

**Bribie Island Borefield:
Groundwater Dependent Ecosystems -
Annual Vegetation Monitoring Report 2017**

Prepared for Seawater

by

3D Environmental

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1.0 Introduction

3d Environmental has been engaged by Seqwater to complete the 2017 annual monitoring report for groundwater dependent vegetation (otherwise referred to as groundwater dependent ecosystems or GDEs) for Seqwater's Banksia Beach Borefield and Water Treatment Plant on Bribie Island. The Water Treatment Plant has not been operational since April 2014 and no water extraction has occurred. This shutdown in operations has triggered a requirement for the long-term shutdown monitoring and sampling regime as outlined within the Borefield Environmental Management Plan (BEMP). This assessment forms a component of the Annual Compliance Report for the borefield, the first of which was issued in December 2015 to address conditions of approval under the Commonwealth Environmental Protection and Biodiversity Conservation Act (EPBC Act 1999). This report follows an initial GDE monitoring survey report prepared by Jacobs (2015) for the 2014 – 2015 reporting period and a subsequent report prepared by 3d Environmental for the 2016 annual reporting period (Bribie Island Borefield – Groundwater Dependent Ecosystems Annual Vegetation Monitoring Report 2016)(3d Environmental 2016).

1.1 Previous Work and Assessment Approach

Two sites were selected for ongoing GDE vegetation monitoring in the Groundwater Model Refinement, GDE Assessment and Monitoring Review (SKM, 2013) prepared for Seqwater. One of these sites is located in an area where drawdown in the shallow aquifer potentially may occur (Site 6 or the 'Impact Site') and the second site is located in an area outside the predicted drawdown zone (Site 5 or the 'Control Site'). Jacobs (2015) established two permanent vegetation monitoring sites at both impact and control localities which were subsequently assessed for floristic composition and structure during two monitoring events completed in September 2014 and February 2015. These events were timed to coincide with the latter part of the dry season and the wet season respectively to account for seasonal responses in vegetation. Ongoing vegetation monitoring events have occurred subsequent to the initial vegetation survey with a specific aim to establish baseline vegetation condition and determine the natural range of variation that occurs in terms of vegetation structure, composition and condition.

1.2 Purpose of Assessment and Scope

The overarching purpose of the vegetation monitoring program is to provide a temporal analysis of natural variations in the structural and floristic composition of coastal heathland. This information is to provide a baseline against which the impacts of possible future groundwater abstraction on groundwater dependent vegetation can be measured. To accomplish this, the scope of the current assessment includes:

- 1) The field assessment of the existing vegetation monitoring sites established by Jacobs (2015) and 3d Environmental (2016) utilising methods compatible with previous assessments.
- 2) Facilitate capture of NDVI imagery to coincide with the two current survey events (April 2017 and October 2017).
- 3) Analyse floristic data collected during the current survey in conjunction with complementary datasets (NDVI and Soil Moisture) to determine condition of vegetation at the control and impact sites as well as assesses seasonal variability. Comparison is to be made with previous monitoring survey results, primarily Jacobs (2015) and 3d Environmental (2016) to assist the baseline characterisation

1.3 Background and Ecological Context

The monitoring sites assessed in this survey are located in 'wet heath' being allocated to Regional Ecosystem 12.2.12 (closed heath on seasonally waterlogged sand plains), which has a "Least Concern" status under Queensland's Vegetation Management Act. Heaths are essentially treeless plant communities dominated by low shrubs and various other ground flora. Australian heaths are invariably associated with oligotrophic (low nutrient) soils deficient in phosphorus and nitrogen (DERM 2010). Wet heaths rely on shallow groundwater for maintenance of their unique structure and composition and the shallow soil profile is likely to be saturated over a considerable proportion of the year. Knowledge of vegetation dependence on groundwater is relatively undeveloped in the Australian context. Recent studies in coastal heathlands in eastern Australia indicate a need for longer term monitoring before definitive statements on the response of vegetation to groundwater drawdown can be made (Griffith et al 2015). Many inferences can however be drawn from Western Australian examples where monitoring of coastal heath vegetation in the groundwater abstraction area of the Swan Coastal Plain has been continuous for a period of several decades (Froend and Summer 2010; Froend et al 2004, Groom 2004, Groom 2003; Groom et al 2001; Groom 2000). Such studies make the following key points:

- The response of terrestrial phreatophytes (species dependent on groundwater for survival) to declines in groundwater levels are unpredictable and variable.
- Phreatophytes associated with formerly shallow stable groundwater sources are likely to be more sensitive to groundwater decline than trees exposed to variable groundwater regimes.
- Rapid declines in groundwater are more likely to accelerate vegetation response with a threshold breach and rapid conversion of vegetation to an alternative ecohydrological state.
- Gradual reductions provide greater opportunity for recharge to occur and promotes gradual floristic transition.
- Protracted extreme groundwater decline may result in a change in species composition, as groundwater sensitive phreatophytes are replaced by species with a greater ability to adapt to a drying sub-surface environment, or those species with deeper rooting systems.

In the context of Bribie Island, the shallow-rooted heath vegetation will be formed by a mix of both phreatophytes and facultative phreatophytes (i.e utilise groundwater although can survive without it). Wet heath vegetation typically has rooting material, mostly from sedges herbs and small shrubs concentrated in the upper 15 cm of soil, the portion of the profile most exposed to periodic cycles of wetting and drying in response to rainfall. There are also a number of deeper rooted species such as *Banksia aemula* and broad-leaf paperbark (*Melaleuca quinquenervia*) with the ability to adapt relatively rapidly to changing groundwater levels through accelerated root growth (Griffith et al 2015). The predicted shallow groundwater level reductions created as a result of borefield abstraction for both the average and dry weather conditions are relatively limited with maximum predicted drawdowns of 0.2 m and 0.3 m respectively and drawdown impacts of 0.1 m extending into the eastern Ramsar area towards Welsby and South Welsby lagoons (Seqwater 2015). Based on Western Australian case studies where groundwater drawdown of several metres over a protracted period was required to illicit a measurable response in vegetation (Groom et al 2000a, 2000b, Groom 2003, 2004, Froend et al 2010), such minor reduction in groundwater levels are unlikely to promote any noticeably shift in the ecological state of vegetation within the drawdown area in the short term with detectible impacts likely over decadal cycles.

On North Stradbroke Island, a monitoring program between 1988 and 2006 in 18 Mile Swamp demonstrated some vegetation composition and structural changes associated with water extraction (Specht & Stubbs 2011). They found broad-leaf paperbark trees expanded into heath and sedgeland areas when water table levels fluctuated in response to drought and water extraction. The paperbarks rapidly grew in height and out competed sedges and smaller shrubs, such as *Leptospermum juniperinum*, thought to have shallower roots (Specht & Stubbs 2011).

2.0 Methods

2.1 Field Survey

Timing: Field survey was completed over two events on the 28th and 29th of April for the post-wet survey and October 12th and 13th 2017 for the early dry season survey.

Transect Methods: Methods for vegetation assessment followed those documented in Jacobs (2015) which was adapted from the Biocondition Methodology (Eyre et al 2015) to provide an assessment of vegetation composition and structure. Each survey locality (plot) was formed by a central 50m transect marked with star pickets and a 50m tape measure stretched tightly between end points. The transect was extended 5m either side of the centreline to provide a 50 m x 10 m plot (0.05ha). Four transects (Plots 5a, 5b, 6a 6b) were established in September 2014 (each had a third star picket placed at the transect mid-point). An addition two transects (5c and 6c) were established in April 2016 although a central picket was not used for these. Specific details of data collected at each plot is provided below with deviations from the methods of Jacobs (2015) identified and discussed in the following sections:

- Canopy intercept of woody species over a measured centre line, from 0 to 50m separated into:
 - Tree (T1) structural layer being trees > 6m height.
 - Upper shrub (S1) structural layers, being shrubs > 1m height.
 - Lower shrub (S2) structural layers being shrubs in the height range of 0.5 to 1m¹.
 - Ground (G) being floristic life forms <0.5m height.
- Species richness for all floristic lifeforms within each 0.05 ha plot totalled for the two survey events. Lifeforms allocated in the assessment are:
 - Trees (single stemmed woody plants > 6m).
 - Shrubs (woody multi-stemmed vegetation)
 - Forbs (herbaceous vegetation that is not a grass or other life form)
 - Native perennial grass / sedge / rush (includes graminoids such as sedges, tussock grasses and restionaceae species. *Lomandra* spp² have also included in this category).
 - Grasstree³ (*Xanthorrhoea* spp.)
- Counts of woody species within the survey plots within height classes (Trees T1; Shrubs S1 and S2). Stem counts were completed in a 2m wide belt transect positioned either side of the centreline tape. This narrow width allows for the accuracy in stem counts required in repeat measure monitoring surveys.
- Groundcover of floristic lifeforms within 10 x 1m² quadrats placed at 10m intervals along the tape measure with the initial quadrat position (Q1) at the 4 – 5m interval on the left side of the

¹ Shrubs in the 0.5 to 1m height range were included in the Ground (G) structural layer in Jacobs 2015.

² Included in the shrub category in Jacobs (2015) although overall cover very low.

³ Not included in the biocondition methodology

tape measure and flipped to measure Q2 on the right. The final quadrats Q9 and Q10 were positioned at 44 – 45m on the left and right side of the transect respectively. Cover measurements utilised the Braun-Blanquet method including % proportions of:

- Native Shrubs < 0.5m. (Specht & Stubbs 2011).
 - Native perennial grass/ sedge/ rush
 - Native forbs
 - Grasstrees
 - Exotic shrubs
 - Leaf litter (% of dead leaf matter)
 - Bare ground (exposed sand).
- Canopy heights were recorded for all canopy intercepts in the T1, S1 and S2 structural layers.

GPS localities of start and end points were recorded in the field and photographs were taken at the transect centre point from centre to start, centre to end, centre to north (right), centre to left. . A generalised plot layout is shown in **Figure 1**.

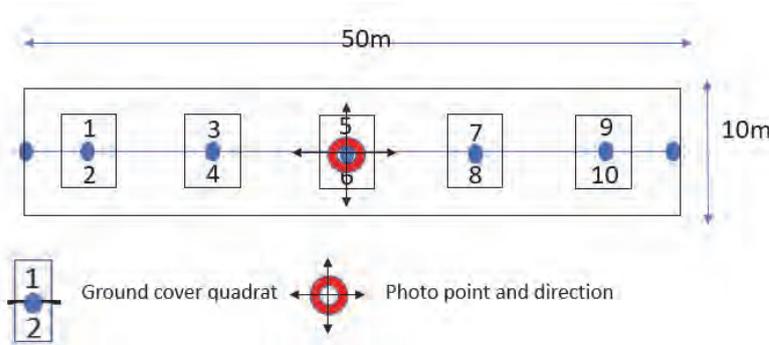


Figure 1. Survey plot layout.

In regard to the assessment of shrub cover, all shrubs >0.5 m height were attributed to the shrub layer and <0.5m to the ground layer, consistent with methods described in Neldner et al (2012). Previous surveys by Jacobs (2015) included shrubs <1m height to the groundlayer, although this was considered impractical in this assessment due to the strong stratification of other groundcover components into the a dense clumping cover typically < 0.5m height.

A total of six plots have been established throughout the course of the survey with plots 5a, 5b, 6b and 6c established by Jacobs (2015) in the previous survey event and an additional two sites (5c and 6c) established in by 3d Environmental during the 2016 survey event. A summary of all sites is provided in **Table 1** with location of transect centrelines provided in **Figure 2**. Floristic and structural data from all transects is provided in **Appendix A**.

Table 1. Monitoring sites established in the study area.

Monitoring Transect No.	Purpose of Site	Lat. / Long. Start	Lat. / Long. Centre	Lat. / Long. Finish	Date Established
5a	Control	-26.9942/ 153.1587	--26.9942/ 153.15905	-26.9942/ 153.15932	26 September 2014
5b	Control	-26.9943/ 153.15879	-26.9944/ 153.15898	-26.9944/ 153.159319	26 September 2014
5c	Control	-26.9946/ 153.15883	NA	-26.9944/ 153.15929	April 4 2016
6a	Impact	-26.985 / 153.15404	-26.9849 / 153.15425	-26.9847/ 153.154487	26 September 2014
6b	Impact	-26.9852/ 153.15415	-26.985 / 153.154376	-26.9849 / 153.15458	26 September 2014
6c	Impact	-26.9852/ 153.15415	NA	-26.9849 / 153.15458	April 4 2016

2.2 Data Analysis

Field data was entered into biocondition datasheets for each individual transect with data summaries to calculate total cover of shrub layers, shrub density as well as components of the ground cover attributed to growth form, leaf litter and bare ground. Data from both April and October survey events is compiled onto individual datasheets for ready comparison. Rather than lumping of data from plots into impact and controls sites, all transects were treated individually, to allow an assessment of the natural variability of habitats within the two areas (impact and control) to be made. A Levene's test to test for homogeneity of Variances was completed on all data across all structural parameters. Statistical analysis was undertaken using the Q-macros (2017) extension in Microsoft Excel. Analysis of Variance (ANOVA) was completed on a number of parameters where Levene's test indicated equal variance. This was used to determine the significance of any differences identified between mean values for structural and floristic features recorded during the data collection process. A Repeat Measures ANOVA, using data from the four 2016 and 2017 survey periods (i.e. April 2016, September 2016, April 2017 and October 2017) was undertaken to evaluate the statistical significance of any changes over time in plant cover and richness data. It also allowed an assessment of whether there are consistent differences in any plant group abundance between Sites 5 and 6. Repeat Measures ANOVA was completed using the Q-macros extension in Excel under the 'ANOVA – Two Factors Without Replication' command. A raw data summary of all statistical calculations is provided in **Appendix C**. As standard practice, p-value < 0.05 was considered indicative of a significant difference in mean values or variance.

2.3 NDVI Analysis

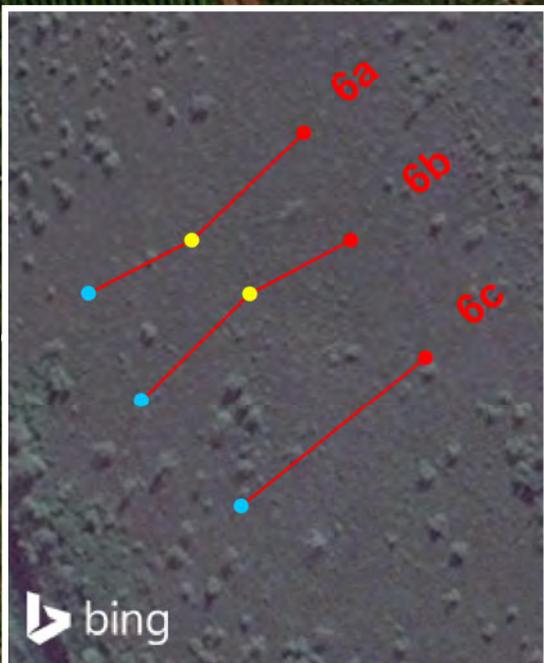
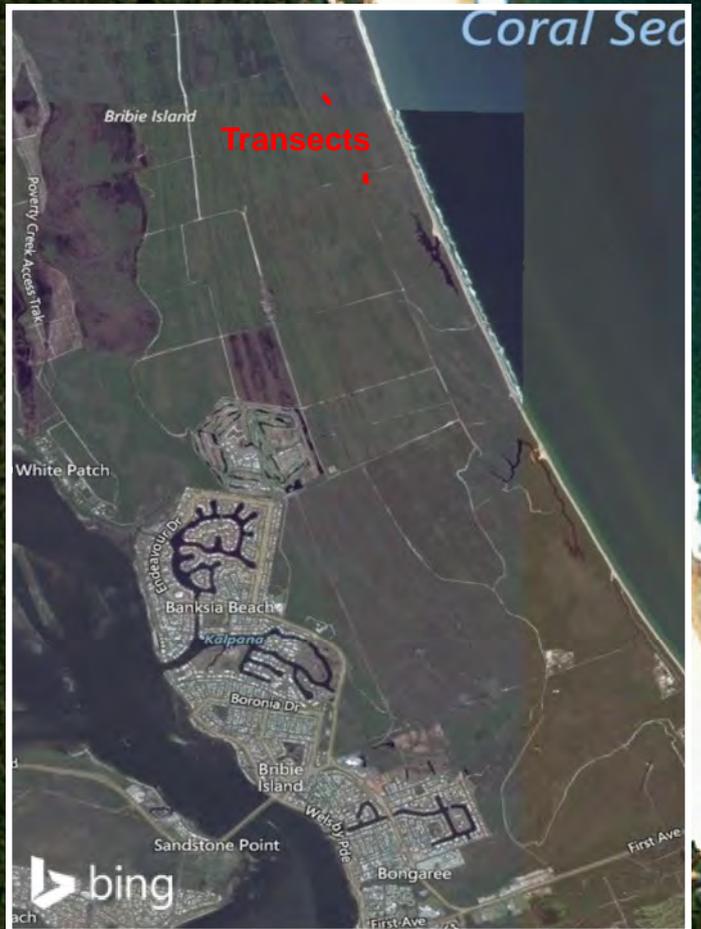
Fresh capture Spot 6 (SPOT6 1.5m Panchromatic 4-band Pan + Bundle imagery) imagery from Geospatial Pty Ltd was acquired to coincide as far as possible with the timing of the field survey events. Images capture was completed on the 26th April and 25 October 2017. The October 2017 capture event was delayed for several days following the field survey due to an extended period of heavy cloud cover and rainfall which greatly limited opportunity for image capture. Raw data from the two Spot 6 images were processed using the ArcGIS image server applying the following equation as standard process:

$NDVI = \arctangent((IR - R)/(IR+R))$ where IR = pixel values from the infrared band, and; R = pixel values from the red band.

This produced a single-band dataset with negative values generated from water (and clouds), bare soil producing values of 0 and higher values produced by green/ living vegetation with greater NDVI values corresponding to varying abundance of green leafy biomass. NDVI values were measured in 1.4 m intervals along each transect for the April and October period with the same interval applied to previous capture periods to ensure consistency between datasets. All values were compiled into an Excel database for interrogation and graphical representation.



6a
6b
6c



5a
5b
5c

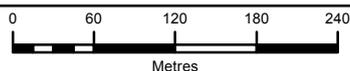
Legend

Site

- Start Point
- Centre Point
- End Point
- Transects

Figure 2. Survey plot localities

Client: Seqwater



Scale 1:5,612

Drawn By DG

Checked DS

File Path

C:\Users\Owner\Documents\Clients\3D Environmental\Bribie\3d_Bribie_A4P.mxd

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2.4 Climate Data

Automated weather stations are positioned at two locations on Bribie Island being:

- National Park Weather Station (AWS Bribie NP) located at -27.028674°, 153.158484°
- WTP Weather Station at Bore 9 (AWS BBWTP) located at -26.968238°, 153.109549°

Rainfall data from both the Bribie NP and AWS BBWTP were used for the analysis although it is likely that values for July, August and September 2016 are erroneous at AWS BBWTP as no rainfall was recorded during these months. There is also no rainfall data for the months of August and September 2017 at either AWS BBWTP and Bribie NP weather stations.

Data from the dedicated Bribie Island weather stations was compared with annual and long-term rainfall averages collected from Beerburrum Forest (-26.96, 152.967), a Bureau of Meteorology station located approximately 10km west of the Island. Annual rainfall averages for this weather station, recorded back to 1898, were utilised during analysis of the climate data and to supplement any identified information gaps.

2.5 Soil Moisture Data

Automated soil moisture loggers installed at the location of the control and impact monitoring sites were used to measure fluctuations in shallow soil moisture in the soil profile. The utility of this data is that it provides additional context to any changes in vegetation condition that could be attributed to seasonal cycles of wetting and drying in the upper soil profile. Sensors were installed to depths of 0 mm (surface), 15mm, 350mm, 650 mm, 950 mm and 1250 mm with automated readings provided between March 22nd and October 12, 2017 for the northern impact site (Northern SMP). The soil moisture logger installed at the southern control site (Southern SMP) mal-functioned during the assessment period and no data was recorded.

3.0 Results

Results of the assessment are detailed below and provide analysis of those factors considered critical to the assessment of vegetation condition, structure and floristic change. The analysis includes assessment of:

- Climate data
- Soil moisture data
- Shrub cover and stem density
- Groundcover composition
- Species richness; and
- NDVI Analysis,

Comparisons between control and impact sites are made and where possible, comparisons between the current and previous survey events (Jacobs 2015) are made.

3.1 Climate and Soil Moisture

Rainfall and soil moisture data are intimately linked and are dealt with consecutively in this section. As previously discussed in **Sections 2.4** and **Sections 2.5**, some datasets were incomplete and hence have not been used in the analysis.

3.1.1 Climate data

Reference to **Figure 3** indicates the initial part of 2017 was extremely dry with well below average rainfall in December 2016, January 2017 and February 2017 at all recording stations. A significant rainfall event occurred in the later portion of March with 254mm and 264mm falling at the AWS BBWPT and Bribie National Park recording stations respectively. This is well above the March average of 173mm. Another above average rainfall event occurred in May 2017 with July, August and September, preceding the dry season survey event, recording well below average rainfall. Overall, the annual period between September 2016 and August 2017 recorded well below average rainfall with 930mm, 746mm and 986mm recorded at the Bribie NP, AWS BBWPT and Beerburrum SF respectively compared to the long-term average rainfall of 1414 mm at Beerburrum SF. This is also well below rainfall reported for the previous period (September 2015 to August 2016) with 1158 mm recorded at Bribie Island NP and 1127 mm in the Beerburrum State Forests.

3.1.2 Soil moisture data

It is apparent from **Figure 4** that significant rainfall events in the summer months have only a marginal influence on soil moisture in the upper soil profile (0 – 350mm). Only a subtle spike in shallow soil moisture is associated with the March 2017 rainfall event, although more sustained replenishment is noted at greater than 350mm depth. The soil profile was at its driest in the months prior to the April 2017 field survey with the extreme rainfall event at the end of March (2017) returning soil moisture from <20% to near saturation (40%) at 650mm dept. This saturation in the upper soil profile was sustained throughout the remainder of the year at least until the October survey event. It is also apparent from **Figure 4** that 950mm represents the position of the permanent groundwater table, which fluctuates seasonally between 650mm and 950mm depth dependent on rainfall and seasonal conditions. The Southern SMP was offline throughout the survey period. It is however assumed that due to similar climatic influences and consistency of landform, responses in soil moisture at the control site would mirror those measured at the Northern SMP.

3.2 NDVI data analysis

The average of NDVI values taken at 1.4 m intervals along vegetation transects is represented in **Figure 5** providing comparison between the 2016 and 2017 survey periods. Full data plots for individual survey points are provided in **Figure 6**. It is difficult to identify any strong correlation between NDVI values, seasonality or soil moisture content and consistently, the highest averages are associated with the April 2016 and October 2017 captures. Survey Plot 6a is the exception where NDVI values recorded in the April 2016 assessment were relatively low compared to other sampled localities. Of note is the strongly negative NDVI values recorded in Survey Plot 5c in the April 2017 capture with an associated strong rebound in NDVI values in October 2017. Reasons for this response will be further investigated during interrogation of the groundcover data.

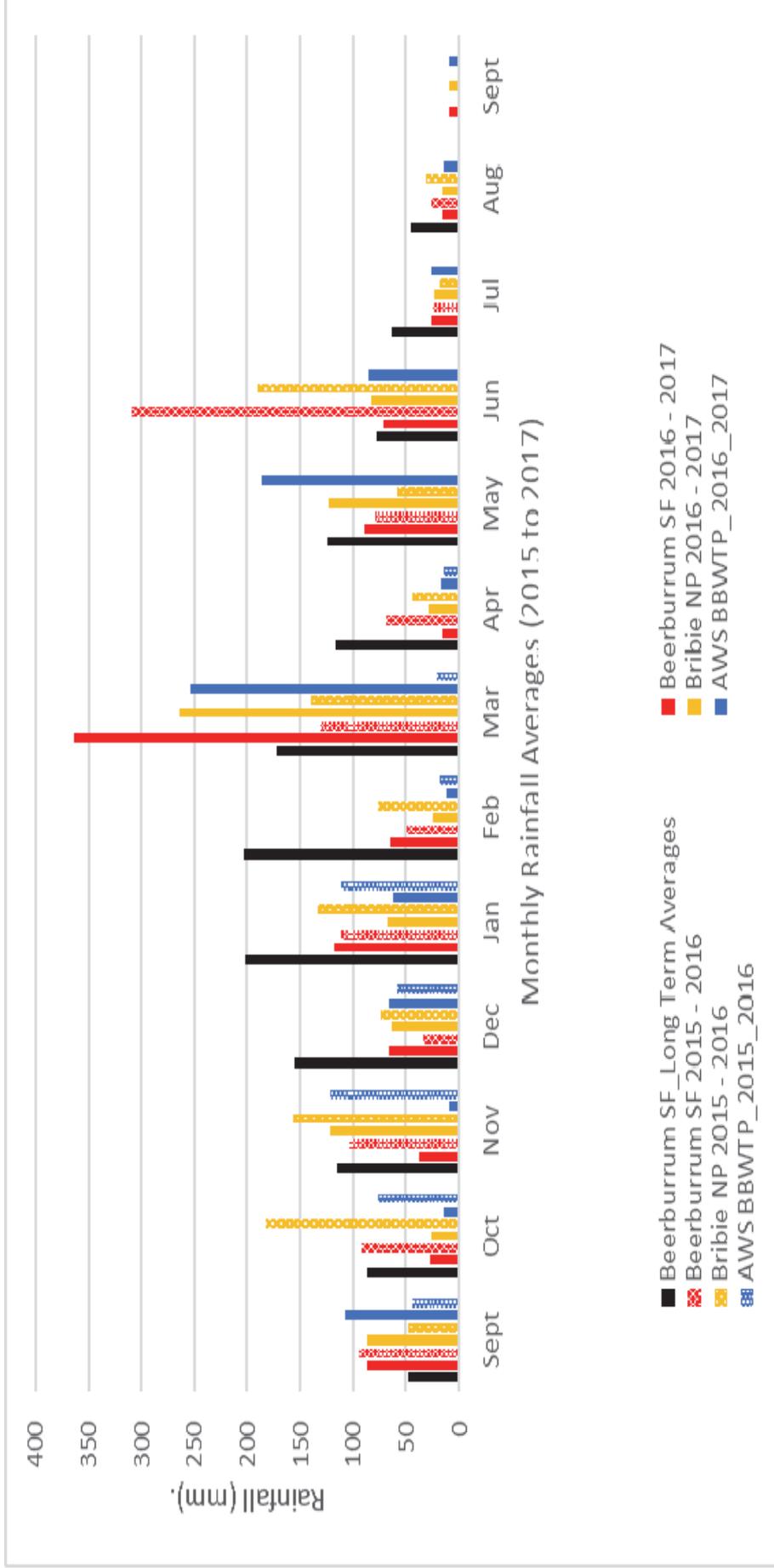


Figure 3. Monthly rainfall for the period from September 2014 to September 2016.

Northern SMP - March 2017 to October 2017

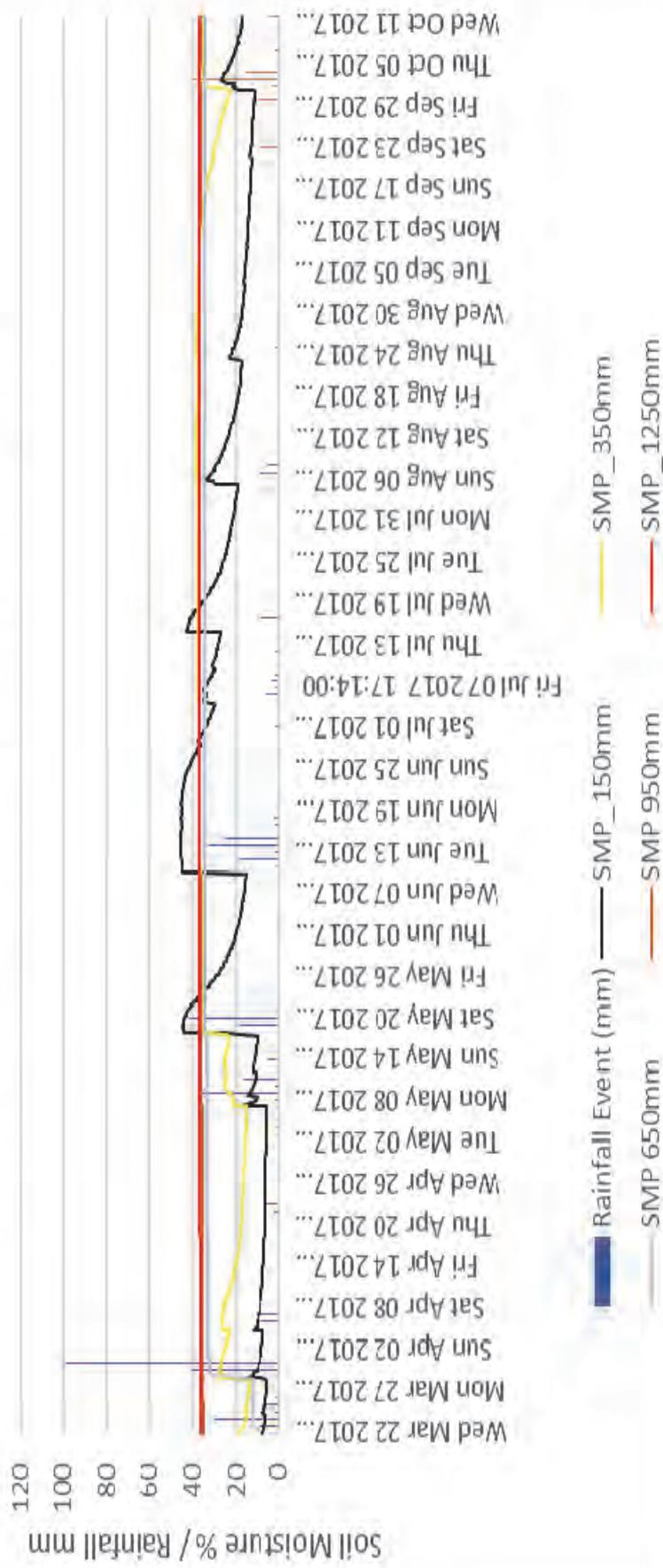


Figure 4. Soil moisture data from the Northern SMP, in the vicinity of the impact monitoring plots (Plot 6a to 6c).

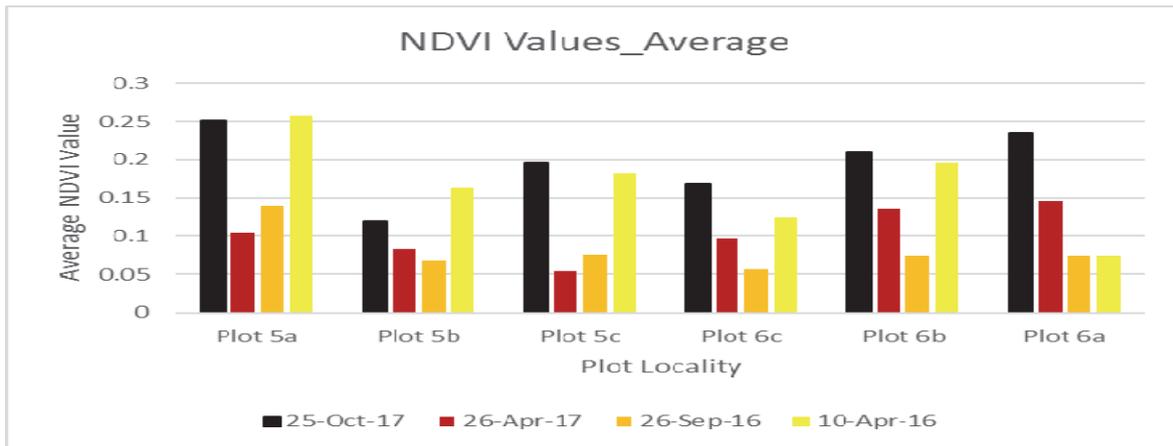


Figure 5. Average NDVI Values for the 2016 and 2017 survey periods.

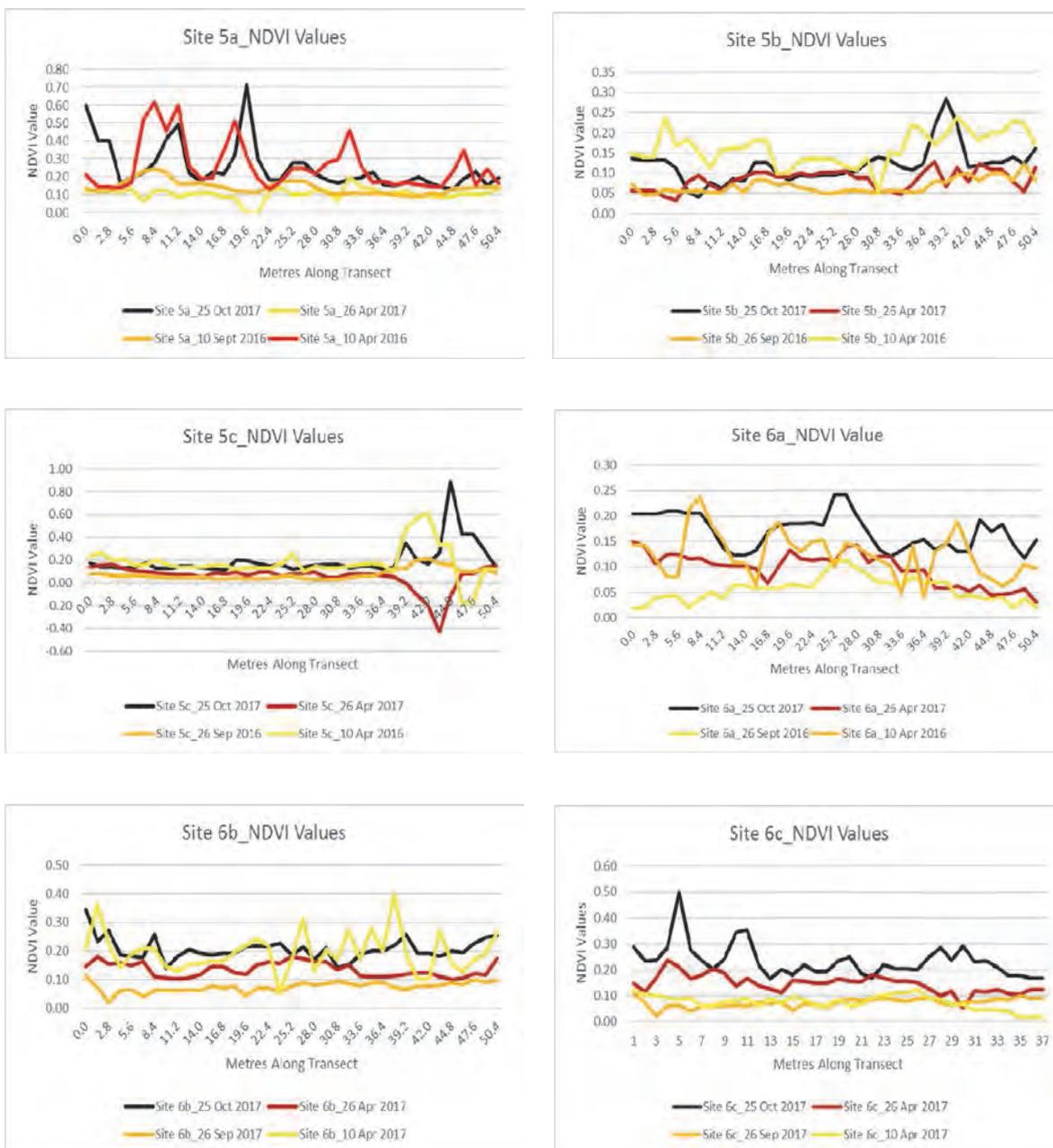


Figure 6. NDVI profiles for individual survey plots at different capture periods.

3.3 Shrub Cover and Stem Density

Shrub cover maintained relatively consistent values for shrubs > 1m for both impact and controls sites between surveys completed in 2016 and 2017 (see **Figure 7**). Although there is some variation evident between survey periods, Levene's and Repeat Measures ANOVA indicate that variations between survey periods are not statistically significant ($F_{3,15} = 0.714$, $P = 0.559$) (see **Appendix C**). It is likely that the variations noted in shrub cover are related to local disturbances such as branch fall or seasonal loss / regeneration of leaf mass that might be expected in a dynamic heathland ecosystem. Similar results are indicated for shrubs 0.5m to 1m tall with a Repeat Measures ANOVA indicating that variations between survey periods are not statistically significant ($F_{3,15} = 1.520$, $P = 0.250$). This is despite a relatively consistent decline in shrub cover in Survey Plot 6b, which was counted by a large increase in small shrub cover in Plot 6a (See **Figure 8**).

As noted in the 2016 survey effort, **Figure 9** demonstrates that the overall stem density for shrubs > 0.5m is much higher in the impact sites (Site 6). There is also a slight although relatively consistent decline in stem density that spans the 2016 and 2017 survey periods in nearly all survey plots although this trend is most pronounced at the impact site (Survey Plots 6a to 6c) than at the control (Survey Plots 5a to 5c). Levenes test applied to data from both the impact and control sites indicates Variance is consistent. A Repeat Measures ANOVA for the impact sites indicates the variation in stem density between survey periods is statistically significant ($F_{3,6} = 124.77$, $P = 0.00$) although for the control sites, variation in stem density between survey events is not significant ($F_{3,6} = 1.96$, $P = 0.221$) (see **Appendix C**).

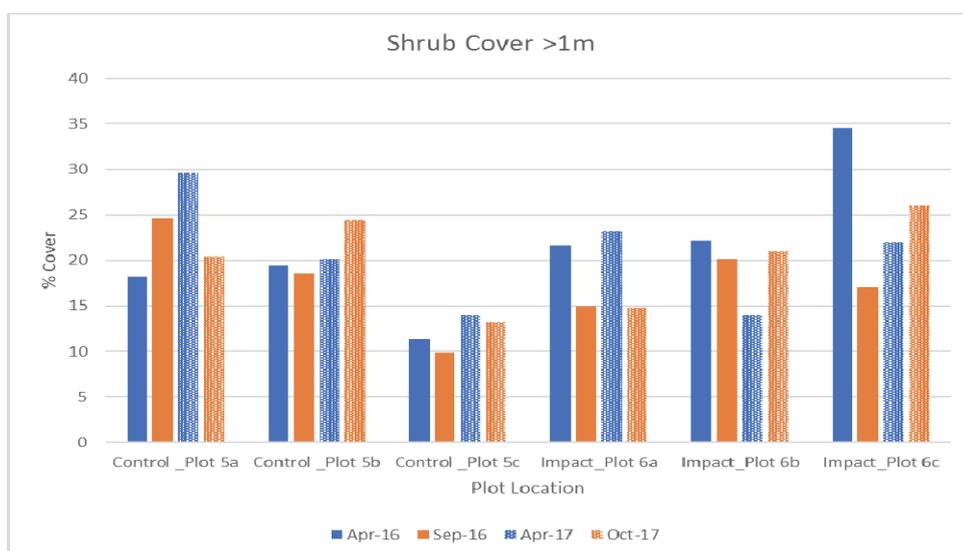


Figure 7. Projected shrub cover for stems > 1m tall.

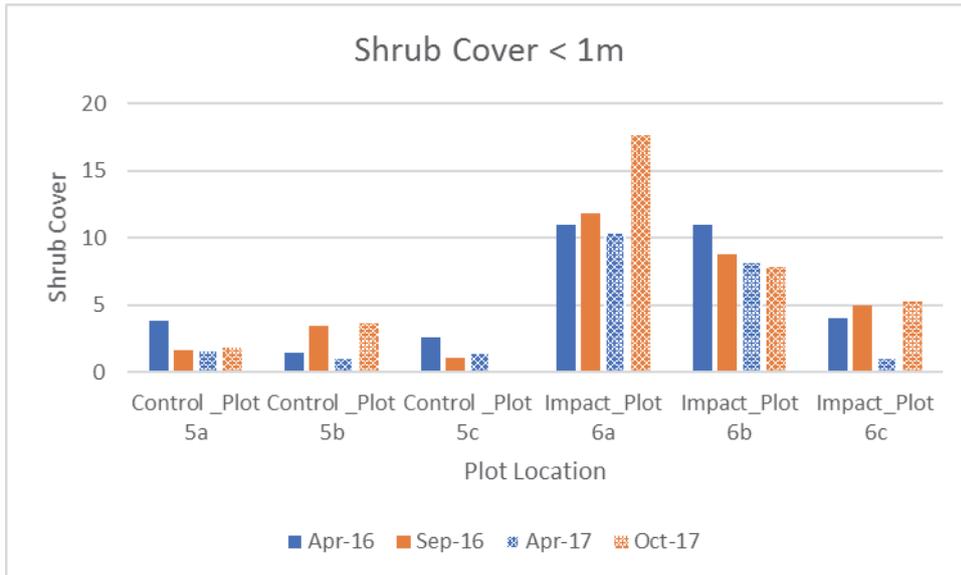


Figure 8. Projected cover for shrubs >0.5m and <1m.

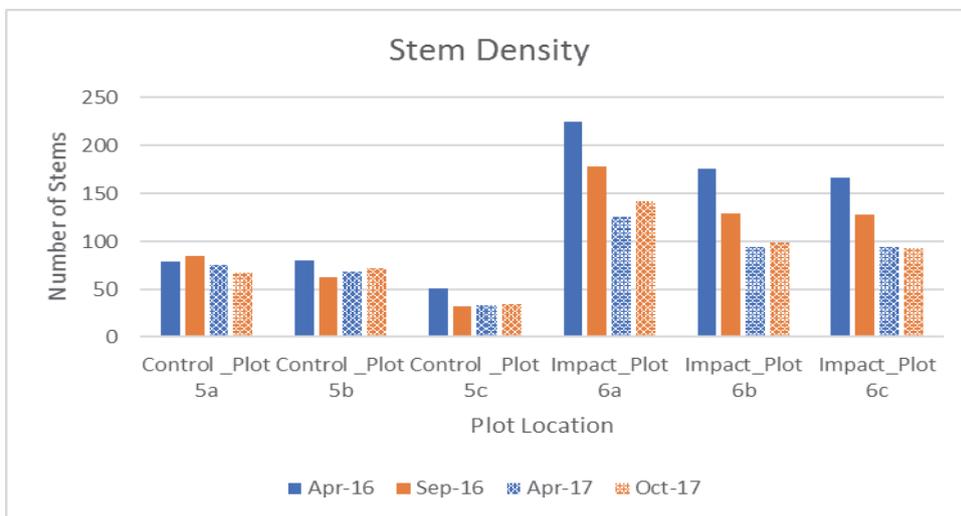


Figure 9. Shrub stem density at impact and control sites.

3.4 Composition and Nature of Groundcovers

The vegetation at both impact and control sites exists in largely natural condition, lacking any significant elements of degradation that may be prompted through changes to hydrological regime, land disturbance and pervasive invasion of exotic species and it is considered that control and impact sites are readily comparable. The composition, structure and floristic trend of groundcover parameters measured during the assessment are documented Section 3.3.1 to Section 3.3.5. A statistical summary is provided in Table 2 for all survey localities and contribution to total cover of various lifeforms over the 2016 and 2017 survey periods.

3.4.1 Native perennial grass / sedge / rush cover

Only minor variations in the abundance of living native grass, sedge and rush cover is evident between sampling events as demonstrated in Figure 10 suggesting that the dominant rush species *Sporodanthus interruptus*, *Caustis recurvata* and *Baloskion tenuiculme* are relatively resilient and not susceptible to dieback during drier periods. Levene's test also indicates that variance in sedge/ rush