TECHNICAL REPORT

CURTIN UNIVERSITY

TREE REPLACEMENT PLAN FOR BLACK COCKATOO HABITAT IMPROVEMENT

JANUARY 2014

CURTIN UNIVERSITY

SYRINX environmental pl

Perth
12 Monger Street
PerthWA, Australia 6000
t +61[0]8 9227 9355
f +61[0]9 9227 5033

Melbourne
2/26-36 High Street
Northcote VICAustralia 3070
t +61[0]3 9481 6288
f +61[0]3 9481 6299

ABN : 39 092 638 410

www.syrinx.net.au

SYRINX ENVIRONMENTAL PL

REPORT NO. RPT-1330-001 V3

LIMITATIONS OF REPORT

Syrinx Environmental PL has prepared this report as an environmental consultant provider. No other warranty, expressed or implied, is made as to the professional advice included in this report. This report has not been prepared for the use, perusal or otherwise, by parties other than the Client, the Owner and their nominated consulting advisors without the consent of the Owner. No further information can be added without the consent of the Owner, nor does the report contain sufficient information for purposes of other parties or for other uses. The information contained in this report has been prepared in good faith, and accuracy of data at date of issue has been compiled to the best of our knowledge. However, Syrinx Environmental PL is not responsible for changes in conditions that may affect or alter information contained in this report before, during or after the date of issue.

Syrinx Environmental PL accepts site conditions as an indeterminable factor, creating variations that can never be fully defined by investigation. Measurements and values obtained from sampling and testing are indicative within a limited time frame and unless otherwise specified, should not be accepted as actual realities of conditions on site beyond that timeframe.

REPORT DETAILS:

Version No.	Date	Author	Reviewer	Comment
1	02.12.2013	RT, MD	KM	Draft V1 to Client
1	03.12.2013		OPY	Review received on Draft V1
2	19.12.2013	RT	CG	Draft V2 to Client
2	20.01.2014		OPY	Review received on Draft V2
3	22.12.2014	RT		Final document issue

Filename/ filepath: *J:\JOB FILES\1330 CUTRP\C - PROJECT\C10 - DELIVERABLES\C10.03 Technical Report*

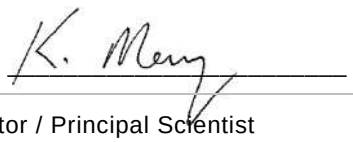
	Signature		Signature
Author: RT		**Reviewer**: KM	
Position: Environmental Scientist		**Position**: Director / Principal Scientist	

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

EXECUTIVE SUMMARY

The Curtin University Tree Replacement Plan for Black Cockatoo Habitat Improvement has been developed to guide the management of the Black Cockatoo habitat trees on Curtin Bentley campus and properties over the next 30 years. The need for this Plan arose as a result of the planned future urban growth via implementation of the Greater Curtin Masterplan and the aging tree population which consists of trees that form a part of a significant roosting site for the Endangered Carnaby's Black Cockatoo.

The importance of the Curtin urban forest has been described in the Urban Forest Management Plan (RPS, 2012) and the strategies for implementation of tree replacements outlined from the urban development perspective, species diversity and suitability to particular environs (e.g. trees for avenue planting, urban core, playing fields etc).

The primary objective of this study is to provide an understanding of the tree resources on Curtin campus and its properties and the importance of those tree resources to the Endangered Black Cockatoos, biodiversity and the functionality they provide to the campus community and beyond.

Under this premise, this study had three goals:

1. Provide baseline information for the evaluation, preservation, and future planting of habitat trees needed to protect and mitigate the loss of food and roosting resource for the Endangered and Vulnerable Black Cockatoos due to future developments and natural senescence of trees through habitat retention and plantings.

2. Provide decision-makers an access to both scientific information and Traditional Ecological Knowledge (TEK) which will guide future tree planting and help justify the degree of funding allocation, maintenance and protection appropriate for the campus tree resources.

3. Provide a draft plan showing areas available for planting (indicating opportunities to increase Black Cockatoo habitat areas) and the species list specifying the areas in which they can be planted based on physical and infrastructure constraints of the site.

To fulfil the goals listed above, this study has used tree inventory data collected by Arbor Centre (2012) which incorporates trees of the Bentley Campus and its properties on Kent Street and Technology Park, in addition to a range of resources to better describe the value and use of trees by the Black Cockatoos. Background information on biodiversity studies at

Curtin and surrounding areas as well as the planting guidelines and latest developments in the nursery propagation and disease management were also analysed in order to derive appropriate recommendations for habitat tree planting at Curtin campus and its properties.

This report consists of four parts and five appendices covering the background to the project and giving context to the study, providing analysis of current Black Cockatoo habitat and the impacts to that habitat as a result of development and providing a draft plan for tree replacement. The key sections from the report are summarised briefly below. The reader, in particular the implementation team who will be conducting the works on ground, is encouraged to follow up on information in this report and maintain knowledge of the future developments in order to successfully implement this plan. Whilst modifications to the plan are possible the general intent and structure of habitat tree planting should remain true to this plan unless early plantings indicate that the recommended species are performing poorly.

GREATER CURTIN MASTERPLAN

The Greater Curtin Masteplan encompasses the grounds of the Curtin Bentley campus (114 ha) and aims to fulfil the University's overall vision to become an educational leader in research and education by 2030. The Masterplan proposes a mixed land use development which incorporates academic, research, commercial, retail and residential buildings. The development envisages construction of new roads and a light rail network as well as a 'living stream' which will form the main public open space spine running along north to south axis through the development, linking existing and former wetlands. The first stage of the development is expected to start in 2014 with the construction of the Main Street Project. Other stages of work will follow incrementally, with the Masterplan outlining 4 stages of works over a 20 year period between 2015 and 2035.

BLACK COCKATOOS

Two species of Black Cockatoo have been recorded on the Bentley Campus: The Forest Red-tailed Black Cockatoo (FRTBC: *Calyptorhynchus banksii naso*) has been recorded feeding in the area, while the Carnaby's Black Cockatoo (*Calyptorhyncus latirostris*) is known to feed and roost at the site in large numbers. Both species are afforded Commonwealth (*EPBC Act 1999*) and State conservation protection (*Wildlife Conservation Act 1950*).

Black Cockatoos are highly adaptive, with both the Carnaby's Black Cockatoo and the FRTBC having modified their behaviour to suit changing food and roosting resources in man-made landscapes. In particular, Carnaby's Black Cockatoos have adapted feeding and roosting behaviour to use pine trees that were planted in the early 1930s for plantation timber in many locations on the Swan Coastal Plan (SCP). Pine plantations and their remnants now serve as vital feeding and roosting sites for the Carnaby's Black Cockatoo.

However, with the continued loss of many of these plantations due to harvesting and the predicted removal of the entire Gnangara plantation by 2031 (Stock et al., 2013), remnant pine areas such as the that found on the Bentley Campus of Curtin University are becoming increasingly important to the maintenance of this endemic species. Together with the pines of the Collier Golf course, Curtin University pines particularly those at the northwest boundary of the campus form 'super roost' for the Carnaby's Black Cockatoo which is one of the largest roosting sites within the Perth Metropolitan Region.

The Forest Red-tailed Black Cockatoo have taken a much longer period to adapt to the changes in available resources on the SCP and were only noted to modify their foraging behaviour and return to former feeding grounds on the SCP in 1995, when the species was recorded feeding on Cape Lilac trees. Since this date the bird has become increasingly common on the SCP with some flocks making regular movements west from the Darling Scarp onto the Plain for foraging and in 2011 the species was observed to breed at Murdoch University.

Protection of the trees that form part of an official 'super roost' area for Carnaby's Black Cockatoos and those trees that are currently or are likely in the future to be used by the FRTBC at the Bentley Campus and surrounding Curtin University properties are vitally important in the maintenance of these endemic and charismatic species. Curtin University has recognised the value of the trees at their properties to the long-term protection of the species' and aim to improve the habitat available to the Black Cockatoos into the future.

IMPACT OF DEVELOPMENT AND THE TREES USEFUL LIFE EXPECTANCY ON BLACK COCKATOO HABITAT

Implementation of the Greater Curtin Masterplan will impact on trees and remnant vegetation on Curtin University properties, many of which contribute to the Black Cockatoo habitat. As such the impacts of the Greater Curtin Masterplan must be considered to ensure development does not compromise the capacity of the site to maintain these vital habitat functions.

In addition to trees that will be lost to development, many of the trees (particularly pine trees) are anticipated to be lost in the coming years as they are reaching the limit of their expected life span.

A total of 2114 trees and 137 shrubs are expected to be lost in the next 30 years due to development and natural senescence on the Bentley Campus alone and 237 trees and 10 shrubs incorporating all Curtin properties outside of campus. Out of the combined predicted loss of 2351 trees and 147 shrubs 1229 trees and 85 shrubs will be lost to natural attrition and 1122 trees and 62 shrubs to development. The loss of trees and shrubs and their

relative value to Black Cockatoos based on the habitat they provide for each 10 year period is outlined in table below.

Habitat tree	Number of Trees and Shrubs lost 0-10 years	Number of Trees and Shrubs lost 10-20 years	Number of Trees and Shrubs lost 10-30 years	Cumulative loss of Trees and Shrubs over 30 years
Feeding, Roosting and Nesting	30	20	2	**52**
Feeding and roosting	375	584	358	**1317**
Feeding Only	312	205	93	**610**
Roosting Only	165	115	92	**372**
Shrubs (feeding only)	61	47	39	**147**
Total trees and shrubs	**943**	**971**	**584**	**2498**
Total for Trees only	***882***	***924***	***545***	***2351***

OFFSET REQUIREMENTS

Aurora Environmental (2013), who had prepared the referral documentation for the Main Street Project which forms a part of the Stage 1 of Greater Curtin Masterplan implementation, have stipulated that all trees that will be removed as a result of development are to be replaced at a ratio of 4 trees to every tree removed.

If all trees that are to be removed for development and lost due to natural attrition over the next 30 years are replaced at this offset rate, 9392 trees and 588 shrubs will need to be planted and will likely require 31 - 47 ha of planting space to accommodate a planting density of 200 – 300 trees per hectare (ha). Estimates of the area available for planting based on the current Masterplan provide only 10 ha of space with approximately 4.5 ha of verge space. As such there are clear conflicts between the current Masterplan and the aim of the University to maintain or improve the habitat available to the Cockatoos on Curtin properties.

In light of the highlighted conflicts this report suggests an alternative replacement ratio, which addresses the replacement based on the value of tree type to the Black Cockatoos and provides suggestions on possible ways to ensure sufficient habitat is retained and replaced into the future. Based on these revised offset ratios a total of 5465 trees and 588 shrubs will need to be replaced occupying an estimated 18 – 27 ha. Given that approximately 14.5 ha of areas for infill planting exist at Curtin Bentley Campus and the verges, additional 4-13ha will be required to plant sufficient number of trees to offset any losses due to Masterplan implementation and the natural senescence of trees. The summary of proposed offsets and the recommended planting schedule are provided in the table below.

Habitat tree	Number of replacement trees to plant 2014 -2017	Number of replacement trees to plant 2018 - 2020	Number of replacement trees to plant 2020 - 2022	Total number of replacement trees to plant 2014 - 2022
Feeding Roosting and Nesting	120	80	8	**208**
Feeding and roosting	937	1460	895	**3293**
Feeding Only	624	410	186	**1220**
Roosting Only	330	230	184	**744**
Shrubs (feeding only)	244	188	156	**588**
Total trees and shrubs	**2255**	**2368**	**1429**	**6053**
Total for Trees only	***2012***	***2180***	***1273***	***5465***

CHALLENGES

In addition to the lack of available space based on the 2013 Masterplan, the report has also highlighted a number of key challenges in relation to the maintenance or improvement of Black Cockatoo habitat within Curtin properties in the short-term.

1. **Provision of roosting trees**

Trees that are likely to present suitable sites for roosting take many years to mature to a height suitable for the birds (a minimum of 8 to 10 years, longer for most species). Since the first stage of the development is scheduled to commence in 2014 with a total of 64 trees to be removed, 46 or more of which are likely roosting and feeding trees, it will be a significant challenge to the University to meet this objective in the short term. The current plan for the first five years (Stage one: Figure 5) is to remove the majority of these trees from a cluster of trees at the north west of campus which are considered important for the Carnaby's Black Cockatoo roosting. This tree removal is likely to have a substantial impact on the birds' use of the site as both roosting and feeding trees will be removed. As noted by Kabat et al (2012a) no trees greater than 8 m should be removed within a 1 km radius of a known large roost area.

2. **Provision of food resources**

As with roosting trees, feeding trees require a substantial period to mature to a stage where they can provide fruiting bodies of significant value to the birds. Although the time taken for foraging trees to provide adequate habitat for the birds (i.e.to produce suitable fruit) is much shorter than that of roosting trees, care must be taken to ensure other food sources are

made available during the lag time between planting and fruiting. A number of low, fast growing shrubby species should be considered as interim food resource options during the period when larger foraging tree are maturing. These smaller shrub species will also provide valuable habitat for a variety of other urban bird species which can form an important part of pollination for valuable fruiting species facilitating the ongoing fruit production.

RECOMMENDATIONS

In addition to offsets a number of recommendations are provided highlighting the need to potentially modify some stages of the redevelopment to minimise impacts to existing habitat, the potential to offset areas not currently incorporated into the Masterplan and options to provide greater opportunities for habitat creation into the future.

Based on our estimates the prospects of replacing trees at an offset ratio of 4:1 (as agreed for Main Street Project), are not feasible within the land constraints of Curtin University properties and the development outlined in the 2013 Great Curtin Masterplan. Hence, consideration of alternative replacement ratios based on the habitat value of each tree type, modifications of the 2013 Greater Curtin Masterplan and potential opportunities in adjacent parkland and bushland areas is critical. This TRP has outlined a number of strategies covering suggested offsets, enhancements and linkages which combined will deliver the objectives Curtin has for improving Black Cockatoo habitat over the long term. To secure these opportunities, Curtin may need to lead a wider Black Cockatoo habitat improvement program (proposed corridors in this report), in conjunction with the Department of Parks and Wildlife (DPaW), indigenous elders, and potentially the National Wildlife Corridor Program. Funding via this latter body may be available.

Key recommendations to be considered are as follows:

1. The below suggested replacement rate will provide 208 food/roost/nest trees, 3293 roost/food trees and 1964 single value (roost or food) trees and 588 food shrubs by 2025 and will require between 18 and 27 ha of space.

Suggested Replacement/Offset Ratios	
• Feeding Habitat only:	1:2
• Feeding and Roosting	1:2.5 (0.5 = 1 pine tree for every 2 lost due to age)
• Feeding Roosting and Nesting	1:4
• Roosting only	1:2
• Feeding – Shrubs only	1:4 (with shrubs only)

2. Tree habitat replacement must be implemented in the next 5 to 10 years to compensate for the lag time between planting and maturity. A total of 46 roosting and/or feeding trees will be lost as a result of Main Street Project in 2014. Full replacement of these trees will not be possible in the immediate future as most

trees will take a minimum of 10 – 20 years to mature to sufficient height to be of value to the Black Cockatoo for roosting and between 6 – 10 years as suitable feeding trees. It is therefore advisable that every effort be made to: a) minimise the loss of habitat trees and b) sufficient replacement roosting and feeding trees are planted immediately to ensure the overall available habitat is not compromised as a consequence of development or natural attrition.

3. Stage one – modify the location of buildings situated to the north west of the Bentley Campus. A large number of trees in this zone have been earmarked for removal during the early stages of development. These trees currently provide significant habitat value to the entire Bentley site and their removal should be seriously reconsidered. Removal of these trees for development will likely influence the value of remaining trees to provide roosting and feeding habitat and further limit the available space for tree in fill planting. Retaining these trees and space will assist in alleviating the impact of loss of roosting trees in the immediate future.

4. Offset — Lot 85 currently retains a substantial area of pine plantation containing both roosting and feeding trees. Under the current Masterplan, development of this site has not been assigned to the first four stages (next 30 years). As a site with clustered trees, with the capacity to have well developed understorey without impacting on safety, and its proximity to the Collier Park Golf Course, this Lot would be an ideal area to retain and conserve into the future to provide long-term habitat for the Black Cockatoos and other fauna (and flora) species.

5. Always seek opportunities to maximise areas for habitat creation.

6. Work collaboratively with Town of Victoria Park and City of South Perth to implement the Green Links that are mapped in this document – including seeking of funding opportunities to ensure creation and maintenance of these links. Verge areas along Kent Street and Hayman Road should be considered for planting in the short term. The planting of the Kent Street verges in particular should be done not only to support the Black Cockatoo but also local biodiversity and hence should comprise predominantly of locally indigenous species.

7. It is strongly recommended that the design and assessment of roof gardens on early stage buildings are undertaken, and followed to quantitatively assess the potential value of these to Black Cockatoos. Use of roof tops could potentially provide 6 ha of additional area that can be used to supplement on ground habitat.

8. All precaution should be taken in order to prevent use of diseased and poor quality planting stock. Use accredited nurseries to obtain plant stock.

9. Use tubestock in preference to larger stock for planting in habitat and buffer areas. Accommodate planting numbers to cover for planting losses due to poor installation, drought and vandalism (losses vary but are usually between 10 – 15% for non irrigated areas in dry seasons).

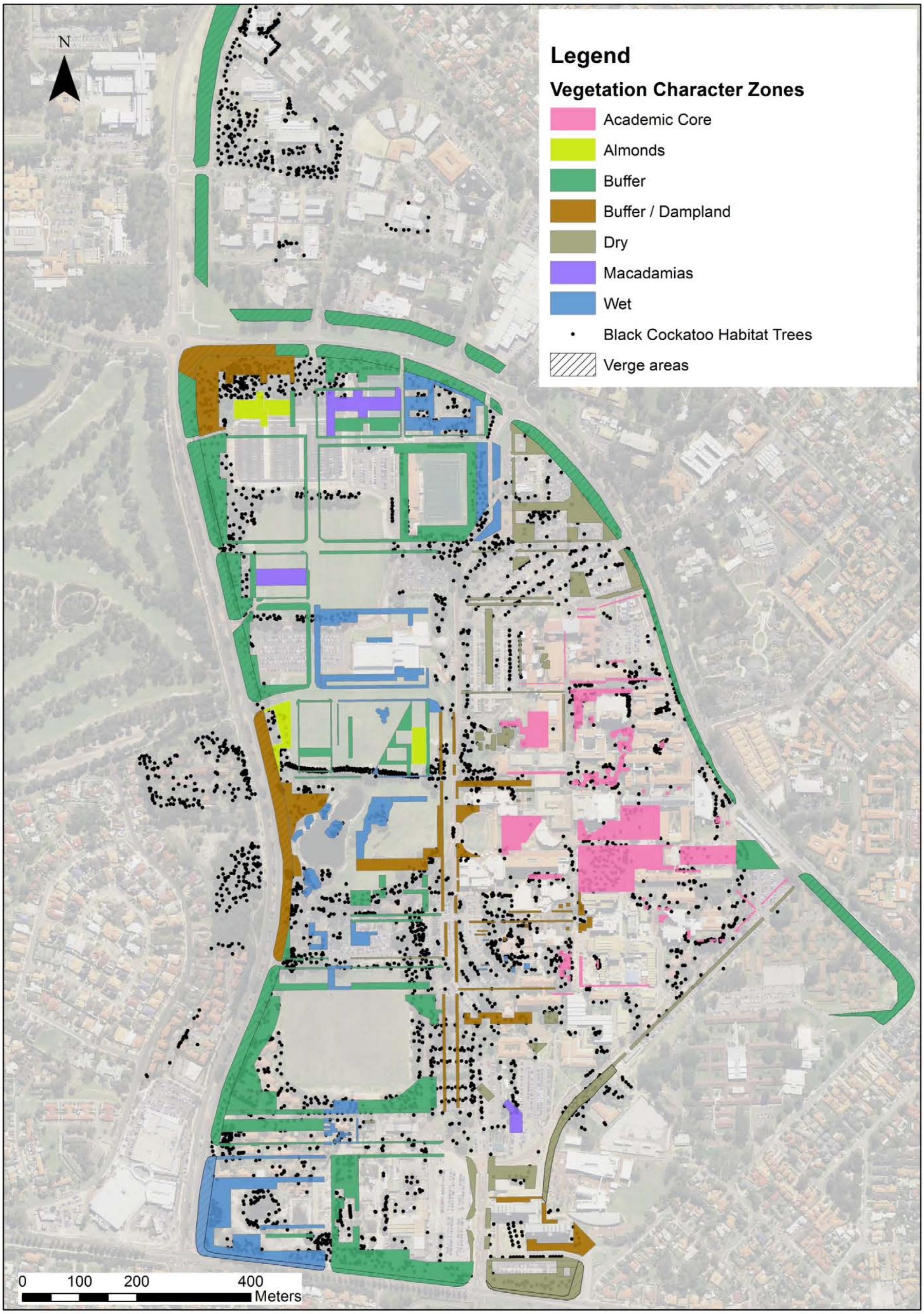
10. Use groundcovers instead of mulch in the areas planted with Proteaceae trees and shrubs. Utilise dwarf cultivars of native plants for planting in the urban core and street scaping to avoid issues with safety.

11. For the areas following the living stream and the dreamtime trail utilise plants which have Noongar meanings / uses and where possible are indigenous to the area.

12. Plant nut trees in areas adjacent to the roosting habitat to ensure their utilisation by Black Cockatoos. Incorporate Almond and Macadamia trees along the western boundary of the site within or adjacent to residential and commercial developments where plants will be protected from wind and have access to irrigation.

13. Pine trees should be planted in the areas currently occupied by pines predominantly as cluster planting facing the Collier Golf Course. Pines can also be planted as street trees and within the academic core and the properties at Technology Park and Guild House / Lot 85.

The proposed Plan and the associated species list with the numbers which amount to the offset totals are provided in Section 12.0 of this report and a copy of the Figures and tables is attached to this executive summary. Section 12.0 also includes planting guidelines on site preparation, plant selection, tree planting and disease control.



Plan indicating areas which can be planted with habitat trees and shrubs indicating appropriate species mix. (see table on next page for details). **Note: additional areas for planting of trees will be needed outside the areas highlighted in this plan to achieve full offset planting.**

Family	Species	Form	Native/Introduced	Habitat (F= Feeding, R=Roosting, N= Nesting)			Approximate offset number of trees required due to potential loss of trees as a result of Masterplan implementation and natural senescence				
Proposed Tree Offsets							**Buffer**	**Buffer / Dampland**	**Wet**	**Dry**	**Academic Core**
Fabaceae	*Acacia saligna*	Tree	Native - WA	F			20		20		
Myrtaceae	*Agonis flexuosa*	Tree	Native - WA	F						100	100
Casuarinaceae	*Allocasuarina fraseriana*	Tree	Native to site	F			100			30	20
Araucariaceae	*Araucaria heterophylla*	Tree	Introduced	F						5	5
Proteaceae	*Banksia ashbyi*	Tree	Native - WA	F						30	20
Proteaceae	*Banksia attenuata*	Tree	Native to site	F			100				
Proteaceae	*Banksia grandis*	Tree	Native to site	F			50	20			50
Proteaceae	*Banksia ilicifolia*	Tree	Native to site	F				20			
Proteaceae	*Banksia littoralis*	Tree	Native - WA	F					10		
Proteaceae	*Banksia menziesii*	Tree	Native to site	F			60			20	20
Proteaceae	*Banksia prionotes*	Tree	Native - WA	F			50			30	
Proteaceae	*Banksia sessilis*	Tree	Native - WA	F			50			20	
Myrtaceae	*Callistemon viminalis*	Tree	Introduced - AU	F						50	50
Cupressaceae	*Callitris preissii*	Tree	Native - WA	F						30	30
Myrtaceae	*Corymbia calophylla*	Tree	Native to site	F	R	N	500	200		50	
Myrtaceae	*Corymbia citriodora*	Tree	Introduced - AU	F	R					20	20
Myrtaceae	*Corymbia ficifolia*	Tree	Native - WA	F						30	30
Myrtaceae	*Corymbia haematoxylon*	Tree	Native - WA	F						30	20
Myrtaceae	*Corymbia maculata*	Tree	Introduced - AU		R					100	
Myrtaceae	*Eucalyptus caesia*	Tree	Native - WA	F						50	50
Myrtaceae	*Eucalyptus gomphocephala*	Tree	Native - WA	F	R	N	500			50	50
Myrtaceae	*Eucalyptus grandis*	Tree	Introduced - AU		R		30				
Myrtaceae	*Eucalyptus loxophleba*	Tree	Native - WA	F							20
Myrtaceae	*Eucalyptus marginata*	Tree	Native to site	F	R		200			50	50
Myrtaceae	*Eucalyptus rudis*	Tree	Native to site		R		400	100	130		
Myrtaceae	*Eucalyptus todtiana*	Tree	Native to site	F			20	10		20	
Proteaceae	*Hakea laurina*	Tree	Native - WA	F			10			30	30
Bignoniaceae	*Jacaranda mimosifolia*	Tree	Introduced	F						50	50
Fabaceae	*Jacksonia sternbergiana*	Tree	Native to site	F			30	20			
Altingiaceae	*Liquidambar styraciflua*	Tree	Introduced	F							50
Proteaceae	*Macadamia integrifolia*	Tree	Introduced - AU	F			20				20
Loranthaceae	*Nuytsia floribunda*	Tree	Native to site	F			25	10		10	10
Pinaceae	*Pinus pinaster*	Tree	Introduced	F	R		400				100
Pinaceae	*Pinus pinea*	Tree	Introduced	F	R		600				100
Rosaceae	*Prunus amygdalus*	Tree	Introduced	F			20			20	20
Proposed Shrub Offsets							**Buffer**	**Buffer / Dampland**	**Wet**	**Dry**	**Academic Core**
Casuarinaceae	*Allocasuarina humilis*	Shrub	Native to site	F			20				
Proteaceae	*Banksia dallanneyi*	Shrub	Native to site	F			10				10
Proteaceae	*Banksia gardneri*	Shrub	Native - WA	F							10
Proteaceae	*Banksia hookeriana*	Shrub	Native - WA	F						10	10
Proteaceae	*Banksia nivea*	Shrub	Native to site	F			10			10	10
Scrophulariaceae	*Eremophila glabra*	Shrub	Native - WA	F			10			10	
Proteaceae	*Grevillea bipinnatifida*	Shrub	Native - WA	F			10	10			
Proteaceae	*Hakea lissocarpha*	Shrub	Native - WA	F			28				
Proteaceae	*Hakea prostrata*	Shrub	Native - WA	F			20	10			
Proteaceae	*Hakea ruscifolia*	Shrub	Native - WA	F							5
Proteaceae	*Hakea trifurcata*	Shrub	Native - WA	F			20				
Proteaceae	*Hakea undulata*	Shrub	Native - WA	F							5
Proteaceae	*Hakea varia*	Shrub	Native - WA	F				20	20		
Fabaceae	*Jacksonia furcellata*	Shrub	Native to site	F				20	20		
Myrtaceae	*Kunzea glabrescens*	Shrub	Native to site	F					20		
Proteaceae	*Persoonia saccata*	Shrub	Native - WA	F			10				
Xanthorrhoeaceae	*Xanthorrhoea preissii*	Grass/Tree	Native to site	F			100	50		50	50

PART 1: INTRODUCTION

1.0 PROJECT BACKGROUND

Curtin University is planning to undergo significant changes over the next 20 years, predominantly associated with infill development of the western half of their property as part of securing a sustainable economic future for the university. In July 2013 Curtin University (Curtin) developed the Greater Curtin Masterplan 2013 (Masterplan) which provides spatial strategies to support Curtin University's Vision *"To be an international leader in research and education – changing minds, changing lives and changing the world".* The Masterplan supports the aspirations of the Western Australian (WA) Government's strategic plan for Perth and Peel – Directions 2031 and beyond and advances on the previous Curtin Town Structure Plan which was completed in 2011.

The Masterplan will be implemented in stages, with the first stage being the Main Street Project expected to be completed in the 2014 – 2015 time period. This stage of works is concerned with redesign of the existing transport network within the northern portion of the Main Campus. The aims of the project are to improve the public transport infrastructure and facilitate better connections to the surrounding road networks. Other stages of work will follow incrementally, with the Masterplan outlining 4 stages of works over the 20 year period between 2015 and 2030. However, it is possible that these works may be extended over a longer time period (30 – 40 years). Implementation of the Masterplan will impact on the existing area of trees and remnant vegetation, which are also under threat due to the natural decline of many of the mature tree species, predominantly pines planted in the 1930's when the primary land use of the site was a pine plantation. As with many other remnant areas in Perth, the loss of native and exotic trees has implications for key fauna species, particularly cockatoos, that use these trees for roosting, nesting and/or feeding. Two key fauna species are known to use vegetation at the Bentley Campus of the Curtin University. Large portions of the campus form part of a locally and regionally significant roost and feeding site for the endangered Carnaby's Black Cockatoo (*Calyptorhyncus latirostris)* and a feeding site for the vulnerable Red Tailed Black Cockatoo (*Calyptorhynchus banksii naso*). In recognition of the importance of campus vegetation to these iconic birds Curtin University aims to preserve the habitat currently used by these Black Cockatoos and where possible improve it so it is sustainable for future.

Hence, Curtin is interested in understanding how to reduce these impacts and improve the habitat of the Black Cockatoos within the university land and associated areas.

2.0 SCOPE OF WORKS

Syrinx Environmental PL (Syrinx) was appointed by Curtin in September 2013 to develop a Tree Replacement Plan (TRP) to improve habitat for Black Cockatoos with the aim of mitigating the loss of habitats due to future developments and to increase available habitats through habitat retention and plantings. The term 'Black Cockatoo' will be used in this report to denote both Carnaby's and Forest Red Tailed Black Cockatoo. The TRP encompasses the Bentley Campus with the Kurrajong Village (Main Campus), Guild House, Erica Underwood House and the Lot 85 (collectively referred to as Curtin properties on Kent Street) and the properties at Technology Park.

The preparation of this TRP involved the review and analysis of the Greater Curtin Masterplan, heritage, environmental (particularly Black Cockatoo information) and aboricultural data consultation with the stakeholders including local government area representatives, Department of Parks and Wildlife representatives (DPaW), indigenous elders, nurseries, research organisations and horticulturalists.

The TRP reflects the vision and recommendations of the Greater Curtin Masterplan and is guided by the principles outlined in the Curtin University Urban Forest Management Plan (RPS, 2012) and Biodiversity Study (Syrinx, 2012). In addition it is reflective of the City of South Perth and Town of Victoria Park Biodiversity Plans and Street Tree and Verge Planting guidelines and policies. The scope included:

- Assessment and mapping of existing Black Cockatoo habitats and corridors based on the existing literature, the field assessment, and consultation with the:
  - Department of Parks and Wildlife (DPaW);
  - City of South Perth and Town of Victoria Park.
  - Indigenous representatives / elders.
- Assessment of existing feeding and roosting habitats including tree and shrub species comprising these.
- Mapping of feeding and roosting habitats as well as their connections with the regional corridors and the nearby Collier Golf Course.
- Assessment of the connection of feeding and roosting habitats to indigenous stories and dreamtime trails.
- Determining the impacts of the proposed Greater Curtin Masterplan on the BC habitat;
- Determining habitat trees (and vegetation) likely to be lost as a consequence of aging or current drought stress;

- Proposing a tree replacement plan (including suitable areas, species list , likely lifespan, availability from nurseries, disease susceptibility, approximate number, planting density, and planting schedule) to ensure no net loss of food sources and roosting areas for Black Cockatoos in the next 30 years.
- Ensuring that the proposed planting / tree replacement provides connection with the local and regional biodiversity corridors, and is in line with the current plans by the LGAs.

Curtin University together with Aurora Environmental Consultants submitted a referral to the Department of Sustainability, Environment, Water, Populations and Communities (SEWPaC) for a permit to clear vegetation for the Main Street Project (predominantly pine trees). These trees are known foraging and roosting habitat for the Black Cockatoo. The offsets provided in the referral are considered in this plan together with the existing available literature on the environmental values of the site. The Department of Environment decision was made on the 27th of November, noting that the action under the proposal was not considered a controlled action under the Federal *EPBC Act 1999.*

3.0 CONSULTATION

This tree replacement plan was developed in consultation with the following individuals and organisations:

- Dr. Odile Pouliquen-Young, (Environmental Sustainability Manager - Properties – Sustainability), Allyson Mullane (Manager, Parks and Gardens), Nathan Sadler (Project Coordinator - Properties – Sustainability) – Curtin University;
- Dr. Geoff Barrett, (Regional Ecologist - Swan Region) and Christine Groom (Research Officer (Carnaby's Black Cockatoo)) – Department of Parks and Wildlife (DPaW);
- Julie Ophel (Environmental Officer - City Environment), Yulia Volobueva (City Environment Coordinator) and John Murray (Streetscapes and Environment Supervisor) – City of South Perth.
- Brendan Nock (Environmental Officer) and Penny Fletcher (Technical Officer - Park Life) – Town of Victoria Park;
- Ron Johnstone (Curator, Ornithology Terrestrial Vertebrates) - Western Australian Museum
- Associate Professor Michael Calver (Associate Professor, Academy, School of Veterinary and Life Sciences, Environmental & Conservation Sciences) – Murdoch University;
- Professor William Stock (Prof. of Environmental Management) – Edith Cowan University;
- Dr Trudy Paap - Centre of Excellence for Climate change, Woodland and Forest Health (Murdoch University)
- Dr Elaine Davison - (Curtin University) Dieback Working Group;

- Juanita Ciampini, (Technical Officer, Vegetation Health Services (V.H.S.) Laboratory) - Department of Parks and Wildlife;
- Western Power, Water Corporation, Department of Agriculture and Food, and several plant nurseries (see Appendix 3, Table 2).

A number of elders were contacted, with two key elders, Kim Collard and Dr Noel Nannup agreeing to meet and discuss information with regards to Black Cockatoo.

- Kim Collard (Kooya Consultancy. website: www.kooya.com.au)

  Formally a Professor at Curtin University, but has since retired and founded his own business, Kooya Consultancy, which works to educate both Aboriginal and non-Aboriginal peoples on the indigenous peoples of Australia.

- Dr Noel Nannup

  Noel Nannup is a Nyungar/Injabarndi man who has worked to promote public awareness of the importance of caring for the environment. His career has been dedicated to educating young Western Australians about the rich cultural heritage of Aboriginal people and their lands; and, throughout that process, Noel has played an active and leading role in reconciliation.

Consultation included individual discussions with elders and research paper authors, as well as a forum workshop with representatives from Curtin, DPaW, City of South Perth, Town of Victoria Park and Curtin University representatives (listed above).

Forum discussions included the impacts of the proposed Masterplan and opportunities for collaborative work as well as opportunities and recommendations as to how the habitat for Black Cockatoos can be conserved and or improved. Any details concerning the habitat improvement and plans for the Collier Golf Course were shared as well as the plans for extending the habitat for Black Cockatoos within the George Street Reserve which is adjacent to the Kensington Bushland to the north of the campus.

PART 2: PROJECT CONTEXT

4.0 SITE DESCRIPTION

The Curtin University is located in Bentley, Western Australia, some 6 km south east of the Perth Central Business District (CBD). The Bentley Campus and its properties are located within the Local Government Areas (LGAs) of the Town of Victoria Park and the City of South Perth (Figure 1). Curtin's properties include the Bentley Campus (which includes Kurrajong Village), buildings within the Technology Park located to the north of the campus, Erica Underwood and Guild House student housing and Lot 85 (empty lot) on Kent Street west of campus. **Please note**: Vickery House (also a Curtin property to the south east of the Bentley campus) does not form part of the Masterplan or this TRP.

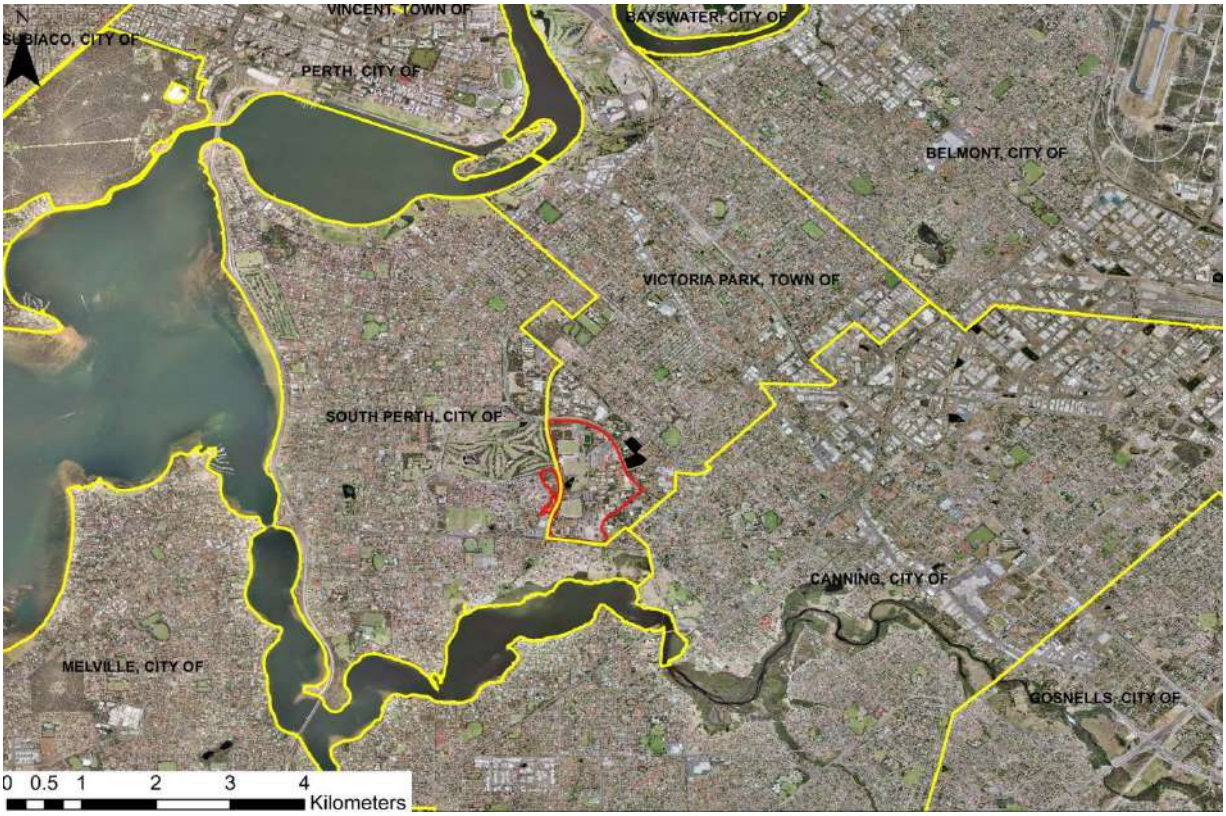


Figure 1 Location of the Bentley Campus and properties on Kent street and in Technology Park

At the most immediate level the study area is surrounded by residential, education, recreational and research and commercial precincts. The southern boundary of the site is less than 500 m from the Canning River and the nearest Bush Forever Site (Bush Forever 333) and less than 250 m from the nearest wetland at Cygnia Cove. To the north (approximately 1km away) is the Kensington Bushland (Bush Forever site 48) (see Figure 2).

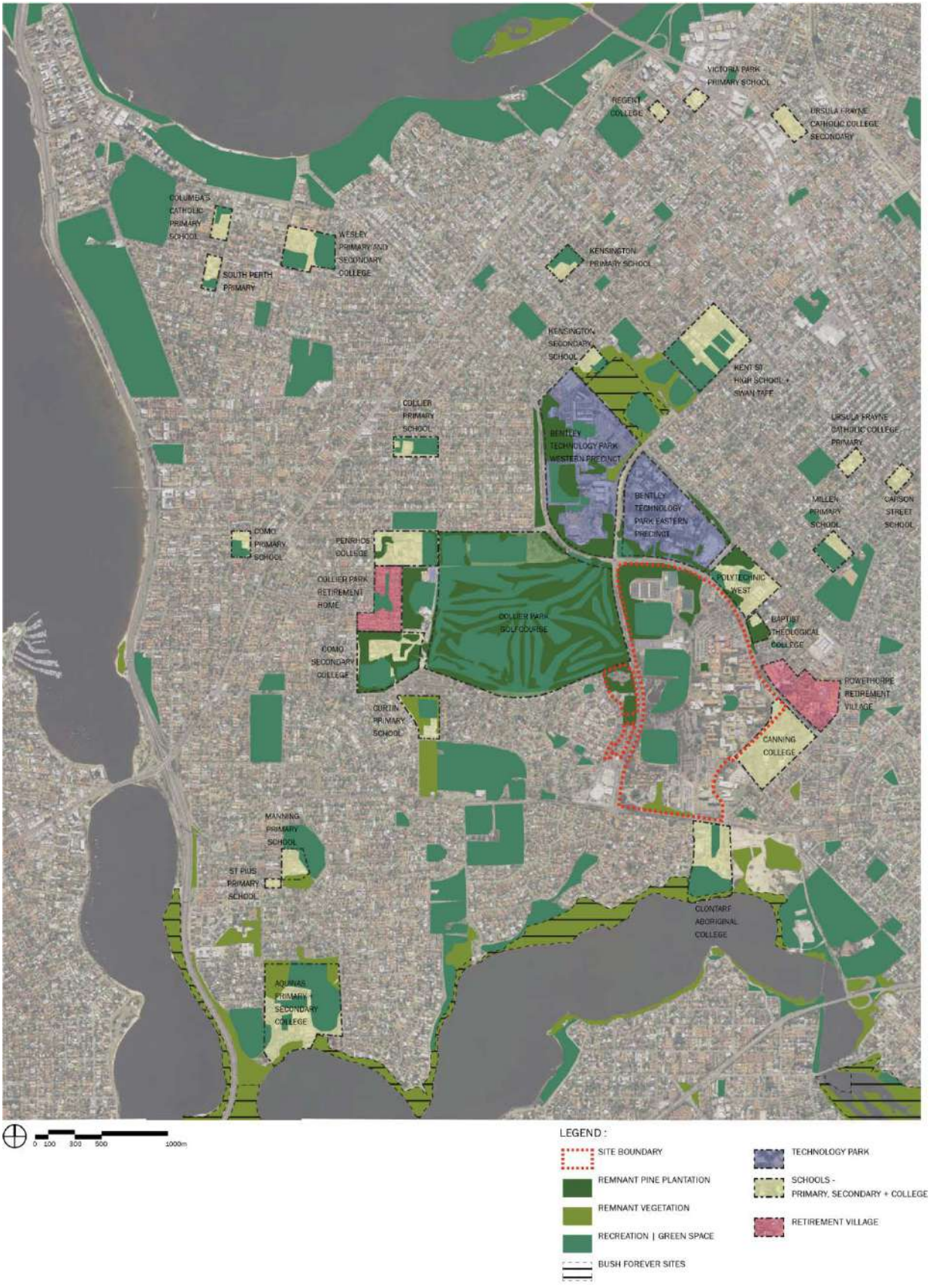


Figure 2 Location of Curtin properties in relation to the surrounding land uses.

4.1 PHYSICAL ENVIRONMENT

The Bentley Campus of Curtin University, its properties and the surrounding environment are located on the Bassendean Sand Dune system on the Swan Coastal Plain (SCP). The topography of the area is undulating and consists of dunal ridges, with a high ridge along the eastern boundary and grading down to interdunal depressions to the west. The highest variability in topography is found at the main campus where elevations range from 22.5 m, Australian Height Datum (AHD) in the academic core to 7.5 m AHD and 10m AHD to the south near Manning Road.

Historically the site supported a number of wetland systems. Today most have been filled with only Jack Finney Lake on the western side of the campus and to the south remaining. This chain of wetlands would have been surface expressions of groundwater, suggesting a former paleodrainage line (Curtin City Project Group, 2013).

4.2 BIOLOGICAL ENVIRONMENT

The Bentley campus, its properties and the surrounding environment are located on Bassendean sands which would have typically supported vegetation of the Bassendean Complex – Central and South. This vegetation complex is characterised by Jarrah – Sheoak – Banksia on the sand dunes with a low woodland of *Melaleuca* spp. and sedgelands on the low lying areas and depressions (Heddle et al., 1980). Common plants found in this complex are *Banksia attenuata* and *Banksia menziesii* with *Eucalyptus marginata* (Jarrah) on the upper ridges and slopes with *Banksia ilicifolia, Banksia littoralis* and *Melaleuca preissiana* on the lower lying moister soils where *Corymbia calophylla* (Marri) replaces Jarrah in dominance The closest natural bushland remnant indicative of this type of vegetation is located at Kensington Bushland 1 km north of the main campus boundary.

Given the proximity to the Canning River and the topographical features of the area, *Eucalyptus rudis* (Flooded Gum) would have occurred naturally on site, particularly to the south of the campus surrounding wet winter depressions and in swales connecting the chain of wetlands to the south west of the site to the Canning River (Syrinx, 2012).

5.0 THE MASTERPLAN

The Greater Curtin Masterplan provides strategies to support the future development of the campus which will infill or replace some buildings within the academic core as well develop new infrastructure and buildings in areas previously occupied by turf, parkland and landscaped gardens.

The proposed Masterplan is provided in Figure 3. Whilst the plan outlines new buildings within Lot 85 and the area currently occupied by the Guild House, they are not presented in the Masterplan documentation, however it is expected that development in these areas will also occur.

The Masterplan currently excludes Lot 85, Guild House, Erica Underwood House and the Curtin Properties within Technology Park. Therefore the Masterplan impacts in this document are only discussed for the Bentley Campus.

The Masterplan proposes a mixed land use development which incorporates academic, research, commercial, retail and residential buildings. New roads and a light rail network are also envisaged. A 'living stream' forms the main POS spine running south to north through the development, linking existing and former wetlands and forming the main drainage network. Other green spines are proposed along an east-west axis within the Bentley Campus and proposed new areas, and green roofs proposed for a significant number of predominantly academic buildings to assist in forming biodiversity linkages, as well as providing sustainable building benefits. The outline of the land use activity and the ground floor area (GFA) they will occupy is presented in Figure 4.

Figure 3 Greater Curtin Masterplan (Curtin University, 2013).

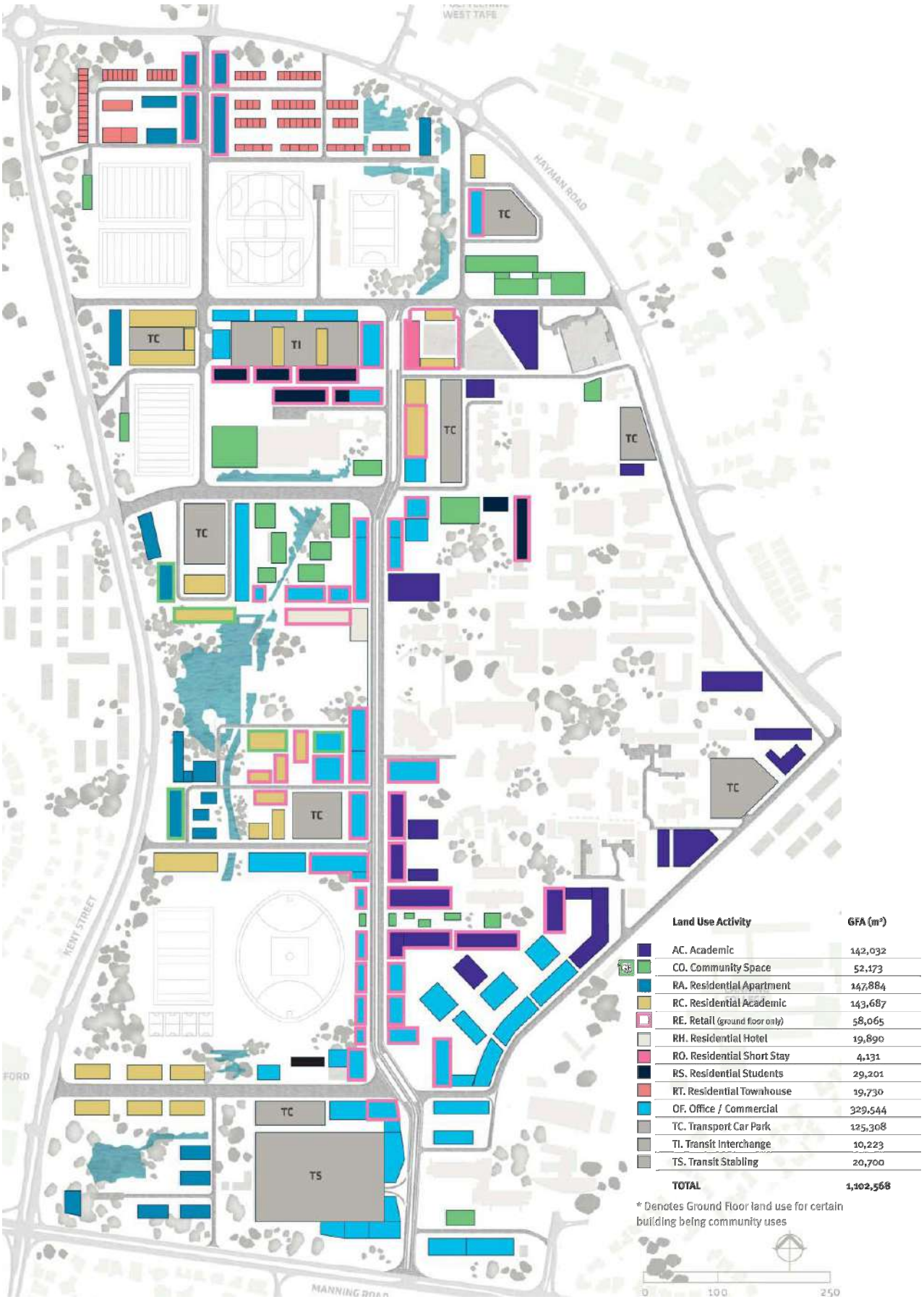


Figure 4 Land Use outline for the Greater Curtin Masterplan (Curtin University, 2013).

5.1 STAGING

The delivery of the Masterplan is proposed over four stages each lasting approximately 5 years. All stages relate to the development within the Bentley Campus boundary with no building development specified for the Curtin properties in Technology Park or on Kent Street. Figure 5 shows the stages of development as presented in the Masterplan document (Curtin University, 2013). Staging for road development and Public Open Spaces (POS) (other than the living stream) has not been presented in the Masterplan, however is likely to progress in tandem with the staging of the development.

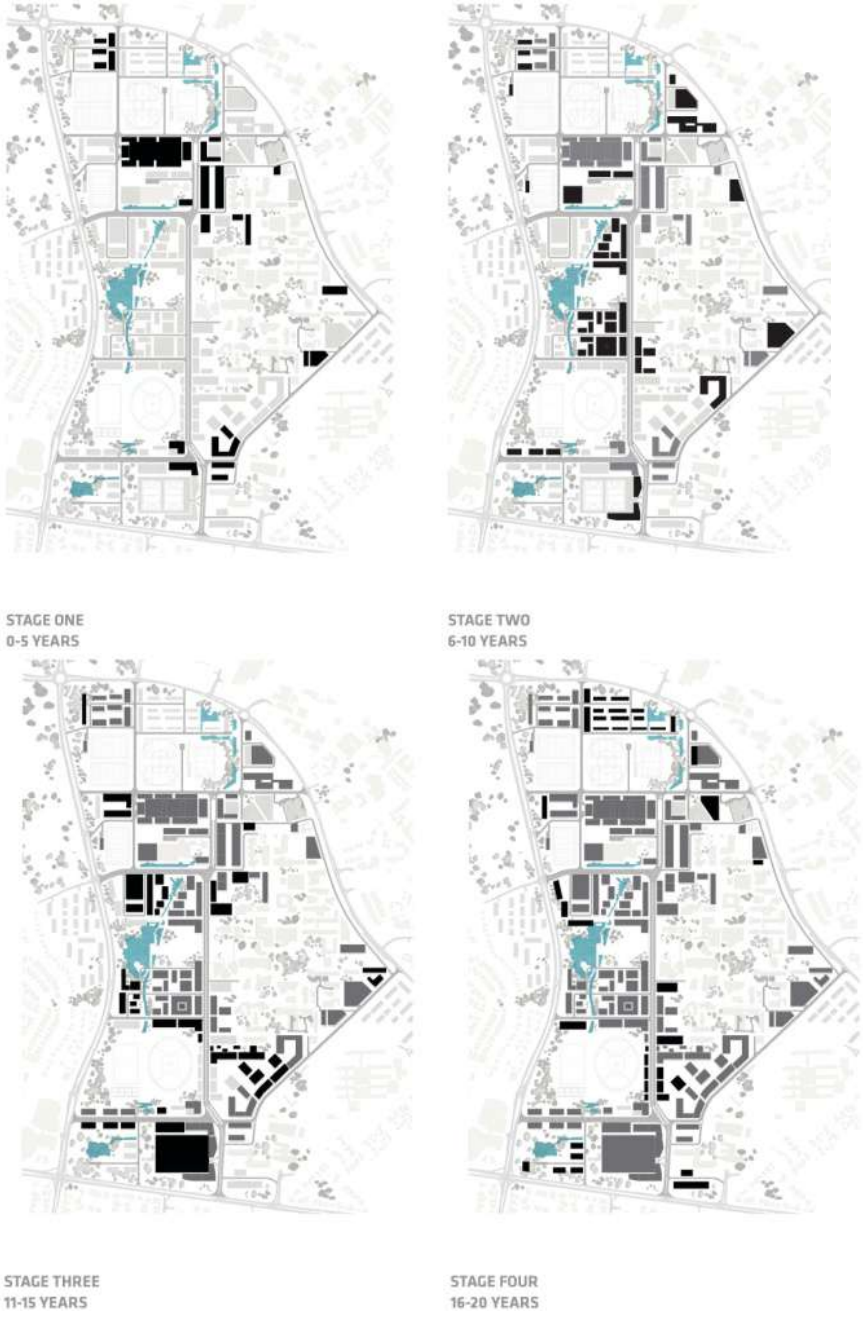


Figure 5 Proposed staged delivery of the Greater Curtin Masterplan (Curtin University, 2013).

6.0 BLACK COCKATOOS AND CURTIN UNIVERSITY

Two species of Black Cockatoo have been recorded using the Bentley Campus for feeding and/or roosting; these are the Carnaby's Black Cockatoo (*Calyptorhyncus latirostris*); the other is commonly called the Forest Red-tailed Black Cockatoo (FRTBC: *Calyptorhynchus banksii naso*).

6.1 CARNABY'S BLACK COCKATOO

Carnaby's Black Cockatoo have been recorded to roost and feed within the Bentley Campus area and together with the adjacent Collier Park Golf Course, the campus forms one of the largest super roost areas in the Swan region (Kabat et al., 2012a and 2012b). Counts over the past few years have indicated that this roost along with Manning Lake appear to be supporting more birds each year. It is possible that clearing pressures throughout the city are driving more and more birds to use these sites. However, many large pines continue to be cleared in the Bentley roost (Kabat et al., 2012a). As identified by Kabat et al (2012a) all large trees (> 8m) within a 500 m radius of core roosting habitat (small roosts < 150 birds) and within 1 km around the centre of large roosts (> 150 birds) are potential roosting habitat and where possible should be retained.

On the Swan Coastal Plain Carnaby's Black Cockatoos favour tall native or introduced Eucalypts (e.g. Marri, Flat-topped Yate (*E. occidentalis*), Salmon Gum (*Eucalyptus salmonophloia*), Wandoo, Karri, Blackbutt, Tuart, Blue Gum (*Eucalyptus globulus*)) as well as exotic pines for roosting. Roost sites tend to be in close association to food and water resources as well as providing protection (Kabat et al., 2012a). Tall trees located high in the landscape are often favoured, but these trees must have a substantial canopy to ensure the birds are well protected from the elements and the birds favour areas with > 5 ha of clumped trees (Geoff Barrett *pers. com.*). Carnaby's Black Cockatoos roost singly with approximately 30 cm space between roosting birds (Johstone and Kirkby, 2008). They also favour the outer thinner branches of trees over those located deeper in the canopy. This habit exposes them to extreme weather if the tree canopy is sparse or not well developed (Christine Groom *pers. com.).*

Carnaby's Black Cockatoos feed on a range of food sources including seeds and flowers of proteaceous shrubs and trees (*Banksia*, *Hakea* and *Grevillea*), myrtaceous trees within remnant heath and woodland habitats, as well as Jarrah (*Eucalyptus marginata*), *Allocasuarina* spp., Marri (*Corymbia calophylla*) and a range of introduced species most notably the seeds of plantation pine (Stock et al 2013). With only 40 % of the birds former feeding habitat remaining (Geoff Barrett *pers. com*.), the trees at the Bentley Campus contribute substantially to the birds available food sources in the area.

6.2 FOREST RED-TAILED BLACK COCKATOO

Until recently all feeding, nesting and roosting areas of these cockatoos were confined to the hill region of Perth — where they resided in the tall marri, and jarrah forest. However, they have been increasingly recorded moving onto the SCP for feeding (mostly on the introduced tree: Cape Lilac, *Melia azedarach*: Johnstone and Storr 1998) and there are now records of breeding on the plain in artificial nesting boxes (Mayne 2011, Manning, 2012). Movements onto the SCP are irregular but they have now been seen there almost every month of the year. The FRTBC roost clustered together in family groups on thick protected perches under the canopy of tall trees (Johnstone and Kirkby 2008).

The FRTBC is an arboreal feeder which primarily feeds on the seeds of Marri and Jarrah. Other foods include Sheoak, Snottygobble, Blackbutt and introduced plant species including Cape Lilac (*Melia azedarach*) and Lemon Scented Gum (*Corymbia citriodora*, Johnstone and Kirkby 1998). They have also been recorded feeding on Mountain Marri, *Corymbia haematoxylon* (Johnstone and Cassarchis, 2004). Cooper et al (2003) identified that Marri is the principle food source for FRTBC and noted that birds will selectively choose Marri trees with high fruit yield. These trees typically had on average four fruit per pod, while trees with low yield or only male nuts were avoided. The FRTBC is not known to eat pines. Immature birds have been recorded to take up to three times as long to open the seeds of Marri or Jarrah compared to adults (Johnstone *et al.,* 2013).

FRTBC roost clustered together in family groups on thick protected perches under the canopy of tall trees (Johnstone and Kirkby 2008). They nest in large hollows of old trees > 209 years old (Johnstone *et al* 2013). Nests are usually 6.5 m to 33 m above ground and nesting trees on average have a breast height circumference of 2.79 m (Johnstone *et al.,* 2013). Birds often have to compete with other hollow users including feral bees. The species usually only lays a single egg (occasionally two) and the juvenile bird will remain with the adults for up to 2 years post fledgling (Johnstone *et al* 2013).

6.3 CARNABY'S BLACK COCKATOO RECOVERY PLAN

Under the 2012 Carnaby's Black Cockatoo Recovery Plan (DEC 2012) there are a number of primary performance criteria that are of direct relevance to the development of the Bentley Campus. The Recovery Plan must achieve a series of performance criteria in relation to feeding habitat and roosting as well as those relating to breeding success, within a ten year period, in order for it to be deemed successful (DEC, 2012). The subset of performance criteria that is of direct relevance to roosting and foraging habitat at the Bentley Campus are detailed below:

1. Estimates of the number of birds and proportion of juveniles across the entirety of known (standardised) night roost sites across the range of the species remains stable or increases, averaged over three consecutive years.

2. The extent of nesting habitat (trees with nesting hollows), feeding habitat (as defined by vegetation complexes or suitable revegetation), and night roosting habitat (as identified through community survey) are maintained throughout the species range.

The Recovery Plan will be deemed to not be successful if, within a ten year period, any of the following occur (note not all criteria are listed):

- The estimated number of adult and proportion of juvenile Carnaby's Black Cockatoo at known night roost sites decreases by more than 10 % averaged over three consecutive years.

- The extent of nesting habitat (trees with nesting hollows), feeding habitat (as defined by vegetation complexes), and night roosting habitat (as identified through community survey) decreases by more than 10 % throughout the species range.

As stated under the recovery plan the action of direct relevance to the Bentley site is to:

'Protect and Manage Important Habitat '.

Complete restoration of the original extent of Carnaby's Black Cockatoo habitat is not possible. It is therefore important to identify those parts of the species' habitat most critical to survival and to protect and manage as much of this important habitat as possible to minimise the impacts of habitat loss. While planting of species that support Carnaby's Black Cockatoo is effective over the long-term and encouraged, protection and regeneration of existing habitat is significantly more efficient and effective. Therefore efforts in this Recovery Plan are primarily directed towards protection and enhancement of existing habitat.

The reproductive output of Carnaby's Black Cockatoo is primarily limited by factors associated with habitat and food requirements during the breeding season. However, sufficient habitat and food resources during the non-breeding season are also critical for both the survival of young and in conditioning breeding birds. Therefore, Recovery Actions have been directed towards the protection of both breeding and non-breeding habitat.

6.3.1 FRTBC Recovery Plan

Although the historic range of the FRTBC included the Perth region, the bird was rarely sighted on the SCP post the early 1900s and the northern range of the species became restricted to remnant vegetation associated with the Darling Scarp. It is possible the largely sedentary nature of the species (Johnstone et al., 2013) restricted its capacity to remain in

historical areas once many of the large nesting and feeding trees had been removed from the plain of the Swan region. However since 1995 there has been a dynamic change in the foraging ecology of many birds in the northern Darling Range, driven primarily by their discovery of the Cape Lilac as a new food source (Johnstone et al., 2013). This has led to a slow expansion of the foraging range with movement of flocks west from the edge of the Darling Scarp onto the SCP.

The 2008 recovery plan is primarily focused on preservation and maintenance of existing natural foraging, nesting and roosting habitat, specifically the marri, jarrah and karri habitats of the northern and southern Jarrah Forest subregions of south-west Western Australia receiving more than 600 mm of rain annually (DEC, 2008). The Recovery Plan 2008 acknowledges that the FRTBC is now frequently observed feeding on Cape Lilac on the SCP.

Action 14.7 of the recovery plan states: "determine and implement ways to minimise the effects of mining and urban development on habitat loss." (DEC, 2008). This action specifically relates to the clearance of jarrah, marri and wandoo forests in south-west Western Australia and is of some relevance to the Bentley Campus with the presence of remnant marri and jarrah species onsite.

Although the generalised distribution of the FRTBC is known, detailed information on the current distribution and habitat that is critical to survival and important populations is unknown. Many actions within the recovery plan relate to the collection of this vital information and it is likely that with increased survey efforts to identify the species feeding and roosting habitat as part of the 2008 Recovery Plan aims, later recovery plans will emphasise the importance of feeding and nesting habitats on the SCP and potentially the Bentley Campus.

6.3.2 Implementation of Recovery Plans for Black Cockatoos

The Department of Environment and Conservation has statutory responsibility for the implementation of the *Conservation and Land Management Act 1984* and the *Wildlife Conservation Act 1950*. It has the lead responsibility for conserving the State's rich diversity of native plants, animals and natural ecosystems, and many of its unique landscapes (DEC 2013). The attainment of objectives and the provision of funding necessary to implement actions within all recovery plans is subject to budgetary and other constraints affecting the department and other parties involved, as well as other priorities (Dec 2008, 2012).

6.4 INDIGENOUS HERITAGE AND TRADITIONAL ECOLOGICAL KNOWLEDGE

"Traditional Aboriginal knowledge of ecological management is knowledge accumulated over more than 2000 generations. Our modern science of ecology is only two generations old" Anne Ross, Cultural Survival Quarterly Mar 2010

6.4.1 Indigenous Groups within the Southwest

The Swan and Canning Rivers are significant sites for Noongar people and as such are listed on the Register of Aboriginal Sites under the *Aboriginal Heritage Act 1972*.

Noongar people's country covers the entire south- western portion of Western Australia. The boundary commences on the west coast at a point north of Jurien Bay, proceeds roughly easterly to a point approximately north of Moora and then roughly south-east to a point on the southern coast between Bremer Bay and Esperance.

Yued, Whadjuk, Binjareb/ Pinjarup and Wardandi Noongar are made up of fourteen different language groups. Each Noongar group correlates with different geographic areas that have ecological distinctions.

6.4.2 Regulatory Changes Regarding TEK

TEK is now a core component of conservation legislation (e.g. Convention of Biological Diversity 2004 and Australia's key piece of environmental legislation, the EPBC Act 1999). The EPBC Act includes TEK in terms of 'a partnership approach to environmental protection and biodiversity conservation' that recognises and promotes 'indigenous peoples' role in, and knowledge of, the conservation and ecologically sustainable use of biodiversity'. Hence, TEK is seen as fundamental to contemporary natural resource management and, through this, to more resilient social-ecological systems (Prober *et. al.*, 2011).

Indigenous seasonal knowledge involving temporal knowledge of biota, landscapes, weather, seasonal cycles, and their links with culture and land uses is one type of TEK (Prober *et. al.*, 2011). Emerging applications include water management and climate change monitoring, with some programs currently underway in parts of Australia (e.g. The Iconic Trails Project coordinated by the Swan River Trust and managed by the South West Aboriginal Land and Sea Council in partnership with the Perth Region Natural Resource Management.) Examples of other policies which all recognize TEK as a valid knowledge system follow.

1. **National Conservation Policy**

The Australian Government has recently changed its approach towards a landscape conservation focus where ecological corridors and creating ecosystem resilience is seen as

an important component of protecting Australia's natural assets of National Environmental Significance. The Draft National Wildlife Corridors Plan released by the National Wildlife Corridors Plan Advisory Group (2012) is the Australian Government's strategy to restore and manage ecological connections in the Australian landscape. It recognises that connectivity is a fundamental requirement of healthy, productive landscapes. It was developed to achieve the aim of biodiversity conservation and sustainable land management that can be better integrated across Australian landscapes in ways that will improve the connectivity and resilience of our natural ecosystems (Environment Australia, 2012). The advisory group proposes a Wildlife Corridors Act as well as developing and supporting existing and prospective corridor initiatives.

"Connections...provide the opportunity to link the landscapes and when you do that for the first time in our history, you actually have a continent-wide template for environmental protection. Unless you acknowledge the entire ecology then you create an unthinkable situation for one of our most iconic species. To be able to allow an area like that to be eligible for a level of protection before we get to the line of last resort, I have to say is good public policy. So we will, as part of the reforms, be going ahead with the recommendations to establish ecosystems of national significance" The Hon Tony Burke MP, former Minister for Sustainability, Environment, Water, Population & Communities. Taken from Address to National Press Club Canberra 24 Aug 2011

2. Global Indigenous Network

In June 2012, Australian Government announced a new program to link indigenous expertise and modern technology to improve the way we manage our environment globally. Together with New Zealand, Brazil and Norway, Australia launched the World Indigenous Network (WIN) at the United Nations Conference on Sustainable Development (Rio +20) in Brazil.

The group's membership comprises of representatives from key Indigenous organisations around and key connections are being made with international and non-government organisations the first major step being the first WIN conference held in Darwin in May 2013 (WIN, 2013).

The aim of the program is to draw on traditions, knowledge and expertise of indigenous communities and people across Australia and the globe as well as cutting-edge science to better manage ecosystems (land and sea), protect the environment and support sustainable livelihoods (WIN, 2013)

3. Australia's Biodiversity Conservation Strategy 2010–2030

Natural Resource Management Ministerial Council has published Australia's Biodiversity Strategy 2010 – 2030 document in October 2010 (NRMMC, 2010) which presents a long-term view of a future in which:

- *the importance of biodiversity to our existence is recognised and, as a consequence, consumption patterns are balanced against the imperatives of the environment;*
- *all Australians including Indigenous peoples, farmers, land managers, industry, governments and community groups such as Landcare are working together to conserve biodiversity;*
- *we have reduced the impacts of existing threats such as invasive species so that their impact on biodiversity is negligible; and*
- *we have managed emerging threats such as changing fire regimes, reduction in water availability and the impacts of climate change to the extent that the threat to the environment is minimised and any damage is reversed*.

4. Australian Curriculum/ Australian Professional Standards for Teachers

By the end of 2016, all schools in Australia will be teaching the same content in English, Maths, Science, History and Geography. Across these five subjects are three cross-curriculum priorities, one of which requires Australian primary and secondary schools to engage in teaching Aboriginal and Torres Strait Islander histories and cultures (ACARA, 2013). This priority is divided across a framework of Country/Place, Culture and People and provides opportunities for all students to deepen their knowledge of Australia by engaging with the world's oldest continuous living cultures (ACARA, 2013).

6.4.3 Indigenous Engagement for this Project

Curtin University's vision is that it be a place of learning that respects indigenous culture and diversity (Curtin University's Reconciliation Action Plan). Understanding the value of the species to indigenous peoples acknowledges and accepts the indigenous link between country, community and wellbeing. Moreover, traditional ecological knowledge is forming a growing role in the development of habitat recovery and improvement plans, given the extensive knowledge period carried within the indigenous oral history, which can link an understanding of species abundance patterns with climate change, fire or other environmental events.

As such a number of aboriginal people with knowledge and/or authority to speak for this area were approached to discuss their knowledge of the birds, if they recalled Black Cockatoos using the area, if there was any knowledge of bird habitat use in the Perth region that might assist with this project, and to make recommendations from their perspective and knowledge base.

Eleven aboriginal sites of significance have been identified and registered with the Department for Indigenous Affairs (DIA) within a 2 km radius of the Bentley Campus. Jack Finney Lake is of particular importance (Aboriginal Heritage id 3304) as are the two springs

located on campus, all of which formed part of an aboriginal dreamtime trail (Dolphin Dreaming). This has been reflected in the Greater Curtin Masterplan, which has an intention of re-establishing and celebrating these trails (Greater Curtin Masterplan, 2013).

6.4.4 Indigenous Connections with Black Cockatoos

The following narrative was recorded by Jenny Hunter (Director, Sync7) through discussions with Noel Nannup and Kim Collard.

The Noongar language has twelve dialects and an alphabet made up of 17 letters (Whitehurst, 1992). The Black Cockatoo can be called "*munatj"* or "*ngoorlak*" (white tailed) or *yiibi* (red tail). "*Ngoolyanak*" means many black cockatoos (Whitehurst, 1992). Noel Nannup also identified that many people call them "*karrak*" (black tailed) or "*yibbi-gibram*".

It was clear that the Black Cockatoo provided an important link between aboriginal peoples and their land. Noel explained that aboriginal people believe that babies are born under moeities. If you were born under the tree where a particular species of bird resides you would adopt the moiety of that bird (e.g., White Cockatoo or the Red-Tailed Black moiety). The moiety formed part of the kinship system and determines the laws that govern your life, including who you can marry (Kim Collard *pers. com* and Noel Nannup *pers. com*.).

"When a child is born in the natural environment the mother buries the placenta under the tree. That tree becomes me — that's how we're connected." Noel Nannup

6.4.5 Traditional Ecological Knowledge of Black Cockatoos

Noel Nannup

Noel Nannup identified that *"black cockatoos only ever visited and went through* [the campus area prior to development]. *Now they come and stay. Nesting sites have disappeared out of further areas."* He noted that Carnaby's Black Cockatoo now reside at the site but there were fewer red-tails. He explained that the Black Cockatoos favoured "*really hard nuts*" and indicated that as a native bird species they should have access to native food

"Native bird = native food. Marri will benefit all cockatoos."... "may be chemicals in introduced trees. Birds are looking for trees that transpire the sweetest oxygen. The birds stay there for a while and it helps with flight. Reading the landscape — it has to be natural."

Noel noted that he felt Carnaby's Black Cockatoo were in more trouble than the red - tails. He advised that we should look at developing corridors with other groups in the region where the cockatoos are also found e.g., Clontarf, Kent St, Department of Agriculture, DPaW,

Bentley TAFE, and Collier Park Golf Course which has a super roost. He also explained that it was important not to focus on just one species

"... everything is equal. Need to consider ethical responsibility".

Other points:

- The issue of canker in Marri trees (native fungus).
- Already many groups are researching in this area. Need to work collaboratively outside of Curtin Uni.

Kim Collard

Kim Collard did not speak specifically about the Back Cockatoos but reflected more on the changes to the landscape that now affect how all living things work.

"We have to protect as much native vegetation as we can. In the past, a possum could travel from Perth to Kalgoorlie through the treetops without ever touching the ground."

"Plants want to help people. They are part of the cycle, for example they provide seeds for the birds…the birds revegetate. Pines (PINE trees) use a lot of water. That's why nothing grows under the pines — can't sustain life because the pines take it all."

Kim discussed planting the right trees for the right conditions, advocating group planting as in nature.

"Branches wouldn't fall if trees stood side by side."

With reference to non-native trees planted today he referred to them as *"waarm boorn"* or *"stranger trees".* Kim Collard talked with Noel Nannup about how this would have affected the Aboriginal people. Noel reminded me that they would have sent the spirit down. And how it would have broken their hearts to be a part of destroying country. We also talked more about the history of Aboriginal people which of course feeds into the present.

We spoke about integrating TEK (traditional ecological knowledge) into the curriculum….weaving it into the different faculties.

"We have a saying….it takes many people to make a spear. Curtin Uni has the capacity to work together and listen to the voices of the First People. For example, students could find out what causes canker."

PART 3: ASSESSMENT AND MAPPING OF THE BLACK COCKATOO HABITAT

7.0 PRE- DEVELOPMENT

This section of the report presents the current status of the Black Cockatoo habitat at Curtin University Bentley Campus and the properties within Technology Park and Kent Street. The habitat descriptions are based on the roosting and feeding potential of the plants found within Curtin properties (trees and shrubs) known to be utilised by the Black Cockatoos in particular the Carnaby's Black Cockatoo. The *Plants Used by Carnaby's Black Cockatoo* list (DEC, 2011) and the available research articles and thesis were used to assess the habitats.

7.1 FEEDING HABITAT

The feeding habitat for Black Cockatoos at Curtin includes both native and non native trees, most notably the pine trees. Whilst many trees provide the seed or the flowers (nectar) for birds to feed on, some (e.g. *Agonis flexuosa*) provide habitat for grubs which birds then utilise.

Using the tree location data (Arbor Centre, 2012), available CAD drawings for tree canopy cover and the aerial photography, the extent of feeding habitat was mapped using cover of all trees considered to provide habitat for Black Cockatoos based on the currently available literature (Figure 6). The tree number forming the feeding habitat and their overall value to Black Cockatoos (based on how much of a habitat they provide e.g., roosting, feeding and nesting potential, their fecundity etc) is presented in Table 1.

Based on the mapping in Figure 6 the largest continuous feeding habitat is found in the north west section of the Bentley Campus, Lot 85 and trees surrounding the Guild House. There is a significant lack of feeding habitat to the south of the Bentley Campus and the Erica Underwood house. The reason for lack of habitat at Erica Underwood housing is due to dense building arrangement and selection of exotic trees and shrubs which are not of habitat value to Black Cockatoos. Likewise, previous clearing of vegetation has resulted in a lack of feeding habitat to the south of the Bentley Campus. In addition, historical imagery (1953 – 1965) of the area (Syrinx, 2012) shows that the southernmost section of the Bentley Campus adjacent to Manning Road did not appear to have been planted with pines but rather had remnant native vegetation. Native flora such as *Eucalyptus rudis* which is currently the dominant species in this area would have been likely to occur there naturally. This tree does not provide a feeding habitat for Black Cockatoo, however, it is utilised for roosting.

Figure 6 Black Cockatoo feeding habitat area for Curtin University and its properties.

Table 1 Feeding habitat trees and shrubs for the Curtin University's Bentley Campus and properties.

Family	Species	Common name	Form	Native/Introduced	Habitat (F= Feeding, R=Roosting, N= Nesting)			Priority for planting	Bentley Campus	Erica Underwood House	Guild House	Technology Park	Lot 85	TOTAL
Proteaceae	*Banksia attenuata*	Slender Banksia/ Coastal Banksia	Tree	Native to site	F			High	8					**8**
Proteaceae	*Banksia grandis*	Bull Banksia/ Giant Banksia	Tree	Native to site	F			High	6					**6**
Proteaceae	*Banksia ilicifolia*	Holly Leaved Banksia	Tree	Native to site	F			High	2					**2**
Proteaceae	*Banksia menziesii*	Firewood Banksia	Tree	Native to site	F			High	37					**37**
Myrtaceae	*Corymbia calophylla*	Marri	Tree	Native to site	F	R	N	High	90		1			**91**
Myrtaceae	*Eucalyptus gomphocephala*	Tuart	Tree	Native - WA	F	R	N	High	41		4			**45**
Proteaceae	*Banksia species*	Banksia	Shrub/Tree	Native - WA	F			Medium	52					**52**
Myrtaceae	*Callistemon* 'Indian Brook'	Indian Brook Bottlebrush	Shrub	Introduced	F			Medium	1			7		**8**
Myrtaceae	*Callistemon* 'Kings Park Special'	King's Park Special Bottlebrush	Tree	Native - WA	F			Medium	22	1	12	12		**47**
Myrtaceae	*Callistemon salignus*	White Flowering Bottlebrush	Tree	Introduced - AU	F			Medium	1					**1**
Myrtaceae	*Callistemon viminalis*	Bottlebrush	Tree	Introduced - AU	F			Medium	244	1				**245**
Cupressaceae	*Callitris preissii*	Rottnest Island Pine	Tree	Native - WA	F			Medium	51			4		**55**
Myrtaceae	*Corymbia citriodora*	Lemon Scented Gum	Tree	Introduced - AU	F	R		Medium	14			1		**15**
Myrtaceae	*Corymbia ficifolia*	WA Red Flowering Gum	Tree	Native - WA	F			Medium	84					**84**
Myrtaceae	*Eucalyptus caesia*	Silver Princess	Tree	Native - WA	F			Medium	34					**34**
Myrtaceae	*Eucalyptus caesia* ssp. *magna*	Silver Princess	Tree	Native - WA	F			Medium	64					**64**
Myrtaceae	*Eucalyptus caesia* subsp. *caesia*	Silver Princess	Tree	Native - WA	F			Medium		1				**1**
Myrtaceae	*Eucalyptus marginata*	Jarrah	Tree	Native to site	F	R		Medium	3		2			**5**
Myrtaceae	*Eucalyptus robusta*	Swamp Mahogany	Tree	Introduced - AU	F	R		Medium	63					**63**
Myrtaceae	*Eucalyptus todtiana*	Prickley Bark	Tree	Native to site	F			Medium				1		**1**
Proteaceae	*Grevillea* species	Grevillea	Shrub	Introduced - AU	F			Medium	50					**50**
Proteaceae	*Hakea laurina*	Pin Cushion Hakea	Shrub/Tree	Native - WA	F			Medium	36			1		**37**
Proteaceae	*Hakea* species	Hakea	Shrub/Tree	Native - WA	F			Medium	3					**3**
Altingiaceae	*Liquidambar styraciflua*	Liquidambar	Tree	Introduced	F			Medium	33	1		55		**89**
Pinaceae	*Pinus pinaster*	Cluster pine/ Maritime Pine	Tree	Introduced	F	R		Medium	1386	7	79	61	66	**1599**
Pinaceae	*Pinus radiata*	Monterey Pine	Tree	Introduced	F	R		Medium	1			21		**22**
Xanthorrhoeaceae	*Xanthorrhoea preissii*	Grass Tree	Grass/Tree	Native to site	F			Medium	94			7		**101**
Xanthorrhoeaceae	*Xanthorrhoea robusti*	Grass Tree	Grass/Tree	Native to site	F			Medium	2					**2**
Fabaceae	*Acacia baileyana*	Cootamundra wattle	Shrub/Tree	Introduced - AU	F			Low	10					**10**
Fabaceae	*Acacia baileyana purpurea*	Purple Leaf Cootamundra wattle	Shrub/Tree	Introduced - AU	F			Low	4					**4**
Myrtaceae	*Agonis flexuosa*	Weeping Peppermint Tree	Tree	Native - WA	F			Low	229		16	2		**247**
Myrtaceae	*Agonis flexuosa* 'After Dark'	Burgundy Weeping Peppermint	Tree	Hybrid of native to WA	F			Low	22			3		**25**
Myrtaceae	*Agonis flexuosa* 'Variegata'	Variegated Weeping Peppermint Tree	Tree	Hybrid of native to WA	F			Low	35					**35**
Araucariaceae	*Araucaria heterophylla*	Norfolk Island Pine	Tree	Introduced	F			Low	6					**6**
Casuarinaceae	*Casuarina cunninghamiana*	She Oak/ River Oak/ Fire Oak	Tree	Introduced - AU	F			Low	59	14	31	61		**165**
Casuarinaceae	*Allocasuarina fraseriana*	WA Oak	Tree	Native to site	F			Low	5			1		**6**
Moraceae	*Ficus carica* 'Black Genoa'	Edible Fig	Tree	Introduced	F			Low	6					**6**
Moraceae	*Ficus macrophylla*	Moreton Bay Fig/ Aust. Banyan	Tree	Introduced - AU	F			Low	1					**1**
Moraceae	*Ficus microcarpa* var.*hillii*	Hills Weeping Fig	Tree	Introduced - AU	F			Low	83					**83**
Moraceae	*Ficus religinosa*	Bo Tree/ Peepul Tree	Tree	Introduced - AU	F			Low	2					**2**
Moraceae	*Ficus rubiginosa*	Port Jackson Fig	Tree	Introduced - AU	F			Low	10					**10**
Bignoniaceae	*Jacaranda mimosifolia*	Jacaranda/ Brazilian Rosewood	Tree	Introduced	F			Low	104			6		**110**
Meliaceae	*Melia azedarach*	Cape lilac	Tree	Introduced	F			Low	8					**8**
Loranthaceae	*Nuytsia floribunda*	W.A. Christmas Tree	Tree	Native to site	F			Low	51		15		27	**93**
Fabaceae	*Tipuana tipu*	Pride of Bolivia	Tree	Introduced	F			Low	65					**65**
								Total	**2422**	**11**	**98**	**170**	**66**	**3643**

The assessment of tree (and shrub) canopy cover as shown in Figure 6 indicates that the Bentley Campus and its properties contribute approximately **20.4 ha of feeding habitat** for Black Cockatoos based on crown cover.

Of this, the largest proportion is found on the Bentley Campus which has approximately 17 ha of feeding tree and shrub habitat, with properties at Technology Park, Lot 85 and Guild House (having 1 to1.1 ha each). Erica Underwood House property has only 0.1 ha of feeding habitat by crown cover.

The list of species used by Black Cockatoos was based on the known foraging species for Carnaby's Black Cockatoo and FTRBC, however the hybrids of these plants *Ficus* and native *Callitris* species were also added. The species defined as forming suitable feeding habitat form 9 % of the total number of trees and shrubs. Out of a total of 3643 plants recorded as suitable feeding habitat, 3376 were trees and 267 were shrubs, grass trees or very small trees like *Callistemon* sp (note, these calculations include all hybrids and species such as *Ficus* and *Callitris*). Based on the value they provide for Black Cockatoo habitat (which includes feeding, roosting and nesting), 5 % of the habitat is considered to be of High, 71 % of Medium and 24 % of Low value.

In terms of feeding value for Cockatoos, the most important species is *Pinus pinaster* which is also the most numerous species on site and forms 44 % of total feeding habitat. The top ten feeding habitat trees and their respective contribution to the habitat based on tree numbers are presented in Figure 7.

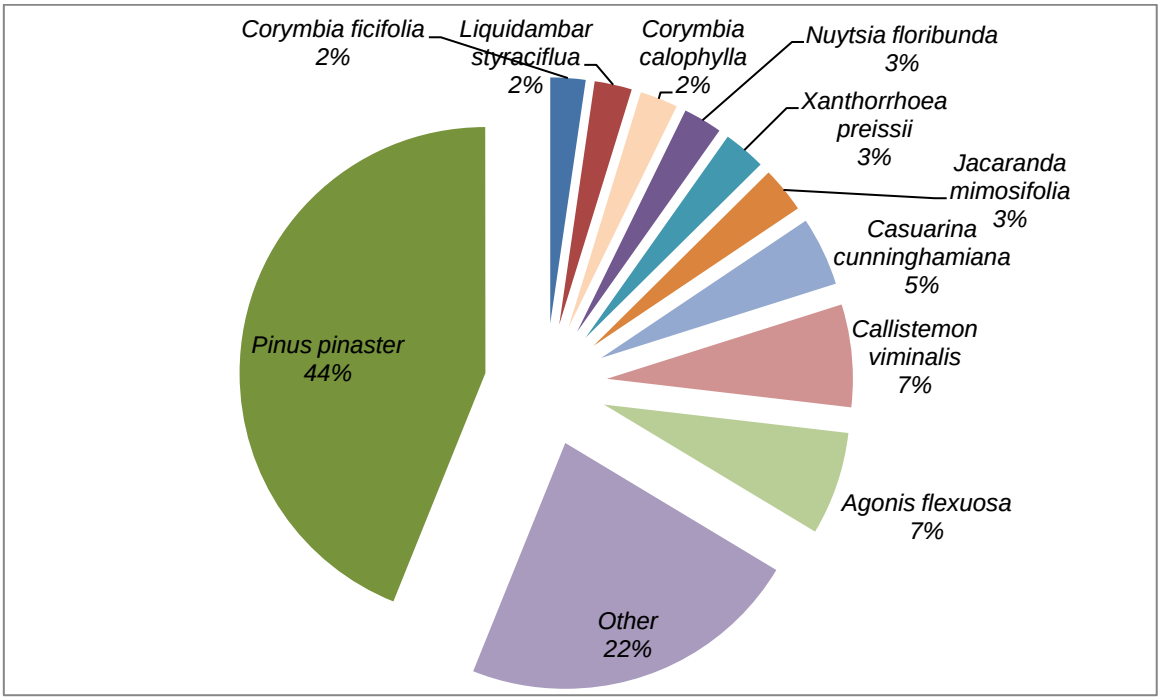


Figure 7 Percentage contribution of top ten feeding habitat species to the overall feeding habitat for Curtin and its properties

7.2 ROOSTING HABITAT

Roosting habitat in this report is defined by any tree which is known to be preferentially used by Black Cockatoos for roosting. This often includes trees utilised for food and nesting, however birds have been known to utilise trees for roosting only, mainly based on the height and crown cover of that particular tree (e.g. *Eucalyptus rudis* and *Eucalyptus camaldulensis*). The mapping of roosting habitat at Curtin and its properties was outlined by the crowns of roosting trees based on the species known to be utilised by Black Cockatoo for this purpose (from literature and observed roosting on site). Figure 8 shows the mapping of roosting habitat and an outline of the extent of the 2012 roost.

Figure 8 Black Cockatoo roosting areas for Curtin University and its properties.

The roosting habitat appears to be congruent with the feeding habitat with the significant difference being in the greater availability of roosting habitat in the southern section of the Bentley Campus (Manning Road) which does not offer feeding habitat for Black Cockatoos. This is contributed to by the dominance in this section of campus of *Eucalyptus rudis* and other Eucalypt species not used for food by the Black Cockatoos.

Based on the crown cover, a total of **22 ha of roosting habitat** was mapped for the Curtin properties with the largest portion (19.3 %) found on Bentley Campus. At the individual property level, the highest roosting habitat by crown cover is found at Lot 85 with 71 % of the total trees recorded being suitable for roosting. The Bentley Campus and Guild House had approximately 36 % of trees as a suitable species for roosting, Technology Park 25 % and Erica Underwood house only 8 %.

The most dominant roosting tree was *Pinus pinaster* comprising 58 % of the total number of roosting trees. *Corymbia maculata* and *Eucalyptus rudis* were the second and third most dominant roosting trees on site comprising 12 % and 9 % of the total roosting trees respectively (Figure 9 and Table 2). The roosting habitat is considered to be good due to mature pine trees, most of which are 10 m and above in height.

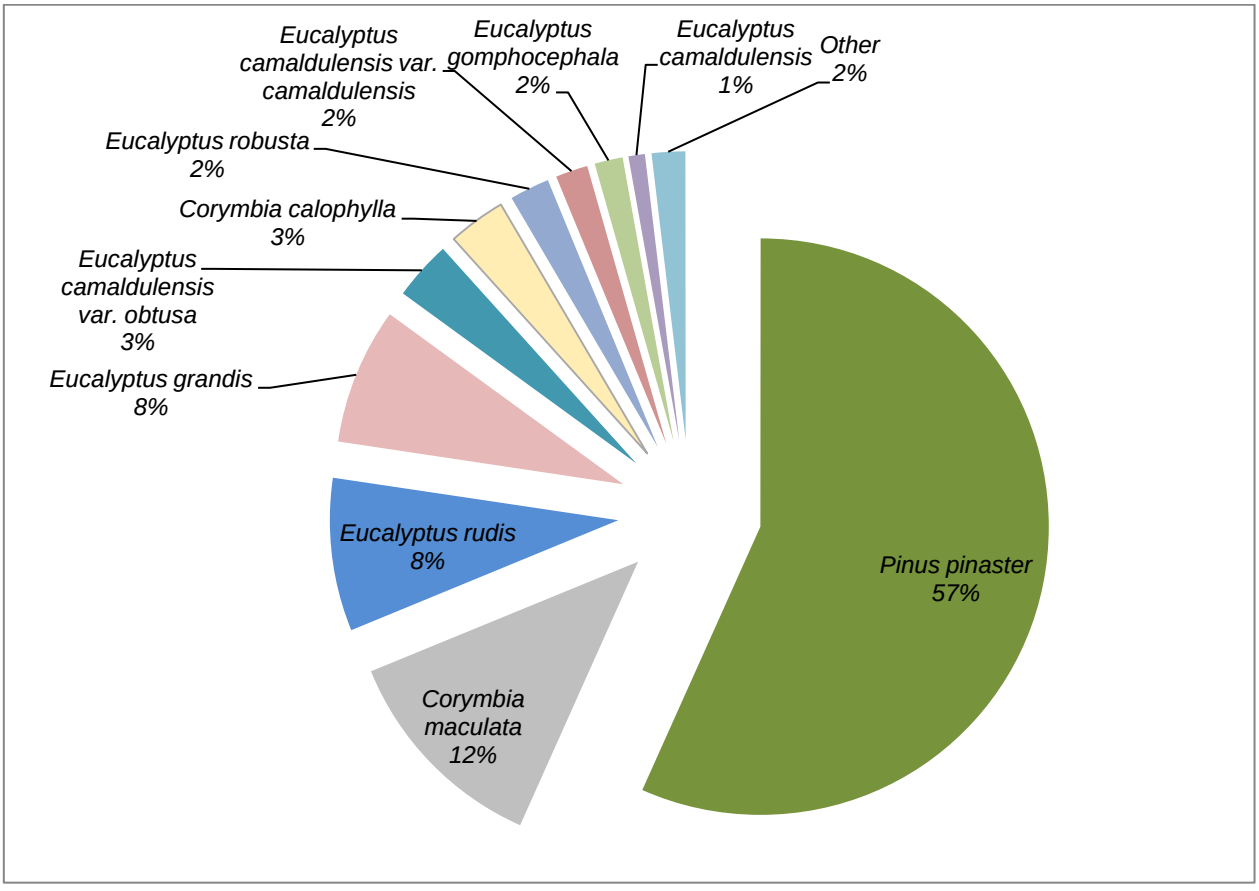


Figure 9 Percentage contribution of top ten roosting habitat species to the overall feeding habitat for Curtin and its properties.

Table 2 Roosting habitat trees and shrubs for the Curtin University's Bentley Campus and properties.

Family	Species	Common name	Form	Native / Introduced	Habitat (F= Feeding, R=Roosting, N= Nesting)			Priority for planting (based on overall value plant provides to Black Cockatoos)	Bentley Campus	Erica Underwood House	Guild House	Technology Park	Lot 85	TOTAL
Myrtaceae	*Corymbia calophylla*	Marri	Tree	Native to site	F	R	N	High	90		1			**91**
Myrtaceae	*Eucalyptus gomphocephala*	Tuart	Tree	Native - WA	F	R	N	High	41		4			**45**
Myrtaceae	*Corymbia citriodora*	Lemon Scented Gum	Tree	Introduced - AU	F	R		Medium	14			1		**15**
Myrtaceae	*Eucalyptus marginata*	Jarrah	Tree	Native to site	F	R		Medium	3		2			**5**
Myrtaceae	*Eucalyptus robusta*	Swamp Mahogany	Tree	Introduced - AU	F	R		Medium	63					**63**
Pinaceae	*Pinus pinaster*	Cluster pine/ Maritime Pine	Tree	Introduced	F	R		Medium	1386	7	79	61	66	**1599**
Pinaceae	*Pinus radiata*	Monterey Pine	Tree	Introduced	F	R		Medium	1			21		**22**
Myrtaceae	*Corymbia maculata*	Spotted Gum	Tree	Introduced - AU		R		Low	298	2		41		**341**
Myrtaceae	*Eucalyptus camaldulensis*	River Red Gum	Tree	Introduced - AU		R		Low	24		2			**26**
Myrtaceae	*Eucalyptus camaldulensis* var. *camaldulensis*	River Red Gum	Tree	Introduced - AU		R		Low	51					**51**
Myrtaceae	*Eucalyptus camaldulensis* var. *obtusa*	River Red Gum	Tree	Introduced - AU		R		Low	93					**93**
Myrtaceae	*Eucalyptus globulus*	Tasmanian Blue Gum	Tree	Introduced - AU		R		Low	11					**11**
Myrtaceae	*Eucalyptus grandis*	Rose Gum/ Flooded Gum	Tree	Introduced - AU		R		Low	212		4			**216**
Myrtaceae	*Eucalyptus rudis*	Flooded Gum / Flooded Red Gum	Tree	Native to site		R		Low	242					**242**
								Total	**2529**	**9**	**92**	**124**	**67**	**2820**

7.3 FEEDING AND ROOSTING HABITATS ADJACENT TO CURTIN

The closest feeding and roosting sites to Curtin (within 6 km radius) are those located to the west and north of the Bentley Campus, with the largest areas being Collier Park Golf course, Technology Park, and Kensington Park to the north and the riparian vegetation to the south lining the shores of the Canning River. Several parks and home gardens also provide a small amount of food and potential roosting sites for cockatoos.

The most significant roost site adjacent to Curtin is Collier Golf Course. This is the largest roost site in the Perth Metropolitan region and thus very significant to the Carnaby's Black Cockatoo in particular. Collier Golf Course and the remnant pines at Curtin and Technology Park form the largest area of available habitat containing tall trees with interlocking canopies that are also a significant food source. The location of the roost sites closely corresponds with the tree height, with Cockatoos appearing to choose trees which are taller than 10m for roosting, as shown in Figure 10. The image of urban tree height was created by CSIRO Urban Monitor based on 2007 digital imagery and was sourced from *Capital City Planning Network : A Vision for Central Perth* (Department of Planning, 2013).

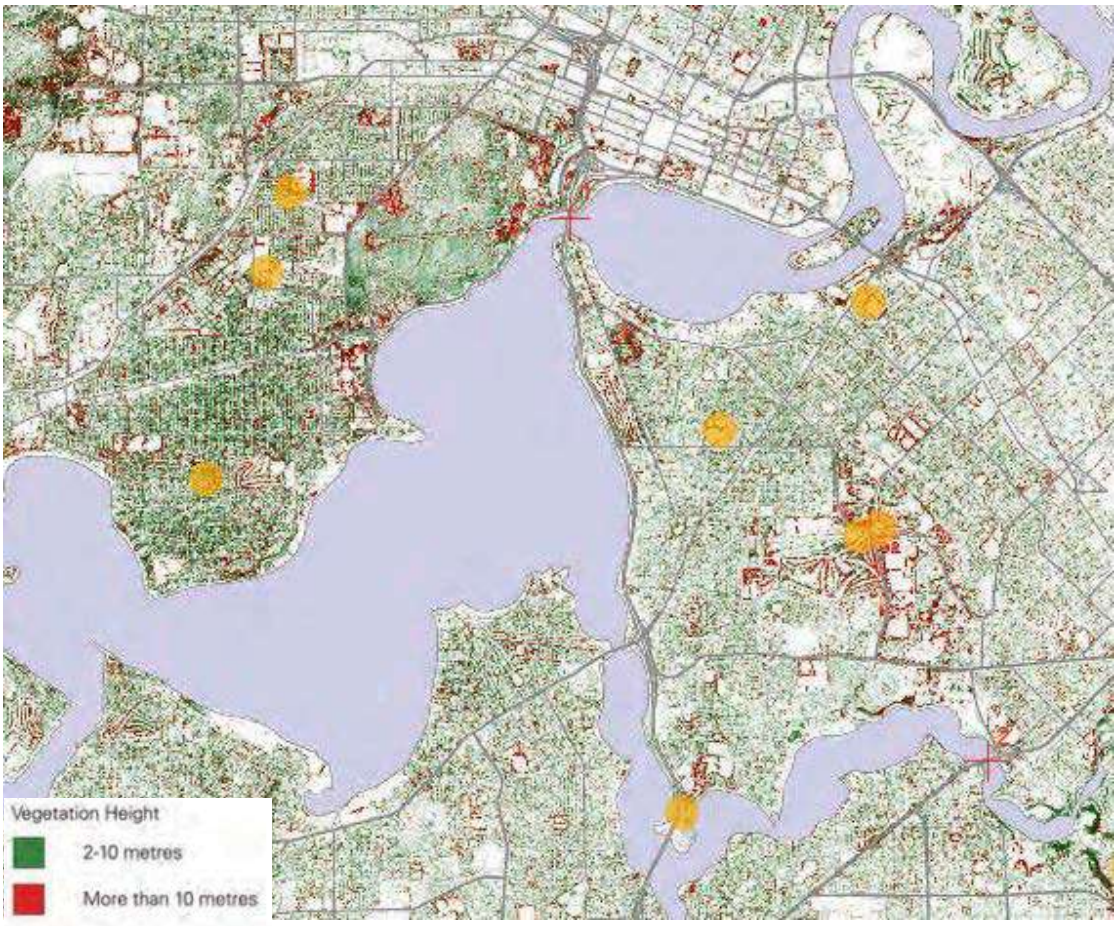


Figure 10 Location of Carnaby's Black Cockatoo roost sites (orange circles) adjacent to Curtin overlain on CSIRO urban tree cover mapping (DoP, 2013).

The locations of the Carnaby's Black Cockatoo roost site for the 2012 – 2013 period for Collier Golf Course and the Bentley Campus is presented in Figure 11 (based on information provided by DPaW during consultation period on this project) together with the roost and feed areas by canopy cover.

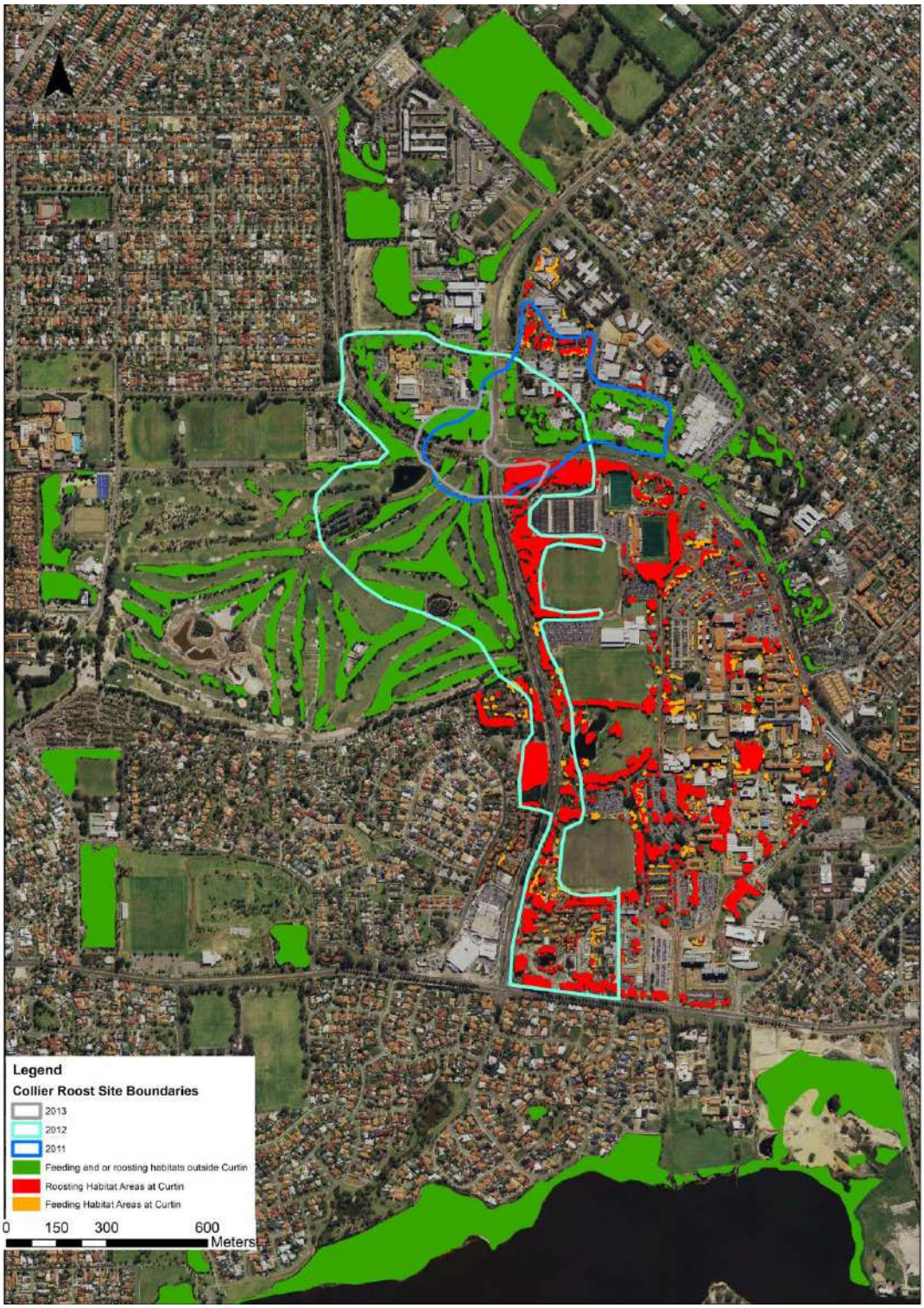


Figure 11 Black Cockatoo (Carnaby's) roosting site adjacent to Curtin including the outline of the Bentley Super roost for the 2011 – 2013 period (based on DPaW data).

The available foraging and roosting habitat indicates that although fragmented, there are links between the Collier and Bentley Campus to the Kensington bushland and to the riparian vegetation south of Curtin. These vegetation links will be discussed in more detail in Section 9.1.3.

8.0 BLACK COCKATOO HABITAT – THE FUTURE

This section of the report analyses the current status (year 2013) of the Black Cockatoo habitat taking into consideration the life expectancy of trees in particular pines and the masterplanning process over the 10 – 30 year period which is the proposed timeline for implementation of the Greater Curtin Masterplan. The analysis is conceptual only and environmental factors such as climate change, disease, future economic priorities and changes to the Masterplan can change the overall outcome. As such, the results of the analysis presented in this report should be used only as an indicator or guide to develop strategies to ensure that the Black Cockatoo habitat is maintained and possibly improved over the next 30 years. It is important to acknowledge following limitations prior to presenting the results of the analysis:

- The analysis was based on the data collected by Arbor Centre (2012) and whilst all trust is placed in the accuracy of that data, the exact location of any particular tree the exact canopy cover and life expectancy may be different upon further investigations. The Useful Life Expectancy (ULE) provided is based on the expected average life of any given species in the Perth region. The site characteristics may favour some species to live much longer (or shorter) than anticipated.

- The current knowledge of the ecology of the tree species present on campus and in particular the habitat trees for Black Cockatoos is limited. Therefore, recommendations given in this report are also limited by the availability of data and are representative of existing knowledge.

- Information on the location of underground services was limited and closer inspection will need to be made prior to planting to determine suitability of the particular plant to the specific area.

- The Masterplan is limited in its presentation of staging particularly with respect to road infrastructure, Public Open Spaces (POS) and playing fields. Therefore, the staging of planting for particular areas is unknown.

- The areas of development may change: for example stage 2 buildings may be developed during stage 4 works which limits the usefulness of the calculations presented in this report in terms of specific timelines for planting.

- The Masterplan (2013) only presents development within the Bentley Campus. As such it is assumed that for 30 years Lot 85, Erica Underwood House, Guild House and Technology Park will remain unchanged beyond natural senescence of trees. For this reason, the analysis of areas outside the campus was made only on losses of trees based on their life expectancy and not due to development.

8.1 CHANGES DUE TO TREE AGE AND ACADEMIC CORE INFILL

The following steps were taken to determine tree losses over the next 30 years due to **a)** senescence of trees (pine trees in particular) and **b)** the development within the academic core of the university (i.e. east end of the campus which is currently occupied by the university buildings and associated infrastructure):

1. Areas impacted (as per current Masterplan 2013) within the academic core were mapped. This included the proposed buildings, pedestrian paths and cycle ways and the main road network.

2. Trees and shrubs with feeding, roosting and nesting potential for Black Cockatoos were identified using the DPaW list (DEC, 2011) and the available scientific literature. Trees with no habitat value to Black Cockatoos were ignored and their losses are not presented. Varieties (e.g., varieties of *Agonis flexuosa*, *Callistemon* spp, and *Ficus* spp. which are not specifically outlined as being utilised by Black Cockatoos on the DPaW list (DEC, 2011) are also included.

The following assumptions were also made:

- Trees with Useful Life Expectancy (ULE) of <10 years as identified by the Arbor Centre (2012) will not survive after 10 years (i.e. by 2025);
- Trees with ULE 10 - 19 years will not survive after 20 years;
- Trees with ULE 20 - 29 years will not survive after 30 years;
- The Main Street Project, road network, pedestrian paths and cycleways and Stage 1 and 2 of the proposed Masterplan works will occur in the first 10 years (between 2015 and 2025).
- The infill buildings of stages 3 and 4 will occur after 10 years between 2025 and 2035.
- No new building will occur after 20 years.
- In order to avoid double counting of data, trees that will be removed due to development but also have a ULE within the expected time frame of that development, were only counted within the losses due to development (e.g., If a tree with a ULE <10 years falls within an area that is also under

development in that same period, that tree is considered lost to development not the age / ULE).

- All trees within a development lot as defined on the Masterplan (2013) were considered at risk of loss. This may not be the case in real life and trees can be conserved close to building sites or as part of street planting if they have good vigour, their roots are not impacted by excavation and their ULE is high.

The trees at risk of loss due to age and development within the academic core are highlighted in Figure 12 to Figure 14. Where legend indicates “Trees with life expectancy of <10 years” this includes trees with ULE of <10 years as well as trees intercepted by proposed development (for graphic representation in these figures only).

Not every tree intercepted by the development boundary will be lost to development, with some trees retained for landscaping purposes depending on the location of the tree with respect to type of building or infrastructure.

A summary of tree losses for this development scenario is presented in Table 3 and Table 4.

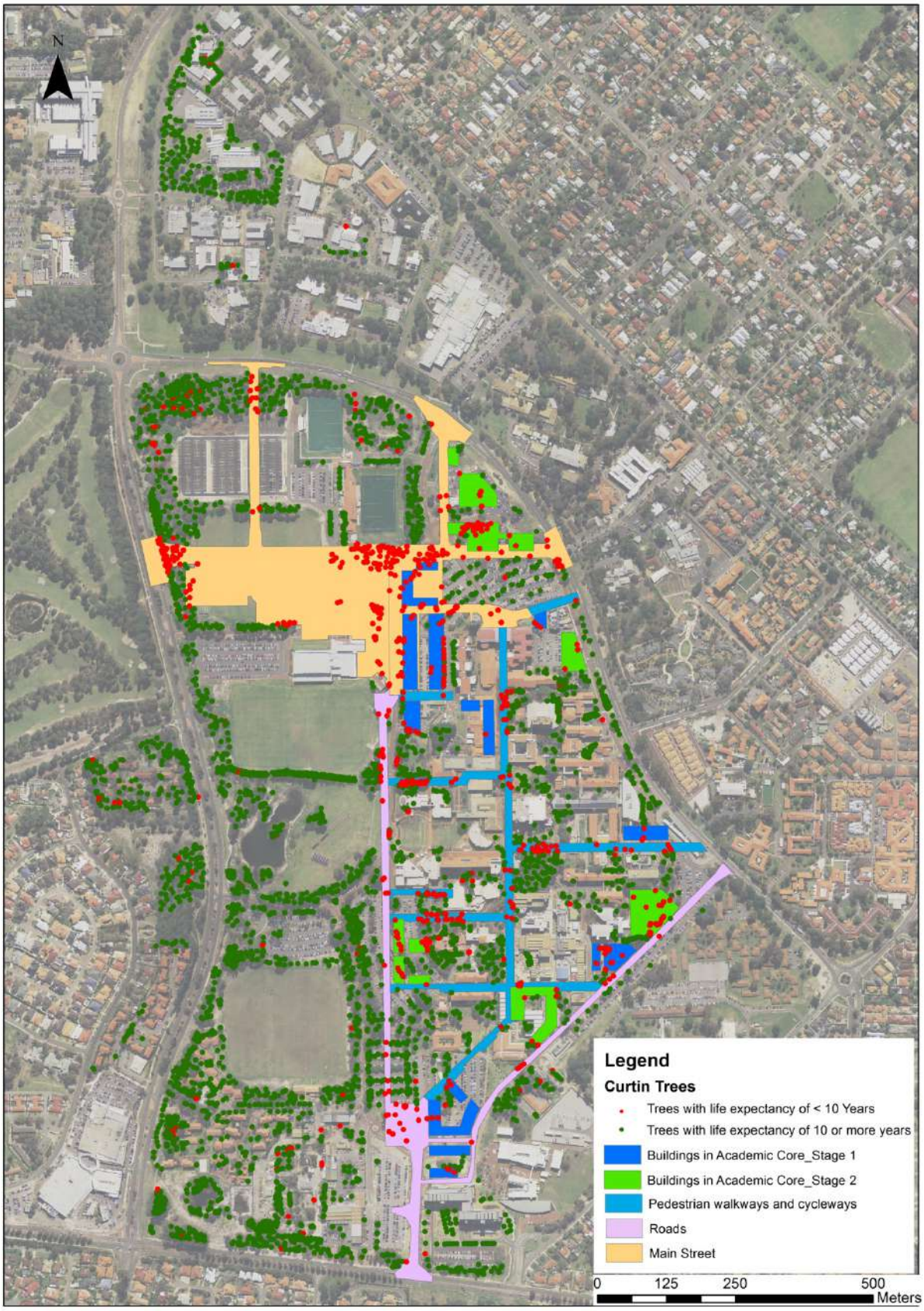


Figure 12 Changes in tree numbers over 10 year period due to natural and climate induced tree deaths (based on tree life expectancy) and the infill within academic core.

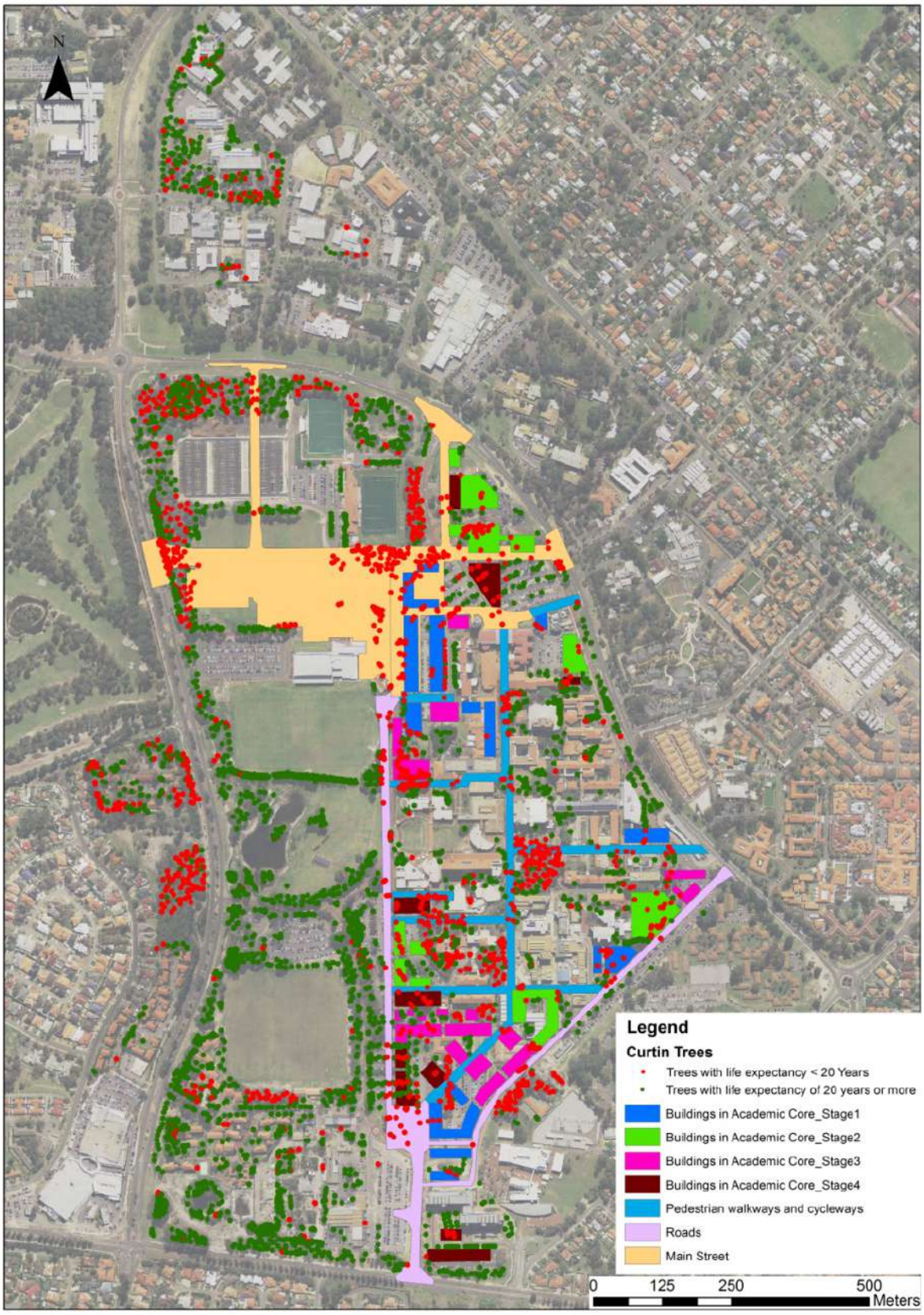


Figure 13 Changes in tree numbers over 20 year period due to natural and climate induced tree deaths (based on tree life expectancy) and the infill within academic core.

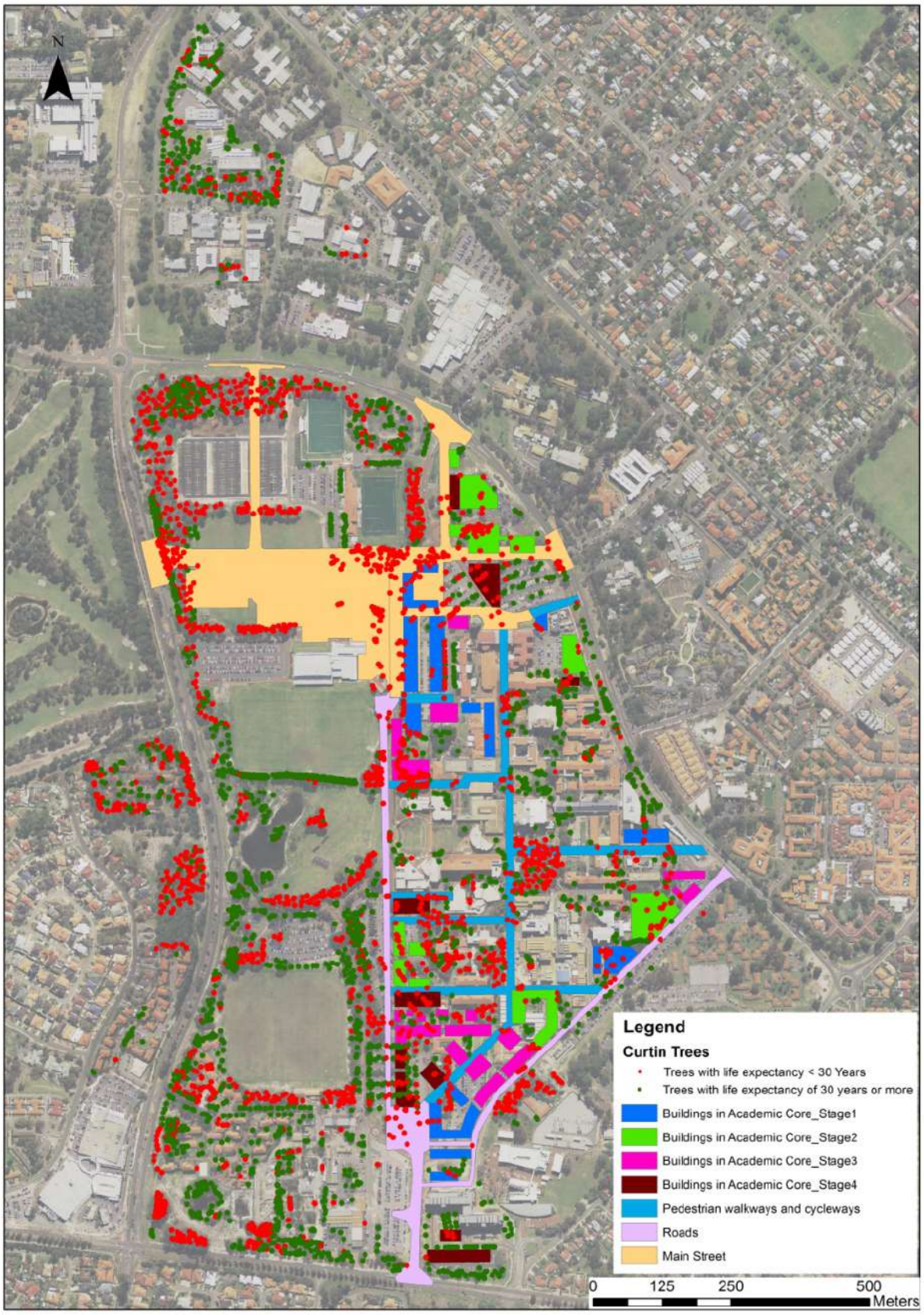


Figure 14 Changes in tree numbers over 30 year period due to natural and climate induced tree deaths (based on tree life expectancy) and the infill within academic core.

Table 3 Number of trees and shrubs expected to be lost in 10 – 30 years time due to age and development within academic core.

Losses of trees and shrubs over time due to age and development within academic core		Bentley campus	Erica Underwood House	Guild House	Lot 85	Technology Park	TOTALS	Total trees and shrubs lost in each decade
0-10 Years	Losses due to ULE < 10 Years	76 (17)		6	3	3 (1)	**88 (18)**	615 (42)
	Losses due to development 0 - 10 Years	527 (24)					**527 (24)**	
10-20 Years	Losses due to ULE 10 - 19 Years	445 (29)	3	66	62	54 (2)	**630 (31)**	720 (32)
	Losses due to development 10 - 19 Years	90 (1)					**90 (1)**	
20-30 Years	Losses due to ULE 20 - 29 Years	625 (42)	6	21	2	11 (7)	**665 (49)**	665 (49)
	TOTALS	**1763 (113)**	**9**	**93**	**67**	**68 (10)**	2000 (123)	

Note: Shrub numbers are presented in brackets.

Table 4 Species with highest losses for 10, 20 and 30 year period including deaths due to age (for all Curtin Properties) and development within academic core only.

Family	Species	Habitat F= Feeding, R=Roosting, N= Nesting			Priority for planting (DEC, 2011)	0 - 10 years	10 - 20 years	20 - 30 years	Cumulative loss of trees over 30 years
Pinaceae	*Pinus pinaster*	F	R		Medium	251	540	440	**1231**
Myrtaceae	*Eucalyptus grandis*		R		Low	17		83	**100**
Myrtaceae	*Callistemon viminalis*	F			Medium	32	15	52	**99**
Myrtaceae	*Agonis flexuosa*	F			Low	57	21		**78**
Myrtaceae	*Corymbia maculata*		R		Low	46	11		**57**
Proteaceae	*Grevillea* species	F			Medium	15	20	15	**50**
Casuarinaceae	*Casuarina cunninghamiana*	F			Low	26	14	8	**48**
Bignoniaceae	*Jacaranda mimosifolia*	F			Low	25	10		**35**
Moraceae	*Ficus microcarpa* var.*hillii*	F			Low		14	14	**28**
Myrtaceae	*Corymbia calophylla*	F	R	N	High	26			**26**
Myrtaceae	*Eucalyptus caesia* ssp. *magna*	F			Medium		25		**25**
Loranthaceae	*Nuytsia floribunda*	F			Low		15	10	**25**
Myrtaceae	*Corymbia ficifolia*	F			Medium	24			**24**
Proteaceae	*Banksia species*	F			Medium			20	**20**

Note: Shrub species highlighted in grey.

As Table 3 and Table 4 highlight, development in the first 10 years contributes to the loss of significantly more trees and shrubs than that expected due to natural senescence. Losses due to development are based on the assumption that all large infrastructure works like roads, light railway, pedestrian pathways, cycleways etc. will be completed within the first 10 years. Trees lost due to development declines significantly in the 10 – 20 year period as established infrastructure allows for the retention of vegetation and the majority of the building footprint is restricted to non Black Cockatoo habitat areas.

The tree losses at a species level relate to their overall abundance. *Pinus pinaster* is a dominant species on site and hence the losses of the species are highest. The *P. pinaster* losses over the 10 – 30 year period are predominantly due to natural senescence. The literature on the life expectancy of *P. pinaster* is suggests that the life expectancy of this species under Australian conditions is approximately 80 years (Department of Environment and Primary Industries, Victoria, 2009). The pines at Curtin have or will be reaching this age in the next 10 – 30 years and thus a large number of trees are expected to be lost due to senescence.

After 10 years a total of 14 % of the existing habitat trees and 16 % of all habitat shrubs will be lost within the academic core due to development or natural senescence. After 20 years 31 % of trees and 28 % shrubs will be lost with a potential cumulative loss of 46 % of the total currently existing habitat trees on campus after 30 years (2000 trees and 123 shrubs) %.

Of the 30 year overall habitat tree loss (incorporating the academic core of campus and all Curtin properties), approximately 62 % is due to losses of *P. pinaster*, 5 % due to losses of *Eucalyptus grandis* and *Callistemon viminalis,* 4 % and for *Agonis flexuosa* and 3 % for *Corymbia calophylla.* The remaining 26 % comprises species known to have limited value to Black Cockatoos in terms of both feeding and roosting. The overall loss of *Pinus pinaster* over 30 years for the academic core infill due to development and natural senescence is 1231 trees from the current 1599 trees across all properties. Therefore, it is expected that only 23 % of pines will remain after the 30 year period.

8.2 CHANGES DUE TO FULL IMPLEMENTATION OF THE MASTERPLAN

The method for determining the changes to Black Cockatoo habitat as a result of implementation of the entire Masterplan was same as for determining the changes due to the academic core infill with the same set of assumptions applied. However, the layers for full implementation of the Masterplan were used to derive figures and calculations.

The impact to Black Cockatoo habitat was expected to be greater due to the to the larger building and infrastructure footprint (Figure 17, Table 5 and Table 6)

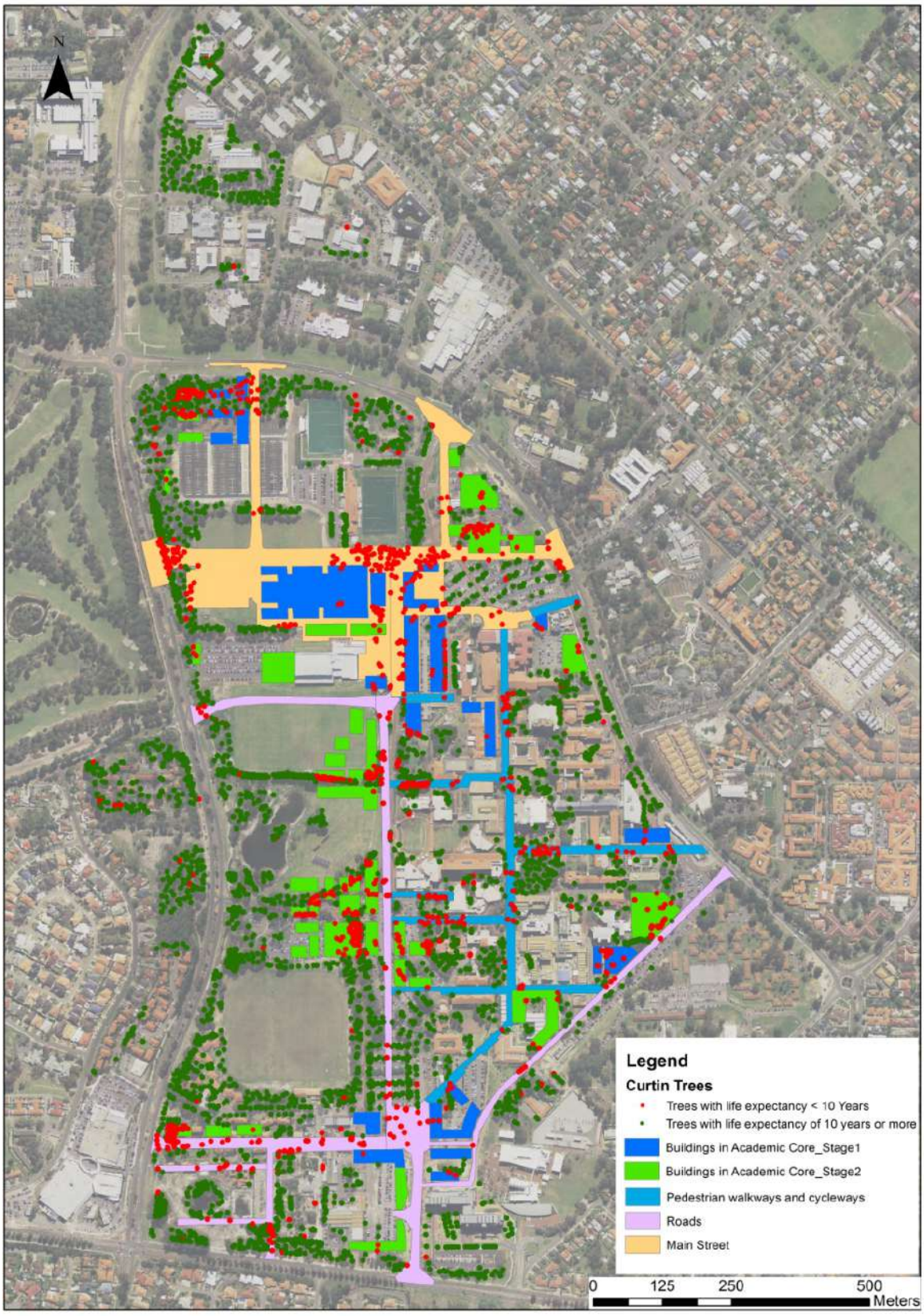


Figure 15 Changes in tree numbers over 10 year period due to natural and climate induced tree deaths (based on tree life expectancy) and the full implementation of the Masterplan.

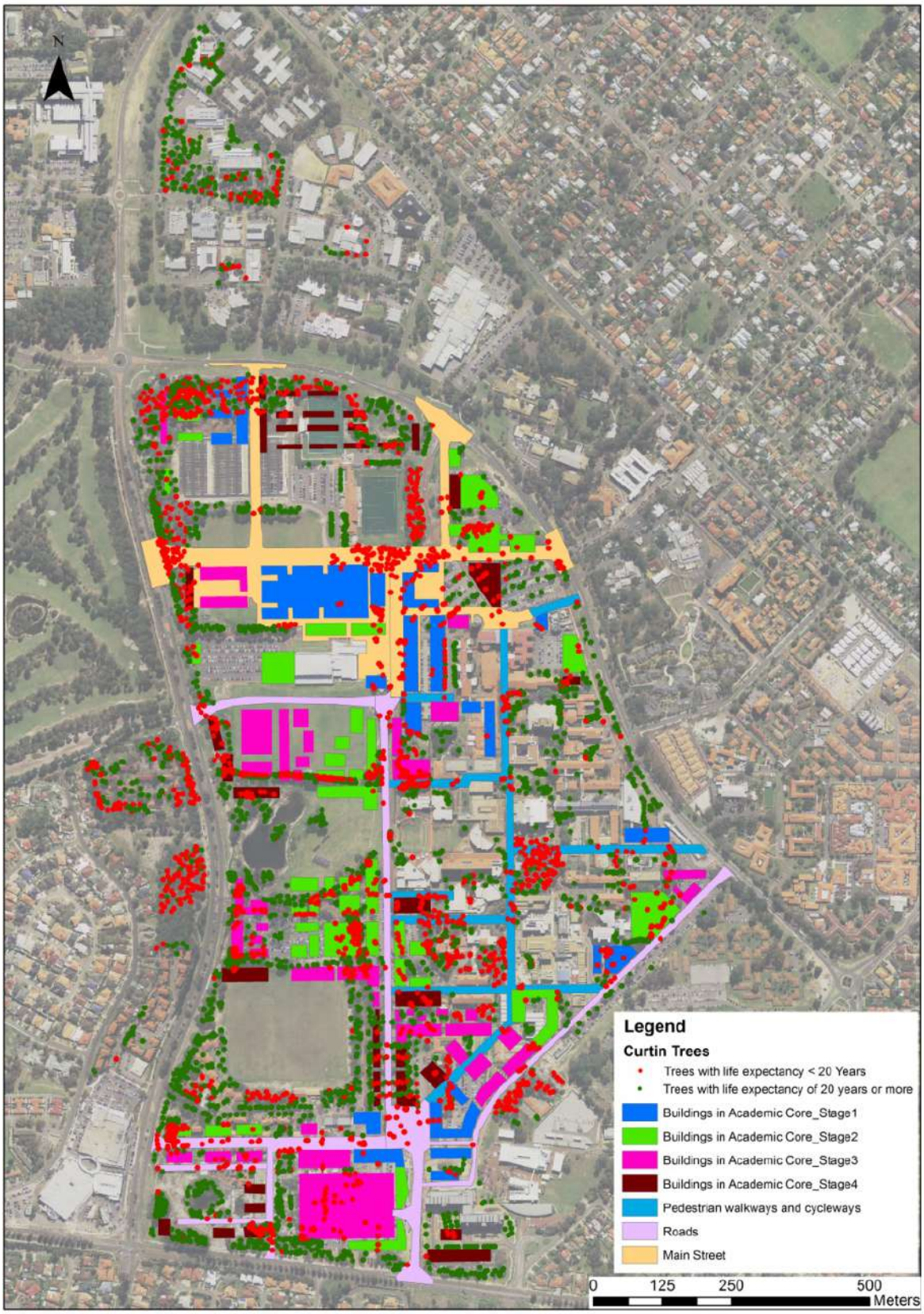


Figure 16 Changes in tree numbers over 20 year period due to natural and climate induced tree deaths (based on tree life expectancy) and the full implementation of the Masterplan.

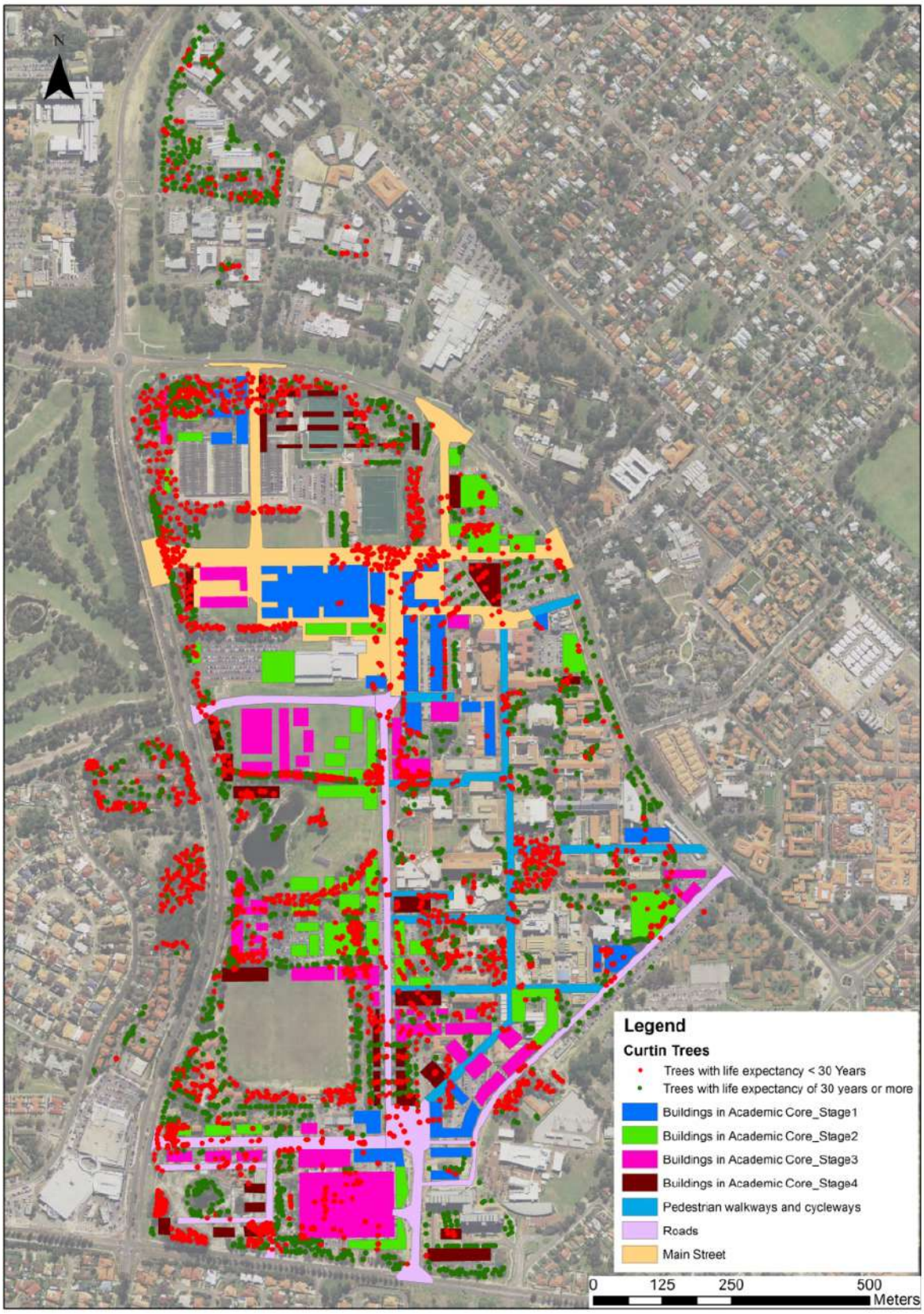


Figure 17 Changes in tree numbers over 30 year period due to natural and climate induced tree deaths (based on tree life expectancy) and the full implementation of the Masterplan.

Table 5 Number of trees and shrubs expected to be lost in 10 – 30 years time due to age for all Curtin properties and full Masterplan implementation

Losses of trees and shrubs over time due to age and development of full Masterplan		Bentley Campus	Erica Underwood House	Guild House	Lot 85	Technology Park	TOTALS	Total trees and shrubs lost in each decade
0-10 Years	Losses due to ULE < 10 Years	67 (16)		6	3	3 (1)	**79 (17)**	**882 (61)**
	Losses due to development 0 - 10 Years	803 (44)					**803 (44)**	
10-20 Years	Losses due to ULE 10 - 19 Years	420 (27)	3	66	62	54 (2)	**605 (29)**	**924 (47)**
	Losses due to development 10 - 19 Years	319 (18)					**319 (18)**	
20-30 Years	Losses due to ULE 20 - 29 Years	505 (32)	6	21	2	11 (7)	**545 (39)**	**545 (39)**
	TOTALS	**2114 (137)**	**9**	**93**	**67**	**68 (10)**	**2351 (147)**	**2351 (147)**

Note: Shrub numbers are presented in brackets.

Table 6 Ten species with highest losses for 10, 20 and 30 year period including deaths due to age for all Curtin Properties and full Masterplan implementation.

Family	Species	Habitat (F= Feeding, R=Roosting, N= Nesting)			Priority for planting (DEC, 2011)	0 - 10 years	10 - 20 years	20 - 30 years	Cumulative Loss over 30 years
Pinaceae	*Pinus pinaster*	F	R		Medium	368	572	347	**1287**
Myrtaceae	*Eucalyptus grandis*		R		Low	38	18	80	**136**
Myrtaceae	*Callistemon viminalis*	F			Medium	43	37	50	**130**
Myrtaceae	*Corymbia maculata*		R		Low	69	52		**121**
Myrtaceae	*Agonis flexuosa*	F			Low	66	27		**93**
Myrtaceae	*Eucalyptus rudis*		R		Low	35	25		**60**
Casuarinaceae	*Casuarina cunninghamiana*	F			Low	29	17	6	**52**
Proteaceae	*Grevillea* species	F			Medium		21	14	**35**
Moraceae	*Ficus microcarpa* var.*hillii*	F			Low		19	11	**30**
Myrtaceae	*Corymbia calophylla*	F	R	N	High	27			**27**
Bignoniaceae	*Jacaranda mimosifolia*	F			Low	27			**27**
Myrtaceae	*Corymbia ficifolia*	F			Medium	26			**26**
Myrtaceae	*Eucalyptus caesia* ssp. *magna*	F			Medium		25		**25**

Note: Shrub species highlighted in grey.

With the implementation of the full Masterplan 54 % habitat tree and shrub species will be lost over 30 years. This is an 8 % greater loss than the losses of trees and shrubs due to infill in the academic core over the same period. The impacts are substantial with 20.2 % reduction of the overall habitat in the first 10 years due to development and to a lesser degree life expectancy, and 41 % reduction over the 20 year period.

Implementation of the full Masterplan and the expected tree senescence will cause a significant reduction in *P. pinaster* numbers with 1287 trees lost due to either senescence (70 %) or development (30 %). Of note is the large number of non-pine trees with roosting potential that will be lost in the process of implementation, including *Eucalyptus grandis Corymbia maculata* and *Eucalyptus rudis* and as a food source *Callistemon viminalis* and *Agonis flexuosa*.

Given that the overall number of *Pinus pinaster* across all Curtin properties currently stands at 1599 trees, implementation of the full Masterplan and expected senescence will result in approximately 80.4 % loss of all pines over 30 years.

8.2.1 Impacts to Individual Species

A total of 43 tree and 9 shrub species* (*Note: the species diversity of *Grevillea, Hakea* and *Banksia* shrub species is likely to be much higher but was not recorded) were identified on campus and Curtin properties as confirmed or potential habitat for Black Cockatoos. This list of species is presented in Appendix 2 with the overall species numbers expected to be lost over the 30 year period both due to development and age of trees. A summary of the habitat trees categorised by their use by Black Cockatoos including the species with the highest losses is presented in Table 7.

Table 7 Summary of the habitat tree categories expected to be lost as a result of development and age based on the full implementation of the Masterplan.

Habitat tree use	Number of individuals lost in 30 years	Species (top two contributing species)
Feeding Roosting and Nesting	52	*Corymbia calophylla, Eucalyptus gomphocephala*
Feeding and roosting	1317	*Pinus pinaster*, Eucalyptus robusta**
Feeding Only	610	*Callistemon viminalis*, Agonis flexuosa, Casuarina cunninghamiana*, Jacaranda mimosifolia*, Corymbia ficifolia Eucalyptus caesia ssp. magna, Tipuana tipu*.*
Roosting Only	372	*Eucalyptus grandis*, Corymbia maculata*, Eucalyptus rudis, Eucalyptus camaldulensis* var. *camaldulensis**
Shrubs (feeding only)	147	*Grevillea* species, *Banksia* species, *Xanthorrhoea preissii, Hakea* species
Total	**2498**	

*****indicates species not native (exotics) to the south-west of Western Australia.

The majority of the species used either for feeding or roosting by Black Cockatoos are not native to Curtin site or Western Australia (Table 7). Therefore, there would be some limitations for these species in terms of their optimal growth conditions and their usefulness to the native bird species such as Black Cockatoo which would have evolved to metabolise the native species seed more efficiently than that of the introduced species. In addition, the diversity of food resources can contribute significantly to the overall health of the birds, a factor which is limiting at the Bentley Campus.

As the traditional knowledge suggests:

"*Native bird = native food. Marri will benefit all cockatoos." "Birds are looking for trees that transpire the sweetest oxygen. The birds stay there for a while and it helps with flight reading the landscape" — it has to be natural*." (Dr Noel Nannup, Elder)

"*Plants want to help people. They are part of the cycle for example they provide seeds for the birds…the birds revegetate. Pines use a lot of water. That's why nothing grows under the pines — can't sustain life because the pines take it all."* (Kim Collard, Elder)

The native species selection and diversity of food and roosting resources would be the key to offsetting the losses of habitat trees at Curtin. However, given the long term disturbance and the lack of food resources in the surrounding bushland areas, the total replacement of existing pines with native bushland would not be considered to be in the best interest for the sustainability of the Black Cockatoo habitat in the short term.

Recent research has indicated that Black Cockatoos target tree species that can provide the most caloric value for the least amount of foraging time. Based on this fact, research articles stipulate the importance of pine plantations as a food source for Carnaby's Black Cockatoo; however, until more recently the nutritional value of the pine seeds compared to the seed of native species was not determined. Given the short period of time in which the natural senescence of pines and the development of the Masterplan will occur, it is important to consider species that will provide high quality habitat value to the Black Cockatoo per unit area and as well as time to maturity.

9.0 ASSESSMENT OF OPPORTUNITIES FOR BLACK COCKATOO HABITAT CONSERVATION AND IMPROVEMENT

9.1 KEY STRATEGIES

Given the conservation status of the Black Cockatoos and the environmental objectives of the Masterplan and the Curtin University's Action Plan for Black Cockatoos the losses of Black Cockatoo habitat will need to be managed to ensure the persistence of these Endangered and Vulnerable species.

The key strategies proposed are as follows:

1. Limiting removal of habitat and managing impacts (e.g. disease);
2. Planting within Curtin properties – direct replacement;
3. Planting within and outside of Curtin properties to form a broader ecological corridor – enhancement/improvement.
4. Extension of Curtin's involvement beyond their boundaries to champion a regional ecological linkage project (national wildlife corridor), which has Curtin as the hub, but involves other partners to elevate the project to a national level, attract funding and future-proof the retention and enhancement of habitat trees and biodiversity within the University. This could be based on the framework from the National Wildlife Corridors Plan (Draft, 2012) linking the known habitats of Black Cockatoos and later other fauna and flora within Curtin University.

9.1.1 Impact Minimisation

Minimising impacts will involve a reconfiguration of the Masterplan as it progresses in design development stages, as well as disease and weed control strategies to maintain the viability of existing and planted trees and shrubs. This TRP does not directly address this strategy; however, it should form part of the scope of work of future development phases, and inform current landscape management plans within the campus and adjacent properties.

9.1.2 Tree Replacement within Curtin Properties

If Curtin is to replace each tree removed to a set ratio, considerations such as space, timing and density must be considered. Whilst the Bentley Campus in its current form can readily accept a significant increase in plantings, this is not the case when superimposed with the Greater Masterplan intentions. Nonetheless, tree replacement within the available Curtin space is a key proposed strategy, and is dealt with in the most detail in this report.

9.1.3 Tree Replacement outside of Curtin Properties - Ecological Linkages

Ecological linkages are often defined as a series of continuous and / or non-continuous patches of remnant vegetation which, by virtue of their proximity to each other, act as stepping stones of habitat which facilitate the maintenance of ecological processes and the movement of organisms within, and across a landscape (Molloy et al 2009).

Traditional ecological understanding is based on large-scale interconnectivity between systems (geology, water, vegetation, fauna and the processes (physical and spiritual) sustaining them, i.e. systems ecology. As a result, the key known assets of significance in the Curtin University region ultimately incorporate linkages associated with land and water with land management based on protecting the integrity of a whole system, rather than individual components. This has been represented in the Greater Curtin Masterplan as the "Living Stream" which will enable the University to represent and acknowledge the many layers and the deeper connections that exist. The Perth Metropolitan Region regional ecological linkages (Del Marco et al, 2004) link Regionally Significant Natural Areas (e.g. Bush Forever Sites) through Local Natural Areas available between them that act as stepping stones, and were designed to provide the framework that can be used to identify ecological linkages locally.

As part of the work for the Capital City Planning Framework (DoP, 2013a), the Perth Biodiversity project team has conducted a vegetation connectivity analysis for the Central Perth region, which included the Curtin site (PBP, 2013). The aim of the analysis was to investigate options for establishing a well connected green network. This network was to assist in maintenance of ecosystem functions provided by green spaces, provide recreational spaces for residents and maintain and improve habitat for fauna such as the Endangered and Vulnerable Black Cockatoos.

The connectivity analysis was based on a methodology developed through the Regional Framework for Local Biodiversity Conservation Priorities for Perth and Peel (PBP, 2011) and has identified the Curtin site (Target area 9 in PBP, 2013) particularly areas along Kent street as one of the possible new green links between Bush Forever Site (BFS) 48 (Kensington Bushland) located to the north of the Bentley Campus and the Bush Forever site 333 which runs along Canning River shore to the south of the campus (Figure 18).

To achieve this connection utilisation of the wide verges along Kent Street and Hayman Road to consolidate current plantings of native vegetation was recommended in addition to recreating habitat using local species within all public spaces between BFS 48 and BFS 333, with particular focus on the Collier Park golf course, areas adjoining Barblett Oval, Edinburgh and South Ovals (these are ovals on Bentley Campus), George Burnett Park, Trinity College playing fields and a POS area adjoining these areas. The location of the links and POS spaces are shown in Figure 19.

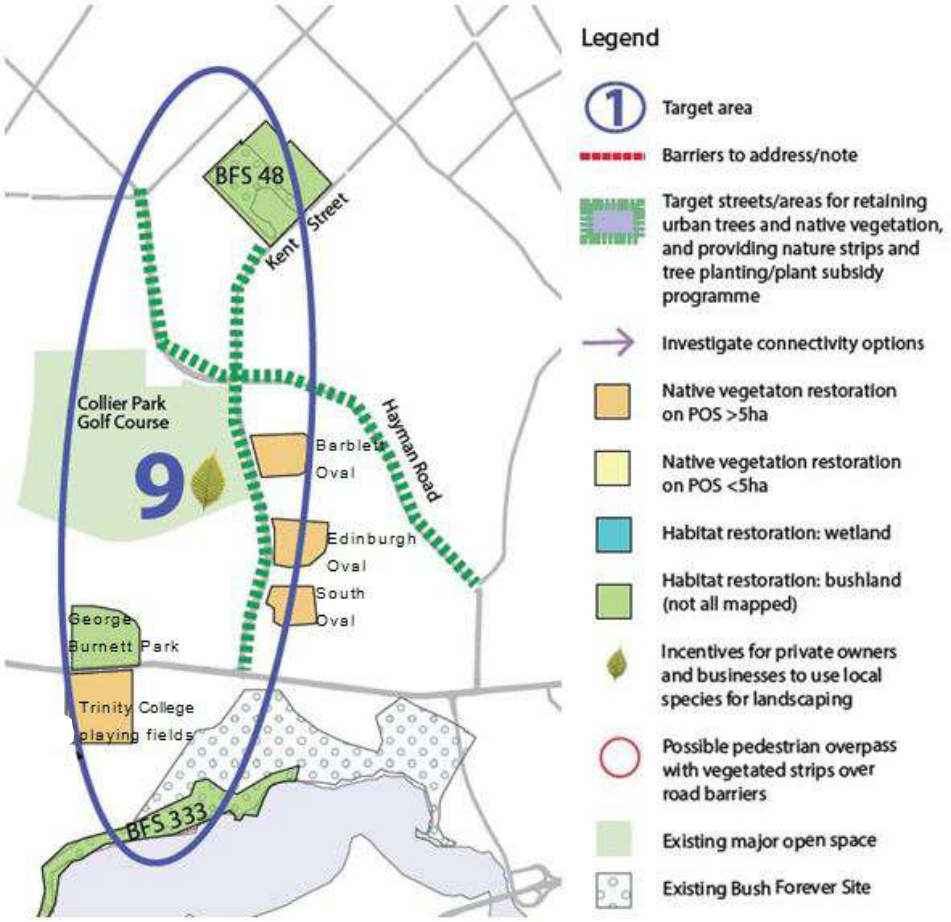


Figure 18 Recommendations for green links along Kent and Hayman Roads. (Source: PBP, 2013).

Note: only a section of the larger figure from PBP, 2013 is used, hence the legend contains items that are not presented in the figure.

When looking at the roosting and feeding sites of Black Cockatoos, in particular the Carnaby's Black Cockatoo, a close correlation can be seen between the availability of food and roosting sites to the proposed green links connecting the natural areas. The outline of the 2012 roost area provided by DPaW, (see Figure 19) shows that the areas on Camus adjacent to Kent Street are the most favoured sites for roosting and feeding (given they are comprised mostly of pines).

Given recommendations by PBP, (2013) and those provided in the Biodiversity Study (Syrinx, 2012) and Integrated Urban Water Management Strategy (Syrinx, 2013) for creation of biodiversity links (which are congruent with PBP analysis), the location of adjacent feeding and roosting sites, possible green links for biodiversity and Black Cockatoo habitat improvement have been drawn and presented in Figure 19. The links align with the dreaming trails (see Greater Curtin Masterplan, 2013) which adds to the cultural connectivity between spaces in addition to ecological links.

Figure 19 Regional and possible local ecological linkages which would support Black Cockatoo habitat creation.

9.1.4 Curtin Living Corridor Initiative

A bigger picture view of the Black Cockatoo Tree Retention Plan and one which could be developed following on from this study, could be a Curtin Living Corridor Initiatives, in which Curtin University could champion the extension of the Living Stream and on-campus biodiversity linkages with a broader corridor network within the Swan and Canning River. Curtin could develop and co-ordinate this program in a partnership model, attract research and delivery funding from national grant programs, and integrate this with their own masterplan development initiatives, and existing research and educational platforms.

A Curtin Living Corridor initiative could be built around cultural, socio-economic and connectivity conservation of land management objectives and could continue the Living Stream concept which has been embedded into the Master Plan. It provides a platform to research, teach and practice and can be incorporated into new academic frameworks.

The corridor could be developed to meet the objectives of a National Corridor (i.e. part of the national corridor network proposed by the Australian Government and articulated within the Draft National Wildlife Corridor Plan (2011), both to meet Curtin University's objectives to *"To be an international leader in research and education – changing minds, changing lives and changing the world"* and to secure its viability (and funding) in the long-term. The corridor could essentially link the known habitats of the Black Cockatoos as a priority.

The key objectives would be as follows:

- **Environmental objective**: to connect and reconnect high value landscapes to enable or recover the sustainability, resilience and evolutionary continuance of habitats, ecosystems, and biota at a large-scale to combat climate change and reverse landscape degradation.
- **Cultural objective**: to maintain connections to country, encourage cross-sharing of knowledge and equalise appreciation of natural landscapes and management of landscapes across spiritual, biodiversity, and cultural spheres.
- **Socio-economic objective**: to develop new economic opportunities for indigenous and non-indigenous locals based on land management activities, new enterprises such as traditional ecological knowledge training and interpretation, and jobs beyond the government sector.
- **Governance objective**: to establish a new long-term model for sustainable conservation championed by Curtin University, managed by local non-government organisations in accordance with traditional on-country management principles, and supported by government.

Key principles that Curtin would need to be aware of in making this a national corridor initiative are as follows:

- Must be meaningful to conservation at a national level and be based on delivery mechanisms that are aligned to new policy and legislation.
- Must be able to grow and be sustainable beyond Curtin's direct involvement.
- Must be elevated to achieve outcomes which are beyond current outcomes to future proof short-term and long-term plans.

Whilst this idea represents a new change for Curtin University as it currently operates, this initiative is well aligned to the future Greater Curtin envisaged within the Masterplan, well aligned to Curtin's physical setting and core habitat status for vulnerable species, and well aligned to a future university based on integrated cultural awareness and knowledge principles. Students of the future, and international students alike, will have growing expectations aligned with their growing awareness and respect for traditional ecological knowledge, sense of place and environmental and cultural responsibility. In this sense, it is opportune for Curtin to consider a program in which it can position itself as a leader in research, education and the practice of biodiversity, culture and people.

Key steps Curtin should take to initiate such a program would include:

- Initiating the consultative process required to connect the existing stakeholders and traditional indigenous land management groups in the Metropolitan area with each other and broker the process for these groups to drive and manage the Corridor Project alongside Curtin University staff and students.
- Integrate and expand on the current work being undertaken by the Noongar community for the Iconic Trails Project by becoming a collaborative partner alongside significant agencies and statutory authorities. In particular this includes the Swan River Trust, the C21, the Committee for Perth, the WA Planning Commission, the Department of Indigenous Affairs, the Eastern Metropolitan Regional Council, Perth Region NRM and the National Trust.
- Undertake a comprehensive assessment of traditional ecological knowledge (TEK) in the Curtin University area. Given that current knowledge is limited with regard to tree species present on campus this would inform future projects and contribute to lowering of costs long term. Record this knowledge in a cultural mapping project to add Curtin University to the Atlas of Living Australia.
- Research other legal/tenure issues affecting culture/conservation issues in the Perth Metropolitan area and the South West of Western Australia. More investigation is needed to ascertain progress made by South West Land and Sea Council who are the representative body of the Noongar People of this area.
- Involve Curtin University students and Indigenous stakeholders in active participation e.g. verge planting to increase ownership and facilitate cross-cultural understanding.

10.0 ASSESSING OFFSET REQUIREMENTS

Offsets must consider both the potential losses and the opportunities for conservation and improvement of habitat. Together with the expected losses of trees due to senescence over the next 30 years the losses of medium to high value vegetation for Black Cockatoos are similar for both the infill of the academic core and the whole Masterplan. The offsets and recommendations provided in this section have therefore been based on the 'worst case scenario' – that is the loss of 54 % of the total Black Cockatoo habitat or the loss of 2,498 trees and shrubs (i.e. 147 shrubs and 2,348 trees). All species that offer or potentially offer habitat to Black Cockatoos (Carnaby's Black Cockatoo, and FRTBC) were considered.

Of all the trees that will be potentially lost across all Curtin properties due to age and the Masterplan development) 54.8 % are comprised of pine trees, with a large number of roosting and feeding trees comprising the remainder of the tree species at risk of loss over next 30 years.

A total of 1,122 trees and 62 shrubs are expected to be lost solely as a result of development over the 30 year period incorporating 391 *Pinus pinaster* trees.

If the proposed 4:1 replacement ratio suggested in the EPBC referral (Aurora Environmental, 2013) is to take place, for every habitat tree lost as a result of the proposed Masterplan development (over 30 year period) the following will need to be planted:

- 4,476 trees;
- 248 shrubs.

If the number of trees lost due to senescence and development are combined this will result in a replacement number of:

- 9,392 trees
- 588 shrubs.

This is not feasible within the Bentley Campus itself, hence a better approach to determining appropriate offsets, as well as a broader ecological corridor strategy, is essential.

10.1 DETERMINING THE RELATIVE VALUE OF INDIVIDUAL SPECIES TO BLACK COCKATOOS

In order to develop an offset strategy, an assessment of the value each species in terms of Black Cockatoos was undertaken first, to determine appropriate replacement ratios. The assessment takes into consideration the value of each species to the cockatoos based on their:

- feeding, roosting and nesting potential;
- endemicity;
- longevity;
- connection to dreamtime;
- amenity value; and
- suitability to the soils, hydrology and the microclimate of Curtin.

The available space for planting considering the existing and proposed infrastructure and amenities is also analysed and presented after species analysis.

10.1.1 Caloric Value of Seeds for Feeding Habitat Trees

Stock et al (2013) examined the caloric value of a number of feed species and their seed production (see Table 1 in Appendix 3) and identified that for Carnaby's Black Cockatoo the energetic contributions of *Banksia* spp. and *Corymbia calophylla* on a per seed basis are much higher than pine. However, he noted that although some species produce much smaller seeds the production per tree or hectare dictates the overall foraging value of the plant. High seed production together with dense stems per ha reduces the amount of time spent foraging and the overall capacity of the bird to achieve its required caloric intake per unit of time. Stock et al (2013) and Stock (pers. com.) noting that the overall value of pine seeds and possibly other species such as nuts (e.g., Almond) may be proportionally higher than that of native species.

Similarly, Johnston (2013) noted that of the 24 plant species used by Carnaby's Black Cockatoo *Banksia sessilis* provided the highest seed input. Although *B. sessilis* seeds are smaller and as such have a much lower calorie content than the larger *Banksia attenuata* or *Banksia menziesii* they produce a larger number of seeds per plant (35 times greater than that of *B. attenuata* and *B. menziesii*). This allows for a greater number of birds to be supported over the same area. Johnston (2013) concluded that *Banksia sessilis* is a vitally important food source however its restricted fruiting period makes it unreliable for year round food and it should always be planted in association with species that can provide food in other periods, such as *B. attenuata*.

Both Stock et al., (2013) and Johnston (2013) identified that large monocultures of high seed producing feed species will provide a suitable resource regardless of seed size as birds are able to get the highest caloric input for each unit of time spent feeding. Although, a monoculture of plants is not desirable for a number of reasons on the Bentley Campus (e.g., disease risk, availability of year round resources, aesthetic value) clusters of plantings that include multiples of the same species will potentially provide a better food resource than scattered single specimens of various species.

Stock (*pers.com*.) identified that on a per ha basis Macadamias were by far the highest caloric producer for Carnaby's Black Cockatoos providing over 1000 times more caloric value compared to *Banksia attenuata*, while, Pecans and Almonds provided 783 and 700 times the value of *B. attenuata* respectively (see Table 2 in Appendix 3). No information is available on the suitability of these trees for roosting but there is anecdotal evidence that both FRTBC and Carnaby's Black Cockatoos both feed on pecans and Almonds, while Carnaby's Black Cockatoos have also been seen feeding on Macadamias.

Given the above information it would be prudent to incorporate variety of plantings within the Curtin developments to supplement for potential foraging habitat losses of pine trees in the future and based on the best available information should include nut tree species.

10.1.2 Diversity

In order to ensure good sources of food year round, a diversity of food plants should be considered. Whilst often not included in standard revegetation plans for urban development, proteaceous species such as *Banksia* will need to be considered as they provide food at the time when seed of the dominant feeding and roosting habitat trees may not be available.

In addition to Black Cockatoos there are several smaller bird species that would benefit from introductions of *Banksia* on site. It is important to note that focussing on providing habitat for a single species or species within the same functional group will not achieve a total ecosystem value that a diversity of vegetation could provide. Limiting species selection to only those species that suit Black Cockatoos may fail to provide sufficient habitat for pollinators, pest management species and soil microbes that will ensure the ongoing health and productivity of planted specimens.

It is important not to focus on just one species *"... everything is equal. Need to consider ethical responsibility".* Dr. Noel Nannup, Elder

Therefore, the selection of plants provided in Appendix 4, whilst focused on the requirements of Black Cockatoos, also looks at the benefits each species may provide to other species, such as honeyeaters for example, which in turn help with pollination and production of seed beneficial for Black Cockatoos.

Maintaining a diversity of species within the Bentley Campus and Curtin properties reduces the future risk to tree populations from disease and pest and climate impacts. RPS (2012) who prepared the Urban Forest Management Plan for Curtin has proposed the following goals in terms of species diversity for Bentley Campus:

- No more than 40 % of population of Myrtaceae;
- No more than 20 % of population of other families;

- No more than 10 % of population of the same Genus;
- No more than 5 % of population of the same Species.

These diversity criteria, however, are not compatible with criteria relating to retention and enhancement of Black Cockatoo roosting and feeding habitat across the campus as a whole. However the criteria may be achievable and appropriate within the academic core and 'Living Stream' areas of the campus.

10.1.3 Time to Maturity

Growth of most species which contribute to Black Cockatoo habitat is relatively slow. On average a 6 – 10 year growth cycle is required for trees to reach maturity (e.g. production of fruit or nuts) in which they can provide adequate foraging and limited roosting habitat. Depending on site conditions and the density of planting, roosting trees usually take 10 - 30 years to reach height that is preferable for use as a roosting habitat.

The approximate time to maturity for the proposed planting (species) is given in Appendix 4.

In terms of roosting habitat the fastest growing tree that would be able to reach similar height to pines and that is indigenous to the area is *Eucalyptus rudis.* When planted in dense stands of 10 - 20 trees per 100 m^2 the trees will grow by vertical trunk extension, promoting a straight trunk - in contrast open planting creates trees with shorter trunks and a wide canopy. Most *Eucalyptus* and *Corymbia* species will respond similarly to the two growing conditions.

Dense plantings (10 – 15 trees per 100 m^2) of *Corymbia calophylla* and *Eucalyptus gomphocephala* will also form a thick canopy that would be available for roosting in a 10 - 20 year time span (see Appendix 4 for example image of the 40 year old dense Marri forest). *Pinus pinea* and *Pinus pinaster* are the introduced species suitable for roosting and can be planted on site to ensure continuity of roosting and feeding habitat sources with the adjacent Collier Golf course.

Whilst *Eucalyptus marginata* can also be planted in dense stands it is very slow growing and will not provide habitat for Black Cockatoo in the short term. The longevity of this species compared to pines and other roost tree options such as *E. rudis* will mean that strategic planting of this species will ensure availability of habitat in 30 years and the persistence of this habitat in the future (100 + years).

In terms of seed production, *Pinus pinaster* has been noted to produce viable seed 5 to 10 years after planting with seed taking approximately 2 years to mature post flowering and individuals flowering most years. *Pinus pinea* seed requires 3 years to mature whereas the seed of native species such as *Corymbia* spp. and *Eucalyptus* spp. reaches maturity (from bud to seed) within 1 - 2 years, with viable production likely to occur 6 — 8 years post

seedling germination (Lee et al 2013). Nut trees such as Almonds and Macadamias produce seed every year and produce fruit at 4 - 7 years of age (Note: varieties of nut trees with low and high seed productions are available).

Given the differences in the frequency of flowering (influenced by climatic conditions and/or the particular species physiology), to ensure availability of food resources year round, it is advisable to plant a variety of species with a greater dominance towards those that are native and more reliable in terms of seed production.

10.1.4 Tree Longevity

Longevity of trees is also considered a key value criteria. Most native tree species that serve as a habitat for Black Cockatoos have a life expectancy of greater than 100 years, provided the climatic conditions are not too severe. *Banksia attenuata* is known to live for 300 years or more (Enright and Lamont, 1992) as is the case with both *Corymbia calophylla, Eucalyptus marginata* and in some instances *Eucalyptus gomphocephala*. The life expectancy of *Pinus pinaster* is approximately 80 years (DEPIV, 2009); however, given higher rainfall and cooler climate it is likely to live much longer. *Pinus pinea* lifespan in Europe can be above 100 years however, it is not known if the same life expectancy can be achieved for the Curtin site.

Most of the species at Curtin that are used for roosting are medium to long lived (e.g. *Eucalyptus rudis, Corymbia maculata*) with life expectancy 25 – 70 years, however examples of mature *Eucalyptus rudis* more than 70 years old are found throughout Perth Metropolitan region.

When it comes to nut trees *Macadamia integrifolia* has a long life span of 100 years or more whereas *Prunus amygdalus* (Almond) trees have a shorter life span of 20 – 30 years, which is similar to Pecans which have a life span of approximately 40 years. The nut production begins the earliest in Almonds (3 – 4 years) however most nut trees will produce a good crop on trees that are approximately 7 - 10 years old.

10.1.5 Site Conditions

Plant ‘the right tree in the right place’ is the common phrase used by gardeners not only to imply the location of a tree with respect to infrastructure but also to the natural distribution of the species within any given area. By selecting tree species based on their suitability to the site (i.e. water, shade, soil, and surrounding environment) it is much easier to reach and maintain revegetation goals. Therefore, species that are suitable as Black Cockatoo feeding and roosting habitat and have potential to contribute to the amenity of the site are considered in preference to the introduced species.

Given that the entire Curtin Bentley Campus and its properties are situated on Bassendean sands interspersed with dunal depressions, the natural vegetation would encompass species typical of a *Banksia attenuata – Banksia menziesii – Eucalyptus marginata – Allocasuarina fraseriana* woodland interspersed with damplands containing tree species of *Melaleuca preissiana, Corymbia calophylla* and in the wetter areas *Eucalyptus rudis*. The topography of the site and a comparison with the adjacent Collier Golf Course was used as one of the guiding features for selection of the sites best suited for the growth of particular species (e.g., *Banksia, Corymbia, Eucalyptus, Melaleuca* and *Pinus* spp

Planting of nut trees is recommended to boost foraging habitat value onsite. *Prunus amygdalus* (Almond) and *Macadamia integrifolia* (Macadamia) are recommended as they best suit site conditions. Whilst Pecans would provide a good food source for Black Cockatoos, they require colder conditions to fruit optimally and would not be recommended for Curtin site. Both Macadamia and Almond are insect pollinated (predominantly bees) however the self pollinating varieties (wind) are also available. Planting nut trees in windy / exposed areas may result in loss of pollen and low fertilisation and this will need to be taken into account when planting these species.

Planting under pine trees will need to consider the shade, accumulation of pine needles which inhibit growth by influencing pH of the soil, and lower soil moisture around pines. A specific set of guidelines for planting in areas with pines is presented in the 13.2.1 of this plan.

10.2 SELECTING AREAS FOR PLANTING

To determine the sites suitable for planting for Black Cockatoo Habitat the following layers were considered:

- Current roosting sites and connectivity of these to adjacent areas used by Black Cockatoos;
- Current spaces vegetated with pines and other habitat trees;
- Spaces that are suitable for planting with respect to full the Masterplan implementation;
- Location of current amenities, particularly sewer and water lines;
- Spaces available for verge planting taking into account the development of the Masterplan.

The “areas available for planting” are all areas which will not be developed as part of the Masterplan 2013 (see green shaded areas in Figure 20).

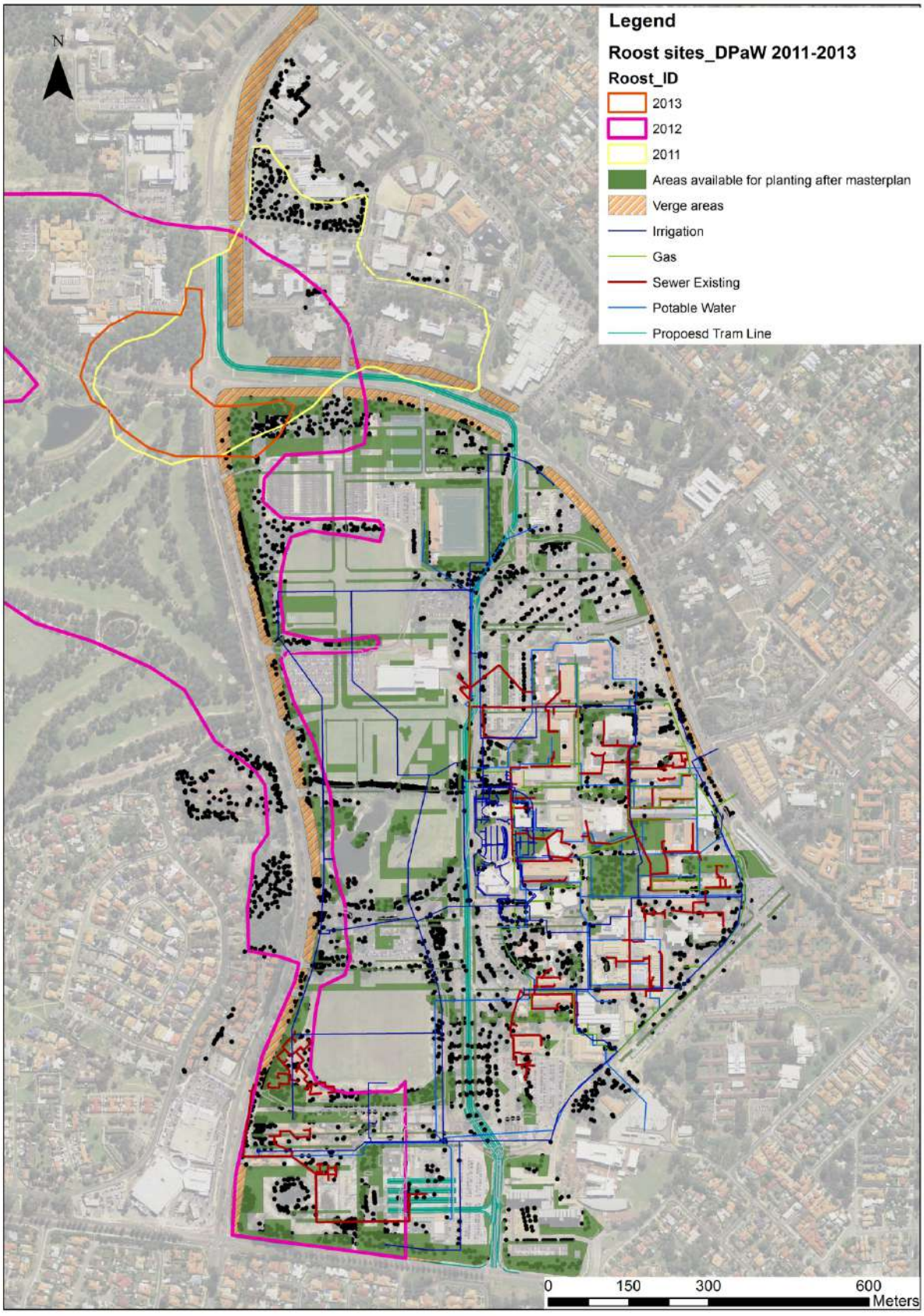


Figure 20 Areas available for planting including location of amenities and roost site boundaries.

The space mapped as 'area available for planting' incorporates areas that have existing vegetation including those that form part of the current Black Cockatoo habitat. To account for the space occupied by existing vegetation, over 50 % of which will persist for 30 years or more, it has been assumed that only 60 % of the 'area available for planting' will have persistent vegetation in the next 30 years leaving only 40 % of the space for infill planting (i.e. from approximately 25 ha 10 ha will be available for infill planting).

No detailed calculations of available space for planting among Curtin properties other than the Bentley Campus has been made due to a lack of availability of property boundary layers, amenities and masterplanning in these areas. If Lot 85 remains undeveloped in addition to the southern part of the Guild Housing property (to the south) additional area of approximately **1.8** ha may be available for planting. Based on the tree location data provided for Technology Park, an area of approximately **1** ha may be available for planting. An assumption was made that only 0.5 ha will be available for planting for these properties in the future.

The additional areas for planting of shrubs and small trees will be available on approximately **6 ha** of roof areas, which if designed well, could contribute significantly to the overall value of habitat for Black Cockatoos. It is strongly recommended that the design and assessment of roof gardens on early stage buildings are undertaken as research projects, and followed to quantitatively assess the potential value of these to Black Cockatoos. At this stage, the roof gardens are not included in calculations within this report, however should be reconsidered once data becomes available at a later stage.

The overall areas of roof gardens for each stage of development is planned to be:

- Stage 1 - 25,000 m^2
- Stage 2 - 13,200 m^2
- Stage 3 – 13,000 m^2
- Stage 4 – 10,000 m^2.

The total available area for planting within the Bentley Campus of Curtin University (containing main streetscape and buffer zones without sporting fields and the large lawn area facing the Jack Finney Lake) after full implementation of the Masterplan is **9.6 ha,** Figure 20. This area calculation incorporates newly created spaces for street trees and garden areas which may not be available for planting until the completion of the Masterplan.

The additional area which can be considered for planting is that of the verge areas along Kent Street and Hayman Road. These areas have been selected to allow for implementation of the Masterplan and construction of the light rail network and the planting will follow guidelines imposed by Town of Victoria Park and City of South Perth. The total area

available for verge planting (including Kent st and Hayman road surrounding Curtin and Technology Park) is approximately 9 ha, 50 % of which (**4.5 ha**) would be available for tree planting given the safety restrictions and the distances required for safe foraging and roosting by the Black Cockatoos.

Taking the above figures and comments into consideration, the total available space within Curtin Bentley Campus and verges for planting replacement trees and shrubs to offset losses is approximately **14.5 ha. Note: this excludes spaces that may be available on roof gardens and on other Curtin properties and includes areas which currently have vegetation.**

Given the stocking rate of 1250 stems per hectare used for *Eucalyptus globulus* plantations (Department of Agriculture and Food, 2005) planting a total of 17,500 trees would be possible on site. However, given the urban environment, marginal water availability, and the requirement of a significant number of species to grow in an open sunny position, this is not recommended.

To obtain large trees which are to remain on site long term and provide large canopy and thus provide habitat for Black Cockatoos as well as amenity values, a stocking rate of 200 - 300 trees per hectare (2 – 3 trees per 100 m^2) is recommended for Curtin. This would allow for re-planting of 2,900 – 4,350 trees and provide space for understory planting of species suitable for Black Cockatoo foraging as well as for amenity value. Dense plantings in groups can still be achieved in winter wet depressions on site where 10 – 15 tree stems per 100 m^2 can be planted.

The proposed 1:4 tree offset within the Curtin properties and verges due only to development, is possible, however, a 1:4 replacement ratio of loss of trees due to development and age collectively would not be considered feasible, as an additional 17 – 33 ha of planting space would be needed (at a rate of 200 – 300 trees per hectare). However, considering the green linkages in the adjacent areas (verges and parklands), the offset could be achieved in collaboration with the local government authorities and the Water Corporation (for planting on or near water compensation basins).

10.3 DETERMINING APPROPRIATE OFFSETS RATIOS

Whilst the 4:1 replacement ratio is considered to be a good replacement for high value trees lost as a result of development, loss of trees due to senescence may not require such high replacement ratios, and in any case, a rationale is required to recommend offsets ratios going forward.

This section proposes offset ratios based on the relative value of trees and shrubs as discussed in Section 10.1. If the following rules are taken into consideration, the total number

of trees and shrubs that will be replaced can be reduced, provided appropriate species of high habitat value for the Black Cockatoo are planted. Proposed ratios for offsets are given below:

- Feeding Habitat only: 1:2
- Feeding and roosting 1:2.5 (0.5 = 1 pine tree for every 2 lost due to age)
- Feeding Roosting and Nesting 1:4
- Roosting only 1:2
- Feeding – Shrubs only 1:4 (with shrubs only)

The summary of total number of trees and shrubs required to be planted to offset losses of habitat due to development and senescence of pines, based on the new proposed ratios, is presented in Table 8 together with the current dominant species and some of the proposed replacement species.

Table 8 Summary of tree losses and the proposed offsets.

Habitat tree	Numbers lost in 30 years	Current Species (top contributing species)	Replacement number of trees and shrubs	Examples of proposed replacement species
Feeding Roosting and Nesting	52	*Corymbia calophylla, Eucalyptus gomphocephala*	208	*Corymbia calophylla, Eucalyptus gomphocephala*
Feeding and roosting	1,317	*Pinus pinaster, Eucalyptus robusta*	3,293	*Pinus pinaster* or *Pinus pinea, Corymbia calophylla Eucalyptus gomphocephala, Eucalyptus marginata*
Feeding Only	610	*Callistemon viminalis, Agonis flexuosa, Casuarina cunninghamiana, Jacaranda mimosifolia, Eucalyptus caesia ssp. magna, Tipuana tipu, Nuytsia floribunda*	1,220	*Banksia attenuata, Banksia menziesii, Banksia grandis, Banksia sessilis, Eucalyptus todtiana, Eucalyptus marginata Allocasuarina fraseriana, Agonis flexuosa, Prunus amygdalus, Macadamia integrifolia, Jacaranda mimosifolia, Nuytsia floribunda, Liquidambar styraciflua*
Roosting Only	372	*Eucalyptus grandis, Corymbia maculata, Eucalyptus rudis, Eucalyptus camaldulensis var. obtusa, Eucalyptus camaldulensis var. camaldulensis*	744	*Eucalyptus rudis, Corymbia calophylla, Eucalyptus gomphocephala*
Shrubs (feeding only)	147	*Grevillea* species, *Banksia* species, *Xanthorrhoea preissii, Hakea* species	588	*Grevillea* species, *Banksia* species, *Xanthorrhoea preissii, Hakea* species
Total	**2,498**		**6,053**	

Compared to the offset with a 1:4 ratio (9,392 trees and 588 shrubs totalling 9,980) the total number of plants in fill planting with the suggested replacement rate would be reduced by 39.4 % (5,465 trees and 588 shrubs). Considering the potential increase in habitat value

associated with the suggested replacement species compared to the existing value provided by the current habitat, this offset is considered achievable and appropriate.

Based on the proposed offset ratios and given a planting rate of 200 - 300 trees per hectare, the additional area required for planting aside from Curtin Bentley Campus and adjacent verge areas is **4 – 13 ha**.

Planting of replacement trees and shrubs particularly those with the high roosting and feeding value should commence as soon as possible and be completed within a short period of time to allow for creation of a mature urban forest by the time the development is completed (in 20 – 30 years time). This planting will also ensure that the habitat for Black Cockatoos will be maintained and improved at a local scale.

At a minimum trees and shrubs that are to be lost due to development and senescence in the first 10 years should be planted within three years, trees to be lost within 20 years should be replaced within three to five years, and trees to be lost within 20 – 30 years should be replaced within five to seven years from 2014. The breakdown of the number of replacement trees and shrubs to be planted in each period is given in Table 9 below.

Table 9 Number of replacement habitat trees and shrubs to be planted between 2014 and 2,022 to offset losses of trees and shrubs lost as a result of full Masterplan development and 0-30 year predicted senescence of trees.

Habitat tree	Number of Trees and Shrubs lost 0-10 years	Number of replacement trees to plant 2014 -2017	Number of Trees and Shrubs lost 10-20 years	Number of replacement trees to plant 2018 - 2020	Number of Trees and Shrubs lost 10-30 years	Number of replacement trees to plant 2020 - 2022
Feeding Roosting and Nesting	30	120	20	80	2	8
Feeding and roosting	375	937.5	584	1460	358	895
Feeding Only	312	624	205	410	**93**	186
Roosting Only	165	330	115	230	**92**	184
Shrubs (feeding only)	61	244	47	188	39	156
Total trees and shrubs	**943**	**2255.5**	**971**	**2368**	**584**	**1429**
Total for Trees only	***882***	***2012***	***924***	***2180***	***545***	***1273***

To ensure availability of space for future planting, and preservation of existing roosting habitat, particularly in the north west section of the development (used by Carnaby's Black Cockatoo for roosting from 2006), it would be prudent to reconsider placement of some of the residential buildings proposed for this area of high habitat value to another area (further south). This modification would result in the loss of one of the proposed small playing fields

(currently a car park). This would constitute a relatively small adjustment to the overall plan considering the availability of other playing fields in the area, and the lack of space for Black Cockatoo Planting. Drawing shown in Figure 21 illustrates this proposed change.

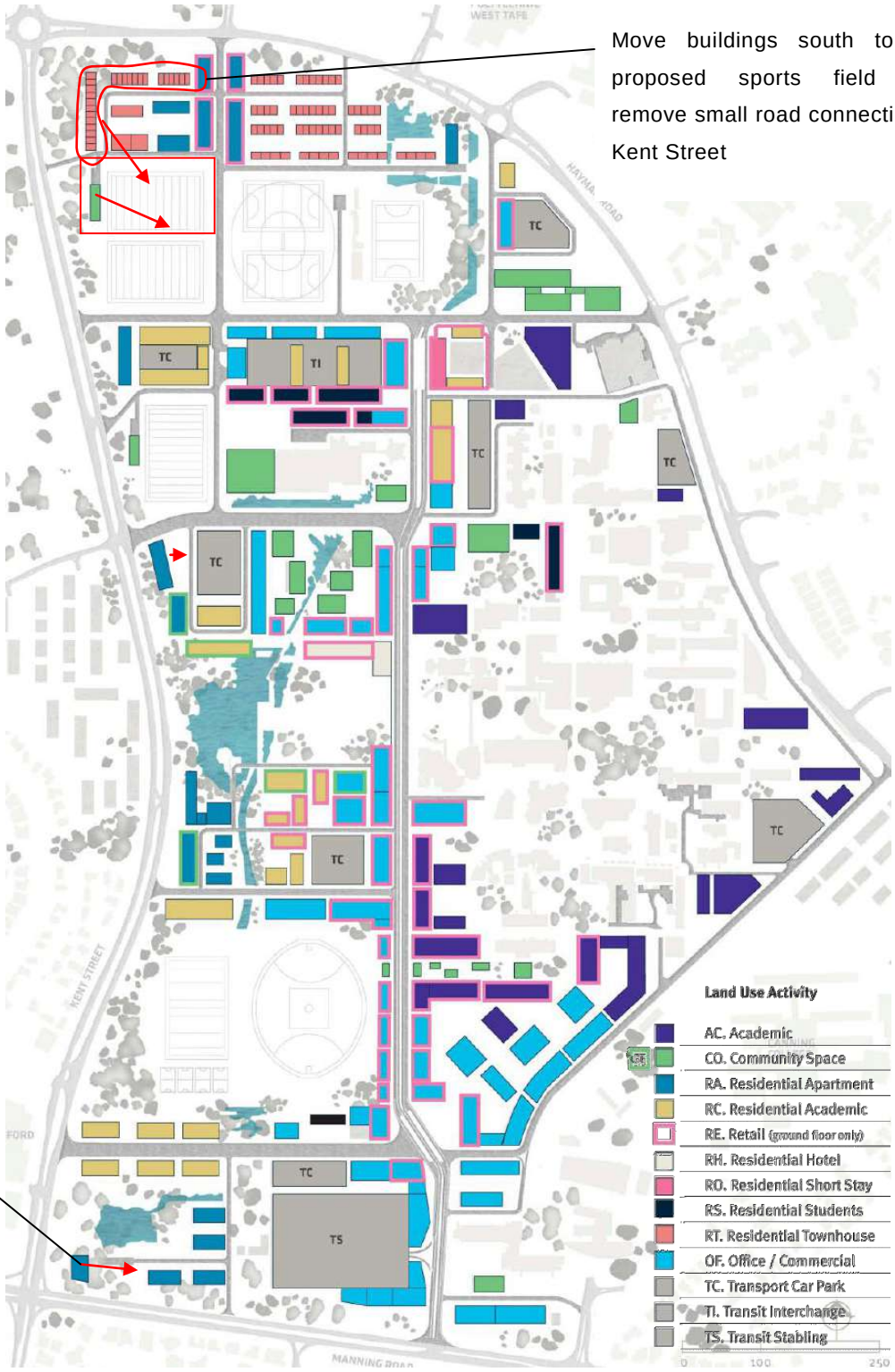


Figure 21 Proposed changes to building placement to conserve and increase area available for Black Cockatoo habitat planting.

PART 4: TREE REPLACEMENT PLAN

This Part outlines a specific planting plan (species, density, areas and timing) that will guide the required habitat replacement, as detailed in the previous sections. The planting plan builds on the agreed outcomes of previous work, such that it integrates these principles and requirements as far as is possible.

Based on the data collected by Arbor Centre (2012), RPS environmental consultants have developed the Urban Forest Management Plan (UFMP) (RPS, 2012) for the Curtin Bentley Campus. This plan analysed the context, history, environment and tree species of Curtin to develop a set of guidelines and criteria to ensure sustainability of the Curtin's urban forest.

The guidelines for tree species diversity, location selection with particular species lists appropriate to location (e.g. parkland, urban core, car parks etc) were selected to achieve shade, amenity, wayfinding, promote social interaction and conserve native flora and habitat. In addition to guidelines, the plan provided the recommendations for succession planting. This was particularly geared towards areas containing trees which had a low life expectancy due to age and general health. The UFMP also provided the current species list for the Bentley Campus which included the average height, spread, value and life expectancy for each species. The UFMP should be referred to prior to planting to confirm the overall landscaping 'look' for specific areas of the urban environment.

The Greater Curtin Masterplan has considered all of the available information to derive strategies to creation of landform and climate responsive planting which provides for habitat and biodiversity increase in the area, increase in amenity value as well as functional value (e.g. vegetation of the living stream). This work has resulted in delineation of vegetation character zones which will be used in this TRP to delineate planting lists for the areas falling within those zones.

11.0 VEGETATION CHARACTER ZONES

Four vegetation character zones have been specified for Bentley Campus along the north to south axis incorporating plants indigenous to the site which would have naturally formed part of the landscape in the past. These vegetation zones and their proposed key plant species are presented in Figure 22.

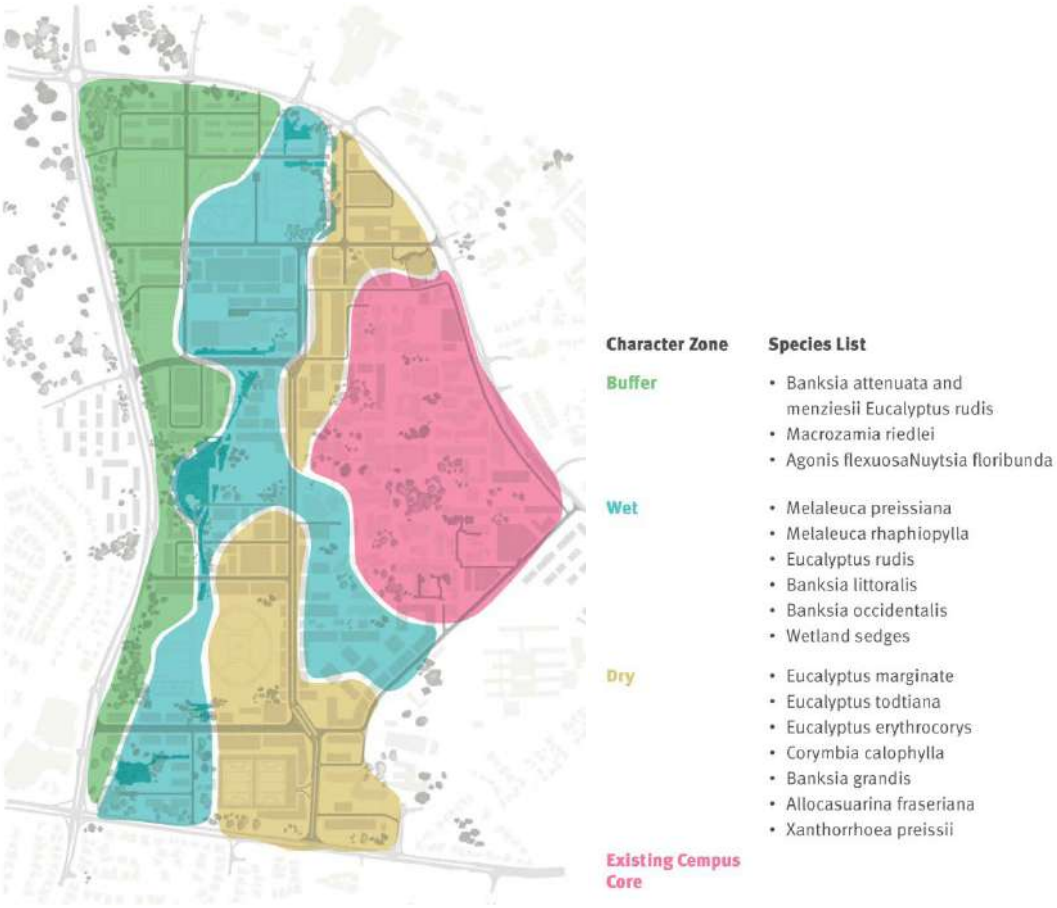


Figure 22 Vegetation Character Zones (Curtin University, 2013)

As can be seen by the key planting species the vegetation zones closely relate to the arrangement of the current Black Cockatoo habitat particularly within the Buffer zone, with opportunities for habitat creation across all zones.

Whilst providing limited opportunity for roosting and food habitat for Black Cockatoo, the Wet Zone will provide for an area where birds would have availability to a clean water source which would be of significant value to the sustainability of the roosting habitat for birds.

Given the above information and the analysis data, areas or “spaces available” for planting were assessed to determine the species composition and guidelines for planting in each particular zone.

12.0 TREE REPLACEMENT PLAN

The Tree Replacement Plan is presented in Figure 23 and the associated planting list provided in Table 10. The plan and the species list are congruent with Masterplan vegetation character zones, with minor changes to planting position of *Corymbia calophylla* and addition of the Dampland. The Dampland is associated with depressions within the Buffer Zone and

utilises 'transitional' species that typically occur at the interface between wet and dry environments. The approximate recommended planting numbers for each habitat species are provided in Appendix 4. Details of planting guidelines relating to Figure 23 and Table 10 are presented in Section 13.0, however, the main points to consider in terms of prioritising works is outlined below.

Ideally the planting should start as soon as possible with the nursery orders for tubestock planting ordered by mid 2014 for planting in winter 2015 and 2016. Given that the verge areas currently have minimal or no vegetation it would be recommended that those areas be planted first in addition to the currently non vegetated areas within the Bentley Campus. Consultation with the Town of Victoria Park and City of South Perth representatives should be undertaken early in 2014 to obtain relevant approvals, conduct appropriate site preparation (e.g. weed control and mulching) and ensure that the planted habitat will be maintained for the future. Opportunities exist to utilise the City of South Perth Nursery which could be of financial benefit to all parties as well as providing a conservation advantage via use of local provenance seed for some of the locally indigenous tree and shrub species.

Soil testing should be conducted to determine presence of disease or pests before the proposed plan is implemented. The plan may need to be modified depending on the findings. Nonetheless, strict hygiene protocols should be followed with all plantings to minimise chances of disease spread.

Given that the verge areas along Kent Street provide an ecological link between the Kensington Bushland and the Canning – Swan River foreshore, the planting of this area should utilise local indigenous species (not all of which will be of direct benefit to Black Cockatoo in terms of feeding and roosting) These species have also been included in Appendix 4. Given the safety and amenity considerations for the verge planting areas the planting will most likely not be entirely reflective of the natural habitat, however it should follow the natural contours of the land and keep the planting theme true to the landscape.

Within campus, and Curtin properties at Technology Park and Guild House planting should use both native and non native plants including pines to provide a sustainable habitat for Black Cockatoos into the future. Where non native plants are used the transition between native and non native planting will need to be taken into consideration to ensure high amenity landscaping is achieved. An experienced landscape consultant should be appointed to provide detailed planting plans for specific areas as the staging of the development progresses to ensure continuity of habitat for Black Cockatoo whilst preserving and enhancing amenity value and the natural and cultural (indigenous) heritage of the area. This TRP and the proposed species list consider these aspects carefully. Whilst some species like *Tipuana tipu* and *Melia azedarach* are used by Black Cockatoos they are invasive weed species and hence omitted from the final planting list presented in Table 10.

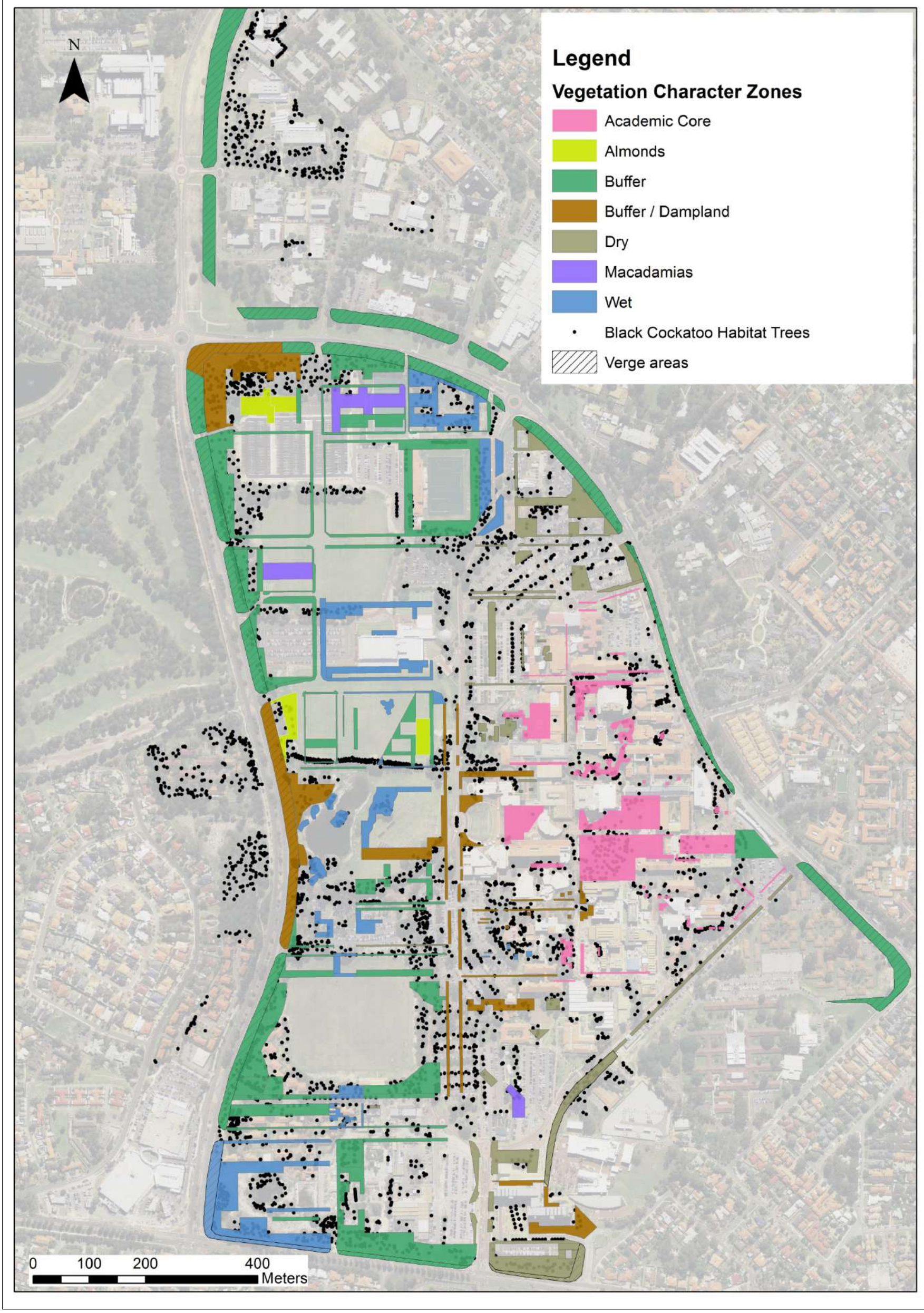


Figure 23 Plan indicating areas which will be available for planting consisting of verges and infill planting areas within Campus.

Note: Most polygons currently have vegetation. Polygons are coloured in accordance with the vegetation character zones which are represented in the species list provided in Table 10 and Appendix 4.

Table 10 Planting allocation of habitat species for each vegetation zone (as per TRP in Figure 23).

Family	Species Name	Growth Form	Black Cockatoo Habitat			Priority for planting	Recommended areas for planting				
			Feeding	Roosting	Nesting		Buffer	Buffer / Dampland	Wet areas	Dry	Academic core street /urban planting
Trees											
Fabaceae	*Acacia saligna*	Tree	Y	N	N	Low	x		x		
Myrtaceae	*Agonis flexuosa*	Tree	Y	N	N	Low				x	x
Casuarinaceae	*Allocasuarina fraseriana*	Tree	Y	N	N	Medium	x			x	x
Proteaceae	*Banksia ashbyi*	Tree	Y	N	N	Medium					x
Proteaceae	*Banksia attenuata*	Tree	Y	N	N	High	x				
Proteaceae	*Banksia grandis*	Tree	Y	N	N	High	x	x			x
Proteaceae	*Banksia ilicifolia*	Tree	Y	N	N	High		x			
Proteaceae	*Banksia littoralis*	Tree	Y	N	N	High			x		
Proteaceae	*Banksia menziesii*	Tree	Y	N	N	High	x			x	x
Proteaceae	*Banksia prionotes*	Tree	Y	N	N	High	x			x	
Proteaceae	*Banksia sessilis*	Tree	Y	N	N	High	x			x	
Myrtaceae	*Corymbia calophylla*	Tree	Y	Y	Y	High	x	x		x	
Myrtaceae	*Corymbia ficifolia*	Tree	Y	N	N	Medium				x	x
Myrtaceae	*Corymbia haematoxylon*	Tree	Y	N	N	Medium				x	x
Myrtaceae	*Eucalyptus gomphocephala*	Tree	Y	Y	Y	High	x			x	x
Myrtaceae	*Eucalyptus grandis*	Tree	N	Y	N	Low	x			x	x
Myrtaceae	*Eucalyptus loxophleba*	Tree	Y	N	Y	Low					x
Myrtaceae	*Eucalyptus marginata*	Tree	Y	Y	N	Medium	x			x	x
Myrtaceae	*Eucalyptus rudis*	Tree	N	Y	N	Low		x	x		
Myrtaceae	*Eucalyptus todtiana*	Tree	Y	N	N	Medium	x			x	
Proteaceae	*Hakea laurina*	Tree	Y	N	N	Medium	x			x	x
Fabaceae	*Jacksonia sternbergiana*	Tree	Y	N	N	Low	x	x			
Proteaceae	*Macadamia integrifolia*	Tree	Y	N	N	Medium					x
Loranthaceae	*Nuytsia floribunda*	Tree	Y	N	N	Low	x	x		x	x
Pinaceae	*Pinus pinaster*	Tree	Y	Y	N	Medium	x			x	x
Pinaceae	*Pinus pinea*	Tree	Y	Y	N	Medium	x				x
Rosaceae	*Prunus amygdalus*	Tree	Y	N	N	Medium					x
Xanthorrhoeaceae	*Xanthorrhoea preissii*	Tree	Y	N	N	Medium	x	x	x	x	x
Shrubs											
Casuarinaceae	*Allocasuarina humilis*	Shrub	Y	N	N	Low	x			x	
Proteaceae	*Banksia dallanneyi*	Shrub	Y	N	N	Low	x				x
Proteaceae	*Banksia gardneri*	Shrub	Y	N	N	Low					
Proteaceae	*Banksia hookeriana*	Shrub	Y	N	N	Medium				x	x
Proteaceae	*Banksia nivea*	Shrub	Y	N	N	High	x			x	x
Myrtaceae	*Callistemon viminalis*	Shrub	Y	N	N	Medium				x	x
Scrophulariaceae	*Eremophila glabra*	Shrub	Y	N	N	Low	x			x	x
Proteaceae	*Grevillea bipinnatifida*	Shrub	Y	N	N	Medium	x	x			
Proteaceae	*Hakea lissocarpha*	Shrub	Y	N	N	Medium	x				
Proteaceae	*Hakea prostrata*	Shrub	Y	N	N	High	x	x			
Proteaceae	*Hakea ruscifolia*	Shrub	Y	N	N	Medium					x
Proteaceae	*Hakea trifurcata*	Shrub	Y	N	N	High	x				
Proteaceae	*Hakea undulata*	Shrub	Y	N	N	High				x	x
Proteaceae	*Hakea varia*	Shrub	Y	N	N	Medium		x	x		
Fabaceae	*Jacksonia furcellata*	Shrub	Y	N	N	Medium		x	x		
Myrtaceae	*Kunzea glabrescens*	Shrub	Y	N	N	Low			x		
Proteaceae	*Persoonia saccata*	Shrub	Y	N	N	Low	x				

This species list incorporates only species which are considered to be of value to Black Cockatoo habitat. Other species which would be suitable for planting on site to support the habitat species identified above is provided in Appendix 4.

13.0 TREE REPLACEMENT AND PLANTING GUIDELINES FOR BLACK COCKATOO HABITAT IMPROVEMENT

These Tree Replacement Plan guidelines are based on the recommendations and align with guidelines from a variety of sources most significantly from the UFMP (RPS, 2012), data collected by Arbor Centre (2012), The Greater Curtin Masterplan (Curtin University, 2013), and Guidelines and policies on tree and vegetation planting from major service providers (water, electricity, telecommunications, gas) and the local government areas (Town of Victoria Park and City of South Perth).

All habitat tree selection, planting, removal and maintenance should occur in accordance with the guidelines outlined below. Planting guidelines for street trees are not provided in this document as street tree planting will need to be considered at a much smaller scale. The guidelines below are mostly applicable in the areas currently occupied by pines or in vacant areas such as verges and lawned / parkland or otherwise bare areas.

Planting of shrubs which also form a significant part of the recommended plant list, follow same rules as those applicable to trees; however, given Curtin University is concerned with the safety aspect relating to the dense planting of vegetation particularly shrubs this TRP presents guidelines specific to shrub planting.

13.1 TREE SELECTION

The following set of guidelines should be applied when selecting trees:

- Select trees appropriate to their settings (refer to Appendix 4) and in accordance with the guidelines presented in the UFMP (RPS, 2012);
- Buy quality tubestock or advanced stock that is free from defects such as excessive root pruning or girdling. Tubestock should be used in preference to advanced trees for the habitat (i.e. Buffer, Dampland and Wet areas) planting
- Consider using trees grown in three dimensional root pruning (3DARRP) pots which encourage vigorous root growth fostering plant establishment of the tree once planted on site and reducing the need for staking (reducing labour costs over time);
- Choose stock that shows good health and vigour, is free from pests and has no signs of disease (refer to Appendix 5 for details on plant diseases affecting species recommended for planting at Curtin).

- When placing order for street trees or amenity trees ensure the nursery supplies trees that have good structural integrity. This will ensure longevity of the trees and reduce maintenance over time;
- Choose trees with a long life span providing both roosting and feeding habitat where possible.
- Chose predominantly indigenous tree and shrub species in the buffer areas and along dreamtime trails.

13.2 TREE PLANTING AND SITE PREPARATION

13.2.1 Site Preparation

- Tree planting should be undertaken in areas that won't be affected by construction of new infrastructure as a priority to offset the impact of construction. Creation of green links and interconnecting canopy covers by maximising tree planting opportunities through tree selection shall be made a priority.
- Area selection: - plant within bare areas, verges, or empty patches within currently vegetated areas. For the location of areas – check plan in Figure 23.
- Determine the total available area for planting and estimate number of plants required.
- Prepare the site – check pH and nutrient levels and check for presence of pathogens such as Dieback or infill materials (e.g. building rubble, and or the waste materials).
- Perform weed control two weeks prior to planting - It is prudent to perform summer and winter weed control as to target a range of species, however the weed control will be driven by individual site locations.
- Remove pine needles from the planting area where present and dispose off site. This should be done for both pine and native trees.
- Mulch should be applied on verges and in garden beds where there is partial or no tree shading to provide benefits to plants exposed to high heat load from paved surfaces, roads etc. Mulch must be weed and pest free, spread to 10 cm thickness and be coarse (fine particle mulches can form crusts which prevent rainfall or other water applied to penetrate to the soil surface).

Mulching is not recommended in areas with pines unless solely for aesthetic purposes. The thick layer of pine needles will form across the surface in a relatively short time especially in areas with mature trees thus the effort of mulching is negated and is unlikely to help the growth of trees.

Application of mulch is not recommended in habitat creation areas planted with proteaceous tree species (including *Banksia, Grevillea, Macadamia* spp.) as they have highly sensitive and dense root network close to the surface. Mulch can affect the roots in the following fashion:

a) Wood chip or pine bark mulches may retain too much moisture which can cause root rot;

b) Composted mulches can introduce a high loading of organic nutrients which may not suitable for these species;

c) Mulches may contain diseases that may suppress the growth and or contribute to plant deaths.

Use ground covering plants or clean gravel instead of mulch application for mulch sensitive species where required.

- Install irrigation in high amenity areas and road entrance verges to maintain good health and vigour of plants.

- For native plants and nut trees use drip irrigation instead of sprinklers.

13.2.2 Tree Planting

Application of the same rules for planting trees across the site is not advisable as the species, site conditions, the size of nursery stock and the final use (e.g. habitat and shade) will dictate how to plant. Given this there are some generic rules which should apply for most habitat tree plantings. The guidelines below are specific to habitat trees supplied as tubestock, however, same rules apply to some smaller mature stock:

- **Plant at the time that would be best for seedling establishment.** This is usually during the high rainfall months (late autumn - winter) with best months to plant being mid of June to mid August. The weather forecast should be checked prior to planting to ensure adequate soil moisture for plants will be available after planting to avoid water stress. There is no allowance in this plan for artificial watering of the buffer areas, after planting therefore, tubestock should be planted following substantial winter rains. The stock will respond well to the end of winter conditions and start to grow ensuring that their root systems will be capable of accessing soil water during

summer months. To ensure high survivability of stock in the exposed areas such as verges, supplementary watering during summer may be needed. Watering in plants after planting is a good idea even if the soil is moist.

- **Plant new seedlings in the open areas** away from trunks of surrounding pines wherever possible.

- Plant **no more than 3 large or 5 medium to small tree seedlings per 100 m^2 on average.** Once seedlings are 2 to 3 years old, 2 or 3 of the poor performing individuals can be cut down and the strong healthy individuals allowed to grow with an average tree density of 2 – 3 trees per 100 m^2. This method allows for the most cost effective way of selecting vigorous and healthy trees ensuring their longevity and habitat creation.

- When planting habitat trees in low traffic streets it is important to consider the crown spread to determine the appropriate distance between trees. For example smaller trees can be planted closer to each other than tall, large crowned trees, particularly if there is a shade requirement (e.g. planting *Jacaranda mimosifolia* can be planted at smaller spacing than *Eucalyptus gomphocephala* or *Eucalyptus rudis*).

- Macadamia and Almond trees should be planted in accordance with the recommendations from the nursery suppliers as different cultivars produce either upright or spreading canopies requiring different distances within and between rows. Windy areas on site should be avoided for nut tree planting as pollination and thus nut productivity may be impacted.

- To plant a seedling or advanced stock, excavate the **planting hole** up to two to three times the size the width of the root ball. The sides of excavation should slope outwards from the bottom of excavation. The depth of the planting hole should be equal to that of the root ball (planting trees too high causes root exposure to air and sunlight and causes damage to the roots and may cause death of the plant).

- After removing the plant from its container place it in the centre of the hole and upright, with the topsoil level of the root ball level with the finished surface of the surrounding soil. Backfill with topsoil and press firmly around the plant to eliminate air pockets. Ensure that topsoil is not placed above the top of the root ball and that the plant stem remains the same height above ground as it was in the container. Figure 24 provides guidance on the depth of planting.

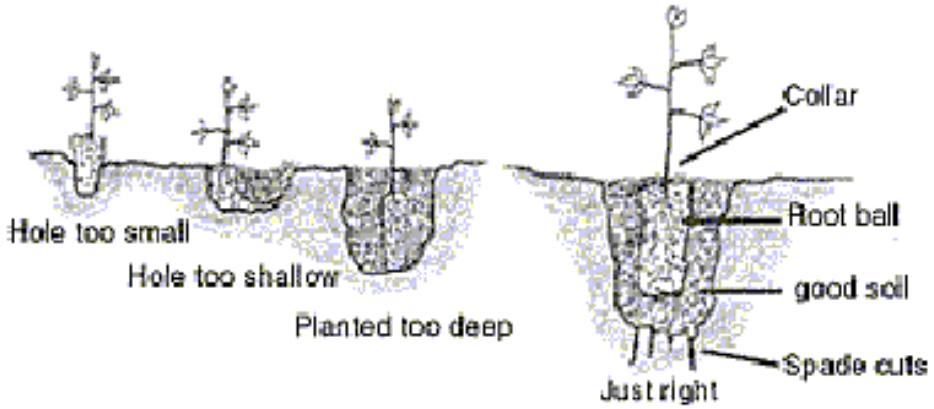


Figure 24 Seedling planting depth guide (taken from Davis (2002))

- **Minimise danger to Black Cockatoo** by planting foraging species at least 6 m away from the road curb. Exception to this rule may be the street trees which offer roosting habitat only (e.g. no chance of nuts or seed spread on the road).

- Minimise **conflicts between trees and infrastructure and amenities**: When choosing a tree, the mature height and spread shall be considered to ensure that it will not interfere with existing or proposed buildings, infrastructure and underground utilities.

  The mature tree height and crown spread may be used to estimate root spread, however often the root spread is much larger than the tree's crown at maturity. As a general rule, the minimum distance from utilities particularly water and sewer lines is 6m, however root barriers can be installed to reduce this distance.
  Specific available guidelines from service providers are summarised below:

- **Amenities : (Water and Sewer, Gas, Power)**
  - Plants that grow taller than 5 m are not to be planted within 6 m of a pipeline or in a pipeline easement.
  - Planting or removal of trees or stump grinding in the vicinity of large mains requires assessment by the Water Corporation.
  - Don't reduce the planting garden depth by removing soil.

There are no legal restrictions to planting near underground power services in Western Australia.

Planting of trees in areas with high traffic and extensive paving will have specific requirements to ensure longevity and healthy growth of the trees and shrubs. Problems with soil compaction and the tree root and trunk expansion need to be considered in order to design the pathways, roads and other infrastructure. Often issues arise with inappropriate

planting of trees, for example planting in a narrow strip between the road and the pathway when a large lawned area is present on the other side of the pathway. Roots which seek water, nutrients and air will grow preferentially towards lawned or non-paved area and in the process may cause lifting and cracking of the pathway.

An experienced contractor should be appointed to produce a specific planting plan that will outline planting procedures in accordance with the site constraints in order to ensure tree longevity and avoid any damage to infrastructure.

Any planting should account for losses due to drought and vandalism. This is usually 10-15% of the total plants planted.

13.2.2.1 Verge landscaping

These guidelines were compiled from Town of Victoria Park and City of South Perth Verge Landscaping Guidelines. These guidelines should apply to all verge areas surrounding the campus and Technology Park.

Installing verge plantings of any type (except for lawn) requires permission from both Town of Victoria Park and City o South Perth to ensure that designs are not hazardous and do not interfere with pedestrian or motorists safety.

- No plant is to be more than 750 mm when mature or of hazardous nature (e.g., thorny or poisonous).
- Loose pea gravel, crushed brick or other stone aggregates are generally not permitted as verge treatments.
- The verge treatment is not to impede pedestrian access.
- There should be no holes, stakes (other than street tree stakes), bollards, dividers, trip hazards or other physical barriers that protrude above the level of the verge.
- The general level and grade of the verge is not to be altered.
- All irrigation pipe work and associated fittings are to be laid at a depth of not more than 300 mm, nor less than 150 mm, below ground level.
- Mulch is to be woodchips or large-particle vegetative mulch material. The finished level should be no higher than the surrounding top of kerb and footpath heights. This may require some soil removal in preparation for your garden.
- Existing street trees are to be protected and not to be pruned or interfered with in any way without approval from the Town.

- Verge treatments are to be setback 1.0 m from the road frontage, and if no footpath is present, a 2 m pedestrian area must be available at the property boundary. Plants should not encroach onto footpaths or roadways.

13.2.2.2 Street Tree Planting on Verges

Following guidelines refer to tree planting and were taken from the City of South Perth Street Tree Management Plan (City of South Perth, 2003). Whilst Town of Victoria Park is in the process of developing the street management rules, their advice with respect to tree planting near roads is to follow City of South Perth Guidelines (Penny Fletcher, Town of Victoria Park, *pers. comm.*).

The location for a tree on the verge shall generally be:

- Three metres measured at right angles from any adjacent property boundary.
- A minimum of 3 m from a vehicle crossover, power pole, fire hydrant, or inspection pit box.
- A minimum of 15 m from a kerb corner alignment on any side of an intersection.
- A minimum of 15 m from the approach side of a pedestrian crossing and 5 m from the departure side;
- Seven metres from any lane way, or vehicle right of way.
- Eight to 15 m between trees depending on the final size of mature specimens, or as a minimum of one tree per property frontage.
- In the case of a single tree, it will be located central to the average size home block.

"These distances may be varied depending on the tree species and specific planting objectives. Variances will also be allowed for the development of an individual streetscape theme where it is recognised that this would benefit the street and ensure that sightlines are maintained to retain safety" (City of South Perth, 2003). The variances may also be allowed where improvement of green corridors or wildlife habitat is proposed as this is one of the aims of the City of South Perth Street Management Plan (City of South Perth, 2003).

13.3 TREE PRUNING

Proper planting, watering, feeding and pruning will lengthen a tree's life, maintain its safety and improve its aesthetics. All pruning of trees should be done in accordance with Australian Standards 'Pruning of Amenity Trees AS 4373-2007" and preferably conducted by an experienced arborist.

Once established experienced arborist is to be engaged to maintain and prune trees as required.

13.4 TREE REMOVAL

An annual tree audit check (by an experienced arborist) should be undertaken to identify stressed or dead trees and undertake tree removal and in-fill planting. Replacement of trees shall occur only due to tree death, poor health or proven risk to people or infrastructure.

Removed trees should be replaced in accordance with the ratios and species list provided in this TRP (see Appendix 4).

Any healthy tree needing removal for development shall be considered for transplanting and or other management options prior to the removal to ensure continuity of habitat for the Black Cockatoo.

The removal of trees should be pre-planned with tree life expectancy in mind and the regular health monitoring which will indicate need for replacement. The replacement trees would be already established in the vicinity of the tree to be removed.

If any of the replacement tree species perform poorly due to heat or water stress they should be replaced with species suited to a drier climate.

13.5 MANAGEMENT OF DISEASE

The annual tree audit check and or incidental observations of any diseased trees should be noted by the experienced arborist or Curtin landscaping team. Following guidelines should be applied in relation to plant diseases present (e.g. Marri canker) and potentially present on site (e.g. Dieback).

- Perform soil and root tissue testing to assess the presence of *Phytophthora* species at Curtin. Sampling should target trees particularly Proteaceae and Myrtaceae (e.g. *Adenanthos* and *Banksia and Corymbia, Eucalyptus and Agonis*) that appear to be under stress.

- If a particular pathogen like *Phytophthora* spp. are found on site consult with the experienced contractor to develop a suitable method of managing that pathogen on site. This may involve application of phosphite (phosphonate) environmentally friendly fungicide by injecting it into trees or spraying the foliage of understorey plants. Phosphate treatment only provides temporary protection and therefore treatment is ongoing (DWG, 2000).

- Develop hygiene protocols for the non infested areas to avoid contamination in the future.

- Ensure soils used for planting are well-drained, and improve their microbial activity through application of disease free composted soil conditioners and mulches.
- Source plant stock that is disease and weed free from accredited nurseries only.
- Source plants which have a well developed root system.
- Avoid overwatering plants. Wherever possible avoid turf and native tree planting combination as the fertiliser and water requirements for these are very different and may affect susceptibility of some trees to disease.
- Use drip irrigation rather than sprinkler irrigation for native plants.
- For trees affected by Marri canker:
  - Cut and dispose affected trees or branches and dispose of site. Where only branches are removed, tree may grow for many years without showing additional symptoms).
  - Cover any wounded areas with the suitable wound paint to prevent infection of the newly cut surfaces.
  - Avoid pruning during wet weather.

For more information on plant diseases affecting species selected for growth on the Bentley Campus refer to Appendix 5.

13.6 MANAGEMENT OF PEST FAUNA

Anecdotal evidence shows that Curtin site is frequented by Eastern/ Long Billed Corellas and Lorikeets which may pose pest problem in terms of competition for food resources particularly with the possible introduction of nut trees such as Almonds.

Should a problem arise with these particular species Curtin University should consult with DPaW to seek advice on how to manage the problem. If the number of birds visiting the site is too high, culling of birds may be required.

REFERENCES

Arbor Centre (2012). Tree Valuation Survey. Report for Curtin University, June 2012.

Aurora Environmental (2013) Referral of Proposed Action: (EPBC 2013/7044) Curtin Main Street - Transformation of Bentley Campus. Accessed online 18 November 2013. http://www.environment.gov.au/cgibin/epbc/epbc_ap.pl?name=current_referral_detail&proposal_id=7044

Australian Curriculum, Assessment and Reporting Authority [ACARA] (2013) F-10 Curriculum. Accessed online December 2013: http://www.australiancurriculum.edu.au

Bleby, T.M., Colquhoun, I.J., and Adams, M.A. (2012) Hydraulic traits and water use of Eucalyptus on restored versus natural sites in a seasonally dry forest in south western Australia. *Forest Ecology and Management* 274, 58-66

Burke, T. (2012) Caring for our Country to support 43 projects across Australia. Media release 8th February 2012. Accessed April 2012 http://www.environment.gov.au/minister/burke/2012/mr20120208.html

CCWFH (2011). Can a microscopic plant pathogen kill a large tuart tree? Centre of Excellence for climate Change Woodland and Forest Health. Research findings 2011. Bulletin NO. 15.

CCWFH (2012). Identifying marri canker disease. Centre of Excellence for climate Change Woodland and Forest Health. Research findings 2012. Bulletin NO. 3.

Chapman, T.F., (2007) An endangered species that is also a pest: a case study of Baudin's Cockatoo *Calyptorhynchus baudinii* and the pome fruit industry in south-west. Western Australia. *Journal of the Royal Society of Western Australia*, 90: 33-40.

Commonwealth of Australia (2013) Aboriginal and Torres Strait Islander Peoples Recognition Act 2013 (No. 18, 2013) - Sect 4. Accessed online November 2013: http://www.austlii.edu.au/au/legis/cth/num_act/aatsipra2013558/s4.html

Convention of Biological Diversity (2004). Decision VII/11: COP 7 – Seventh Ordinary Meeting of the Conference of the Parties to the Convention of Biological Diversity, Kuala Lumpur, Malaysia (9 – 20 February 2004), UN Doc. UNEP/CBD/7/21, accessible at http://www.cbd.int/decisions/cop/?m=cop-07

Cooper CE, Withers PC, Mawson PR, Bradshaw SD, Prince J, et al. (2002) Metabolic ecology of cockatoos in the south-west of Western Australia. *Australian Journal of Zoology* 50: 67–76.

Cooper, C., Withers, P.C., Mawson, P.R., Johnstone, R., Kirkby, T., Prince, J., Bradshaw, S.D., and Robertson, H. (2003) Characteristics of marri (*Corymbia calophylla*) fruits in relation to the foraging behaviour of the forest red-tailed black cockatoo (*Calyptorhynchus banksii naso*). *Journal of the Royal Society of Western Australia*, 86: 139-142.

Curtin City Project Group (2013) Greater Curtin Master Plan. Report prepared by AECOM, Arup, Block Branding, CBRE, Donaldson and Warn, Pracsys and Syrinx Environmental PL on behalf of Curtin University, Curtin University. Curtin. Western Australia.

DAF (2013) European House Borer. Department of Agriculture and Food http://www.ehb.wa.gov.au/. Accessed on 24 November 2013.

DEC (2008) Forest Black Cockatoo (Baudin's Cockatoo *Calyptorhynchus baudinii* and Forest Red-Tailed Black Cockatoo *Calyptorhynchus banksii naso*) Recovery Plan. Pp42. Department of Environment and Conservation, Australian Government. Perth.

DEC (2012) Carnaby's Cockatoo (*Calyptorhynchus latirostris*) Recovery Plan. Western Australian Wildlife Management Program No. 52. Department of Environment and Conservation (October 2012) pp52. Australian Government, Perth.

DEC (2011) Plants used by Carnaby's Black Cockatoo. List prepared by Christine Groom, DEC, 15th April 2011. www.dec.wa.gov.au/plantsforcarnabys and Search tool http://www.dec.wa.gov.au/apps/plantsforcarnabys/index.php Accessed online on October 31, 2013.

DEC (2013) Threatened Species — Policies: Conserving threatened species and ecological communities. Department of Environment and Conservation http://www.dec.wa.gov.au/management-and-protection/threatened-species/policies.html

Del Marco, A., Taylor, R., Clarke, K., Savage, K., Cullity, J. and Miles, C. (2004). Local Government Biodiversity Planning Guidelines for the Perth Metropolitan Region. Western Australian Local Government Association and Perth Biodiversity Project, Perth.

Department of Agriculture and Food (2005) Tree Note No. 27: Growing Tasmanian blue gum : overview : in the greater than 600 mm rainfall zone. Available online: http://www.agric.wa.gov.au/PC_92528.html#yield.

Department of Environment and Primary Industries, Victoria (2009). Maritime Pine. Note Number:AG1086. Accessed online on 25 November, 2013 http://www.dpi.vic.gov.au/forestry/private-land-forestry/individual-species/maritime-pine

Department of Planning (2013) *Capital City Planning Network :a vision for Central Perth.* Published by Western Australian Planning Commission, Perth, Western Australia.

DWG (2000). Managing phytophthora dieback. Guidelines for Local Government. Prepared by the Dieback Working Group. April 2000.

DWG (2013). Dieback Working Group. What is Dieback? Information retrieved from http://www.dwg.org.au/go/about-dieback. Accessed on 21 November 2013.

EMS (2010) EMS — Biodiversity Management Plan: Black-Cockatoo Action Plan (for Carnaby's and Forest Red-tailed Black Cockatoos). In *EMS — Biodiversity Management Plan*, Murdoch University. Murdoch

Enright, N. J.; Lamont, B. B. (1992). "Recruitment variability in the resprouting shrub Banksia attenuata and non-sprouting congeners in the northern sandplain heaths of southwestern Australia". Acta Oecologica 13 (6): 727–41.

George, A. S. (1996). The Banksia Book – 3rd edition. Kangaroo Press, Kenthurst, NSW.

Garnett, S. T., Szabo, J. and Dutson, G., (2011). The Action Plan for Australian Birds 2010. CSIRO Publishing, Collingwood, Victoria.

Heddle, E.M., Loneragan, O.W. and Havel, J.J (1980). Vegetation Complexes of the Darling System Western Australia. In the Department of Conservation and Environment (1980). Atlas of Natural Resources – Darling System Western Australia.

IUCN (2013) IUCN Red List of Threatened Species. Version 2013.1 www.iucnredlist.org. Accessed on 13 November 2013

http://www.wanaturalists.org.au/news/a-tale-of-two-cockatoos/

Johnston, T. (2013) Food resource availability for Carnaby's cockatoo *Calyptorhynchus latirostris* on the Swan Coastal Plain. *School of Natural Sciences*, Edith Cowan University. pp. 140, Perth.

Johnstone, R.E., Kirkby, T., and Sarti, K. (2013) The breeding biology of the Forest Red-tailed Black Cockatoo *Calyptorhynchus banksii naso* Gould in south-western Australia. I. Characteristics of nest trees and nest hollows. Pacific Conservation Biology 19, 121-142

Johnstone, R.E. and Storr, G.M. (1998) Handbook of Western Australian Birds, Volume 1 Non-Passerines (Emu to Dollarbird). Western Australian Museum, Perth, WA.

Johnstone, R. E., Cassarchis, C. (2004) Review of cockatoo research project and Cockatoo Care 2004. Water Corporation and the Western Australian Museum, Perth.

Johnstone, R.E. and Kirkby, T. (1999) Food of the forest red-tailed black cockatoo *Calyptorhynchus banksii naso* in south-west Western Australia. *Western Australian Naturalist* 22, 167-177

Johnstone, R., Johnstone, C., and Kirkby, T. (2011) Black Cockatoos on the Swan Coastal Plain: Carnaby's Cockatoo (*Calyptorhynchus latirostris*), Baudin's Cockatoo (*Calyptorhyncus baudinii*) and the Forest Red-tailed Black Cockatoo (*Calyptorhynchus banksii naso*) on the Swan Coastal Plain (Lancelin-Dunsborough), Western Australia. Studies on distribution, status, breeding, food, movements and historical changes, Report for the Department of Planning, Western Australia. Perth, Western Australia.

Kabat, A.P., Scott, R., Kabat, T.J. and Barrett G. (2012a). 2011 Great Cocky Count: Population estimates and identification of roost sites for the Carnaby's Cockatoo (*Calyptorhynchus latirostris*). Report prepared by BirdLife Australia for the WA Department of Environment and Conservation, February, 2012.

Kabat, T.J., Barrett, G., and Kabat, A.P. (2012b) 2012 Great Cocky Count: identification of roost sites for Carnaby's Black-Cockatoo (*Calyptorhynchus latirostris*) and population count for the DEC Swan Region. In Final Report September 2012, BirdLife Australia, Department of Environment and Conservation and Australian Wildlife Conservancy. Perth Western Australia.

Lee, J., Finn, H., and Calver, M. (2013) Feeding activity of threatened black cockatoos in mine-site rehabilitation in the jarrah forest of south-western Australia. Australian Journal of Zoology 61, 119-131

Manning, J. (2012) Another black cockatoo chick hatches at Murdoch. Murdoch University http://media.murdoch.edu.au/another-black-cockatoo-chick-hatches-at-murdoch. September 13, 2012.

Mayne, H. (2011) Red-tailed Black Cockatoo breeds in metro area for first time. Murdoch University http://media.murdoch.edu.au/red-tailed-black-cockatoo-breeds-in-metro-area-for-first-time. Jul 14th, 2011 @ 01:24 pm.

Menz, M.H.M., Dixon, K.W., and Hobbs, R.J., (2013) Hurdles and opportunities for landscape-scale restoration. Science, 339: doi: 10.1126/science.1228334.

Molloy, S., Wood, J., Hall, S., Wallrodt, S. and Whisson, G. (2009). South West Regional Ecological Linkages Technical Report, Western Australian Local Government Association and Department of Environment and Conservation, Perth.

Natural Resource Management Ministerial Council (2010) Australia's Biodiversity Conservation Strategy 2010-2030, Australian Government, Department of Sustainability, Environment, Water, Population and Communities, Canberra.

National Wildlife Corridors Plan Advisory Group (2012). Draft National Wildlife Corridors Plan. Environment Australia, Canberra, Australia, Commonwealth of Australia.

Noongar Dictionary, compiled by Rose Whitehurst, 1992, Noongar Language and Culture Centre.

NSWDPI (2013) Myrtle rust. NSW Government http://www.dpi.nsw.gov.au/biosecurity/plant/myrtle-rust#Resources-and-factsheets-br-. Accessed on 24th November 2013

Paap, T. (2006) The incidence, severity and possible causes of canker disease of *Corymbia calophylla* (marri) in the southwest of Western Australia. In School of Biological Sciences and Biotechnology, Murdoch University. PhD thesis, Perth, Western Australia.

Perth Biodiversity Project [PBP] (2013). Central Perth Regional Parklands Concept - Vegetation Connectivity Analysis. Technical Report Prepared for Department of Planning February 2013. Perth, Western Australia.

Perth Biodiversity Project [PBP] (2011). Regional Framework for Local Biodiversity Conservation Priorities for Perth and Peel. Unpublished report.

Prober, S. M., M. H. O'Connor, and F. J. Walsh. (2011). Australian Aboriginal peoples' seasonal knowledge: a potential basis for shared understanding in environmental management. Ecology and Society, 16(2): 12. [online] URL: http://www.ecologyandsociety.org/vol16/iss2/art12/

RPS (2012). Urban Forest Management Plan. Technical Report Prepared for Curtin University.

Scott PM, Burgess TI, Barber PA, Shearer BL, Stukely MJC, Hardy GE, Jung T (2009). *Phytophthora multivora* sp. nov., a new species recovered from declining *Eucalyptus, Banksia, Agonis* and other plant species in Western Australia. Persoonia 22, 1-13.

South West Aboriginal Land and Sea Council [SWALSC] (2011). Final Report, Swan and Canning Rivers Iconic Trails Project, Living Culture, Living Land and its people. South West Aboriginal Land & Sea Council, Cannington, Western Australia.

Stock WD, Finn H, Parker J, Dods K (2013) Pine as Fast Food: Foraging Ecology of an Endangered Cockatoo in a Forestry Landscape. PLoS ONE 8(4):e61145.

Syrinx Environmental (2013) Greater Curtin - Integrated Urban Water Management Strategy. Unpublished technical Report Prepared for Curtin University, May 2013.

Syrinx Environmental (2012) Curtin University Biodiversity Study. Unpublished technical Report Prepared for Curtin University, November 2012.

Watanarojanaporn, N.,Boonkerd,N.,Wongkaew,S.,Prommanop,P.,Teaumroong, N., (2011). Selection of arbuscular mycorrhizal fungi for citrus growth promotion and *Phytophthora* suppression. *Scientia Horticulturae,* 128: 423–433.

World Indigenous Network [WIN] (2013). World Indigenous Network: About Us. Acessed online December, 2013 :http://www.worldindigenousnetwork.net/

APPENDICES

Appendix 1 : Ecology and Habitat Requirements of Black Cockatoos.

BLACK COCKATOOS

Three species of Black Cockatoo are endemic to the south-west of Western Australia (Johnstone and Storr 1998). Two are colloquially called white tailed and include the Baudin's Cockatoo (*Calyptorhynchus baudinii*) and the Carnaby's Black Cockatoo (*Calyptorhyncus latirostris*); the other is commonly called the Forest Red-tailed Black Cockatoo (FRTBC: *Calyptorhynchus banksii naso*). They are a very distinctive part of the avifauna in the south-west of Western Australia and all three species have experienced range retractions and substantial declines in populations over the last 50 years (Johnstone et al., 2011).

All three species are highly adaptive in terms of their food choices and as their native food sources have been removed, all species have exploited other available resources, including orchards and pine plantations. This has brought them into clear conflict with orchardists and foresters who will shoot or poison them to protect crops. Clearing and fragmentation of their native habitat, the loss of nesting hollows, high competition for suitable available nesting hollows, the incremental loss of alternative food sources including large pine plantations such as the Gnangara plantation, and vehicle strikes have all contributed to the loss of these charismatic species.

Only two species have been recorded using the Bentley Campus for feeding or roosting; these are the Carnaby's Black Cockatoo and the FRTBC.

CONSERVATION STATUS

In recognition of the substantial declines in population sizes and range retraction, all three Black Cockatoos have been afforded both state and federal conservation protection. Carnaby's Black Cockatoo are considered Endangered under Schedule 1 of the Western Australian *Wildlife Conservation Act 1950* and under the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999.* It is listed as Endangered under the IUCN (IUCN 2013) and is listed on Appendix II of CITES. It is estimated that over 40 000 individuals remain (Barrett pers. com.). The FRTBC is listed as vulnerable under both Western Australian (Schedule 1) and Commonwealth Legislation, with estimates of approximately 12 000 to 15 000 individuals remaining. IUCN only recognises the broader species listing of the Red-tailed Black Cockatoo and therefore only affords it the 'Least Concern' category. This species has however, been split into three subspecies, none of which have been reassessed under IUCN. As reported by Garnett et al (2011) the northern sub-species is widely distributed and common, but the two southern subspecies, *graptogyne* and *naso,* are under threat.

DISTRIBUTION

The FRTBC is a subspecies of red-tailed cockatoo found in the southern parts of Western Australia. The *C. banksii naso* subspecies occurs primarily in the humid to subhumid zones of the south-west. The bird resides in the hilly interior, north to Gingin, Gidgegannup and east to Mt Helena, Chidlow, Wooroloo, Wundowie, the Lakes, Christmas Tree Well near Brookton, banister, Kojonup, Mount Barker and south to the Porongurup range. Sometime in the 1900's a range retraction of the species resulted in the FRTBC rarely being seen on the Swan Coastal Plain (SCP). However sometime around 1995 a major shift in the foraging ecology of the species and the previously sedentary species can now be observed moving up to 19km away from their home range to feed on Cape Lilacs on the SCP (Johnstone and Storr 1998; Johnstone et al., 2013). The is now observed as a casual year round visitor to some Perth suburbs including Kensington and Bentley to search for food (Johnstone and Storr 1998). Murdoch University's Black Cockatoo Action Plan has reported sighting the species in increasingly large numbers in the Melville area and a number have been reported inspecting artificial nesting tubes on the campus itself (EMS 2010) with reported breeding occurring in 2011 and 2012 (Mayne, 2011; Manning 2012).

Carnaby's Black Cockatoo is endemic to the south-west of Western Australia and its range currently extends north to the lower Murchison River and east to Nabawa, Wilroy, Waddi Forest, Nugadona, Manmanning, Durokoppin, Noogar (Moorine Rock), Lake Cronin, Ravensthorpe Range, the head of the Oldfield River, 20km ESE of Coondingup and Cape Arid, occasional birds are also seen on Rottnest Island (Johnstone and Storr 1998). The species has steadily moved south-west since the 1950's with an increasing number of individuals seen year round on the Swan Coastal Plain. With only 40 % of the birds former feeding habitat remaining (Geoff Barrett *pers. com*.), this shift is presumably due to a loss of habitat and food sources in the north eastern parts of its original range. The species now commonly roosts within the Bentley Campus and the adjacent Collier Park Golf Course officially recognised as a super roost site for the species (Kabat *et al.*, 2012).

ECOLOGY

FRTBC was previously a relatively common species in Western Australia which is now considered rare to uncommon with patchy distribution in its former range. It is estimated that there are only between 12 000 and 15 000 individuals left. The species usually flies in pairs or small flocks and is seldom seen in large flocks (up to 200). The species is postnuptial nomadic with most individuals tending to move west after breeding (known to breed in all months but peaks in autumn and winter: Johnstone *et al.,* 2013). The species typically breeds in the hilly interior of the south-west and was only recently recorded to breed on the SCP in the Melville area (Mayne, 2011; Manning 2012). The species forms lifelong monogamous pairs and they usually begin breeding at about 4 years of age. They nest in

large hollows of old trees and will typically produce a single chick each year. They have been recorded to live up to 45 years in captivity (DEC, 2008)

Carnaby's Black Cockatoo can live up to 40 or 50 years and pairs bond for life. The species exhibits a seasonal migratory behaviour, residing in the wheat belt during the breeding months (July to December) and migrating to higher rainfall areas such as the SCP during the non-breeding season. The species exhibits optimum foraging patterns whereby they choose resources which will enable them to receive the maximum energy intake per unit feeding time (Johnston, 2013). Areas with a high density of food resources minimise the number of movements made by the birds between plants. This reduces the energy expenditure for foraging and feeding. Monocultures which produce a large numbers of seeds per unit area are therefore highly attractive to the species. Johnston (2013) has identified that plants that produce a large number of seeds and which are in close proximity to one another are an extremely valuable food resource since the net energy intake per feeding unit time is maximised compared to plants that produce fewer seeds and are spread over larger areas.

HABITAT

The FRTBC usually inhabits dense Jarrah, Karri and Marri forests which receive more than 600 mm of annual rainfall. In Bungendore Park and Jarrahdale they are found in forests with an understorey of *Banksia grandis*, Snottygobble (*Persoonia azedarach*), Sheoak (*Allocasuarina fraseriana*) and *Dryandra* spp. with scattered Blackbutt (*Eucalyptus staeri)* and Wandoo (*Eucalyptus wandoo*) (Johnstone and Kirkby 1999; DEC 2008). FRTBC roost clustered together in family groups on thick protected perches under the canopy of tall trees (Johnstone and Kirkby 2008). Since the early 1900's all feeding, nesting and roosting areas of these cockatoos were confined to the hill region of Perth, where they resided in the tall marri, and jarrah forest. Birds typically only moved within a 4 km radius of the roost to feed (Johnstone et al., 2013). However, since 1995 they have been increasingly recorded moving onto the SCP for feeding (Johnstone et al., 2013) and there are now records of breeding on the plain in artificial nesting boxes (Mayne 2011, Manning, 2012). Movements onto the Swan Coastal Plain are irregular but they have now been seen there almost every month of the year.

On the Swan Coastal Plain Carnaby's Black Cockatoo tend to roost in tall native or introduced Eucalypts (e.g. Marri, Flat-topped Yate (*E. occidentalis*), Salmon Gum (*Eucalyptus salmonophloia*), Wandoo, Karri, Blackbutt, Tuart, Blue Gum (*Eucalyptus globulus*)) as well as exotic pines. Roost sites tend to be in close association to food and water resources as well as providing protection (Kabat et al., 2012a). Tall trees located high in the landscape are often favoured but these trees must have a substantial canopy to ensure the birds are well protected from the elements and the birds favour areas with > 5 ha of clumped trees (Geoff Barrett *pers. com.*). Unlike FRTBC, Carnaby's Black Cockatoo roost singly with approximately 30 cm space between roosting birds. They also favour the outer

thinner branches of trees over those located deeper in the canopy. This habit exposes them to extreme weather if the tree canopy is sparse or not well developed.

In the 2012 Great Cocky Count eight large Carnaby's Black Cockatoo roosts (>150 birds) were recorded on the Swan Coastal Plain. The Pinjar Power Station supports the largest roost with over 2000 birds reported in the 2012 survey (Kabat et al 2012b). In the Swan region, Bentley continues to be the largest roost in the region closely followed by Manning Lake. Many of the roosts previously identified in the southern peri-urban and peel regions of the Swan have seen continued declines in roosting birds or are no longer active; four have been completely cleared of roosting habitat. It is possible increasing numbers at the Bentley and Manning roosts are a result of these clearing pressures. However, many large pines continue to be cleared in the Bentley roost. As identified by Kabat et al (2012a) all large trees (> 8m) within a 500 m radius of core roosting habitat (small roosts < 150 birds) and within 1 km around the centre of large roosts (> 150 birds) are potential roosting habitat and where possible should be retained.

FORAGING AND FOOD RESOURCES

The FRTBC is an arboreal feeder which primarily feeds on the seeds of Marri and Jarrah. Other foods include Sheoak, Snottygobble, Blackbutt and introduced plant species including Cape Lilac (*Melia azedarach*) and Lemon Scented Gum (*Corymbia citriodora*, Johnstone and Kirkby 1998). They have also been recorded feeding on Mountain Marri, *Corymbia haematoxylon* (Johnstone and Cassarchis, 2004). Cooper et al (2003) identified that Marri is the principle food source for FRTBC and noted that birds will selectively choose Marri trees with high fruit yield. These trees typically had on average four fruit per pod, while trees with low yield or only male nuts were avoided. The FRTBC is not known to eat pines. Immature birds have been recorded to take up to three times as long to open the seeds of Marri or Jarrah compared to adults (Johnstone *et al.,* 2013).

Carnaby's Black Cockatoo feed on a range of food sources on the Swan Coastal Plain including seeds and flowers of proteaceous shrubs and trees (*Banksia*, *Hakea* and *Grevillea*), myrtaceous trees within remnant heath and woodland habitats, as well as Jarrah (*Eucalyptus marginata*), *Allocasuarina* spp., Marri (*Corymbia calophylla*) and a range of introduced species most notably the seeds of plantation pine (Stock et al 2013). Over 87 species of plants have been identified as providing food either from seeds or flowers or because of the high insect load the plants carry.

Carnaby's Black Cockatoo require approximately 60 Banksia cones per day (Geoff Barrett *pers. com*). Pines are about 27 % higher in energy than the native species, but have 45 % less protein than the high N seeds of Proteaceae (*Banksia* and *Hakea* spp.). The total energetic contributions of *Banksia* spp and *Corymbia calophylla* are very high, with pines containing less energy at the individual seed level, however, this does not take into account

the energy expended in foraging for each food type and handling times for each (Stock et al 2013). As identified by Johnston (2013) the monoculture of pine plantations provide a very high density of seeds per unit area compared to scattered remnant bushlands and thus these areas are actively sought by birds to provide the highest caloric input per unit of time spent foraging.

Johnston (2013) noted that of the 24 plant species used by Carnaby's Black Cockatoo in her study *Banksia sessilis* had the largest number of infructescences and follicles manipulated by Carnaby's Black Cockatoo. It was noted that although *B. sessilis* seeds are smaller and as such have a much lower calorie content than the larger *Banksia attenuata* or *Banksia menziesii* they produce a larger number of seeds (35 times greater than that of *B. attenuata* and *B. menziesii*). This allows for a greater number of birds to be supported over the same area. Johnston (2013) concluded that *Banksia sessilis* is a vitally important food source however its restricted fruiting period makes it unreliable for year round food and it should always be planted in association with species that can provide food in other periods, such as *B. attenuata*.

NESTING

FRTBC prefers marri trees that are older than 209 years old for nesting (Johnstone *et al* 2013). Nests are usually 6.5 m to 33 m above ground and nesting trees on average have a breast height circumference of 2.79 m (Johnstone *et al.,* 2013). Birds often have to compete with other hollow users including feral bees. The species usually only lays a single egg (occasionally two) and the juvenile bird will remain with the adults for up to 2 years post fledgling (Johnstone *et al* 2013).

Carnaby's Black Cockatoo nest in the hollows of live or dead eucalypts, including smooth barked Salmon Gum and Wandoo (DEC 2012) but nests have also been found in other *Eucalypts* including York Gum (*Eucalyptus loxophleba*) and Tuart, Flooded Gum (*Eucalyptus grandis*) and Rough Barked Marri (*Corymbia calophylla*). Nesting occurs from July to mid-December in the semi-arid and sub-humid interior from three springs south to the Stirling Range. Records suggest the breeding range is expanding westward and south into the Jarrah - Marri forests of the Darling Scarp and into the Tuart forests of the Swan Coastal Plain (Johnstone and Kirkby, 2011), with numerous records at Gingin, Boonanarring, Mooliabeenee, Yanchep, Baldivis, near Mandurah, Lake Clifton and near Bunbury (Johnstone and Kirkby, 2011). The birds lay one to two eggs (mostly two) but only one is reared.

Appendix 2 Tree losses assessment at species level for 10, 20 and 30 year periods considering full implementation of the Masterplan.

Family	Species	Form	Native/Introduced	Habitat (F= Feeding, R=Roosting, N= Nesting)			Priority for planting (DPaW, 2011)	Bentley Campus						Erica Underwood House				Guild House				Lot 85				Technology Park				All Curtin Properties			
								Loss of trees and shrubs due to development in 0-10 years	Loss of trees and shrubs due to ULE<10 years	Loss of trees due to development in 10-20 years	Loss of trees and shrubs due to ULE 10-19 years	Loss of trees and shrubs due to ULE 20-30 yrs	Bentley Campus Total Tree and Shrub Losses 0-30 years	ULE 10 - 19 Years	ULE 20 - 29 Years	ULE 30 - 39 Years	Erica Underwood House Total Tree and Shrub Losses 0-30 years	ULE < 10 Years	ULE 10 - 19 Years	ULE 20 - 29 Years	Guild House Total Tree and Shrub Losses 0-30 years	ULE < 10 Years	ULE 10 - 19 Years	ULE 20 - 29 Years	Lot 85 Total Tree and Shrub Losses 0-30 years	ULE < 10 Years	ULE 10 - 19 Years	ULE 20 - 29 Years	Technology Park Total Tree and Shrub Losses 0-30 years	Overall losses of trees and shrubs due to age and development 0-10 years	Overall losses of trees and shrubs due to age and development 10-20 years	Overall losses of trees and shrubs due to age and development 20-30 years	Cumulative loss of individual species over 30 years
Fabaceae	*Acacia baileyana*	Shrub/ Tree	Introduced - AU	F			Low	0	4	1	3	0	**8**				**0**				**0**				**0**				**0**	4	4	0	**8**
Fabaceae	*Acacia baileyana purpurea*	Shrub/ Tree	Introduced - AU	F			Low	1	1	0	2	0	**4**				**0**				**0**				**0**				**0**	2	2	0	**4**
Myrtaceae	*Agonis flexuosa*	Tree	Native - WA	F			Low	64	2	20	5	1	**92**				**0**		2	1	**3**				**0**				**0**	66	27	2	**95**
Myrtaceae	*Agonis flexuosa* 'After Dark'	Tree	Hybrid of native to WA	F			Low	3	4	2	0	0	**9**				**0**				**0**				**0**				**0**	7	2	0	**9**
Myrtaceae	*Agonis flexuosa* 'Variegata'	Tree	Hybrid of native to WA	F			Low	0	0	0	0	0	**0**				**0**				**0**				**0**				**0**	0	0	0	**0**
Casuarinaceae	*Allocasuarina fraseriana*	Tree	Native to site	F			Low	0	0	0	0	0	**0**				**0**				**0**				**0**		1		**1**	0	1	0	**1**
Araucariaceae	*Araucaria heterophylla*	Tree	Introduced	F			Low	1	0	1	0	0	**2**				**0**				**0**				**0**				**0**	1	1	0	**2**
Proteaceae	*Banksia attenuata*	Tree	Native to site	F			High	0	0	0	0	1	**1**				**0**				**0**				**0**				**0**	0	0	1	**1**
Proteaceae	*Banksia grandis*	Tree	Native to site	F			High	1	0	1	0	0	**2**				**0**				**0**				**0**				**0**	1	1	0	**2**
Proteaceae	*Banksia ilicifolia*	Tree	Native to site	F			High	0	0	0	0	0	**0**				**0**				**0**				**0**				**0**	0	0	0	**0**
Proteaceae	*Banksia menziesii*	Tree	Native to site	F			High	4	3	4	1	1	**13**				**0**				**0**				**0**				**0**	7	5	1	**13**
Proteaceae	*Banksia species*	Shrub/ Tree	Native - WA	F			Medium	21	2	1	2	12	**38**				**0**				**0**				**0**				**0**	23	3	12	**38**
Myrtaceae	*Callistemon* 'Indian Brook'	Shrub	Introduced	F			Medium	1	0	0	0	0	**1**				**0**				**0**				**0**			7	**7**	1	0	7	**8**
Myrtaceae	*Callistemon* 'Kings Park Special'	Tree	Native - WA	F			Medium	11	0	0	0	0	**11**			1	**1**		1	3	**4**				**0**			1	**1**	11	1	4	**16**
Myrtaceae	*Callistemon salignus*	Tree	Introduced - AU	F			Medium	0	0	0	0	0	**0**				**0**				**0**				**0**				**0**	0	0	0	**0**
Myrtaceae	*Callistemon viminalis*	Tree	Introduced - AU	F			Medium	42	1	23	13	50	**129**	1			**1**				**0**				**0**				**0**	43	37	50	**130**
Cupressaceae	*Callitris preissii*	Tree	Native - WA	F			Medium	12	1	8	0	2	**23**				**0**				**0**				**0**		3	1	**4**	13	11	3	**27**
Casuarinaceae	*Casuarina cunninghamiana*	Tree	Introduced - AU	F			Low	26	1	3	4	3	**37**				**0**		4	3	**7**				**0**	2	6		**8**	29	17	6	**52**
Myrtaceae	*Corymbia calophylla*	Tree	Native to site	F	R	N	High	27	0	8	3	0	**38**				**0**		1		**1**				**0**				**0**	27	12	0	**39**
Myrtaceae	*Corymbia citriodora*	Tree	Introduced - AU	F	R		Medium	3	0	4	1	0	**8**				**0**				**0**				**0**				**0**	3	5	0	**8**
Myrtaceae	*Corymbia ficifolia*	Tree	Native - WA	F			Medium	18	8	7	0	3	**36**				**0**				**0**				**0**				**0**	26	7	3	**36**
Myrtaceae	*Corymbia maculata*	Tree	Introduced - AU		R		Low	67	2	52	0	0	**121**				**0**				**0**				**0**				**0**	69	52	0	**121**
Myrtaceae	*Eucalyptus caesia*	Tree	Native - WA	F			Medium	7	1	2	2	3	**15**				**0**				**0**				**0**				**0**	8	4	3	**15**
Myrtaceae	*Eucalyptus caesia* ssp. *magna*	Tree	Native - WA	F			Medium	12	3	0	25	3	**43**				**0**				**0**				**0**				**0**	15	25	3	**43**
Myrtaceae	*Eucalyptus caesia* subsp. *caesia*	Tree	Native - WA	F			Medium	0	0	0	0	0	**0**	1			**1**				**0**				**0**				**0**	0	1	0	**1**
Myrtaceae	*Eucalyptus camaldulensis*	Tree	Introduced - AU		R		Low	0	0	0	0	0	**0**				**0**				**0**				**0**				**0**	0	0	0	**0**
Myrtaceae	*Eucalyptus camaldulensis var. camaldulensis*	Tree	Introduced - AU		R		Low	9	0	1	1	8	**19**				**0**				**0**				**0**				**0**	9	2	8	**19**
Myrtaceae	*Eucalyptus camaldulensis var. obtusa*	Tree	Introduced - AU		R		Low	11	0	14	2	0	**27**				**0**				**0**				**0**				**0**	11	16	0	**27**
Myrtaceae	*Eucalyptus globulus*	Tree	Introduced - AU		R		Low	0	3	1	1	1	**6**				**0**				**0**				**0**				**0**	3	2	1	**6**

Family	Species	Form	Native/Introduced	Habitat (F= Feeding, R=Roosting, N= Nesting)			Priority for planting (DPaW, 2011)	Bentley Campus						Erica Underwood House				Guild House				Lot 85				Technology Park				All Curtin Properties			
								Loss of trees and shrubs due to development in 0-10 years	Loss of trees and shrubs due to ULE<10 years	Loss of trees due to development in 10-20 years	Loss of trees and shrubs due to ULE 10-19 years	Loss of trees and shrubs due to ULE 20-30 yrs	Bentley Campus Total Tree and Shrub Losses 0-30 years	ULE 10 - 19 Years	ULE 20 - 29 Years	ULE 30 - 39 Years	Erica Underwood House Total Tree and Shrub Losses 0-30 years	ULE < 10 Years	ULE 10 - 19 Years	ULE 20 - 29 Years	Guild House Total Tree and Shrub Losses 0-30 years	ULE < 10 Years	ULE 10 - 19 Years	ULE 20 - 29 Years	Lot 85 Total Tree and Shrub Losses 0-30 years	ULE < 10 Years	ULE 10 - 19 Years	ULE 20 - 29 Years	Technology Park Total Tree and Shrub Losses 0-30 years	Overall losses of trees and shrubs due to age and development 0-10 years	Overall losses of trees and shrubs due to age and development 10-20 years	Overall losses of trees and shrubs due to age and development 20-30 years	Cumulative loss of individual species over 30 years
Myrtaceae	*Eucalyptus gomphocephala*	Tree	Native - WA	F	R	N	High	2	1	6	1	2	**12**				**0**		1		**1**				**0**				**0**	3	8	2	**13**
Myrtaceae	*Eucalyptus grandis*	Tree	Introduced - AU		R		Low	35	3	18	0	80	**136**				**0**				**0**				**0**				**0**	38	18	80	**136**
Myrtaceae	*Eucalyptus marginata*	Tree	Native to site	F	R		Medium	0	0	0	0	0	**0**				**0**		1		**1**				**0**				**0**	0	1	0	**1**
Myrtaceae	*Eucalyptus robusta*	Tree	Introduced - AU	F	R		Medium	1	2	3	0	8	**14**				**0**				**0**				**0**				**0**	3	3	8	**14**
Myrtaceae	*Eucalyptus rudis*	Tree	Native to site		R		Low	35	0	25	0	3	**63**				**0**				**0**				**0**				**0**	35	25	3	**63**
Myrtaceae	*Eucalyptus todtiana*	Tree	Native to site	F			Medium	0	0	0	0	0	**0**				**0**				**0**				**0**				**0**	0	0	0	**0**
Moraceae	*Ficus carica* 'Black Genoa'	Tree	Introduced	F			Low	1	0	0	0	0	**1**				**0**				**0**				**0**				**0**	1	0	0	**1**
Moraceae	*Ficus macrophylla*	Tree	Introduced - AU	F			Low	0	0	0	0	0	**0**				**0**				**0**				**0**				**0**	0	0	0	**0**
Moraceae	*Ficus microcarpa* var.*hillii*	Tree	Introduced - AU	F			Low	21	0	19	0	11	**51**				**0**				**0**				**0**				**0**	21	19	11	**51**
Moraceae	*Ficus religinosa*	Tree	Introduced - AU	F			Low	4	0	1	0	0	**5**				**0**				**0**				**0**				**0**	4	1	0	**5**
Moraceae	*Ficus rubiginosa*	Tree	Introduced - AU	F			Low	0	0	1	0	0	**1**				**0**				**0**				**0**				**0**	0	1	0	**1**
Proteaceae	Grevillea species	Shrub	Introduced - AU	F			Medium	10	5	1	20	14	**50**				**0**				**0**				**0**				**0**	15	21	14	**50**
Proteaceae	*Hakea laurina*	Shrub/ Tree	Native - WA	F			Medium	2	0	0	0	4	**6**				**0**				**0**				**0**	1			**1**	3	0	4	**7**
Proteaceae	**Hakea** species	Shrub/ Tree	Native - WA	F			Medium	0	0	1	0	2	**3**				**0**				**0**				**0**				**0**	0	1	2	**3**
Bignoniaceae	*Jacaranda mimosifolia*	Tree	Introduced	F			Low	27	0	15	0	0	**42**				**0**				**0**				**0**				**0**	27	15	0	**42**
Altingiaceae	*Liquidambar styraciflua*	Tree	Introduced	F			Medium	9	0	3	0	0	**12**				**0**				**0**				**0**			1	**1**	9	3	1	**13**
Meliaceae	*Melia azedarach*	Tree	Introduced	F			Low	5	0	0	0	0	**5**				**0**				**0**				**0**				**0**	5	0	0	**5**
Loranthaceae	*Nuytsia floribunda*	Tree	Native to site	F			Low	9	4	8	10	3	**34**				**0**				**0**			1	**1**				**0**	13	18	4	**35**
Pinaceae	*Pinus pinaster*	Tree	Introduced	F	R		Medium	330	28	61	351	321	**1091**	1	6		**7**	6	56	14	**76**	3	62	1	**66**	1	41	5	**47**	368	572	347	**1287**
Pinaceae	*Pinus radiata*	Tree	Introduced	F	R		Medium	1	0	0	0	0	**1**				**0**				**0**				**0**		3	3	**6**	1	3	3	**7**
Fabaceae	*Tipuana tipu*	Tree	Introduced	F			Low	5	0	8	0	1	**14**				**0**				**0**				**0**				**0**	5	8	1	**14**
Xanthorrhoeaceae	*Xanthorrhoea preissii*	Grass/ Tree	Native to site	F			Medium	9	4	14	0	0	**27**				**0**				**0**				**0**		2		**2**	13	16	0	**29**
Xanthorrhoeaceae	*Xanthorrhoea robusti*	Grass/ Tree	Native to site	F			Medium	0	0	0	0	0	**0**				**0**				**0**				**0**				**0**	0	0	0	**0**
								847	**83**	**337**	**447**	**537**	**2251**	**3**	**6**	**1**	**10**	**6**	**66**	**21**	**93**	**3**	**62**	**2**	**67**	**4**	**56**	**18**	**78**	**943**	**971**	**584**	**2498**

Appendix 3 Caloric Value of Seeds Used by Black Cockatoos.

Table 1 Caloric value of key food species for Carnaby's Black Cockatoos and Forest Red Tailed Black Cockatoos.

Species	# seeds to meet FMR Carnaby's (726 kJ/d)	# seeds to meet FMR FRTBC (934)	# seeds/ha or tree^	References
Acacia saligna	4030			Stock et al. 2013
Allocasuarina fraseriana	637 nuts/day	819 nuts/day		Cooper et al 2002
Banksia attenuata	567		14 406 seeds/ha	Johnston 2013; Stock et al. 2013
Banksia grandis	660		200 seeds/ ha	Johnston 2013; Stock et al. 2013
Banksia littoralis	2814			Stock et al. 2013
Banksia menziesii	615		19 300 seeds/ha	Johnston 2013; Stock et al. 2013
Banksia prionotes	1668		158 244 seeds/ha	Johnston 2013; Stock et al. 2013
Banksia nobilis	2933			Stock et al. 2013
Banksia sessilis	6109		1 491 737 478 seeds/ha	Johnston 2013; Stock et al. 2013
*Brassica napus**	9108			Stock et al. 2013
Corymbia calophylla	764	840	240 seeds /tree^	Stock et al. 2013; Abbott 1984
Eucalyptus marginata	7546	7688	1600 seeds/tree^	Stock et al. 2013; Abbott 1984
Hakea incrassata	1002		?	Stock et al. 2013
Hakea laurina	2346		?	Stock et al. 2013
Hakea preissii	6547		?	Stock et al. 2013
*Pinus pinaster**	1471		158 025 seeds/ha	Johnston 2013; Stock et al. 2013
*Pinus pinea**	873		?	Stock et al. 2013
Xanthorrhoea preissii	2133		?	Stock et al. 2013

* indicates species exotic to Western Australia; **FMR** = Field Metabolic Requirements for Carnaby's Black Cockatoo (after Cooper et. al. 2002).

Table 2 The value of each potential food tree on a per hectare basis. (Stock pers. com)

Tree species	kJ/g seed	kJ/ha	Ratio	References	Assumptions
Banksia attenuata	18.267	50 000	1	Johnston (2013)	1500 infruct/ha = good food source
Pinus pinaster	24.9	200 000	4	Stock et al (2013)	Gnangara pine data
Macadamia orchard	30	391 300 000	783	Stock pers. com	based on 100 trees/ha, yield 13kg/tree
Pecan orchard	29	52 920 000	1058	Stock pers. com	based on 100 trees/ha, yield 18kg/tree
Almond orchard	25	350 000 000	700	Stock pers. com	based on 100 trees/ha yield 18kg/tree

Infruct = infructescence or the fruiting body in which the follicles are fully developed.

Appendix 4 List of Tree and Shrub Species recommended as replacement plants for Curtin Tree Replacement Plan

Family	Species	Common name	Form	Native/Introduced	Habitat (F= Feeding, R=Roosting, N= Nesting)			Priority for planting (DPaW, 2011)	Approximate offset number of trees required due to potential loss of trees as a result of Masterplan implementation and natural senescence				
Proposed Tree Offsets									**Buffer**	**Buffer / Dampland**	**Wet**	**Dry**	**Academic Core**
Fabaceae	*Acacia saligna*	Orange Wattle	Tree	Native - WA	F			Low	20		20		
Myrtaceae	*Agonis flexuosa*	Peppermint Tree	Tree	Native - WA	F			Low				100	100
Casuarinaceae	*Allocasuarina fraseriana*	WA Oak	Tree	Native to site	F			Low	100			30	20
Araucariaceae	*Araucaria heterophylla*	Norfolk Island Pine	Tree	Introduced	F			Low				5	5
Proteaceae	*Banksia ashbyi*	Ashby's Banksia	Tree	Native - WA	F			Medium				30	20
Proteaceae	*Banksia attenuata*	Slender Banksia	Tree	Native to site	F			High	100				
Proteaceae	*Banksia grandis*	Bull Banksia	Tree	Native to site	F			High	50	20			50
Proteaceae	*Banksia ilicifolia*	Holly Leaved Banksia	Tree	Native to site	F			High		20			
Proteaceae	*Banksia littoralis*	Swamp Banksia	Tree	Native - WA	F			High			10		
Proteaceae	*Banksia menziesii*	Firewood Banksia	Tree	Native to site	F			High	60			20	20
Proteaceae	*Banksia prionotes*	Acorn Banksia	Tree	Native - WA	F			High	50			30	
Proteaceae	*Banksia sessilis*	Parrot Bush	Tree	Native - WA	F			High	50			20	
Myrtaceae	*Callistemon viminalis*	Bottlebrush	Tree	Introduced - AU	F			Medium				50	50
Cupressaceae	*Callitris preissii*	Rottnest Island Pine	Tree	Native - WA	F			Medium				30	30
Myrtaceae	*Corymbia calophylla*	Marri	Tree	Native to site	F	R	N	High	500	200		50	
Myrtaceae	*Corymbia citriodora*	Lemon Scented Gum	Tree	Introduced - AU	F	R		Medium				20	20
Myrtaceae	*Corymbia ficifolia*	WA Red Flowering Gum	Tree	Native - WA	F			Medium				30	30
Myrtaceae	*Corymbia haematoxylon*	Mountain Marri	Tree	Native - WA	F			Medium				30	20
Myrtaceae	*Corymbia maculata*	Spotted Gum	Tree	Introduced - AU		R		Low				100	
Myrtaceae	*Eucalyptus caesia*	Silver Princess	Tree	Native - WA	F			Medium				50	50
Myrtaceae	*Eucalyptus gomphocephala*	Tuart	Tree	Native - WA	F	R	N	High	500			50	50
Myrtaceae	*Eucalyptus grandis*	Rose Gum	Tree	Introduced - AU		R		Low	30				
Myrtaceae	*Eucalyptus loxophleba*	York Gum	Tree	Native - WA	F			Low					20
Myrtaceae	*Eucalyptus marginata*	Jarrah	Tree	Native to site	F	R		Medium	200			50	50
Myrtaceae	*Eucalyptus rudis*	Flooded Gum / Flooded Red	Tree	Native to site		R		Low	400	100	130		
Myrtaceae	*Eucalyptus todtiana*	Prickley Bark	Tree	Native to site	F			Medium	20	10		20	
Proteaceae	*Hakea laurina*	Pin cushion Hakea	Tree	Native - WA	F			Medium	10			30	30
Bignoniaceae	*Jacaranda mimosifolia*	Jacaranda	Tree	Introduced	F			Low				50	50
Fabaceae	*Jacksonia sternbergiana*	Stinkwood	Tree	Native to site	F			Low	30	20			
Altingiaceae	*Liquidambar styraciflua*	Liquidambar	Tree	Introduced	F			Medium					50
Proteaceae	*Macadamia integrifolia*	Macadamia	Tree	Introduced - AU	F			Medium	20				20
Loranthaceae	*Nuytsia floribunda*	Christmas Tree	Tree	Native to site	F			Low	25	10		10	10
Pinaceae	*Pinus pinaster*	Maritime Pine	Tree	Introduced	F	R		Medium	400				100
Pinaceae	*Pinus pinea*	Stone Pine	Tree	Introduced	F	R		Medium	600				100
Rosaceae	*Prunus amygdalus*	Almond Tree	Tree	Introduced	F			Medium	20			20	20

Family	Species	Common name	Form	Native/Introduced	Habitat (F= Feeding, R=Roosting, N= Nesting)			Priority for planting (DPaW, 2011)	Approximate offset number of trees required due to potential loss of trees as a result of Masterplan implementation and natural senescence				
Proposed Shrub Offsets									**Buffer**	**Damp**	**Wet**	**Dry**	**Core**
Casuarinaceae	*Allocasuarina humilis*	Dwarf Sheoak	Shrub	Native to site	F			Low	20				
Proteaceae	*Banksia dallanneyi*	Couch Honeypot	Shrub	Native to site	F			Low	10				10
Proteaceae	*Banksia gardneri*	Prostrate Banksia	Shrub	Native - WA	F			Low					10
Proteaceae	*Banksia hookeriana*	Hooker's Banksia	Shrub	Native - WA	F			Medium				10	10
Proteaceae	*Banksia nivea*	Honeypot Dryandra	Shrub	Native to site	F			High	10			10	10
Scrophulariaceae	*Eremophila glabra*	Tar Bush	Shrub	Native - WA	F			Low	10			10	
Proteaceae	*Grevillea bipinnatifida*	Fuschia Grevillea	Shrub	Native - WA	F			Medium	10	10			
Proteaceae	*Hakea lissocarpha*	Honeybush	Shrub	Native - WA	F			Medium	28				
Proteaceae	*Hakea prostrata*	Harsh Hakea	Shrub	Native - WA	F			High	20	10			
Proteaceae	*Hakea ruscifolia*	Candle Hakea	Shrub	Native - WA	F			Medium					5
Proteaceae	*Hakea trifurcata*	Two-leaved Hakea	Shrub	Native - WA	F			High	20				
Proteaceae	*Hakea undulata*	Wavy-leaved Hakea	Shrub	Native - WA	F			High					5
Proteaceae	*Hakea varia*	Variable-leaved Hakea	Shrub	Native - WA	F			Medium		20	20		
Fabaceae	*Jacksonia furcellata*	Grey Stinkwood	Shrub	Native to site	F			Medium		20	20		
Myrtaceae	*Kunzea glabrescens*		Shrub	Native to site	F			Low			20		
Proteaceae	*Persoonia saccata*	Snottygobble	Shrub	Native - WA	F			Low	10				
Xanthorrhoeaceae	*Xanthorrhoea preissii*	Grass Tree	Grass/Tree	Native to site	F			Medium	100	50		50	50

Additional plant species that are found in surrounding remnant vegetation areas that can be used for planting to enhance the overall ecosystem value of the area. These plants are of no direct benefit to Black Cockatoos however they support a range of other smaller birds and invertebrates. The Buffer, Dampland and Wet areas should be considered as a priority for these species.

Family	*Species*	Common name	Form	Buffer	Buffer / Dampland	Wet	Dry	Academic core
Fabaceae	*Acacia lasiocarpa*	Panjang	Shrub	x			x	x
Fabaceae	*Acacia pulchella*	Prickly Moses	Shrub	x				
Fabaceae	*Acacia stenoptera*	Narrow Winged Wattle	Shrub	x				
Fabaceae	*Acacia willdenowiana*	Grass Wattle	Shrub		x			
Proteaceae	*Adenanthos cygnorum*	Common Woollybush	Shrub	x	x			
Haemodoraceae	*Anigozanthos manglesii*	Mangles Kangaroo Paw	Herb	x			x	x
Hemerocallidaceae	*Arnocrinum preissii*		Shrub	x			x	x
Myrtaceae	*Astartea scoparia*		Shrub			x		
Poaceae	*Austrostipa compressa*		Grass	x			x	
Poaceae	*Austrostipa elegantissima*		Grass	x			x	
Cyperaceae	*Baumea juncea*	Bare Twigrush	Sedge			x		
Fabaceae	*Bossiaea eriocarpa*	Common Brown Pea	Shrub	x				
Myrtaceae	*Calothamnus quadrifidus*		Shrub	x			x	x
Myrtaceae	*Calothamnus sanguineus*		Shrub		x	x		
Myrtaceae	*Calytrix angulata*	Yellow Starflower	Shrub	x	x			
Myrtaceae	*Calytrix flavescens*		Shrub	x				
Myrtaceae	*Calytrix fraseri*		Shrub	x				
Proteaceae	*Conospermum stoechadis*	Common Smokebush	Shrub	x			x	x
Ericaceae	*Conostephium pendulum*		Shrub	x				
Ericaceae	*Conostephium preissii*	Pearl Flower	Shrub	x				
Haemodoraceae	*Conostylis aculeata*	Prickly Conostylis	Herb		x	x		
Haemodoraceae	*Conostylis juncea*		Herb	x	x			
Haemodoraceae	*Conostylis setigera*	Bristly Cottonhead	Herb		x			
Hemerocallidaceae	*Corynotheca micrantha*	Sand Lily	Herb	x				
Goodeniaceae	*Dampiera linearis*	Common Dampiera	Herb		x	x		
Dasypogonaceae	*Dasypogon bromeliifolius*	Pineapple Bush	Herb		x	x		
Fabaceae	*Daviesia decurrens*	Grey Stinkwood	Shrub	x	x		x	x
Fabaceae	*Daviesia divaricata*	Marno	Shrub	x	x			
Fabaceae	*Daviesia triflora*		Shrub	x	x			
Restionaceae	*Desmocladus flexuosus*		Rush		x	x		
Hemerocallidaceae	*Dianella revoluta*	Blueberry Lily	Herb	x	x		x	x
Myrtaceae	*Eremaea pauciflora*		Shrub	x			x	x
Fabaceae	*Gastrolobium capitatum*		Shrub	x				
Fabaceae	*Gompholobium tomentosum*	Hairy Yellow Pea	Shrub	x	x		x	x
Haemodoraceae	*Haemodorum spicatum*		Herb	x				
Fabaceae	*Hardenbergia comptoniana*	Native Wisteria	Climber	x			x	x
Lamiaceae	*Hemiandra pungens*	Snakebush	Shrub	x	x		x	x
Dilleniaceae	*Hibbertia huegelii*		Shrub		x			
Dilleniaceae	*Hibbertia hypericoides*	Yellow Buttercups	Shrub	x	x			x
Dilleniaceae	*Hibbertia racemosa*	Stalked Guinea Flower	Shrub		x			
Fabaceae	*Hovea trisperma*	Common Hovea	Shrub	x	x			
Myrtaceae	*Hypocalymma angustifolium*	White Myrtle	Shrub			x		
Myrtaceae	*Hypocalymma robustum*	Swan River Myrtle	Shrub	x	x		x	x
Fabaceae	*Kennedia prostrata*	Scarlet Runner	Shrub		x	x	x	x
Goodeniaceae	*Lechenaultia floribunda*	Free-flowering Leschenaultia	Shrub		x	x		
Ericaceae	*Leucopogon conostephioides*		Shrub	x				
Anarthriaceae	*Lyginia barbata*		Rush	x	x		x	x
Molluginaceae	*Macarthuria australis*		Herb		x			
Zamiaceae	*Macrozamia riedlei*	Zamia	Cycad	x	x		x	x
Myrtaceae	*Melaleuca preissiana*	Moonah	Tree		x	x		
Myrtaceae	*Melaleuca rhaphiophylla*	Swamp Paperbark	Tree			x		

Family	*Species*	Common name	Form	Buffer	Buffer / Dampland	Wet	Dry	Academic core
Cyperaceae	*Mesomelaena pseudostygia*		Sedge	x	x		x	x
Iridaceae	*Patersonia occidentalis*	Purple Flag	Herb		x	x	x	x
Proteaceae	*Petrophile linearis*	Pixie Mops	Shrub	x	x		x	x
Proteaceae	*Petrophile macrostachya*		Shrub	x			x	x
Rutaceae	*Philotheca spicata*	Pepper and Salt	Shrub	x	x			
Haemodoraceae	*Phlebocarya ciliata*		Herb		x	x		
Amaranthaceae	*Ptilotus polystachyus*	Prince of Wales Feather	Herb	x	x		x	x
Goodeniaceae	*Scaevola repens*		Shrub	x	x			
Cyperaceae	*Schoenus curvifolius*		Sedge	x	x		x	x
Myrtaceae	*Scholtzia involucrata*	Spiked Scholtzia	Shrub	x	x			
Asparagaceae	*Sowerbaea laxiflora*	Purple Tassels	Herb	x	x			
Proteaceae	*Stirlingia latifolia*	Blueboy	Shrub	x	x		x	x
Proteaceae	*Synaphea spinulosa subsp. spinulosa*		Shrub	x			x	x
Asparagaceae	*Thysanotus patersonii*		Herb	x			x	x
Asparagaceae	*Thysanotus sparteus*		Herb	x			x	x
Myrtaceae	*Verticordia densiflora*	Compacted Featherflower	Shrub	x	x		x	x
Xanthorrhoeaceae	*Xanthorrhoea brunonis*		Grass tree	x	x			

Note: Several nurseries sell dwarf or prostrate varieties of plants which may be more suitable for use in the academic core, verges and the dryland area gardens and streetscapes. Some of the plants available are shown below (courtesy of Lullfitz Nursery http://www.lullfitz.com.au/georges_lists/georges_favourite_wa_plants.asp).

Acacia lasiocarpa (prostrate)

Grevillea bipinnatifida (prostrate)

Calothamnus quadrifidus (prostrate)

Grevillea crithmifolia (prostrate)

Forest of Marri and Jarrah 40 yrs with some older trees (~10 trees /100m^2).

Appendix 5 Plant Diseases and Pests

PLANT DISEASE AND PESTS

Phytophthora dieback caused by the water mould *Phytophthora cinnamomi* and canker disease caused by the fungus *Quambalaria coyrecup* are two of the most relevant and concerning diseases affecting native plant species in the south-west Western Australia. Of these Marri canker is currently present at Curtin however the status of the Dieback is not known. Soil testing for Dieback will determine if the proteaceous species can be planted on site.

DIEBACK

Phytophthora dieback is a plant disease that affects native plants, horticultural crops and garden plants worldwide. Worldwide, there are over 50 species of Phytophthora and all of which cause plant disease. The three species that most commonly cause disease in native vegetation in Australia are *P.cinnamomi, P. citricola* and *P. megasperma.* Of these three species, *Phytophthora cinnamomi* is the most destructive species, infesting large areas of native vegetation in Western Australia and responsible for most plant deaths in remnant vegetation of the state (DWG, 2000).

In Western Australia, the most common native plants susceptible to *Phytophtora cinnamomi,* and relevant to Carnaby's Black Cockatoo, are Jarrah (*Eucalyptus marginata*), *Banksia*, *Grevillea* and several Proteaceae species. *Pinus radiata* pine, a horticultural species largely used by Carnaby's Black Cockatoo is also susceptible to Phytophthora dieback.

The Dieback Working Group (DWG) report that over 40 % of native WA plant species are susceptible to Phytophthora dieback and over 50 % of the WA's rare or endangered flora species are susceptible (DWG, 2013). In the southwest of WA Phytophthora dieback is found in areas receiving more than 400 mm annual rainfall between Eneabba and east of Esperance (DWG, 2000). It is found throughout the Perth metropolitan area, with significant clusters of disease outbreaks in the Banksia woodlands of the southern and northern suburbs of Perth and the Jarrah forest in the eastern metropolitan area (DWG, 2013).

Phytophthora cinnamomi lives in the soil and in plant tissues and causes root rot in susceptible plants. Affected plants have a limited ability to uptake and transport water and nutrients and often die as a result of the disease. Phytophthora spores naturally spread through soil pore water, however human activity has contributed significantly to a rapid widespread distribution of the pathogen (DWG, 2000).

Another emergent pathogen species of the same genus is *Phytophthora multivora*. This species is reported to be associated with tuart (*Eucalyptus gomphocephala*) decline and affected plants show significant root damage (CCWFH 2011; Scott et al., 2009).

A recent study of the stressed or dying vegetation within remnant bushland, parks and street trees on the Swan Coastal Plain was performed by Barbor et al, (2013). This study identified nine *Phytophthora* species including two previously undescribed species on a range of native and non native hosts. Of the *Phytophthora* species isolated *P. multivora* was recorded most often and was present most commonly in park trees followed by native bushland and street trees. Genera of plants affected were *Agonis, Allocasuarina, Brachychiton, Calothamnus, Casuarina, Corymbia, Eucalyptus, Ficus,* and *Xanthorrhoea*.

Phosphite (phosphonate) is considered a cheap, environmentally friendly fungicide used to fight *Phytophthora* dieback and has proven to be an effective treatment. Research has shown that it increases the resistance of susceptible plants to Phytophthora dieback (DWG, 2000). Phosphite has to enter the plant's water system to be effective, and this can be done by injecting it into trees or spraying the foliage of understorey plants. Phosphate treatment only provides temporary protection and therefore treatment is ongoing (DWG, 2000).

Barbor et al (2013) and Scott et al.,(2012) state that there is a clear relationship between the health of native trees and presence of beneficial bacteria and mycorrhizal fungi in the depauperate sandy soils of Western Australia. This suggests that the maintenance of the beneficial soil microbes is of high priority to the success of planting in the areas with possible *Phytophthora* infestation. Studies of citrus trees inoculated with indigenous arbuscular mycorrhiza and had shown a lower amount of dieback than in the control plants (Watanarojanaporn et al.,2011) which gives indication as to the importance of beneficial microbes in increasing resistance to *Phytophthora.*

Dieback Disease at Curtin

The review of the historical and current literature for the Bentley Campus and the surrounds do not show presence of dieback in the area. There appear to have been no testing on Curtin grounds and Kensington Bushland also does not appear to have records of Dieback testing being performed. No evidence of dieback was seen in the remnant patch of native bushland on campus (Syrinx, 2012), proteaceous plants with signs of stress on site was mostly related to soil disturbance and compaction.

Given that a significant number of plants susceptible to dieback are also highly important to the habitat of Black Cockatoos, it would be prudent to perform soil testing prior to a large scale planting effort, particularly in areas with vegetation stress (Dr Elaine Davison, Curtin University, Dieback Working Group, pers comm.).

MARRI CANKER

In the last decade, canker disease has contributed to the decline in Marri (*Corymbia calophylla*) in southwest WA (Paap, 2006). Cankers are present on marri in WA and occur on trunks, branches and twigs of trees. Canker also affects the red flowering gum (*Corymbia*

ficifolia), commonly used in ornamental planting. The fungal pathogen *Quambalaria coyrecup* is the causal agent of the disease and is thought to be native to WA. Once symptoms are observed, trees do not appear to recover and eventually die (Paap, 2006). Spores of the fungus are spread by rain, splash, wind, insects and pruning (CCWFH 2012).

Canker disease appears to be endemic to the southwest and its infestation appears to be related to human disturbance (fragmented and disturbed areas appear be more susceptible to canker than areas of undisturbed forest) and this can also be related to stress (Trudy Paap, *pers comm*).

According to the Centre of Excellence for climate Change Woodland and Forest Health (CCWFH), the canker disease can be recognised by the following symptoms (CCWFH 2012):

- The bark surrounding the affected area cracks and sheds and large amounts of kino (gum) are produced;
- Large round and oval target-like lesions are formed. The tree produces a defence response to isolate the disease but with time the pathogen penetrates this barrier and reinvades the tree;
- The fungus *Q. coyrecup* can be observed sporulating (producing spores) on the diseased area. This is visible as a powdery white mass. Spores can be spread via wind, rain, splash, insects and pruning; and
- Once the disease has progressed to the point of girdling the host, it has effectively ring barked the tree. This results in death of the affected limb or entire tree in the case of affected trunk.

No effective treatments are available for canker at present and CCWFH is currently testing phosphite and nutrient solutions to boost plant health and possibly lower susceptibility to canker.

The CCWFH (2012) indicate that while controls or management options for canker have not yet been developed seedling recruitment and planting understory species is encouraged.

Canker at Curtin

Tree data collected by the Arbor centre (Arbor Centre, 2012) indicate that most of the tree on campus had good form and vigour with 53 % having a life expectancy of 50 years.

A total of 28 trees were found to be affected by marri canker. Of these, 12 Marri (*Corymbia calophylla*), 13 Red flowering Gum (*Corymbia ficifolia*) and three spotted gums (*Corymbia maculata*) were found to be affected.

In relation to the tree management, a regular monitoring of trees is recommended to observe any symptoms of the disease. If noted on branches the affected branch can be cut and the tree may grow unaffected for many years without showing additional symptoms.

Planting density does not seem to affect the canker spread. Healthy marri trees have been observed side by side to badly infected trees in the bushland areas (Trudy Paap, *pers comm*). Whilst spores are spread by wind, rain and insects, susceptibility to canker appears to depend on individual tree condition, with nutrient deficient or injured trees being more susceptible to canker than healthy, well nourished trees.

MYRTLE RUST

Myrtle rust is caused by the fungus *Puccinia psidii (*syn. *Uredo rangelii).* It is native to south American and was first detected in commercial nursery properties in NSW in April 2010. It has now spread to Queensland and Victoria (NSWDPI, 2013). The fungus infects many Australian natives from the Myrtaceae family, including eucalypts, bottlebrush and tea tree. It forms pustules or orange spores on infected leaves, shoots, flower buds and fruits. The spores are then blown by wind or can be transported by honey bees, other insects, on clothes and via infected plant material. Leaves of infected plants may become buckled or twisted and may die as a result of infection. Sometimes these infected spots are surrounded by a purple ring. Older lesions may contain dark brown spores. Infection on highly susceptible plants may result in plant death (NSWDPI, 2013).

Myrtle rust has not yet been detected in Western Australia, however as the infection can be spread by wind it is highly probable the disease may affect plants in Western Australia in the future. There is no known way to eradicate the disease. Impacted plants should be treated with a fungicide before removal.

EUROPEAN HOUSE BORER

European House Borer (EHB) is a serious pest of untreated dry softwood, including pinewood (DAF, 2013). EHB was first detected in Western Australia in 2004 and has been found in susceptible dead trees, logs and living trees with dead wood (dried out damaged branches or trunks). EHB also infests susceptible roof timbers, wall frames, flooring, architraves, door frames and timber articles such as pine furniture, shipping crates, pallets and transport supporting timber and frames. Following the discovery, action was taken to determine the extent of EHB infestation, and to prevent further spread. This has effectively contained of the pest to defined Perth locations. Without appropriate action, EHB has the potential to infest homes built with untreated pinewood structural timber (DAF, 2013).

EHB has been found only in the Perth metropolitan area, with the exception of one find in Albany. EHB infestation has been discovered in one Perth home (DAF, 2013).

Although no EHB have been found at the Bentley Campus, nor in any of the immediate surrounds many of the Black Cockatoos feeding sites are remnant pines which potentially could be threatened by infestation by the European House Borer (EHB). If an infestation was to occur on site it would require all infested pines to be clear felled as a requirement under the Agriculture and Related Resources Protection (European House Borer) Regulations (DAF, 2013).