Forestry Corporation of NSW

Koondrook-Perricoota Forest Vegetation Monitoring

Stand and Tree Condition Monitoring 2017

August 2017

Koondrook-Perricoota Forests Autumn Tree and Stand Condition Monitoring 2017

This report may be cited as: Forbes, J. and Wills, T. (2017) Koondrook-Perricoota Forest Autumn Tree and Stand Condition Monitoring 2017. Unpublished report for the Forestry Corporation of New South Wales, prepared by GHD Pty Ltd.

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Please note: the primary outputs of this project are the stand and tree condition datasets (Microsoft Excel format) and the analysed hemispherical photographs of the stand canopy (BMP format).

Acknowledgements:

The authors wish to thank Linda Broekman of Forestry Corporation of New South Wales for assisting GHD in undertaking the monitoring, providing past data and advice, and Jessica Holding, Alastair MacGillivray, Laura Bateson, John Davies and Stacey Harwood (from GHD) for assisting with fieldwork.

Scope and Limitations

Cover photograph: Photograph of site S83.

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Executive summary

The Forestry Corporation of New South Wales (FCNSW) engaged GHD to conduct the Stand and Tree Condition Monitoring Program at Koondrook-Perricoota Forest, New South Wales, for 2017. This project is part of the Murray Darling Basin Authority (MDBA) funded *The Living Murray* (TLM) *Program*. The Living Murray is a joint initiative funded by the New South Wales, Victorian, South Australian, Australian Capital Territory and Commonwealth governments, coordinated by the MDBA.

The purpose of the program is to survey and report on tree condition and stand condition at permanently established monitoring sites across Koondrook-Perricoota Forest. The stand condition data will be incorporated into the Stand Condition Model developed by the Australian Centre for Biodiversity, Monash University (Cunningham *et al*. 2009; 2011) upon submission to the MDBA.

The stand and tree condition surveys were undertaken in April and May 2017. The surveys represent the eighth year of data collection for the TLM stand condition program (surveys undertaken to date: 2009, 2010, 2012, 2013, 2014, 2015, 2016 and 2017) and the seventh year of data collection for the tree condition program (surveys undertaken to date: 2010, 2012, 2013, 2014, 2015, 2016 and 2017). This report presents the findings of the 2017 round of stand and tree condition monitoring undertaken at Koondrook-Perricoota Forest and compares stand and tree condition data across six monitoring periods (2010 and 2012 to 2017).

The biggest flood in 25 years occurred along the Murray River in 2016, with peak flows at Koondrook-Perricoota reaching 57,000 ML per day (FCNSW 2016). This means there are now two large, unregulated flood events documented within the data collection period, and this has enabled trends in tree and stand condition in response to flooding to be identified with more certainty.

Between 2016 and 2017 **more** trees showed signs of **recovery**, e.g. new tip growth and reproduction, which is consistent with the response of the forest following the breaking of the Millennium drought in 2010. **Fewer** trees are currently exhibiting signs of **environmental stress**, e.g. cracked bark and leaf die-off.

Monitoring data (2016-2017) indicate that the health of the established canopy trees at Koondrook-Perricoota has improved in response to the 2016 flood, represented by increases in stand condition, Plant Area Index (PAI) and crown condition. This increase in health is likely to continue into 2018 and 2019, given that the positive effect of the flood event in 2010-2011 lasted approximately three years before declining, and this decline was in progress until the 2016 flood. The forest needs large-scale floods that inundate large sections of the floodplain to gain any improvement, and improvement appears to be amplified if more than one large flood occurs each decade.

In 2017, the percentage of Red Gum Flood Dependent Understorey (FDU) sites with a Crown Condition Index above 6.1 (indicating 'healthy' condition) is 81% for Red Gum FDU and 100% for Red Gum FTU and Box Woodland WRCs. This meets the ecological objectives set out in the *Environmental Water Management Plan* for the forest (MDBA 2012) of having 80% of River Red Gum Forest in a healthy condition, 30% of Red Gum Woodland and 50% of Box Woodland (healthy defined as Tree Index of 4 or above).

This report is subject to, and must be read in conjunction with, the limitations set out in Section 2.2 and the assumptions and qualifications contained throughout the Report.

Abbreviations

CCS	Crown Condition Score
DBH	Diameter at Breast Height
FCNSW	Forestry Corporation of New South Wales
FDU	Flood Dependent Understorey
FTU	Flood Tolerant Understorey
KP	Koondrook-Perricoota Forest
KPOC	Koondrook-Perricoota Operating Committee
%LBA	Percentage Live Basal Area
MDBA	Murray-Darling Basin Authority
NSW	New South Wales
RRG	River Red Gum
PAI	Plant Area Index
SCS	Stand Condition Score
TLM	The Living Murray Program
WRC	Water Regime Class

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Appendices

1. Introduction

1.1 Project context

The Forestry Corporation of New South Wales (FCNSW) engaged GHD to conduct the Stand and Tree Condition Monitoring Program at Koondrook-Perricoota Forest, New South Wales, for 2017. This Project is part of the Murray Darling Basin Authority (MDBA) funded *The Living Murray* (TLM) *Program*. The stand and tree assessments form a component of the broader Vegetation Condition Monitoring program.

The purpose of the program is to survey and report on tree and stand condition at permanently established monitoring sites across Koondrook-Perricoota Forest. The stand condition data will be incorporated into the Stand Condition Model developed by the Australian Centre for Biodiversity, Monash University (Cunningham *et al*. 2009; 2011) upon submission to the MDBA.

The stand and tree condition surveys were undertaken in April-May 2017. The surveys represent the eighth year of data collection for the TLM stand condition program (surveys undertaken to date: 2009, 2010, 2012, 2013, 2014, 2015, 2016 and 2017) and the seventh year of data collection for the tree condition program (surveys undertaken to date: 2010, 2012, 2013, 2014, 2015, 2016 and 2017). Only data from 2010 onwards were available for analysis in this report. Table 1 outlines the data sources from previous monitoring rounds.

Flooding in the Forest occurred in 2010-2011 when significant rainfall resulted in natural floods; however, managed flood events at Koondrook-Perricoota in 2014 and 2015 did not reach any stand and tree condition sites. Significant rainfall across the catchment in 2016 led to a large natural flood in late 2016, which covered the whole forest and reached all stand and tree condition sites. The 2016 flood was the largest in 25 years (L. Broekman, FCNSW, pers. comm.).

This report focuses on describing the current condition of the Forest and trends in condition over the monitoring program.

Table 1 Dates of monitoring of Stand and Tree Condition

Year	Data collected by
2010	Australian Ecosystems
2012	Fire, Flood and Flora
2013 to 2017	GHD

1.2 Koondrook-Perricoota Forest

The Koondrook-Perricoota Forest is located in southern New South Wales and covers approximately 32,000 ha. It is part of the second largest River Red Gum Forest in Australia (MDBA 2012; see Figure 2). The Forest is a large mosaic of River Red Gum (*Eucalyptus camaldulensis*), Black Box (*E. largiflorens*) and Grey Box (*E. microcarpa*) communities, interspersed by wetland ecosystems. As a TLM Icon site, Koondrook-Perricoota Forest is recognised for its environmental, social, cultural and economic values.

The Forest forms part of a significant vegetation corridor across south-east Australia, providing refuge for many regionally and internationally significant species (FCNSW 2012). The ecological significance of the Forest has been recognised, nationally as a Living-Murray Icon site and internationally as a Ramsar wetland.

Flooding regime is the primary driver for vegetation community distribution and condition within the Forest. The health of River Red Gum trees (and to a lesser extent Black Box and Grey Box trees) is driven by flooding. Changed flow regimes due to river regulation have reduced the frequency, duration and timing of floods within the Forest. As a result, there has been widespread decline in the condition of vegetation, particularly River Red Gum tree health and understorey structure and composition (MDBA 2012).

A severe period of extended below average rainfall (known as the Millennium drought) occurred across eastern Australia between 2001 and 2010, with the decade being the driest and warmest on record[1]. This drought exacerbated the situation, where for approximately 10 years there was little if any flooding experienced in the Forest (FCNSW 2012; MDBA 2012).

The period of extended drought was eventually broken during a seven-month period of significant rainfall across Australia, resulting in high Murray River flows (commencing in September 2010). As a result, in 2010 to 2011 flows averaging between 10,000 to 38,000 ML/day above the long-term average were recorded (peaking at 50,000 ML/day in December 2010/January 2011), and flooding of the Forest occurred during this period. Murray River flows trended downward again in 2012 and 2013, with smaller floods than those experienced in 2010/2011 occurring in 2012 and 2013.

A suite of engineering works was completed in 2013, which now allow the Forest to receive managed flooding events to supplement baseline flow conditions. The first environmental watering event occurred in August – October 2014, with 26.3 GL delivered to the Forest. Total flood extent (area of Forest that was inundated) was 4,500 Ha (calculated from Landsat imagery after inflows). Inflow rate peaked at 1,000 ML/d, which is less than the 2013 unmanaged event. The stand and tree condition sites did not receive floodwaters during the event.

The largest flood event on the Murray River in 25 years occurred in 2016, due to significant winter rainfall across the catchment (BoM 2017; Figure 1). Peak flows of up to 57,000 ML/d were recorded at Torrumbarry Weir, and satellite images taken during the 2016 event show the entire forest being flooded, including all stand and tree condition monitoring sites (Appendix F). The 2016 event was the first time since the 2010/2011 flood that the entire forest had been inundated.

1.3 Ecological objectives for Koondrook-Perricoota Forest

The overarching **ecological objective** for Koondrook-Perricoota Forest (as outlined in the Environmental Water Management Plan for the Forest; MDBA 2012) is to maintain and restore a mosaic of healthy floodplain communities. This would be indicated by:

- 80% of permanent and semi-permanent wetlands in healthy condition
- 30% of River Red Gum Forest in a healthy condition (healthy is defined as having a Tree Index of 4 or above)
- Successful breeding of thousands of colonial waterbirds in at least three years out of 10
- Healthy populations of resident native fish in wetlands

The second objective relates to the stand and tree condition monitoring: 30% of River Red Gum Forest in a healthy condition.

[1] Bureau of Meteorology: http://www.bom.gov.au/climate/data/index.shtml?bookmark=200

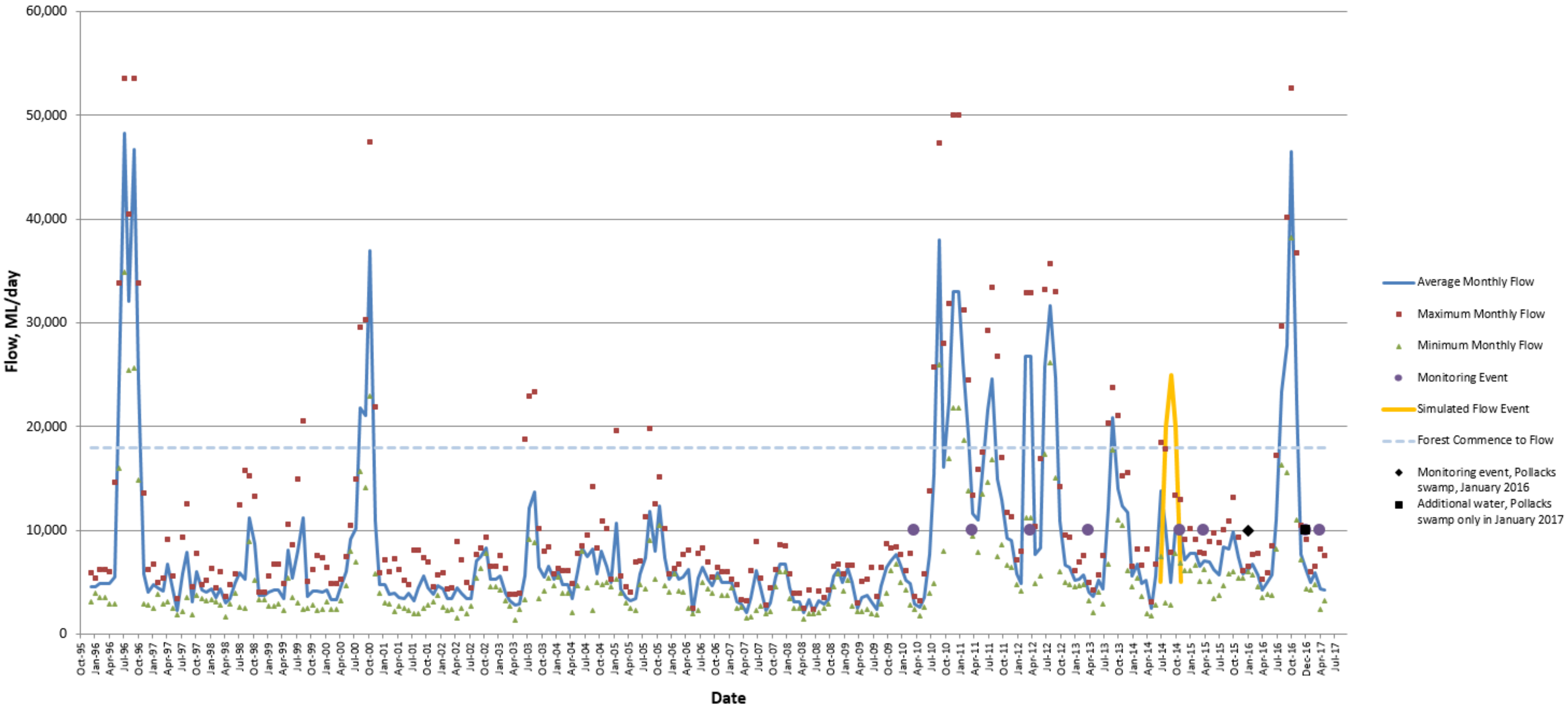
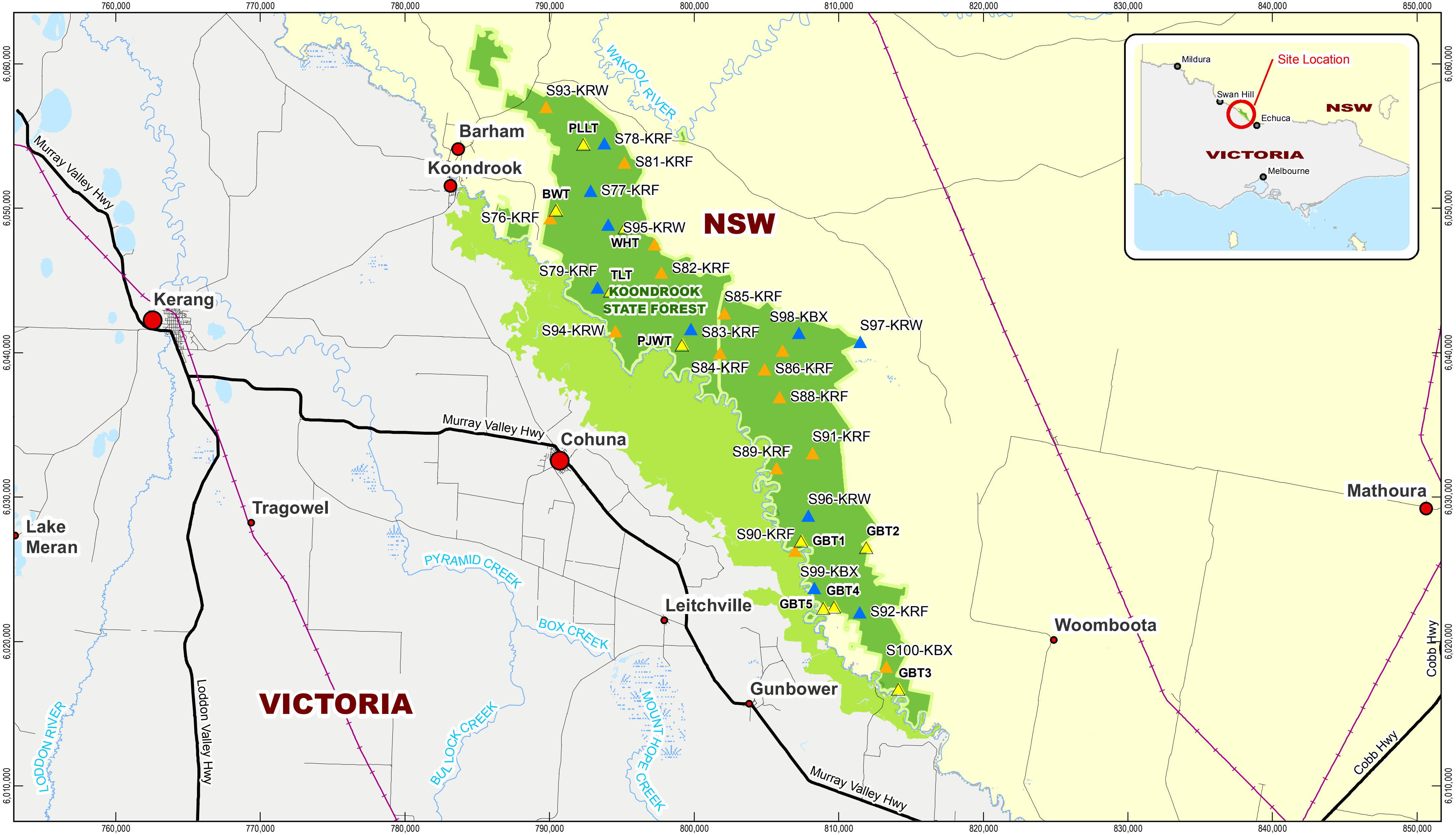


Figure 1 Flow Downstream of Torrumbarry Weir, ML/day (January 1996 to May 2017) (MDBA 2017)[2]

[2] MDBA 2017: flow data downstream of Torrumbarry Weir: https://riverdata.mdba.gov.au/torrumbarry-weir-downstream



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0 1 2 4 6 8 10
Kilometers

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 54

N

LEGEND

Tree and stand condition monitoring sites

- Stand
- Tree and Stand
- Tree
- Rail
- Highway
- Sealed road
- Major water course
- Lake
- Swamp
- Gunbower Forest
- Koondrook-Perricoota Forest
- Towns

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Monitoring for Koondrook-Perricoota Forest

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Date | 26 May 2016

Figure 2

Location Map

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180 Lonsdale Street Melbourne VIC 3000 Australia T 61 3 8687 8000 F 61 3 8687 8111 E melmail@ghd.com W www.ghd.com

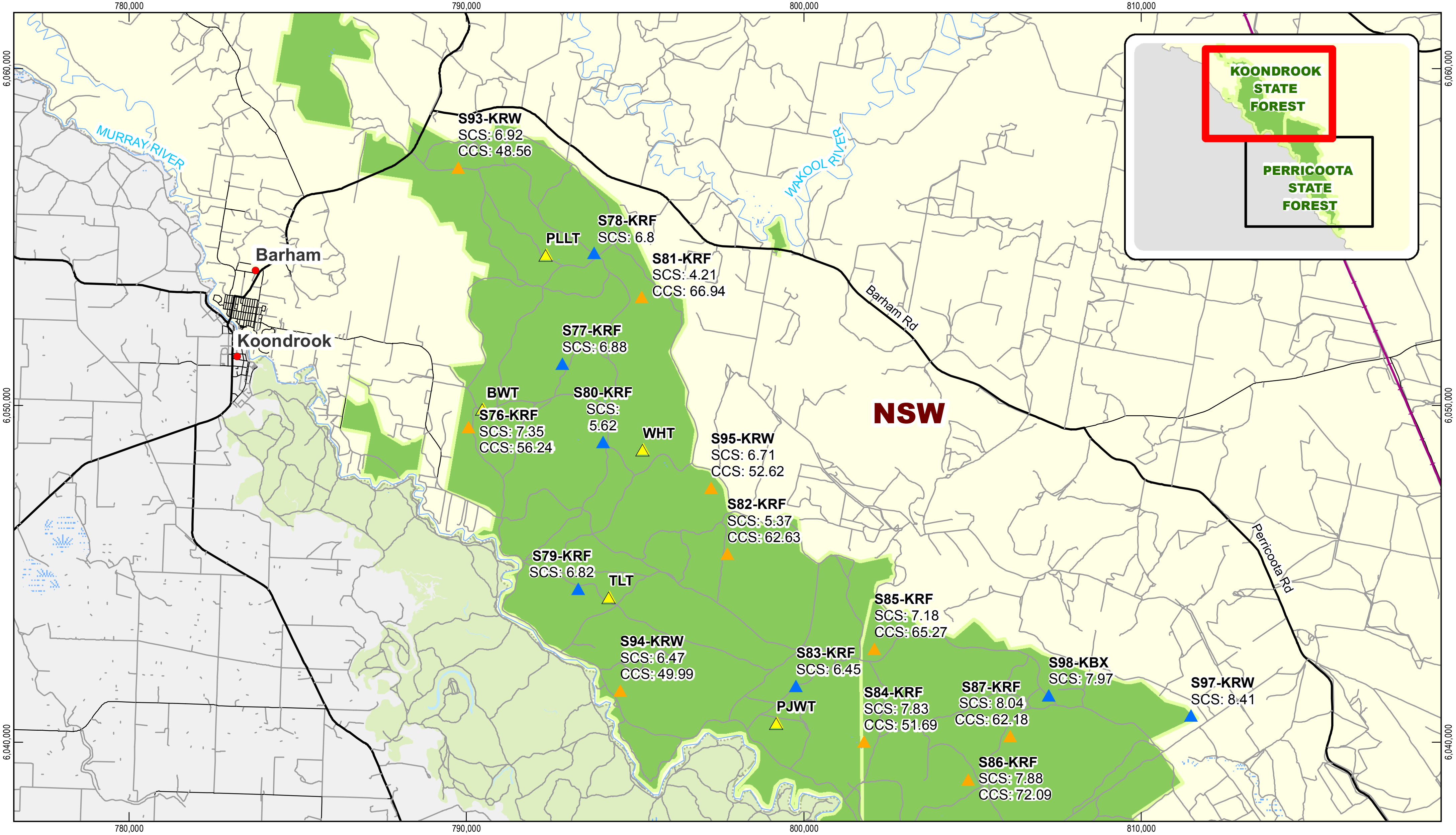
Data source: DSE, VicMap, 2014; Geoscience Australia, Koondrook and Perricoota State Forest boundaries, 2012. Created by:emelero-blanca

2. Methods

2.1 Field survey

Stand and tree condition surveys were undertaken between 4 April and 5 May 2017. Stand condition data were collected at 25 pre-established sites and tree condition data were collected at a subset of 15 of the stand condition sites (site details are provided in Appendix A), as well as at 10 additional sites located along waterways and wetlands established in 2015. The locations of sites are shown in Figure 3. Surveys were undertaken in accordance with *Ground Based Survey Methods for The Living Murray Assessment of River Red Gum and Black Box Condition, Version 12* (Souter *et al*. 2010) and *Field protocol for assessing stand condition of river red gum, black box and coolabah populations across the Murray-Darling Basin (Cunningham 2016)*.

In 2012, five of the monitoring sites (sites S80-KRF, S86-KRF, S88-KRF, S91-KRF and S96-KRW) could not be accessed due to flooding, and in that year alternative sites were used (Alt S91-KRF and Alt S80-KRF). This year (2017) and in 2010, 2013, 2014 and 2015 all sites were accessible and thus the alternative sites were not assessed.



Paper Size A4

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Kilometres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 54

N

LEGEND

Tree and stand condition monitoring sites

- Stand
- Tree and Stand
- Tree
- Rail
- Major water course
- Lake
- Swamp
- Koondrook-Perricoota Forest

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Tree and Stand Condition Assessment Sites at Koondrook-Perricoota Forest

Figure 3

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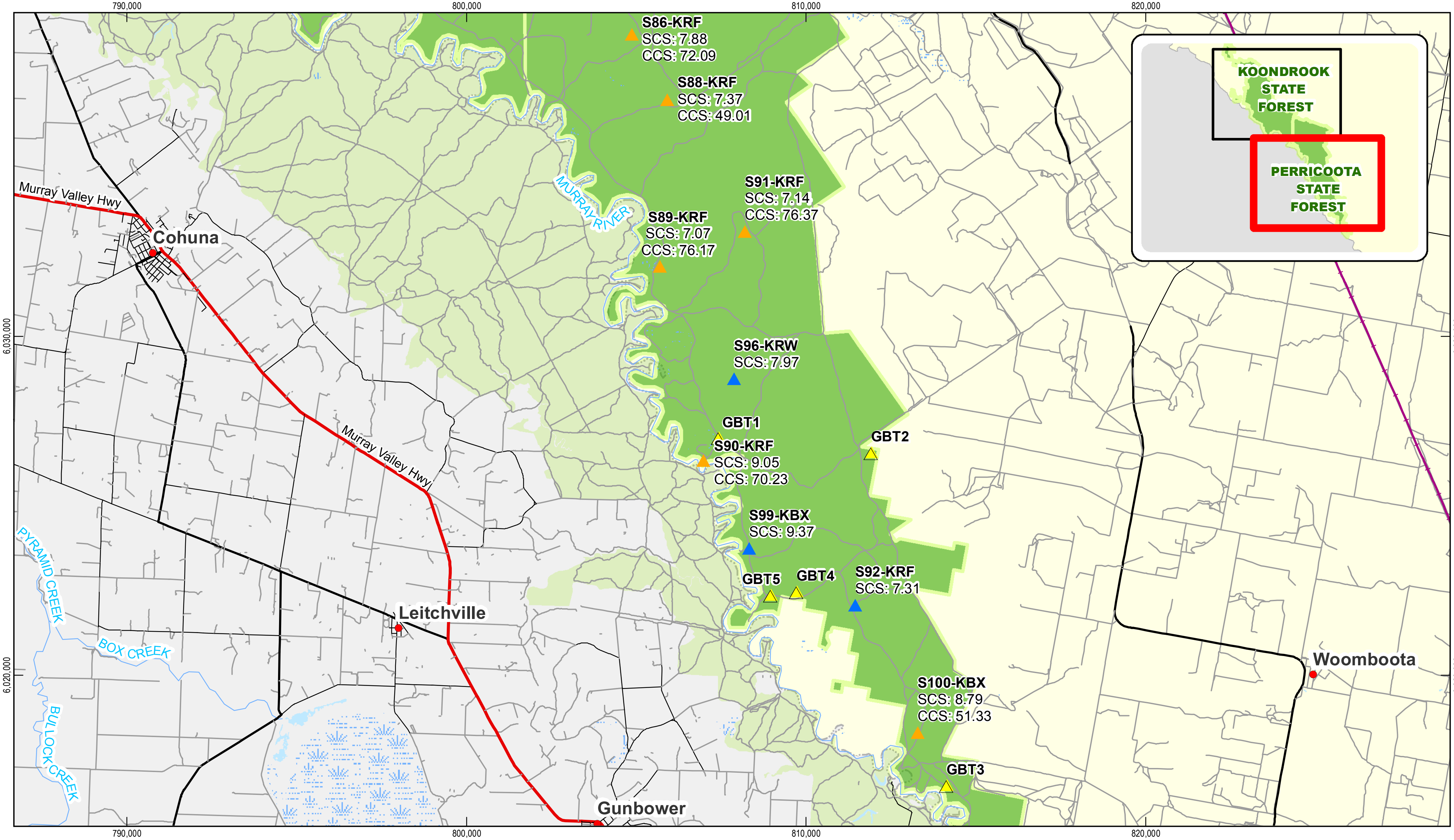
180 Lonsdale Street Melbourne VIC 3000 Australia T 61 3 8687 8000 F 61 3 8687 8111 E melmail@ghd.com W www.ghd.com

Data source: DSE, VicMap, 2013; Geoscience Australia, Koondrook and Perricoota State Forest boundaries, 2012, GHD, Borrow Pit, Grassland Sites, 2014. Created by:emelero-blanca



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Map Projection: Transverse Mercator
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Monitoring for Koondrook-Perricoota Forest

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GHD

Tree and Stand Condition Assessment Sites at Koondrook-Perricoota Forest

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Data source: DSE, VicMap, 2013; Geoscience Australia, Koondrook and Perricoota State Forest boundaries, 2012, GHD, Borrow Pit, Grassland Sites, 2014. Created by:emelero-blanca

2.1.1 Stand condition assessment

The stand condition assessment involved measuring three indicators: percentage live basal area (%LBA), plant area index (PAI) and crown extent. Three variables were assessed at each stand condition site (n = 25) to inform these indicators (see Appendix B, Table B 1 for further detail):

- Diameter at breast height (DBH)
- Live/dead status
- Crown extent

The DBH measurements and live/dead assessments were undertaken for all trees with >10 cm DBH; whereas the assessment of crown extent was limited to the 30 permanently marked trees. Crown extent was measured using a categorical scale (see Appendix B, Table B 2 for categories).

A digital hemispherical photograph was taken from the fixed position at the centre of each site using a Nikon D3100 camera with a Sigma 4.5 mm F2.8 EX DC Circular Fisheye lens. In order to avoid direct sunlight on the canopy, photographs were typically taken during the 90 minutes after sunrise, or the 90 minutes before sunset. Where suitable conditions existed (particularly on overcast days), some photographs were taken outside of these time windows. This approach was necessary to complete the photos within the time allocated to fieldwork.

It should be noted that in 2016, the lens cap was not fully removed whilst taking hemispherical photographs. This error resulted in each hemispherical photograph being taken with a narrower field of view and the outer rim of each photo being excluded. This means that 2016 hemispherical photographs contain less area, which we calculated to be an average of 18.7%. The way in which the smaller area of 2016 hemispherical photographs was accounted for in the data analysis is described in the Stand and Tree condition monitoring report for 2016 (Forbes and Wills 2016).

2.1.2 Tree condition assessment

The condition of 30 permanently marked live trees with a DBH >10 cm was measured at each tree condition assessment site (n = 25, totalling 750 trees). There are ten assessments that form the minimum requirements for TLM assessment of RRG/BB condition (Souter *et al*. 2010):

- Crown extent
- Crown density
- Bark condition
- Recovery: New tip growth
- Recovery: Epicormic growth
- Decline: Leaf die off
- Decline: Mistletoe
- Tree dominance
- Reproduction
- Diameter at breast height (DBH)

A brief description of each of the TLM variables/indicators and their respective categories is provided in Appendix C.

Additional contextual information was collected at each assessment site, and a photograph was taken at the pre-established photo-point to enable qualitative assessment of temporal change in tree condition (Appendix G). Category scales were used to report all variables and are presented in Appendix C, Table C1 to C9.

2.2 Water regime classes

Water regime classes (WRCs) are a spatial classification of the floodplain into areas within common water regimes and ecological characteristics (Ecological Associates 2011). The use of WRCs enables trends in condition to be investigated for each WRC, with reference to flooding of the Forest.

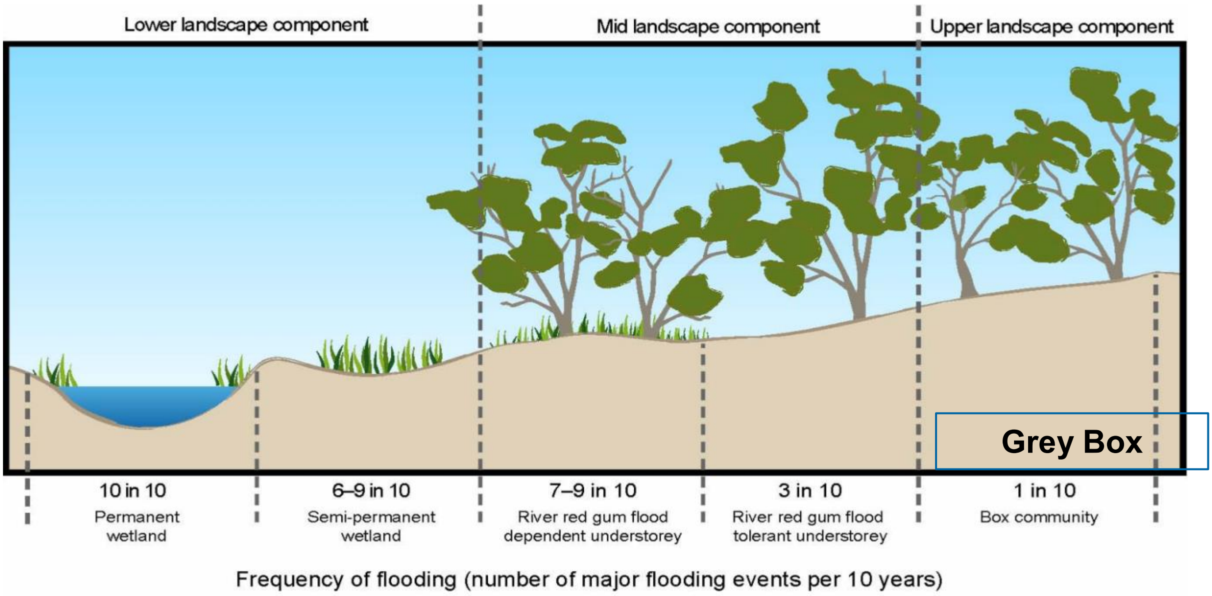
River Red Gum (RRG) is the predominant overstorey species, occupying over 80% of Koondrook–Perricoota Forest (MDBA 2012). It usually forms a pure stand, but does occur with other eucalypt species on less frequently flooded sites. The health of the River Red Gum Forest depends on the frequency, size, duration and timing of flooding, along with antecedent conditions. Black Box communities occur in areas prone to lower frequency, and shorter duration flooding. The Forest also supports extensive areas of Grey Box Woodland, some of which would have been flooded regularly under natural conditions (almost every year).

The following four WRCs are included in the monitoring program at Koondrook-Perricoota Forest, in order of decreasing water requirements:

- **River Red Gum Forests with flood dependent understorey (RRG FDU)**. River Red Gum Forest requires regular inundation to promote the flood dependent understorey (macrophytes) (MDBA 2012)
- **River Red Gum Woodlands with flood tolerant understorey (RRG FTU)**. River Red Gum Woodlands require less frequent flooding than the RRG Forests because the understorey is not flood dependent (MDBA 2012)
- **Black Box Woodland** (Box Woodlands require little watering; MDBA 2012)
- **Grey Box Woodland** (proposed to have the lowest water requirements but this varies across the Forest). The lower 200 ha of Grey Box Woodland is inundated by flows of 35,000 ML/d. Under natural conditions these flows would have occurred almost every year with an average duration of more than two months (Ecological Associates 2011). At flows of 60,000 ML/d, 474 ha is inundated and would have experienced inundation events twice in ten years with average durations of less than two weeks. This suggests that some areas of Grey Box may be more tolerant of flooding than others.

The position of the four Water Regime Classes in the landscape is illustrated in Figure 4, along with the ideal flood regime for each WRC. Note that this is a very broad indication of vegetation associations, geomorphic setting and natural flood regime. As over 80% of the Forest supports River Red Gum Forests/Woodlands and these vegetation types have higher water requirements than the other woodlands, the majority of established stand and tree condition sites are located within the Red Gum with FDU.

Due to the small number of Black Box Woodland and Grey Box Woodland sites included in the Stand and Tree Condition Assessment, these two WRCs have been pooled and treated as a single Water Regime Class (Box Woodland) for this report.



Source: Ecological Associates (2006) and MDBA (2012)

Figure 4 Water Regime Classes (vegetation associations) and ideal flood regime at Koondrook-Perricoota Forest

2.3 Data analysis

Stand and Tree condition data were analysed for 2017 to determine the current condition of the forest. Data across years were compared to determine if the condition of the Forest is improving or declining over time.

The Friedman Test is the non-parametric alternative to the one-way repeated measures ANOVA. It is used when the same sample of subjects or cases is measured at three or more points in time, or under different conditions (Pallant 2005). Because of uncertainty about whether or not the underlying assumptions of ANOVA had been violated, this test was used to investigate if there were significant differences in stand and tree condition between years.

For stand condition attributes, mean values were compared across years. Boxplots were also generated to show the distribution of scores for each variable. The length of the box is the variable's interquartile range and contains 50% of cases. The line across the inside of the box represents the median value. The whiskers protruding from the box denote the variable's smallest and largest values. Circles represent outliers and stars represent extreme cases.

For tree condition attributes (which are categorical), frequency histograms were generated to determine the current frequency distribution, and observe changes in frequency distribution over years.

2.3.1 Stand condition assessment

For each stand condition site, the following indicators were analysed:

- Percentage Live Basal Area (% LBA)
- Plant Area Index (PAI)
- Mean crown extent (30 permanently marked trees)

Stand condition data are combined to provide an overall measure of stand condition across the Koondrook-Perricoota forest, and all TLM monitoring sites more broadly.

LBA (%) was calculated as follows:

- The basal area (BA) of each stem is calculated using formula:
  - BA (cm^2) = π x [dbh (cm)/2]^2
  - Total LBA is calculated by summing the BA for all live trees
  - Total BA is calculated by summing the BA for all trees, live and dead
  - The percentage of LBA = 100 x (total live BA / total BA)

To calculate PAI, the digital hemispherical photographs (stand canopy) were classified using the image analysis software MultiSpec Application Version 3.3 (Purdue University 2011). The classification process involves grouping an image into 'clusters' based on the colour. In this case, images were classified into 15 clusters. Plant Area Index (PAI) was then calculated for the classified images using LAI tool within Winphot 5.00 (ter Steege 1996).

To determine whether stand condition assessment sites could be considered in a healthy condition, the stand condition data were combined to give a Stand Condition Score (SCS), as per Cunningham (2009) and Cunningham et. al. (2011). This involved standardising each value to a maximum of 10, and then averaging the three values for each site as follows:

- %LBA (as a decimal) was multiplied by 10
- Crown extent data (in percentages) were converted to the 6-tier scale as per Cunningham *et al*. (2009; 2011), in which 0 = 0%, 1 = 1-20%, 2 = 21-40%, 3 = 41-60%, 4 = 61-80%, and 5 = 81-100%, and the average crown extent for the site then multiplied by 2[3]
- PAI was standardised relative to the maxima recorded within each WRC within the Koondrook-Perricoota forest across all years. Cunningham *et al.* (2009; 2011) standardise PAI relative to the maximum measured for the vegetation type within a bioregion. In the absence of this figure, the maxima for each WRC was used. This value was then multiplied by 10, i.e. = PAI / (highest PAI across all monitoring years for relevant WRC) * 10). As the maximum PAI value for each WRC increased in 2017, new maxima were relevant to the PAI standardisation calculations, and therefore all PAI values collected from 2010-2017 were retrospectively standardised to the new maxima.

The calculation of Stand Condition Score can be represented by the following equation:

$$\begin{aligned} \mathit{Stand\ Condition\ Score} &= \mathit{Average}\ ((\mathit{Crown\ Extent\ Category}\ \times\ 2) + (\%\mathit{LBA} \times 10) \\ &+ (\mathit{PAI}/(\mathit{PAI\ maxima\ for\ water\ regime\ class\ across\ all\ monitoring\ periods}) \\ &\times 10)) \end{aligned}$$

Stand condition score is allocated to one of the following categories (Table 2).

Table 2 Scale used to categorise Stand Condition Score

Category	Stand Condition Score
Good	8.1 – 10.0
Moderate	6.1 – 8.0
Poor	4.1 – 6.0
Degraded	2.1 - 4.0
Severely Degraded	0 – 0.2

[3] It should be noted that only one assessor's assessment of crown extent was recorded in the field, rather than two assessors as required by the updated stand condition assessment field protocol (Cunningham 2016). Data analysis was therefore conducted using one crown extent value per tree rather than two. This information was passed onto FCNSW and the MDBA in May 2017, who were still able to use the data in their basin-wide modelling despite this being consistent with Souter et. al. (2012) instead of Cunningham (2016).

2.3.2 Tree condition assessment

For each tree condition site, the frequency of trees within each category was determined for each variable.

Crown Condition Score (CCS) was also calculated for each tree assessed (n=450 for 2010, 2012 and 2014, n=750 for 2015 and 2016). Crown Condition is recognised as a useful mode for detecting real change in tree health (Henderson 2011), and the use of the categorical scale presented in Table 3 is an appropriate scale for presentation of the data (Souter *et al* 2010). The Crown Condition Score is calculated as per Henderson (2011), as follows:

$$Crown\ Condition\ Score\ (CCS) = \sqrt{(Canopy\ Extent\ \times Canopy\ Density)}$$

Table 3 Categorical Scale used for analysis of Crown Condition

Category	Crown Condition Score
Dead	0
Very poor	1 - 20
Poor	21 - 40
Moderate	41 - 60
Good	61 - 80
Very good	81 - 100

Presentation of results

Results of the tree condition assessment (Figure 13 to Figure 19) are presented with two sets of data side-by-side for 2015, 2016 and 2017. These are referred to in figures as 2015a and 2015b, 2016a and 2016b, and 2017a and 2017b, where ‘a’ and ‘b’ represent different datasets; ‘a’ where n=450 and the data for the 10 additional tree condition assessment sites established in 2015 are not included (RGFDU n=11, RGFTU n=3, Box Woodland n=1), and ‘b’ where n=750 and the data for the 10 additional tree sites are included (RGFDU n=16, RGFTU n=3, Box Woodland n=6). This is due to the data for the additional tree sites being collected in the field at the time of establishment in 2015, but not being incorporated in that year’s analysis. In order to provide a direct comparison between data including the 10 new sites and also without, it was felt that this was the easiest way to visually identify the effect that the 10 new sites may be having on the dataset and the subsequent results.

2.1 Quality control and metadata management

Stand and tree data were collected digitally in 2017 directly on to a hand-held tablet. This meant a reduction in data-handling, and thus a reduction in the possibility of transcription errors during data entry. On completion of data entry at each site, the botanist collecting the data examined the data file to check for errors or missing data, and amend these if found.

The data files GHD received in 2013 were set up by the Forestry Corporation of NSW and previous consultants (Australian Ecosystems 2010; Bennetts and Jolly 2012). GHD has entered this year’s data (2017) into the data files in accordance with the previous data entry procedure.

2.2 Limitations and assumptions

In addition to data collected by GHD in 2013-2017, GHD has used previous years’ data collected by other consultants for comparison and has not verified or checked these data.

2.2.1 Sample size

In the monitoring program, River Red Gum Forest appears to be well represented, however, there was only one tree condition site for Black Box Woodland prior to 2015. Similarly, there are few River Red Gum Flood Tolerant Woodland sites represented in the current monitoring program. Given that the majority of stand and tree condition sites occurred outside areas that were inundated during the 2014 managed watering event, it was decided to establish an additional 10 tree condition sites in autumn 2015: five within Grey Box Woodland and five along waterways and creeklines that are more likely to be inundated during small scale events (such as the managed event of 2014) (Table 1, Table 4).

Table 4 List of Stand and tree assessment sites

Site ID	Forest Type	Water Regime Class	Assessment Type
S76-KRF	River Red Gum Forest	Red Gum FDU	Tree and Stand
S77-KRF	River Red Gum Forest	Red Gum FDU	Stand
S78-KRF	River Red Gum Forest	Red Gum FDU	Stand
S79-KRF	River Red Gum Forest	Red Gum FDU	Stand
S80-KRF	River Red Gum Forest	Red Gum FDU	Stand
S81-KRF	River Red Gum Forest	Red Gum FDU	Tree and Stand
S82-KRF	River Red Gum Forest	Red Gum FDU	Tree and Stand
S83-KRF	River Red Gum Forest	Red Gum FDU	Stand
S84-KRF	River Red Gum Forest	Red Gum FDU	Tree and Stand
S85-KRF	River Red Gum Woodland	Red Gum FTU	Tree and Stand
S86-KRF	River Red Gum Forest	Red Gum FDU	Tree and Stand
S87-KRF	River Red Gum Forest	Red Gum FDU	Tree and Stand
S88-KRF	River Red Gum Forest	Red Gum FDU	Tree and Stand
S89-KRF	River Red Gum Forest	Red Gum FDU	Tree and Stand
S90-KRF	River Red Gum Forest	Red Gum FDU	Tree and Stand
S91-KRF	River Red Gum Forest	Red Gum FDU	Tree and Stand
S92-KRF	River Red Gum Forest	Red Gum FTU	Stand
S93-KRW	River Red Gum Woodland	Red Gum FTU	Tree and Stand
S94-KRF	River Red Gum Forest	Red Gum FDU	Tree and Stand
S95-KRF	River Red Gum Woodland	Red Gum FTU	Tree and Stand
S96-KRW	River Red Gum Woodland	Red Gum FTU	Stand
S97-KRW	River Red Gum Woodland	Red Gum FTU	Stand
S98-KBX	Box Woodland	Black Box Woodland	Stand
S99-KBX	Box Woodland	Grey Box Woodland	Stand
S100-KBX	Box Woodland	Black Box Woodland	Tree and Stand
BWT	River Red Gum Forest (est 2015)	Red Gum FDU	Tree

Site ID	Forest Type	Water Regime Class	Assessment Type
PJWT	River Red Gum Forest (est 2015)	Red Gum FDU	Tree
PLLT	River Red Gum Forest (est 2015)	Red Gum FDU	Tree
TLT	River Red Gum Forest (est 2015)	Red Gum FDU	Tree
WHT	River Red Gum Forest (est 2015)	Red Gum FDU	Tree
GBT1	Box Woodland (est 2015)	Grey Box Woodland	Tree
GBT2	Box Woodland (est 2015)	Grey Box Woodland	Tree
GBT3	Box Woodland (est 2015)	Grey Box Woodland	Tree
GBT4	Box Woodland (est 2015)	Grey Box Woodland	Tree
GBT5	Box Woodland (est 2015)	Grey Box Woodland	Tree

Water Regime Class Key
Red Gum FDU forest
Red Gum FTU woodland
Box woodland

2.2.2 Experimental design

The following potential limitations of the current data sets must be acknowledged when analysing and interpreting the data:

- Use of a ‘repeated measures’ design, because the same trees were monitored each year, rather than different, randomly chosen trees each year
- Pseudoreplication: the actual unit of replication may be the ‘site’, not the individual tree sampled in each site across the years

2.2.3 Hemispherical photograph analysis

The analysis of hemispherical photographs is subjective, and can be influenced by several variables, including:

- The first stage of the procedure (performed in Multispec) involves the assessor making 15 subjective judgements on whether parts of the image are to be analysed as vegetation or sky
- Each of the 15 judgements can make a substantial difference in the amount of ‘black’, i.e. vegetation, included in each photo
- Photos from different years being assessed by different people
- Different programs being used for the Multispec procedure in different years, i.e. Paintnet in 2015, Powerpoint in 2013, 2014, 2016 and 2017

3. Results

3.1 Stand condition assessment

The stand condition assessment involved measuring three variables: percentage live basal area (%LBA), plant area index (PAI), and crown extent, which are known to be reliable and objective indicators of condition of stands of River Red Gum (Cunningham *et al*. 2009; 2011).

3.1.1 Stand Condition Score

Stand Condition Score (SCS) is a combination of the three stand condition attributes; LBA, PAI and crown extent. Results from 2010 to 2014 indicate that SCS increased gradually following the breaking of the Millennium drought in 2011 (Figure 5, n = 25 sites). These results suggest that stand condition responds gradually to flooding, and takes several years (three years in this instance) to reach a peak response following a major flood event. Results in 2017 indicate that SCS has responded strongly to the 2016 flood, after two years of declining condition (2014-2016), and is currently at the highest level since commencement of monitoring.

The Friedman test indicates that the mean increase (0.000) in SCS between 2016-2017 is significant (P<0.05, Appendix D). The difference in mean SCS score between 2010 (end of drought conditions) and the subsequent six survey periods is significant for all years (Figure 5 and Appendix D, Table D6).

Water Regime Classes

When examined according to WRC, Box woodland consistently had the highest median SCS across all monitoring periods, followed by RRG FTU, while RRG FDU was consistently the lowest (Figure 6). The median SCS suggests that RRG FTU sites responded most rapidly to watering in the short time (approximately six months) that had elapsed between the 2016 flood and the 2017 monitoring (Figure 6), while RRG FDU and Box Woodland sites had responded positively but not as substantially as RRG FTU.

No sites in any WRC had SCSs categorised as ‘degraded’ or ‘severely degraded’ in 2017 (Appendix D). Fourteen of the sites had improved by one category from 2016 to 2017, with one site progressing from degraded to poor, nine sites improving from poor to moderate, and four sites moving from moderate to good. For RRG FDU (the dominant WRC), the majority of stand sites (75%) were in the ‘moderate’ condition category in 2017. Only one RRG FDU site was in ‘good’ condition.

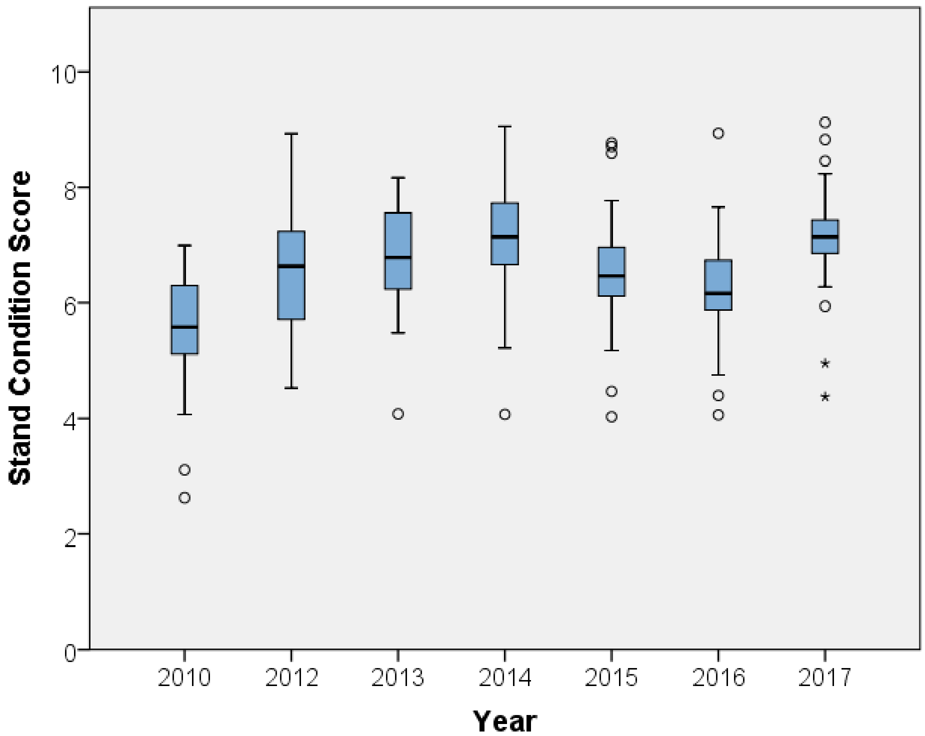


Figure 5 Change in Stand Condition Score over time

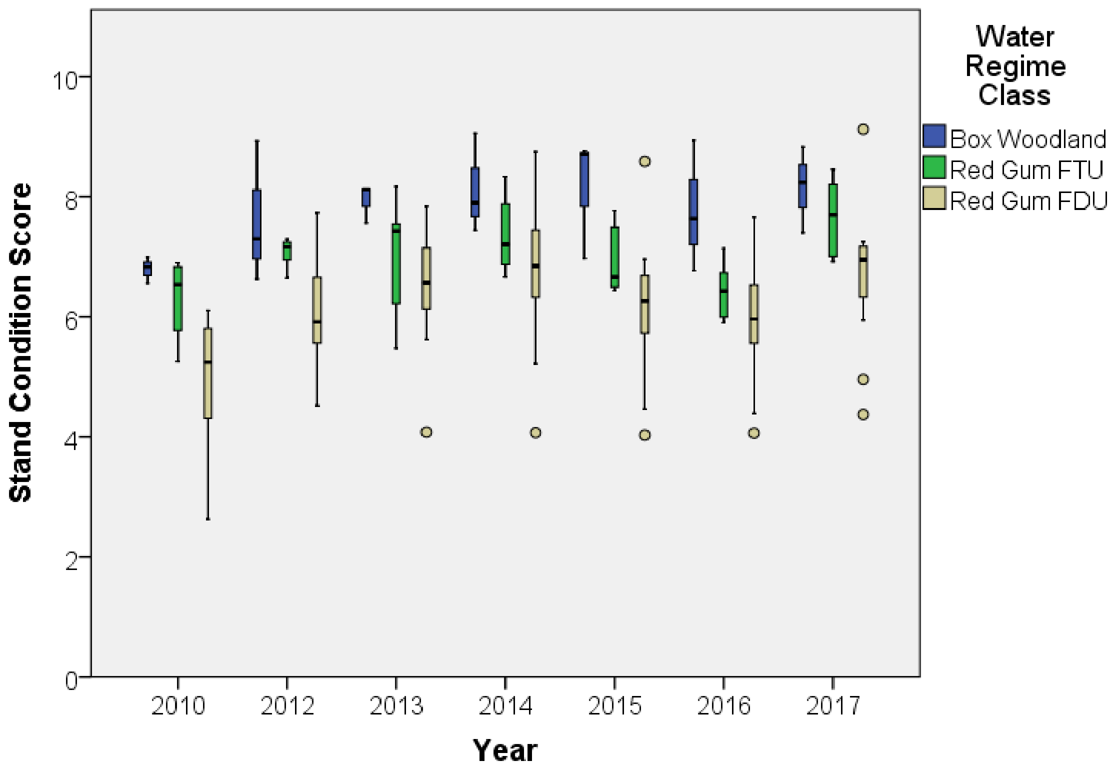


Figure 6 Change in Stand Condition Score according to Water Regime Class over time

3.1.2 Plant area index

Plant area index (PAI) is the area of leaves and stems per unit ground area without adjustment for clumping of canopy components. Data for PAI were compared across years (2010, 2012, 2013, 2014, 2015, 2016 and 2017).

The results indicate that there was a progressive increase in mean PAI for three years following the 2010/11 event, after which it declined to a low point in 2016. Mean PAI has quickly rebounded with a 53% increase following the 2016 flood, with 2017 PAI the highest observed since inception of the monitoring program (Figure 7). The magnitude of the increase is similar to that observed after the 2010 flood (Appendix D, Table D2).

The Friedman test indicates that the average increase (0.35) in PAI between 2016-2017 is significant (P<0.001, Appendix D). The difference in mean PAI score between 2010 (end of drought conditions) and the subsequent six survey periods is also significant (Figure 7 and Appendix D, Table D6).

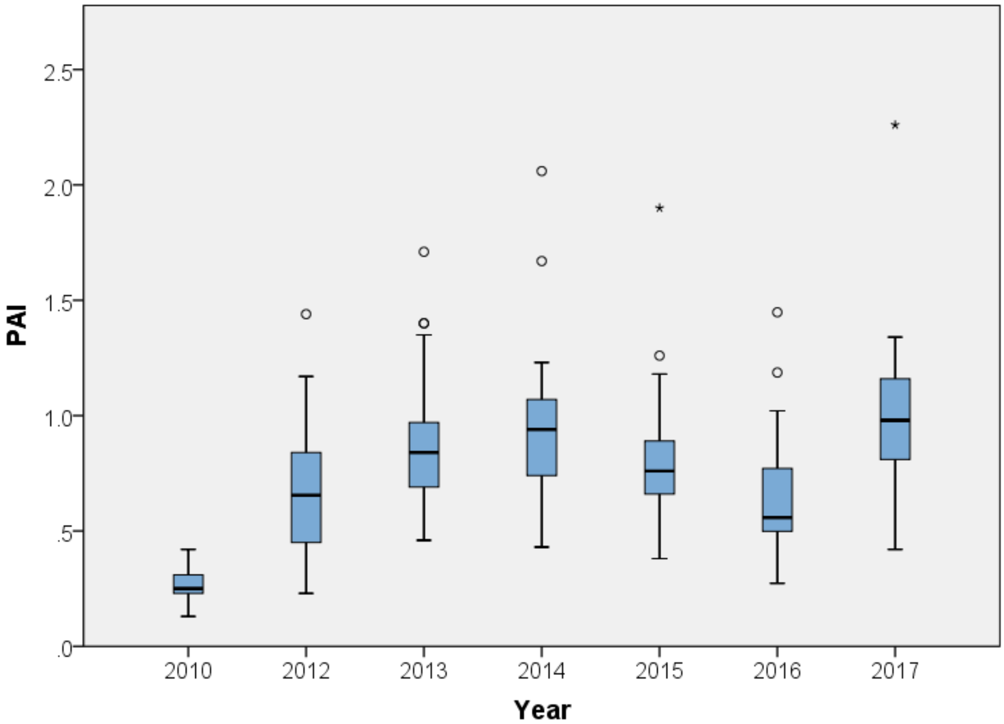


Figure 7 Change in Plant Area Index (PAI) over time

Water Regime Classes

An increase in PAI across all three WRCs was observed between 2016-2017 (Figure 8, n=16 RRG FDU, n=6 RRG FTU, n=3 Box Woodland), with the most pronounced response in RRG FDU and FTU WRCs. This represents a departure from the decreasing PAI trend across WRCs from 2014 to 2016, when the forest was experiencing dry conditions.

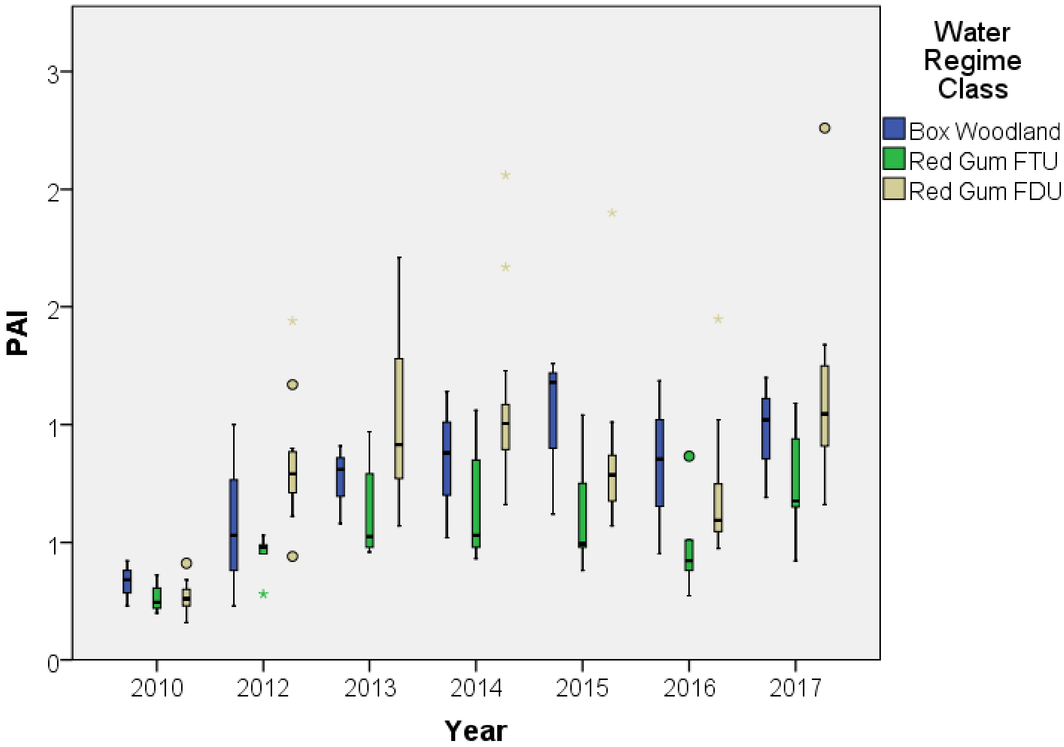


Figure 8 Change in Plant Area Index (PAI) according to Water Regime Class over time

3.1.3 Live basal area

Percentage live basal area (%LBA) is the percentage of a stand's basal area (i.e. the area occupied by tree trunks within the 2500 m^2 site) that is contributed by live trees. The results indicate that %LBA has plateaued since 2012, differing by only 1% over the past five years (Figure 9, n=25 sites, Appendix D Table D3)).

The results of the Friedman test indicate that there is a significant difference in %LBA over time (Appendix D, Table D6); however, the only significant difference in year to year data is between 2010 and 2017 (p=0.007) (Appendix D, Table D5). Unlike PAI, this variable does not display a quick response to flooding.

Water Regime Classes

This significant increase from 2010 to 2017 is primarily driven by changes in %LBA in the Red Gum FDU. Percentage LBA at Red Gum FTU and Box Woodland Sites (Figure 10, n=16 Red Gum FDU; n=6 Red Gum FTU; n=3 Box Woodland) showed little change over time.

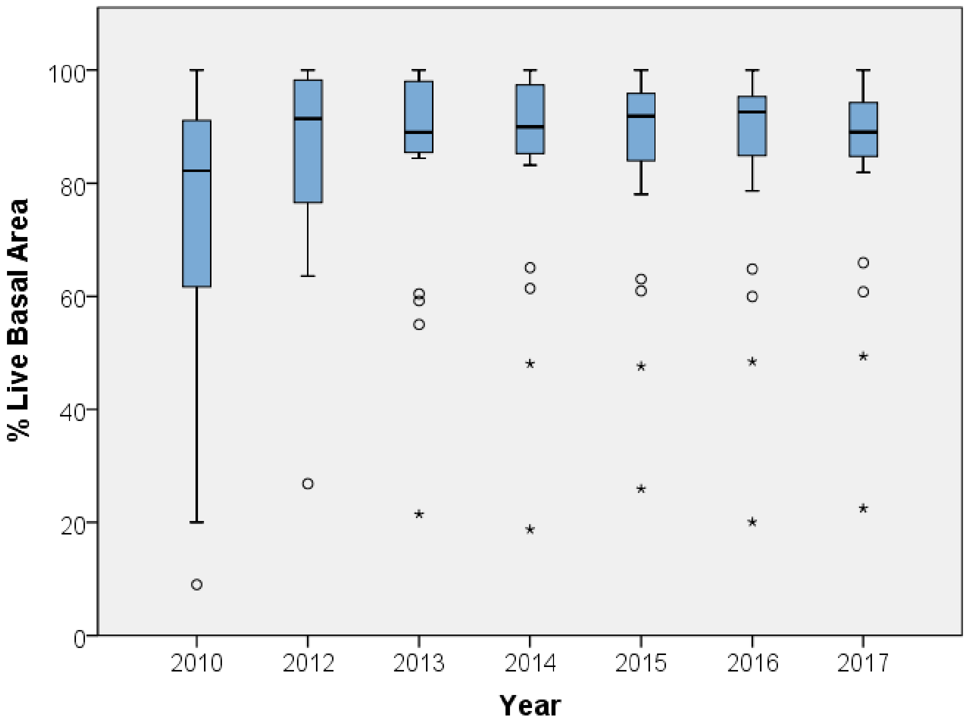


Figure 9 Change in Percentage Live Basal Area (%LBA) over time

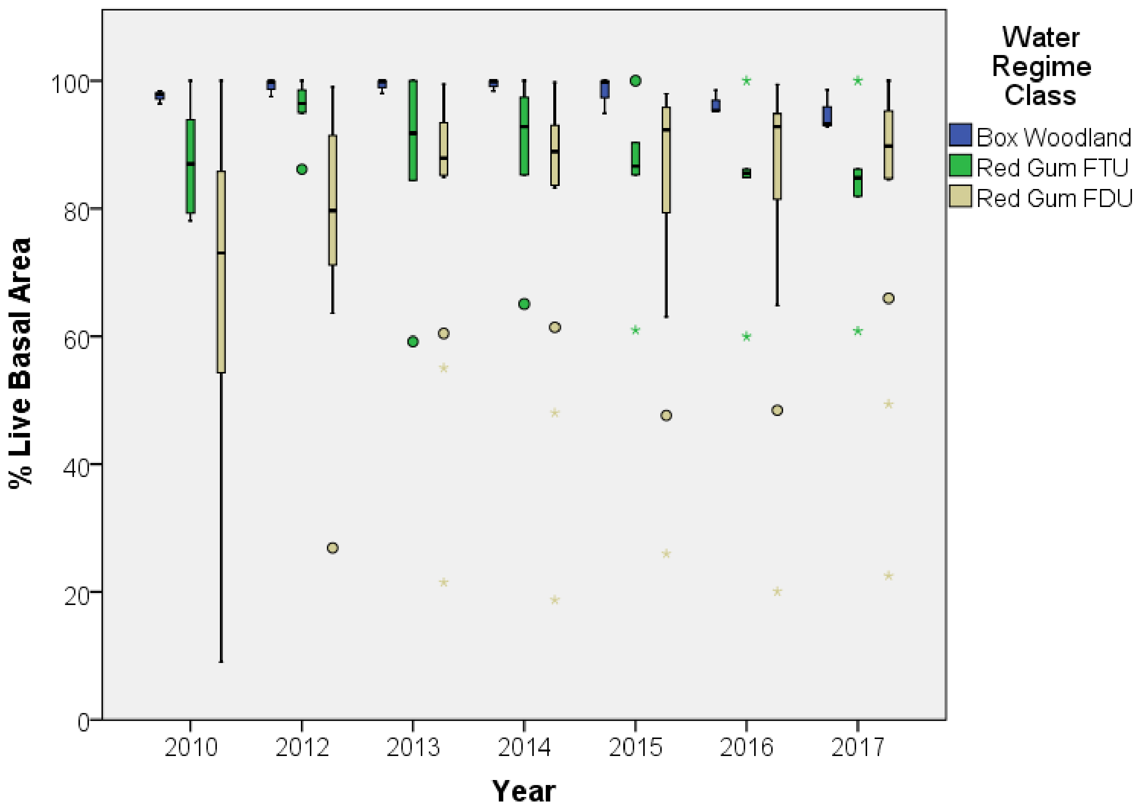


Figure 10 Change in Percentage Live Basal Area (%LBA) according to Water Regime Class over time

3.1.4 Crown extent

Crown extent is the percentage of the potential crown that contains foliage.

The results indicate that mean crown extent remained relatively stable from 2010 to 2014, after which it decreased in 2015 and 2016 during drier conditions (Appendix D, Table D4). Crown extent then increased from 2016-2017 ($P<0.001$) (Appendix D, Table D6), with the increase being the largest in a year since the commencement of monitoring (Figure 11, n=25 sites).

Water Regime Classes

This trend from 2016-2017 shows the largest increase in the RRG WRCs, especially RRG FTU. The Box Woodland WRC has not responded since the 2016 flood (Figure 12, n=16 Red Gum FDU; n=6 Red Gum FTU; n=3 Box Woodland, Appendix D).

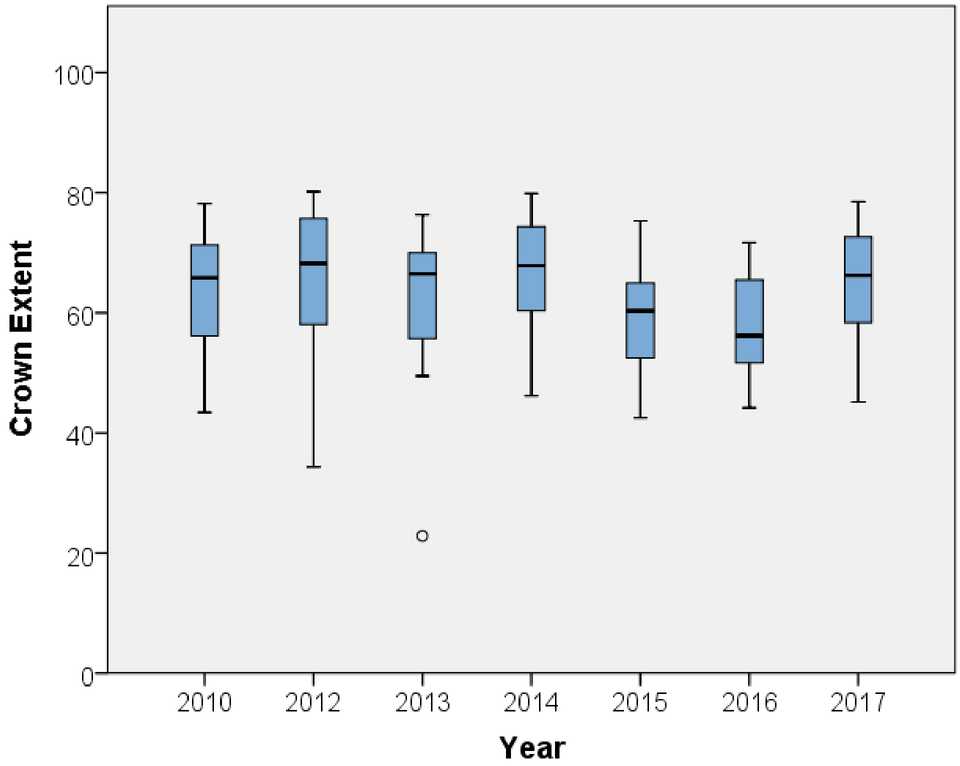


Figure 11 Change in Crown Extent (%) over time

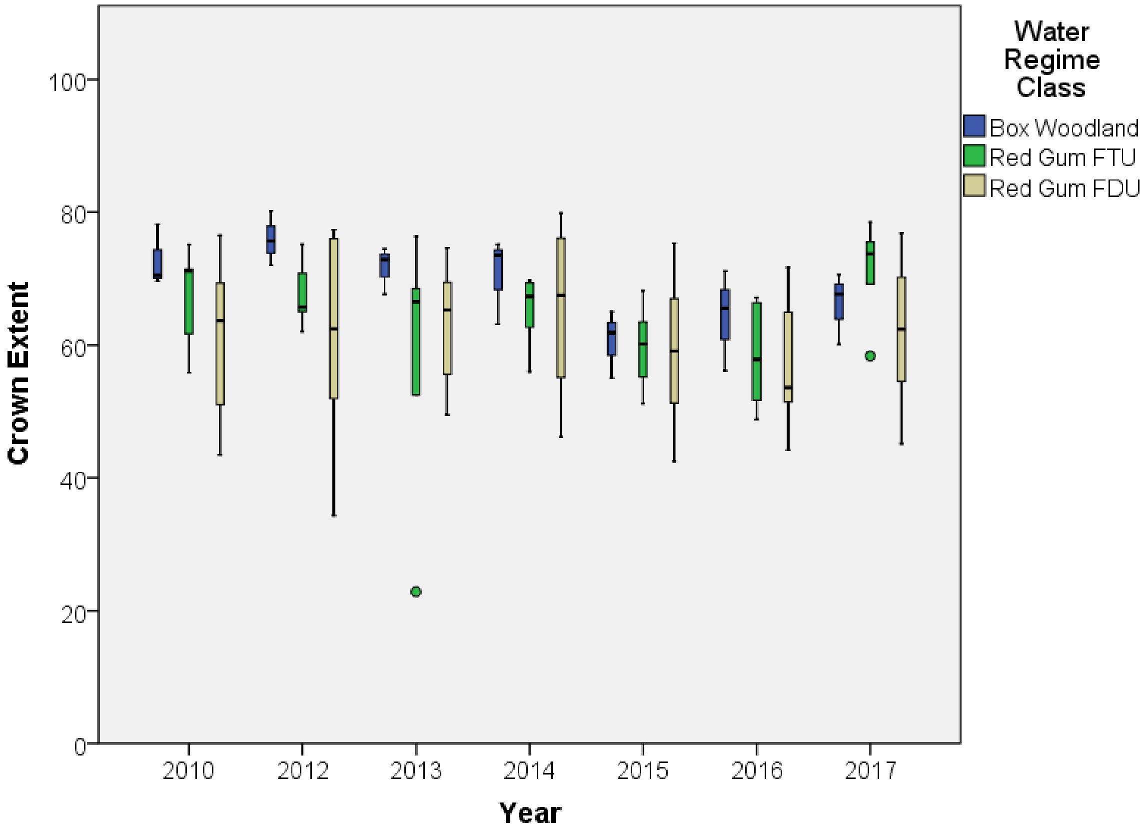


Figure 12 Change in crown extent (%) according to Water Regime Class over time

3.2 Tree condition assessment

The following sections present a summary of the current results (2017) for tree condition and a comparison of each of the tree condition attributes across monitoring years (2010, and 2012 to 2017). Reporting on the Crown Condition Score (CCS) is also included, calculated by combining the crown extent score and the crown density score (as described in Section 2.3.2). For each box plot and histogram, two sets of data have been presented, to show the effect of adding data from the additional 10 tree condition assessment sites established in 2015 (as described in Section 2.3.2).

3.2.1 Crown Condition Score – Overall

Mean Crown Condition Scores across monitoring years are shown in Figure 13 and the frequency of trees in each Crown Condition Score category is shown in Figure 14 (and Appendix E, Table E 4). These graphs present data for all trees included in the monitoring program across Koondrook-Perricoota Forest. It should be noted that n = 15 (2010, 2012, 2013, 2014, 2015a, 2016a and 2017a) and n = 25 (2015b, 2016b and 2017b).

The 2017 CCS is the highest recorded since 2010, and indicates a substantial response following the 2016 flood. This response mirrors that observed in 2012 after the 2010/11 flood. The datasets 2015b-2017b, which have an increased sample size, also reflect the increasing Crown Condition scores since the 2016 flood.

Figure 14 shows an increase in the number of trees in the good and very good crown condition categories in 2017. More trees are now in good or very good condition that at any time since monitoring commenced in 2010. Trees in the poor and very poor categories are also at their lowest numbers since monitoring commenced.

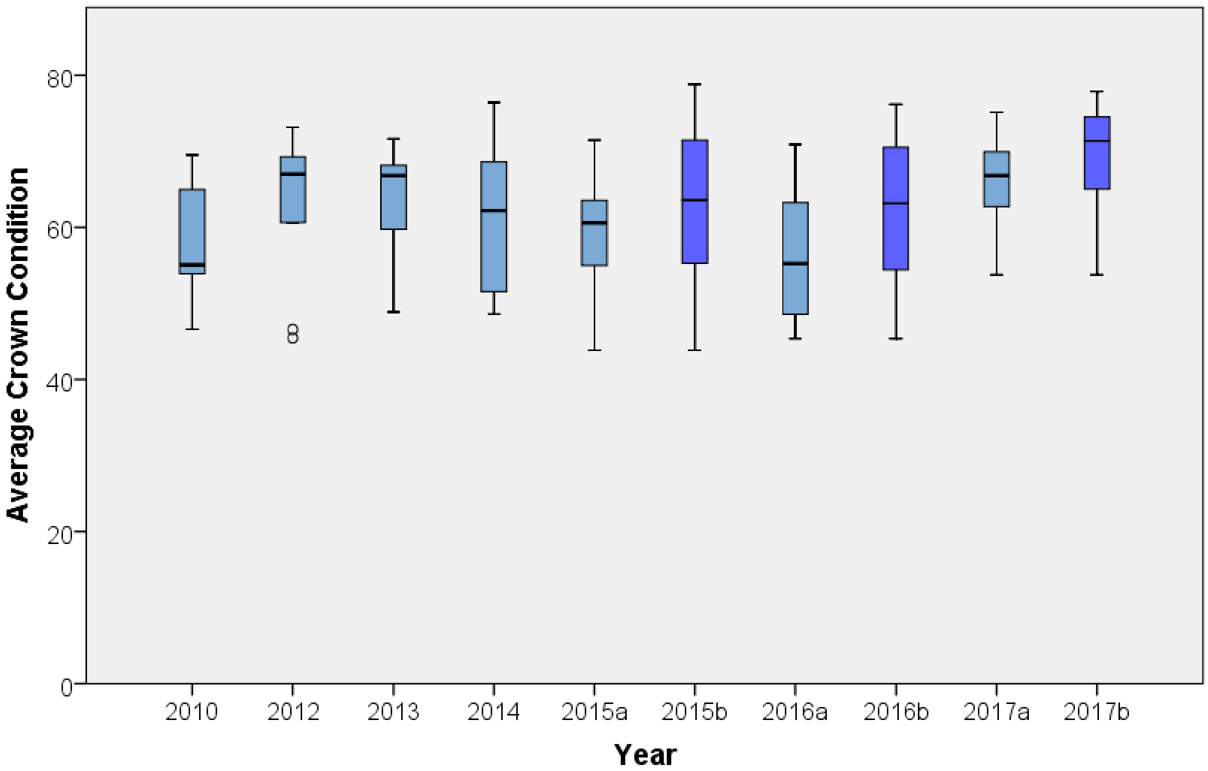


Figure 13 Mean Crown Condition Score (CCS) over time

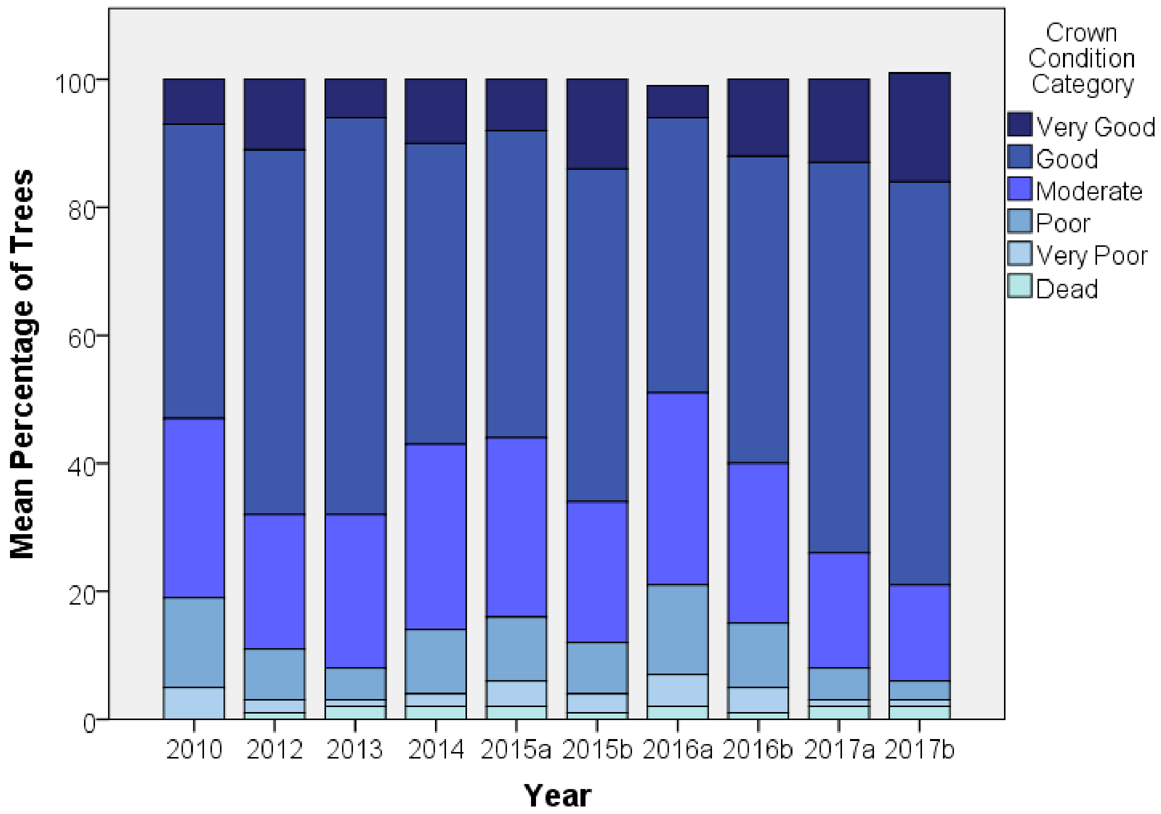


Figure 14 **Frequency of trees according to Crown Condition Category (CCS) over time**

3.2.2 Crown Condition Score – Water Regime Classes

When examined according to WRC, mean CCS of trees in Box Woodland and RRG FDU has improved from 2016 to 2017 (Figure 15). This follows a declining trend from 2013 to 2016 as conditions in the forest became dry after the 2010 flood. The Box Woodland results are difficult to interpret accurately due to low replication.

Frequency histograms are provided in Figure 16 for each of the Water Regime Classes - showing percentage of trees in each crown condition score across years. RRG FDU and RRG FTU follow the overall trend combining all WRCs, with 2017 data indicating increasing crown condition, with more trees recorded in the very good and good categories and fewer trees recorded in the poor and very poor categories than at any other time since commencement of monitoring (Appendix E, Table E5). It is difficult to interpret change in Box Woodland WRC due to dramatic changes in sample size between 2010-2014 and 2015-2017.

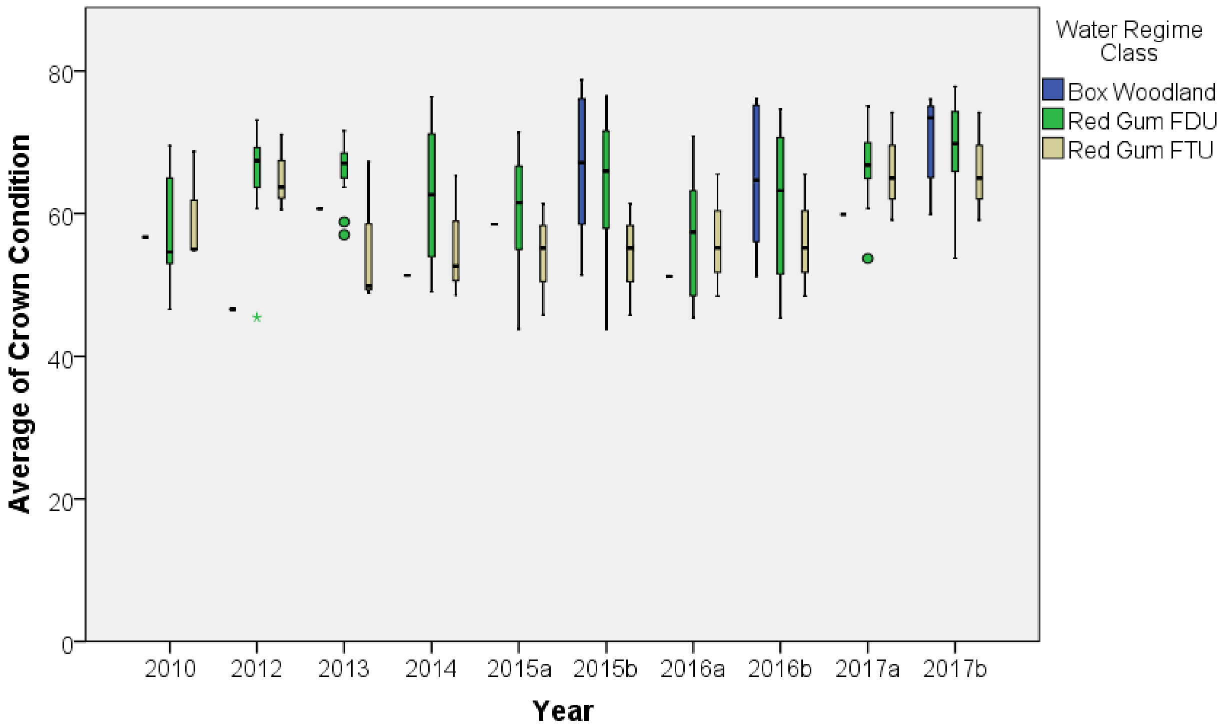
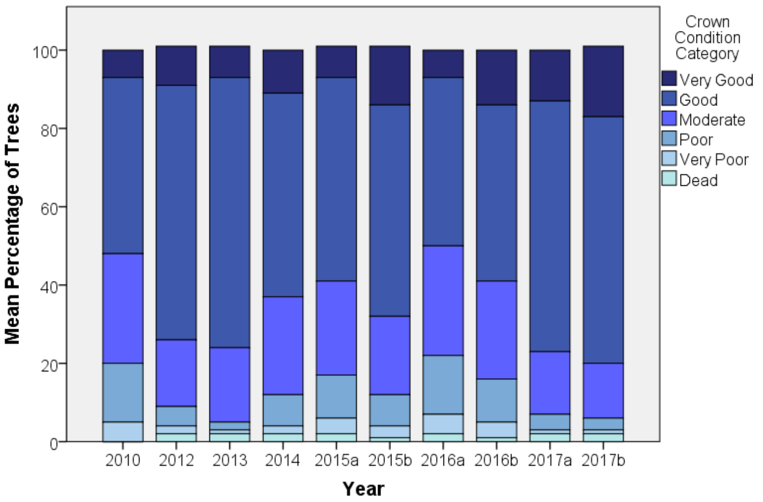
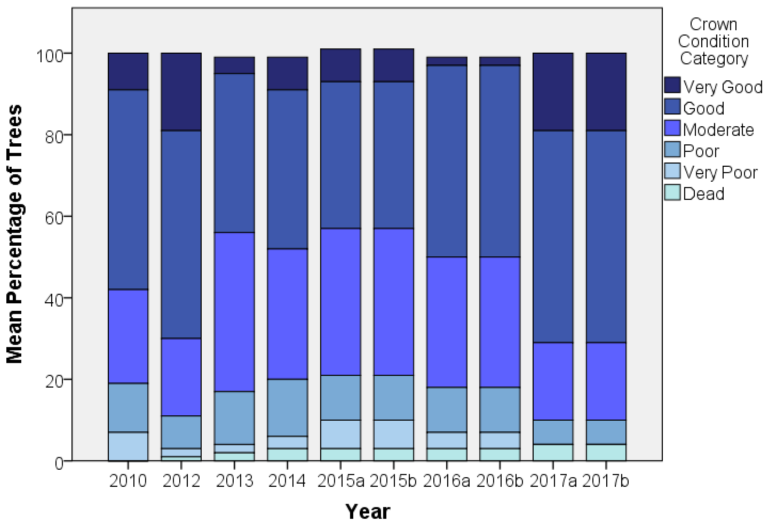


Figure 15 Crown Condition Score (CCS) according to Water Regime Class over time

a) **Red Gum FDU**



b) **Red Gum FTU**



c) **Box Woodland**

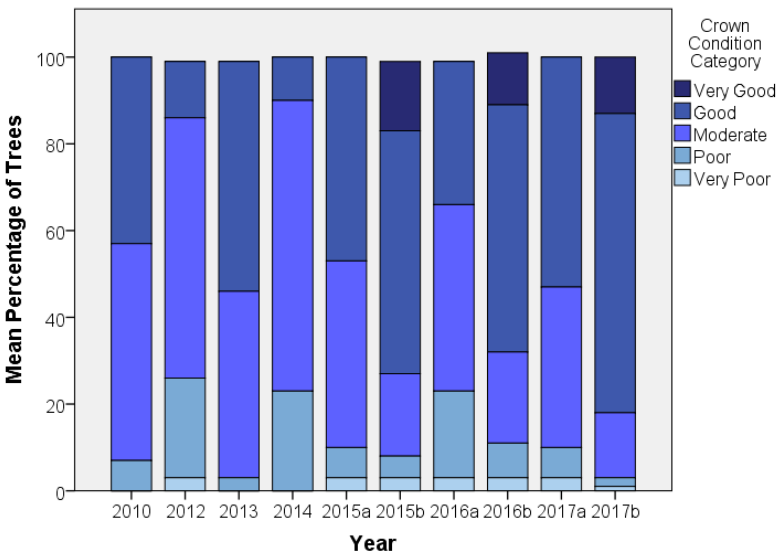


Figure 16 Frequency of trees according to Crown Condition Score (CCS) over time: (a) Red Gum FDU, (b) Red Gum FTU, (c) Box Woodland

3.2.3 Condition trajectory

Over time, changes in the following tree condition attributes are thought to indicate condition trajectory and whether trees are recovering from environmental stress (epicormic growth, new tip growth and reproduction) or showing signs of stress (leaf-die off, bark cracking and mistletoe load) (Bacon et. al. 1993). The frequencies of each tree condition attribute over the seven monitoring periods are presented in Figure 17 and Figure 18 (and in Appendix E, Table E6).

Recovery

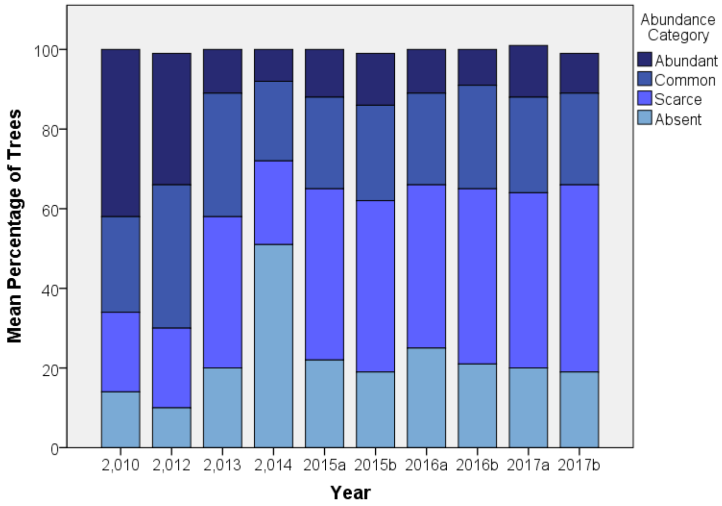
The number of trees exhibiting signs of recovery clearly increased in 2017. A substantial increase in the number of trees exhibiting new tip growth were observed from 2016 to 2017, which was very similar to the response shown in 2012 following the 2010/11 flood (Figure 17). The extent and dominance of epicormic growth on trees did not change in 2017, and has remained stable since 2015. These results are in contrast to the 2012 post-flood results, which show a much larger proportion of trees exhibiting abundant and common epicormic growth (Figure 17). The number of trees reproducing and having abundant signs of reproduction also increased in 2017; however, this is in contrast to the 2012 results, which show a clear decline in trees reproducing post-flood (Figure 17).

Signs of stress

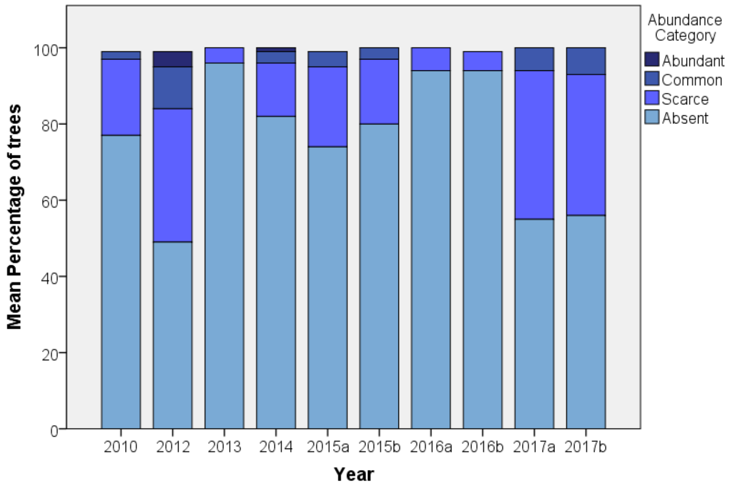
Fewer trees showed signs of stress in 2017 than between 2015-2016, where the time since major flooding was the greatest. Fewer trees showed signs of leaf die-off in 2017 compared to 2016, and more trees were intact or showed only minor bark cracking in 2017 compared to 2016. Based on these two variables, the trees in the forest are in their best condition since 2014, following the major flood of 2010/11 (Figure 18).

Mistletoe load is negligible across monitoring years and was absent in 99% of trees in the forest in 2017.

a) Epicormic growth



b) New tip growth



c) Reproduction

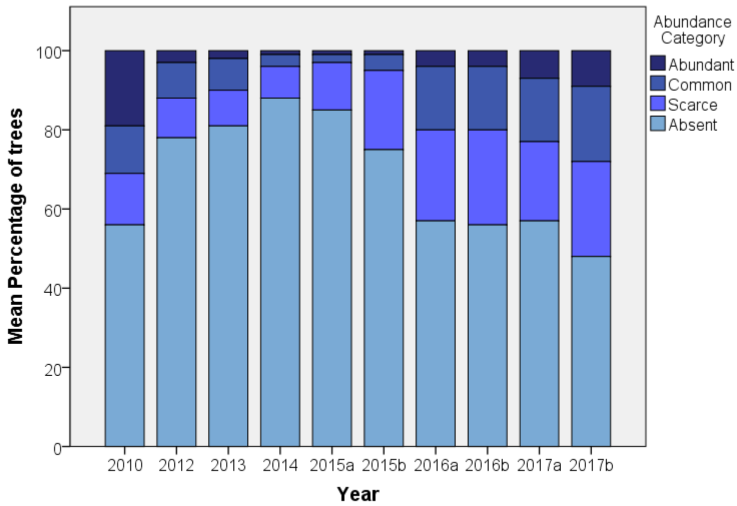
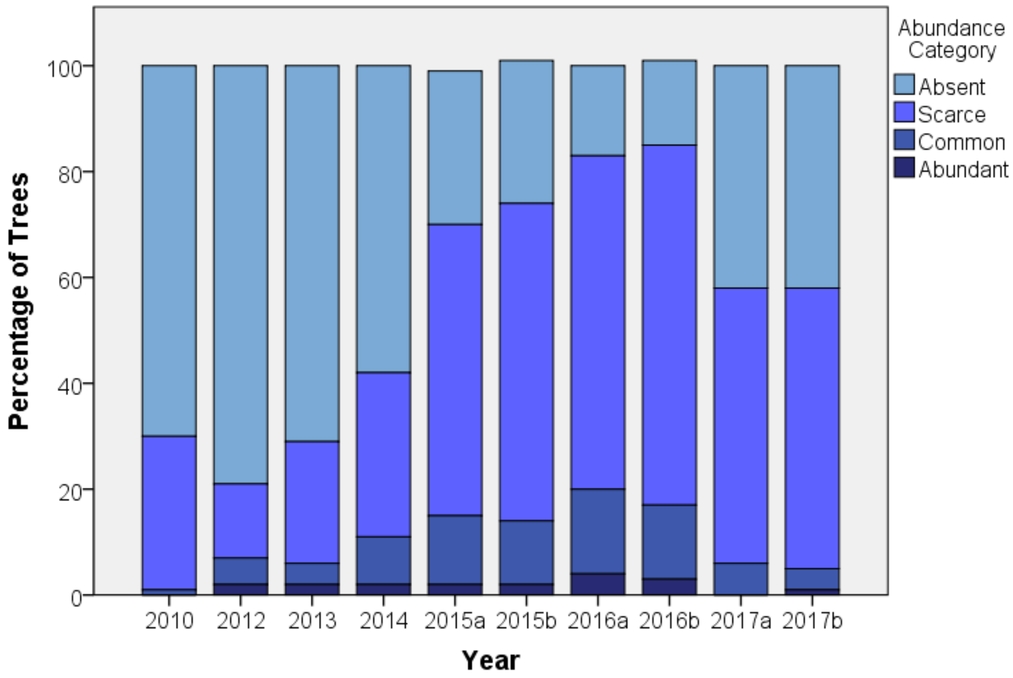


Figure 17 Frequency histograms for positive tree condition trajectory attributes over time: (a) epicormic growth, (b) new tip growth and (c) reproductive behaviour

a) Leaf die-off



b) Bark condition

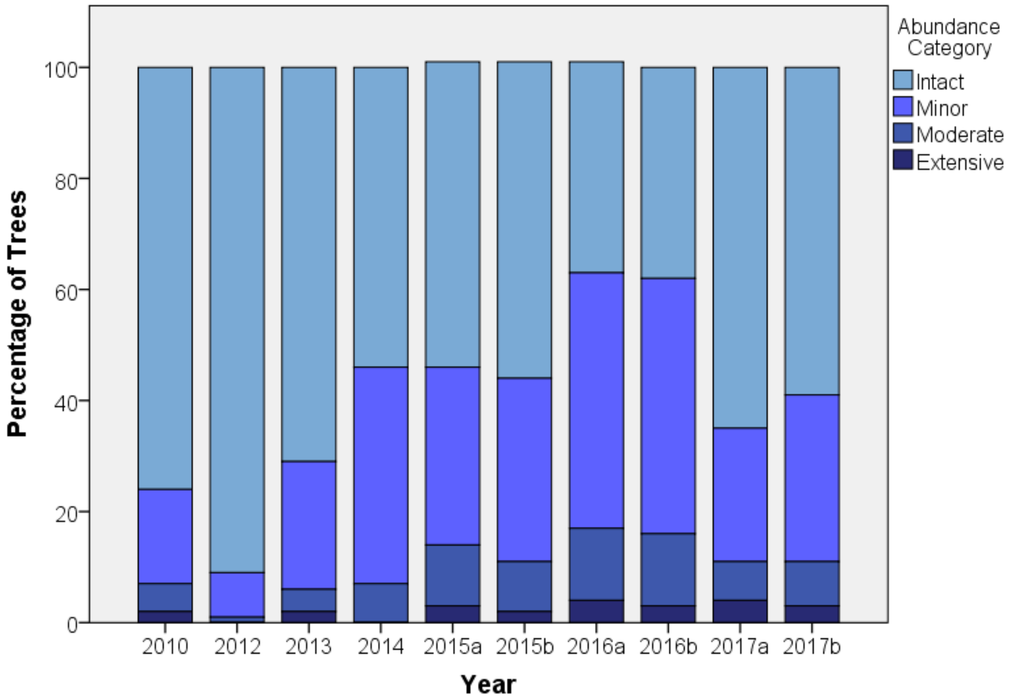


Figure 18 Frequency histograms for negative tree condition trajectory attributes over time: (a) leaf die off and (b) bark condition

3.2.4 Site contextual information

Site contextual information collected at Koondrook-Perricoota included a degree of insect damage, weeds and recruitment (i.e. presence of seedlings and saplings). The results for 2017 and across the seven-year monitoring period are presented below.

Dominance of trees

The frequency of trees across all dominance classes (defined in Souter et al. 2010) appears to be stable across most monitoring years. The additional tree sites established in 2015 caused an increase in the percentage of co-dominant trees recorded. The frequencies are presented in Figure 19 and Appendix E (Table E8). Slightly more trees were recorded in the dominant category in 2017; however, this is not a notable increase.

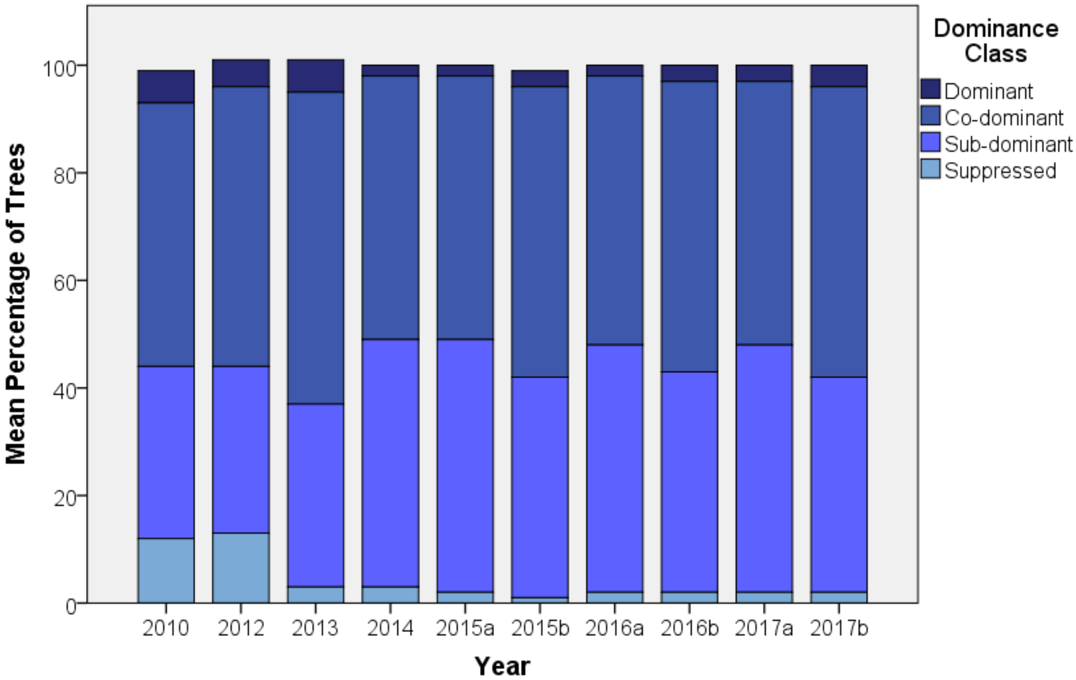


Figure 19 Frequency of trees according to dominance class over time

Insect damage

Insect or pathogen attack may lead to reductions in tree growth and health (MDBA 2009). Furthermore, new growth produced in response to water availability may be more attractive to insect herbivores than older growth. Trees stressed by salinity and waterlogging are also more susceptible to damage by insect pests and pathogens (Marcar *et al*. 1995; cited in MDBA 2009).

Insect damage is common throughout the tree condition sites at Koondrook-Perricoota in 2017 (44% of trees exhibiting common insect damage; Appendix E, Table E7), and has not experienced any notable change since 2016. An increase in the number of sites exhibiting insect damage occurred from 2010-2016, however these differences are small and do not paint a clear picture of insect damage becoming more frequent due to stressful conditions in the forest. No sites were considered to have abundant insect damage in 2017.

Weeds

Weeds have the potential to impact recruitment of eucalypts and other native species, through overcrowding and using available soil moisture. Flooding a forest/woodland following a prolonged dry period can lead to increased weed growth in the understorey (Casanova and Brock 2000).

Weeds are present at the majority of tree condition sites (72% sites), which is a 16% increase in sites containing weeds since 2016, where only 56% of sites contained weeds. Weed abundance remains typically low overall, however the number of sites at which weeds were considered 'common' also increased from one site in 2016 to four sites in 2017 (Appendix E, Table E7). The flood has clearly facilitated an increase in weed abundance across the forest, which is reflected in the data for understorey and wetland vegetation collected in 2017 (Forbes and Wills 2017).

Recruitment

Recruitment indicates whether a stand is regenerating. Seedling survival in the first year after germination is a critical stage in RRG stand regeneration. The main factors affecting initial survival and establishment are soil moisture and seedbed conditions (MDBA 2009).

The number of sites containing seedlings and saplings has increased marginally in 2017 (Appendix E, Table E7), although this was a relatively small increase in sites (n=2). The addition of new tree sites caused the number of sites with no seedlings and saplings to increase between 2015 and 2016, and there was an increase in the number of sites where seedlings and saplings were scarce, and common. Previously (2015) there was a decline in sites where seedlings and saplings were common and an increase of sites where they were considered scarce.

3.2.5 Photo points

Photos taken at each tree condition site are provided in Appendix F for 2010-2017.

4. Discussion

The 2017 monitoring round marks the first year that all stand and tree sites have been inundated by floods since the breaking of the Millennium Drought in late 2010 / early 2011. Data collected in 2017 show an overall trend of improved tree and stand condition, after two years (2014-2016) of exhibiting increasing signs of stress and decline in vegetation condition associated with the absence of forest-scale flooding. Several variables have responded positively to the 2016 flood, with many reaching an equivalent or better condition than in 2012 (following the 2010/11 flood event). These variables include stand condition, PAI, crown condition and the number of trees exhibiting new growth. The time-span of the dataset now provides greater certainty in regard to how long these improvements are expected to last, and highlights the importance of long-term datasets in being able to understand the time ecological variables in the forest take to respond to environmental watering.

4.1 Overall condition

4.1.1 Stand Condition

Recent monitoring data (2016-2017) indicate that within six months of the 2016 flood event, stand condition improved substantially. Prior to 2016, SCS showed a gradual increase over several years following the 2010 flood (2012-2014), indicating that the impact of flooding on stand condition lasts approximately three years before condition indicators begin to decline. The decline in SCS from 2014-2016, occurred three years after flooding and during a period of below-average rainfall across the catchment. Based on the gradual increase of SCS observed after the 2010/11 flood event, we would expect that SCS would continue to increase for another one to two years after 2017, as the response of trees to flooding consolidates over time.

Plant Area Index

Of the three variables comprising the SCS, PAI is undoubtedly the variable that responds most rapidly to flooding. A large, rapid response in PAI occurred in 2017, which is the highest PAI score observed since commencement of monitoring. The response of PAI to flooding also appears to consolidate over several years, as seen by the gradual increase in PAI between 2010 and 2014. Based on this observation, PAI is predicted to continue to increase beyond 2017 for two to three years even in the absence of further flooding. When observing responses according to WRC, the Red Gum WRCs responded the most strongly to SCS and PAI variables. This is in contrast to Box Woodland, where SCS showed a lack of response, and PAI increased only moderately. This is possibly due to Box Woodland having a pre-existing high score for stand condition, and therefore little room for improvement, or that Grey Box and Black Box are slower to respond to flooding. Akeroyd et. al. (1998) found that the health of Black Box trees improved in the short-term following a flood, however it is unknown if those trees were in an unhealthy state prior to their study taking place.

Live Basal Area

A lack of response, or perhaps a lack of *rapid* response to flooding was observed in LBA and crown extent. LBA has been relatively stable since commencement of monitoring and responds much slower to flooding/drought than other indicators (e.g. PAI). A small increase in LBA was observed in 2017 (compared to 2010), and this trend is predicted to consolidate over the next three to four years. The response of LBA is obviously slow and future state of decline or improvement is likely to be dependent on stand density, where denser stands have a greater likelihood of decline (Horner et. al. 2009).

Crown Extent

Median crown extent increased from 2016-2017; however, this variable has also remained relatively stable since commencement of monitoring. When examined according to WRC, RRG FTU has experienced a notable increase, while RRG FDU showed a small increase, and Box Woodland remained relatively stable. Box Woodland may take longer to respond to flooding at Koondrook-Perricoota due to being located higher on the floodplain, receiving smaller duration of inundation and perhaps less frequency of inundation (depending on the size of the flood) than River Red-gum sites (Slavich et. al. 1999). It may also be because Box Woodland is adapted to lower frequency flooding (Ecological Associates 2011) and is therefore inherently more resilient to drought.

4.1.2 Tree Condition

Figure 14 shows an increase in the number of trees in the good and very good crown condition categories in 2017. More trees are now in good or very good condition that at any time since monitoring commenced in 2010. Trees in the poor and very poor categories are also at their lowest numbers since monitoring commenced.

Tree condition appears to be showing a consistent, positive response to the 2016 flood, whether including or excluding data from the 10 additional tree condition assessment sites established in 2015. Crown condition increased in 2017, following a period of decline between 2015-2016. The positive response in crown condition in 2017 is reminiscent of the increase observed following the 2010/11 flood. Based on the previous response to the 2010/11 flood, crown condition appears to respond within six months of a major flood, but declines within two years of flooding, rather than showing a gradual increase over three years, such as shown in the stand condition data. Crown condition increased in 2017 across all WRCs, but particularly in the Red Gum WRCs, which are dependent on higher frequency flooding than the Box Woodland WRCs.

The proportion of trees in the good and very good crown condition categories was the highest since monitoring commenced in 2010, while trees in the poor and very poor category were at their lowest proportion since 2010. Based on the response to the 2010/11 flood, we expect a further increase in crown condition improvement (i.e. more trees in very good and good categories, and less in the poor and very poor categories) in 2018 across the Red Gum WRCs as the response to the 2016 flood manifests itself fully. In contrast, the response of Box Gum woodland is harder to interpret due to low sample size.

Tree dominance responds slowly to flooding and it is difficult to observe change thus far. The effect of the 2016 flood is unknown and may cause a decrease in trees in the sub-dominant and suppressed categories due to more resources being available (water and nutrients) for tree growth, or it may enable trees that are co-dominant to become dominant.

Given the response to the 2016 flood, and how it resembles the pattern following the 2010/11 flood, we postulate that the improvement in crown condition experienced after the 2010 flood (following 13 years of drought) will be amplified by the 2016 flood, resulting in consolidated improvement in several tree condition variables. Our data suggest that multiple forest-wide floods are preferable to isolated events, after which forest condition variables return to their previous state of lower condition (e.g. 2010 condition). Furthermore, we suggest that at Koondrook-Perricoota, a series of significant flood events act to reinforce the positive tree and stand condition benefits gained by previous floods.

4.1.3 Other indicators of improvement or decline in condition

Tree condition attributes such as reproduction, bark cracking and new tip growth appear to rapidly respond to flood, showing positive change within six months, and then declining in the absence of flood within a year. More trees directed effort into reproduction in 2017, which is in contrast to the preceding trend following the 2010 flood, where a notable decrease in trees reproducing was observed (2012-2015). Larger bud crops are produced in response to flooding (Jensen 2008), however it is noted that the size of a flower crop is determined by soil moisture levels over the year leading up to flowering (Jensen 2008), and that the dry conditions before the flood may not have been conducive to higher levels of reproduction. It is possible that little change in reproduction actually occurred between the 2016 and 2017 monitoring rounds and the results were influenced by the 10 tree assessment sites added in 2015 (five of which were Grey Box sites). Looking to the future, the 2016 flood is likely to be a major source of stimulation for reproduction of trees in the forest. Bud crops present in 2016/2017 are expected to be retained and perhaps increase in a large flowering/fruiting response later in 2017 and into 2018.

Greater numbers of trees have directed resources into new growth in 2017, and this is consistent with the increase in new tip growth observed following the 2010 flood. New growth appears to respond rapidly to flooding and then dissipate within a year. New growth is likely to increase or maintain current levels in 2017 and potentially 2018, and then start to decline in the absence of further flooding.

Evidence of recruitment at monitoring sites was surprisingly low across the duration of the monitoring program. This may be because trees were stressed prior to the 2016 flood, and stressed trees reduce seed fall significantly, possibly reducing recruitment potential by an order of magnitude (Jensen 2008b). There is also evidence it can take two years for River Red-gum seedlings to develop deep enough roots to survive, suggesting that the soil moisture levels required for seedling establishment would be delivered by more than one flood event (Jensen 2008b). Irrespective of this, there is anecdotal evidence for recruitment at Koondrook-Perricoota over the past seven years, but in highly localised areas that are largely not picked up by the sites surveyed as part of the monitoring program. These areas may have longer inundation duration and retain higher soil moisture than other sites.

As expected, weed growth increased due to increased soil moisture and nutrient levels (Casanova and Brock 2000), with the greatest increase evident in RRG FDU sites. Weed abundance is anticipated to decrease in the coming one to two years in the absence of any further forest-wide flooding. However, if flooding frequency increases, weed abundance is also likely to increase.

The number of trees experiencing leaf die-off and bark cracking clearly decreased in 2017, as was the case following the 2010 flood. The 2016 flood appears to have restored leaf dieback and bark cracking on trees to the lowest frequency since 2012/2013. In the absence of future floods, we would expect these variables to deteriorate again each year.

4.2 Response to floods within the monitoring period (2010 to 2017)

Unregulated floods occurred in Koondrook-Perricoota in 2010-2011 and 2016 (during the monitoring period; see Figure 1). Extensive flooding in 2010/2011 ended the drought, providing an opportunity to monitor ecological floodplain recovery (Doody *et al.* 2014). At Koondrook-Perricoota, the floods in 2010-2011 (peaking at > 50,000 ML/day) would have been sufficient to flood River Red Gum with FDU, a significant portion of River Red Gum with FTU and some but not all areas of Black Box or Grey Box Woodland (Ecological Associates 2011). Environmental water was delivered to Koondrook-Perricoota Forest in winter-spring 2014 and spring 2015, however neither of these managed flood events reached stand and tree condition monitoring sites. The large flood event of 2016 peaked at 57,000 ML/day and reached all sites across the forest, including stand and tree sites (Linda Broekman, FCNSW, pers. comm.).

Now that the stand and tree dataset spans seven years and two major flood events, clear trends and patterns have emerged. Variables such as crown condition, epicormic and new tip growth, leaf die-off and bark cracking respond positively within one year of a flood event (shown in increases from 2010-2012 and 2016-2017). Variables including crown condition score, PAI, stand condition and crown extent respond slower to flooding, taking one to three years for the response to fully mature, indicating the effect of flooding is enduring and the improvement of the forest is realised several years after a flood event (Cunningham *et al.* 2013). Responses appear consistent across all WRCs. Data for PAI and stand condition also suggest that multiple flood events can have an amplification effect on forest condition, with multiple floods within a decade building on the response from the previous flood and improving condition more than an isolated event. Absence of flooding for several years (i.e. four years or more) causes all condition indicators across the board to decline.

4.3 Meeting objectives

4.3.1 Objectives

The **ecological objectives** outlined in the *Environmental Water Management Plan* for the forest (MDBA 2012) include:

- *Objective 2: Protect and enhance diverse, healthy vegetation communities* (equivalent First Step Decision objective: 30% of river red gum forest in healthy condition)

The specified targets to achieve this are:

Red Gum Forest with Flood-dependent Understorey:

- Restore 50% of the area of river red gum forest that has been lost since river regulation
- 80% of the current river red gum forest area in a ‘healthy’ status (Tree Health Index 4 or above)
- Less than 20% of current river red gum forest considered ‘unhealthy’ (Tree Health Index 2 or below)

River Red Gum woodland with Flood‑tolerant Understorey:

- 30% of the current river red gum woodland area in a ‘healthy’ status (Tree Health Index 4 or above)
- 70% of current river red gum woodland area maintained at or improved to better than ‘unhealthy’ (Tree Health Index 2 or below)

Black Box woodland:

- 50% of the current black box area in a ‘healthy’ state (Tree Health Index 4 or above)

4.3.2 Assessment against objectives

The MDBA (2012) Tree Health Index states that a healthy area of forest or woodland will receive a score of 4 or 5 out of 5. This Index does not correlate directly to scales used in either of the stand or tree condition monitoring methods, but rather uses both crown condition and extent of epicormic growth to determine forest health (GHD 2014). Due to the Tree Health Index (MDBA 2012) not directly correlating to the indexes used for categorising data as per the methods, assessing data against the monitoring objectives is challenging. For this reason, we have presented targets against two measures of health, stand condition and crown extent (Table 5).

Crown extent score is categorised according to a six-tier scale (0 = dead tree), in which a crown extent score above 61 equates to a score of 4 or 5, and regarded as a 'healthy area of forest' according to MDBA (2012). A stand condition score above 81 equates to 'good' condition. When tree health data from 2017 monitoring are examined according to WRC using **crown extent** score, the following is noted:

- RG FDU: 56% of sites receive a 4 or 5 out of 5, indicating over half of the sites are in a 'healthy' condition, and 44% of sites are in moderate condition. Despite several sites having improved in condition since 2016, the target of 80% of river red gum forest having a healthy status was not met in 2017.
- RG FTU: 84% of sites received a score or 4 or above, thus meeting the 30% target for RG FTU areas of the forest in healthy condition.
- Box Woodland: 67% of sites were considered healthy, meeting the 50% target. However, it should be noted that using the crown extent six-tier scale, Box Woodland sites have met the target every year since commencement of monitoring.

When examined by WRC using 2017 **stand condition scores**, the following is noted:

- RG FDU: 81% of sites are in 'good' or 'moderate' condition, thus meeting the 80% target of river red gum forest having a healthy status.
- RG FTU: 33% of sites are considered 'good' condition, and 67% are considered moderate condition (score of 4 out of 5), thus meeting the 30% target for RG FTU areas of the forest in healthy condition.
- Box Woodland: 67% of (two out of three) sites are considered good condition and 33% considered moderate condition, thus meeting the 50% target for Box woodland areas of the forest in healthy condition.

Table 5 shows the years in which the target has been met for WRCs, according to both the crown extent and stand condition scales. The target for healthy status of the RG FDU WRC was only met in 2014 and 2017. This is consistent with the data which show a three-year time period in which stand condition within which red gum forest and woodland improved in response to the 2010 flood. Based on this trend, it would be expected that over the next two years (in the absence of flood), the percentage of RG FDU with 'healthy' status would increase even further.

The number of RG FTU sites with a 'healthy' status reached target every year using the crown extent scale and stand condition scale, and experienced an increase from 67% of healthy sites in 2016 (the lowest SCS recorded across all monitoring years) to 100% sites considered 'healthy' in 2017.

There is insufficient replication in the Box Woodland WRC to accurately assess change in Box Woodland across the forest. Nevertheless, using the crown extent scale, the target has been met every year. When the stand condition score is used as an index of tree health, Box Woodland achieves 100% of sites considered 'healthy' in all years.

Table 5 Percentage of forest area considered healthy[4] over time

Vegetation type	WRC	2010		2012		2013		2014		2015		2016		2017	
		CE	SCS	CE	SCS	CE	SCS	CE	SCS	CE	SCS	CE	SCS	CE	SCS
River Red Gum Forest	RG FDU	44%	7%	50%	33%	63%	75%	63%	81%	44%	63%	38%	38%	56%	81%
River Red Gum Woodland	RG FTU	40%	75%	100%	100%	83%	83%	83%	100%	50%	100%	50%	67%	83%	100%
Box Woodland	BW	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	67%	100%	67%	100%

Key to table:

CE Crown extent, assumed to be similar to the Tree Health Index referred to in MDBA (2012)

SCS Stand Condition Score, calculated as per Section 2.3.1

[4] Health has measured in two ways; 1) according to Tree Health Index referred to in MDBA (2012) (p. 17) and 2) according to stand condition score

4.3.3 Summary

In summary, the data indicate that the health of the established canopy trees at Koondrook-Perricoota has increased in response to the 2016 flood, and this increase is likely to continue into 2018 and 2019. The positive effect of the flood event in 2010-2011 lasted approximately three years before declining, and this response is expected to be mirrored following the 2016 flood. The forest needs large-scale floods that inundate large sections of the floodplain to gain any improvement, and evidence suggests that improvement is amplified if large floods follow in succession before the forest has a chance to deteriorate in condition.

Cunningham *et al.* (2013) acknowledge that the response of trees to wet conditions may be delayed, with crowns expanding over the coming years. This is reflected in improvements observed in condition between 2012-2014, and the subsequent decline between 2014-2016, and suggests that these effects only last two to three years.

Additional environmental watering is likely to be required after 2019 (in the absence of unregulated floods) to maintain and improve condition of trees across the Forest, particularly in Red Gum FDU WRC; otherwise, the condition of the forest will begin to decline. Evidence strongly suggests that small-scale watering events that do not inundate the wider floodplain will not lead to improvement of stand and tree condition across the forest.

4.4 Recommendations

Our recommendations are:

- Continue monitoring stand and tree condition annually, because long-term data are required to determine trends in condition in response to drought and flooding, to inform management intervention and measure the effectiveness of management intervention (e.g. environmental watering) in improving forest condition.
- Remove mistletoe load from the parameters measured for assessing tree condition. Changes are negligible across the monitoring period (2010-2017), and do not appear to be an important indicator of stress in trees in Koondrook-Perricoota Forest.
- Investigate the viability of alternative methods to measure PAI. Smartphone Applications to measure canopy cover (e.g. CanopyApp[5]) have been developed in recent years, and provide a rapid, repeatable and reliable method for measuring canopy cover, and analysing images with minimal user error, without the timing constraints and post-field trip data processing requirements of the hemispherical photo method.
- Expand the Koondrook-Perricoota Monitoring Program Review to incorporate 'points of reference' for selected tree and/or stand condition indicators in each WRC in a similar manner to that recently undertaken by Wills *et al.* (2016). This would help to define critical thresholds for particular indicators of condition (e.g. PAI), which would alert managers when intervention is necessary and environmental flows need to be deployed to reduce stress levels in the Forest.

[5] http://www.unh.edu/research/blog/2014/01/rci-student-operator-develops-canopyapp

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Appendices

Appendix A – Stand and Tree Condition Site Details

Site ID	Forest Type	Water Regime Class	Assessment Type	Closest Road/Track	Easting	Northing	Survey Date	# trees
S76-KRF	River Red Gum Forest	Red Gum FDU	Tree and Stand	Little Bonum Rd	246885	6050522	12/04/2016	40
S77-KRF	River Red Gum Forest	Red Gum FDU	Stand	Smoke Hut Trl	249543	6052600	12/04/2016	68
S78-KRF	River Red Gum Forest	Red Gum FDU	Stand	Crooked Creek Rd; near intersection with Twenty Two Trl	250266	6055896	12/04/2016	100
S79-KRF	River Red Gum Forest	Red Gum FDU	Stand	Twins Lagoon Rd; near Crooked Creek	250432	6045948	13/04/2016	70
S80-KRF	River Red Gum Forest	Red Gum FDU	Stand	Crooked Creek Rd; near intersection with Four Posts Trl	250874	6050327	12/04/2016	95
S81-KRF	River Red Gum Forest	Red Gum FDU	Tree and Stand	Crooked Creek Rd; between Fence Trl and Twenty Two Trl	251768	6054679	12/04/2016	94
S82-KRF	River Red Gum Forest	Red Gum FDU	Tree and Stand	No. 1 Harvest Rd	254762	6047239	13/04/2016	92
S83-KRF	River Red Gum Forest	Red Gum FDU	Stand	Unnamed Trk off Myloc Rd	257039	6043446	14/04/2016	98
S84-KRF	River Red Gum Forest	Red Gum FDU	Tree and Stand	Rusty Gate Trl	259147	6041921	14/04/2016	142
S85-KRF	River Red Gum Woodland	Red Gum FTU	Tree and Stand	Fence Trl	259261	6044721	14/04/2016	30
S86-KRF	River Red Gum Forest	Red Gum FDU	Tree and Stand	Unnamed Trk off Horseshoe Sandhill Rd; near Burrumburry Creek	262290	6040989	21/04/2016	49
S87-KRF	River Red Gum Forest	Red Gum FDU	Tree and Stand	Horseshoe Sandhill Rd	263457	6042351	15/04/2016	113
S88-KRF	River Red Gum Forest	Red Gum FDU	Tree and Stand	Belbins Rd; near Burrumburry Creek	263457	6039127	20/04/2016	197
S89-KRF	River Red Gum Forest	Red Gum FDU	Tree and Stand	River Rd	263532	6034210	20/04/2016	71
S90-KRF	River Red Gum Forest	Red Gum FDU	Tree and Stand	Unnamed Trk off River Rd; near Murray River	265173	6028576	19/04/2015	151
S91-KRF	River Red Gum Forest	Red Gum FDU	Tree and Stand	Clarkes Lagoon Rd; near Burrumburry Creek	265938	6035418	20/04/2016	65
S92-KRF	River Red Gum Woodland	Red Gum FTU	Stand	River Rd; near intersection with Bells Landing Rd	269867	6024579	19/04/2016	36
S93-KRW	River Red Gum Woodland	Red Gum FTU	Tree and Stand	Crooked Creek Rd; near Barbers Creek	246109	6058177	11/04/2016	61
S94-KRF	River Red Gum Forest	Red Gum FDU	Tree and Stand	River Rd; near intersection with Logging Rd	251849	6042992	13/04/2016	80
S95-KRF	River Red Gum Woodland	Red Gum FTU	Tree and Stand	Fence Trl	254163	6049157	21/04/2016	112
S96-KRW	River Red Gum Woodland	Red Gum FTU	Stand	Evans Crossing Rd; near Horseshoe Creek	265906	6031059	20/04/2016	53
S97-KRW	River Red Gum Woodland	Red Gum FTU	Stand	Unnamed Trk; near intersection with Belbins Rd	268755	6043277	15/04/2016	88
S98-KBX	Box Woodland	Black Box Woodland	Stand	Boysons Trl	264502	6043634	14/04/2016	34
S99-KBX	Box Woodland	Grey Box Woodland	Stand	River Rd; near intersection with Bells Landing Rd	266670	6026075	19/04/2016	74
S100-KBX	Box Woodland	Black Box Woodland	Tree and Stand	River Rd; near intersection with Lock Rd	271956	6020966	19/04/2014	141
BWT	River Red Gum Forest	Red Gum FDU	Tree	Bonum Sandhill Road, near intersection with River Road	247267	6051076	4/05/16	30
PJWT	River Red Gum Forest	Red Gum FDU	Tree	Off Boysons Trail	256544	6042338	5/05/16	30
PLLT	River Red Gum Forest	Red Gum FDU	Tree	Long Lagoon Road	248862	6055744	5/05/16	30

Site ID	Forest Type	Water Regime Class	Assessment Type	Closest Road/Track	Easting	Northing	Survey Date	# trees
TLT	River Red Gum Forest	Red Gum FDU	Tree	Twin Lagoons Road, near intersection with Charley Road	251354	6045713	4/05/16	30
WHT	River Red Gum Forest	Red Gum FDU	Tree	Crooked Creek Trail	251972	6050214	5/05/16	30
GBT1	Box Woodland	Grey Box Woodland	Tree	River Road	265554	6029264	4/05/16	30
GBT2	Box Woodland	Grey Box Woodland	Tree	Bullock Head Road	270028	6029104	4/05/16	30
GBT3	Box Woodland	Grey Box Woodland	Tree	Freemans Road	272870	6019531	5/05/16	30
GBT4	Box Woodland	Grey Box Woodland	Tree	Bells Landing Road	268138	6024855	5/05/16	30
GBT5	Box Woodland	Grey Box Woodland	Tree	River Road	267400	6024806	4/05/16	30

Trees = The number of trees with >10 cm DBH surveyed in 2016 within each 0.25 ha site. Eastings and Northings are to Site Bench Tree ± 10 m. Coordinates are GDA94, Zone 55H.

Water Regime Class Key
Red Gum FDU forest
Red Gum FTU woodland
Box woodland

Appendix B – Attributes and Variables measured during the 2017 Stand Condition Assessment

Table B 1 Attributes and variables measured at each stand condition site

Attribute	Variables	Sample Size
Live Basal Area (%)	DBH Live/Dead Assessment	All trees >10 cm DBH within the 0.25 ha site
Crown Extent	Crown Extent	30 permanently marked trees >10 cm DBH within the 0.25 ha site
Plant Area Index	Hemispherical Photo	1 photograph per site where plots are 50 x 50 m, 2 photographs for assessment plots >70 m in length[6].

Table B 2 Assessment of crown extent at stand condition sites

Score	Description	% of assessable crown holding leaves
0	None	0%
1	Minimal	1-10%
2	Sparse	21-40%
3	Poor	41-60%
4	Declined	61-80
5	Full	81-100%

[6] This has been updated as per the updated stand condition monitoring methods: *Field protocol for assessing stand condition of river red gum, black box and coolabah populations across the Murray-Darling Basin* (Cunningham 2016).

Appendix C – Attributes and Variables measured during the 2017 Tree Condition Assessment

Table C 1 Attributes and variables assessed to inform the TLM Tree Condition Assessment

Attribute	Variables	Sample Size
Crown condition	Crown extent Crown density	30 permanently marked live trees > 10 cm DBH at each site
Tree condition trajectory	Epicormic growth New tip growth Leaf die-off Extent of bark cracking	
Tree status	Diameter at breast height (1.3 m) Dominance class Extent of reproduction Mistletoe load	
Contextual site information	Disturbance Insect damage Other biological stresses Presence of saplings/seedlings	Assessment of the site as a whole
Photo points	Digital photos	At least one photo point per site

Assessment of crown extent

Crown extent is the percentage of the assessable crown in which there are live (green) leaves. This includes branches that have leaves at their base and middle but not at their tips. Crown extent will diminish as foliage is progressively lost from the branches. The assessment of crown extent includes epicormic growth. In the TLM method, crown extent is reported using categories listed in Table C 2. The percentage of assessable crown holding leaves was also recorded to the nearest 5%. It is important to note that old trees may have substantial gaps in the canopy as the canopy structure (branches) spread apart.

Assessment of crown density

Crown density is assessed as the amount of skylight blocked by portion(s) of the crown containing live leaves, i.e. the higher the density of live leaves, the higher the amount of skylight blocked by foliage. Only live leaves in the crown contribute to the estimate of density. In the TLM method, crown density is reported using categories listed in Table C 2 (the same categories used for reporting crown extent).

Table C 2 Assessment of crown extent and crown density

Score	Description	% of assessable crown holding leaves
0	None	0%
1	Minimal	1-10%
2	Sparse	21-40%
3	Poor	41-60%
4	Declined	61-80
5	Full	81-100%

Epicormic Growth

Growth of new shoots from the main trunk, or major support branches of the tree is classed as epicormic growth and indicates that environmental conditions are suitable for tree growth. In the TLM method, assessment of epicormic growth records the presence and absence of *live* epicormic shoots as per the categories listed in Table C3.

Table C 3 Categories for reporting: epicormic growth, new tip growth or leaf die-off

Score	Description	Definition
0	Absent	Effect is not visible
1	Scarce	Effect is present but not readily visible
2	Common	Effect is clearly visible
3	Abundant	Effect dominates the appearance of the tree

Assessment of new tip growth

Growth of new shoots from branch tips (i.e. not epicormic growth) is classed as new tip growth. New tip growth is typically yellow/light green in colour and thus easily distinguishable on the tree. In the TLM method, assessment of new tip growth is reported using categories listed in Table C 3.

Assessment of leaf die-off

The relative abundance of dead leaves on the tree is assessed as leaf die-off. In the TLM method, assessment of leaf die-off records the presence and visual effect of dead and partially dead leaves, when assessed over the entire assessable crown. Leaf die-off is reported using categories listed in Table C 3.

Assessment of reproductive status

In the TLM method, reproduction status is determined by noting whether or not the tree has reproductive material present (e.g. woody capsules, buds and/or flowers). Extent of reproduction is recorded as the combined relative abundance of buds, flowers and fruit assessed within the assessable crown. Extent of reproduction is reported using categories listed in Table C 4.

Table C 4 Categories for reporting extent of reproduction

Score	Description	Definition
0	Absent	Reproductive behaviour is not visible
1	Scarce	Reproductive behaviour is present but not readily visible
2	Common	Reproductive behaviour is clearly visible
3	Abundant	Reproductive behaviour dominates the appearance of the tree

Assessment of bark condition

Long-term dead trees have no bark and have lost all of their medium and fine branches. Very stressed trees have cracked bark, which are vertical cracks in the bark, generally found on the trunk that exposes the heartwood. Trees with cracked bark have generally lost all of their leaves or only have dead leaves. In the TLM method, bark condition is reported using the categories provided in Table C 5.

Table C 5 Assessment of bark condition

Score	Description and range
0	No bark (long term dead)
1	Extensive areas of cracked bark
2	Minor areas of cracked bark
3	Intact bark

Assessment of mistletoe load

The presence of any mistletoe is noted and the severity of infestation is also noted. Assessment of mistletoe load is reported using categories listed in Table C 6.

Table C 6 Assessment of mistletoe load

Score	Description	Definition
0	Absent	Effect is not visible
1	Scarce	Effect is present but not readily visible
2	Common	Effect is clearly visible
3	Abundant	Mistletoe dominates the appearance of the tree

Assessment of insect damage

In the TLM method, insect attack is assessed over the site as a whole and categorised as per Table C 7.

Table C 7 Assessment of insect damage

Category	Definition
Absent	Not visible or minor damage to some trees
Scarce	Some trees have scattered damage within the crown
Common	Most trees have significant damage within the crown
Abundant	All trees have significant damage within the crown

Assessment of other biological stresses

The presence and type of any other biological stresses, such as weeds or feral animals, is noted, and the severity of stress is also noted. Assessment of other biological stresses is reported using categories listed in Table C 8.

Table C 8 Assessment of other biological stresses observed during site assessment

Category	Definition
Absent	Not visible or minor presence within the site
Scarce	Scattered occurrence throughout the site
Common	Present throughout the majority of the site
Abundant	Present throughout the entire site

Assessment of seedlings and saplings

In the TLM method, the abundance and health of seedlings and saplings is noted. Assessment of seedlings and saplings is reported using categories listed in Table C 9.

Table C 9 Category scale for reporting presence of seedlings and saplings

Category	Definition
Absent	No seedlings/saplings found
Scarce	Less than 10 seedlings/saplings present
Common	10-50 seedlings/saplings present
Abundant	Greater than 50 seedlings/saplings present

Appendix D – Stand Condition Data

Table D 1 Stand Condition Score (SCS) 2010 to 2017

Site	2010	2012	2013	2014	2015	2016	2017
S76-KRF	5.95	7.17	7.27	7.24	6.93	6.68	7.13
S77-KRF	5.11	5.61	6.56	6.76	6.41	6.49	7.22
S78-KRF	5.18	6.00	6.24	6.65	5.99	6.28	6.85
S79-KRF	5.30	5.82	6.57	6.72	5.67	5.76	6.28
S80-KRF	4.07		6.03	5.48	6.24	6.06	7.02
S81-KRF	2.63	4.52	4.08	4.07	5.17	4.75	5.94
S82-KRF	3.11	5.56	5.62	5.22	4.03	4.06	4.37
S83-KRF	5.31	5.55	6.56	6.33	4.46	4.39	4.96
S84-KRF	4.66	7.23	7.57	7.65	6.28	5.88	7.25
S85-KRF		6.95	7.54	7.14	6.44	6.16	7.00
S86-KRF			7.02	7.73	6.47	6.04	6.88
S87-KRF	5.58	6.14	6.31	7.80	6.33	5.88	6.84
S88-KRF			7.70	7.22	6.11	5.71	7.14
S89-KRF	6.11	6.04	6.78	6.94	6.91	6.97	7.14
S90-KRF	6.03	7.73	7.84	8.75	8.59	7.66	9.12
S91-KRF	5.81		6.60	7.01	6.96	6.56	7.21
S92-KRF	6.76	7.29	7.43	7.27	6.57	5.90	7.44
S93-KRW	6.30	7.24	5.48	6.87	6.76	6.73	7.96
S94-KRF	4.31	5.36	5.78	6.32	5.79	5.40	6.38
S95-KRF	5.26	6.65	6.22	6.67	6.49	5.99	6.92
S96-KRW			7.43	7.88	7.49	6.70	8.46
S97-KRW	6.90	7.17	8.17	8.33	7.77	7.14	8.20
S98-KBX	6.55	6.63	7.56	7.44	6.97	6.77	7.40
S99-KBX	6.83	8.93	8.12	9.06	8.71	8.94	8.83
S100-KBX	6.99	7.30	8.12	7.90	8.77	7.63	8.24
Mean	**5.46**	**6.54**	**6.82**	**7.06**	**6.57**	**6.26**	**7.13**

Water Regime Class Key
Red Gum FDU forest
Red Gum FTU woodland
Box woodland

Table D 2 Plant Area Index (PAI) 2010 to 2017

Site	2010	2012	2013	2014	2015	2016	2017
S76-KRF	0.25	0.74	1.06	0.74	0.78	0.59	0.91
S77-KRF	0.27	0.61	0.69	0.84	0.66	0.56	0.81
S78-KRF	0.31	0.84	0.90	1.03	0.67	0.72	0.89
S79-KRF	0.16	0.44	0.57	0.66	0.57	0.50	0.66
S80-KRF	0.23	0.42	1.35	0.96	0.89	0.77	1.29
S81-KRF	0.22	0.9	0.94	0.98	0.83	0.47	1.11
S82-KRF	0.3	0.87	1.21	1.08	0.85	1.02	1.16
S83-KRF	0.25	0.7	0.93	0.85	0.67	0.56	0.93
S84-KRF	0.22	1.17	1.40	1.23	1.01	0.56	1.26
S85-KRF	0.13	0.28	0.46	0.43	0.38	0.27	0.42
S86-KRF			0.75	1.07	0.68	0.52	0.91
S87-KRF	0.3	0.72	0.76	1.67	0.71	0.53	1.16
S88-KRF			1.40	1.05	0.82	0.69	1.34
S89-KRF	0.34	0.74	0.85	0.94	0.79	0.89	0.98
S90-KRF	0.41	1.44	1.71	2.06	1.9	1.45	2.26
S91-KRF	0.27	0.29	0.84	0.94	1.01	0.71	1.24
S92-KRF	0.25	0.49	0.54	0.48	0.48	0.38	0.65
S93-KRW	0.24	0.48	0.51	0.58	0.48	0.45	0.7
S94-KRF	0.24	0.84	0.78	1.09	0.76	0.59	0.98
S95-KRF	0.2	0.45	0.48	0.48	0.51	0.39	0.65
S96-KRW			0.97	1.06	0.75	0.51	0.94
S97-KRW	0.36	0.53	0.79	0.85	1.04	0.87	1.09
S98-KBX	0.23	0.23	0.58	0.52	0.62	0.45	0.69
S99-KBX	0.34	1.00	0.81	1.14	1.18	1.19	1.2
S100-KBX	0.42	0.53	0.91	0.88	1.26	0.85	1.02
Mean	**0.3**	**0.7**	**0.89**	**0.94**	**0.81**	**0.66**	**1.01**

Water Regime Class Key
Red Gum FDU forest
Red Gum FTU woodland
Box woodland

Table D 3 % Live Basal Area (%LBA) 2010 to 2017

Site	2010	2012	2013	2014	2015	2016	2017
S76-KRF	87.3	99.1	99.2	99.2	91.9	95.36	100.00
S77-KRF	61.4	67.9	93.7	93.6	94.0	99.45	96.24
S78-KRF	81.8	77.6	87.3	87.3	78.1	96.26	84.89
S79-KRF	72.0	97.9	93.1	93.8	95.8	78.68	93.63
S80-KRF	62.0		60.5	61.4	63.1	94.25	65.94
S81-KRF	9.0	26.9	21.5	18.8	26.0	64.85	22.52
S82-KRF	20.0	63.6	55.0	48.1	47.6	20.06	49.40
S83-KRF	88.2	93.0	94.4	89.6	90.5	48.44	90.50
S84-KRF	50.0	81.8	89.0	90.9	90.3	90.38	84.86
S85-KRF		100.0	100.0	97.4	97.4	85.10	97.46
S86-KRF	100.0		99.5	99.7	97.9	97.43	87.60
S87-KRF	74.2	74.4	88.5	88.2	80.7	94.19	85.25
S88-KRF	42.8		86.3	87.5	95.8	84.21	94.24
S89-KRF	88.1	89.9	93.2	92.5	93.5	94.35	93.05
S90-KRF	82.6	84.9	85.5	84.1	84.0	92.99	84.55
S91-KRF	84.3		85.6	83.2	86.5	92.62	86.13
S92-KRF	100.0	96.4	100.0	100.0	100.0	86.15	100.00
S93-KRW	87.0	98.6	89.0	89.6	92.7	100.00	97.77
S94-KRF	58.7	75.5	84.9	90.0	86.7	87.03	81.91
S95-KRF	79.3	86.1	84.4	85.3	85.2	85.92	84.75
S96-KRW	78.1		59.2	65.1	61.0	84.88	60.80
S97-KRW	93.9	95.0	94.5	96.0	94.9	59.98	92.86
S98-KBX	98.4	100.0	100.0	100.0	100.0	95.29	93.20
S99-KBX	97.9	99.9	99.9	99.9	99.8	95.25	98.60
S100-KBX	96.4	97.5	98.0	98.4	98.0	98.55	89.05
Mean	**74.7**	**85.3**	**85.7**	**85.58**	**85.25**	**84.47**	**84.61**

Water Regime Class Key
Red Gum FDU forest
Red Gum FTU woodland
Box woodland

Table D 4 Mean Crown Extent (%) 2010 to 2017

Site	2010	2012	2013	2014	2015	2016	2017
S76-KRF	74.3	76.2	64.8	76.8	68.8	71.67	76.8
S77-KRF	64.3	65.2	65.7	66.3	65.2	64.00	72.8
S78-KRF	55.2	56.5	53.7	60.3	51.7	52.50	64.5
S79-KRF	62.8	50.3	70.0	71.2	60.3	65.00	54.5
S80-KRF	43.4		55.0	54.2	46.7	48.83	54.5
S81-KRF	45.8	77.3	55.8	53.8	50.8	52.33	58.4
S82-KRF	56.5	59.7	55.7	55.2	52.5	51.17	52.6
S83-KRF	46.9	34.3	55.5	55.0	50.0	51.67	51.9
S84-KRF	72.7	77.2	74.1	75.3	57.8	56.83	66.3
S85-KRF		75.2	76.3	69.7	62.3	67.17	77.0
S86-KRF	68.4		71.0	76.8	69.0	54.67	61.1
S87-KRF	63.5	71.3	62.3	65.0	54.0	52.50	60.3
S88-KRF	67.3		72.2	74.3	61.2	51.17	63.6
S89-KRF	63.9	55.2	66.5	68.7	69.2	67.00	70.7
S90-KRF	76.5	75.8	67.4	79.8	75.3	64.83	73.4
S91-KRF	70.2		68.8	77.8	71.8	66.33	69.7
S92-KRF	71.2	70.8	64.5	66.8	58.0	48.83	69.2
S93-KRW	61.7	65.0	43.3	56.0	51.2	53.17	67.7
S94-KRF	44.2	39.7	49.5	46.2	42.5	44.17	45.2
S95-KRF	55.9	62.0	52.5	62.7	55.2	51.67	58.3
S96-KRW	71.4		68.5	67.8	63.5	62.50	74.8
S97-KRW	75.1	65.7	68.5	69.3	68.2	66.33	78.5
S98-KBX	70.5	75.7	74.5	75.2	61.8	65.50	67.7
S99-KBX	78.2	80.2	72.8	73.5	65.0	71.17	70.6
S100-KBX	69.6	72.0	67.7	63.2	56.8	56.17	60.2
Mean	**63.7**	**65.3**	**63.9**	**66.4**	**59.6**	**58.29**	**64.8**

Water Regime Class Key
Red Gum FDU forest
Red Gum FTU woodland
Box woodland

Table D 5 Friedman test results for overall SCS, PAI, %LBA and crown extent over time period 2010-2017

Attribute	SCS	PAI	%LBA	Crown Extent
P Value	<0.001	<0.001	<0.001	<0.001

Key to Table

SCS = Stand Condition Score

PAI = Plant Area Index

%LBA = Percentage Live Basal Area

Table D 6 Friedman test results breakdown for SCS, PAI, %LBA and crown extent over time period 2010-2017

	2010				2012				2013				2014				2015				2016				2017			
Variable	**SCS**	**PAI**	**%LBA**	**CE**	**SCS**	**PAI**	**%LBA**	**CE**	**SCS**	**PAI**	**%LBA**	**CE**	**SCS**	**PAI**	**%LBA**	**CE**	**SCS**	**PAI**	**%LBA**	**CE**	**SCS**	**PAI**	**%LBA**	**CE**	**SCS**	**PAI**	**%LBA**	**CE**
2010	NA	NA	NA	NA	yes	yes	no	No	yes	yes	no	no	yes	yes	no	no	yes	yes	no	no	yes	yes	yes	yes	yes	yes	yes	no
2012	yes	yes	no	no	NA	NA	NA	NA	yes	no	no	no	yes	yes	no	no	no	no	no	no	no	no	no	yes	yes	yes	no	no
2013	yes	yes	no	no	yes	no	no	no	NA	NA	NA	NA	no	no	no	no	no	no	no	no	yes	yes	no	yes	no	no	no	no
2014	yes	yes	no	no	yes	yes	no	no	no	no	no	no	NA	NA	NA	NA	yes	no	no	no	yes	yes	no	yes	no	no	no	no
2015	yes	yes	no	no	no	no	no	no	no	no	no	no	no	no	no	no	NA	NA	NA	NA	yes	yes	no	no	yes	yes	no	yes
2016	yes	yes	yes	yes	no	no	no	yes	yes	yes	no	yes	yes	yes	no	yes	yes	yes	no	no	NA	NA	NA	NA	yes	yes	no	yes
2017	yes	yes	yes	no	yes	yes	no	no	no	no	no	no	no	no	no	no	yes	yes	no	yes	yes	yes	no	yes	NA	NA	NA	NA

Appendix E – Tree Condition Data

Table E 1 Mean crown extent at tree condition sites 2010-2017

	Vegetation Type	Mean Crown Extent %						
		2010	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**
S76-KRF	River Red Gum Forest	80.7	76.2	70.7	76.8	68.83	71.67	76.8
S81-KRF	River Red Gum Forest	76.0	77.3	77.0	75.5	69.83	70.83	72.8
S82-KRF	River Red Gum Forest	74.3	79.3	75.7	73.5	68.67	67.33	64.5
S84-KRF	River Red Gum Forest	69.7	80.2	78.2	72.2	54.33	46.00	54.5
S85-KRF	River Red Gum Woodland	72.0	75.2	76.3	70.2	62.33	67.17	54.5
S86-KRF	River Red Gum Forest	55.0		73.8	75.8	66.50	52.00	58.4
S87-KRF	River Red Gum Forest	61.2	71.3	64.7	66.7	55.83	53.17	52.6
S88-KRF	River Red Gum Forest	52.5		66.2	69.8	56.17	47.50	51.9
S89-KRF	River Red Gum Forest	49.3	57.8	70.3	72.5	73.33	71.33	66.3
S90-KRF	River Red Gum Forest	65.5	75.8	68.5	78.8	74.00	64.83	77.0
S91-KRF	River Red Gum Forest	63.3		68.8	78.1	71.00	66.33	61.1
S93-KRW	River Red Gum Woodland	53.0	68.2	46.3	60.5	54.00	56.17	60.3
S94-KRW	River Red Gum Forest	44.2	45.7	57.8	51.7	43.00	50.33	63.6
S95-KRW	River Red Gum Woodland	52.2	63.7	49.0	61.8	51.83	53.67	70.7
S100-KBX	Box Woodland	69.3	70.3	67.7	62.7	56.00	54.67	73.4
BWT	River Red Gum Forest	N/A	N/A	N/A	N/A	76.33	77.00	69.7
PLLT	River Red Gum Forest	N/A	N/A	N/A	N/A	75.33	70.50	69.2
PJWT	River Red Gum Forest	N/A	N/A	N/A	N/A	77.33	72.83	67.7
TLT	River Red Gum Forest	N/A	N/A	N/A	N/A	73.67	75.67	45.2
WHT	River Red Gum Forest	N/A	N/A	N/A	N/A	76.67	75.33	58.3
GBT1	Box Woodland	N/A	N/A	N/A	N/A	76.50	76.00	74.8
GBT2	Box Woodland	N/A	N/A	N/A	N/A	72.00	70.33	78.5
GBT3	Box Woodland	N/A	N/A	N/A	N/A	58.17	61.83	67.7
GBT4	Box Woodland	N/A	N/A	N/A	N/A	78.50	77.33	70.6
GBT5	Box Woodland	N/A	N/A	N/A	N/A	67.84	67.00	60.2
Average		**62.5**	**70.1**	**67.4**	**69.8**	**66.31**	**64.67**	**64.8**

Water Regime Class Key
Red Gum FDU forest
Red Gum FTU woodland
Box woodland

Table E 2 Mean crown density at tree condition sites 2010-2017

	Vegetation Type	Mean Crown Density %						
		2010	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**
S76-KRF	River Red Gum Forest	62.2	63.3	64.8	43.8	54.67	57.17	71.54
S81-KRF	River Red Gum Forest	63.3	72.3	62.3	61.3	59.33	62.33	75.10
S82-KRF	River Red Gum Forest	56.7	60.0	62.0	57.0	55.83	60.00	67.85
S84-KRF	River Red Gum Forest	66.0	56.3	61.8	39.0	46.83	45.67	64.72
S85-KRF	River Red Gum Woodland	68.3	69.2	60.8	62.4	61.17	64.67	74.13
S86-KRF	River Red Gum Forest	57.5		70.7	69.5	62.67	47.00	68.25
S87-KRF	River Red Gum Forest	59.3	70.7	63.7	59.5	55.50	56.50	65.08
S88-KRF	River Red Gum Forest	53.2		53.8	36.9	55.33	50.33	60.72
S89-KRF	River Red Gum Forest	61.2	66.5	70.3	80.6	69.17	71.00	74.04
S90-KRF	River Red Gum Forest	46.7	60.5	66.3	63.7	66.67	51.83	66.80
S91-KRF	River Red Gum Forest	49.2		66.0	75.5	72.50	57.67	66.77
S93-KRW	River Red Gum Woodland	66.2	66.7	58.2	41.8	57.13	55.33	64.96
S94-KRW	River Red Gum Forest	55.0	51.0	60.2	52.8	46.17	48.00	53.71
S95-KRW	River Red Gum Woodland	63.3	61.5	55.5	46.6	41.50	44.33	59.11
S100-KBX	Box Woodland	47.5	32.7	55.3	43.5	62.50	49.83	59.89
BWT	River Red Gum Forest	N/A	N/A	N/A	N/A	69.33	70.00	71.66
PLLT	River Red Gum Forest	N/A	N/A	N/A	N/A	68.50	63.83	74.55
PJWT	River Red Gum Forest	N/A	N/A	N/A	N/A	76.00	74.67	74.48
TLT	River Red Gum Forest	N/A	N/A	N/A	N/A	64.50	66.83	71.33
WHT	River Red Gum Forest	N/A	N/A	N/A	N/A	76.67	74.67	77.82
GBT1	Box Woodland	N/A	N/A	N/A	N/A	76.00	74.67	75.07
GBT2	Box Woodland	N/A	N/A	N/A	N/A	69.50	68.50	72.30
GBT3	Box Woodland	N/A	N/A	N/A	N/A	46.33	51.33	65.02
GBT4	Box Woodland	N/A	N/A	N/A	N/A	79.50	75.33	76.02
GBT5	Box Woodland	N/A	N/A	N/A	N/A	61.17	55.50	74.53
Average		**67.4**	**60.9**	**62.1**	**55.6**	**62.18**	**59.88**	**69.02**

Water Regime Class Key
Red Gum FDU forest
Red Gum FTU woodland
Box woodland

Table E 3 Mean Crown Condition Score (CCS) 2010-2017

Site	2010	2012	2013	2014	2015	2016	2017
S76-KRF	70.82	69.45	67.69	58.03	60.59	63.33	71.54
S81-KRF	69.38	74.79	69.28	68.05	63.57	66.00	75.10
S82-KRF	64.90	68.99	68.51	64.73	61.53	63.13	67.85
S84-KRF	67.81	67.20	69.52	53.03	49.80	45.35	64.72
S85-KRF	70.14	72.11	68.14	66.19	61.44	65.53	74.13
S86-KRF	56.24		72.23	72.60	63.50	48.69	68.25
S87-KRF	60.24	71.00	64.16	62.98	55.23	54.36	65.08
S88-KRF	52.83		59.68	50.79	54.74	47.58	60.72
S89-KRF	54.93	62.01	70.33	76.44	70.84	70.86	74.04
S90-KRF	55.29	67.73	67.41	70.85	69.71	57.41	66.80
S91-KRF	55.80		67.40	76.79	71.42	61.16	66.77
S93-KRW	59.22	67.42	51.91	50.31	55.15	55.19	64.96
S94-KRW	49.29	48.26	58.99	52.25	43.82	48.24	53.71
S95-KRW	57.48	62.58	52.15	53.68	45.76	48.42	59.11
S100-KBX	57.39	47.93	61.19	52.21	58.49	51.19	59.89
BWT	N/A	N/A	N/A	N/A	72.35	73.15	71.33
PLLT	N/A	N/A	N/A	N/A	71.68	66.90	74.55
PJWT	N/A	N/A	N/A	N/A	76.44	73.13	77.82
TLT	N/A	N/A	N/A	N/A	68.40	70.49	71.66
WHT	N/A	N/A	N/A	N/A	76.41	74.64	74.48
GBT1	N/A	N/A	N/A	N/A	76.10	75.18	75.07
GBT2	N/A	N/A	N/A	N/A	70.22	68.83	72.30
GBT3	N/A	N/A	N/A	N/A	51.38	56.02	65.02
GBT4	N/A	N/A	N/A	N/A	78.74	76.11	76.02
GBT5	N/A	N/A	N/A	N/A	64.04	60.52	74.53
Average	**60.12**	**64.96**	**64.57**	**61.93**	**63.65**	**61.66**	**69.02**

Water Regime Class Key
Red Gum FDU forest
Red Gum FTU woodland
Box woodland

Table E 4 Frequencies of trees in each Crown Condition Score (CCS) Category 2010-2017

		Crown condition category					
		dead	**very poor**	**poor**	**moderate**	**good**	**very good**
2010	Count		24	62	127	206	31
	% within year		5	14	28	46	7
2012	Count	5	7	27	75	206	40
	% within year	1	2	8	21	57	11
2013	Count	7	4	21	110	279	29
	% within year	2	1	5	24	62	6
2014	Count	10	9	45	132	211	43
	% within year	2	2	10	29	47	10
2015*	Count	9	106	57	163	390	106
	% within year	1	3	8	22	52	14
2016*	Count	9	92	77	186	358	92
	% within year	1	4	10	25	48	12
2017*	Count	13	4	23	109	475	126
	% within year	2	1	3	15	63	17
Grand Total	Count	53	246	312	902	2125	467
	% across years	1.29	5.99	7.60	21.97	51.77	11.38

* 2015 - 2017 data include the 10 additional tree sites established in 2015, so n=750. As such, percentages for 2015 presented in this table in the 2015 report will be different as they exclude the 10 additional tree sites (n=15).

Table E 5 Frequencies of trees in each Crown Condition Score (CCS) Category by Water Regime Class 2010-2017

Water Regime Class & Year	Crown Condition Category						
	dead	**very poor**	**poor**	**moderate**	**good**	**very good**	**Grand Total**
Box Woodland							
2010			2	15	13		30
2012		1	7	18	4		30
2013			1	13	16		30
2014			7	20	3		180
2015		6	9	35	101	29	180
2016		5	14	37	102	22	180
2017		1	4	27	124	24	180
Red Gum FDU							
2010		18	49	91	149	23	330
2012	4	4	13	40	156	23	240
2013	5	2	8	62	228	25	330
2014	7	6	25	83	173	36	330
2015	6	13	38	96	257	70	480
2016	6	19	53	120	214	68	480
2017	8	3	8	59	305	97	480
Red Gum FTU							
2010		6	11	21	44	8	90
2012	1	2	7	17	46	17	90
2013	2	2	12	35	35	4	90
2014	3	3	13	29	35	7	90
2015	3	6	10	32	32	7	90
2016	3	4	10	29	42	2	90
2017	5		11	23	46	5	90
Grand Total	**53**	**101**	**312**	**902**	**2125**	**467**	**4110**

Table E 6 Frequencies of condition trajectory attributes in tree condition sites 2010-2016 (n = 450 in 2010, 2013-2014 ; n=360 in 2012; n=750 in 2015-2017)

	New Tip Growth							Epicormic Growth							Reproduction						
	2010	2012	2013	2014	2015	2016	2017	2010	2012	2013	2014	2015	2016	2017	2010	2012	2013	2014	2015	2016	2017
absent	346	177	431	367	599	707	417	63	37	89	231	147	155	143	252	282	362	397	566	421	362
scarce	95	126	17	65	127	41	278	91	73	169	95	325	331	356	59	37	42	37	151	181	177
common	7	41	1	15	22	1	53	106	130	140	89	177	193	175	55	32	34	13	29	119	143
abundant	2	16	0	3	2	1	2	190	120	51	35	101	71	76	84	9	11	3	4	29	68

Bark Condition							
	2010	2012	2013	2014	2015	2016	2017
Intact bark	344	326	320	244	424	284	440
Minor cracking	75	30	104	175	244	345	228
Moderate							60
Extensive cracking	23	3	18	30	16	21	20
No bark	8	1	7	1	0	0	2

	Leaf die-off							Mistletoe load						
	2010	2012	2013	2014	2015	2016	2017	2010	2012	2013	2014	2015	2016	2017
absent	314	286	321	261	200	117	313	346	355	444	447	732	738	744
scarce	131	49	104	138	448	508	401	95	5	4	2	17	10	5
common	4	17	18	41	89	102	33	7	0	1	0	1	2	1
abundant	1	8	7	10	13	23	3	2	0	0	1	0	0	0

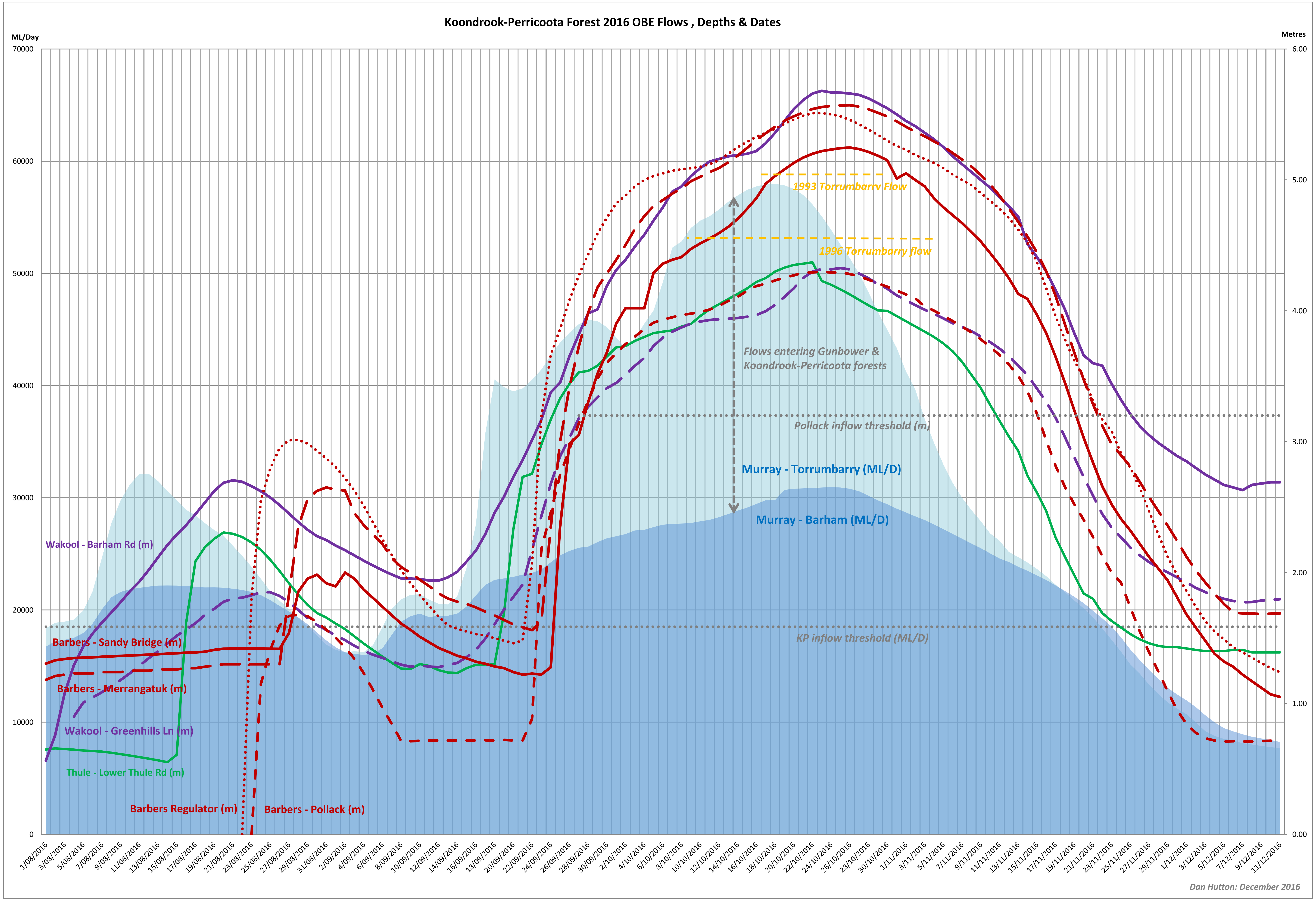
Table E 7 Frequencies of site context attributes at tree condition sites 2010-2016 (n=15 in 2010, 2013 to 2015; n=12 in 2012, n=25 in 2015-2017)

	Insect Damage							Weeds							Seedlings / Saplings						
	2010	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2010**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2010**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**
absent	2	0	0	0	0	1	1	6	0	1	1	3	11	7	0	0	0	0	1	8	6
scarce	4	3	6	6	5	11	13	4	9	11	13	11	13	14	6	5	9	8	10	14	16
common	7	8	9	9	10	12	11	5	3	3	1	1	1	4	7	4	3	4	2	3	3
abundant	2	1	0	0	0	1	0	0	0	0	0	0	0	0	2	3	3	2	1	0	0

Table E 8 Frequencies of trees in each dominance category at tree condition sites 2010-2016 (n=15 in 2010, 2013 to 2015; n=12 in 2012, n=25 in 2015-2017)

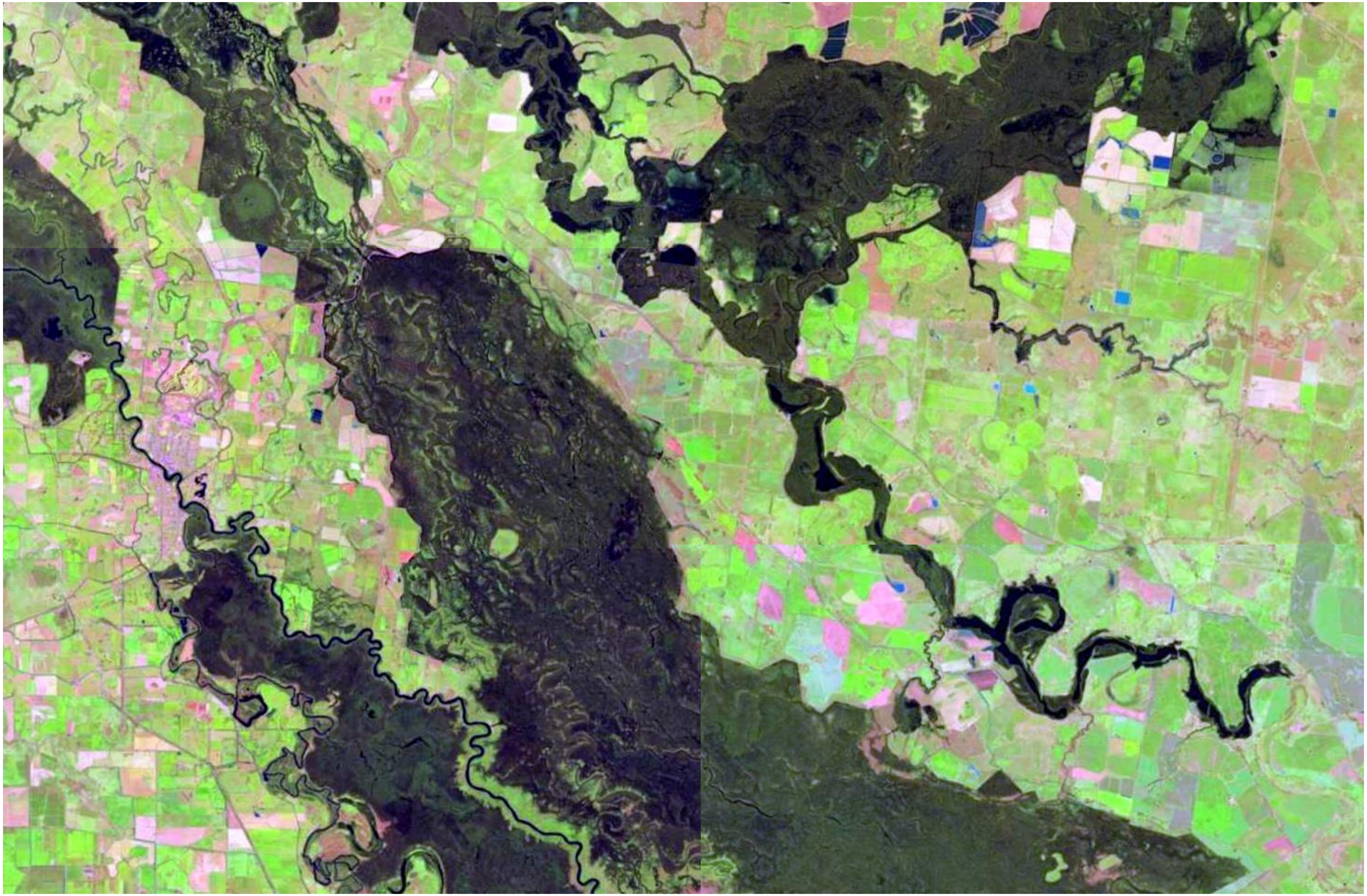
	2010	2012	2013	2014	2015	2016	2017
Suppressed	56	46	12	15	11	16	17
sub-dominant	145	110	152	207	311	305	303
co-dominant	221	187	259	220	403	404	398
Dominant	28	17	26	8	25	25	32

Appendix F – 2016 FCNSW Flood Data



Koondrook-Perricoota Forest 2016 OBE Flows , Depths & Dates
ML/Day
Metres
1993 Torrumbarry Flow
1996 Torrumbarry flow
Flows entering Gunbower & Koondrook-Perricoota forests
Pollack inflow threshold (m)
Murray - Torrumbarry (ML/D)
Murray - Barham (ML/D)
Wakool - Barham Rd (m)
Barbers - Sandy Bridge (m)
KP inflow threshold (ML/D)
Barbers - Merrangatuk (m)
Wakool - Greenhills Ln (m)
Thule - Lower Thule Rd (m)
Barbers Regulator (m)
Barbers - Pollack (m)
Dan Hutton: December 2016

KP 2016 OBE Landsat 8 October 26th – Koondrook



Appendix G – Tree Condition Assessment Photo-points 2010 - 2017

					
S76 Site Photo 2012 (KRF)	S76 Site Photo 2013 (GHD)	S76 Site Photo 2014 (GHD)	S76 Site Photo 2015 (GHD)	S76 Site Photo 2016 (GHD)	S76 Site Photo 2017 (GHD)
					
S81 Site Photo 2012 (KRF)	S81 Site Photo 2013 (GHD)	S81 Site Photo 2014 (GHD)	S81 Site Photo 2015 (GHD)	S81 Site Photo 2016 (GHD)	S81 Site Photo 2017 (GHD)
					
S82 Site Photo 2012 (KRF)	S82 Site Photo 2013 (GHD)	S82 Site Photo 2014 (GHD)	S82 Site Photo 2015 (GHD)	S82 Site Photo 2016 (GHD)	S82 Site Photo 2017 (GHD)
					
S84 Site Photo 2012 (KRF)	S84 Site Photo 2013 (GHD)	S84 Site Photo 2014 (GHD)	S84 Site Photo 2015 (GHD)	S84 Site Photo 2016 (GHD)	S84 Site Photo 2017 (GHD)
					
S85 Site Photo 2012 (KRF)	S85 Site Photo 2013 (GHD)	S85 Site Photo 2014 (GHD)	S85 Site Photo 2015 (GHD)	S85 Site Photo 2016 (GHD)	S85 Site Photo 2017 (GHD)

					
S86 Site Photo 2012 (KRF)	S86 Site Photo 2013 (GHD)	S86 Site Photo 2014 (GHD)	S86 Site Photo 2015 (GHD)	S86 Site Photo 2016 (GHD)	S86 Site Photo 2017 (GHD)
					
S87 Site Photo 2012 (KRF)	S87 Site Photo 2013 (GHD)	S87 Site Photo 2014 (GHD)	S87 Site Photo 2015 (GHD)	S87 Site Photo 2016 (GHD)	S87 Site Photo 2017 (GHD)
					
S88 Site Photo 2012 (KRF)	S88 Site Photo 2013 (GHD)	S88 Site Photo 2014 (GHD)	S88 Site Photo 2015 (GHD)	S88 Site Photo 2016 (GHD)	S88 Site Photo 2017 (GHD)
					
S89 Site Photo 2012 (KRF)	S89 Site Photo 2013 (GHD)	S89 Site Photo 2014 (GHD)	S89 Site Photo 2015 (GHD)	S89 Site Photo 2016 (GHD)	S89 Site Photo 2017 (GHD)
					
S90 Site Photo 2012 (KRF)	S90 Site Photo 2013 (GHD)	S90 Site Photo 2014 (GHD)	S90 Site Photo 2015 (GHD)	S90 Site Photo 2016 (GHD)	S90 Site Photo 2017 (GHD)

					
S91 Site Photo 2012 (KRF)	S91 Site Photo 2013 (GHD)	S91 Site Photo 2014 (GHD)	S91 Site Photo 2015 (GHD)	S91 Site Photo 2016 (GHD)	S91 Site Photo 2017 (GHD)
					
S93 Site Photo 2012 (KRF)	S93 Site Photo 2013 (GHD)	S93 Site Photo 2014 (GHD)	S93 Site Photo 2015 (GHD)	S93 Site Photo 2016 (GHD)	S93 Site Photo 2017 (GHD)
					
S94 Site Photo 2012 (KRF)	S94 Site Photo 2013 (GHD)	S94 Site Photo 2014 (GHD)	S94 Site Photo 2015 (GHD)	S94 Site Photo 2016 (GHD)	S94 Site Photo 2017 (GHD)
					
S95 Site Photo 2012 (KRF)	S95 Site Photo 2013 (GHD)	S95 Site Photo 2014 (GHD)	S95 Site Photo 2015 (GHD)	S95 Site Photo 2016 (GHD)	S95 Site Photo 2017 (GHD)
					
S100 Site Photo 2012 (KRF)	S100 Site Photo 2013 (GHD)	S100 Site Photo 2014 (GHD)	S100 Site Photo 2015 (GHD)	S100 Site Photo 2016 (GHD)	S100 Site Photo 2017 (GHD)

					
			TLT Site Photo 2015 (GHD)	TLT Site Photo 2016 (GHD)	TLT Site Photo 2017 (GHD)
					
			PLLT Site Photo (2015) (GHD)	PLLT Site Photo (2016) (GHD)	PLLT Site Photo 2017 (GHD)
					
			WHT Site Photo (2015) (GHD)	WHT Site Photo (2016) (GHD)	WHT Site Photo 2017 (GHD)
					
			BWT Site Photo (2015) (GHD)	BWT Site Photo (2016) (GHD)	BWT Site Photo 2017 (GHD)
					
			PJWT Site Photo (2015) (GHD)	PJWT Site Photo (2016) (GHD)	PJWT Site Photo 2017 (GHD)
					

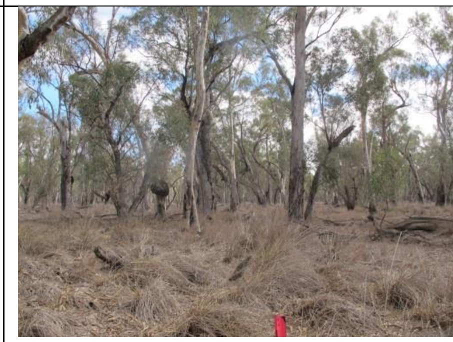
			GBT1 Site Photo (2015) (GHD)	GBT1 Site Photo (2016) (GHD)	GBT1 Site Photo 2017 (GHD)
					
			GBT2 Site Photo (2015) (GHD)	GBT2 Site Photo (2016) (GHD)	GBT2 Site Photo 2017 (GHD)
					
			GBT3 Site Photo (2015) (GHD)	GBT3 Site Photo (2016) (GHD)	GBT3 Site Photo 2017 (GHD)
					
			GBT4 Site Photo (2015) (GHD)	GBT4 Site Photo (2016) (GHD)	GBT4 Site Photo 2017 (GHD)
					
			GBT5 Site Photo (2015) (GHD)	GBT5 Site Photo (2016) (GHD)	GBT5 Site Photo 2017 (GHD)

*Photo for site S84 was not able to be located, may have been accidentally deleted. Instead a photo for the understorey assessment was inserted, as this gives some indication of the site condition.

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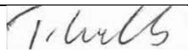
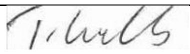
Document Status

Rev No.	Author	Reviewer		Approved for Issue		
		Name	Signature	Name	Signature	Date
Draft A						04/07/17
0	J Forbes	T Wills		T Wills		21/08/17

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