Appendix D

Threatened Ecological Community Review (van Etten 2019)

INDEPENDENT STUDY OF THREATENED ECOLOGICAL COMMUNITY, LOT 102 FARRALL ROAD, MIDVALE

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Background/Context

Swan Coastal Plain Floristic Community Type 20c, titled "Shrublands and Woodlands of the eastern side of the Swan Coastal Plain" (hereafter referred to as FCT 20c), is a Threatened Ecological Community recognised and listed as "Critically Endangered" by the WA Government. It is also listed as Endangered under the EPBC Act.

The community is described as shrubland or woodland of *Banksia attenuata* and *Banksia menziesii*, sometimes with *Allocasuarina fraseriana,* with a reasonably dense shrub layer that typically includes species such as *Adenanthos cygnorum, Hibbertia huegelii, Scaevola repens* var. *repens, Allocasuarina humilis, Bossiaea eriocarpa, Hibbertia hypericoides* and *Stirlingia latifolia*. Typical ground species include herbs such as *Conostylis aurea, Trachymene pilosa, Lomandra hermaphrodita, Burchardia umbellata* and *Patersonia occidentalis*; the sedges *Mesomelaena pseudostygia and Lyginia barbata* usually occur in the community (Gibson et al. 1994, DEP 1996, English & Blyth 2000, DEC 2006). The community was originally described by Gibson et al. (1994) who collected and analysed data from approximately 509 quadrats (each 100 m^2) placed across the central and southern Swan Coastal Plain to derive some 30 floristic community types. FCT 20c was recognised and described as one of these FCTs within the broader classification, being based on 9 quadrats from the Talbot Road bushland area (Gibson et al. 1994).

FCT 20c is mainly restricted to sandy and gravelly soils of the Ridge Hill Shelf, a landform located at the base of the Darling Scarp and mostly formed in the early Pleistocene when sea levels were much higher than present and coastal dunes were deposited and subsequently lithified into sandstone with laterite capping in some areas. In addition, colluvium (scree) washed down from the Darling Plateau and Scarp also forms part of the Ridge Hill Shelf. The sandy soils associated with FCT 20c may therefore represent very old marine dunes or deposits of eroded laterite. The Ridge Hill Shelf occurs as a narrow (~3 km wide), discontinuous and extremely complex geomorphological unit at the boundary between the Darling Scarp and the Swan Coastal Plain.

Peet Stratton Pty Ltd ('Peet', the proponent) wish to develop Lot 102 Farrall Rd, Midvale (hereafter known as "Lot 102"), for a housing subdivision as part of a wider residential development and they have engaged Emerge Associates (consultants) to prepare a referral and associated documentation on their behalf for the purposes of environmental assessment.

Although the occurrence of FCT 20c at Lot 102 was considered in earlier studies, a study by Tauss & Associates (2016) confirmed and mapped the presence of this TEC at the site, although patches were in varying condition. The presence of FCT 20c at Lot 102 has been accepted in the referral documentation as three patches of FCT 20c in good or better condition (Emerge Associates 2017). These three mapped patches of FCT 20c are accepted as real entities for the purposes of this study (as per the study brief) and it is beyond the scope of this study to evaluate the methodology by which these were determined, or their validity.

The scope of this independent study as endorsed by the EPA is to provide advice regarding the following:

1. The significance of the occurrences of the TEC within the proposal area, relative to the known extent of the TEC outside of the proposal area.

2. The potential impact of the proposal on the TEC occurrences, including consideration of the impacts of the development on hydrological processes and other potential impacts such as increased fragmentation and edge effects, weed invasion, recreational use, fire management and rubbish dumping.

3. The long-term likely survival and sustainability of the occurrences under both predevelopment and proposed development scenarios.

4. Consideration of the buffer and management actions required to protect the occurrences within the site from impacts including increased fragmentation, hydrological change, increased weed invasion, dust, inappropriate fire regimes, rubbish dumping and recreational impacts.

5. The management actions required for the occurrences to be rehabilitated and to what standard the rehabilitation should be undertaken to.

6. The location and size of an area/areas recommended for retention of the TEC within the site.

The methodology used to address these six items is primarily based on the author's expertise and experience with these matters, but is also guided by IUCN criteria for assessment of threatened ecosystems (see Appendix 3), site visits, aerial photograph interpretation, and previous studies and reports on the site, broader region and the TEC.

Glossary of Abbreviations & Terminology Used in this Report:

AOO = area of occupancy. Note: IUCN use number of $10km^2$ grids occupied by the community or ecosystem, but in this report I have used estimates of known area of occurrence as fairly accurately mapped at fine scale.

Buffer = an area or strip around a core protected area designed to reduce edge effects and impacts from adjoining landuses.

Edge effect = any difference in environment between the edge and the interior of a particular vegetation patch.

EOO =extent of occurrence, equivalent to the area which incorporates all known occurrences of the community or ecosystem, typically measured using minimum convex polygon method.

Emerge = Emerge Consulting main consulting company engaged by the proponent (Peet) for environmental documentation including the Referral document

FCT 20c = Floristic Community Type 20c as determined by Gibson et al. 1994 and described as Shrublands and Woodlands of the Eastern Swan Coastal Plain. It is listed as a "Critically Endangered" Threatened Ecological Community (TEC) in WA.

DBCA = Department of Biodiversity, Conservation and Attractions (WA)

IUCN = International Union for the Conservation of Nature

POS = public open space

RVMP = Rehabilitation and Vegetation Management Plan prepared by Emerge Associates for Lot 102

TEC = threatened ecological community

1. The significance of the occurrences of the TEC within the proposal area, relative to the known extent of the TEC outside of the proposal area;

Based on information obtained from DBCA (Table 1), the known Area of Occupancy (AOO) of FCT 20c is *c.* 129 ha, 94% of which is found at two localities (Talbot Rd Reserve and adjacent bushland in Midvale; and the former Bushmead Rifle Range site in Helena Valley) which are roughly 6 km apart. Both areas are reasonably well protected and managed, Talbot Rd ostensibly by DBCA (although tenure and management is divided amongst three bodies), and Bushmead under covenant agreement between the private landowners and DBCA.

Other known occurrences of FCT 20c are located at Clifford Rd, Maddington and Stirling Crescent, Hazelmere (Table 1). Both of these are located within small bushland remnants under Main Roads jurisdiction and are therefore not formally protected or managed. Both are also highly vulnerable given they occur in areas where clearing for upgrades to adjacent road intersections on the Tonkin & Roe Hwys, respectively, may occur sometime in the future.

The Extent of Occurrence (EOO) of FCT 20c is approximately 34 km^2 (using the minimum convex polygon method). However if the small, isolated Maddington occurrence is excluded, the EOO is just 17 km^2 (again using minimum convex polygon).

Based on Criteria B of the IUCN Red list of Ecosystems ("Restricted Geographic Distribution"), FCT 20c should be listed as Critically Endangered due to both its very small EOO (B1) and AOO (B2) in combination with likely major reduction in its distribution given large amount of clearing for agriculture and urban on lower slopes of the Ridge Hill Shelf where FCT 20c mostly occurs (i.e. overall it fits criteria B1(a)i/B2(a)i; see Appendix 3). This agrees with State TEC listing ('critically endangered') and 'endangered' under the Commonwealth Environment Protection and Biodiversity Conservation Act 1999 (EPBC Act).

The reported presence of FCT 20c at Lot 102, Farrall Rd represent the fifth known discrete occurrence of this TEC, albeit less than 1 km from Talbot Rd Reserve. Although the occurrence is small (<1 ha in total), it is significant given the status of the community and the limited number of sites from which it is currently known.

Of the four known patches of FCT 20c (on the DBCA database; see Table 1 in Appendix 2 and map in Appendix 5) at Lot 102, the largest is Farrell06 at 0.40 ha (which represents 0.31% of its known AOO). This patch occurs in the area which is proposed to be kept by the proponent (as part of a larger area of POS). Of this patch, 0.07 ha has been deemed to be in very good condition and 0.22 ha in good condition, with the remainder (~0.105 ha) in poor to degraded condition (and therefore not mapped by Emerge, but is proposed to be rehabilitated, see below).

Two other patches of FCT 20c which occur in close proximity to each other on the eastern boundary of Lot 102 are Farrell04 (0.15 ha, or 0.12% of known AOO) and Farrell03 (0.05 ha; 0.039% of AOO)(see map at Appendix 5 for locations). These were mapped as mostly being in good condition, although from my observations they both contain areas which are degraded to some degree. Farrell04 comprises very open shrubland dominated by *Adenanthos cyaneum* with no *Banksia* overstorey and high grassy weed cover (see Photo 2 in Appendix 4). In my opinion, it is better classed as 'degraded' overall (according to scale of Keighery 1994) due to previous disturbances, including partial clearing, as well as the low cover of native understorey shrubs. Farrell03 has a small number of *Banksia* trees but again a quite open shrub understorey, but with generally lower grassy weed cover than Farrell04 (see Photo 3 in Appendix 4). The general condition rating of 'good' is supported for Farrell03. The low shrub/ground cover layer of the vegetation at both Farrell03 and

Farrell04 is much more open and has much greater weed cover than patches of FCT 20c found at Talbot Rd (see Photo 5 in Appendix 4).

A fourth patch on the DBCA database but not mapped by Emerge* as it is in degraded condition is Farrell05 which covers an estimated 0.03 ha (0.023% of known AOO). This patch occurs along an old fenceline (and therefore very narrow and linear in shape) and is highly degraded being dominated by grassy weeds with very low native species richness (see Photo 4 in Appendix 4). I support it not being included in the mapped extent of FCT 20c at Lot 102 Farrall Rd due to its poor condition, and for this reason I focus on the other three larger patches in this assessment.

(*NOTE: Emerge in the Referral document identify and map three occurrences of FCT 20c (rather than 4 as per the DBCA database). This is because Emerge only included areas of SCP 20c identified in the Tauss study that are in good or better vegetation condition, and not areas mapped as degraded or poorer in condition. According to Emerge: "The site therefore contains a total of 0.5 ha of the FCT 20c TEC, including:

- 0.3 ha located adjacent to the Bush Forever site in 'very good' (725 m^2) and 'good' (2,225 m^2) condition which is proposed to be retained as part of this proposal [This corresponds to parts of Farrell06 in good and very good condition].
- 0.2 ha located on the eastern boundary of the site in 'good' condition located in two patches of 500 m^2 and 1,500 m^2 which is proposed to be removed as part of this proposal." [This corresponds to Farrell03 and Farrell04 respectively])

Although the known occurrences of FCT 20c have been mapped and their area fairly accurately established, it is quite conceivable that further occurrences of FCT 20c will be found in the wider local area in the future. Although this TEC has been widely searched for over many years, this has not been done in a systematic nor co-ordinated fashion. Much of the identification of FCT 20c occurrences has arisen opportunistically via development proposals where patches of bushland to be cleared are surveyed and assessed against the original (and sometimes updated) SCP floristic database(s). The TEC seems to be concentrated on the western edge of the Ridge Hill Shelf which has been heavily (>90%) cleared, so the chances of finding large areas of this community would appear to be slim (English and Blyth 2000, DEC 2006).

One potential approach to find new areas of FCT 20c could be predictive modelling based on soil type and/or other biophysical features of the community. For example, as FCT 20c seems to be mainly found on sandy soils on the western edge of the Ridge Hill Shelf (particularly so at Lot 102), a map of remnant vegetation on this soil type (e.g. using soil-landscape mapping type "Forrestfield Phase 1" or "Soil type 22" from King and Wells (1990) – refer to Appendix 1 for further information) may reveal patches of remnant bush with good potential to be FCT 20c.

CONCLUSION & RECOMMENDATIONS: The identification of FCT 20c at Farrall Rd represents an additional, albeit small, occurrence of this TEC and therefore is significant. It is important that a substantial proportion of this occurrence is protected. A targeted, strategic survey of the areas of the Ridge Hill Shelf landform with potential to have FCT 20c is recommended, ideally based on a predictive modelling approach, to more firmly establish the actual locations and area of this TEC.

2. The potential impact of the proposal on the TEC occurrences, including consideration of the impacts of the development on hydrological processes and other potential impacts such as increased fragmentation and edge effects, weed invasion, recreational use, fire management and rubbish dumping;

This evaluation of potential impacts of the proposal on the TEC is based on: 1) the planned retention of Bush Forever Site 309 and 0.3 ha of FCT 20c in good to very good condition within the Public Open Space (POS) of the southern portion of Lot 102; and 2) clearing of the other mapped patches of FCT 20c on the eastern side of Lot 102.

Potential Impacts:

i) Clearing of Vegetation

Clearing of the three small patches (Farrell03, 04 & 05 on the DBCA database; Table 1; Appendix 5) would represent a loss of 0.23 ha or ~0.18% of the known area of FCT 20c. This will not change the listing of the TEC based on IUCN criteria as it already is in the most vulnerable extant ("non-collapsed") category ("Critically Endangered"). Although this loss is minor in terms of its overall distribution, it represents approximately 40% of the area of FCT 20c in good or better condition at Lot 102, or 36% over all patches at Lot 102 irrespective of condition. However the patch to be retained is clearly the largest and in the best overall condition, and has most potential to be protected, managed and sustained (see 3. below).

ii) Hydrology

From existing reports and databases, including the Perth Groundwater Atlas (DoW 2014), minimum groundwater heights across the site are at approximately 11 m AHD (i.e. above general sea level) with groundwater flowing in a westerly direction. As the land on the eastern side of the Lot 102 is 20-26 m AHD, this suggests a relatively deep groundwater system of at least 10 m below surface across most of the site. This concurs with observations of the railway cutting on eastern edge of Lot 102 which is at least 10 m deep in places. The railway cutting also shows consistent light yellow sand throughout the profile, which suggests no or few impeding layers. Soil cores as part of geotechnical studies at the site (Douglas Partners 2014) confirm deep sandy soils, although in the northern and central parts of the Lot 102, the sand grades into a clayey sand with some lateritic gravel at around 2m (which subscribes to general descriptions of the Yoganup formation of the Ridge Hill Shelf). Therefore it appears that the upland areas on the eastern side of Lot 102, where FCT 20c mostly occurs, comprises of relatively deep, well-drained, siliceous sand, which also concurs with soil mapping and descriptions of the area (see Appendix 1).

In terms of plants accessing groundwater at this depth, it is likely to marginal for *Banksia attenuata, B. menziesii* and *Adenanthos cygnorum* as even though these are all deep-rooted species, most roots are <9m long. Although there may be some use of groundwater in winter/spring by these species, they are unlikely to be dependent on this groundwater. For the understorey shrub and herb species, most of which have shallow roots, groundwater access is highly unlikely (Farrington et al. 1989; Zenich et al. 2002; Groom 2004).

iii) Fragmentation and Edge Effects

The patches of vegetation in good or better condition within Lot 102, including those of FCT 20c, are already highly fragmented due to past clearing and vegetation disturbance in and around Lot 102. Land to the east of Lot 102 was cleared in the early 1980s for housing and the railway cutting on the eastern boundary dates from at least 1965. Land on the western side of Lot 102 has been heavily cleared for agriculture or other uses from at least 1950 and consists of the quite different vegetation and soil (palusplain wetlands of *Melaleuca* and open woodland on heavy soils) than Lot 102. The nearest significant patch of native vegetation currently is Talbot Rd Reserve (which includes relatively large patches of FCT 20c within an area of over 100 ha) some 700 m to the east (based on closest boundaries).

Partial clearing and damage to vegetation has occurred across large sections of Lot 102, although the cause and history of such disturbances are not fully known. Aerial photographs from the 1950s show tree cover and overall vegetation density to be generally higher at Lot 102 than today and more continuous across the landscape, especially to the east of Lot 102 (with continuous vegetation to Talbot Rd bushland and beyond). However by 1965 there appears to have been a reduction in tree and shrub cover in and around Lot 102 which corresponds to around the time of railway construction. The cause of this decline in vegetation is not clear, but appears to affect the larger area (so possibly fire, although there are signs of physical disturbance via tracks etc.). By the late 1970s there has been some recovery of vegetation at Lot 102 but it is now more patchy and open than the 1950s. Despite this apparent recovery, there appears to have been a general decline in tree and shrub cover on Lot 102 since the 1980s.

Clearing of northern and central parts within Lot 102 for housing development will mean that the remaining patch of FCT 20c in the SE corner will become more isolated although this could be compensated for by increasing the effective size of this remnant via restoration (see 5. below). The impact of increased isolation is difficult to assess and will be very much dependent of the current degree of gene exchange within the individual species (which is mainly related to the distribution and reproductive characteristics of the individual species, including their pollination type, breeding system and seed dispersal strategies). Therefore the impact will be somewhat independent of the current mapped patches of FCT 20c. That is because some of the species occurring in patches of FCT 20c at the site are already quite restricted to certain parts of the Lot 102, whereas others are widespread occurring sporadically across the whole site.

Edge effects in ecology are identifiable as any difference in environment between the edge and the interior of a particular vegetation patch (Murcia 1995) and are a well-studied ecological phenomenon. Environmental characteristics which differ across edges are many and varied. They cover many components of the environment including the atmosphere (eg microclimate), vegetation (e.g. structure, composition, functioning), fauna and their habitat, and soil (Murcia 1995). Typically edge effects are multi-faceted and inter-related, with direct, or primary, effects (e.g. changes in microclimate and soil exposure from extra solar radiation at the edge) often leading to secondary (or indirect) changes in plant and animals density which can, in turn, either further exacerbate or ameliorate the primary changes. Effects may be long lasting or temporary, and can be either rapid or slow to develop; similarly, they can be relatively stable once the effect has occurred, particularly if effective management occurs, or they can develop in a progressive fashion, working their way from the edge into the interior of the vegetation or habitat over time.

Although edges and their effects can be natural (e.g. where two distinct environments or vegetation types meet such as between wetland and Banksia woodland in southern portion of the study area), in this assessment they will refer to newly created edges caused by vegetation clearing or major disturbance. As such, for many of the existing patches of vegetation in good or better condition, including that of FCT 20c, there is already, and has long been, a substantial edge effect present. In terms of clearing of vegetation for development, a new edge will be created along the northern boundary of the retained section of vegetation; however as this edge will mostly be in an area of cleared/degraded land, there is unlikely to be a substantially enhanced edge effect at this new boundary. Further with successful rehabilitation of the disturbed land in the retained area, the overall edge effect will be reduced, particularly for the retained patch of FCT 20c in good condition as the vegetation surrounding it should be in improved condition and present less hostile surroundings (depending, of course, on the success of restoration efforts).

The main edge effect of concern within the study area is weed invasion from degraded/cleared areas into patches of good or better vegetation, and the main weeds of concern are grassy weeds such as perennial veldt grass (*Ehrharta calycina*) and African love grass (*Eragrostis curvula*) which produce large quantities of wind-dispersed seeds. For the retained patch of FCT 20c, there is already some invasion of these grasses (and other weeds), which will likely worsen over time. The weed seed bank in the topsoil of this patch is likely to be substantial and hence the vegetation will be vulnerable to disturbance (as grassy weeds will likely to establish *en masse* following disturbance and will tend to out-complete native plant species in early stages of growth). The best solution is to actively control weeds (via herbicide treatment or other means), promote establishment of native vegetation within and around the retained vegetation (as dense vegetation will tend to suppress sun-loving grassy weeds) and minimize vegetation disturbances. Consequently, there is considerable potential for active restoration (establishment of native plants combined with active weed control) to reduce edge effects associated with weed invasion. Control of weeds in the developed area outside of the retained area, as well in the railway easement and areas to the south (other private owners) will also be important in minimising weed invasion into the retained vegetation.

iv) Fire

Associated with grassy weed invasion is increased fire hazard as these grasses will substantially increase fuel loads and their continuity (van Etten 1995; Brown & Brooks 2002); without these grassy weeds, the open and disturbed nature of the vegetation would generally translate to a low fire risk. The whole Lot 102 area is particularly vulnerable to grassy weed invasion given the sandy soils, past disturbances and open vegetation, and could easily enter a downward spiral (known as the grass-fire cycle) where grassy weeds promote fire which in term promote further grasses and so on. The incidence of fire may increase with more people (both accidental and arson), although the presence of people may also lead to earlier detection and suppression of fires, thereby limiting their extent.

The best management approach to deter and break the fire-weed cycle is to control weeds via active weed control and revegetation of native vegetation.

v) Trampling/recreational impacts

The presence of more people will mean remaining native vegetation will be more vulnerable to trampling and physical damage. However, such potential impacts can be effectively managed via fencing and directed access (e.g. via limestone or other semi-sealed pathways and effective use of dense revegetation).

vi) Rubbish dumping

As with recreational impacts, the presence of more people will increase dumping of rubbish (both purposeful and accidental). Dumping and littering is likely to be most acute in the construction phase given the large amount of waste generated combined with little wind protection. However dumping may decline in the longer term as more people will also mean more surveillance (most rubbish dumping is done in more remote areas where perpetrators feel they are not being watched). Also vegetation patches which are fenced and clearly marked as conservation areas tend to experience less rubbish dumping as they are identified as areas of value to the local community and more broadly.

Other impacts include plant dieback caused by *Phytophthora* spp. It is not known if this soil-borne pathogen is present at the site, however the vegetation is unlikely to highly vulnerable given the deep, well-drained, sandy soil (although some root-to-root spread may be possible).

Most of the impacts recognised above can be minimised via prudent and timely management, but this requires organisation(s) to take responsibility and to provide adequate and ongoing resources. Given the interest shown in protecting native vegetation at the site by some members of the community, a collaborative approach between State, local government, developer and local community should be explored.

Conclusion/Recommendation: **The loss of FCT 20c due to proposed vegetation clearing at Lot 102 is substantial at the site level, but minor overall (representing <0.2% of its known area). The current proposal does preserve the best and largest patch of FCT 20c at the site (representing around two thirds of its extent at Lot 102), and with sufficient effort, resources and money this could be protected and even enhanced over the long term. The main impacts needing to be managed are weed invasion and associated increased fire risk, and these will require ongoing weed control combined with revegetation. Other impacts appear negligible or are relatively easily managed.**

3. The long-term likely survival and sustainability of the occurrences under both pre-development and proposed development scenarios;

Assessment of the potential for long-term survival of the FCT 20c patches addresses some important but conceptually difficult ecological questions. Survival of a plant community is interpreted here as avoiding the collapse of the ecological community. Central to this is the idea of an ecological threshold, which is a point of no return in terms of a level of degradation or change of a community from which it can no longer recover (and so is now in a transformed or novel ecological state). So one approach is to prevent degradation of the community to a stage beyond which it can't recover, although identifying such thresholds is particularly challenging. However it is accepted that through appropriate interventions even a highly degraded community can be restored provided enough resources and effort are expended (although this point is widely debated within restoration ecology). The question of whether a highly degraded Banksia woodland community can be restored is addressed under item 5 below.

The pre-development scenario is interpreted here as the current condition, actions and status (i.e. basically unmanaged land likely to have ongoing threats and impacts in terms of fire, weeds etc.) Patches of FCT 20c at the site are currently small and quite fragmented (see 1. and 2. above), so they would be unlikely to be viable over the long term given persistent threats and edge effects. The two smallest patches of FCT20c (Farrell03 and Farrell04 as per Table 1 and Appendix 5) would be particularly vulnerable to edge effects given their size (0.15 ha and 0.05 ha); for instance, if an edge effect of only 20 m is applied, only 11 m^2 and no effective core area remain, respectively (assuming the patches are circular, which they roughly are). Small patches left within an urban matrix would be even more threatened and difficult to maintain. All patches of FCT 20c at Lot 102 have at least some level of grassy weed invasion, with some parts dominated by weeds. Without control of such weeds, the patches are likely to transition into grass-dominated open woodland/shrubland ecosystems which would be compositionally, structurally and functionally different from the TEC, especially in terms of fire regime and nutrient cycling. Although the conservation advice for FCT 20c released by the Commonwealth states that all patches are important irrespective of condition, there is likely to be point in the degradation cycle where the community is: 1) is not recoverable even with serious intervention; and 2) no longer identifiable as that particular community as its characteristics have changed so much.

The post-development scenario involves clearing all but the southern portion of Lot 102 to protect the largest patch of FCT 20c (as well as the wetland and surrounding buffer zone). This larger patch is less vulnerable to edge effects because of its size and connectivity with other retained vegetation, but also would be more protected if revegetation within the proposed buffer surrounding the patch is successful (see 4. below).

Conclusion and Recommendations: All patches of FCT 20c at Lot 102 are vulnerable and unlikely to survive over the long term without management given ongoing weed invasion, lack of recruitment and other threats, in combination with their size and isolation. The largest patch is potentially viable provided effective buffer, restoration and management prescriptions are applied.

4. Consideration of the buffer and management actions required to protect the occurrences within the site from impacts including increased fragmentation, hydrological change, increased weed invasion, dust, inappropriate fire regimes, rubbish dumping and recreational impacts;

A buffer in a conservation sense is an area or strip around a core protected area designed to eliminate or reduce impacts of the surrounding land uses on the protected area. They typically comprise of intermediate areas with some native vegetation, some human uses and less strict protection. Such buffers not only have the potential to reduce weed invasion and other edge effects and to improve the quality of water runoff/drainage, but can also increase the effective habitat area for many species.

However, buffers will only be effective if they are well planned, implemented and managed. An unmanaged or poorly managed buffer applied around patches of FCT 20c at the development site could actually worsen impacts on the TEC; for instance, the potential for high weed cover to develop in the buffer will result in substantial weed seed dispersal into the core patches of FCT 20c. Further, such weed cover will increase chances of fire entering the core patches.

An alternative to a buffer is a hard edge around areas to be protected (e.g. sturdy, rabbit-proof fence, with limestone or other sealed track at the boundary) although this would still require ongoing weed control (at the edges) and possibly would more costly to establish and maintain. However given the relatively small areas of FCT 20c to be protected, buffers are the preferred approach, although fencing or other forms of access control around the perimeter of the POS is also recommended.

It is recommended that the width of the buffer around retained patch(es) of FCT 20c should be at least 25 m (although it recognised that there may not be 25 m of land available to the east of the retained patch in the SE corner of Lot 102 where it abuts the railway corridor). This width is based on observations of weed invasion into Banksia woodland, although it is recognised that there has been no extensive peer-reviewed study of effective buffer widths for this vegetation type and that weed invasion distances into bushland vary widely with many factors contributing to the degree and distance of weed invasion. Although buffer widths of 25+ m are recommended here, consideration should also be given to creating a connected and continuous area with other retained vegetation (such as the *Melaleuca* wetland in the SW corner).

It is also important that buffers are actively rehabilitated and managed. Areas of native tree/shrub cover will mean less weeds (especially shade intolerant grassy weeds) and ultimately can become self-sustaining and contribute to improved habitat and greater area of TEC if well done. Also rabbit control in the buffer is important given their propensity for soil and vegetation disturbance.

Retention of and a buffer around FCT 20c in the SE corner of Lot 102 (i.e. Farrell06) will also help protect significant wetland vegetation associated with Bush Forever Site 309 and will help preserve the transition from upland to wetland in this area. All together the buffer and retained areas contribute to a larger area of protection which thereby means lower edge to area ratio, and hence less edge effect, as well as other benefits including more effective management and less monetary cost per area under management. The benefit of maintaining one large intact area versus several small ones, especially if restoration of buffer can be successful, is well known in conservation.

A similarly sized buffer around the other two patches of FCT 20c in good condition (i.e. Farrell03 & Farrell04, which are relatively close together and therefore could be combined as a single buffer; see Appendix 5) would protect both patches but would be more difficult and costly to implement because of the highly degraded nature of the vegetation in this buffer zone and the overall larger area of this buffer (compared to the buffer around Farrell06 which has considerable amount of native vegetation on or near its western boundary). Also the area of buffer around Farrell03/04 would be considerably larger than the area it is designed to protect which would create some challenges. For instance, even at the minimum buffer width of 25 m, the area of the buffer around Farrell03/04 would be approximately 0.9 ha (relative to combined area of the two FCT 20c patches of 0.2 ha) compared to the buffer area around Farrell06 which is approximately 0.6 ha.

CONCLUSION AND RECOMMENDATIONS: A revegetated buffer around retained patch(es) of FCT 20c is recommended. These buffers should be relatively wide (at least 25 m) and be a focus of active restoration and management so they not only protect core areas but also in time may increase the effective area of the TEC. A buffer applied around the largest patch of FCT 20c would be smaller in area than a similar-sized combined buffer around the other two patches of FCT 20c in good condition.

5. The management actions required for the occurrences to be rehabilitated and to what standard the rehabilitation should be undertaken to;

Restoration of degraded Banksia woodland has had mixed success (Thorn et al. 2018), although high quality restoration is possible given good planning, correct techniques and adequate resources (Stevens et al. 2016). However the effort, money and resources required shouldn't be underestimated, especially where the ecological community has been degraded or disturbed for considerable time (i.e. over timeframes of decades rather than years, as experienced at Lot 102). Restoration success in Banksia woodlands is strongly linked to the availability of native seed in the topsoil and retained vegetation (Stevens et al. 2016), so where weed-dominated and long-degraded, which is the case for much of the FCT 20c vegetation at Lot 102, it would be expected that the regeneration potential via topsoil would be limited and would favour weed species over natives (although testing of soil seed store is recommended as there may be some long-lived native seed persisting). If and where an adequate viable soil seed bank remains for at least some native species, an initial restoration approach comprising weed control, some soil roughening (to break surface soil crusting) and perhaps application of smoke water (to stimulate germination) and/or water surfactants (to reduce water repellency) could be explored. However the main approach over much of the FCT 20c patches and surrounding buffer would be direct seeding and planting as per the RVMP. In general, the approach and techniques to rehabilitation outlined in the RVMP are sound and are supported. Specifically, the importance of weed control and trialling of transplanting key species from areas to be cleared are good initiatives and are encouraged.

Areas in very good condition, such as within the patch of FCT 20c in the SE corner of Lot 102 (Farrell06), have potential to be restored to excellent condition given their reasonably intact structure and relatively high native plant diversity. However, even for these areas, it may not be not possible or desirable to restore the community to its original condition, particularly as the original condition, including the original component species of the community at the site, remain unclear; it also may not be feasible or achievable without exorbitant costs. A preferable option is to define clear restoration goals in terms of structure, function, quality and composition which are both achievable and appropriate for the site. For instance, a functional goal within the mapped patches of FCT 20c could be to obtain a vegetation dominated by native species of the locality with low weed cover (especially grassy weeds which can transform this community). Structurally it could be to obtain an open woodland of Banksia (5-20% cover) with relatively dense shrub understorey (>50% cover). Composition could focus on dominant and common species as per the FCT 20c description in TEC listing and recovery plans (English and Blyth 2000; DEC 2006). However species selection should focus on species already occurring at the site (rather than just those representative of the broader community) to avoid introduction of new species (i.e. those not previously occurring at the site) given there is known floristic variation within the FCT 20c floristic group with locality (DEC 2006).

Rehabilitation of the proposed buffer zone(s) around the retained patch of FCT 20c, which is currently in poor to degraded condition, will require less ambitious goals focussed more on the achieving the functional goals of buffer. These goals should be compatible and complementary with the rehabilitation goals for the FCT 20c patch and therefore would ideally focus on achieving a broadly similar vegetation structure and composition to other patches of FCT 20c, and to maintain a relatively low weed cover. Therefore they could ultimately achieve vegetation representative of FCT 20c in good condition, albeit over longer timeframes.

CONCLUSION AND RECOMMENDATIONS: Overall, the goal of rehabilitation should be to achieve good or better condition vegetation representative of the FCT 20c occurrences at the site, although the timeframe to achieve these goals will vary with condition of the vegetation.

6. The location and size of an area/areas recommended for retention of the TEC within the site.

The primary area recommended for retention is the largest patch of FCT 20c in the south-east corner of Lot 102 (representing some 0.3 ha of FCT 20c in good and very good condition, and some 0.40 ha overall). A buffer around this patch of at least 25 m is also recommended and successful restoration and management of this buffer would not only help protect this retained patch but also may, ultimately, increase its effective size. Retention of this FCT 20c patch and surrounding buffer will also mean continuity with and improved protection of the important *Melaleuca* wetland at Bush Forever Site 309 including retention of the upland to wetland transition (which may contain species not found in either community). Altogether the retention of the FCT 20c patch, buffer, wetland and wetland-upland transition represents the best opportunity to effectively and sustainably protect a relatively large expanse of native vegetation with particularly important conservation values. This relatively large and continuous area also has potential recreational and aesthetic value to the local people provided access is carefully managed.

The other two patches of FCT 20c in reported good condition are more vulnerable given their size and isolation and are not recommended to be retained unless an effective buffer zone can be also implemented of at least 25 m width. Without ongoing management (e.g. weed control, active revegetation etc) of this buffer zone, as well as the patches of FCT 20c themselves, these two patches of FCT 20c are not considered viable, especially as they appear to be already somewhat degraded with relatively high weed cover in places and a very high proportion of their area susceptible to edge effect. Implementation of restoration and ongoing management of core and buffer will be relatively expensive over both the short and long term, especially given this buffer zone will be much larger in area than the areas it is designed to protect (even at the minimum buffer width of 25 m). Therefore serious questions need to be raised regarding the potential returns on investment here, especially given that there are risks involved of poor or substandard outcomes (as experience in other Banksia woodland restoration). In other words, the costs involved may not justify the potential outcome and risks involved.

FINAL CONCLUSIONS AND RECOMMENDATIONS: Clearly, the highest priority should be given to retention and conservation actions in and around the largest patch of FCT 20c in the south-east corner of the site (i.e. Farrell06), including application of an appropriate protective buffer. Active restoration and management is the best approach for the long-term protection of this occurrence, and this will also improve protection of neighbouring environmental assets, such as the *Melaleuca* wetland. Keeping the other smaller patches of FCT 20c will be problematic given their size, condition and isolation, and the cost of implementation relative to area protected. Currently retention of these smaller patches is not recommended unless adequate funds are available for restoration and long-term management of the patches and surrounding buffer of at least 25 m width. Largely this is a pragmatic recommendation based on what is best achieved with a likely limited budget, especially when considering the funding which is likely to be available for management over the long term (which is required). However it also recognises the priority which should be given to protect larger, more connected, more diverse and better quality remnants of native vegetation in our urban environment.

Appendices

Appendix 1: Soil – landform descriptions of the study area

a) Heddle et al. (1980) Soil-Vegetation Association mapping: Guildford Complex – Fluvial (riverine) sediments. However this appears to be a map resolution error as the site is clearly Ridge Hill Shelf landform and Forrestfield vegetation complex given it elevation and soil type. Based on soil mapping the site is located within Forrestfield complex.

b) King, P D, and Wells, M R. (1990), Darling Range rural land capability study. Department of Agriculture and Food, Western Australia, Perth. Report 3.

Soil type 22 (or F1)

"Deep yellow-brown sands (soil type 22) occupy a significant portion of foothills within the study area. These sands are considered by McArthur and Bettenay (1960) to be weathered from laterite, and by others, such as Woods (1979) and Biggs (1977), to be fossil shoreline beach and dune deposits. "

Soil type 22 (F1). Deep siliceous yellow-brown sands, and pale or bleached sands with yellow-brown subsoils: Principal profile forms: Uc1.2, Uc5.11, Uc2.21, Uc4.21. Land units: Fl. Deep, uniform gravel free sands occur over a relatively large proportion of the foothills to the Darling Scarp. The deep siliceous or podzolized sands exhibit very dark grey to brown sand and loamy sand topsoils some 15 cm deep. In the case of the podzolized soils, the topsoils overlie a pale sandy subsurface A2 horizon that may be bleached or unbleached to depths of 60 cm. Below these surface horizons, yellowish brown to yellow coarse sand to clayey sand subsoils extend to depths greater than 3 m. The sands are apedal, have a sandy fabric, are well to rapidly drained and have an acid reaction trend.

c) Soil-landscape mapping (compilation from Dept of Agriculture):

SOUTH WEST AGRIGULTURE REGION REPORT Printed: 12/03/2018
symbol: 213Fo__Ff1 **name:** Forrestfield (D Range) F1 Phase
brief description: Foot and low slopes < 10% with deep rapidly drained siliceous yellow brown sands, and pale or bleached sands with yellow-brown subsoil. Shrubland of unidentified species.
soil: Deep rapidly drained siliceous yellow brown sands, and pale or bleached sands with yellow-brown subsoil.
soil notes: Two areas originally mapped as Karrakatta (Ks) by Pym (1955) in the foothills Swan Valley have been included in this map unit which is predominantly occurs in the Darling Range Survey.
landform: Foot and low slopes < 10%.Well drained gravelly yellow or brown duplex soils with sandy topsoil.
geology:
vegetation: Shrubland of unidentified species.
location:
other information: Appears on the published Darling Range mapping (Land Resources Series 3 - King and Well, 1990) as F1

Appendix 2: Known occurrences of FCT 20c

From Approved Conservation Advice 21 July 2017:

"As at April 2017, there are approximately 130 ha of the ecological community remaining. Occurrences 1 and 2, as identified in WA DEC (2006), are found at Talbot Road Bushland in Stratton (Occurrence 1), and at Bushmead Rifle Range in Helena Valley (Occurrence 2). Additional patches were recently verified at other locations including the following; further north within Talbot Rd Bushland; at the intersection of the Great Eastern Highway bypass and Roe Highway; on Farrall Rd in Midvale; and at the junction of Clifford St and Tonkin Hwy Maddington (DPaW pers comm 2017). Other occurrences may be present in the region and be identified through further surveys and mapping, but overall extent will remain small."

Table 1: Information on FCT 20c Occurrences extracted from the DBCA database (date of access 21/11/2017)

Name	**Location**	**Size ha / Tenure**	**Condition**
STIRLCRES PLOT2 (Stirling Crescent)	Bush Forever site 401 Hazelmere	6.63 ha total ~4.5 ha Main Roads WA Balance private land	2015 90% Excellent 10% Very Good
CLIFFORD03 (Clifford Rd)	Bush Forever site 53 Maddington	0.84 ha Main Roads WA	2016 Excellent
TALB02 (Talbot Rd south)	Bush Forever site 306 Stratton/Swan View	66.85 ha total ~38.4ha DBCA managed ~17ha Cemeteries Board ~10.9ha UCL	2014 10% Good 90% Excellent
BUSHM02 (Bushmead)	Bush Forever site 213 Bushmead	49.91 ha Private land, under covenant with DBCA	2011 Good to Degraded Species richness/ condition highly impacted by historical issues
Farrell06	Lot 102 Farrall Rd Midvale	0.40 ha	2016 Good
Farrell05	Lot 102 Farrall Rd Midvale	0.03 ha	2016 Good
Farrell04	Lot 102 Farrall Rd Midvale	0.15 ha	2016 Good
Farrell03	Lot 102 Farrall Rd Midvale	0.05 ha	2016 Good
TALBNth15 (Talbot Rd north)	Lot 6 Talbot Rd Stratton	4.27 ha Recently acquired for conservation Managed by DBCA	2017 10% Good 90% Excellent
TOTAL		129.13	

Appendix 3

Table 2: IUCN Red List Criteria for ecosystems (version 2.2) (Bland et al. 2017)

A. Reduction in geographic distribution over ANY of the following time periods:					
			CR	EN	VU
A1	Present (over the past 50 years).		≥ 80%	≥ 50%	≥ 30%
A2a	Future (over the next 50 years).		≥ 80%	≥ 50%	≥ 30%
A2b	Future (over any 50 year period including the present and future).		≥ 80%	≥ 50%	≥ 30%
A3	Historic (since 1750).		≥ 90%	≥ 70%	≥ 50%
B. Restricted geographic distribution indicated by EITHER B1, B2 or B3:					
			CR	EN	VU
B1	Extent of a minimum convex polygon enclosing all occurrences (Extent of Occurrence)		≤ 2,000 km^2	≤ 20,000 km^2	≤ 50,000 km^2
	AND at least one of the following (a-c):				
	(a) An observed or inferred continuing decline in **EITHER**:				
	i. a measure of spatial extent appropriate to the ecosystem; **OR**				
	ii. a measure of environmental quality appropriate to characteristic biota of the ecosystem; **OR**				
	iii. a measure of disruption to biotic interactions appropriate to the characteristic biota of the ecosystem.				
	(b) Observed or inferred threatening processes that are likely to cause continuing declines in geographic distribution, environmental quality or biotic interactions within the next 20 years.				
	(c) Ecosystem exists at …		1 location	≤ 5 locations	≤ 10 locations
B2	The number of 10 × 10 km grid cells occupied (Area of Occupancy)		≤ 2	≤ 20	≤ 50
	AND at least one of a-c above (same sub-criteria as for B1).				
B3	A very small number of locations (generally fewer than 5) **AND** prone to the effects of human activities or stochastic events within a very short time period in an uncertain future, and thus capable of collapse or becoming Critically Endangered within a very short time period (B3 can only lead to a listing as VU).				VU
C. Environmental degradation over ANY of the following time periods:					
			Relative severity (%)		
		Extent (%)	≥ 80	≥ 50	≥ 30
C1	The past 50 years based on change in an <u>abiotic</u> variable affecting a fraction of the extent of the ecosystem and with relative severity, as indicated by the following table:	≥ 80	CR	EN	VU
		≥ 50	EN	VU	
		≥ 30	VU		
			≥ 80	≥ 50	≥ 30
C2	The next 50 years, or any 50-year period including the present and future, based on change in an <u>abiotic</u> variable affecting a fraction of the extent of the ecosystem and with relative severity, as indicated by the following table:	≥ 80	CR	EN	VU
		≥ 50	EN	VU	
		≥ 30	VU		
			≥ 90	≥ 70	≥ 50
C3	Since 1750 based on change in an <u>abiotic</u> variable affecting a fraction of the extent of the ecosystem and with relative severity, as indicated by the following table:	≥ 90	CR	EN	VU
		≥ 70	EN	VU	
		≥ 50	VU		
D. Disruption of biotic processes or interactions over ANY of the following time periods:					
			Relative severity (%)		
		Extent (%)	≥ 80	≥ 50	≥ 30
D1		≥ 80	CR	EN	VU

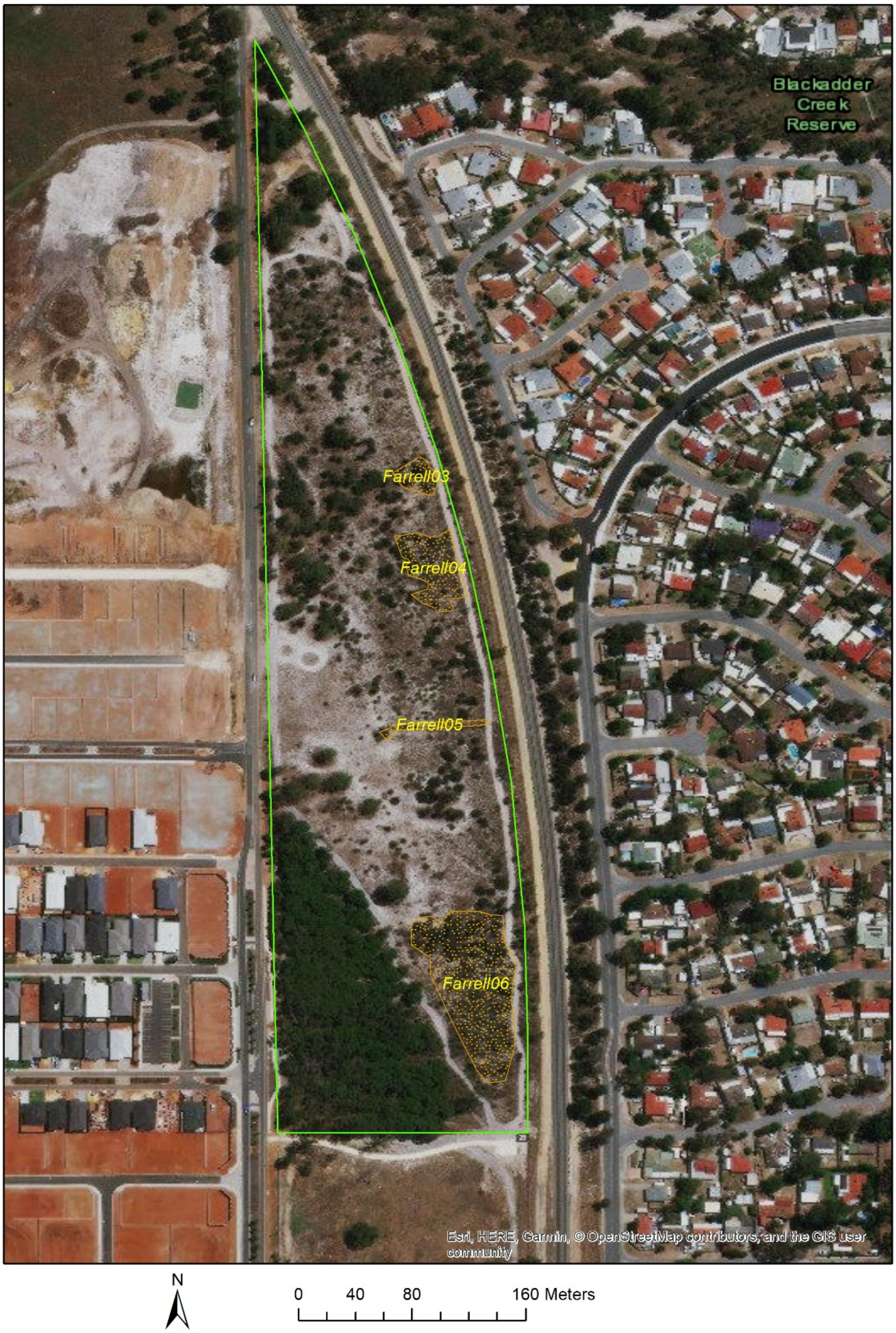
	The past 50 years based on change in a biotic variable affecting a fraction of the extent of the ecosystem and with relative severity, as indicated by the following table:	≥ 50	EN	VU	
		≥ 30	VU		
			≥ 80	≥ 50	≥ 30
D2	(D2a) The next 50 years, or (D2b) any 50-year period including the present and future, based on change in a biotic variable affecting a fraction of the extent of the ecosystem and with relative severity, as indicated by the following table: OR	≥ 80	CR	EN	VU
		≥ 50	EN	VU	
		≥ 30	VU		
			≥ 90	≥ 70	≥ 50
D3	Since 1750, based on a change in a biotic variable affecting a fraction of the extent of the ecosystem and with relative severity, as indicated by the following table:	≥ 90	CR	EN	VU
		≥ 70	EN	VU	
		≥ 50	VU		
E. Quantitative analysis					
			CR	EN	VU
… that estimates the probability of ecosystem collapse to be:			≥ 50% within 50 years	≥ 20% within 50 years	≥ 10% within 100 years

Appendix 4: Site Photos (taken by Eddie van Etten, December 2018)

	**Photo 1**. Largest patch of FCT 20c at Lot 102 in good to very good condition (Farrell06 on DBCA database).
	**Photo 2**. 2nd largest patch of FCT 20c at Lot 102 (Farrell04 on DBCA database). Although mapped as good condition, note the high grassy weed cover, sparse tree/tall shrub layer (with no Banksia) and patchy low shrub layer.
	**Photo 3**. 3rd largest patch of FCT 20c (Farrell03 on DBCA database) in generally good condition although patches of weed dominated vegetation occur, such as in foreground

	**Photo 4**. Small 4th patch of FCT 20c (Farrell05 on DBCA database) can be seen along the fenceline mostly in the middle of photo to background. This linear patch is degraded with few native species
	**Photo 5**. FCT 20c at Talbot Road Bushland Reserve – note open Banksia overstorey and dense shrub understory with few weeds

Appendix 5: Map of Lot 102 study area (green-bordered polygon) with locations and areas of four patches of FCT 20c on the DBCA TEC database shown (labelled Farrell03 to Farrell06).



REFERENCES

Bland, L.M., Keith, D.A., Miller, R.M., Murray, N.J. and Rodríguez, J.P. (eds.) (2017). Guidelines for the application of IUCN Red List of Ecosystems Categories and Criteria. Gland, Switzerland: IUCN. ix + 99pp.

Brown, K. & Brooks, K. (2002) Bushland Weeds: A practical guide to their management, with case studies from the Swan Coastal Plain and beyond. Environmental Weeds Action Network (Inc).

Department of Environment and Conservation (2006) Interim Recovery Plan 2006-2011 for the shrublands and woodlands of the eastern side of the Swan Coastal Plain (community type 20c). Interim Recovery Plan No. 230. Department of Environment and Conservation, Perth.

Department of Environmental Protection (1996) System 6 and part System 1 update program. Unpublished bushland plot and area records. EPA, Perth, Western Australia.

Douglas Partners (2014). Report on Geotechnical and Preliminary Acid Sulphate Soil Investigation Proposed Residential Development Lots 50, 102 and 427 Farrall Road, Midvale, WA. Unpublished report prepared for Peet Stratton Pty Ltd.

English, V. and Blyth, J. (2000) Eastern Shrublands and Woodlands (Swan Coastal Plain Community 20c): Interim Recovery Plan 2000-2003, Department of Conservation and Land Management, Perth.

Emerge Associates (2017) Rehabilitation and Vegetation Management Plan, report prepared for Peet Stratton Pty Ltd, Subiaco.

Farrington P, Greenwood EA, Bartle GA, Beresford JD, Watson GD (1989) Evaporation from Banksia woodland on a groundwater mound. J Hydrol 105:173–186.

Gibson, N., Keighery, B., Keighery, G., Burbidge, A. and Lyons, M. (1994) A floristic survey of the southern Swan Coastal Plain. Department of Conservation and Land Management and the Conservation Council of Western Australia, Perth.

Groom, P. K. (2004) Rooting depth and plant water relations explain species distribution patterns within a sandplain landscape. Functional Plant Biology, 31(5), 423-428.

Heddle, E.M., Loneragan, O.W. and Havel, J.J. (1980) Vegetation of the Darling System. IN: DCE 1980 Atlas of Natural Resources, Darling System, Western Australia. Department of Conservation and Environment, Perth, Western Australia.

Keighery, B.J. (1994) Bushland plant survey. A guide to plant community survey for the community. Wildflower Society of WA (Inc.), Nedlands, Western Australia.

King, P D, and Wells, M R. (1990), Darling Range rural land capability study. Department of Agriculture and Food, Western Australia, Perth. Report 3.

Tauss & Associates (2016) Winter Flora & Vegetation Survey: Lot 102 Farrall Rd Stratton, WA. Report prepared for Blackadder–Woodbridge Catchment Group Inc.

Thorn, S., Hobbs, R. J., & Valentine, L. E. (2018). Effectiveness of biodiversity offsets: An assessment of a controversial offset in Perth, Western Australia. *Biological Conservation* 228, 291-300.

Stevens, J., Rokich, D.P., Newton, V.J., Barrett, R.L. & Dixon, K.W. (2016). Banksia woodlands: a restoration guide for the Swan Coastal Plain. UWA Press, Nedlands.

van Etten, E.J. (1995) The problem of weeds in bushland - implications for fire management. In: Burning Our Bushland: Proceedings of a Conference about Fire and Urban Bushland, pp.62-69. J. Harris (ed.). Urban Bushland Council (WA), Perth.

Zencich, S. J., Froend, R. H., Turner, J. V., & Gailitis, V. (2002). Influence of groundwater depth on the seasonal sources of water accessed by Banksia tree species on a shallow, sandy coastal aquifer. Oecologia, 131(1), 8-19.