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Yanchep Rail Extension Part 2
Fauna Underpass Assessment Statement

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1 Introduction

The Public Transport Authority (PTA) has proposed an extension of the Joondalup Rail Line between its current terminus at Butler to Yanchep, with Part 1 of this extension being from Butler to Eglington, including two new stations at Alkimos and Eglinton, and Part 2 (Yanchep Rail Extension Part 2 (YRE2)) (see Figure 1), being from Eglinton to Yanchep, with a new station at Yanchep. An Environmental Review Document (ERD) for the YRE2 proposal is being prepared for submission to the Environmental Protection Authority (EPA) and scrutiny through a Public Environmental Review (PER). Associated infrastructure such as road bridges are included in the Part 2 proposal but will not be used for transport immediately following completion of construction. The future location of the extension of the Mitchell Freeway is unconfirmed.

Approximately a third of the length of the YRE2 proposal passes through the Ningana Bushland Bush Forever Site (Ningana Bushland) (Ref. No. 289) which consists of stabilized Quindalup dunes supporting vegetation including Eucalypt and Banksia woodlands in Good or better condition, mixed tall shrubland and herbland on secondary dunes, plantation eucalypt woodlands, *Acacia* shrublands and highly disturbed areas (GHD 2018). Ningana Bushland is 640.83 ha and extends from near Bush Forever Site No. 288 (Yanchep National Park) in the east to Bush Forever Site No. 397 (Coastal strip from Wilbinga to Mindarie) in the west. The initial risk and impact assessment undertaken in preparation of the ERD identified that the railway line will fragment the Ningana Bushland and lead perhaps to the reduction in its overall carrying capacity for large fauna. To overcome this potential impact, the PTA has currently proposed several fauna underpasses under the railway intended to allow the free flow of animals between the two sub-divisions of the Ningana Bushland. These underpasses will be approximately 1.2 metres (m) tall by 1.2 m wide to deter people from using them.

Concerns have been raised by the EPA that the underpasses may not achieve the desired outcome, either because of currently proposed locations or that fauna may not use them as anticipated. As a result, the PTA, through its main environmental consultants Eco Logical Australia, has requested Bamford Consulting Ecologists (BCE) undertake a review of:

- The likely efficacy of the proposed fauna underpasses for the YRE2 project with emphasis on their location and design.
- The alternatives for fauna crossings through Ningana Bushland.
- The potential for fauna to temporarily use the constructed road bridges prior to use by road traffic.

In support of this study, a site inspection was conducted on 28th November 2018 along the rail corridor in the Ningana Bushland to familiarise the consultant with the site and the layout of vegetation and landforms. The inspection was conducted by Drs Mike Bamford and Barry Shepherd. This report presents the results of the review and contains suggestions about the likely success of such fauna underpasses, and recommendations on the locations if they are indeed constructed.

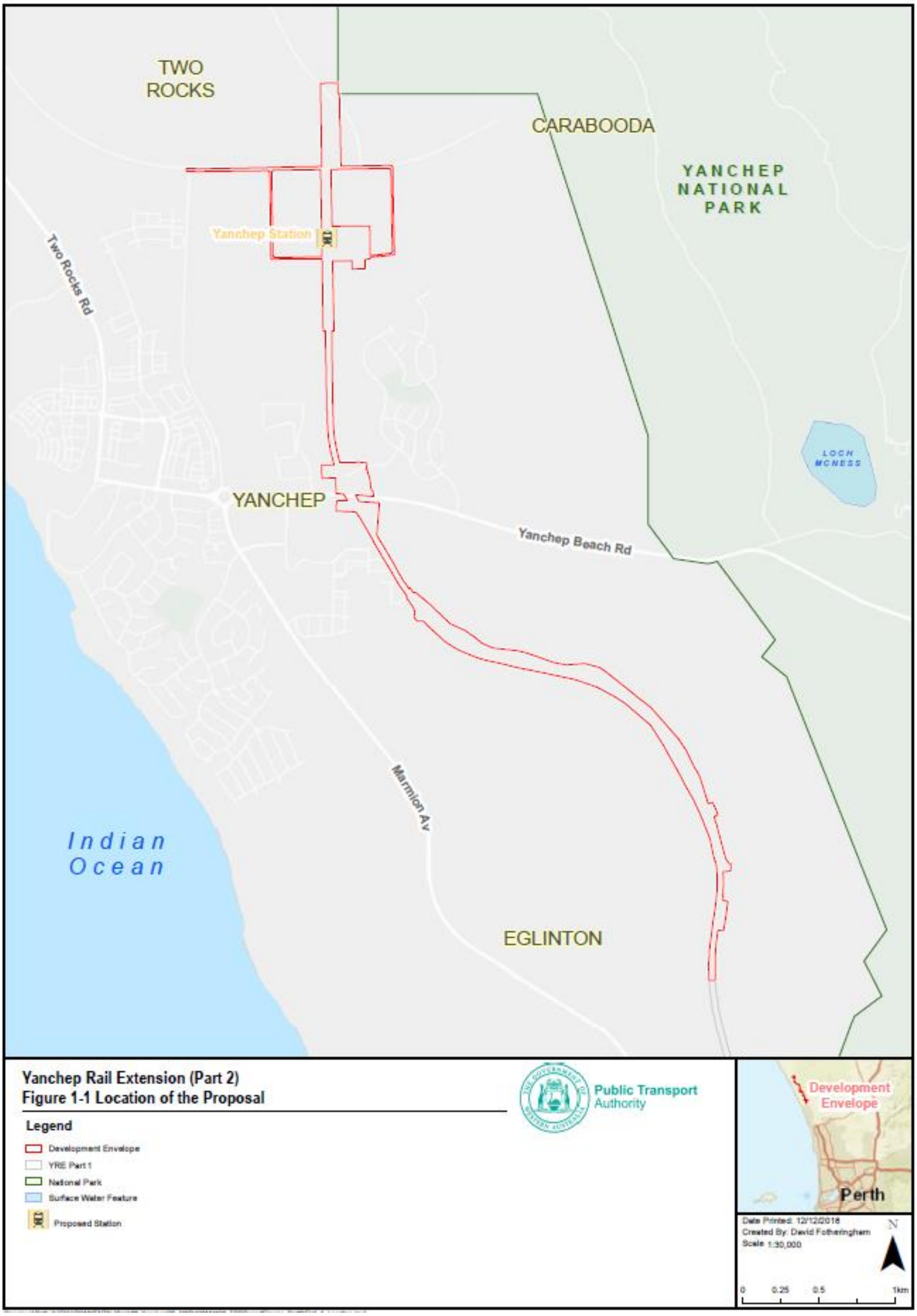

Figure 1 - Yanchep Rail Extension Part 2 (YRE2) Development Envelope.

2 Site Inspection Results

2.1 Habitat and fauna observations

The site inspection conducted on the 28th November 2018 traversed the proposed railway line through the Ningana Bushland from north to south and back. Of note was the variation in habitat type and quality. Dense, low shrublands with thicket in dune valleys were present in the north, and stands of Banksia woodland were present in the north and south. In the south were eucalypt plantations and generally degraded shrublands. Shrublands, thickets and Banksia woodlands offer good structure for a range of species some of which are known to be vulnerable to urbanisation. These included Splendid Fairy-wrens and White-breasted Robins, both of which were restricted to the dense shrublands in the north. No signs of Quenda or Brush Wallabies were found, but Echidna diggings were recorded at several locations along the route. GHD recorded Brush Wallabies through direct observation during their visit (GHD, 2018). Signs of Western Grey Kangaroos were plentiful throughout and several were seen. Most activity of kangaroos was in the south where vegetation was degraded. Fox and cat tracks traversed the entire route of the YRE2 and a Fox earth (burrow) was also located. One Emu dropping was found in Banksia woodland near the southern border and was estimated to be no more than a few months old. Individuals of *Lomandra* spp. were found in the low scrubland habitats on the dunes. This is a foodplant of the Graceful Sun-Moth which was previously recorded by GHD (2018) and is known to be a poor disperser, and to be sensitive to habitat fragmentation.

The lack of Quenda signs was surprising and evidence such as foraging holes would have been found if they were present in at least moderate numbers. Because of this, a motion camera survey is strongly suggested as this increases the likelihood of detecting Quenda when they are at low densities. Quenda would be the primary mammalian candidates for underpasses and without this species, underpasses may be less justifiable.

2.2 Fauna movement corridors

No locations were found that indicated well defined fauna movement corridors along the YRE2 route. Echidna diggings were found at several locations along the route, but this species is highly mobile and not restricted to any habitat type. Movements of other fauna such as smaller reptiles and birds of dense shrublands (such as White-breasted Robin) are likely to be linked to habitats and features in the landscape such as thickets in valleys. Underpasses should therefore be sited in locations that link similar habitats and in landscape features such as valleys that may offer more shelter. Movement of small fauna species with limited dispersal abilities such as fossorial reptiles and some invertebrates are likely to be at a highly localised scale linked to their preferred habitat features. Examination of their movements would be prohibitive and possibly unnecessary due to their lack of mobility and need for underpasses.

3 Mitigation Options for Habitat Fragmentation

3.1 Fragmentation and Associated Hazards

That fragmentation may have a negative (but avoidable) impact on wildlife has been addressed by Watson and Halley 1999, Zenger *et al.* (2005), DEWHA (2008) and Main Roads WA (2010). Most concerns centre around resultant risk of road kill as fauna move between the divided plots (Dufty, 1989, Jones, 2000, Klocker *et al.* 2005), or that the remaining parcels of land are not able to support viable population of the species (How and Shine 1999, How and Dell 2000, Dell and Banyard 2000, Bamford 2008, Bamford and Calver 2012). Generally, it is larger fauna that are recorded as being at risk of fragmentation (Bamford and Calver, 2012). However, vulnerability to fragmentation is also likely to be dependent on density and reproductive strategy.

Parcels of land have a limited capacity to support fauna; this is especially true of large fauna and those with inherently low natural densities. Simply put, smaller parcels of land do not contain enough of the right resources to support viable populations of such species. Fragmentation occurs when a sub-division of land divides an otherwise viable fauna population into smaller sub-populations, one or other of which no longer has the resilience to be self-sustaining and thus becomes locally extinct. This happens for various reasons but all amount to a lower level of resilience through fewer individuals of a given species. This can be through reproductive limitations, genetic isolation leading to unviable genetic bottlenecking or genetic drift, but significantly through the vulnerability inherent in smaller populations whereby the remaining small group of animals may succumb to a singular event, such as influx of predators, disease, or weather event. Fauna may also be indirectly vulnerable through lack of resilience against even relatively minor perturbations in the smaller parcel of habitat remaining, e.g. fire, localised drought or plant pathogen.

The causes of fragmentation can also introduce additional pressures or hazards on the remaining small populations through proximity to man-made features associated with the development such as: pets from housing; noise, lighting and spread of weeds.

3.2 Mitigation Options

Underpasses (or overpasses, rope bridges etc.) are often proposed as a solution to fragmentation but are not suitable to connect all fauna species. Not all fauna are comfortable with entering tunnel structures especially if they are long, too small or offer too little shelter. In addition, some fauna have limited mobility and underpasses may not be accessible because of barriers such as open ground, or simply because an underpass is beyond the dispersal range of an individual. Rope bridges are suitable only to arboreal or flying species and may need precise placement so they can be accessed.

Conversely, artificial connectivity may also convey negative influences such as pests or introduced predators. Such features should therefore be carefully considered and only selected where the evidence in support outweighs the evidence against their construction. The design and maintenance of the underpass is also crucial and incorrect placement or shape may be a hazard, or the underpass may simply remain unused.

Whether the development proceeds with or without underpasses, a priority would be to reduce the risk of fauna mortality by installing fencing either side of the alignment prior to construction. This reduces mortality during construction and fencing is crucial to encourage animals to use underpasses and overpasses. There is a low mortality risk for fauna crossing railway lines.

Landscaping around the entrance of the underpasses will need to be provided to ensure fauna can move from the natural bushland to the entrance of the underpass, otherwise fear of predation may prevent them from crossing open space. It is also important that the underpass links similar habitats at either end as many species likely to use them are dependent on certain habitats; encouraging a certain species to move from a habitat it is associated with to one that it isn't, could lead to its demise.

Lighting should be avoided close by underpass entrances which may otherwise deter animals from approaching the entrance at night when most movements occur or make those that do venture towards the entrance vulnerable to predation.

Fencing will be the primary control to reduce rail kill and will be needed with or without underpasses or other crossings. Specifications should be as per Main Roads WA (2010) and utilise fine mesh at the base of the fencing to prevent small mammals and reptiles from passing through.

3.3 Primary Purpose of Connecting Structures

Fauna underpasses and other features have been adopted primarily to allow animals access to habitat separated by linear development such as roads and railways (DEWHA, 2008). Reasons to incorporate such structures in developments and maintain fauna connectivity include the following:

- maintaining genetic mixing between two or more sub-populations that were previously considered a single population
- reduce road/rail kill by providing a safe alternate crossing
- provide resilience (by maintaining population size) to the fauna in either land parcel against environmental events and changes in habitats including, fire, influx of predators, pests and disease
- maintain natural behaviour of fauna such as dispersal of young, mating dispersal or localised migration.

Maintenance of genetic diversity within a sub-population requires only occasional exchanges of individuals between the fragmented habitat at frequencies dependent on reproductive biology. Mills and Allendorf (1996) proposed that very low migration rates would be sufficient to maintain genetic diversity in otherwise isolated populations. Underpasses therefore do not need to be very efficient if an isolated population is secure from stochastic extinction events but could, in time, suffer loss of genetic diversity. Note that loss of genetic diversity can also be addressed through the occasional introduction of individuals (such as from rehabilitated animals) and thus genetic mixing can be achieved without an underpass.

While maintenance of genetic diversity requires only the occasional movement of individuals across a barrier, the other functions of underpasses listed above (reduction of mortality, population resilience and maintenance of natural behaviour) require a high level of usage of the structure by the animals involved.

All forms of crossings have been shown to have negative possibilities as well as positive ones, not least the use of them by feral animals and especially predators such as Foxes, Cats and rats. Crossings have been shown to benefit feral predators in facilitating their movement across linear infrastructure and it is possible they will prey on native species that use the underpasses. Both aspects need to be considered when planning the construction of crossings and for ongoing management of reserves either side of a railway or road.

3.4 Forms of Connecting Structures

There are no creeks or gullies on the Ningana Bushland that may otherwise have provided a “natural” location for underpasses; for engineering reasons the proposed underpasses for the YRE2 are located in existing valleys at four points along the railway. Concrete box culverts 1.2m by 1.2m are proposed, but many different styles of underpass can be used depending on the suite of species predicted to use them, these include:

- corrugated steel pipes
- concrete pipes
- box culverts
- buried arches.

Corrugated steel pipes and concrete pipes offer little shelter and can impinge movement so are not discussed further.

Alternatives to underpasses are discussed by van der Ree *et al.* (2008) and include bridges where the habitat lies underneath and overpasses where habitat is formed on top. Other linkages include aerial rope bridges, tree canopy connectivity and traffic management options, but the two latter options are only applicable to relatively narrow roads so are not considered further. Therefore, alternatives to simple underpasses include:

- vegetated bridge underpass
- rope bridges
- vegetated bridge overpass.

3.3.1 *Box Culverts*

Box culverts are typically constructed from reinforced concrete and are designed to take traffic loading at a reduced height of fill (see Figure 2). Typically box culverts consist of a U-shaped section with a separate lid slab. For the purpose of wildlife crossings, the U-shape section is generally inverted onto a concrete base (or footing) to form a tunnel. Box culverts ranging in size up to approximately 3 m x 3 m have been used as underpasses in Europe, Canada, the USA and, more recently, in Australia. Landscaping around the entrance of the underpasses needs to be provided to ensure fauna can move from the natural bushland to the entrance of the underpass, otherwise fear of predation may prevent them from crossing open space. Vegetation growth into the openings at either end of a box culvert are unlikely to extend more than 1 m.

The Australian Museum Business Service (1997) commented on the strengths and weaknesses of box culverts. They found that these structures allowed unobstructed views of habitat on each side of the passage and were used by species such as kangaroos, wallabies and possums when the culvert size was approximately 3 m high by 3 m wide. The PTA (unpubl. records) has summarised underpasses used under major roads in Perth and the South-West, providing information on lengths, dimensions, presence/absence of ‘furniture’ inside the underpass and use by fauna. Most underpasses are box culverts c.20m in length with dimensions commonly of 0.6 by 0.6 m and 1.2 by 1.2 m, but some are longer (c50-70 m) and some have internal dimensions 0f 2-3 m. A few are bridges and allow combined pedestrian and human movement. Fauna use is noted for a range of species, including Western Grey Kangaroos using structures as small as 0.6m by 0.6m and 68 m in length. Weaknesses of underpass structures noted by the Australian Museum Business Service (1997) include:

- may be subject to inundation if located in drainage lines

- may be subject to puddles or pond formation
- subject to substrate washout
- concrete floor does not allow for vegetation growth.

The concrete floor appeared to be the main problem as once puddles accumulated many fauna species would not traverse the underpass. It was recommended that these types of structures should not be used in conjunction with streams. Taylor and Goldingay (2003) comment that box culverts are an effective underpass but if they are to be used on drainage lines and areas of inundation, then the culvert design would need to incorporate the provision of dry passage, such as raised ledges or multi levels.

Figure 2: Example of a typical box culvert used in North America to help facilitate small animal movement under a busy road. (Sourced: Parks Canada).

PTA's original fauna fragmentation mitigation proposal was to install four fauna underpasses beneath the rail alignment in Ningana Bushland (refer to Figure 4).

3.3.2 *Buried Arch Tunnels*

Typically there are two types of buried arch tunnels used as wildlife passages. The precast concrete arch (referred to as BEBO tunnel, see Figure 3 and the multi plate steel arch. These two systems are often used in conjunction with box culverts, particularly when facilitating movement by a wide range of fauna species along long stretches of highway. The arch tunnels are commonly used to traverse creeks when bridge structures are impractical, or where it is important to gain the maximum width and height for the underpass design.

The entrances should be sited close to vegetation or vegetation planted up to the tunnel entrances to give shelter for species that don't readily cross open ground. A small amount of vegetation may be encouraged to grow at each of the entrances to these larger tunnels but unlikely than more than a few metres of vegetation either side. Small "courtyards" that are open to sunlight could be formed between the railway lines which may help some vegetation grow half way through the tunnel and effectively reduce the length of the underpass.

Figure 3: Example of BEBO Arch System (source: Civil Mining & Construction)

The Australian Museum Business Service (1997) reported on fauna usage of three underpasses beneath the F3 freeway between Sydney and Newcastle. In a summary of strengths and weaknesses between the underpass structures they comment that the large, open underpasses were very successful, and the 10 m buried steel arch tunnel studied:

- was used by a diverse range of native species
- had the potential to be improved with the placement of 'furniture'
- the openness allowed adequate light
- provided greater view to habitat at each end.

Hyde and Chirgwin (2004) comment that in situations where the tunnel length will exceed 20 m, buried arch style underpasses that provide openings greater than 6 m can allow the passage of the greatest number of species.

The only weakness observed with the tunnel structure was that the size may be overwhelming for some animals, because large areas of open ground need to be traversed. Access to prey by predators was also easy because of the open areas. Both of these weaknesses may be overcome by selective placement of 'furniture' (e.g. logs, rocks, brushing) in selected locations.

3.3.3 *Vegetated Underpass Bridges*

Natural vegetation that is recreated below any bridge will maintain habitat connectivity with the advantage of potentially providing shelter and foraging opportunities. Large openings of this nature are likely to encourage the maximum number of species to transit, including birds. Large areas of habitat created in this way will also offset the total area of habitat lost to the development. Habitat under bridges is limited to where light levels can be maintained for photosynthesis. It is acknowledged that large bridges that would facilitate vegetation growth beneath are likely to be prohibitively expensive especially if it is created purely for wildlife.

3.3.4 *Rope Bridges*

Some arboreal species such as Western Ring-tailed and Brush-trailed Possums may be present and could use rope "ladders" such as described by Chambers and Bencini (2014). Rope bridges can span 25 metres or more and can be staged across the freeway and railway linking vegetation on both sides. Several towers would need to raise the rope bridge above railway, freeway and any other infrastructure, and shelters or resting platforms could be used on one or more of the towers. There may be regulations restricting such structures over electrical power lines that run along the railway which would need to be complied with. The location of rope bridges needs to be carefully selected so that possums can access them from trees.

3.3.5 *Vegetated Overpass Bridges*

Where bridges are vegetated on top of the structure, it has to be designed so that it has adequate soil allowing sustained plant growth. Planted bridges offer semi-natural shelter and foraging opportunities which can encourage a wide range of species to traverse including bats and birds. Herpetofauna are thought to establish territories within these habitat formations (McGregor *et al*. 2015). Bridge crossings are expensive options but highly effective if designed and built sympathetically.

Temporary use by fauna of concrete bridge structures of the scale needed for the YRE2 will only provide short-term connections for species that are prepared to venture into wide open space. Some larger macropods such as Western Grey Kangaroos may do so, but few other native species are likely to do so. If they did they may also become vulnerable to predation. Conversely, foxes and cats will rapidly adapt to open concreted surfaces. Indeed, virtually any sort of underpass or overpass will facilitate the movement of these feral predators.

3.4 Key Fauna Species for YRE2

No species that are known to use the Ningana Bushland and that would benefit from purpose-built crossings (underpass or overpass) are considered Threatened under State or Commonwealth legislation. The Chuditch *Dasyurus geoffroyii* has been listed for the area (GHD 2018) but this species is an irregular visitor or rare vagrant this far onto the Coastal Plain and the design of underpasses or other crossings for the YRE2 would be of no conservation value for it. The presence of Threatened fauna could otherwise trigger the need for highly complex underpasses or overpasses regardless of the expense and include ongoing reserve management if necessary.

While no Threatened species could benefit from underpasses installed in the YRE2 project, prior knowledge of the area and results presented in GHD (2018) have identified a number of Priority fauna species that may require or could benefit from maintaining connectivity between the two fragmented stands of habitat. These are:

1. Brush Wallaby - *Notamacropus irma* (Priority 4, DBCA
2. Quenda - *Isoodon fusciventer* (Priority 4, DBCA)
3. Jewelled Ctenotus - *Ctenotus gemmula* (Priority 3, DBCA)
4. Black-striped Snake - *Neelaps calonotos* (Priority 3, DBCA)
5. Graceful Sun-Moth – *Synemon gratiosa* (Priority 4, DBCA).

The Brush Wallaby is likely to be adversely affected by the YRE2 due to its inherently low density (home range areas of 5-10ha, possibly exclusive for males; Bamford and Bamford 1999), already heavily fragmented and isolated populations on the coastal plain, and vulnerability to vehicles. Connectivity is thus important for the Brush Wallaby and fencing of the rail important to reduce mortality. The Quenda is also vulnerable to fragmentation but can occur in higher densities than the larger macropods. However, Quenda would be very vulnerable to urbanisation around the Ningana Bushland if the reserve is not managed properly and could rapidly become locally extinct. The above two reptile species are likely to be advantaged by connectivity and would benefit from cover through long underpasses where they may be vulnerable to predation like any other reptile or frog.

No signs of any of these species were detected during the site inspection which is not unexpected for the two reptiles or Brush Wallaby, but if Quenda were present in normal densities it is likely that signs such as foraging holes would have been found. GHD (2018) also noted the apparent absence of the Quenda but it has been recorded at Yanchep (BCE records). It could therefore recolonise the project area at any time and underpasses would facilitate this. Foodplants of the Graceful Sun-Moth were recorded in the low shrubland vegetation. A day-flying species, the sun-moth could probably disperse across the rail, but the effect of such structures on flying invertebrates is largely unknown.

In addition to impacts and benefits to Priority species, the persistence of overall fauna biodiversity needs to be considered with respect to fragmentation of the Ningana Bushland. Small species with poor dispersal (many invertebrates, reptiles) may be unaffected because they can maintain viable populations in fragmented landscapes, while birds that readily fly over the development may also be unaffected. Insectivorous bats do not need underpasses, but may utilise them for roosting, especially if pipes are built into the roof of the underpass. Species that may be affected by fragmentation and that are not of listed significance, but which still contribute to local biodiversity, include some large reptiles at low population densities (e.g. Carpet Python), birds that may be reluctant to fly across the rail (White-breasted Robin, Splendid and White-winged Fairy-wrens, White-browed Scrubwren) and some mammals (Western Grey Kangaroo, Echidna, Brush-tailed Possum, Honey Possum, Moodit (Bush Rat)). The Western Grey Kangaroo, Echidna and White-breasted Robin were observed during the site inspection, and the Moodit has previously been recorded at Quinns Rock (BCE records). The Emu was also recorded but the Ningana Bushland is considered too small to support a viable population of this species. The Grey Kangaroo is a special case in that exclusion of the species may benefit the Ningana Bushland due to the degradation of vegetation that can result from grazing and trampling. Such degradation was already evident. The Grey Kangaroo has been recorded using 1.2m high underpasses (Chachelle *et al.* 2016) and 0.6 m by 0.6 m underpasses (PTA unpubl. records).

A decision to install underpasses, and what sort of underpasses to install, needs to consider both benefits and risks; this is discussed below in section 4.

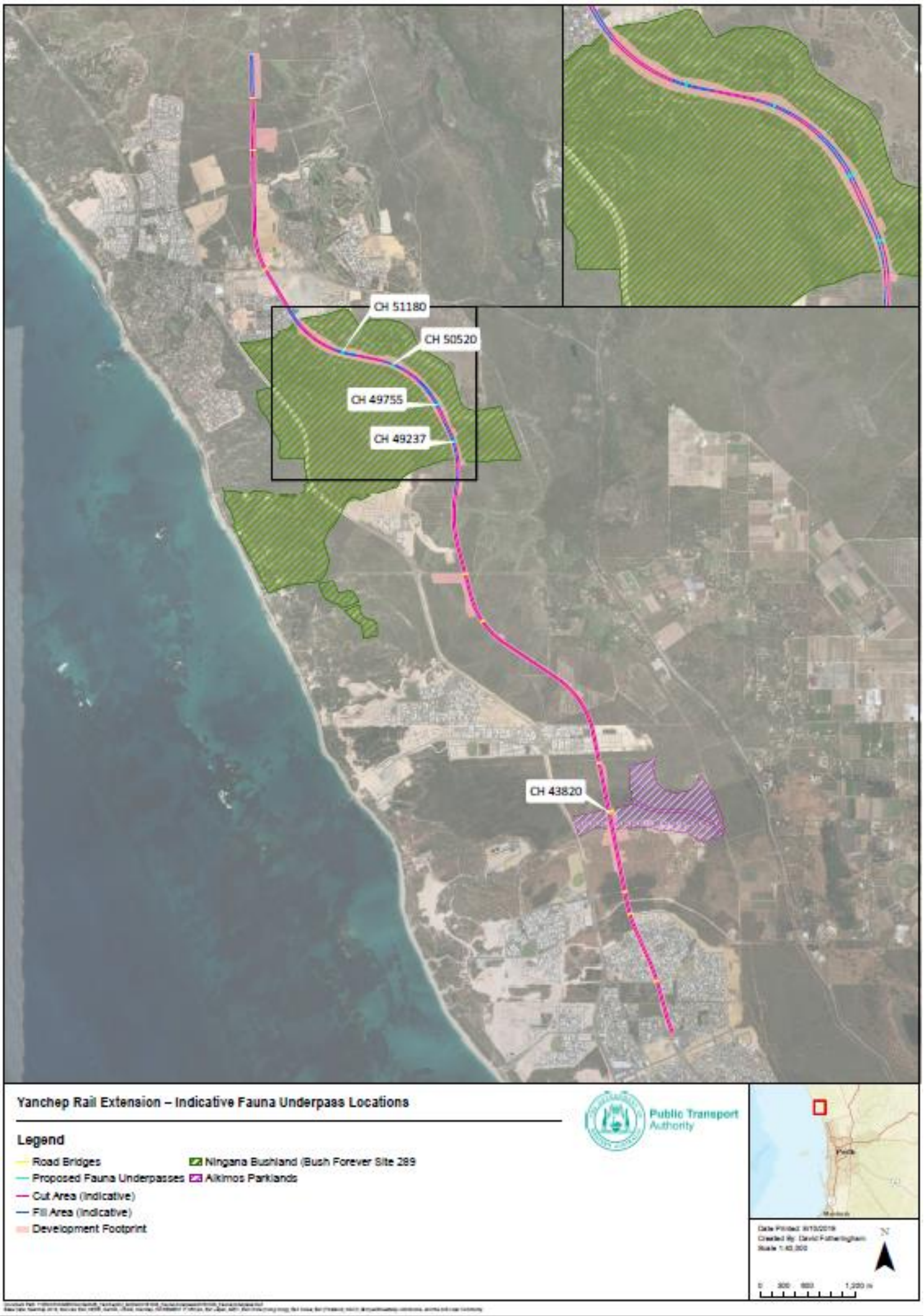

Figure 4. Yanchep Rail Extension showing indicative locations of fauna underpasses in Ningana Bushland.

4 The Role of Underpasses in Fauna Conservation in Ningana Bushland

Sections of the Mitchell Freeway and railway further south range from 60 to 80 m wide. In the case of the YRE2, the underpasses are likely to be a minimum of 60-70 m from entrance to entrance and may be 80 m or more once embankments and vegetation connectivity are accounted for. This is severely long and likely to constrain the use by most fauna. A combination of different underpass designs is most likely to suit the mixed fauna of the Ningana Bushland.

Goosem *et al*. (2004) and Hyde and Chirgwin (2004) suggested that tunnel lengths in excess of 20 m need to have height x width x length openness ratio that provides large cross sections (no less than 3 m x 3 m) before the majority of species will transit through, and this is supported by counts of bandicoots shown to be less willing to use tunnel underpasses as length increased (Harris, 2007). This may be due to some animals appearing to favour the ability to view the habitat on the other side of the tunnel (Australian Museum Business Service, 1997). VicRoads suggest a minimum of 3 m high and a span of 10 m wide for a range of fauna that include large macropods. Emus are unlikely to use underpasses of the culvert type. Smaller species of reptile and mammal appear unrestricted by tunnel size (Mata, *et al.* 2005) but may be put off by large open structures that don't offer shelter.

In addition to the cross section of the underpass, Jackson and Griffin (2000) noted that the location of the underpass is important, and distances between separate underpasses serving the same length of road or railway should not be too great otherwise fauna are less likely to find and use them. This is however, specific to each project and will depend primarily on the length of linear development being considered with longer projects requiring a larger number of crossings to adequately serve the fauna community.

Clevenger and Waltho (2005) suggested that underpasses should not be built for particular species, but that underpasses be provided to serve as large a section of the fauna community as possible; this may involve the use of several underpass designs and structures depending on the diversity of the community present. Conversely, some species or whole faunal groups known to be vulnerable to habitat fragmentation are unlikely to utilise tunnels or may suffer as a result of trying. Both these are discussed in the following.

4.1 Reptiles and Frogs

Several species of frog can be expected on the Ningana Bushland. The Turtle Frog can persist even in small reserve fragments and therefore would not require underpasses for their ongoing presence. In contrast, species such as the Moaning Frog and Banjo Frog may disperse into the Ningana Bushland from wetlands to the east and would probably decline and could even die out from the location without underpasses.

Some reptiles can be vulnerable to habitat fragmentation if bush remnants and populations are small and isolated. Many reptile species are likely to take advantage of underpasses including skinks and snakes (Chacelle *et al.* 2016) and, depending on the length and cover within the underpass, most are likely to transit through. Cover needs to be leaf-litter, coarse mulch and branches lying on or close to the ground, providing almost continuous protection for the reptiles. However, it needs not to form a barrier to larger species such as Quenda, ducks and wallabies. If there is no cover or shelter, reptiles may be vulnerable to predation or may simply not risk exposure by entering the underpass. Fossorial reptiles such as some skinks, legless lizards and blind snakes are less likely to enter underpasses especially if the floor of the underpass is relatively bare; if they were to enter, they would be vulnerable to predation or desiccation due to their limited mobility on hard surfaces. Soil, rocks, shelter structures and mulch laid throughout the underpass would help reptiles pass safely. If there is a risk of the underpass becoming waterlogged for any part of its length, it could pose a risk to reptiles. If partial flooding was possible, two or more readily accessible raised walkways should be constructed through the underpass to permit smaller fauna to pass without risk of drowning.

The large Gould's Goanna is almost certainly present in Ningana Bushland but large goannas in general do not occur in high densities, making them sensitive to fragmentation because small populations are vulnerable to local extinction. They will, however, have a larger chance of survival if linkages between the Ningana Bushland parcels are maintained. The ecology of rare skinks like the Jewelled Sandplain Ctenotus is not well documented but they seem to disappear quickly from disturbed areas so are likely to be more at risk if the remaining fragments of Ningana Bushland are not connected. The Carpet Python may already be extinct in the Ningana Bushland (due to roadkill, habitat loss and deliberate killing) but persists in the broader area. If still present it would be unlikely to survive with or without underpasses, and would be vulnerable to roadkill (snakes are very hard to guide with fencing). The Dugite is almost certainly present and persists even in small, isolated remnants in the urban landscape. It would almost certainly persist in Ningana Bushland with or without underpasses.

4.2 Birds

With the exception of some ducks, birds are unlikely to take advantage of small cross section tunnel-type underpasses especially if they are long. Larger tunnels of a couple of metres diameter may be used by some birds and off-ground "furniture" would probably aid their movement. Providing semi-arboreal furniture throughout the length of the underpass may help some species pass through. Many birds have very poor vision in reduced light and would be reluctant to fly through a darkened tunnel. Openings in the roof of the underpass would reduce their resistance to moving through but open bridge designs are likely to be the only structures that small birds such as fairy wrens and robins would use. The availability of above-ground furniture would help reduce the risk of birds becoming waterlogged or drowning should the underpass become inundated.

Many bush birds currently expected to be present on the Ningana Bushland are vulnerable not only to fragmentation and isolation but also urbanisation that will follow. Fairy wrens, robins and whistlers are some of the first animals to become locally extinct following urban spread (Bamford, 2008; Gleeson and Gleeson, 2012; Davis *et al*., 2013). While the increased abundance of cats, rats, foxes, dog walking and other human activity is likely to be the major reasons for these localised extinctions, larger areas of habitat are more likely to provide better chances of survival especially if the remaining high-quality Banksia habitats were set aside as reserves. Many of the smaller bush birds may be reluctant to cross the open landscape of the rail alignment and those that fly close to the ground will be vulnerable to mortality. Smaller bush birds would therefore benefit from habitat connectivity but not necessarily tunnel-type underpasses. Jones (Undated) reported that fairy-wrens and robins readily took to using a vegetated overpass where they would not have crossed the road without.

4.3 Mammals

Large wallabies and kangaroos are likely to use and benefit from underpasses (Chachelle *et al.* 2016) provided the cross section is adequately large as a proportion to the length (Main Roads WA 2010). Mid-sized marsupials such as Quenda are also likely to use underpasses but may be reluctant if they are too long and without shelter. They may also fall prey to foxes and cats by being restricted in their escape options. Artificial hides and shelters of varying size through the underpass may help reduce the risk of individuals being caught. Semi-arboreal furniture can also play a role for smaller mammals such as Honey Possums, but may also allow introduced rats to transit while eluding cats and foxes

Of greatest concern for Quenda is the willingness Foxes and probably Cats have for tunnel underpasses through which to gain access to new hunting grounds (Australian Museum Business Service, 2001; Harris *et al.* 2010). Quenda (apparently not currently present in the NBFS) may thus do better without underpasses. With or without underpasses, for reserve management anywhere in the urban environment, control of Foxes, Cats and rats would be essential. Surrounding development can play an important role and there is potential for covenants regarding management of domestic Cats, better waste management to help limit rat and fox numbers and keep dogs under tight control when in reserves.

The Echidna is present in the Ningana Bushland (evidence of one animal found during the site inspection), but the area is too small to support a viable population. It is probably also too small to support a viable population of the Brush Wallaby. Underpasses would be used by these species and they would be less at risk from Foxes than the Quenda, so there would be some slight benefit to the viability of populations in Yanchep National Park to the east through the provision of access into the NBFS.

Arboreal species such as Western Brush-tailed Possums may be present on the NBFS but are likely to be confined to habitats with larger trees and Banksia woodlands especially given the prevalence of foxes; where foxes are absent this species will readily seek refuges in logs and rock piles at ground level. Rope ladder aerial bridges have proved useful for this species. Before committing to rope ladders, however, it may be prudent confirming their presence through motion camera monitoring. If they are present, active management for Brush-tailed Possums will be necessary to maintain their presence after urbanisation. If active management is not committed to, rope ladders will be an inappropriate expense.

It is expected that great emphasis will be placed on good design and the elimination of the potential for the underpass to flood. However, good design may not be able to limit partial flooding. Smaller mammals in particular may be deterred from transiting, risk drowning or being trapped by predators if an underpass is flooded. If partial flooding cannot be confidently excluded throughout the lifetime of the underpass, shelves should be constructed along the underpass to allow small fauna dry passage. An underpass with a slight incline along its entire length and designed not to pool at the lower end would reduce the risk of pooling within the structure. There seems to be no particular information on appropriate floor gradient for fauna as underpasses are almost always more or less level because they lie beneath a level structure (road and/or rail).

While no bats of conservation concern are likely to be present in the NBFS, common species may take advantage of roosting opportunities in underpasses and may use larger underpasses to transit through. Larger bats such as the White-striped Freetail Bat are likely to readily cross even the largest of roads but some of the smaller bats may be reluctant to cross very wide roads. Vegetated overpasses are known to be used by microbats (Jones, Undated; McGregor *et al*., 2017).

4.4 Summary of expected use of underpasses by fauna in Ningana Bushland

The fauna of Ningana Bushland is likely to show a range of responses to underpasses and a range of impacts from the rail proposal. These are summarised in Table 1. Few species would actually require the underpasses as proposed to persist in Ningana Bushland as viable populations: Brush Wallaby and Echidna, and possibly also the Carpet Python and Gould's Goanna (although these reptiles may be able to pass through or scale the fence). Underpasses would reduce the risk of local extinction of the Quenda; although local extinction can be addressed through re-introductions. Many other of the listed species might use the underpasses occasionally or even regularly, but would not need this function for viable populations to persist. This includes the Western Grey Kangaroo. Small, sedentary birds would get little if any benefit from underpasses as proposed. Vegetated overpasses that provide not just connectivity but habitat continuity would be used by all species.

Table 1. Summary of fauna species or groups of species known or expected to occur in Ningana Bushland, and their probable reliance on underpasses. The potential impact without an underpass assumes that the railway will be fenced so most terrestrial species cannot cross the rail.

Fauna species	**Predicted use of proposed underpasses (box culverts)**	**Potential impact to species without proposed underpasses (box culverts)**	**Preferred fauna crossing infrastructure**
Brush Wallaby - *Notamacropus irma* (Priority 4, DBCA)	Will use box culverts readily	Ningana Bushland probably too small to support a viable population without connectivity	Will use a range of structures: underpasses, vegetated overpasses and bridges
Quenda - *Isoodon fusciventer* (Priority 4, DBCA)	Will use box culverts readily	Ningana Bushland could probably support a viable population without connectivity, but would be at some risk of local extinction from events such as fire	Will use a range of structures: underpasses, vegetated overpasses and bridges
Jewelled Ctenotus - *Ctenotus gemmula* (Priority 3, DBCA)	Use of box culverts probably limited	If the species is present, Ningana Bushland could support a viable population without connectivity	Vegetated overpasses
Black-striped Snake - *Neelaps calonotos* (Priority 3, DBCA)	Use of box culverts probably limited	If the species is present, Ningana Bushland could probably support a	Vegetated overpasses

		viable population without connectivity	
Graceful Sun-Moth – *Synemon gratiosa* (Priority 4, DBCA).	Unlikely to use box culverts	Ningana Bushland could support a viable population without connectivity	Vegetated overpasses but could fly across rail
Common Brushtail Possum *Trichosurus vulpecula*	Will use box culverts (but may be very vulnerable to predation on the ground)	Ningana Bushland probably too small to support a viable population without connectivity, but individuals could scale fencing and cross the rail so the rail would not form a barrier	Underpasses, vegetated overpasses, bridges and rope bridges
Emu *Dromaius novaehollandiae*	Will not use box culverts as proposed	Ningana Bushland too small to support a viable population without connectivity	Large underpasses (minimum 2m height), vegetated overpasses and bridges
Echidna *Tachyglossus aculeatus*	Will use box culverts readily	Ningana Bushland too small to support a viable population without connectivity	Underpasses, vegetated overpasses and bridges.
Western Grey Kangaroo *Macropus fuliginosus*	Will use box culverts; possibly only young females	Ningana Bushland could support a viable population without connectivity, but the population could cause degradation of the native vegetation	Underpasses, vegetated overpasses and bridges.
Large lizards and snakes	May readily use box culverts	Species such as Gould's Goanna and Carpet Python may not persist in Ningana bushland without connectivity. Fence may present a barrier to large specimens but some animals may be able to cross this barrier	Underpasses, vegetated overpasses and bridges.

Small to medium lizards and snakes	Use of box culverts probably limited. Use assisted by provision of 'furniture' in underpass	Ningana bushland could support viable populations without connectivity	Underpasses, vegetated overpasses and bridges.
Bats	Unlikely to use box culverts for movement, but may roost in them	Box culverts not needed for connectivity	Would use vegetated overpasses and bridges, but would fly over railway
Small, sedentary birds (eg. White-breasted Robin, White-browed Scrubwren, Splendid Fairy-wren, Grey Shrike-thrush)	Use of box culverts probably limited	Box culverts of limited value but birds would occasionally fly over the railway.	Would use vegetated overpasses and bridges, but would fly over railway at least occasionally.
Moaning Frog *Heleiporus eyrei*	Would readily use box culverts	Assuming fence of cyclone mesh or similar, the rail would not present a barrier to movement	Underpasses, vegetated overpasses and bridges. Could also cross rail if fence allows passage

5 Discussion

AS NZS ISO 31000: 2009 Risk Management identifies that the first consideration of reducing a hazard or anticipated impact should be avoidance of the risk. It is assumed alternative locations for the railway (and freeway) have been investigated and options to traverse around the Ningana Bushland either east or west have been eliminated. Only once all alternatives to the location have been considered and omitted should the use of underpasses or other means of maintaining connectivity and reducing road/rail kill be considered for implementation. It is then a question of considering whether or not underpasses are needed for preserving fauna biodiversity within the Ningana Bushland under the specific circumstance of the rail (and eventually freeway) alignment passing through the area.

Note that it also must be assumed that the land tenure of Ningana Bushland will be secure and that it is included in the conservation reserve system. In the long term, the Ningana Bushland will also require conservation-oriented management such as weed control, fire management, feral species control and access management. With urbanisation likely to follow the railway and freeway, securing and managing the Ningana Bushland will be essential for underpasses to even be considered. The area is already badly weed-invaded in parts, and even during the brief site visit a trail-bike rider was observed and it was clear from the tracks that this was a regular occurrence.

'No underpass' is an option that should always be considered especially if there is doubt about the likely success of the initiatives being considered. As already noted, Harris *et al.* (2010) identified a correlation between foxes using underpasses and the disappearance of a population of Quenda the underpasses were intended for. In that example, it may have been wiser to spend the money elsewhere on conservation than on a series of tunnels that served only a handful of common reptiles, facilitated movement of introduced predators and actually contributed to the local extinction of the Quenda. A similar argument with respect to Quenda could be applied to the Ningana Bushland. It may be that secure conservation management but without underpasses may improve the survival chances of many more species than if underpasses were provided.

The ‘no underpass’ option also needs to be considered with respect to management of the Western Grey Kangaroo in the Ningana Bushland. Kangaroos in small urban reserves can become aggressive pests (Herbert, 2007) and cause habitat degradation (DEC, 2009), but they can also suppress grassy weeds. Therefore, underpasses that suit the Grey Kangaroo may not be desirable and removing them from the reserve may eventually be required as urbanisation around the Ningana Bushland progresses. Alternatively, an active management programme may be required to keep the number of kangaroos to a sustainable level.

Suitable management of reserves can help control stressors on fauna brought about by urbanisation. Maintenance and improvement of habitat quality and restrictions on uses of the reserve which may otherwise lead to degradation and compromise wildlife survival would be key to maintaining the highest carrying capacity of any reserve whether fragmented or not. Of significant importance for maintaining populations of smaller mammals, reptiles and birds is the incursion of introduced species such as foxes, cats and rats. Maintenance of reserves for fauna essentially requires intensive control of all introduced predators in particular. It is unrealistic to remove human activity from reserves surrounded by development but restrictions on the type of activities permitted is feasible.

Considering all above comments and information, it is apparent that underpasses would have some conservation application in the Ningana Bushland, primarily for some frogs, larger reptiles and medium-sized mammals (although the latter appear to be absent currently). Fencing associated with underpasses would reduce rail kill of such species but would probably do little to reduce roadkill of small, low-flying birds that would also not benefit from underpasses. Grey Kangaroos would use underpasses infrequently, but often-enough to reduce the risk of in-breeding. However, it could be argued that Grey Kangaroos should be excluded from the 300ha section of the Ningana Bushland that lies between the proposed rail and Marmion Avenue. Such exclusion could be achieved by not having underpasses, or by having underpasses fitted with a grid that allowed transit of small animals only, although there might be a risk of small joeys becoming separated from their mother. The need for general conservation management of Ningana Bushland may be more important for maintaining biodiversity than the installation of underpasses.

Even if underpasses are approved for installation, a key consideration to their value is their length. Main Roads WA (2010) specifies that underpasses with lengths greater than 20 m generally have low use by macropods and VicRoads (2012) say culvert underpasses should not exceed 25 m. Therefore, attention should be given to limiting the width of the railway corridor or splitting the underpasses into shorter sections. If, however, the underpasses cannot be divided into shorter sections and remain long and small in cross section, they are likely to advantage only a few species such as some frogs, many reptiles and native small mammals such as Quenda (if present); but will also favour feral Foxes, Cats and rats which is likely to be detrimental to native fauna. For this reason, an ongoing feral predator control programme may be prudent. Indeed, management is likely to be essential to maintain biodiversity within Ningana Bushland with or without underpasses.

Enabling temporary use of road bridges by fauna prior to use by road traffic may provide a short-term option for species that will venture into open hard-paved areas, but few native species would. Temporary provision of shelter structures on road bridges would assist in fauna usage. Unfortunately, Foxes and Cats would probably be key species to benefit from road bridges with such treatments.

Fauna present in Ningana Bushland is diverse and underpass provisions should be likewise diverse to suit as much of the community present as possible. The underpasses currently proposed (1.2m by 1.2m box culverts that could exceed 70m in length) may be of little real value for fauna conservation. Most small species would not need the limited population connectivity provided by such underpasses to maintain genetic diversity at least in the medium term (many decades), and isolation effects upon larger species (Quenda, Grey Kangaroo if latter is retained) could be offset by occasional management introductions. Without underpasses, the Echidna and Brush Wallaby would probably disappear from Ningana Bushland and the proposed underpasses would be used by these species. Realistically, the population benefits to local populations of these species would be slight. Small birds that rely on dense vegetation and are poor at dispersal may be most at risk from fragmentation and would be unlikely to use the proposed narrow, long underpasses.

Underpasses as proposed may be of little benefit to retaining biodiversity within Ningana Bushland, especially with increasing pressure as development proceeds around the area. If alternatives to the proposed underpasses are available, then the best option would be a short rail bridge that provides habitat continuity, perhaps spanning one of the deep interdune swales in the north of Ningana Bushland. However, this would require open 'courtyards' between road and rail for the vegetation to survive, and would introduce a new suite of management issues due to human activities in such a structure. If underpass design cannot be reconsidered and the proposed 1.2m by 1.2m culverts are the only option, then it is suggested they be installed, and fauna activity be monitored, as such underpasses can always be closed and later re-opened as management options change. Table 2 summarises the advantages and disadvantages of underpasses as proposed, the 'no underpass' option, overpasses and a rail bridge.

Management with or without underpasses is a key consideration to the maintenance of fauna biodiversity within Ningana Bushland. Management actions should include:

- Feral animal control (Foxes, Cats, possibly rats and rabbits)
- Domestic animal management
- Management of human access include off road vehicles
- Fire management
- Rehabilitation of degraded vegetation (notably in the south of the rail alignment within YRE2 where the vegetation is either degraded or consists of eucalypt plantations with little understorey)
- Grey Kangaroo management
- Weed control.

Table 2. Comparison of various options to addressing connectivity concerns related to the railway proposal through Ningana Bushland.

Fauna crossing option	Advantages	Disadvantages
Current proposal: Four underpasses 1.2m by up to 1.2-3m box culvert 70m average length (refer to Figure 4).	• Will allow some movement by fauna across the development • Limited human access • Clearing beyond rail footprint not required • Lowest cost of crossing options • Can be fitted with 'furniture' to provide cover	• Feral predators may target fauna using underpass • Length will limit fauna use • May be subject to flooding • Restricted location options along alignment • May require monitoring • May require maintenance
Rail bridge maintaining connectivity underneath	• High fauna use likely • Clearing beyond rail footprint may not be required • Vegetation can be retained and/or revegetation carried out • Drainage infrastructure not required • Low maintenance cost	• High cost • Difficult to control human access • Erosion risk to raised rail • Will be used by feral predators that may target native fauna
Non-vegetated overpass (road bridge) (can be 'furnished with logs and litter)	• Short-term option for species that will venture into open hard-paved areas	• Very high cost • Will require maintenance • Difficult to control human access • Visual impact affecting human amenity • Will be used by feral predators that may target native fauna • May require additional clearing • May require maintenance • Short-term option for species that will venture into open hard-paved areas – not favoured by native fauna.
'No mitigation' option	• No cost for installation and management • May release some funds for other conservation management actions in the area	• Combined with fencing, the rail will be a barrier for some species and local extinction possible for a few (e.g. Brush Wallaby)

	• Minimises human access • No additional clearing • Will not encourage feral predators or increase predation pressure on target species such as Quenda	• Will require active management of some species to allow species to persist or to limit population size

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