11.

3.11.4 Recommendations for future vegetation surveys

It is recommended that T11 be moved closer to the swamp area (Porcupine Creek) as shown in Figure 3-32. The current site was chosen based on proximity to trees used in other reports relating to Barwon Downs and this rationale is no longer a driving factor. The vegetation at the swamp is more likely to be of interest to this and future surveys.

3.12 Site T12

The location of site T12 is presented in Figure 3-35. Site T12 is located on the north-east side of Gold Hole Road north on an unnamed tributary of Dividing Creek in Greater Otway National Park. This site is located downstream from site T13 and is in a gentle sloping valley. There is no defined channel at the tributary within the transect and no surface water was observed.

The start of the transect is located ~ 5m north of Gold Hole Road in thick scrub at the base of a Swamp Gum located south of the waterway and continues at a bearing of due north across the tributary. The start location is on the same side of the waterway and opposite side of the road of bore TB12, which is approximately 25 m from the start location.

The site is a reference site, located outside the zone of influence from the bore where the Lower Tertiary Aquifer is confined.

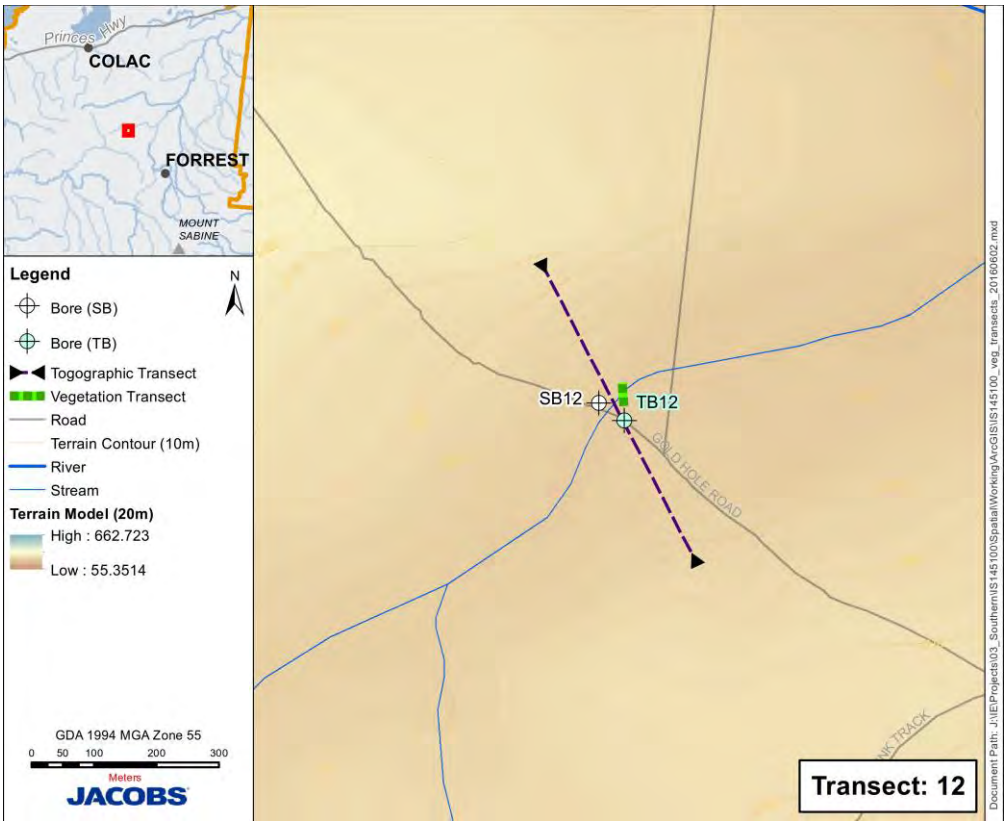


Figure 3-35 : Location of site T12.

3.12.1 Vegetation description

Located within a wide valley, this site has an open overstorey of Swamp Gum to a height of ~20 m over a shrub layer dominated by Prickly Moses (*Acacia verticillata*) although relatively diverse with a further 9 species detected. The presence of dense Prickly Moses is peculiar only to this site and unusual in that this species occurs readily in surrounding drier forests where water availability is lower than at this site and therefore is assigned as a category 2 or opportunistic species. Other shrub species such as Blanket Leaf (*Bedfordia arborescens*) and Scented Paperbark (*Melaleuca squarrosa*) are more typical of rainforest or swamp communities but in low abundance at this site. The ground layer was dominated by scrambling grasses with a sparse but diverse ground layer comprising a number of ferns (5 species) and herb species (12).

Interestingly, although many groundwater dependent species were detected, more than 50% of the vegetation cover is due to plants classified as opportunistic species (Category 2). Opportunistic terrestrial species dominate at this location.

3.12.2 Evidence of change from 2015

A statement in the previous report noted that special attention should be given to the persistence of ground ferns at this site given they are most likely to be susceptible to changes in the availability of ground water. As noted below, fern cover has declined in line with general decreases noted for most species at the site.

The vegetation cover from two surveys, conducted in 2014 and 2016, is shown in Figure 3-36; species have been categorised based on their reliance on water availability. The changes detected at this site involve a decrease in the overall vegetation cover estimates (120% in 2015 to 102%) due entirely to a reduction in the cover of species in functional group 2 (76% to 57%). The drop in cover is not due to changes in any one species or plant group in particular but rather a general reduction in cover overall. The largest change was a drop in the cover of Forest Wire-grass (*Tetrarrhena juncea*) from 13% to 7%. A rise in the litter present at the site (31% to 43%) was also recorded which would support this finding.

Overall the change does not appear to be related to changes in water availability given differences were only detected in species in functional group 2, defined as opportunistic species, whilst cover of functional groups 3 and 4 barely changed.

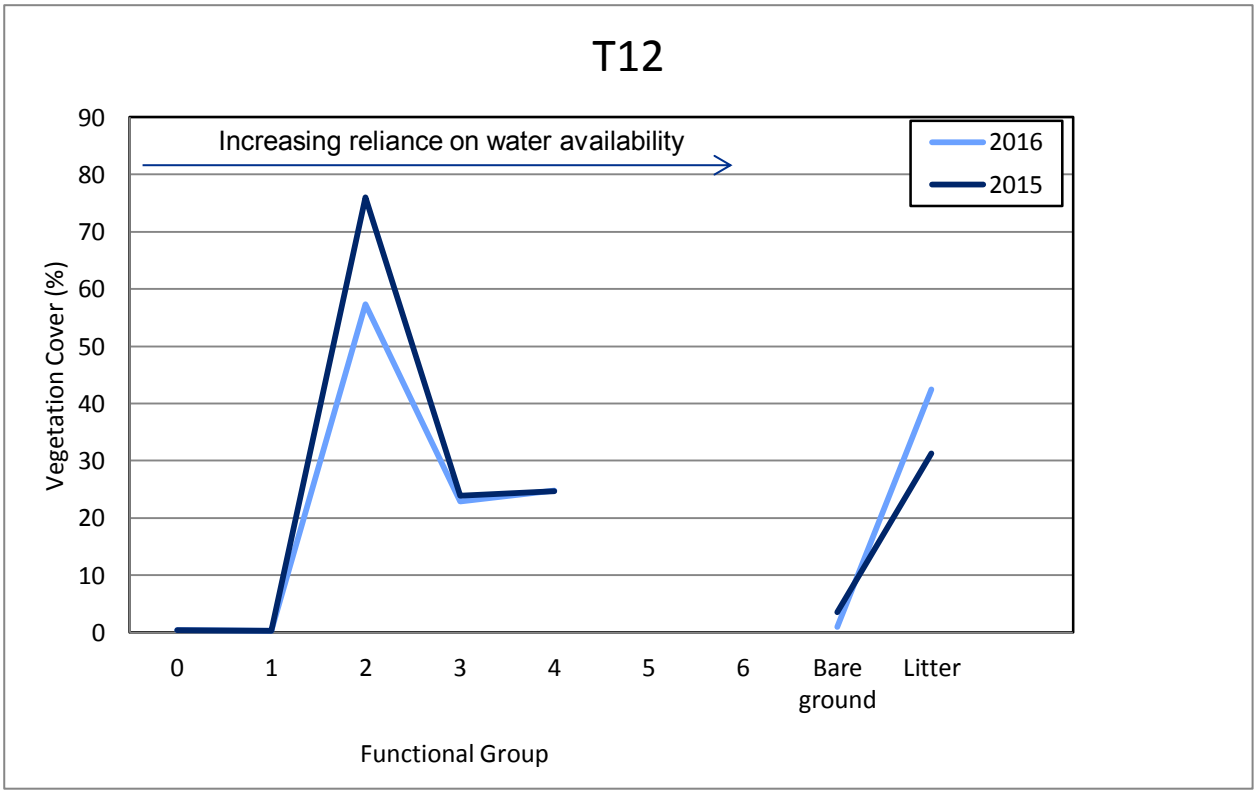


Figure 3-36 : Vegetation cover at site T12 according to functional grouping based on species reliance on water availability.

3.12.3 Link between vegetation changes and hydrogeology

A conceptual cross section across the site is shown in Figure 3-37. This shows there are thick alluvial sediments (~10m) that contain groundwater underlying a tributary of Dividing Creek. The watertable at the vegetation survey site lies within the shallow alluvial aquifer and is likely to be within 5 to 10 m of the ground surface all year round. Although groundwater levels in the soil bore indicate that there could be a perched watertable at the transect site.

Water level trend in TB12 shows a declining trend, with a seasonal response. Groundwater levels have declined by ~3m since September 2014 (refer Appendix B for more information). This is consistent with below average rainfall conditions.

The decline in cover of opportunistic species are unlikely to be related to a change in groundwater given that the majority of these species are unlikely to be accessing groundwater on an ongoing basis. These species are likely to be more reliant on rainfall and the decline in cover is consistent with below average rainfall conditions. Larger woody plant species at this site are likely to have access to groundwater. T

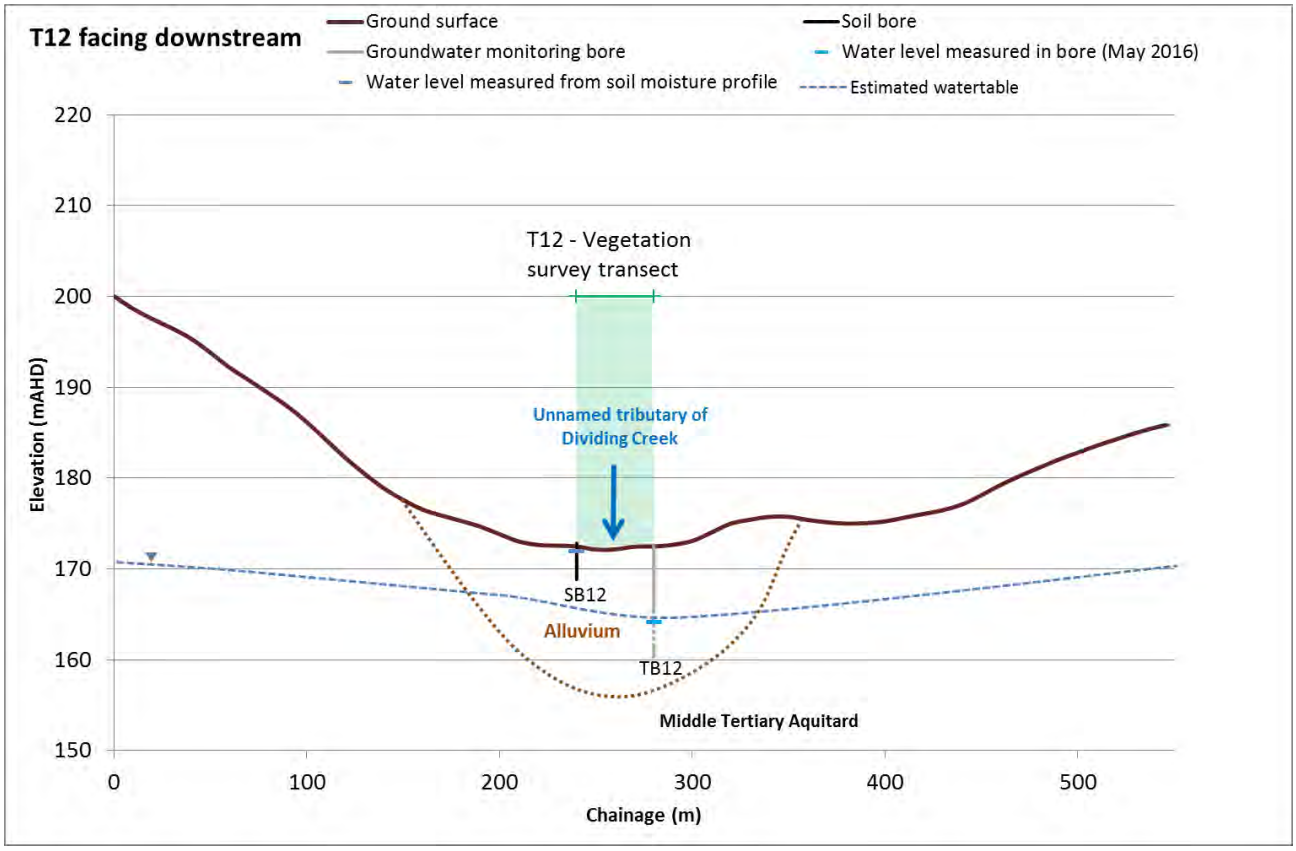


Figure 3-37 : Conceptual cross section of site T12.

3.12.4 Recommendations for future vegetation surveys

As a general trend of declining cover was noted in this report, the ongoing trajectory of all functional groups should be noted in future surveys.

3.13 Site T13

The location of site T13 is presented in Figure 3-38. Site T13 is located on the west side of Parkes Lodge Road near an unnamed tributary of Dividing Creek in Greater Otway National Park. This site is upstream from Site T12. The transect is located ~ 10m east of Parkes Lodge Road in thick heathy scrub occurring in a wide (~250 m) flat valley. The start of the transect at the base of a Swamp Gum and continues at a bearing of 8°. No defined waterway occurs within the transect. The current transect is located ~ 40 m north of TB13.

The entire site was burnt in a controlled burn in 2015. The transect was able to be relocated based on photos and GPS co-ordinates but the burning may have introduced an error of up to 3 m as a result of the changes in vegetation compared to past photos.

The site is a reference site, located outside the zone of influence from the bore where the Lower Tertiary Aquifer is confined.

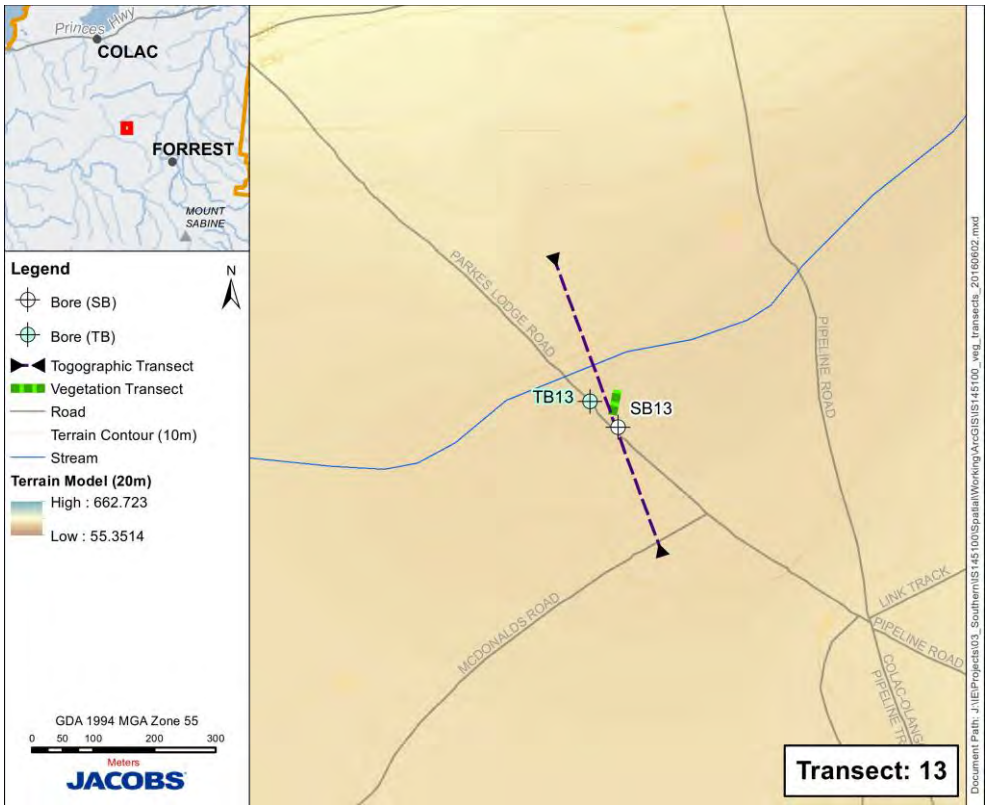


Figure 3-38 : Location of site T13

3.13.1 Vegetation description

The burning of the site has resulted in a regenerating site comprising a range of heathy shrubs, predominantly Prickly Tea-tree (*Leptospermum continentale*) and Scrub Sheoak (*Allocasuarina paludosa*) along with a range of epacids (*Epacris impressa* and *lanigera, Sprengelia incarnata, Leucopogon virgatus, Acrotriche prostrata*). The epacids are growing presently to 0.5 m and predominantly regenerating from the base of burnt plants as well as from significant numbers of seedlings. Small sedges were common throughout with the Sword-sedges (*Lepidosperma gunnii* and *L. laterale*) most dominant. Scattered Swamp Gums (*Eucalyptus ovata*) are still present to ~3m tall scattered throughout the heath. Twining sedges and rushes (*Caustis flexulosa* and *Empodisma minus*) were also common throughout.

3.13.2 Evidence of change from 2015

The previous report recommended that particular attention be given to the persistence of ground ferns at this site. Whilst this recommendation is largely moot given the burning of the site in the past year, Annual Fern (*Anogramma leptophylla*) was not re-detected though was present in 3 quadrats in 2015. Swamp Selaginella (*Selaginella ulginosa*) was again detected in all quadrats and appears to be recovering well.

The vegetation cover from two surveys, conducted in 2014 and 2016, is shown in Figure 3-39; species have been categorised based on their reliance on water availability.

Despite the change predicated by the fire, the functional group analysis shows little change (Figure 3-39). This reflects the rapid regeneration of the shrubs and sedges which dominated this site and still do, as well as the relatively sparse cover common in the species present. Most species previously detected were re-located including some un-identified orchids and small ferns within the transect with some native opportunistic species were also recorded in 2016. Future monitoring should pay particular attention to the regrowth of sedges and shrubs which dominate the site.

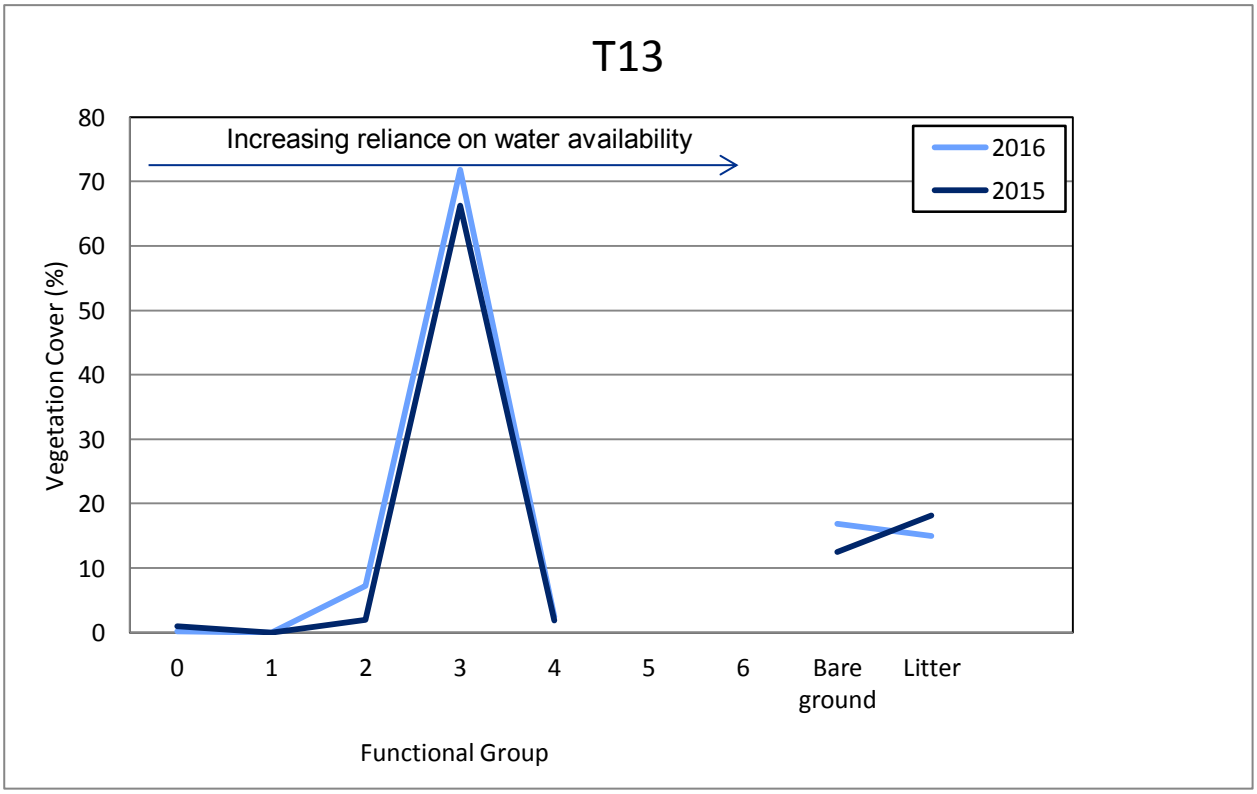


Figure 3-39 : Vegetation cover at site T13 according to functional grouping based on species reliance on water availability.

3.13.3 Link between vegetation changes and hydrogeology

A conceptual cross section across of site T13 is shown in Figure 3-40. The watertable at the vegetation survey site lies within the shallow alluvial aquifer and is within 5 m of the ground surface. Most vegetation is likely to have access to groundwater.

The water levels in TB13 have decline by ~2 m since October 2015 and are ~ 1 m lower than the same time the previous year (refer Appendix B for more information). This is consistent with below average rainfall conditions. The groundwater level at the start of May 2016 was ~5 m below ground surface.

The vegetation at this site is recovering from a recent fire and therefore the evapo-transpiration rates have been reduced during the time of declining groundwater. At the time of assessment the foliage is approaching pre-fire levels and therefore this site could experience stress if groundwater continues to decline. The presence of the aquitard may assist in maintaining soil moisture within the alluvium.

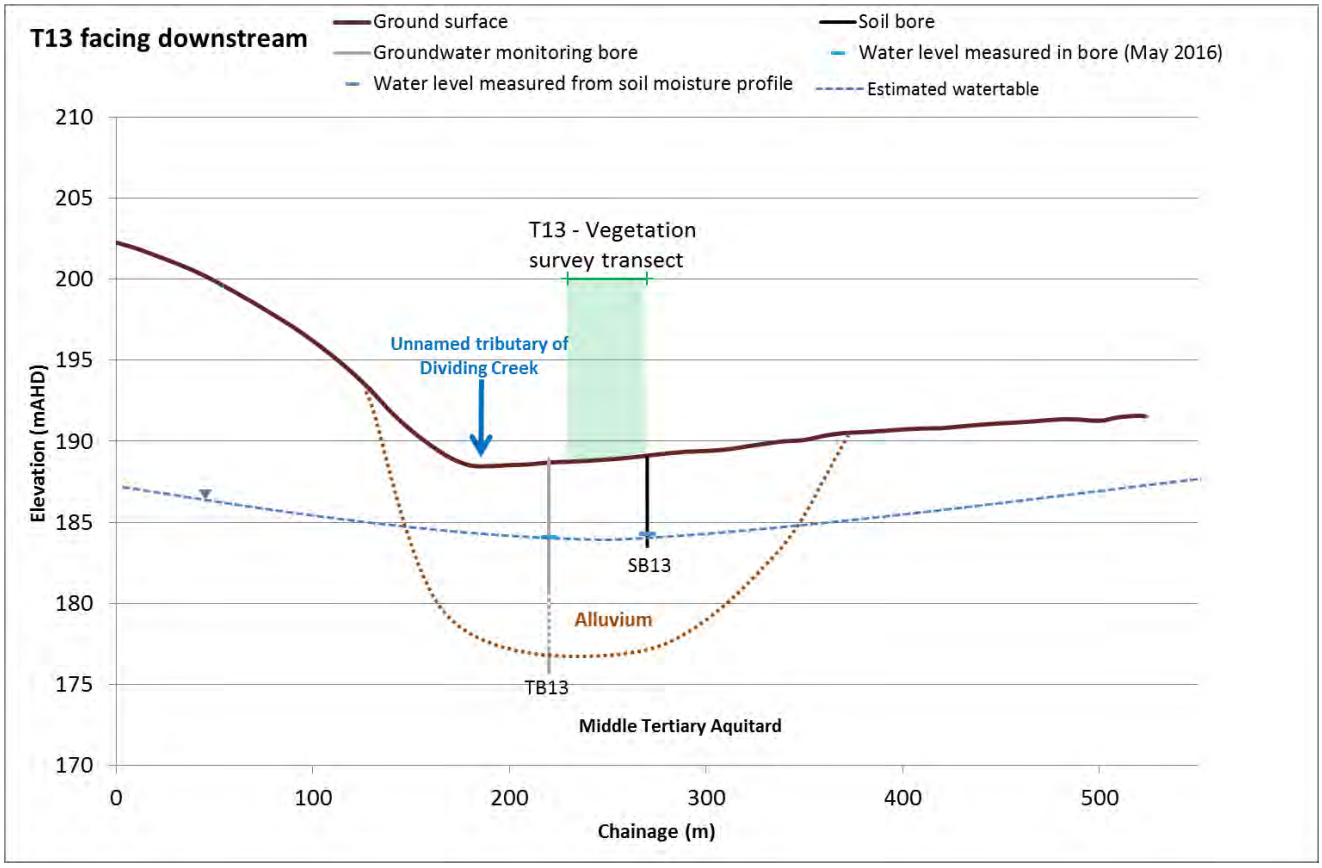


Figure 3-40: Conceptual cross section of site T13.

3.13.4 Recommendations for future vegetation surveys

The same site should be monitored in the future but future vegetation surveys will need to interpret change in the context of a site recovering from fire. Particular attention should be given to the occurrence of species and their individual recovery response (i.e. do some perform better than others following fire) and also if additional species are detected that have not been described in this or previous reports.

3.14 Site T14

The location of site T14 is presented in Figure 3-41. Site T14 is located between Robinson Road and an unnamed access track running east off Robinson Road 30 m north of the intersection with Cashin Road. There is a small parking area and picnic ground where the access track leaves Robinson Road. The transect crosses a small tributary which flows in to Ten Mile Creek which at this location is a large waterway running along Cashin Road. The small tributary has a defined channel in Q3 which had pooled water present at the time of assessment but was not noticeably flowing. The valley in which the tributary is located is relatively steep along the path of the tributary compared to other sites.

The start of the transect is located ~ 5 m east of the unnamed access track and ~50 m north west of the intersection with Robinson Road at the base of a large tree and continues at a bearing of 319°. The site is a reference site, located outside the zone of influence from the bore where the Lower Tertiary Aquifer is confined.

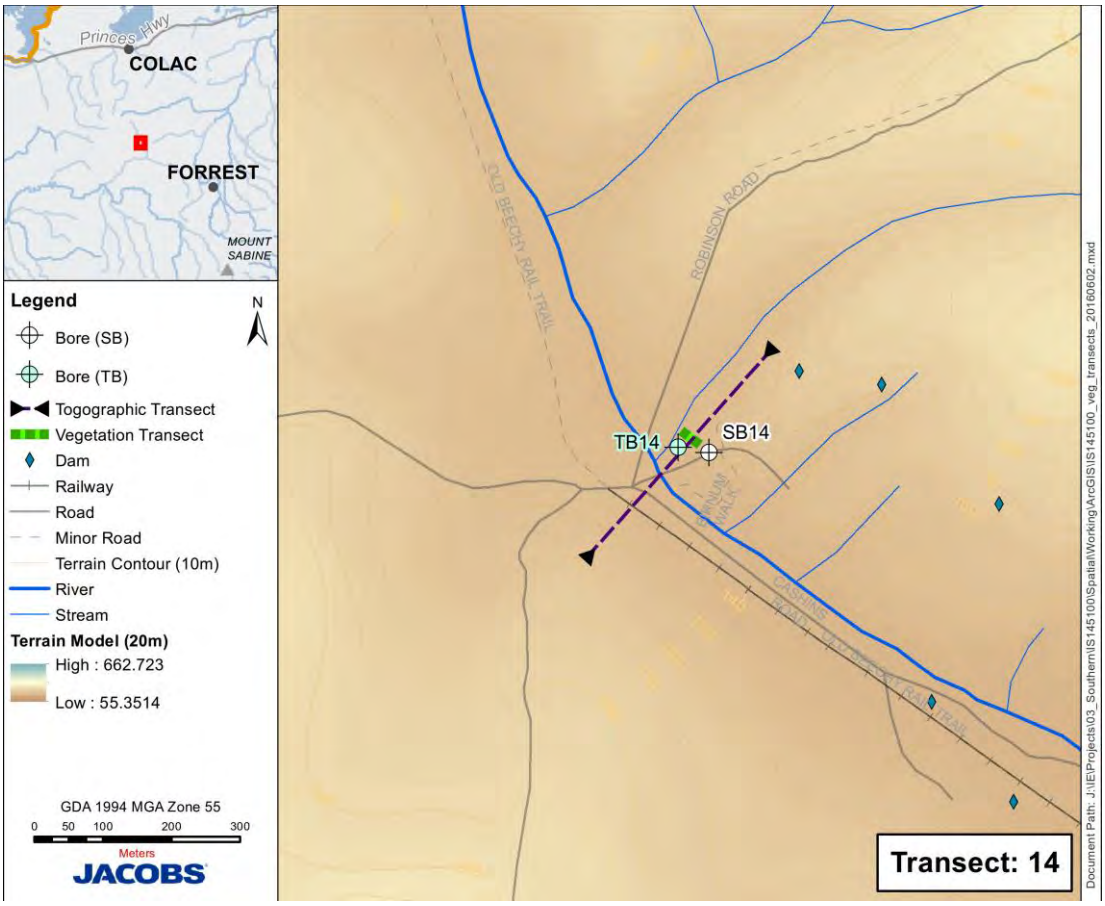


Figure 3-41 : Location of site T14.

3.14.1 Vegetation description

This forest community was dominated by a tall overstorey of Messmate and Manna Gum (*Eucalyptus obliqua* and *viminalis*). The trees in the surrounding area were larger than regularly encountered at other sites and the surrounding forest supported Wet Forest in comparison with the Heathy Dry forest encountered outside the assessed valleys elsewhere. The eucalypt canopy occurred over a dense shrub layer of Scented Paperbark (*Melaleuca squarrosa*) and rare Currant-wood (*Monotoca glauca*) with Tree Ferns (*Dicksonia antarctica and Cyathea australis*) also present. The ground layer was dominated by ferns (38% average cover), predominantly Scrambling Coral-fern (*Gleichenia microphylla*) and Hard Water-fern (*Blechnum wattsii*), and large sedges (*Gahnia radula* and *Lepidosperma elatius,* together comprising 13% cover). Litter levels were high (average of 54% cover) with relatively few herbs and grasses observed. The density of the multiple strata resulted in cover estimates totalling more than 170% across this site.

3.14.2 Evidence of change from 2015

The previous report noted that the ongoing persistence of ground ferns at this site should be given particular attention. As noted below, there were only minor changes in the cover of individual fern species either individually or as a whole.

The vegetation cover from two surveys, conducted in 2014 and 2016, is shown in Figure 3-36; species have been categorised based on their reliance on water availability. Very little change in the vegetation from March 2015 to April 2016 could be discerned from the analysis of function groups (Figure 3-42). Most vegetation was present was defined as being groundwater dependent (groups 3 and 4) as could be expected given it was dominated by ferns. There is little change in the cover of individual species over the intervening period either. Some minor components of the vegetation, e.g. Forest Mint (*Mentha laxiflora*) that were detected in 2015 only as scattered individuals, were not relocated in 2016 though this absence is unlikely to be meaningful given the small numbers previously noted.

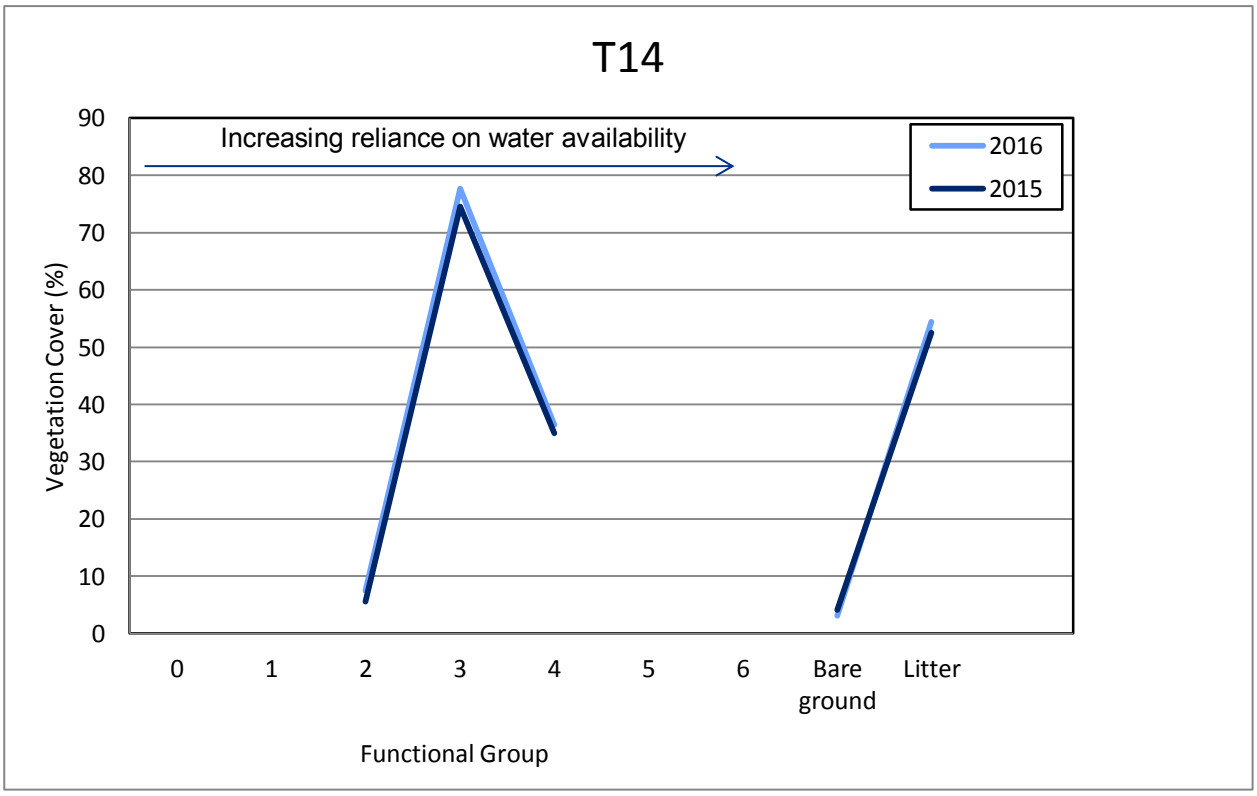


Figure 3-42 : Vegetation cover at site T14 according to functional grouping based on species reliance on water availability.

3.14.3 Link between vegetation changes and hydrogeology

A conceptual cross section of site T14 is shown in Figure 3-43. This shows there are thick alluvial sediments (~10m) that contain groundwater in the valley floor overlying the Middle Tertiary Aquifer. The watertable at the vegetation survey site lies within the shallow alluvial aquifer and is likely to be within 10 m of the ground surface. Some vegetation is likely to have access to groundwater. Water levels in TB14 remained stable only fluctuating by ~2 m over the duration of the monitoring period.

The lack of change in the vegetation is a result of the stable groundwater levels at this location. The presence of surface water within the tributary indicates that the soil moisture remains high and provides a readily accessible water source for the time being. Should rainfall continue to remain below average, it is likely that a reduction in soil moisture could result in decline in cover of shallow rooted fern species.

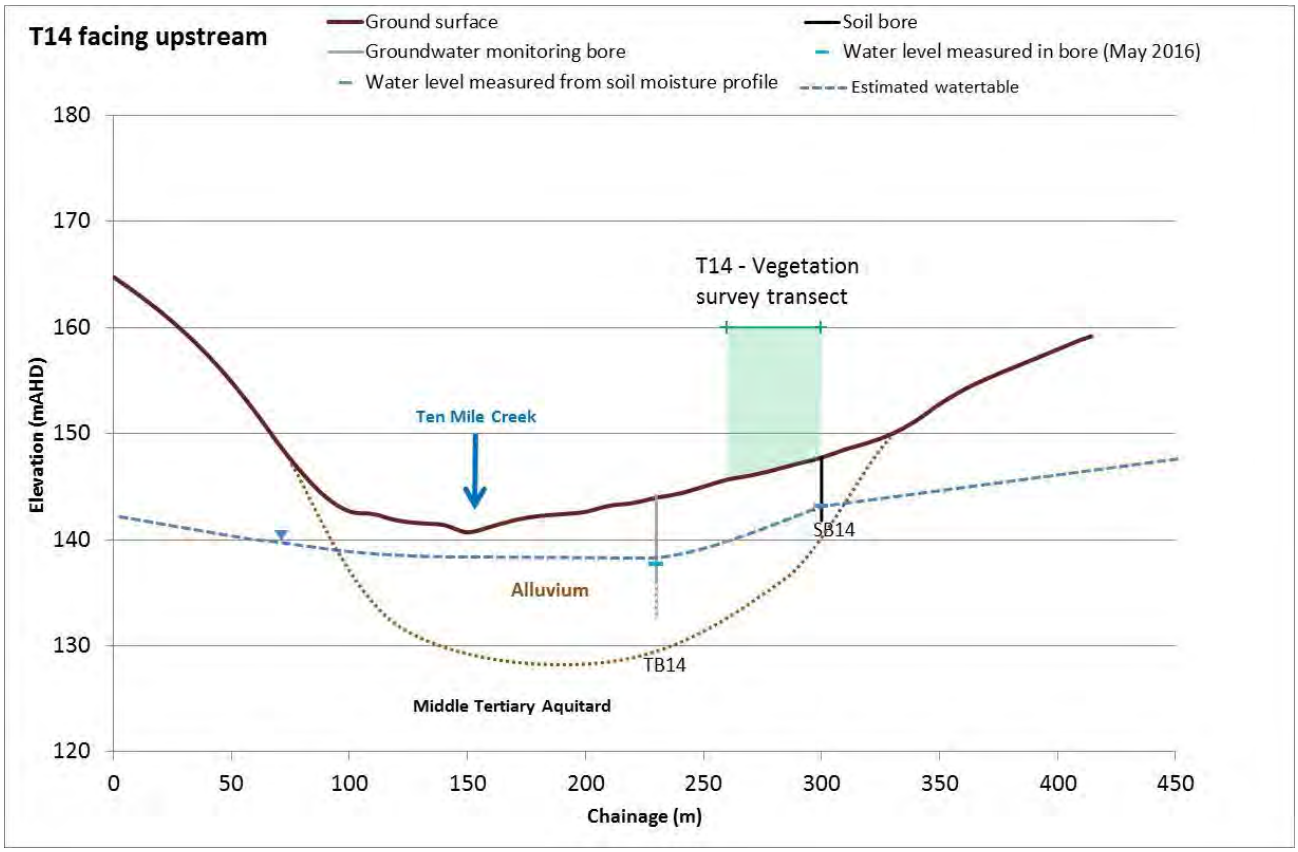


Figure 3-43 : Conceptual cross section of site T14

3.14.4 Recommendations for future vegetation surveys

There are no specific recommendations for future surveys at this site.

3.15 Summary of Results

A summary of the results at each site is provided in Table 3-1.

Table 3-1 Summary of changes in vegetation and groundwater levels at each site

Site	Vegetation Change 2014 to 2016	Groundwater Change 2014 - 2016
T1	• Little change in the type of vegetation present at the site. • General drop in the vegetation cover recorded across the site in all functional groups largely driven by a reduction in moss cover and increase in litter.	• Watertable in shallow alluvial aquifer is within 2 m of the surface. • Groundwater levels declined in response to below average rainfall conditions.
T2	• Little change in the type of vegetation present at the site. • Notable decrease in cover in species requiring at least periodic inundation of root zone for continuing survival (functional group 4). • Changes driven by general thinning of the canopy of larger woody species (Swamp Gums and Scented Paperbark), in response to drying conditions.	• Watertable in LTA aquifer is at least 3 m below the surface. • Groundwater monitoring bores are located in the valley and on higher groundwater and are both dry.
T3	• Absence of standing water at the site compared to previous assessment (38% to absent). • Sedges and rushes reliant on near constant surface water have largely died and remaining live vegetation in poor health. • This has not translated to a large drop in cover and it is expected that this will occur in time.	• Localised perched aquifer reliant on rainfall and surface water (i.e. not connected to regional groundwater system). • Watertable in Lower Tertiary Aquifer and is 15 m below the surface. • Groundwater monitoring bore shows a steady trend with no seasonal fluctuations.
T4	• Little change in the type of vegetation present at the site. • Marked decline in the cover of vegetation in functional groups 3 and 4, both of which have been defined as being groundwater dependent. • Construction works associated with planned burned occurred recently upstream of site.	• Local perched aquifer reliant on recharge from rainfall and surface water. • Watertable has declined in response to below average rainfall conditions. • Regional groundwater is 30 m below the surface in the Lower Tertiary Aquifer shows a steady trend.
T5	• Transect has been burnt since last survey. • Consequent reduction in cover in the groundwater dependant functional groups 3 and 4 and increase in litter cover and bare ground. As species regenerate and recover, these values will drop.	• Watertable is at least 5 m below the surface and lies in the LTA aquifer. • Groundwater trend is steady, despite below average rainfall conditions
T6	• Little change in the type of vegetation present at the site, with most vegetation falling into functional group 3. • Noticeable reduction in the cover of all functional groups • Change in vegetation cover is unlikely to be the result of seasonal changes and could be the result of observer error.	• Watertable in shallow alluvial aquifer in the valley is within 2 m of the surface. Outside the valley, the watertable is in the Lower Tertiary Aquifer. • Groundwater levels declined slightly in response to below average rainfall conditions.
T7	• Little change in the type of vegetation present at the site, with most vegetation falling into functional group 3 (species reliant on readily available water but are not tolerant of regular inundation of the root zone).	• Watertable in shallow alluvial aquifer in the valley is within 2 m of the surface. Outside the valley, the watertable is in the Lower Tertiary Aquifer. • Groundwater levels declined slightly in response to below average rainfall

Site	Vegetation Change 2014 to 2016	Groundwater Change 2014 - 2016
	• Noticeable drop in cover in Pouched Coral-fern, due to increased exposure.	conditions.
T8	• Little change in the type of vegetation present at the site, with most vegetation falling into functional group 3 • Slight decline in vegetation cover, largely attributed to decline in fern species.	• Watertable in shallow alluvial aquifer in the valley is within 2 m of the surface. Outside the valley, the watertable is in the aquitard (MTD). • Groundwater levels declined slightly in response to below average rainfall conditions.
T9	• Small increase in the cover of species in functional group 3 (more dependence on groundwater) and a small drop in cover species functional group 4. • Changes in the species cover less than 5% and typically less than 1%.	• Watertable in alluvial aquifer is within 3-5 m of the surface. • Groundwater levels show seasonal fluctuations and slight declining trend in response to below average rainfall conditions.
T10	• Little change in the type of vegetation (<5%). • Small drop in cover of some species was offset by increase in other species cover.	• Watertable in shallow alluvial aquifer is within 5 m of the surface. Outside the valley, the watertable is in the aquitard (MTD). • Groundwater levels show seasonal fluctuations and slight declining trend in response to below average rainfall conditions.
T11	• Significant change in the type of vegetation present at the site. • However Water-ferns, were markedly reduced in cover (from 20% to 3% average cover), which has been offset by an increase in large sedge cover.	• Watertable in shallow alluvial aquifer is within 5 m of the surface. Outside the valley, the watertable is in the aquitard (MTD). • Groundwater levels show seasonal fluctuations and slight declining trend in response to below average rainfall conditions.
T12	• Decrease in the overall vegetation cover estimates due to a reduction in the cover of species in functional group 2. • Differences were detected in species in functional group 2, defined as opportunistic species, whilst cover of functional groups 3 and 4, defined as groundwater dependent, were less noticeable.	• Watertable in shallow alluvial aquifer is within 5-8 m of the surface. Outside the valley, the watertable is in the aquitard (MTD). • Groundwater levels show seasonal fluctuations and declining trend in response to below average rainfall conditions.
T13	• Despite the change predicated by the entire site being burnt by fire, the functional group analysis shows little change in any of the groups present. • Reflects the rapid regeneration of the shrubs and sedges which dominated this site.	• Watertable in shallow alluvial aquifer is within 5 m of the surface. Outside the valley, the watertable is in the aquitard (MTD). • Groundwater levels show seasonal fluctuations and slight declining trend in response to below average rainfall conditions.
T14	• Little change in the type of vegetation present at the site.	• Watertable in shallow alluvial aquifer is within 2-5 m of the surface. Outside the valley, the watertable is in the aquitard (MTD). • Groundwater levels show slight seasonal fluctuations and marginal declining trend in response to below average rainfall conditions.

4. Discussion of results

This discussion should be prefaced by stating that the region has experienced below average rainfall since the last vegetation monitoring round was undertaken. The groundwater level response to the below average rainfall conditions has varied between sites and throughout the catchment. The Barwon Downs borefield has not been used since 2010, however pumping recently commenced in April 2016.

The results of this vegetation monitoring round have been combined with an enhanced understanding of the local hydrogeology at each site. This enabled a greater understanding of key triggers (e.g. changes in rainfall, surface water or groundwater level) for potential vegetation changes. The below average rainfall conditions has placed significant stress on the vegetation in the catchment, so the importance of groundwater in maintaining vegetation is likely to become apparent.

4.1 Vegetation Condition and changes from previous monitoring

Overall there was no noticeable difference between impact/reference sites and confined/unconfined sites.

Vegetation species has not changed markedly at most sites, however, two sites (T5 and T13) had been burnt by controlled burns since the last survey. It was investigated at each site if the transect could be relocated to an un-burnt area, however this was not possible at either location so the same transect was examined at both locations. Vegetation is regenerating at both sites with almost all species previously detected re-recorded. Those that were absent were scattered individuals whose absence is not interpreted as being significant.

Site T3 was affected by a marked drop in the water table and a significant decline in surface water. T3 is located within the zone of impact where the LTA is unconfined. The sedges and rushes that dominated the site are in poor health and the species dependent on water inundation that were previously prevalent across the site were not recorded at this assessment. Given the borefield has not been used since 2010, this is attributed to the below average rainfall conditions, At the remaining sites, the vegetation was not markedly changed, with the same vegetation strata and composition recorded.

Overall, no statistically significant difference was detected in the vegetation cover of species considered dependent on groundwater. This would suggest that despite the changing conditions, there has not been a significant shift in vegetation condition of groundwater dependent ecosystems across the catchment. This is not surprising given the relatively short period since the previous monitoring round.

Comparison of the data at each site does reveal some significant changes in vegetation cover of functional groups and of individual species or plant groups. Most notable is the change of fern cover. With the exception of Bracken, all ferns are classified as functional groups 3 and 4, and are therefore defined as likely to be groundwater dependent. Ferns have relatively shallow and simple roots and are the species most likely to decline in response to drying conditions as experienced over the past year. Notable declines in fern cover was noted at sites T7, T8, T9. The decline in ferns has corresponded with a decline in the water table at these sites which in turn has declined in response to below average rainfall. Larger tree-ferns are still largely unaffected (at sites T7, T11 and T9) though these species are typically deeper rooted. This would suggest that sites are beginning to show the signs of lower water availability, induced by lower than average rainfall. These sites represent a range of impact and reference sites in areas where the aquifer is confined and unconfined indicates this is a response to below average rainfall across the site.

Ongoing monitoring while the borefield is operating is recommended and this is discussed further in Section 5.2.

4.2 Groundwater trends

The majority of monitoring bores shows declining groundwater trends in response to below average rainfall conditions, as the borefield has not operated since 2010.

The majority of sites are located in valleys where there is a shallow alluvial aquifer overlying the Lower Tertiary Aquifer or the Mid Tertiary Aquitard. The shallow alluvial aquifers typically show seasonal fluctuations up to 2 m and many sites also show a longer term declining trend as a result of below average rainfall conditions. Groundwater trends in the underlying Lower Tertiary Aquifer of Mid Tertiary Aquitard typically show stable groundwater trends with little or no seasonal response. Two sites have localised perched aquifers (T3 and T4) where groundwater levels are at or close to the surface. These perched systems are not connected to the regional groundwater system which is the Lower Tertiary Aquifer at both locations.

4.3 Link between vegetation condition and groundwater trends

At all sites, groundwater is relatively close to the surface and accessible by vegetation. Vegetation will rely more heavily on groundwater resources when there is less rainfall and species with shallow root systems (e.g. ferns) will be impacted first. This is to be expected as these plants do not have a highly developed or deep root system. In almost all sites (site T2 being an exception), there was little change in the condition of larger woody species that will have access to water at deeper levels than other vegetation types.

Statistical tests between the confined and unconfined aquifer sites, or between impact and reference sites, did not show significant differences in the cover or proportion of groundwater dependent species. This suggests that vegetation condition is consistent across the catchment.

It has become clearer since the previous report that the link between groundwater and the vegetation present at sites is highly variable and localised. For example:

- Changes in the cover of ferns at certain sites can be linked to declines in soil moisture and watertable when close to the surface (e.g. sites T8 and T7).
- Declines in vegetation cover of groundwater dependent functional groups measured at site T10 are significant but the shallow rooted ferns are absent at this site and other species are more resilient to change (i.e. larger sedges and shrubs).

At the remaining sites, groundwater changes are not large and are unlikely to have resulted in changes in the ability of plants to access groundwater at this time.

5. Conclusions and recommendations

5.1 Conclusions

This assessment of the vegetation monitoring sites provides additional data for the background condition of the groundwater dependent ecosystems in the vicinity of the Barwon Downs borefield. Given the borefield has not operated since 2010, the study highlighted the natural response of the ecosystems to changing environmental conditions, which in this case is below average rainfall conditions since January 2015.

Key findings of the study are highlighted below:

- Vegetation conditions are showing signs of a decline in response to below average rainfall over the past year.
- Changes in vegetation conditions are not statistically significant across the catchment.
- The decline in vegetation condition was consistent across the catchment with no difference between reference and impact sites, or unconfined and confined sites.
- Localised responses are apparent at sites T7, T8 and T9 where there has been a noticeable decline in fern species. These sites are in a range of hydrogeological settings.
- At Site T3 there was a loss of surface water and a decline in vegetation condition. The surface water in the wetland is dependent on rainfall and a local perched aquifer in the alluvium that is not connected to the regional groundwater system.

5.2 Recommendations

The current licence conditions require vegetation monitoring to be conducted every 5 years. According to the licence conditions, another vegetation survey is required in 2021. However, given the Barwon Downs borefield has recently been turned on, there are benefits in conducting another round of vegetation monitoring before this time. Vegetation will be exposed to several potential stresses over the next 5 years such as variable rainfall, evaporation, temperature as well as groundwater extraction. Understanding the inherent resilience in the vegetation to natural climate variability is imperative to understand the potential impacts on vegetation from groundwater extraction.

A risk based approach can be adopted to determine an appropriate frequency for ongoing vegetation monitoring. A low risk approach involves regular monitoring (i.e. annually), which provides greater confidence in the results and understanding of key drivers of potential changes. A higher risk approach involves less monitoring, resulting in less confidence and understanding of the drivers behind potential changes.

To reduce the risk and ensure there is sufficient confidence in understanding the key drivers behind potential changes in vegetation condition (i.e. rainfall or changes in groundwater levels), this report makes the following recommendations:

- Vegetation surveys be conducted every 2 years, whilst the borefield is operating and every 5 years when the borefield is not operational. These surveys should take note of the individual recommendation listed for each site.
- Vegetation monitoring should be conducted in mid to late autumn as this is the period when stress in the groundwater dependent ecosystems is most likely to be evident.
- No targeted fauna monitoring is recommended at this time as burrowing-cray holes were still evident at site T2. This finding should be revisited in future monitoring events.
- Relocate the transect at site T11 to better connect with the groundwater dependent ecosystems in the area.
- Review remote sensing data after each period of borefield use to monitor potential changes in the regional vegetation condition that is not possible in the site by site assessment.

6. References

Carr, GW (2002) 'Barwon Downs aquifer flora' Unpublished report prepared for Barwon Water by Ecology Australia

Carr, GW and Muir, AM (1994) 'Inventory and assessment of flora and faunal values of the Barwon Downs aquifer outcrop areas and associated streams, Otway Ranges, Victoria' Unpublished report prepared for Barwon Water by Ecology Australia.

Casanova, MT (2011) 'Using water plant functional groups to investigate environmental water requirements.' Freshwater Biology 56, 2637-2652

Doeg T, Muller K, Nicol J, VanLaarhoven, J (2012) Environmental water requirements of groundwater dependent ecosystems in the Musgrave and southern basins prescribed wells area on the Eyre Peninsula. Technical Report DFW 2012/16. Government of South Australia – Department of Water

Jacobs (2015) Barwon Downs Vegetation Monitoring Report 2014/15. Unpublished report for Barwon Water prepared by Jacobs Australia

Orellana, F., P. Verma, S. P. Loheide II, and E. Daly (2012), 'Monitoring and modeling water-vegetation interactions ingroundwater-dependent ecosystems, Rev. Geophys., 50, RG3003, doi:10.1029/2011RG000383.

SKM and Ecology Australia (2008) 'Barwon Downs Flora Study'. Unpublished report prepared by SKM.

SKM (2013) 'Barwon Downs Monitoring Program - STAGE 1 Field Investigations and Monitoring Program Scope', Unpublished report for Barwon Water prepared by SKM.

Walsh NG, Entwisle JT (1994–1999) 'Flora of Victoria. Vols 2–4.' Inkata Press: Melbourne

Appendix A. Detailed Results of Vegetation Survey

Site Name	T1	Site Location	Big Swamp on Boundary Creek east of Colac-Forrest Road
Latitude GDA94	-38.4233	VBA Survey ID	1107850
Longitude GDA94	143.69535	VBA Site ID	715615
Geology	Unconfined	Start Co-ordinates	E 735298, N 5743774
Ref/Imp	Impact	End Co-ordinates	E 735248, N 5743822

			Recorded Information								Summary information				
Scientific Name	**Common Name**	**Conservation Status**	**Q1**	**Q2**	**Q3**	**Q4**	**Q5**	**Q6**	**Q7**	**Q8**	**Average**	**Std Dev**	**Max**	**Min**	**No quads**
Acacia melanoxylon	Blackwood							1			0.13		1	1	2
Acetosella vulgaris	Sheep Sorrel	*	1	10							1.38		10	1	2
Eucalyptus ovata	Swamp Gum		10	5	1	1					2.13	4.27	10	1	4
Holcus lanatus	Yorkshire Fog	*	1								0.13		1	1	1
Leptospermum continentale	Prickly Tea-tree		1	10	5	45	35	65	65	65	36.38	27.94	65	1	8
Pteridium esculentum	Austral Bracken		20	30	50	10	15	5	5	1	17.00	16.32	50	1	8
Senecio glomeratus	Annual Fireweed							1			0.13		1	1	2
Bare ground			60	45	25	15	30	5	10	5	24.38	19.90	60	5	8
Litter			20	15	40	35	20	45	60	60	36.88	17.72	60	15	8
Moss			15	30	35	45	50	50	30	35	36.25	11.88	50	15	8

Site Name	T2	Site Location	On Boundary Creek at unnamed access track~ 650 m upstream of Peat Swamp
Latitude GDA94	-38.4233	VBA Survey ID	1084235
Longitude GDA94	143.68766	VBA Site ID	715616
Geology	Unconfined	Start Co-ordinates	E 734632, N 5744000
Ref/Imp	Impact	End Co-ordinates	E 734654, N 5744034

			Recorded Information								Summary information				
Scientific Name	**Common Name**	**Conservation Status**	**Q1**	**Q2**	**Q3**	**Q4**	**Q5**	**Q6**	**Q7**	**Q8**	**Average**	**Std Dev**	**Max**	**Min**	**No quads**
Acacia melanoxylon	Blackwood		1	1				1			0.38	0.00	1	1	3
Acaena novae-zelandiae	Bidgee-widgee						1				0.13		1	1	2
Blechnum nudum	Fishbone Water-fern				5	5	1	5	10	1	3.38	3.33	10	1	7
Blechnum wattsii	Hard Water-fern			1	1		1	1	1	1	0.75	0.00	1	1	7
Bossiaea cordigera	Wiry Bossiaea		1								0.13		1	1	1
Cardamine spp.	Bitter Cress			1		1		1			0.38	0.00	1	1	4
Carex appressa	Tall Sedge			5	5	15	10	1	30	15	10.13	9.69	30	1	8
Coprosma quadrifida	Prickly Currant-bush				10	1	1	1	1	1	1.88	3.67	10	1	7
Crassula helmsii	Swamp Crassula			1					1	1	0.38	0.00	1	1	4
Dianella tasmanica	Tasman Flax-lily		1								0.13		1	1	1
Dicksonia antarctica	Soft Tree-fern									1	0.13		1	1	2
Epilobium billardierianum subsp. intermedium	Variable Willow-herb								1		0.13		1	1	2
Eucalyptus obliqua	Messmate Stringybark					10					1.25		10	10	2
Eucalyptus ovata	Swamp Gum		30	25	20	15			5	5	12.50	10.33	30	5	6
Gahnia sieberiana	Red-fruit Saw-sedge		10	15	5	25	10	5	1	20	11.38	8.16	25	1	8
Gleichenia microphylla	Scrambling Coral-fern		55	10	5		1		15	35	15.13	20.79	55	1	6
Gonocarpus micranthus	Creeping Raspwort						1	1	1		0.38	0.00	1	1	4
Gonocarpus tetragynus	Common Raspwort			1							0.13		1	1	2
Gratiola peruviana	Austral Brooklime			5	1	5		5	1		2.13	2.19	5	1	6

Scientific Name	Common Name	Conservation Status	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Average	Std Dev	Max	Min	No quads
Hydrocotyle pterocarpa	Wing Pennywort			1			1	1	1	1	0.63	0.00	1	1	6
Isolepis inundata	Swamp Club-sedge			5			5	20	1	5	4.50	7.36	20	1	6
Lepidosperma elatius	Tall Sword-sedge		1	15	30	5		1			6.50	12.36	30	1	5
Leptospermum lanigerum	Woolly Tea-tree		10				10	10		35	8.13	12.50	35	10	4
Lotus spp.	Trefoil	*				1					0.13		1	1	2
Melaleuca squarrosa	Scented Paperbark		15	20	15	15	25	30	10	5	16.88	7.99	30	5	8
Poa tenera	Slender Tussock-grass		1		1	1					0.38	0.00	1	1	3
Polystichum proliferum	Mother Shield-fern						1	1			0.25	0.00	1	1	3
Pteridium esculentum	Austral Bracken		5								0.63		5	5	1
Rubus anglocandicans	Common Blackberry						1				0.13		1	1	2
Senecio glomeratus	Annual Fireweed				1	1	1				0.38	0.00	1	1	4
Senecio spp.	Groundsel			1							0.13		1	1	2
Tetrarrhena juncea	Forest Wire-grass		1	1	1	1	1				0.63	0.00	1	1	5
Bare ground			1	5	1	1	5	5	5	10	4.13	3.09	10	1	8
Litter			45	30	45	35	50	20	30	30	35.63	10.16	50	20	8
Moss			5	10	15	5	10	15	10	5	9.38	4.17	15	5	8
Water								20			2.50		20	20	2

Site Name	T3	Site Location	Unnamed swamp 250 west of Maintenance Track running north of Westwood Road
Latitude GDA94	-38.4262	VBA Survey ID	1107852
Longitude GDA94	143.65868	VBA Site ID	715617
Geology	Unconfined	Start Co-ordinates	E 732087, N 5743543
Ref/Imp	Impact	End Co-ordinates	E 732097, N 5743503

Recorded Information

Summary information

Scientific Name	Common Name	Conservation Status	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Average	Std Dev	Max	Min	No quads
Amphibromus neesii	Common Swamp Wallaby-grass							1		1	0.25		1	1	2
Amphibromus recurvatus	Dark Swamp Wallaby-grass		55	55	50	45	20		10	10	30.63	20.82	55	10	7
Baumea articulata	Jointed Twig-sedge			1		1	5	40	30	20	12.13	16.49	40	1	6
Baumea rubiginosa s.s.	Soft Twig-sedge							10	5	5	2.50	2.89	10	5	3
Carex appressa	Tall Sedge		20	5							3.13		20	5	2
Eucalyptus ovata	Swamp Gum		10	25			25	1	15	10	10.75	9.42	25	1	6
Euchiton involucratus s.s.	Star Cudweed		1								0.13		1	1	1
Holcus lanatus	Yorkshire Fog	*	1	1		1			1	1	0.63	0.00	1	1	5
Hypochaeris radicata	Flatweed	*	1	1			1	1		1	0.63	0.00	1	1	5
Juncus procerus	Tall Rush		5	10	20	20	15	1	5	15	11.38	7.23	20	1	8
Lachnagrostis filiformis s.s.	Common Blown-grass		1	1	1	1	30		30	15	9.88	13.77	30	1	7
Luzula meridionalis var. flaccida	Common Woodrush				1	1	1				0.38	0.00	1	1	3
Senecio minimus	Fireweed			1	1	1	1	1	1	1	0.88	0.00	1	1	7
Senecio tenuiflorus	Fireweed			1							0.13		1	1	1
Bare ground			1	5	15	1	5	5	1	5	4.75	4.59	15	1	8
Litter			20	10	15	25	30	20	15	10	18.13	7.04	30	10	8
Moss			1	1	1		1		1		0.63	0.00	1	1	5
Water											0.00		0	0	0

Site Name	T4	Site Location	At an unnamed tributary of Boundary Creek immediately north of unmarked access track, ~ 1.2 km west of Maintenance track
Latitude GDA94	-38.4202	**VBA Survey ID**	1107853
Longitude GDA94	143.66735	**VBA Site ID**	715618
Geology	Unconfined	**Start Co-ordinates**	E 732901, N 5744483
Ref/Imp	Impact	**End Co-ordinates**	E 732928, N 5744212

Recorded Information

Summary information

Scientific Name	**Common Name**	**Conservation Status**	**Q1**	**Q2**	**Q3**	**Q4**	**Q5**	**Q6**	**Q7**	**Q8**	**Average**	**Std Dev**	**Max**	**Min**	**No quads**
Acacia verticillata	Prickly Moses			1		1					0.25		1	1	2
Asplenium flabellifolium	Necklace Fern										0.00		0	0	0
Blechnum nudum	Fishbone Water-fern			1		10	1	5	1		2.25	3.97	10	1	5
Dianella tasmanica	Tasman Flax-lily			1				1			0.25		1	1	2
Dicksonia antarctica	Soft Tree-fern							1			0.13		1	1	1
Eucalyptus obliqua	Messmate Stringybark			1				15	10	25	6.38	10.01	25	1	4
Eucalyptus ovata	Swamp Gum		15	10	15	15	20				9.38	3.54	20	10	5
Gahnia sieberiana	Red-fruit Saw-sedge			5					1	15	2.63	7.21	15	1	3
Gonocarpus tetragynus	Common Raspwort							1			0.13		1	1	1
Lepidosperma elatius	Tall Sword-sedge		15	15	35	15	25	20	20	20	20.63	6.78	35	15	8
Leptospermum lanigerum	Woolly Tea-tree		10	5					20	35	8.75	13.23	35	5	4
Lomandra longifolia	Spiny-headed Mat-rush							1			0.13		1	1	1
Melaleuca squarrosa	Scented Paperbark		10	10	25	20	10	20	5		12.50	7.32	25	5	7
Poa tenera	Slender Tussock-grass		10	15	10	10	10	10	1	1	8.38	4.87	15	1	8
Pteridium esculentum	Austral Bracken		1	1	5	5	15	5	1		4.13	4.96	15	1	7
Senecio glomeratus	Annual Fireweed							1			0.13		1	1	1
Tetrarrhena juncea	Forest Wire-grass		5	5	5	10	10	5	10	1	6.38	3.29	10	1	8
Bare ground			1	1	1	1	1	1	5	5	2.00	1.85	5	1	8
Litter			40	45	40	35	40	50	65	60	46.88	10.67	65	35	8
Moss			1	1	1	1	1	1	1	1	1.00	0.00	1	1	8

Site Name	T5	Site Location	~70 m west Field and Game Track in Otway State Forest
Latitude GDA94	-38.4229	VBA Survey ID	1107854
Longitude GDA94	143.64523	VBA Site ID	715619
Geology	Unconfined	Start Co-ordinates	E 730923, N 5743952
Ref/Imp	Reference	End Co-ordinates	E 730899, N 5743970

Recorded Information

Summary information

Scientific Name	Common Name	Conservation Status	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Average	Std Dev	Max	Min	No quads
Acacia verticillata	Prickly Moses					1			1		0.25	0.00	1	1	3
Allocasuarina misera	Slender Sheoak			1							0.13		1	1	2
Amperea xiphoclada var. xiphoclada	Broom Spurge		1		1						0.25		1	1	2
Asplenium flabellifolium	Necklace Fern		1	1	1	1	1				0.63	0.00	1	1	5
Banksia marginata	Silver Banksia		1		1		1				0.38	0.00	1	1	3
Dianella tasmanica	Tasman Flax-lily		1	1	1			1			0.50	0.00	1	1	4
Empodisma minus	Spreading Rope-rush		5	20	5	1	1				4.00	7.86	20	1	5
Eucalyptus obliqua	Messmate Stringybark		1	1			5	5	20	15	5.88	7.86	20	1	6
Eucalyptus ovata	Swamp Gum		15	10	1	10	5	15	5	10	8.88	4.94	15	1	8
Eucalyptus radiata subsp. radiata	Narrow-leaf Peppermint				20	10	5				4.38	7.64	20	5	4
Gahnia sieberiana	Red-fruit Saw-sedge		5	1		1	5	1	10	5	3.50	3.32	10	1	7
Gonocarpus tetragynus	Common Raspwort		1		1	1		1	1		0.63	0.00	1	1	5
Goodenia humilis	Swamp Goodenia		1		1		1				0.38	0.00	1	1	3
Lepidosperma elatius	Tall Sword-sedge		5	1	1	1	10	5	10		4.13	4.03	10	1	7
Leptospermum lanigerum	Woolly Tea-tree		1	1	1		1				0.50	0.00	1	1	4
Lomandra filiformis	Wattle Mat-rush		1			1					0.25		1	1	2
Melaleuca squarrosa	Scented Paperbark		1	1	1	1	1	5	1	5	2.00	1.85	5	1	8
Pteridium esculentum	Austral Bracken		5	5	1	1	5	1	1		2.38	2.14	5	1	7
Tetrarrhena juncea	Forest Wire-grass		1		5	5	5	5	5	5	3.88	1.51	5	1	7
Viola hederacea sensu Entwisle (1996)	Ivy-leaf Violet		1	1		1					0.38	0.00	1	1	3
Xanthosia dissecta s.s.	Native Parsley				1	1					0.25	0.00	1	1	3
Bare ground			10	10	5	10	10	10	5	15	9.38	3.20	15	5	8
Litter			60	55	70	70	70	60	65	65	64.38	5.63	70	55	8
Moss			1	5	5	5	1	1		5	2.88	2.14	5	1	7

Site Name	T6	Site Location	Located at unnamed tributary of Boundary Creek on an unnamed access track off Landons Road ~ 400 m from turnoff
Latitude GDA94	-38.4296	**VBA Survey ID**	1107855
Longitude GDA94	143.62805	**VBA Site ID**	715613
Geology	Unconfined	**Start Co-ordinates**	
Ref/Imp	Reference	**End Co-ordinates**	

Recorded Information

Summary information

Scientific Name	**Common Name**	**Conservation Status**	**Q1**	**Q2**	**Q3**	**Q4**	**Q5**	**Q6**	**Q7**	**Q8**	**Average**	**Std Dev**	**Max**	**Min**	**No quads**
Amperea xiphoclada var. xiphoclada	Broom Spurge		1								0.13		1	1	1
Dianella tasmanica	Tasman Flax-lily		5	1	1		5			1	1.63	2.19	5	1	5
Empodisma minus	Spreading Rope-rush		10	1	5	1	1			1	2.38	3.71	10	1	6
Epacris impressa var. impressa	Common Heath		1								0.13		1	1	1
Eucalyptus obliqua	Messmate Stringybark			25	40	25	35	15			17.50	9.75	40	15	6
Eucalyptus ovata	Swamp Gum						1	30	10	25	8.25	13.38	30	1	5
Eucalyptus radiata subsp. radiata	Narrow-leaf Peppermint		10								1.25		10	10	1
Gahnia sieberiana	Red-fruit Saw-sedge		1	10							1.38		10	1	2
Gonocarpus tetragynus	Common Raspwort		1								0.13		1	1	1
Lepidosperma elatius	Tall Sword-sedge		10	40	30	45	25	60	60	65	41.88	19.45	65	10	8
Leptospermum lanigerum	Woolly Tea-tree		30		1	5	5	5	15	15	9.50	10.01	30	1	7
Lomandra longifolia	Spiny-headed Mat-rush				1						0.13		1	1	2
Melaleuca squarrosa	Scented Paperbark			1	5	5	1	5		1	2.25	2.19	5	1	7
Monotoca glauca	Currant-wood	**r**	10	1							1.38		10	1	2
Poa tenera	Slender Tussock-grass			1		1	5	5	5	5	2.75	2.07	5	1	7
Pteridium esculentum	Austral Bracken		5	1	1	5			1		1.63	2.19	5	1	5
Tetrarrhena juncea	Forest Wire-grass		5	5	5	5	10	1	1	1	4.13	3.09	10	1	8
Bare ground			10	1	1	1	1	1	1	1	2.13	3.18	10	1	8
Litter			40	35	40	35	45	40	30	25	36.25	6.41	45	25	8
Moss			1	1	1	1	1	1	1	1	1.00	0.00	1	1	8

Site Name	T7	Site Location	Located at unnamed tributary of Boundary Creek on an unnamed access track off Landons Road ~ 400 m from turnoff
Latitude GDA94	-38.4386	**VBA Survey ID**	1107856
Longitude GDA94	143.60679	**VBA Site ID**	715613
Geology	Unconfined	**Start Co-ordinates**	E 727517, N 5742297
Ref/Imp	Reference	**End Co-ordinates**	E 727483, N 5742294

Recorded Information

Summary information

Scientific Name	**Common Name**	**Conservation Status**	**Q1**	**Q2**	**Q3**	**Q4**	**Q5**	**Q6**	**Q7**	**Q8**	**Average**	**Std Dev**	**Max**	**Min**	**No quads**
Acacia melanoxylon	Blackwood		1	1	1						0.38	0.00	1	1	3
Acaena novae-zelandiae	Bidgee-widgee			1							0.13		1	1	2
Amperea xiphoclada var. xiphoclada	Broom Spurge									1	0.13		1	1	2
Anogramma leptophylla	Annual Fern										0.00		0	0	1
Baumea tetragona	Square Twig-sedge		1			1	1				0.38	0.00	1	1	3
Blechnum nudum	Fishbone Water-fern				1						0.13		1	1	2
Blechnum wattsii	Hard Water-fern					1	1				0.25	0.00	1	1	3
Cassytha glabella	Slender Dodder-laurel		1								0.13		1	1	1
Dicksonia antarctica	Soft Tree-fern			1	30	25	5				7.63	14.38	30	1	5
Empodisma minus	Spreading Rope-rush		5	1	1			5	5		2.13	2.19	5	1	5
Eucalyptus obliqua	Messmate Stringybark								30	30	7.50	0.00	30	30	3
Eucalyptus radiata subsp. radiata	Narrow-leaf Peppermint								10	10	2.50	0.00	10	10	3
Gahnia sieberiana	Red-fruit Saw-sedge			1	1	1					0.38	0.00	1	1	4
Gleichenia dicarpa	Pouched Coral-fern		40	20	25	40	35	50	25		29.38	10.69	50	20	7
Holcus lanatus	Yorkshire Fog	*			1						0.13		1	1	2
Juncus planifolius	Broad-leaf Rush							5	1		0.75	2.83	5	1	3
Leptospermum continentale	Prickly Tea-tree							5	5		1.25	0.00	5	5	3
Leptospermum lanigerum	Woolly Tea-tree		10	35	1	5	5				7.00	13.68	35	1	5
Lindsaea linearis	Screw Fern				1	1					0.25	0.00	1	1	3
Lomandra filiformis	Wattle Mat-rush									1	0.13		1	1	2
Lomandra longifolia	Spiny-headed Mat-rush							1	1	1	0.38	0.00	1	1	4
Melaleuca squarrosa	Scented Paperbark		10	5	30	15	10	1			8.88	10.11	30	1	6
Monotoca glauca	Currant-wood	r		1					25	45	8.88	22.03	45	1	4

Scientific Name	Common Name	Conservation Status	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Average	Std Dev	Max	Min	No quads
Poa tenera	Slender Tussock-grass				1		1				0.25	0.00	1	1	3
Pterostylis spp.	Greenhood									1	0.13		1	1	2
Rubus anglocandicans	Common Blackberry	*		1	1	1					0.38	0.00	1	1	4
Senecio velleioides	Forest Groundsel				1						0.13		1	1	2
Bare ground			1	1	1	1	1	1	1	10	2.13	3.18	10	1	8
Litter			45	55	30	35	15	40	50	80	43.75	19.23	80	15	8
Moss			5	20	30	40	10	10	1	1	14.63	14.22	40	1	8

Site Name	T8	Site Location	Located at unnamed tributary of Dividing Creek immediately south of Westwood Track ~250 m west of intersection with Westwood Road
Latitude GDA94	-38.4429	**VBA Survey ID**	1107857
Longitude GDA94	143.68372	**VBA Site ID**	715614
Geology	Confined	**Start Co-ordinates**	E 734219, N 5741628
Ref/Imp	Impact	**End Co-ordinates**	E 734181, N 5741631

Recorded Information

Summary information

Scientific Name	Common Name	Conservation Status	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Average	Std Dev	Max	Min	No quads
Acacia verticillata	Prickly Moses							1		1	0.25	0.00	1	1	3
Acaena novae-zelandiae	Bidgee-widgee		1		1						0.25		1	1	2
Asperula scoparia subsp. scoparia	Prickly Woodruff			1	1			1			0.38	0.00	1	1	4
Asplenium flabellifolium	Necklace Fern							1			0.13		1	1	2
Blechnum nudum	Fishbone Water-fern		30	35	10		20	1	5	1	12.75	13.94	35	1	7
Blechnum wattsii	Hard Water-fern		1	1	1						0.38	0.00	1	1	3
Calochlaena dubia	Common Ground-fern		1			20					2.63		20	1	2
Coprosma quadrifida	Prickly Currant-bush		1	1							0.25		1	1	2
Dianella tasmanica	Tasman Flax-lily							1			0.13		1	1	2
Dicksonia antarctica	Soft Tree-fern		5	1	15	1	5				3.38	5.73	15	1	5
Eucalyptus brookeriana	Brooker's Gum	**r**		1		1		25		5	4.00	11.49	25	1	5
Eucalyptus obliqua	Messmate Stringybark								25	5	3.75	14.14	25	5	3
Gahnia sieberiana	Red-fruit Saw-sedge		5	1	10	20	40	15	35	5	16.38	14.42	40	1	8
Geranium sp. 2	Variable Crane's-bill					1	1	1			0.38	0.00	1	1	4
Gonocarpus micranthus	Creeping Raspwort							1			0.13		1	1	2
Hydrocotyle hirta	Hairy Pennywort						1	1			0.25	0.00	1	1	3
Juncus spp.	Rush							1			0.13		1	1	2
Lepidosperma elatius	Tall Sword-sedge				1	1	1	5	1	35	5.50	13.65	35	1	7
Leptospermum lanigerum	Woolly Tea-tree										0.00		0	0	1
Luzula meridionalis	Common Woodrush							1			0.13		1	1	2
Melaleuca squarrosa	Scented Paperbark		20	10	10	10	5		5	5	8.13	5.35	20	5	7
Poa tenera	Slender Tussock-grass		1	5	1	5	10	10	5	10	5.88	3.80	10	1	8

Scientific Name	Common Name	Conservation Status	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Average	Std Dev	Max	Min	No quads
Senecio glomeratus	Annual Fireweed		1	1							0.25		1	1	2
Senecio minimus	Shrubby Fireweed			1	1	1	1	1		1	0.75	0.00	1	1	7
Tetrarrhena juncea	Forest Wire-grass		1	5	15	15	10	5	10	5	8.25	5.09	15	1	8
Viola hederacea sensu Entwisle (1996)	Ivy-leaf Violet		1	1	1		1				0.50	0.00	1	1	4
Bare ground			1	1	1	1	1	5	1	1	1.50	1.41	5	1	8
Litter			50	55	55	45	40	35	50	35	45.63	8.21	55	35	8
Moss			5	5	10	1	1	5	1	1	3.63	3.25	10	1	8

Site Name	T9	Site Location	located on Porcupine Creek on Pipeline Road ~ 2km north of intersection with Colac-olangolah Pipeline Track
Latitude GDA94	-38.4992	**VBA Survey ID**	1218415
Longitude GDA94	143.65894	**VBA Site ID**	715612
Geology	Confined	**Start Co-ordinates**	E 731875, N 5735445
Ref/Imp	Impact	**End Co-ordinates**	E 731855, N 5735470

Recorded Information

Summary information

Scientific Name	**Common Name**	**Conservation Status**	**Q1**	**Q2**	**Q3**	**Q4**	**Q5**	**Q6**	**Q7**	**Q8**	**Average**	**Std Dev**	**Max**	**Min**	**No quads**
Acacia melanoxylon	Blackwood		10	5		20	20	15	5		9.38	6.89	20	5	6
Acaena novae-zelandiae	Bidgee-widgee							1			0.13		1	1	1
Asperula conferta	Common Woodruff		1							1	0.25		1	1	2
Austrocynoglossum latifolium	Forest Hound's-tongue							1		1	0.25		1	1	2
Blechnum nudum	Fishbone Water-fern					25	15		5		5.63	10.00	25	5	3
Brassicaceae spp.	Crucifer								1		0.13		1	1	1
Bursaria spinosa subsp. spinosa	Sweet Bursaria		10	1				1	1	5	2.25	3.97	10	1	5
Cerastium glomeratum s.l.	Common Mouse-ear Chickweed	*		1	1	1					0.38	0.00	1	1	3
Clematis aristata	Mountain Clematis		1	1	1	1	1		1	1	0.88	0.00	1	1	7
Coprosma quadrifida	Prickly Currant-bush		10	10	10	10	15	1	5	1	7.75	4.95	15	1	8
Dianella tasmanica	Tasman Flax-lily		1	1					1	1	0.50	0.00	1	1	4
Dichondra repens	Kidney-weed			1		1					0.25		1	1	2
Echinopogon ovatus	Common Hedgehog-grass				1	1	1	1	1		0.63	0.00	1	1	5
Eucalyptus brookeriana	Brooker's Gum	r	25	35	40	30	30	10	20	5	24.38	12.08	40	5	8
Eucalyptus obliqua	Messmate Stringybark						5	25	10	15	6.88	8.54	25	5	4
Eucalyptus radiata subsp. radiata	Narrow-leaf Peppermint									15	1.88		15	15	1
Gahnia sieberiana	Red-fruit Saw-sedge		5				5		1	10	2.63	3.69	10	1	4
Geranium sp. 2	Variable Crane's-bill		1	1			1	1			0.50	0.00	1	1	4
Gonocarpus tetragynus	Common Raspwort									1	0.13		1	1	1
Goodenia lanata	Trailing Goodenia									1	0.13		1	1	1
Gynatrix pulchella s.s.	Hemp Bush								1		0.13		1	1	1

Scientific Name	Common Name	Conservation Status	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Average	Std Dev	Max	Min	No quads
Hypochaeris radicata	Flatweed	*			1		1	1	1		0.50	0.00	1	1	4
Leptospermum lanigerum	Woolly Tea-tree		1								0.13		1	1	1
Lomandra filiformis	Wattle Mat-rush				1						0.13		1	1	1
Lomandra longifolia	Spiny-headed Mat-rush									1	0.13		1	1	1
Notelaea ligustrina	Privet Mock-olive		5	1	15	1	1	1	1	1	3.25	4.95	15	1	8
Olearia argophylla	Musk Daisy-bush		1	5	5	5		1	5		2.75	2.07	5	1	6
Poa sieberiana	Grey Tussock-grass			5	1	1	1	5	5	1	2.38	2.14	5	1	7
Poa tenera	Slender Tussock-grass			1	1			5		1	1.00	2.00	5	1	4
Poaceae spp.	Grass								1		0.13		1	1	1
Pomaderris aspera	Hazel Pomaderris			15		30	20	10		25	12.50	7.91	30	10	5
Pteridium esculentum	Austral Bracken		5	5	5				1	5	2.63	1.79	5	1	5
Pterostylis spp.	Greenhood		1	1						1	0.38	0.00	1	1	3
Rubus parvifolius	Small-leaf Bramble								1		0.13		1	1	1
Senecio velleioides	Forest Groundsel			1					1		0.25		1	1	2
Tetrarrhena juncea	Forest Wire-grass		5	5	5	1	1	1	5	5	3.50	2.07	5	1	8
Viola hederacea sensu Entwisle (1996)	Ivy-leaf Violet						1				0.13		1	1	1
Bare ground			1	1	1	5	5	1	5	1	2.50	2.07	5	1	8
Litter			50	65	65	60	60	65	55	60	60.00	5.35	65	50	8
Moss			1	5	5	5	5	1	5	1	3.50	2.07	5	1	8

Site Name	T10	Site Location	located on Porcupine Creek on Pipeline Road ~ 2km north of intersection with Colac-olangolah Pipeline Track
Latitude GDA94	-38.4597	**VBA Survey ID**	1218412
Longitude GDA94	143.61789	**VBA Site ID**	715620
Geology	Confined	**Start Co-ordinates**	E 728420, N 5739932
Ref/Imp	Impact	**End Co-ordinates**	E 728436, N 5739895

Recorded Information

Summary information

Scientific Name	**Common Name**	**Conservation Status**	**Q1**	**Q2**	**Q3**	**Q4**	**Q5**	**Q6**	**Q7**	**Q8**	**Average**	**Std Dev**	**Max**	**Min**	**No quads**
Acacia melanoxylon	Blackwood		1								0.13		1	1	1
Acrotriche prostrata	Trailing Ground-berry							1			0.13		1	1	2
Amperea xiphoclada var. xiphoclada	Broom Spurge									1	0.13		1	1	2
Banksia marginata	Silver Banksia							1			0.13		1	1	2
Billardiera mutabilis	Common Apple-berry					1		1		1	0.38	0.00	1	1	4
Dianella tasmanica	Tasman Flax-lily					1	1			1	0.38	0.00	1	1	4
Empodisma minus	Spreading Rope-rush						1	1		1	0.38	0.00	1	1	4
Eucalyptus ovata	Swamp Gum		5		5	25	10	5	5		6.88	8.01	25	5	6
Eucalyptus radiata subsp. radiata	Narrow-leaf Peppermint									1	0.13		1	1	2
Gahnia sieberiana	Red-fruit Saw-sedge		30	30	20	20	5		50	30	23.13	13.76	50	5	7
Gonocarpus tetragynus	Common Raspwort						1	1		1	0.38	0.00	1	1	4
Goodenia humilis	Swamp Goodenia						1		1		0.25	0.00	1	1	3
Juncus spp.	Rush									1	0.13		1	1	2
Lepidosperma elatius	Tall Sword-sedge		1	1	25	20	20	45	10		15.25	15.41	45	1	7
Leptospermum lanigerum	Woolly Tea-tree		45	55	45	35	35	30	20	40	38.13	10.67	55	20	8
Lindsaea linearis	Screw Fern							1		1	0.25	0.00	1	1	3
Lomandra filiformis	Wattle Mat-rush							1	1	1	0.38	0.00	1	1	4
Lomandra longifolia	Spiny-headed Mat-rush						5	5	5		1.88	0.00	5	5	4
Melaleuca squarrosa	Scented Paperbark		5	5	5	5	5	5	10	5	5.63	1.77	10	5	8
Monotoca glauca	Currant-wood	**r**					1	5	1	5	1.50	2.31	5	1	5
Poa sieberiana	Grey Tussock-grass						1				0.13		1	1	2
Poa tenera	Slender Tussock-grass							1	1	1	0.38	0.00	1	1	4
Pomaderris aspera	Hazel Pomaderris										0.00		0	0	1

Scientific Name	Common Name	Conservation Status	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Average	Std Dev	Max	Min	No quads
Pteridium esculentum	Austral Bracken		1	1			5	1	1		1.13	1.79	5	1	5
Selaginella uliginosa	Swamp Selaginella						1				0.13		1	1	2
Tetrarrhena juncea	Forest Wire-grass						1				0.13		1	1	2
Viola hederacea sensu Entwisle (1996)	Ivy-leaf Violet				1		1	1			0.38	0.00	1	1	4
Xanthosia dissecta s.s.	Native Parsley									1	0.13		1	1	2
Bare ground			10	5	1	1	1	1	1	1	2.63	3.29	10	1	8
Litter			55	70	60	65	60	50	50	40	56.25	9.54	70	40	8
Moss			5	5	5	10	5	10	5	20	8.13	5.30	20	5	8

Site Name	T11	Site Location	Located at Porcupine Creek immediately east of crossing of Pipeline Road
Latitude GDA94	-38.4849	VBA Survey ID	1084205
Longitude GDA94	143.64186	VBA Site ID	715586
Geology	Confined	Start Co-ordinates	E 730431, N 5737070
Ref/Imp	Reference	End Co-ordinates	E 730416, N 5737039

Recorded Information

Summary information

Scientific Name	Common Name	Conservation Status	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Average	Std Dev	Max	Min	No quads
Acacia melanoxylon	Blackwood									1	0.13		1	1	1
Acacia verticillata	Prickly Moses		1	1					5	5	1.50	2.31	5	1	4
Acaena novae-zelandiae	Bidgee-widgee		1								0.13		1	1	1
Amyema pendula	Drooping Mistletoe			1	5	1			1	1	1.13	1.79	5	1	5
Blechnum nudum	Fishbone Water-fern		1	1	15	1	5				2.88	6.07	15	1	5
Blechnum wattsii	Hard Water-fern					1	1				0.25		1	1	2
Cyathea australis	Rough Tree-fern			5	1	35	20	1			7.75	14.86	35	1	5
Dianella tasmanica	Tasman Flax-lily		1	5	5	1			5	1	2.25	2.19	5	1	6
Eucalyptus brookeriana	Brooker's Gum	r	15	40	35	25	25	25	10		21.88	10.41	40	10	7
Eucalyptus obliqua	Messmate Stringybark		20					5	5	25	6.88	10.31	25	5	4
Gahnia sieberiana	Red-fruit Saw-sedge		10	15		10	15	40	10	35	16.88	12.72	40	10	7
Gonocarpus micranthus	Creeping Raspwort						1				0.13		1	1	1
Goodenia lanata	Trailing Goodenia									1	0.13		1	1	1
Lepidosperma elatius	Tall Sword-sedge		35	10	20	30	15	10	35	15	21.25	10.61	35	10	8
Leptospermum lanigerum	Woolly Tea-tree								5	5	1.25		5	5	2
Melaleuca squarrosa	Scented Paperbark		1	5	20	15	15	15	1	1	9.13	7.90	20	1	8
Olearia lirata	Snowy Daisy-bush			5							0.63		5	5	1
Oxalis spp.	Wood Sorrel						1				0.13		1	1	1
Pteridium esculentum	Austral Bracken		10	10			5	5	5		4.38	2.74	10	5	5
Rubus parvifolius	Small-leaf Bramble					1					0.13		1	1	1
Stellaria pungens	Prickly Starwort		1								0.13		1	1	1
Tetrarrhena juncea	Forest Wire-grass		10	10	15	10	10	10	10	10	10.63	1.77	15	10	8
Viola hederacea sensu Entwisle (1996)	Ivy-leaf Violet								1		0.13		1	1	1
Bare ground			1	1	1	1	1	1	1	1	1.00	0.00	1	1	8
Litter			50	60	50	60	45	55	55	55	53.75	5.18	60	45	8
Moss			1	5	5	5	5	5	5	5	4.50	1.41	5	1	8

Site Name	T12	Site Location	In Otway Forest Park on northern side of Gold Hole Road at un-named tributary of Dividing Creek
Latitude GDA94	-38.457	**VBA Survey ID**	1107858
Longitude GDA94	143.6493	**VBA Site ID**	714870
Geology	Confined	**Start Co-ordinates**	E 731169, N 5740151
Ref/Imp	Reference	**End Co-ordinates**	E 731169, N 5740189

Recorded Information

Summary information

Scientific Name	Common Name	Conservation Status	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Average	Std Dev	Max	Min	No quads
Acacia mucronata subsp. longifolia	Narrow-leaf Wattle				1	1		5	1	5	1.63	2.19	5	1	5
Acacia verticillata	Prickly Moses		20	15	10	10	5	45	5	15	15.63	12.94	45	5	8
Acaena novae-zelandiae	Bidgee-widgee		1	1		1					0.38	0.00	1	1	3
Asperula conferta	Common Woodruff				1		1				0.25		1	1	2
Bedfordia arborescens	Blanket Leaf				1	5		5		1	1.50	2.31	5	1	4
Billardiera mutabilis	Common Apple-berry		1					1	1	1	0.50	0.00	1	1	4
Blechnum nudum	Fishbone Water-fern				1	1	1				0.38	0.00	1	1	3
Blechnum wattsii	Hard Water-fern				5	1	5				1.38	2.31	5	1	3
Cassinia longifolia	Shiny Cassinia				1						0.13		1	1	1
Cassytha glabella	Slender Dodder-laurel							1			0.13		1	1	1
Cassytha pubescens s.s.	Downy Dodder-laurel								1	1	0.25		1	1	2
Cirsium vulgare	Spear Thistle	*	1	1							0.25		1	1	2
Coprosma quadrifida	Prickly Currant-bush		1								0.13		1	1	1
Cyathea australis	Rough Tree-fern				30		1				3.88		30	1	2
Empodisma minus	Spreading Rope-rush		1								0.13		1	1	1
Eucalyptus ovata	Swamp Gum		20	20	15	25	40	20	10	10	20.00	9.64	40	10	8
Eucalyptus radiata subsp. radiata	Narrow-leaf Peppermint							10	10	10	3.75	0.00	10	10	3
Euchiton spp.	Cudweed				1						0.13		1	1	1
Gahnia sieberiana	Red-fruit Saw-sedge		5	5	5	40	10				8.13	15.25	40	5	5
Galium spp.	Bedstraw							1			0.13		1	1	1
Geranium sp. 2	Variable Crane's-bill		1	1	1	1	1	1	1	1	1.00	0.00	1	1	8
Gleichenia dicarpa	Pouched Coral-fern				1	1	1				0.38	0.00	1	1	3
Gonocarpus tetragynus	Common Raspwort			1	1		1		1		0.50	0.00	1	1	4

Scientific Name	Common Name	Conservation Status	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Average	Std Dev	Max	Min	No quads
Hypericum gramineum s.l.	Small St John's Wort				1			1			0.25		1	1	2
Lepidosperma elatius	Tall Sword-sedge		1								0.13		1	1	1
Leptospermum continentale	Prickly Tea-tree						1		1	1	0.38	0.00	1	1	3
Leptospermum lanigerum	Woolly Tea-tree				1	1		1			0.38	0.00	1	1	3
Lomandra longifolia	Spiny-headed Mat-rush					1	5	15	50	45	14.50	22.83	50	1	5
Melaleuca squarrosa	Scented Paperbark		1	1		5					0.88	2.31	5	1	3
Monotoca glauca	Currant-wood	r							1		0.13		1	1	1
Olearia lirata	Snowy Daisy-bush				1	1					0.25		1	1	2
Oxalis spp.	Wood Sorrel				1	1	1		1		0.50	0.00	1	1	4
Poa tenera	Slender Tussock-grass		10	5	15	1	1		1	1	4.25	5.61	15	1	7
Pteridium esculentum	Austral Bracken		25	20			10	10	15	10	11.25	6.32	25	10	6
Pultenaea gunnii	Golden Bush-pea		1		1	1	1				0.50	0.00	1	1	4
Senecio velleioides	Forest Groundsel		1			1	1	1			0.50	0.00	1	1	4
Tetrarrhena juncea	Forest Wire-grass		1	5	10	5	10	10	5	10	7.00	3.46	10	1	8
Viola hederacea sensu Entwisle (1996)	Ivy-leaf Violet		1	1	1	1	1	1			0.75	0.00	1	1	6
Bare ground			1	1	1	1	1	1	1	1	1.00	0.00	1	1	8
Litter			45	45	30	40	45	45	45	45	42.50	5.35	45	30	8
Moss			5	10	5	1	1	1	1	1	3.13	3.31	10	1	8

Site Name	T13	Site Location	on North side of Parkes Lodge Rd ~200m north of Mcdonalds Road intersection
Latitude GDA94	-38.4682	VBA Survey ID	1218414
Longitude GDA94	143.63163	VBA Site ID	715424
Geology	Confined	Start Co-ordinates	E 729592, N 5738949
Ref/Imp	Reference	End Co-ordinates	E 729603, N 5748989

Recorded Information

Summary information

Scientific Name	Common Name	Conservation Status	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Average	Std Dev	Max	Min	No quads
Acrotriche prostrata	Trailing Ground-berry									1	0.13		1	1	2
Allocasuarina paludosa	Scrub Sheoak		10	15	30	10	15	35	30	30	21.88	10.33	35	10	8
Cassytha pubescens s.s.	Downy Dodder-laurel			1							0.13		1	1	2
Caustis flexuosa	Curly Wig		5	5	5	10	5	10	10	15	8.13	3.72	15	5	8
Epacris impressa	Common Heath							1	1	1	0.38	0.00	1	1	4
Epacris lanuginosa	Woolly-style Heath				1		1				0.25	0.00	1	1	3
Eucalyptus ovata	Swamp Gum		1	5	1	1		1	1	5	1.88	1.95	5	1	7
Gahnia radula	Thatch Saw-sedge								10	10	2.50	0.00	10	10	3
Gonocarpus micranthus subsp. micranthus	Creeping Raspwort		1	1	1	1		1	1	1	0.88	0.00	1	1	7
Juncus bufonius	Toad Rush						1		1	1	0.38	0.00	1	1	4
Lepidosperma gunnii	Slender Sword-sedge		1	1		1		1	1	1	0.75	0.00	1	1	6
Lepidosperma laterale	Variable Sword-sedge		10	15	15	25	25	5		1	12.00	9.21	25	1	7
Leptospermum continentale	Prickly Tea-tree		20	25	15	20	15	25	25	20	20.63	4.17	25	15	8
Leucopogon virgatus	Common Beard-heath								1	1	0.25	0.00	1	1	3
Lindsaea linearis	Screw Fern		1								0.13		1	1	1
Lomandra filiformis	Wattle Mat-rush		1	1		5	1	1	1	1	1.38	1.51	5	1	7
Lomandra longifolia	Spiny-headed Mat-rush									1	0.13		1	1	2
Melaleuca squarrosa	Scented Paperbark									1	0.13		1	1	2
Opercularia varia	Variable Stinkweed			1	1	1		1	1	1	0.75	0.00	1	1	7
Orichidaceae spp.	Orchid			1	1		1				0.38	0.00	1	1	4
Poa tenera	Slender Tussock-grass			1	1	1	1	5	5	5	2.38	2.14	5	1	8
Pultenaea gunnii	Golden Bush-pea		1		1	1	1		1	1	0.75	0.00	1	1	6
Rytidosperma spp.	Wallaby Grass					1	1	1	1		0.50	0.00	1	1	5
Selaginella uliginosa	Swamp Selaginella		1	1	1	1	1		1		0.75	0.00	1	1	6
Sprengelia incarnata	Pink Swamp-heath		1					1	1	1	0.50	0.00	1	1	4
Tetrarrhena distichophylla	Hairy Rice-grass		5	1			1	1	1	1	1.25	1.63	5	1	6
Viola hederacea sensu Entwisle (1996)	Ivy-leaf Violet				1	1	1	1	1		0.63	0.00	1	1	6

Scientific Name	Common Name	Conservation Status	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Average	Std Dev	Max	Min	No quads
Wahlenbergia stricta subsp. stricta	Tall Bluebell			1							0.13		1	1	2
Xanthosia dissecta s.s.	Native Parsley		1	1	1	1	1	1		1	0.88	0.00	1	1	7
Bare ground			20	15	15	15	20	20	15	15	16.88	2.59	20	15	8
Litter			30	15	15	15	15	10	10	10	15.00	6.55	30	10	8
Moss			1	1	1	1	1	1	1	1	1.00	0.00	1	1	8

Site Name	T14	Site Location	Located east of Robinson Road approximately 150 m north of intersection with Cashin's Road
Latitude GDA94	-38.4592	VBA Survey ID	1218411
Longitude GDA94	143.59752	VBA Site ID	715585
Geology	Confined		
Ref/Imp	Reference		

Recorded Information

Summary information

Scientific Name	Common Name	Conservation Status	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Average	Std Dev	Max	Min	No quads
Acacia melanoxylon	Blackwood							1			0.13		1	1	2
Blechnum wattsii	Hard Water-fern		20	5	5	10	20	15	10	15	12.50	5.98	20	5	8
Cyathea australis	Rough Tree-fern									25	3.13		25	25	2
Dicksonia antarctica	Soft Tree-fern								10	1	1.38	6.36	10	1	3
Eucalyptus obliqua	Messmate Stringybark		20	5		5					3.75	8.66	20	5	3
Eucalyptus viminalis subsp. viminalis	Manna Gum		10	20	25	30	30	30	5	5	19.38	11.16	30	5	8
Gahnia radula	Thatch Saw-sedge		5	5	5	25	30	20	10		12.50	10.58	30	5	7
Gleichenia microphylla	Scrambling Coral-fern		25	5	30	5	10	20	20	10	15.63	9.43	30	5	8
Lepidosperma elatius	Tall Sword-sedge		5	1						1	0.88	2.31	5	1	3
Melaleuca squarrosa	Scented Paperbark		30	20	40	40	40	30	30	25	31.88	7.53	40	20	8
Monotoca glauca	Currant-wood	r					10	15	5		3.75	5.00	15	5	4
Polystichum proliferum	Mother Shield-fern		5	55	10					10	10.00	23.45	55	5	4
Rubus parvifolius	Small-leaf Bramble									1	0.13		1	1	2
Tetrarrhena juncea	Forest Wire-grass		5	1	1	1	5	5	5	5	3.50	2.07	5	1	8
Bare ground			1	5	5	1	1	1	10	1	3.13	3.31	10	1	8
Litter			55	55	50	65	55	50	50	55	54.38	4.96	65	50	8
Moss			1	1	1	5	1	5	5	5	3.00	2.14	5	1	8

Appendix B. Local Hydrogeology

B.1 Site T1

The groundwater conditions at the site are as follows:

- The site is underlain by an alluvial aquifer, which is overlying the Mid Tertiary Aquitard (MTD). The alluvial aquifer encountered in SB1 consists of silt, sand and clay. Groundwater levels have not been directly measured at this location. The closest groundwater monitoring bores are 0.5 km to the east. There are three nested bores at this location – TB1a, TB1b, TB1c. TB1a monitors groundwater levels in the shallow alluvial aquifer, TB1b monitors the underlying aquitard and TB1c monitors the Lower Tertiary Aquifer.
- Local nested bores show there is an upward gradient from the underlying aquitard to alluvial aquifer which indicates that the groundwater levels in the aquitard have not been significantly affected by drawdown in the Lower Tertiary Aquifer (LTA). It is likely that the groundwater elevation in the MTD is above the ground level at the swamp and Big Swamp is likely to be a groundwater discharge site.
- TB1a is located 500 m to the east (downstream) of the transect location and is screened in the alluvial aquifer. The water level in this bore has ranged from 0.2 to 2.5 m below ground level over the monitoring period of July 2014 to May 2016. The hydrographs for the three monitoring bores are shown in Figure 6-1.The hydrograph for TB1a shows a declining groundwater trend consistent with below average rainfall conditions. The groundwater levels show seasonal fluctuations of about 2 m. The hydrograph for TB1b also shows at seasonal response, with seasonal fluctuations around 1 m.
- Groundwater levels in TB1c have been rising since monitoring commenced in June 2015. This bore is monitoring the LTA aquifer, which has been influenced by pumping from Barwon Downs. Groundwater levels in this aquifer are recovering (rising) after a period of pumping.
- The groundwater at the vegetation survey site is likely to be within 2 m of the ground surface where most vegetation can access the groundwater.

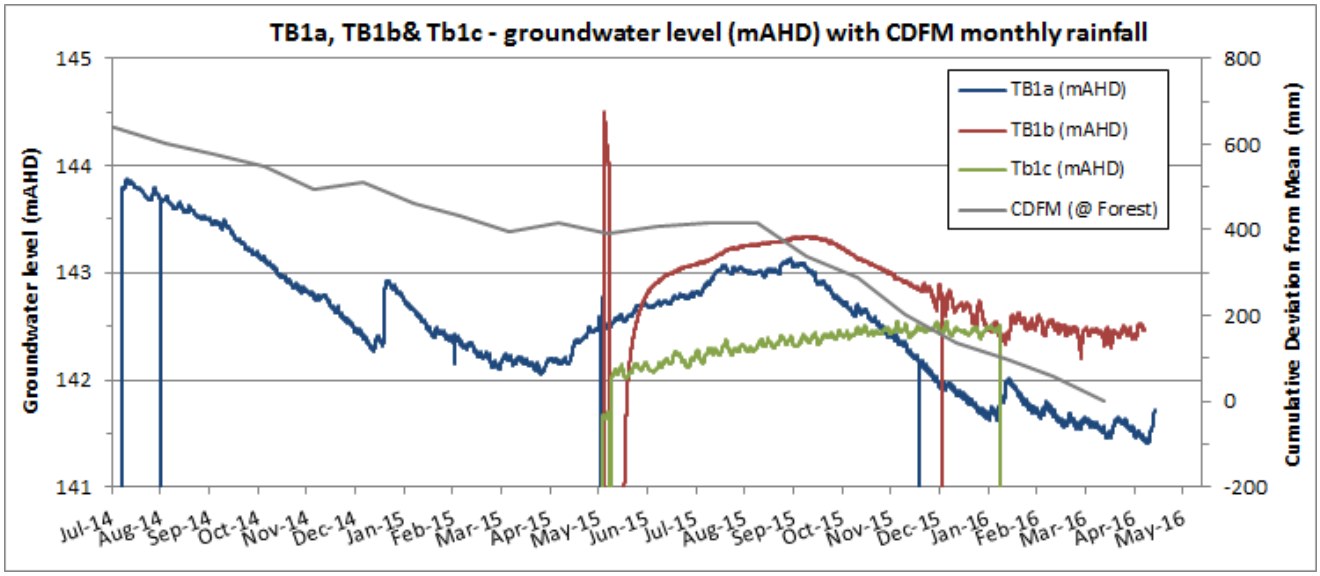


Figure 6-1 : Hydrograph for Bores TB1a, b, c

B.2 Site T2

The groundwater conditions at the site are as follows:

- The site is underlain by the LTA. Recent alluvial sediments are present in the valley floor but based on the soil log from SB2 these are very thin and of limited extent. The LTA encountered in SB2 and TB2 consists of light grey, yellow and brown sand and silt.
- Based on the soil water profile at SB2 the depth to groundwater was around 1.2 m in 2014 and groundwater elevation is likely to be at or just below the elevation of the stream bed. TB2a, b and c (located 25 m above the soil bore and transect) are all dry. The hydrograph for TB2b is shown in Figure 6-2. Groundwater was recorded in TB2b, but levels declined below the base of the bore in May 2015. Groundwater levels within the LTA in this area have declined in response to pumping and levels have declined by up to 20 m from pre-pumping groundwater levels.
- The groundwater at the vegetation survey site is likely to be within 1 or 2 m of the ground surface where most vegetation can access the groundwater.

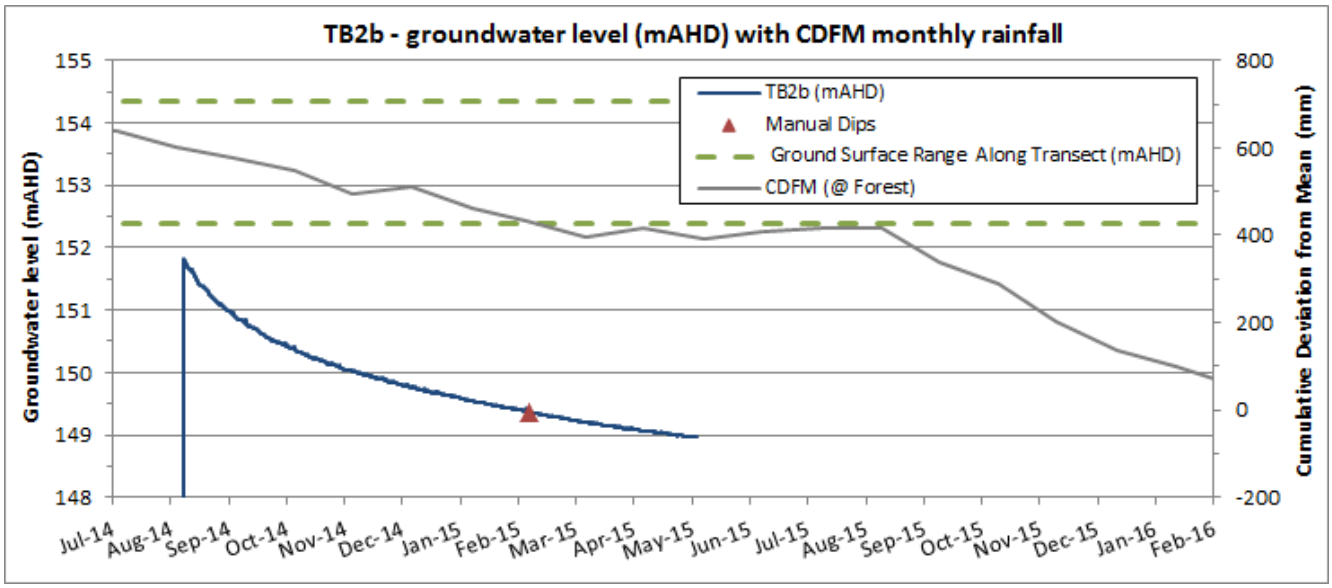


Figure 6-2 : Hydrograph for Bores TB2b

B.3 Site T3

The groundwater conditions at the site are as follows:

- The site is underlain by the LTA. Recent alluvial sediments are likely to be present in the valley floor but the thickness and extent of these sediments are unknown. The LTA encountered in TB3 consists of light brown, grey and orange sands, gravels and clays.
- No soil bore was drilled at this site. The water level in TB3 (located 200 m from the transect) has remained stable around 32m below ground level throughout the September 2014 to May 2016 monitoring period. The hydrograph for Figure 6-3. The hydrograph for TB3 shows very little change in water level, despite below average rainfall conditions.
- The groundwater at the vegetation survey site is around 15 m below the ground surface and it is not likely that vegetation is accessing groundwater.

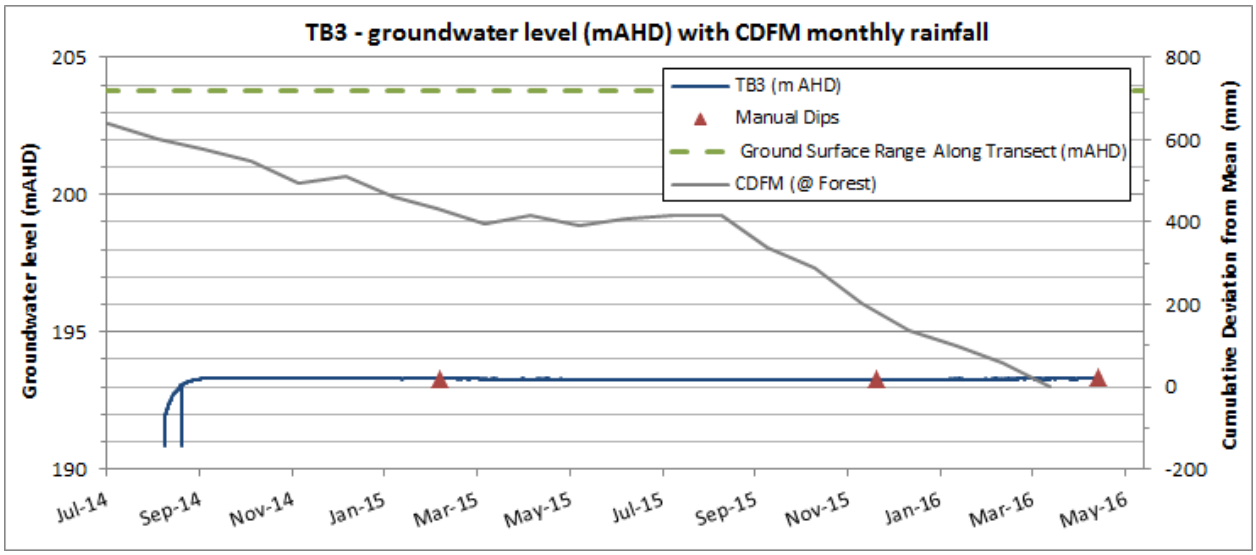


Figure 6-3 : Hydrograph for bores TB3

B.4 Site T4

The groundwater conditions at the site are as follows:

- The site is underlain by recent alluvial deposits which are in turn underlain by LTA. The alluvials consist of sands and clayey sands to approximately 10 m overlying clay material to 20 m. The underlying LTA consists of yellow brown sand.
- Based on the soil water profile at SB4 and TB4b the depth to groundwater has fluctuated between 1 and 4 m. However, TB4b has been dry since December 2015, so the depth to watertable is now greater than 4 m.
- The shallow sandy alluvial material has the potential to store water at a local scale. However, the presence of this local shallow groundwater is dependent on the creek flowing or recharge from rainfall. Water levels in the perched aquifer show strong seasonal fluctuations in response to rainfall patterns.
- The hydrograph for TB4b is shown in Figure 6-4. The hydrograph for this bore shows a slight decline of ~0.5m in water levels from August 2014 to April 2015 followed by a shaper decline of ~1.5 m over the next month. Water levels increased by ~2m from May to October 2015. A rapid decline in water levels on the 11th of December 2015 coincided with a sampling event; the bore has remained dry since. Over the period of monitoring rainfall has been below average.
- TB4a and TB4c are screened deeper in more clayey material and the LTA. The clayey material screened in TB4a is not saturated and groundwater levels in the LTA are more than 30 m below the ground level.
- The groundwater within the LTA was more than 30 m below the ground surface and vegetation is unlikely to have access to this regional groundwater source. Perched groundwater in the shallow sandy alluvial material is likely to exist at a local scale only, when recharged by surface water or rainwater.

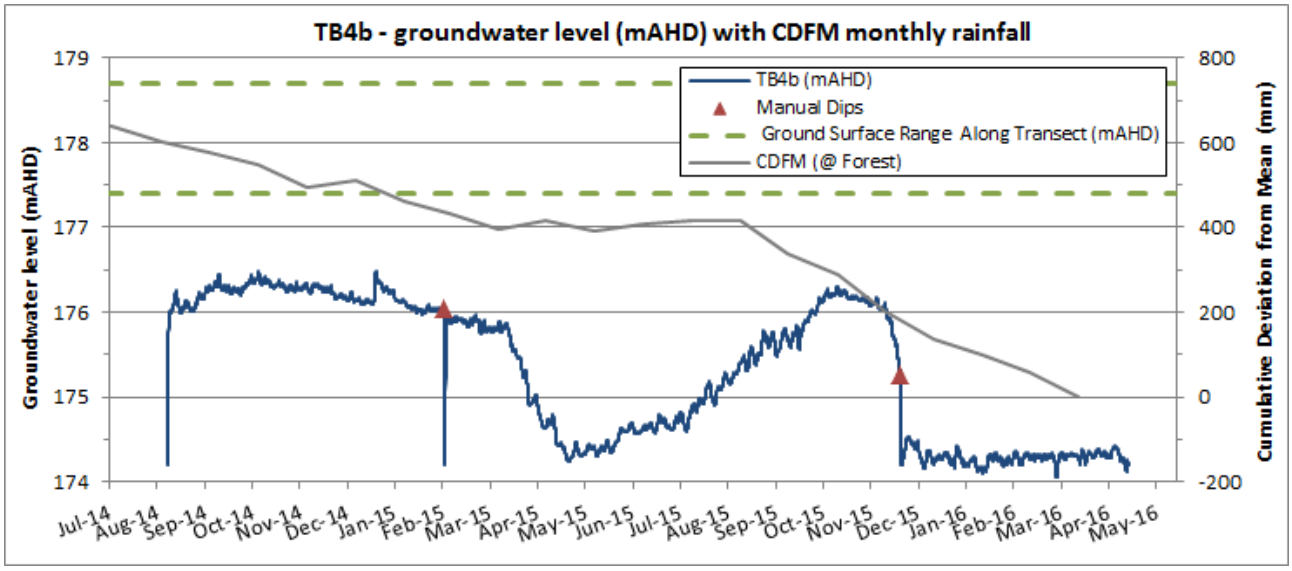


Figure 6-4 : Hydrograph for Bore TB4b

B.5 Site T5

The groundwater conditions at the site are as follows:

- The site is underlain by the LTA. Recent alluvial sediments are likely to be present in the valley floor but these are likely to be thin and of limited extent. The soil and groundwater bores did not intersect alluvial sediments, however these bore are located on higher ground away from the valley floor. The LTA encountered in SB5 and TB5 consists of orange, brown and grey silty and clayey sands and gravels with some sandy clay.
- The watertable was not encountered in SB5 and therefore the groundwater at this location is more than 3.3 m below ground level.
- The water level in TB5 (located further from the transect than SB5) has ranged from 21 to 20.5 m below ground level over the monitoring period of September 2014 to May 2016. The hydrograph for TB5 is shown in Figure 6-5. The hydrograph for TB5 shows that overall the water level is relatively stable over the monitoring period with a slight increase of 0.5m from December 2015 onwards, despite below average rainfall conditions over the monitoring period.
- Based on the available information, the groundwater at the vegetation survey site is inferred to be between 5 and 10 m below the ground surface and a limited number of vegetation species will have access to the groundwater.

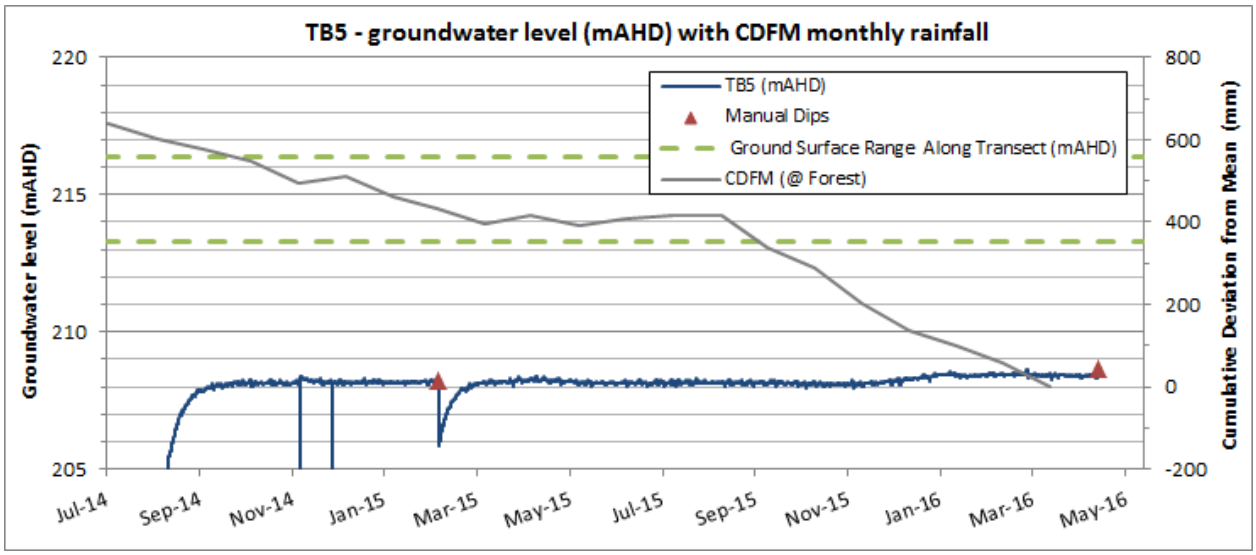


Figure 6-5 : Hydrograph for Bore TB5.

B.6 Site T6

The groundwater conditions at the site are as follows:

- The site is underlain by the LTA. Recent alluvial sediments are present in the valley floor but based on the soil log from SB6 these are thin and of limited extent. The LTA encountered in SB6 and TB6 consists of orange and brown silty sands and gravels with some sandy clay.
- The water level in TB6 (located on the opposite side of the watercourse to the soil bore and transect) has ranged from 17.1 to 17.6 m below ground level over the monitoring period September 2014 to May 2016. The hydrograph for TB6 is shown in Figure 6-6. The hydrograph for TB6 shows overall the water level is quite stable around 17.3 m below ground surface. There is a slight decline of ~ 0.5m from January 2015 to May 2016. Over the monitoring period rainfall has been below average.
- The groundwater at the vegetation survey site is within 2 m of the ground surface and most vegetation is likely to have access to the groundwater.

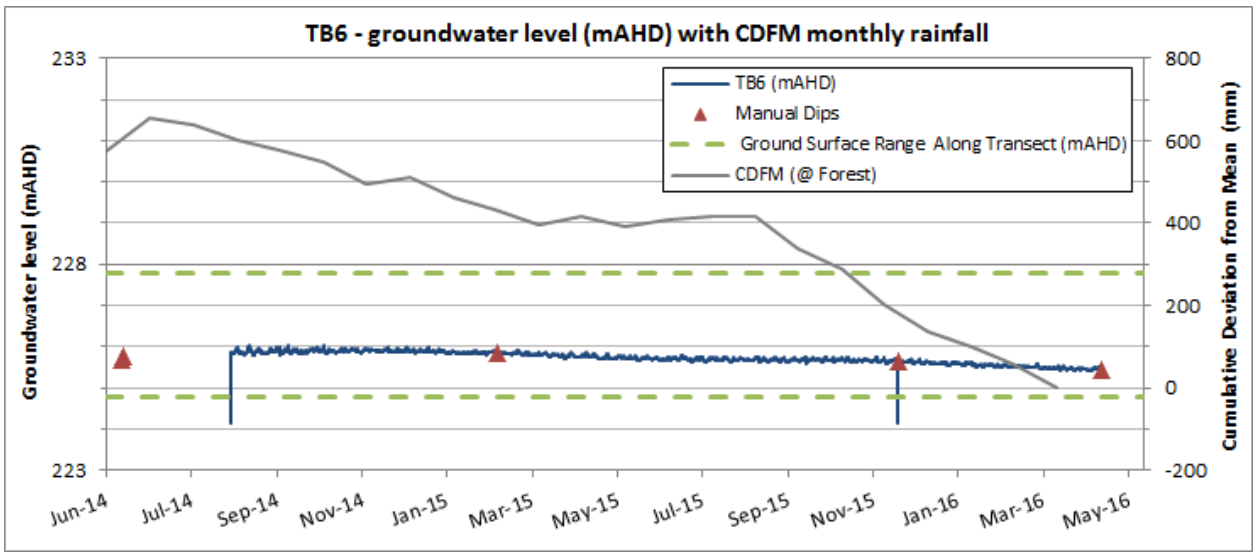


Figure 6-6 : Hydrograph for Bore TB6.

B.7 Site T7

The groundwater conditions at the site are as follows:

- The site is underlain by the LTA. Recent alluvial sediments could be present in the valley floor but based on the soil log from SB7 these are thin and of limited extent. The soil and groundwater bores did not intersect alluvial sediments, however the bores are located outside the valley floor. The LTA encountered in SB7 and TB7 consists of medium brown to orange and light grey clayey sands and silts with some silty clay.
- The water level in TB7 (located within 50 m of the soil bore) has ranged from 2.1 to 3.2 m below ground level over the monitoring period of August 2014 to May 2016. The hydrograph for TB7 is shown in Figure 6-7.
- The hydrograph for TB7 shows an overall small declining trend in water levels similar to the trend in the rainfall cumulative difference from mean. Over the monitoring period rainfall has been below average.
- The groundwater at the vegetation survey site is currently within 2 m of the ground surface and most vegetation is likely to have access to the groundwater.

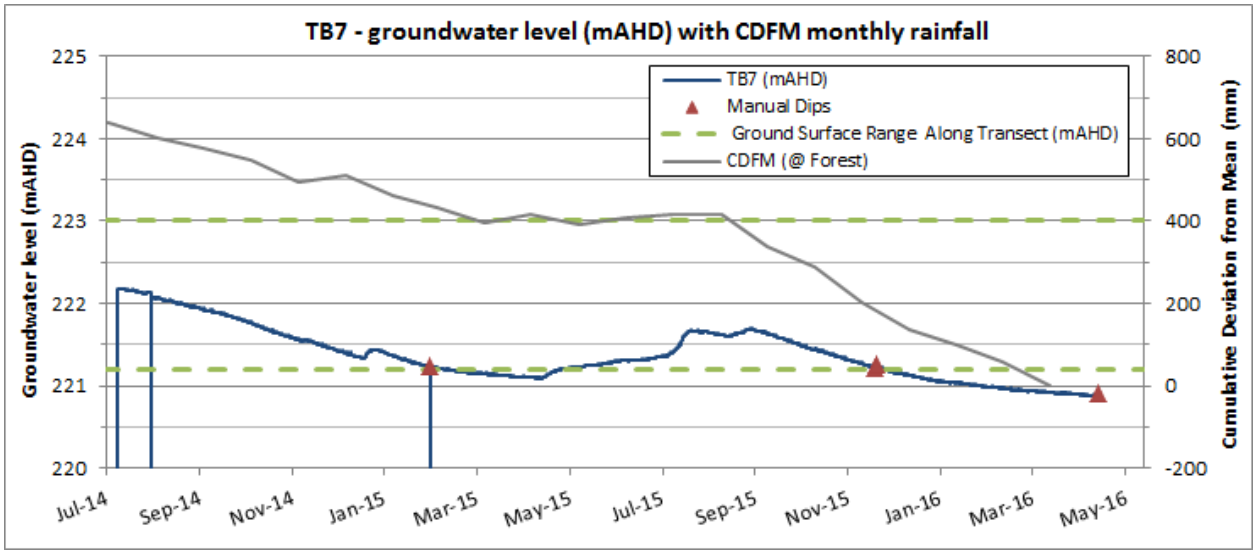


Figure 6-7 : Hydrograph for Bore TB7.

B.8 Site T8

The groundwater conditions at the site are as follows:

- The site is underlain by the aquitard (MTD). Recent alluvial sediments are present in the valley floor and based on the soil log from SB8 these are around 3 m thick consisting of sand. The MTD encountered in SB8 and TB8 consists of grey and orange silty clay underlain by dark brown ligneous clay or peat.
- The water level in TB8 (located between the soil bore and the creek bed) has ranged from 3.6 to 4.4 m below ground level over the monitoring period of September 2014 to May 2016. The hydrograph for Bore TB8 is shown in Figure 6-8.
- The hydrograph for TB8 shows an overall slight declining trend in water levels similar to the trend in the rainfall cumulative difference from mean. Over the monitoring period rainfall has been below average.
- The groundwater at the vegetation survey site within the creek bed is within 2 m of the ground surface and most vegetation is likely to have access to the groundwater.

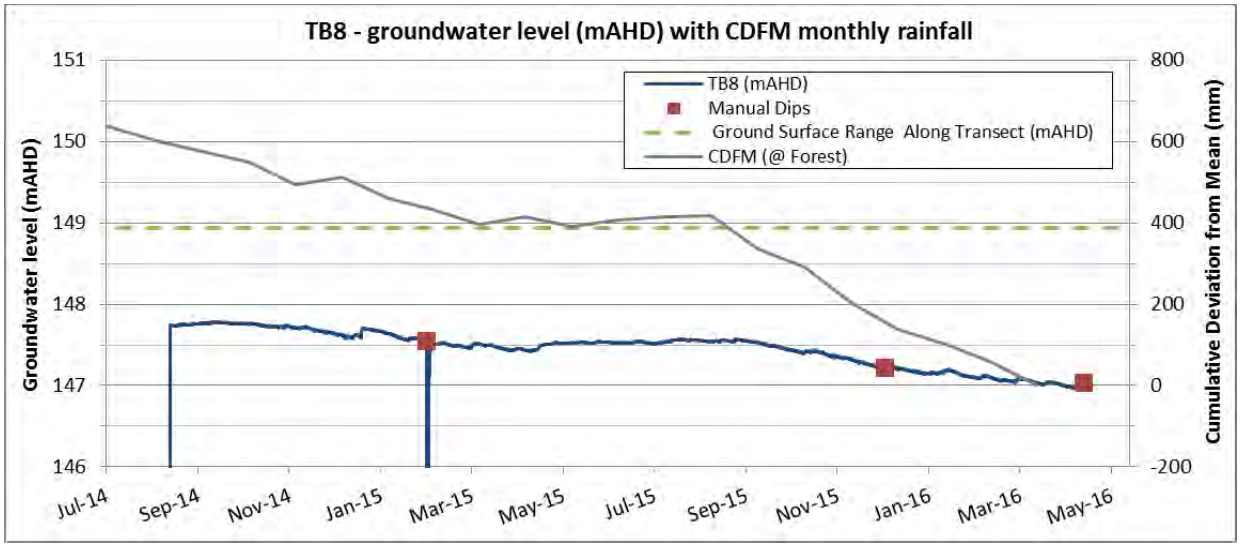


Figure 6-8 : Hydrograph for Bore TB8.

B.9 Site T9

The groundwater conditions at the site are as follows:

- The site is underlain by the alluvial sediments consisting of predominately clay with some sand and silt.
- The water level in TB9 (located adjacent to the creek bed) has ranged from 2.8 to 5.2 m below ground level over the monitoring period of August 2014 to May 2016. The hydrograph for Bore TB9 is shown in Figure 6-9.
- The hydrograph for TB9 shows a decline of ~1.5 m between October and May and an increase between May to September 2015. Overall the hydrograph shows a declining trend. Over the monitoring period rainfall has been below average.
- The groundwater at the vegetation survey site within the creek bed is around 5 m of the ground surface and some vegetation is likely to have access to the groundwater.

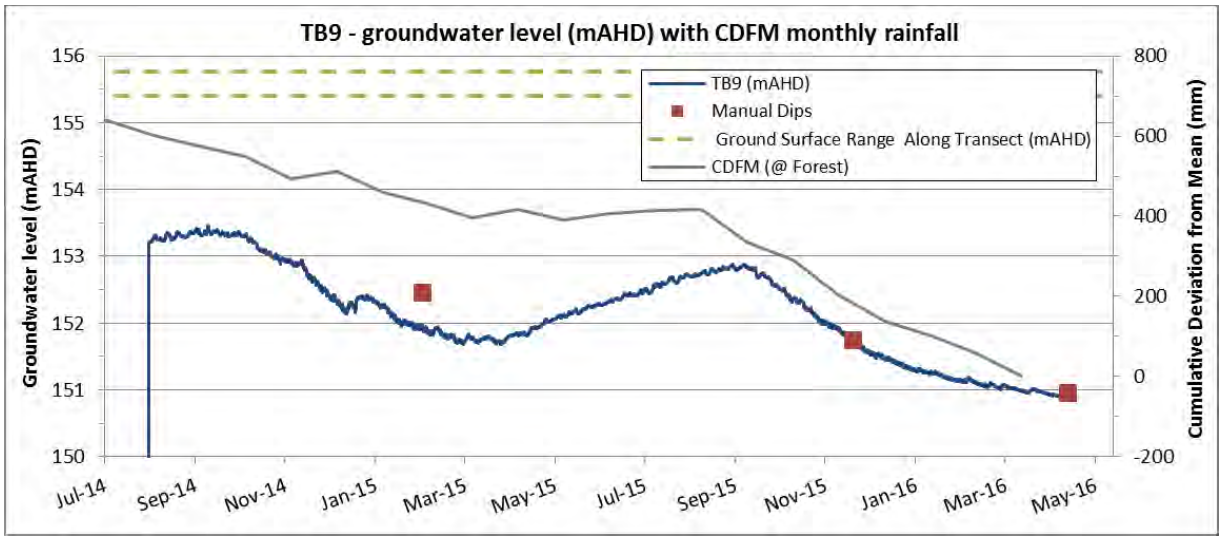


Figure 6-9 : Hydrograph for Bore TB9.

B.10 Site T10

The groundwater conditions at the site are as follows:

- The site is underlain by the alluvial sediments consisting of predominately clay and some silt and sand. The MTD underlies the alluvium.
- The water level in TB10 (located between the creek and soil bore) has ranged from 4.2 to 6.9 m below ground level over the monitoring period of September 2014 to May 2016. The hydrograph for Bore TB10 is shown in Figure 6-10.
- The hydrograph for TB10 shows an overall declining trend in water levels; water levels decreased by ~2.5m. Over the monitoring period rainfall has been below average.
- The groundwater at the vegetation survey site within the creek bed is more than 5 m below the ground surface and some vegetation will have access to groundwater.

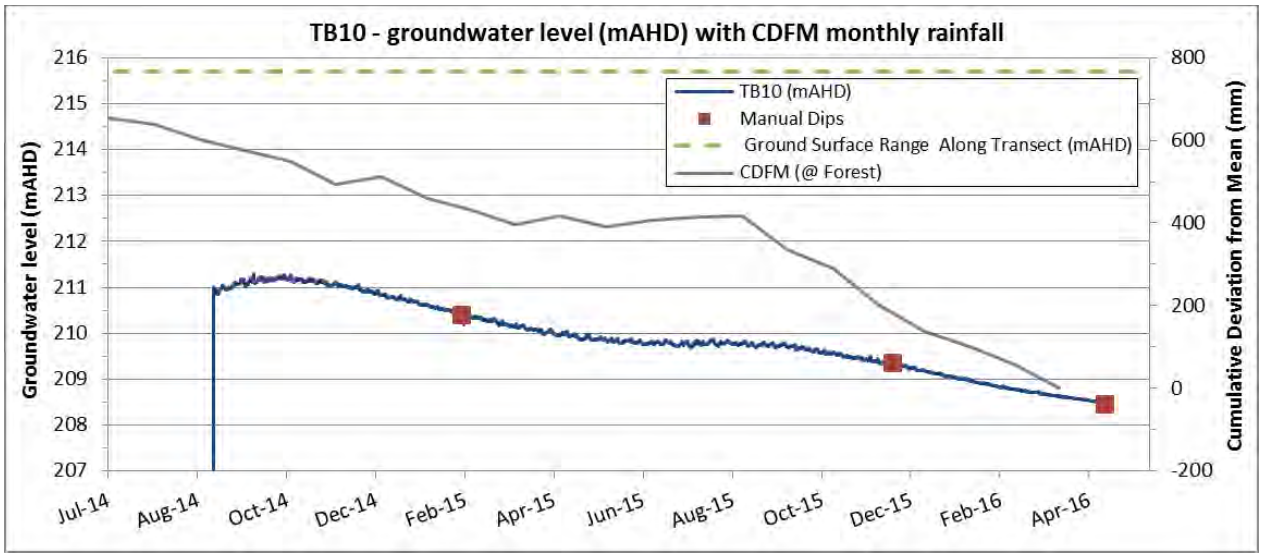


Figure 6-10 : Hydrograph for Bore TB10.

B.11 Site T11

The groundwater conditions at the site are as follows:

- The site is underlain by the alluvial sediments consisting of silty and sandy clay. The MTD underlies the alluvium.
- The water level in TB11 (located at a similar elevation to the stream bed) has ranged from 0.7 to 4.6 m below ground level over the monitoring period of September 2014 to May 2016. The hydrograph is shown in Figure 6-11.
- The hydrograph for TB11 shows that water levels show seasonal fluctuation of about 3 m with a slight declining trend, consistent with below average rainfall.
- The groundwater at the vegetation survey site within the creek bed is within 5 m of the ground surface and some vegetation is likely to have access to groundwater.

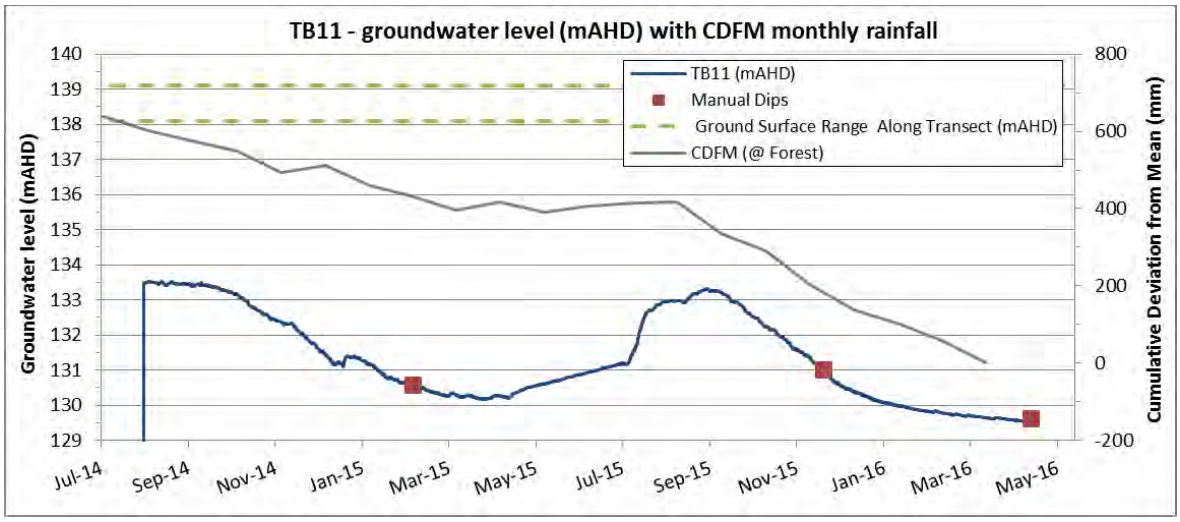


Figure 6-11 : Hydrograph for Bore TB11.

B.12 Site T12

The groundwater conditions at the site are as follows:

- The site is underlain by the alluvial sediments consisting of yellow-brown sandy and silty clay. The MTD underlies the alluvium.
- Based on the soil water profile at SB12 the depth to groundwater was around 1 m in 2014 although this is likely to be due to perched groundwater. TB12 is located within 40 m of the soil bore and records a deeper groundwater level. The water level in TB12 has ranged from 4.8 to 8.4 m below ground level over the monitoring period of September 2014 to May 2016. Groundwater is likely to be below the elevation of the stream bed. The hydrograph for bore TB12 is shown in Figure 6-12.
- The hydrograph for TB12 shows overall a decline in water levels by ~3m. Water level rose slightly by 1m between August and September 2015. Over the monitoring period rainfall has been below average.
- The groundwater at the vegetation survey site within the creek bed is within 5 to 10 m of the ground surface and some vegetation is likely to have access to groundwater. The soil bore indicates that some perched groundwater may be present in the top 1 m of the alluvium where the soil is sandier, which is likely to be supported by rainfall runoff.

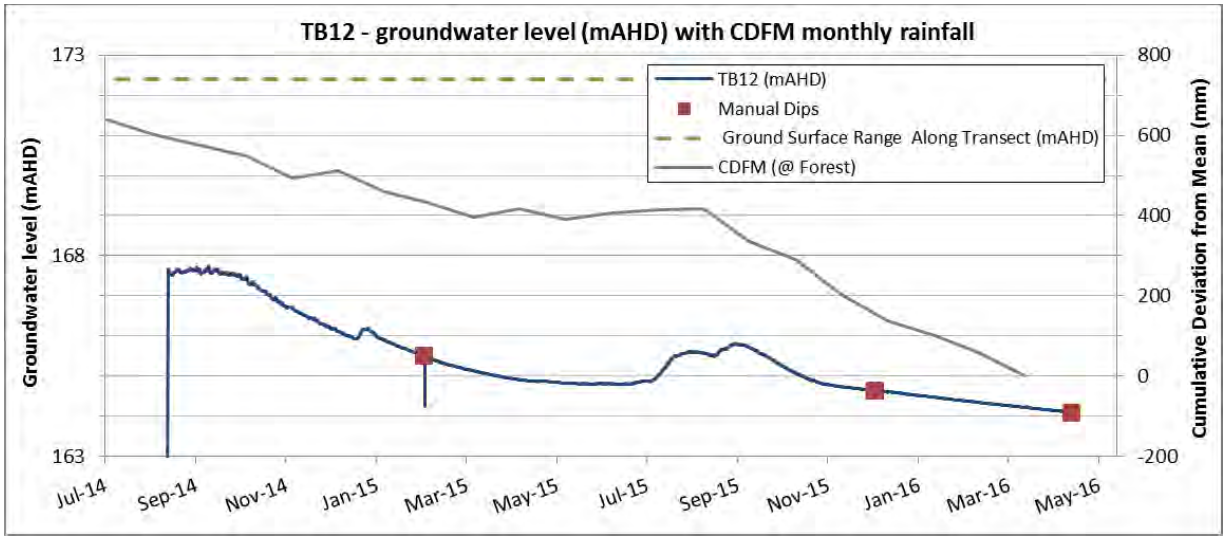


Figure 6-12 : Hydrograph for Bore TB12.

B.13 Site T13

The groundwater conditions at the site are as follows:

- The site is underlain by the alluvial sediments consisting of predominately clay with some silt. The MTD underlies the alluvium.
- The water level in TB13 (located at a similar elevation to the stream bed) has ranged from 2.5 to 4.9 m below ground level over the monitoring period of September 2014 to May 2016. The hydrograph for Bore TB13 is shown in Figure 6-13.
- The hydrograph for TB13 shows overall a declining trend in water levels with seasonal variability. Water levels rose by 1m between May and October 2015 and generally declined by 1.5 m over October to May. Over the monitoring period rainfall has been below average.
- The groundwater at the vegetation survey site near the creek bed is within 5 to 10 m of the ground surface and some vegetation is likely to have access to groundwater.

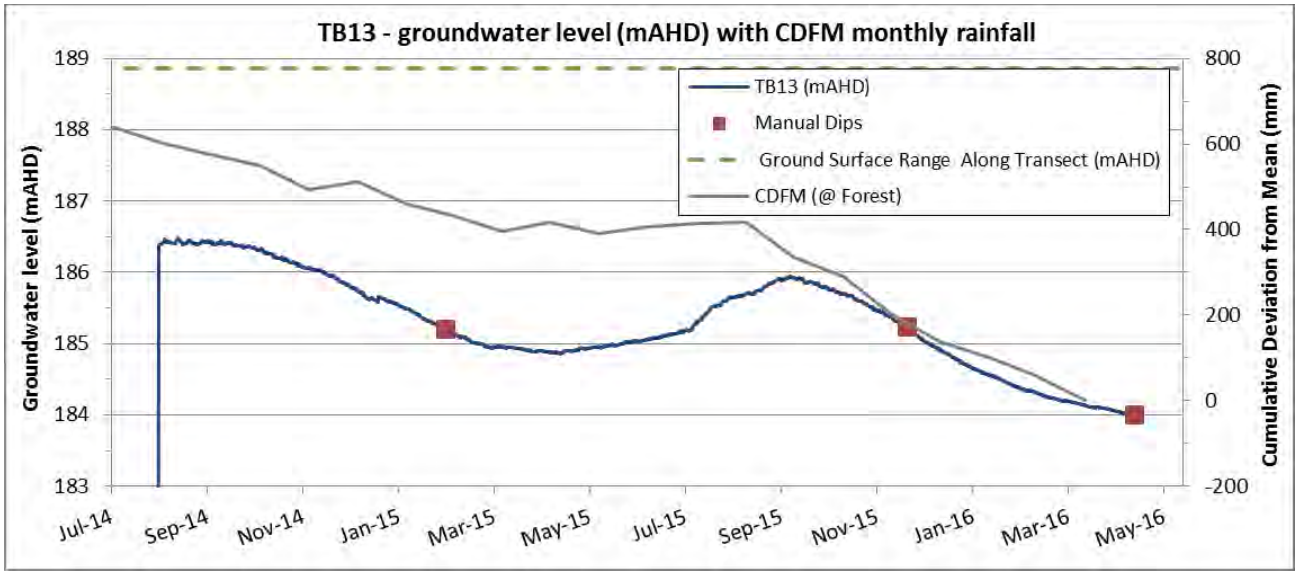


Figure 6-13 : Hydrograph for Bore TB13.

B.14 Site T14

The groundwater conditions at the site are as follows:

- The site is underlain by the alluvial sediments consisting of clay, sandy silt and silty sand. The MTD underlies the alluvium. This site is just downstream of outcropping LTA.
- The water level in TB14 (located between the soil bore and Ten Mile Creek) has ranged from 0.6 to 2.3 m below ground level over the monitoring period of September 2014 May 2016.
- The hydrograph for TB14 shows an overall small declining trend in water levels with limited seaonsality. Water levels rose by ~0.7m between April and September 2015 and generally declined between September and April. Over the monitoring period rainfall has been below average. The hydrograph for Bore TB14 is shown in Figure 6-14.
- The groundwater at the vegetation survey site near the creek bed is within 5 m of the ground surface and some vegetation could access groundwater.

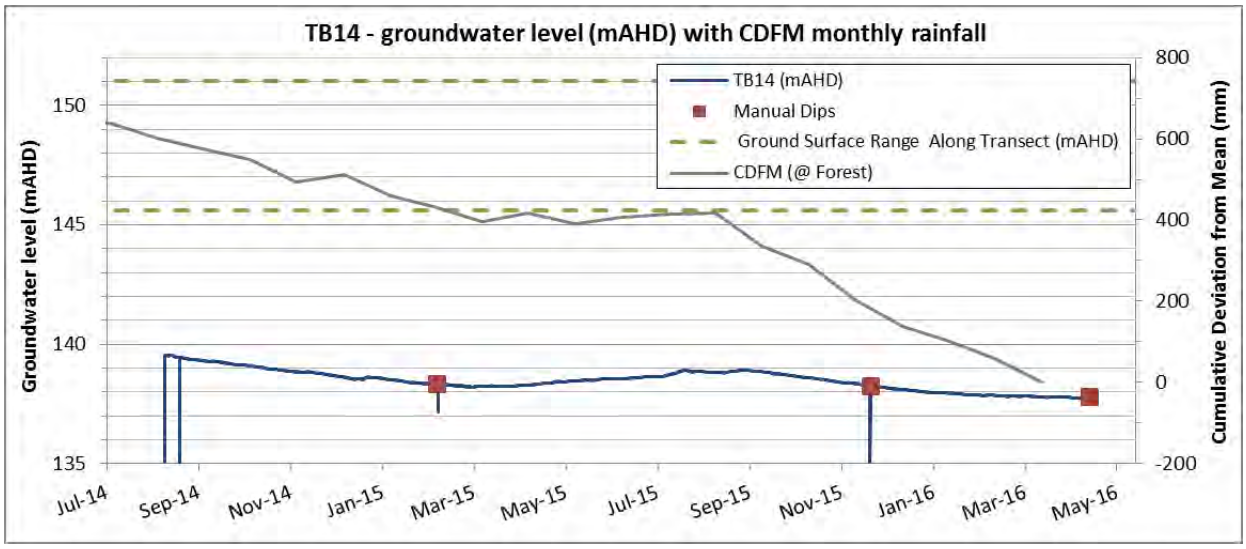


Figure 6-14 : Hydrograph for Bore TB14.

Appendix C. Site photographs

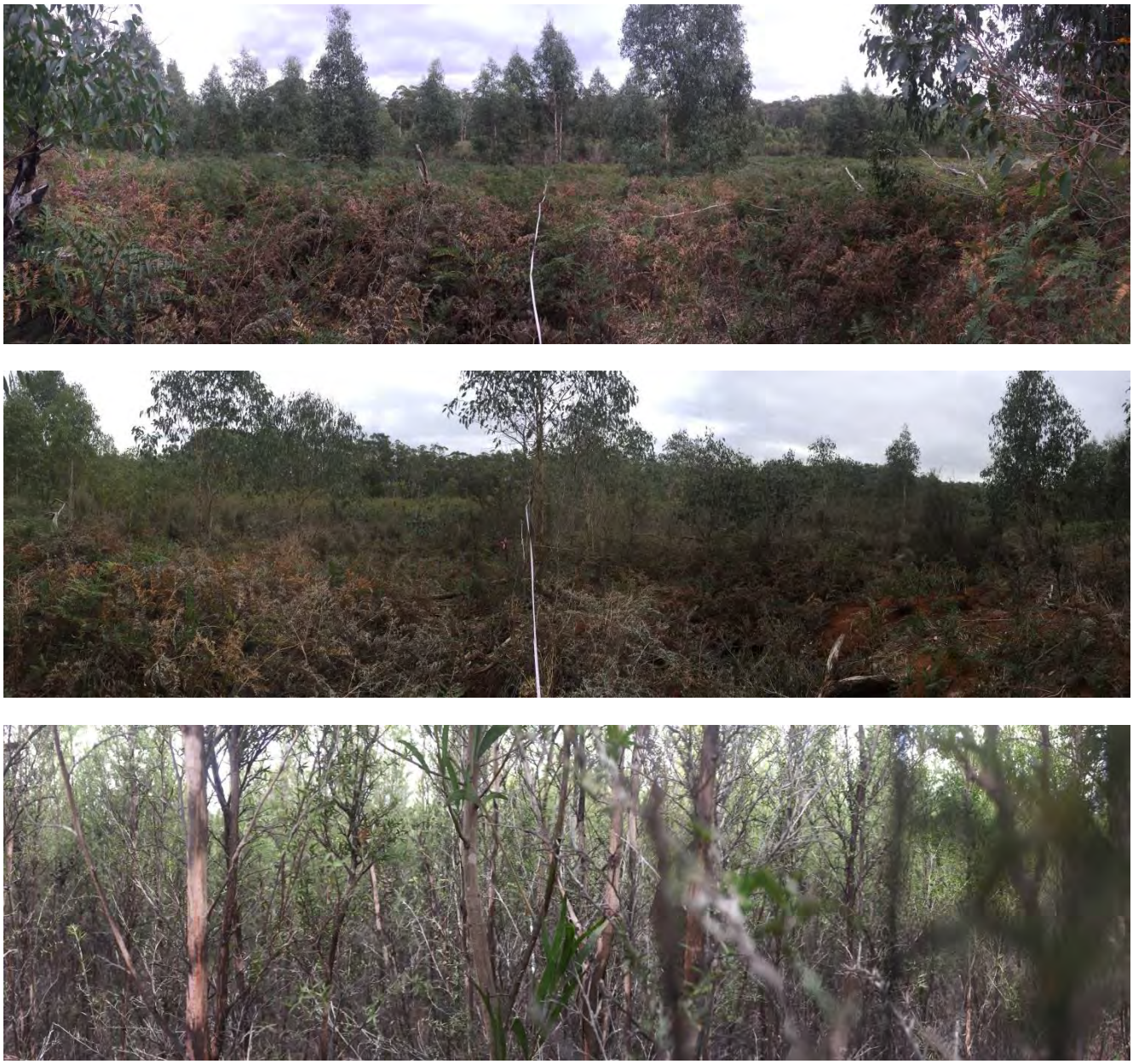


Figure C.1 : T1 at 0m, 30m looking toward the end of the transect and at 70m.

Figure C.2 : T2 at 0m looking toward the end of the transect (panorama), looking to left (waterway) and right respectively at 26m,and at 40m looking toward the start (panorama).

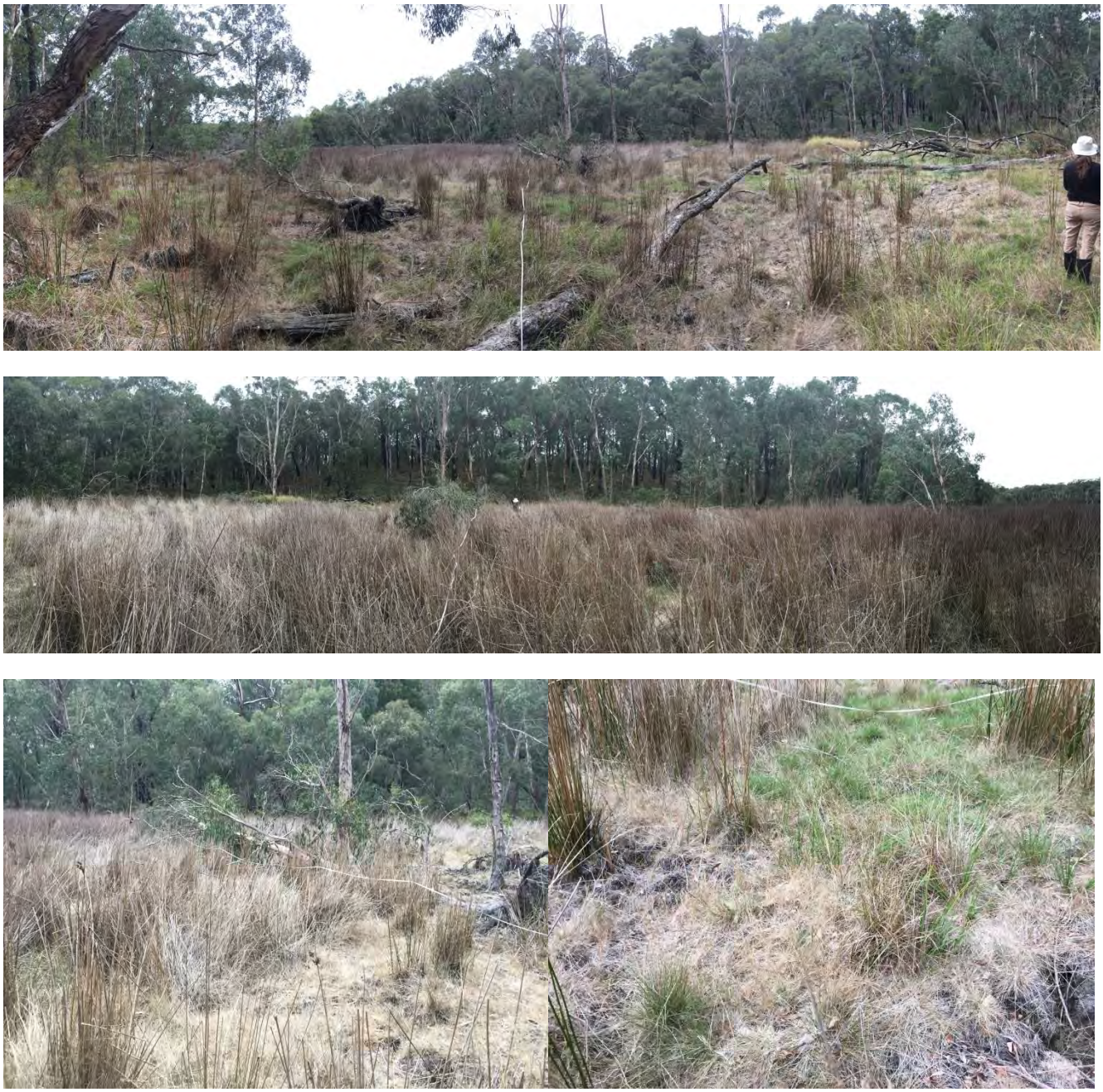


Figure C.3 : T3 at 0m looking toward the end of the transect (panorama) and at 40m looking toward the start (panorama). The remaining photos of Q4 and 5 looking at the fallen Swamp Gum in the transect and detail of the dying sedges and new growth of grass in Q4.

Figure C.4 : T4 at 0m looking toward the end of the transect (panorama) and at 40m looking toward the start (panorama). The remaining photos of Q4 and detail of the works taken along the track immediately upstream of the site.

Figure C.5 : T5 at 0m looking toward the end of the transect (panorama) and at 40m looking toward the start (panorama). The site was burnt in 2015 and is recovering.

Figure C.6 : T6 at 0m looking toward the end of the transect (panorama) and at 40m looking toward the start (panorama).

Figure C.7 : T7 at in order at 0m looking toward the end of the transect (panorama), at 40m looking toward the start (panorama), at 25m looking toward start (panorama).

Figure C.8 : T8 at in order at 0m looking toward the end of the transect (panorama), at 40m looking toward the start (panorama), at 20m looking toward start (panorama).

Figure C.9 : T9 in order at 0m looking toward the end of the transect (panorama), at 40m looking toward the start (panorama), at 20m looking toward start (panorama) and at 20m looking toward end (panorama).

Figure C.10 : T10 at in order at 0m looking toward the end of the transect (panorama), at 40m looking toward the start (panorama), at 20m looking toward end (panorama).

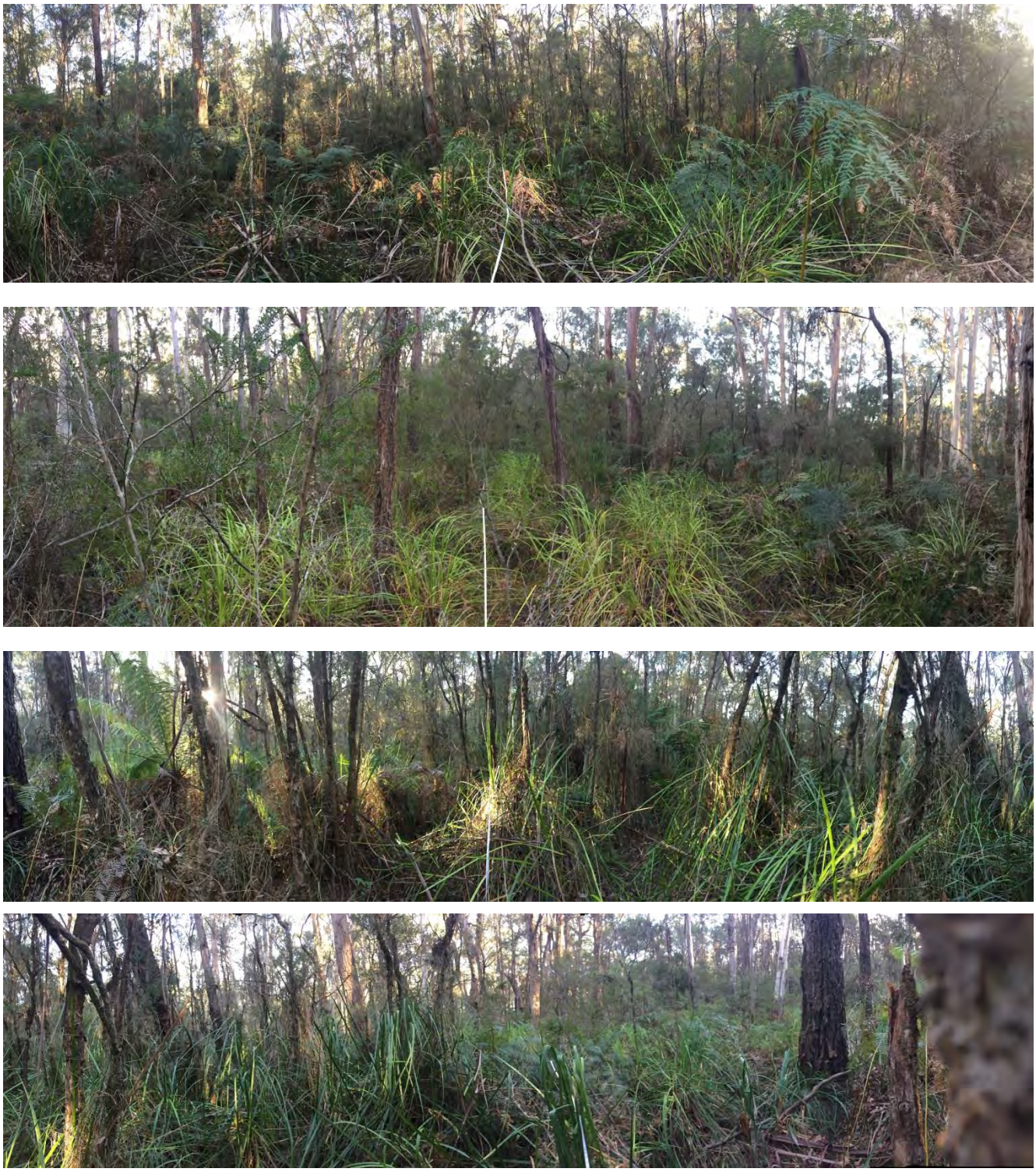


Figure C.11 : T11 at in order at 0m looking toward the end of the transect (panorama), at 40m looking toward the start (panorama), at 20m looking toward start (panorama) and at 20m looking toward end (panorama).

Figure C.12 : T12 in order at 0m looking toward the end of the transect (panorama), at 40m looking toward the start (panorama), at 20m looking toward start (panorama) and at 25m looking toward end (panorama).

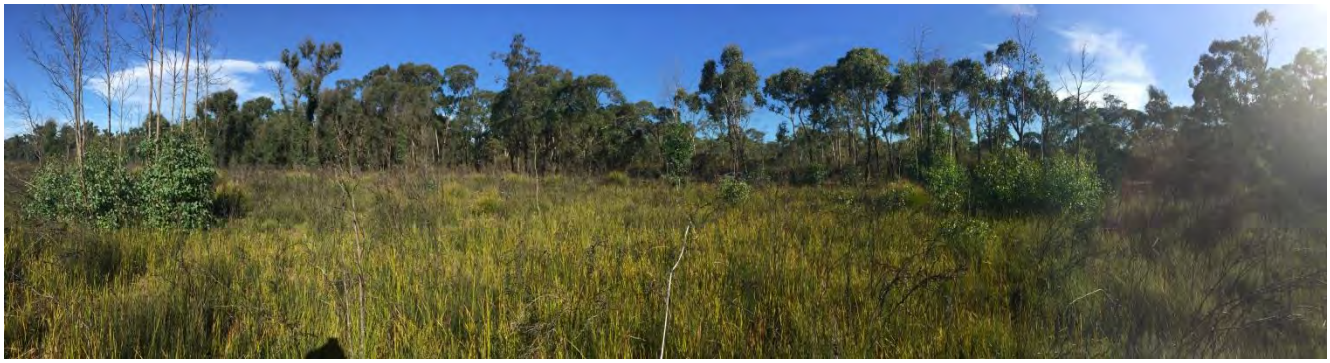


Figure C.13 : T13 in order at 0m looking toward the end of the transect (panorama), at 40m looking toward the start (panorama), at 23m looking toward start (panorama) and at 20 m looking toward end (panorama).

Figure C.14 : T14 in order at 0m looking toward the end of the transect (panorama), at 40m looking toward the start (panorama), at 23m looking toward start (panorama) and at 20 m looking toward end (panorama).