‘Return of the Shadow:’ Reintroducing the Brush-tailed Rock Wallaby to the ACT

PART A: A desktop study of brush-tailed rock wallaby (*Petrogale penicillata*) habitat in the Australian Capital Territory as a guide for on-ground site assessment in 2019: an analysis of potential reintroduction sites.

Photo Credit: Rena Gaborov

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Introduction

The brush-tailed rock wallaby (BTRW) *Petrogale penicillata* is a small macropod that is endemic to eastern Australia occurring from south-eastern Queensland to western Victoria and central New South Wales (Eldridge and Close in Van Dyck and Strahan, 2008). There is no sub-species of the BTRW but it has been split into three evolutionarily significant units (ESU) that correspond with where they fall in the BTRWs geographic range (Hazlitt *et al*., 2014). They are aptly called Northern, Central and Southern the Australian Capital Territory (ACT) falls in the southern section of the Central ESU.

The BTRW has declined and its range has contracted significantly to the north east in the last 150 years (Woinarski *et al*., 2012). It is listed nationally under the EPBC ACT (1999) as vulnerable. There are only two known isolated populations left in Victoria, one which has been reintroduced (Taggert *et al*., 2015). Populations in central and southern New South Wales are also extremely volatile with management needed for their survival (Menkhorst and Hynes, 2011). In the ACT, the BTRW is considered extinct but is listed as 'Endangered' and an Action Plan has been developed for the species (ACT Government, 2013).

Reintroductions of animals back into their former range is an important tool to achieve conservation outcomes (ICUN, 2013). Over 10% of Australia's mammal fauna has become extinct since European occupation (Woinarski *et al*., 2015) with a further 111 mammal species listed federally as threatened (Aust. Government, 2018). Several reintroductions for the purpose of conservation have occurred in Australia with mixed success (Short *et al*., 1992; Clayton *et al*., 2014). Failures overwhelmingly were due to original threats still existing at the reintroduction site. To reduce the risk of failure reintroductions should follow guidelines set out by the ICUN (2013) which follow the precautionary principle and refer to Recovery Plans and Action Plans designed for the species (ACT government, 2013).

The following document is a desktop analysis of possible reintroduction sites for the BTRW in the ACT. It firstly reviews historical surveys of former BTRW sites, and then sets parameters to be used when considering sites for reintroduction. The review contains a list of suggested sites; including maps and resources requirements for ground surveys. A list of stakeholders that will be involved with assessing and possible reintroduction of BTRW into the ACT is incorporated.

Records of *Petrogale penicillata* in the Australian Capital Territory.

In 1996, the late Peter Ormay researched and compiled an account of the known historic records and anecdotal observations of the brush-tailed rock-wallaby (BTRW) within the ACT. Since that time, and despite casual and targeted searches by ecologists and rangers, no new confirmed observations of BTRW have been made. The information presented here is largely drawn from Ormay (1996) and Reside and Martin (1996). The areas indicated as potential habitat are considered by the authors to have large complex rocky habitat, reasonable access to a reliable water supply and represent what is generally accepted by experts as potential BTRW habitat.

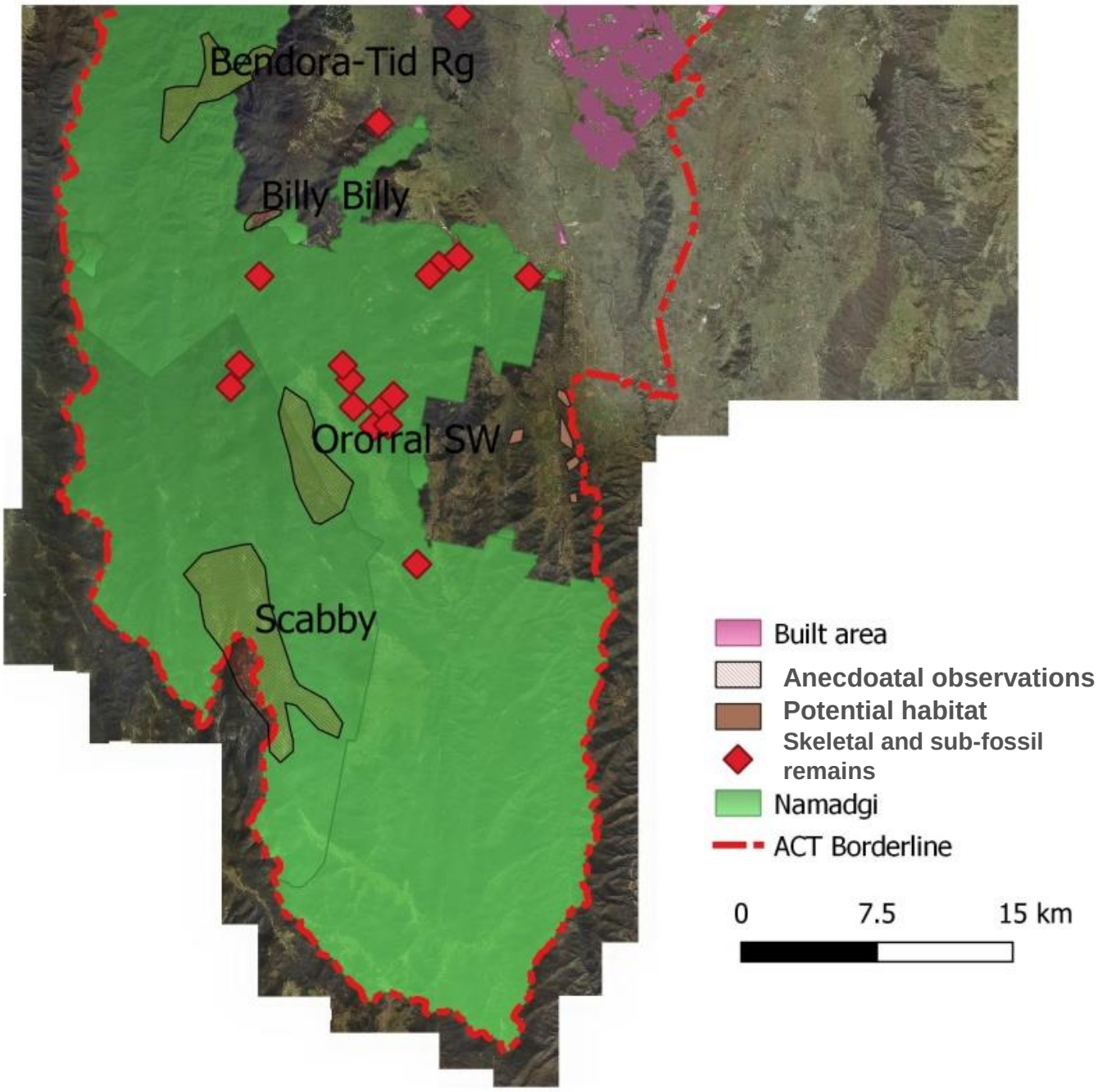

Figure 1. Southern ACT, Australia, indicating all known skeletal and areas of high incidence of sub-fossil records, anecdotal observations and unsurveyed, potential habitat. for brush-tailed rock wallaby (*Petrogale penicillata*).

Table 1. The list of sites where evidence for past brush-tailed rock wallaby (*Petrogale penicillata*) occupation has been confirmed by the discovery of skeletal remains or high incidence of sub-fossil scat. Both survey reports were from 1996.

Date	Record	Location	Survey Reference	Comment
12/08/1968	Skeletal	Kambah Pool	ANWC	Skull in ANWC, data needs review.
01/01/1982	Sub-fossil faecal deposit	Orroral Ridge	Short reported in Ormay	
01/01/1982	Sub-fossil faecal deposit	Orroral Ridge	Short reported in Ormay	
20/04/1982	Sub-fossil faecal deposit	Orroral Ridge - Logoland	Ormay	
24/05/1982	Sub-fossil faecal deposit	McKeahnie	Ormay	
24/05/1982	Sub-fossil faecal deposit	McKeahnie	Ormay	
16/06/1982	Skeletal and sub- fossil faecal deposit	Gibraltar	Ormay	
05/08/1982	Sub-fossil faecal deposit	Booroomba Stn	Ormay	
06/08/1982	Sub-fossil faecal deposit	Booroomba Stn	Ormay	
11/08/1982	Sub-fossil faecal deposit	Booroomba Rocks - Bushfold Flats	Ormay	
16/08/1994	Sub-fossil faecal deposit	Honeysuckle Crag	Ormay	
16/08/1994	Sub-fossil faecal deposit	Honeysuckle Crag	Ormay	
01/01/1995	Sub-fossil faecal deposit	Mt Tennent	Todkill reported in Ormay	
13/09/1996	Skeletal	Rockview Orange Ledge	Reside and Martin	1 skull, 2 vertebral columns and 2 hind legs, 3 pelvic girdles (disarticulated). Some skin and fur still attached.
14/09/1996	Skeletal	Rockview Orange Ledge	Reside and Martin	2 vertebrae
15/09/1996	Skeletal	Orroral Ridge	Reside and Martin	assorted skeletal remains of at least 7 individuals
15/09/1996	Skeletal	Orroral Ridge	Reside and Martin	Pelvis and associated vertebrae
15/09/1996	Skeletal	Orroral Ridge	Reside and Martin	2 skulls and a long bone
16/09/1996	Skeletal	Square Rock, no other detail	Reside and Martin	Several long bones, vertebral column, several individuals.
17/09/1996	Sub-fossil faecal deposit	Rendezvous Creek (site1)	Reside and Martin	Less than 50 scats
19/09/1996	Sub-fossil faecal deposit	Cotter Gap	Reside and Martin	Less than 20 scats
23/09/1996	Sub-fossil faecal deposit	Bendora Dam South-Cliffs	Reside and Martin	Less than 20 scats
16/09/1996	Sub-fossil faecal deposit	Ridge North of Corrin Dam Road	Reside and Martin	Less than 20 scats

Ormay (1996) also interviewed residents of the areas immediately to the northeast of Namadgi National Park and recorded their historic observation (Table 2, Figure 2). No confirmed observations of the species have been made since the 1950's.

Table 2. List of historic, anecdotal observations made between the 1930's-1950's of the Brush-tailed rock wallaby in the ACT, Australia (Ormay, 1996). HS = Homestead.

Location	Observer	Approximate AGD66 Grid ref.
1.5 km E of Naas Valley HS	L. Tong	884553
Billy Range 1.5 km S Naas HS	G. Crawford	850571
Clear Range near Glencoe	G. Crawford	882531
Clear Range E of Naas Valley HS	L. Tong	879553
Clear Range ENE of Naas Valley HS	L. Tong	874590

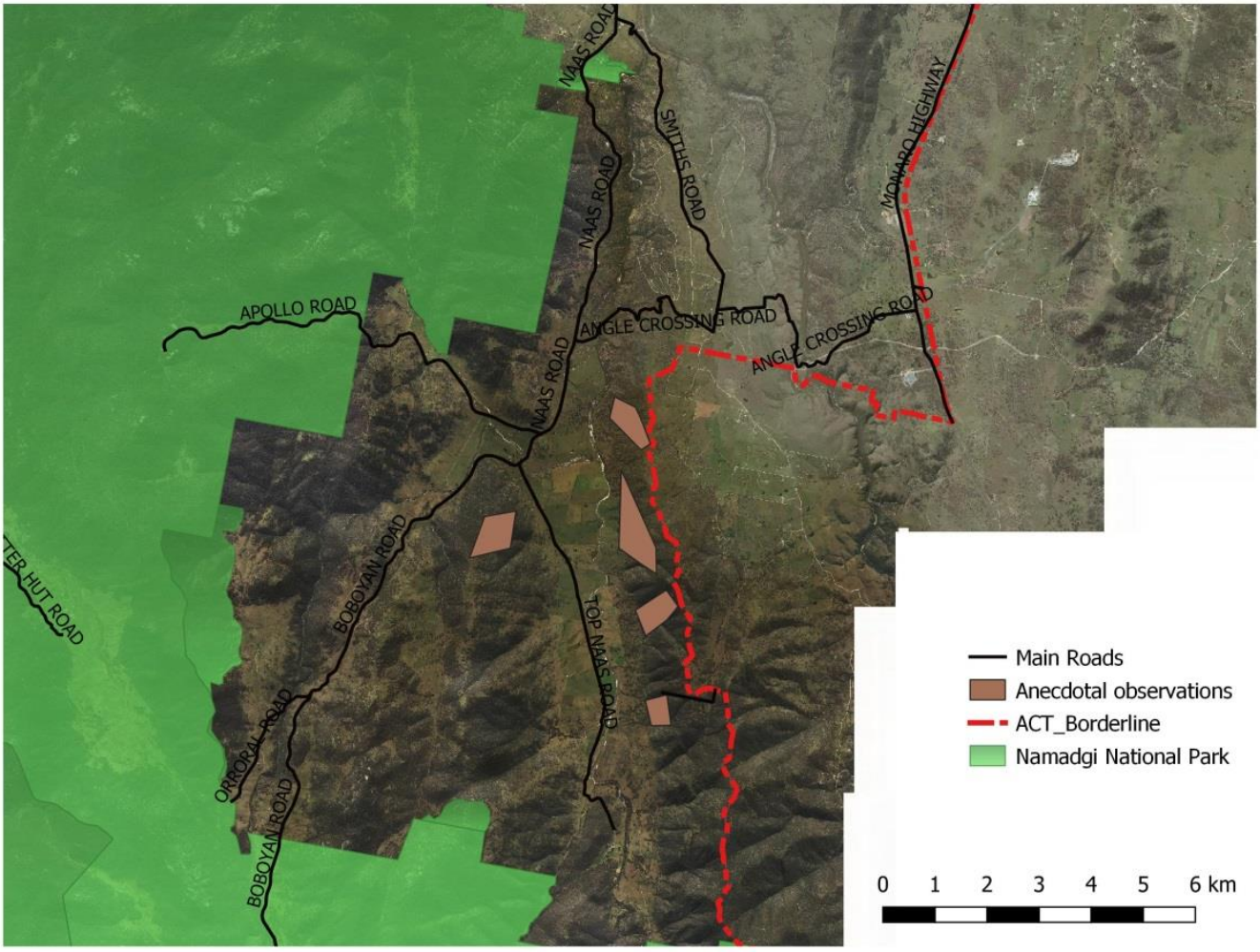

Figure 2. Areas where local residents last observed *Petrogale penicillata* in the ACT, Australia (Ormay 1996). The last observations were made in the 1950's.

In addition to areas where BTRW have been known to exist in the past, there are other areas of suitable habitat in Namadgi National Park where BTRWs may have existed, but where survey data is lacking. A number of these areas have been briefly visited by the authors (Table 3; Fig 3) but require further survey to ascertain if the habitat values at these locations are suitable for release of BTRW. The areas presented below (Fig. 3), while not exhaustive represent relatively large areas of contiguous habitat that may be suitable as reintroduction sites.

Table 3. Other areas of potential Brush-tailed rock wallaby (*Petrogale penicillata*) habitat in the ACT, Australia and their respective area (Corrigan unpublished observations). Note - add a few land marks to this map to orientate the reader.

Nominal location	Area (Ha)
Bendora-Tidbinbilla Range	1189
Scabby Range	3904
Orroral SW	1471
Billy Billy Rocks	121

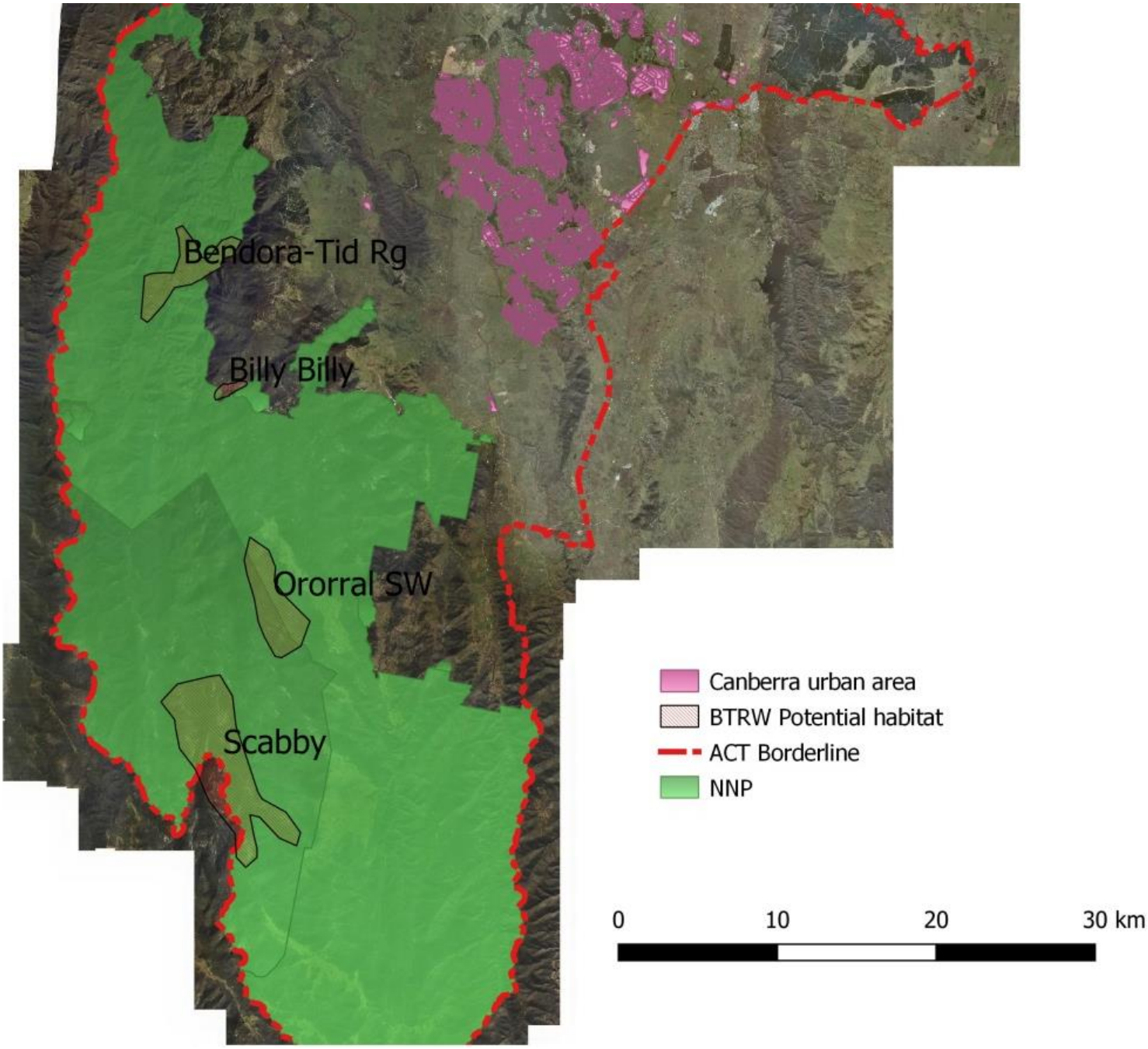

Figure 3. Areas of potentially suitable habitat for a Brush-tailed rock wallaby (*Petrogale penicillata*) reintroduction into the ACT, Australia.

Identify site parameters to be used for grading sites as suitable for future translocation.

To identify what is required for a site to be suitable for reintroduction several factors need to be considered. The species ecology will influence resource requirements. The most recent historical or extant sites may have attributes more favourable to the species. Threatening processes that initially caused a decline or extinction, if still existing, will inevitably cause a reintroduction to fail if not addressed. Access for management will also be required. The following section will:

1. Review important factors that need to be considered for a brush-tailed rock wallaby reintroduction.
2. Parameters will then be identified from this information and are listed in Table 5

Threatening Processes to the BTRW in the ACT

Site parameters for reintroduction need to consider threatening processes currently operating. These may be novel or the original threats that caused the species to decline. Reintroductions of mammals on mainland Australia to unfenced areas have often been unsuccessful due to a failure to adequately perceive and respond to the extent of the threating processes at the site level. This has proved to be particularly so for the threat posed by introduced predators, namely the red fox *Vulpes vulpes* and feral cat *Felis catus* (Clayton *et al*., 2014; Short *et al*. 1992).

The brush-tailed rock-wallaby (BTRW) was once considered a common inhabitant of rocky terrain across the Great Dividing Range from southern Queensland to western Victoria (Short and Milkovits, 1990). Threating processes such as hunting, poisoning and predation by feral animals is believed to have caused the drastic decline of the BTRW from the mid 19th century by 50-90% (Lunney *et al*., 1996; Short and Milkovits, 1990). The small colonies remaining in the central and southern part of the species former range are also now highly vulnerable to demographic and environmental stochastic events (E.g. Dovey *et al*., 1997).

Introduced Predators

Predation by the introduced red fox *Vulpes vulpes* is perceived to have had the greatest impact on the current status of the BTRW (Lunney *et al*., 1996; Short and Milkovits, 1990). Major declines of the BTRW, as well as many other native species in the so called 'critical weight range' (0.3-5kg) appear to correlate with the spread of the red fox northward following European settlement (Short and Milkovits, 1990; Johnson, 2006). In a recent reintroduction of the BTRW in the Grampians, predation by the red fox was considered the main factor slowing and limiting population establishment (Taggart *et al*., 2015).

Foxes are agile climbers and can access the rocky habitat of the BTRW (Rolls, 1964). Ormay (1996) reported that Le Souef and Burrell in 1926) had observed that a quiet intruder could shoot or even take the BTRW by hand when it was in its den. Rolls (1964) also reports foxes taking advantage of this quiet behavioural trait of the BTRW, stating that unless caves are inaccessible to foxes, they will be easily predated by them.

In the ACT the BTRW were thought to have become extinct in the early 1950's with the last known population persisting in Gibraltar Range till 1959 (Ormay 1996). The persistence at this site is believed to be due to fox baiting at a nearby sheep farm and the site having more complex rock (Ormay, 1996). Some locals interviewed by Ormay (1996) who lived on the Clear Range, ACT (see anecdotal observation in Figure 2) stated that the disappearance of the BTRW appeared to coincide with the release of myxomatosis in

1950 to control rabbits. A prey switch by foxes and probably feral cats following rabbit decline, to hunt more native prey has been suggested for the rapid disappearance of the BTRW in these areas of the ACT. Recent evidence suggesting that rabbit abundance is closely linked to introduced predator abundance and thus negative impacts on native fauna has been outlined previously (Pedler et al. 2016)

The feral cat (*Felis catus*) is found in all Australian environments (Denny *in* Van Dyck and Strahan, 2008) it has been directly associated with declines of the black-flanked rock-wallaby, *Petrogale lateralis,* in the Anangu Pitjantjatjara Yankunytjatjara Lands of South Australia and a population of allied rock-wallaby *P. assimilis* in Black Rock Queensland (Ward *et al*., 2011, Spencer, 1990;). The latter was believed to be caused by one individual cat, that over a four-year period reduced the rock wallaby population by well over 50% (Spencer, 1990). The decline of the BTRW has generally been associated with the red fox rather than the feral cat (Lunney *et al*., 1996; Short and Milkovits, 1990; Taggart et al. 2015). In Wombeyan Caves, New South Wales, however reintroductions and then successive augmentations of BTRWs were generally not successful because of predation believed to mostly be associated with cats which lived in the colony (Short *et al*., 1992). Predation of BTRW by cats is difficult to determine, cats can predate prey at least as large as itself (approximately 4 kg), however data from diet studies found they generally predate mammals under 1kg (Dickman, 1996; Fancourt, 2015). Feral cats may be particularly threatening to BTRW emerging from the pouch (approx. 600g) reducing recruitment which is what was purported to be the case at Wombeyan Caves. Interestingly, feral cats are also the primary host of *Toxoplasma gondii*, a parasitic disease spread by cats and known to effect a wide variety of native wildlife (Abbott 2006; Henderson 2009).

In little River Gorge, Victoria BTRW and cats inhabit the rocky refuges with no known effects to the population (Gaborov, 2018). However, the ability for cats to prey select and target juvenile BTRW's means cohabitation becomes an impending risk to population recovery. There are currently no landscape scale control methods for cats, therefore low densities at sites and monitoring after a release with intervening management if needed, seems to be the only current solution to this threat.

The wild dog and/or dingo will predate BTRW (E.g. Lunney *et al*., 1996). At an extant BTRW site in East Gippsland, Reside and Martin (1997) described a wild dog they believed to be waiting at the base of rock scree to ambush BTRW when they came off the rocks to forage or drink. Wild dogs / dingoes however have not been associated with the overall historical decline of BTRW and is less agile in the rocky refuges of the BTRW than the red fox or feral cat. It has also been proposed that wild dogs may supress the presence of meso-predators, i.e. foxes and cats, but the evidence for this is controversial and would likely vary with habitat type and slope (Wang and Fisher, 2012; Allen *et al*., 2015; Fleming *et al*., 2012; Nimmo *et al*., 2015). In the case of the BTRW, if tolerance of the red fox within their habitat is only at extremely low densities, the pressure on foxes brought by wild dogs may only be sufficient in particular habitat. It is however worth considering, that BTRW declines and extinctions appear to follow a north to south and a west to east cline, with the areas to the south and west having greater densities of sheep, foxes and goats, and less wild dogs and BTRW, in contrast to regions to the east and west (Short and Milkovits, 1990).

In regard to current threatening processes operating in the ACT, potential predation by red foxes appears to be the greatest threat to the successful reintroduction of the BTRW. Ormay (1996), Connolly (1995) and Reside and Martin (1997) also suggested that foxes were the main concern for reintroductions of BTRW into the ACT but suggested that reintroductions would be possible with adequate predator control. Recent reintroductions have shown that BTRW are highly sensitive to foxes at low densities (ACT government, 2013). It is therefore vital that predator densities are known and minimal in sites selected for reintroduction of the BTRW in the ACT.

The review of 109 reintroductions of macropods by Clayton *et al*., (2014) overwhelmingly found success of releases was determined by the absence of foxes and cats at the release site. Some species have no safe level of the presence of these predators.

Competition

Competition for food resources and refuges could affect the success or a BTRW reintroduction (ACT government, 2013). Competition has not had the same effect on BTRW as predation (Short 1982) but the pressure for food and/or water resources may create a need for BTRW to move further away from the safety of rocky refuges, thus increasing their vulnerability to predation. Short (1982) describes rabbits pre myxomatosis stripping all vegetation. Although there has been no evidence from native species threatening mainland macropod reintroductions in the ACT there is areas of abundant red-necked wallabies and Eastern-grey kangaroos within former BTRW sites. Several species of deer are now established in the northern Australian Alps including the ACT and these species collectively may compete for food resources with BTRW (AALC 2017). High numbers of herbivores may thus create competition for food (and exchange of disease) and will need to be considered in a reintroduction of BTRW into the ACT.

Some of these species may also compete with BTRW for secure dens sites. Feral goats for instance can be destructive in BTRW habitat and compete directly for refuges (Dovey *et al*. 1997; Copley 1983; Sharp *et al*, 2014; 2015). Short (1989) believed goats and higher fox densities may have been a major influence in the decline of BTRW west of the divide. In the ACT goats were known in historical sites of the BTRW however they have been eradicated from Namadgi National Park (NNP) (Ormay 1996). In East Gippsland, Victoria, feral cats are known to den in the rocky refugia of the BTRW and it is possible that they may compete or be excluding BTRW from some den sites.

Climatic processes

The effects of drought and fire can directly threaten and severely compound other threats to BTRW. All Australian marsupials have evolved to cope with the regular drought cycles referred to as El Nino events (Tyndale-Biscoe, 2001). The effects of El Nino events on species, however, have changed since European colonisation due to increased pressures associated with habitat loss, habitat fragmentation, vegetation changes, and the introduction of exotic predators and competitors. Clayton *et al*. (2014) reviewed macropod translocations in Australia between 1969-2006 and found that drought was one of the three main causes of reintroduction failure. Ormay (1996) refers to BTRW declining in drought because they ran out of food stripped by rabbits. There is also the risk that animals may have to travel further for water taking them further from their rocky refuges and exposing them to heightened risks of predation.

Current global climate change (GCC) is resulting in increased drought frequency and severity and with this increasing risk of wildfire in Australia (CSIRO, 2018). GCC is a threat that was not apparent when BTRW became extinct in the ACT but its influence on survival of BTRW today needs to be considered.

Landscape scale fires are known in the Australian high country, typically occurring every 70-150 years (Zylstra 2006). It is possible that such an event could adversely affect any reintroduced BTRW populations within the ACT. Specific fire management and mitigation measures will need to be considered for all potential release sites.

Disease

There are a number of introduced parasites that the BTRW may host. Two that have been found in BTRW are *Echinococcus granulosus* (hydatids) and *Toxoplasmosis gondii* (Barns *et* al., 2010). *E. granulosus* was found to severely impede breathing which often eventuated in mortality (Barnes *et al*., 2010). Hydatids is contracted from eating oocysts from feedstuffs contaminated by infected Canid scat. In the Kosciusko

National Park, Jenkins and Morris (2008), found a 100% prevalence of *E. granulosus* in wild dogs, 50% in foxes and infections in all macropod species with swamp wallaby *Wallabia bicolor*, a sympatric macropod to the BTRW, containing 69%. Although the high prevalence of hydatids in Southern Australia alludes to *E. granulosus* being entrenched in much of the environment Barnes *et al*. (2007) found hydatids prevalence in clusters.

There are a range of other diseases and pathogens known to infect BTRW, the status of any sylvatic organisms will need to be determined and specialist advice sought prior to any reintroduction.

Resource Requirements by the BTRW

The BTRW spends most of the day resting in caves regularly sunning itself on surrounding rocky ledges close to its den (Eldridge and Close in Van Dyck and Strahan, 2008). It leaves its refuge at night to forage in surrounding areas. Several studies have examined the ecological requirements of BTRW (Murray *et al*., 2008 and 2011; Short, 1982 and 1989; Piggots *et al*., 2006).

Rock Complexity

Complex rocky habitat overwhelmingly appears to be the most important resource for survival of BTRW (Short 1982; Lobert, 1988; Malam; 2012; Murray *et al*., 2008 and 2011; Taggart et al. 2008). In the Grampians Malam (2012) found 90% of historical sites were driven by rock complexity and cliff density. Similar finding have been reported by Murray (2011; 2008), Lobert (1988), Short (1982) and Jarman & Bayne (1997) who all reported that at the site scale, increasing rock complexity was the strongest predictor of BTRW. This was not evident between sites from different geographical areas (Murray *et al*., 2011).

What makes up this complexity is refuges that have multiple entrances for easy escape (Short 1982; Waldgrave-Knight, 2002; Taggart et al. 2008) ledges and boulder piles (Lobert, 1988; Short, 1982). Large boulder piles and ledges were considered important for sun and shade, hiding from predators and escape (Waldgrave-Knight, 2002; Short 1982; Lobert 1988; Murray *et al*., 2008; Murray *et al*., 2011). In EG Waldgrave-Knight (2002) found ledges were within 10 metres of caves and there was a preference for larger cave entrances, (greater than a metre). Short (1982) found occupied sites had significantly more caves, more ledges, more overhangs and more routes to foraging grounds as compared to areas where rock-wallabies were absent.

At the landscape level for sites in NSW and Queensland Murray *et al*., (2011) found the slope leading to the refuge to be an important aspect attributed to predator deterrence. Several but not all studies found that north to northeast or northwest facing rocks were more favourable to BTRW (Short, 1982; Lobert, 1988; Waldgrave-Knight, 2002).

Waldgrave-Knight, (2002) and Ormay (1996) both observed connectivity to other refuges which is important for persistence of reintroduced animals. BTRW males and occasionally females will disperse from their natal range (Piggots *et al*., 2006) and the less hostile the environment the more likely the animal will survive dispersal. This connectivity also assists reintroduction as there is more than one area to release animals and integration occurs naturally over time which may lead to a more successful reintroduction (Taggart *et al*., 2015).

Lithology has also been put forward as an attribute to predicting BTRW habitat however Murray *et al*., (2011) believed lithology to be important at the landscape level only. This was reinforced by Malam (2012) who found lithology to be of little importance in the Grampians. This is most likely due to one rock type

dominating an area. Which probably makes lithology of little benefit in predicting sites in the ACT. Short (1982) and Lobert (1988) did find orange rock to be a predictor of BTRW presence, orange rock generally occurring in an area where erosion is active thus giving rise to increased rock / habitat complexity.

Food

The BTRW diet is general and diverse consisting of a range of grass, forbs and shrubs (Tuft *et al*., 2011a; Short, 1989; van Eeden *et al*., 2011) There has been speculation that the BTRW diet could simply be a product of the vegetation dominant in the environment (Malam 2012; Tuft *et al*., 2011b; van Eeden *et al*.,2011). This is supported by BTRW habitat modelling where density of vegetation and vegetation type has not been significant parameters for predicting BTRW occupation (Short 1982; Malam, 2012). For Murray *et al*., (2011) vegetation at the landscape but not local scale was a confident predictor of BTRW occupation. It is worth considering that the diversity of vegetation mosaics in former BTRW sites may have changed due to increased fire frequency over short intervals or conversely in long unburnt sites, and thus may affect the suitability of sites for future BTRW reintroductions into the ACT.

Although, contrasting to historical accounts of BTRW in the ACT by (Ormay, 1996), many authors (Malam, 2012; Tuft *et al*., 2011b; pers. obs.) suggest that much foraging occurs in and around refuge areas. Tuft *et al*., (2011b) however found this was a deliberate foraging strategy to avoid predators. It is therefore important that an understorey of shrub, herb and grass predominates the vegetation in and around a reintroduction site.

Free Water

There is no mention of free water as a predictor of BTRW occupancy in the Grampians by Malam (2012), although this is a common resource in this region. Taggart *et al*. (2008) however, considered water in the Grampian BTRW reintroduction site selection because drought has been implicated in BTRW extinctions and drought frequency and duration are predicted to increase with the onset of climate change (CSIRO, 2018). Recent studies by West et al. (2017) also suggested that water is critical to the survival of black-footed rock wallabies especially to juvenile and sub-adult co-horts, and thus may directly impact population growth and establishment in drier times.

As mentioned already the further BTRW need to travel out of their refuges for resources the more vulnerable they are to predation. Currently 38 of 40 known BTRW in an extant population in East Gippsland include a river as part of their home range (Gaborov, 2018). Considering current and future climatic forecasts it seems a precautionary approach should be taken to availability of free water at any site being assessed for suitability for BTRW reintroduction.

Therefore, sites with suitable resources to support BTRW must contain complex rocky refugia in large and connected areas to ensure the animals safety and persistence in locations that provide ready access to food and water, so that during drought and or periods of heightened competition animals are not forced out of suitable habitat in search of essential resources (Taggart et al. 2008). Former BTRW habitat within the ACT may thus prove to be ideal for future reintroductions of BTRW into the ACT, however potential changes to these sites (eg. those driven by fire or drought), particularly those with respect to vegetation need to be examined.

Management Access

A reintroduction for the purpose of conservation does not need general public access but does need access for predator control, monitoring of the target population and monitoring of other threats. It is also a possibility that fire management (mitigation or promotion) may need to take place to promote food resources or to protect the site from large uncontrolled wildfire. The ease of site access depends on how often a task must be done and the availability of human and financial resources to do it.

Table 4. Parameters considered important in grading BTRW sites in the ACT

Site Parameter	Justification	Comment
A very low density of predators particularly the red fox	Predation by introduced predators is attributed to most declines and failed reintroduction of the BTRW and other medium mammals in Australia. Canids carry hydatid tapeworm which negatively effects BTRW.	How low a fox density should be for BTRW is currently unknown. Sites will have to be controlled for feral predators before reintroduction takes place.
Very complex rocky refugia at site level	Considered in all research as the most important resource attribute for predicting BTRW persistence	Use of aerial photography and ground assessment to class complexity
Connectivity of rock complexity	Easy dispersal (size of site) and mixing with other reintroduced BTRW	Most complex rock has connectivity, but some may be isolated
An understorey of grass, forb and shrubs within and around the refuge	It is a foraging strategy to graze close their rocky refuge to avoid predation.	General vegetation assessment at high priority sites
Free water within proximity to the site	Frequency and prevalence of drought drawing animals out of secure refuge. Dehydration and its potential effects on survival of juveniles and sub-adults	'proximity' to secure refugia needs to be defined.
Access for management	Control predators, monitor BTRW, predators and competitors	At minimal baiting and remote camera monitoring would need to take place at regular intervals. Control of both foxes and feral cats ideal
Avoid high densities of macropods, rabbits and/or ungulates with similar diet / shelter needs to BTRW	Puts pressure on BTRW population to move further away from best refugia when resources are low.	Zero tolerance of goats at release sites.
Sites should have evidence or known to be previously occupied by BTRW	There is prior knowledge that BTRW could survive at the site	

Sites, Access & resource requirements for on-ground site assessments.

Sites

From information on site suitability and historical sites with high use by BTRW (Reside and Martin, 1996; Ormay, 1996) as well as unsurveyed areas with potential BTRW habitat a list to be assessed for BTRW reintroduction has been compiled (Table 5). Information to assist with accessing sites and the time that may be required to survey each site is also provided but should be considered an estimation. There are 14 sites on the list 4 of which are unsearched areas and may make up multiple sites. Of the 10 historical sites six can be merged into the Orroral Complex leaving 5 historical sites for assessment.

It may also be more efficient for the areas that have never been searched (Refer to Figure 3 & Table 5) to initially do a helicopter survey to access the most likely and suitable sites for on ground survey. Depending on the number of potential locations, those sites could be searched within the current (2019) funding phase or if there are numerous potential sites, some may need to be searched at a later stage. Availability of a helicopter would also impact the time required to move between and thus survey potential release sites.

Access

Ground surveys, seasonal considerations

Several sites are at high elevations, greater than 1000m. These sites can present problems for assessment due to troublesome snow and wet and cloudy weather at particular times of the year, which will affect driving, walking and camping. Boggy ground on some roads may restrict driving to some sites, where as snow can affect human safety and accessibility. For these reasons it will be more valuable if ground surveys are conducted in mid-late spring or autumn. More daylight hours will also influence the time needed for site surveys particularly if sites take a few hours to walk into.

Road conditions for some of the smaller roads will need to be discussed with local Park Rangers before starting. Camping may be the best option with some sites such as central Scabby, however further investigation is needed before areas targeted for ground surveys are finalized.

Table 5. Sites and access information. Historical sites (H) and potential areas that have never been searched (NS) for BTRW. The information assumes the site survey team are going by car and accessing the site on foot. Distance = distance from the nearest road to the GPS point/s at which evidence of BTRW has been found historically.

Site Name	Closest Road	Distance (km) in straight line	Road Access	Elevation m.	GPS coordinate (GDA 94 MGA 55)	Survey Days	Comments
Square Rock (H)	Corrin Rd	0.6-0.7	Yes	1300	671109 6065806	2	Square rock walking Trail is 5km 1 way goes to summit. May consider using if terrain is difficult
Gibraltar (H)	Tidbinbilla Reserve Rd	0.2	Yes	800-1000	676600 6074100	2	
Bendora Tidtbinbilla Range(NS)	Corrin Rd/ TNR Cascades Trail	2.2- 2.8	Yes	1100 - 1400	general area see map	3	Previously unsurveyed for BTRW
Billy Billy (NS)	Corrin Rd/Fishing Gap Rd	1.8-2	Yes	1150-1450	general area see map	3	Previously unsurveyed for BTRW. Fishing Gap Rd access through TNR
Mt. Tennent (H)	Tks off Nass Rd	0.4	possibly gates, weather permitted	650-800	685900 6065600	2	
Baroomba St (H)	Blue gum Creek rd.	1.5	possibly gates, weather permitted	900-1200	680900 6066200 682000 6066700	3	
Orroral Ridge/Legoland (H)	Apollo Rd turn into Sentinel Rocks/Belfry Carpark	2	Yes	1350	675713 6060884 676000 6059900 676200 6058400	2	2km is furthest point Legoland is 600m
Orroral Ridge southern section (NS)	Apollo Rd turn into Sentinel Rocks/Belfry Carpark	1.1	Yes	1270	676000 6059900	1	
Orroral Ridge (N. White witches) (H)	Apollo Rd	0.25	Yes	1250	678213 6057784	1	Go from Honeysuckle Collimation Tower go 500m along tk at Boggy Flat walk SE 5-10min. on adjacent ridge
Orroral (SE Belfry)(H)	Apollo Rd	0.25	Yes	1250	678213 6057584	-	Go from Honeysuckle Collimation Tower go NW along main ridge for 1.5km-NE 200m cross gully head 1km N main ridge 2nd face then 600m to last
Honeysuckle Crag (H)	Apollo Rd	0.47	Yes	1270	677800 6058400	1	

					678400 6059000		
Rock View Orange Ledge (H)	Boboyan Rd or Orroral Rd	1.2	Yes	900	679813 6049884	1-2	West 1km from parks depot cross Gudgenby . head upslope
Orroral Southwest (H)	Orroral Rd/Cutter Hut Rd	2.2-0.7	gate on part	1100-1500	general area see map	3-4	Previously unsurveyed for BTRW. Gate on Orroral Rd. after intersection Granite Tors Rd
Scabby (NS)	Sam's River Fire Trail, Yaouk Trail unnamed	0.5-5	gates, weather permitted	1150-1600	general area see map	6-8	Previously unsurveyed for BTRW. Access Southern section from Tk. off Boboyon Rd

Resource requirements for field surveys

Personnel

2-3 people that have experience in:

- identifying optimal BTRW habitat
- walking in remote rocky areas
- at minimum Advanced First Aid (preferably Wilderness First Aid)
- understanding of communication protocols and equipment
- 4WD experience
- Identification of BTRW scat

Transport to sites

- 4WD with recovery gear
- Camping may be necessary for some site inspections
- Possibly a helicopter for initial assessment of the 4 areas that have never been surveyed particularly Scabby and Bendora-Tidtinbilla Range

BTRW Site Surveys

Site Survey Technique

At each site the survey team will assess the parameters in Table 5. Rock complexity will be assessed by describing and counting the number of caves, cave entrances, ledges and ledge proximity to caves, boulder piles present at the site, slope going to the site and aspect. Food availability will be assessed by looking at proximity to suitable vegetation and foraging grounds in relation to the refuge. All sites will note the proximity to a water source. Competition will be accessed by looking at the occupancy of other species. This will be done by identifying of scat and tracks at sites as well as looking for browsing pressure on plant resources. Predator occupancy can also be assessed through opportunistic scat and other sign (eg. kill sites)

identification found while surveying sites (see data sheet appendix 1). Site data will be mapped which will assist with carrying capacity and connectivity of the refugia, at the site.

Sites will be ranked against each other from the results of this data. Sites will not have numerical scores as less important aspects may outweigh vital parameters. For example, a site may be excellent in all aspects and therefore rank highest but have a high abundance of predators therefore a reintroduction would inevitably fail. Parameters indicate that to be successful for reintroduction of BTRW sites must have:

- Low abundance of feral predators
- Need to contain rock complexity and connectivity
- Forbs, grasses and shrubs available in the environment
- Have available water
- Den sites available

Sites without these attributes will not be suitable. Once these attributes are affirmed, they can be ranked against each other for management access and possible competition. Management Access needs to be decided by parties involved in carrying out the reintroduction. Competition will be prioritised if food has been depleted (number 3 above) and if den sites are heavily used (number 4).

Specific Equipment for BTRW site assessments

Note: An estimate of the numbers of days for 2 people walking from the nearest road is given in table 5 above. An additional cost of collating the data sheet (see appendix 1) into an electronic version should be taken into account as well as collating the data and reporting it after site assessments.

- 2 GPS
- Electronic Data Sheets (see appendix)
- Back up hard copy data sheets
- Site Maps
- Head torch
- Measuring tape
- Handheld camera
- Clinometer
- Binoculars
- Scat envelopes
- Snap lock bags for scats and remains
- (for remote camera deployment see appendix)
- Satellite phone or Spot Device
- 2 UHF radios
- Spare batteries for all gear
- Personal gear including First Aid, compass, spare batteries etc.

Stakeholder contacts

An initial stakeholders and possible stakeholders are in table 6 below. The list is by no means complete but and can be expanded as needed.

Table 6. List of stakeholders and possible stakeholders for a reintroduction of the BTRW into the ACT (NB. Environmental Non-government Organisation (ENGO)

Stake holder	Type	Relationship to Project	Key contact	Email	Phone
FAUNA Research Alliance	ENGO	Initial assessment; Project development; Project Business Management and Finance	David Taggart & Carmen McCartney (wrote initial grant)	david.taggart@adelaide.edu.au; carmen.mccartney@newcastle.edu.au	DT 0413941122 CM 0412637933
World Wildlife Fund (WWF)	ENGO	Donor	Darren Grover	DGrover@wwf.org.au	
Perpetual	Philanthropy	Donor			
Coles		Donor			
ACT Parks and Conservation Service Directorate	Government	Exec Director of ACT Parks and Conservation Service	Ian Walker		437198706
ACT Conservation Directorate	Government	Threatened species policy and project oversight	Margaret Kitchin		419492741
ACT Parks and Conservation Service	Government	Regional Manager, National Parks and Catchments Region	Pete Cotsell		02 62051226 0448228489
ACT Parks and Conservation Service (area rangers)	Government	land manager at sites			
ACT Parks and Conservation Service (bushfire management)	Government	manages planned burns			
ACT Parks and Conservation Service (Pest animals manager)	Government	manages pest species in NNP			
Adjacent Landholders	landholder	may need to access sites through their land?	unknown if any		
Aussie Ark	ENGO	Breed BTRW in NSW have large enclosure	Tim Faulkner, Operation Manager	tfaulkner@reptilepark.com.au	

ACT Parks and Conservation Service, Tidbinbilla Nature Reserve	Government	Breed BTRW in the ACT have large BTRW enclosure close to release sites. May be able to supplement in future			
FAUNA Research Alliance / University of Adelaide	Interdepartmental	Involved with reintroduction of BTRW for ACT and Vic; extensive BTRW knowledge & field expertise; Research student supervision, Captive breeding expert	Dave Taggart	david.taggart@adelaide.edu.au	
Wildlife Unlimited (WU)	Environmental Consultant	Consultant involved in historic BTRW knowledge ACT, initial ACT assessment, extensive BTRW knowledge and field expertise, ACT project development	Jim Reside & Rena Gaborov	wildlifeunlimited@wideband.net.au	427526367
Ecodiversity	Environmental Consultant	Historic BTRW knowledge, Involved in initial ACT assessment, extensive BTRW knowledge and field expertise, Reintroduction expertise, ACT Project development	Tony Corrigan	tonycorrigan7@gmail.com	428100179
Schultz Foundation	Veterinarian / ENGO	Veterinary Consultant & BTRW health expert / Donor / Research student supervision / BTRW captive breeding and reintroduction expert	David Schultz	david.schultz2@bigpond.com	408271686
Wildlife Geneticist / National BTRW Recovery Team	Australian Museum	Australian BTRW Genetic expert / Research Student supervision	Mark Eldridge	mark.eldridge@austmus.gov.au	02 93206320
Australian National University (ANU)	University	Possible involvement through research students	PhD student and supervisor		
University of Canberra	University	Possible involvement through research students	PhD student and supervisor		
Conservation Volunteers (ACT)	ENGO	May volunteer as active in the area	Email Coordinator		

National Parks Association of the ACT	ENGO	Volunteer management in NNP	President (Esther)		0429 356 212
Canberra Bushwalking Club	Club	Possible land use conflict, possible information exchange		president@canberrabushwalkingclub.org	
Field Naturalist Association of Canberra	Association	Information exchange		rosemaryvb@gmail.com	
Conservation Council (ACT Region)	ENGO	Cross promotion, support	Clare Henderson (interim ED)	info@conservationcouncil.org.au	(02) 6229 3200
Canberra Climbers Association	Association	Possible land use conflict, possible information exchange	Zac Zaharias (president)	committee@canberraclimbing.org.au	
NSW Environment Department & Central NSW BTRW Recovery Team Representative	Threatened Species, NSW Environment Department	Extensive knowledge of BTRW; Extensive BTRW field and reintroduction expertise in NSW;	Dr Deb Ashworth	Deborah.ashworth@environment.nsw.gov.au	(02) 95856953

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Appendix

Data Sheet For site assessments

The following is made to be an electronic data sheet

Site Name **Tracklog Name (start from car)**

Coordinate Start Point

GPS DATUM and coordinate system

Write more notes on blank sheet with **site name** at the top

Predator sign (if no predator sign seen please state in comments)

field Id of species	type of sign	GPS WP	Coordinate	Comments
Fox	scat (collect mammal?)			
Cat	track			
Dog	sighting			
goanna	bones			
quoll	other (state, if kill describe)			

Other animals Sign

field Id of species	type of sign	Coverage at sight	Comments
Deer	scat	once	
Rabbit	track	<10 locations	
possum unknown	sighting	>10 locations	
common brushtail possum	bones	continuous	
mountain brushtail possum	other (state)		
macropod			
swamp Wallaby			
red-necked Wallaby			
eastern-grey kangaroo			
euro			

Rock (fill data for each individual pile, overhang or ledge)

Caves	**Yes/No**	Number	Describe	Image no
No. of entrances				
width of entrances				
vicinity of ledges				
no. of ledges close by				
aspect				
GPS coordinate				

Boulder Piles	**Yes/No**	**Overhangs**	**Yes/No**	**Ledges**	**Yes/No**
~ area		aspect		aspect	
caves present within (Y/N/unsure)		number		number	

image no	image no	image no

Slope

What was the approximate slope angle leading to general refuge area

Vegetation (take some images)

General vegetation class in area?

Is there much vegetation in the rocky refuge?
If yes ~ area

Describe distance, access and ~ area of closest forage area to rocky refuge?

How many foraging areas are close to rocky refuge?

For each approximated area above state % of that areas covered by;

herbs
grasses
shrubs

Is groundcover heavily browsed (if you can't tell at a glance the answer is no) if yes describe extent

Water

Distance to closest water body (not including rock seepage)

Flow	**type**	**~area**
none	creek	
trickle	dam	
rapid	soak	
	other	

Is there water visible in the rocks, if yes describe?

Site Access

Time taken from closest road to access site (in minutes)

Describe any difficulties accessing the site e.g. river crossings, thick vegetation, cliffs

Is this site being used by other people, if yes describe?

Are there any other comments on the site?

Data sheet for BTRW sign

Site Name

BTRW Sign Data Form (only fill out if sign found)

Personnel

GPS WP	GPS Coordinate	

Type

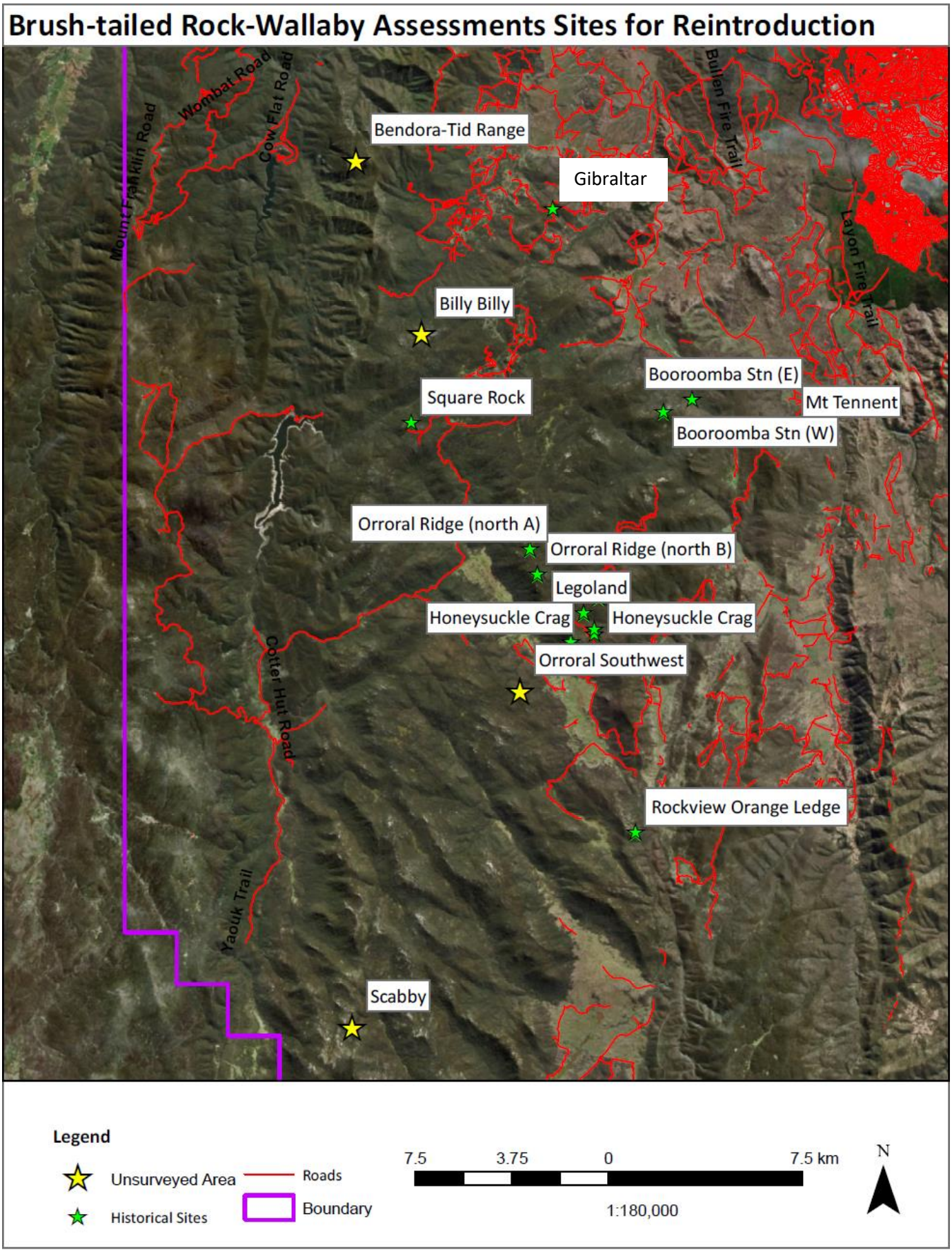
scat	colour	quantity
bones	type	
other remains (describe)		

Location Found (e.g. Inside cave, amongst rock pile)

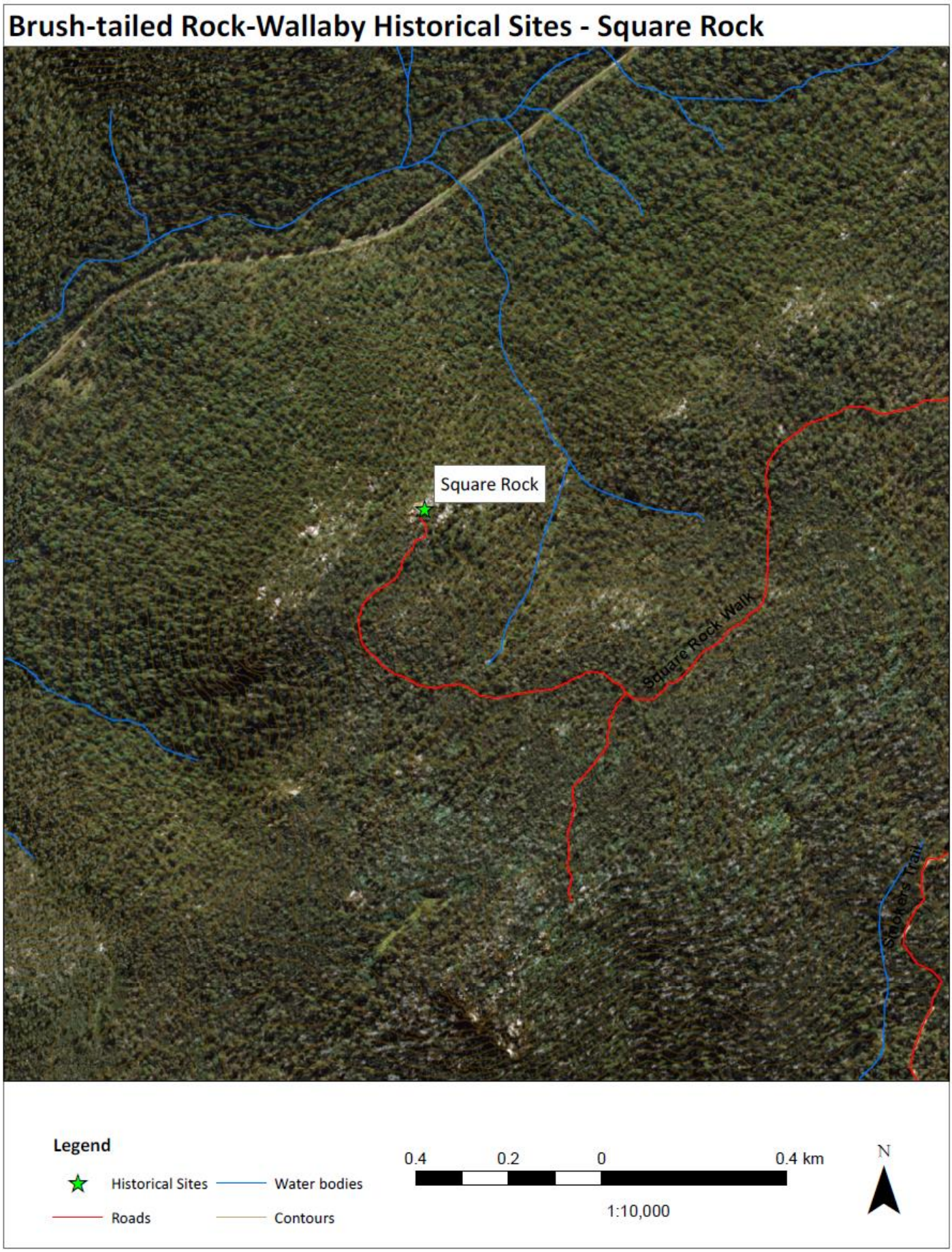
Image no.

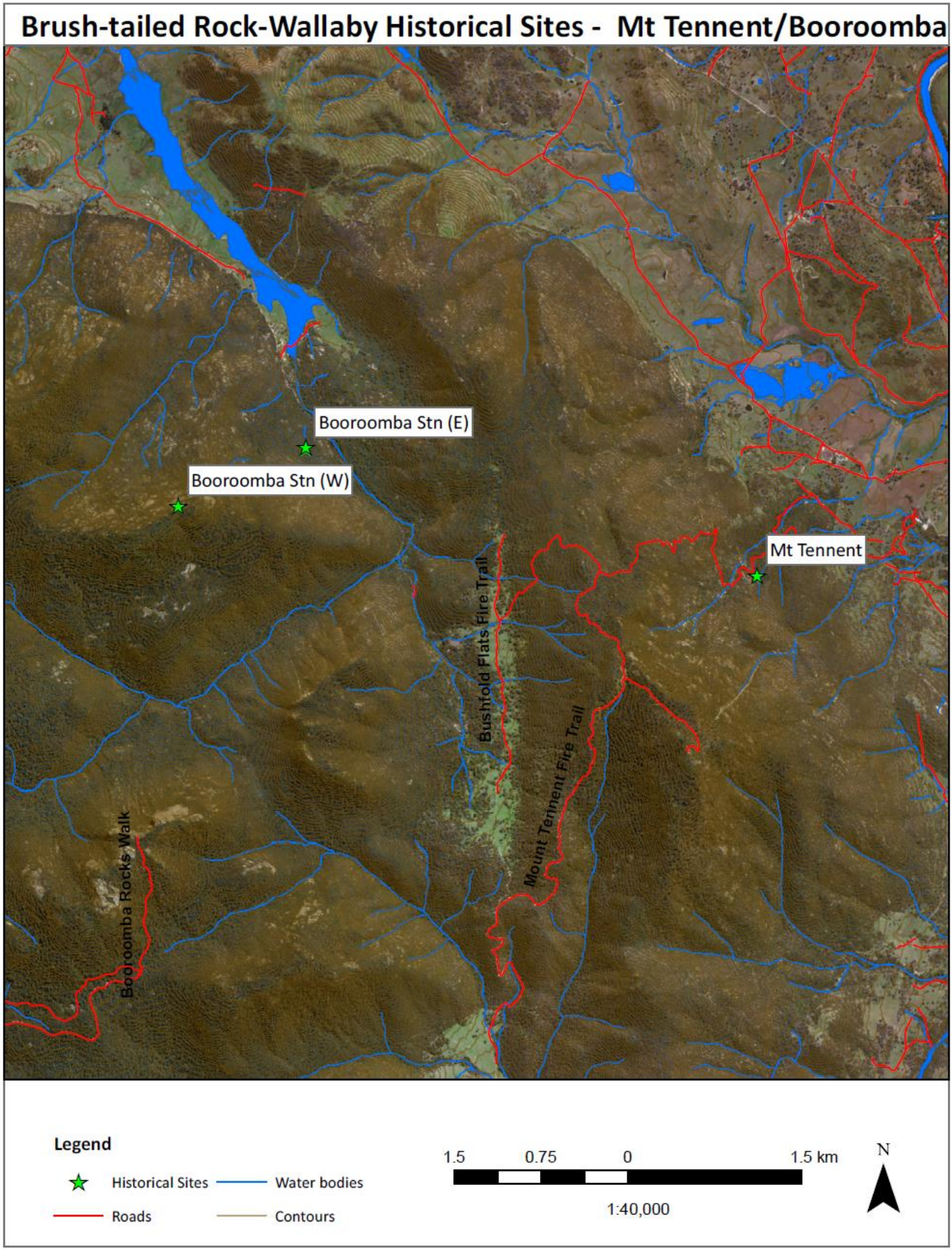
Collected Yes/no

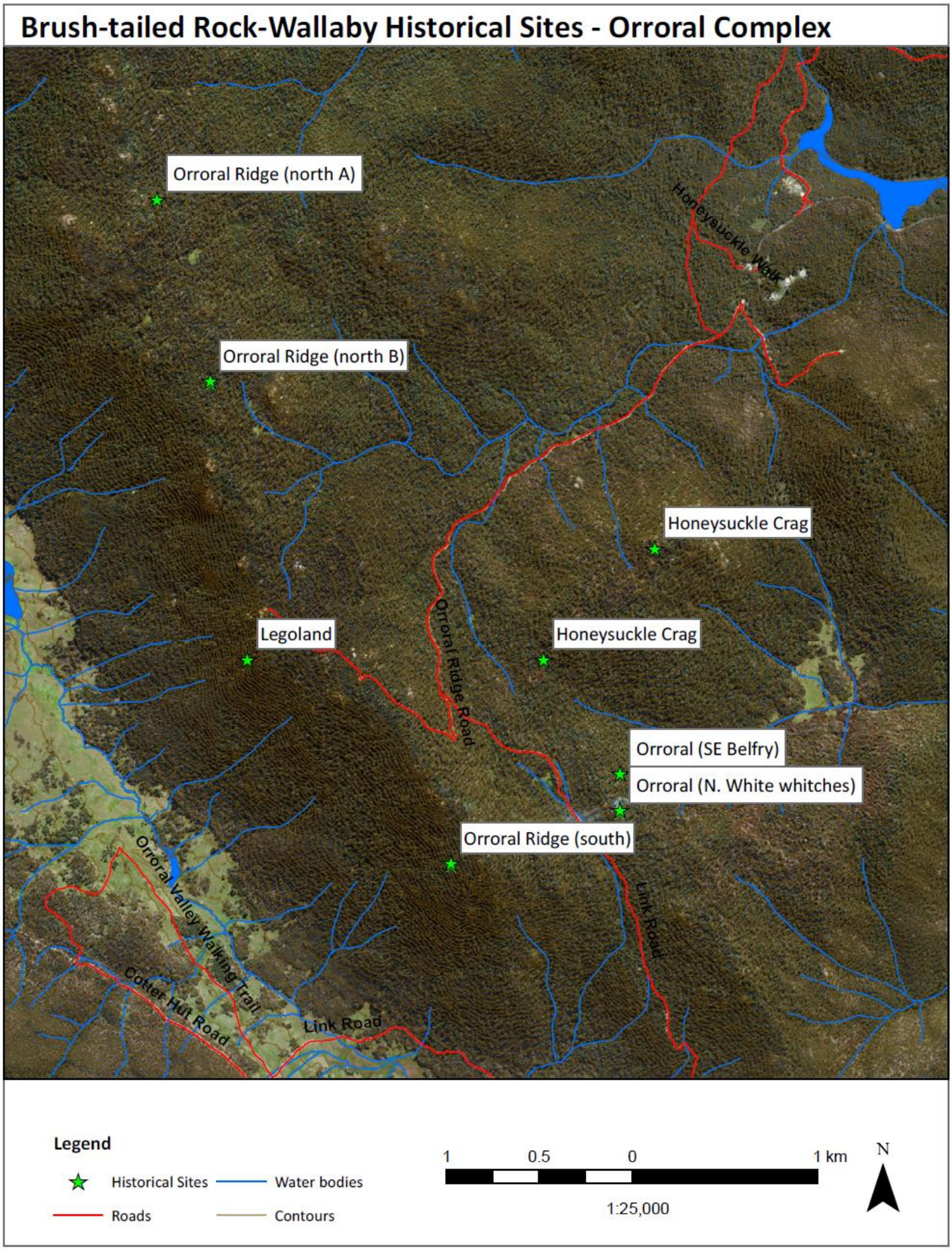
Maps for Site Assessments

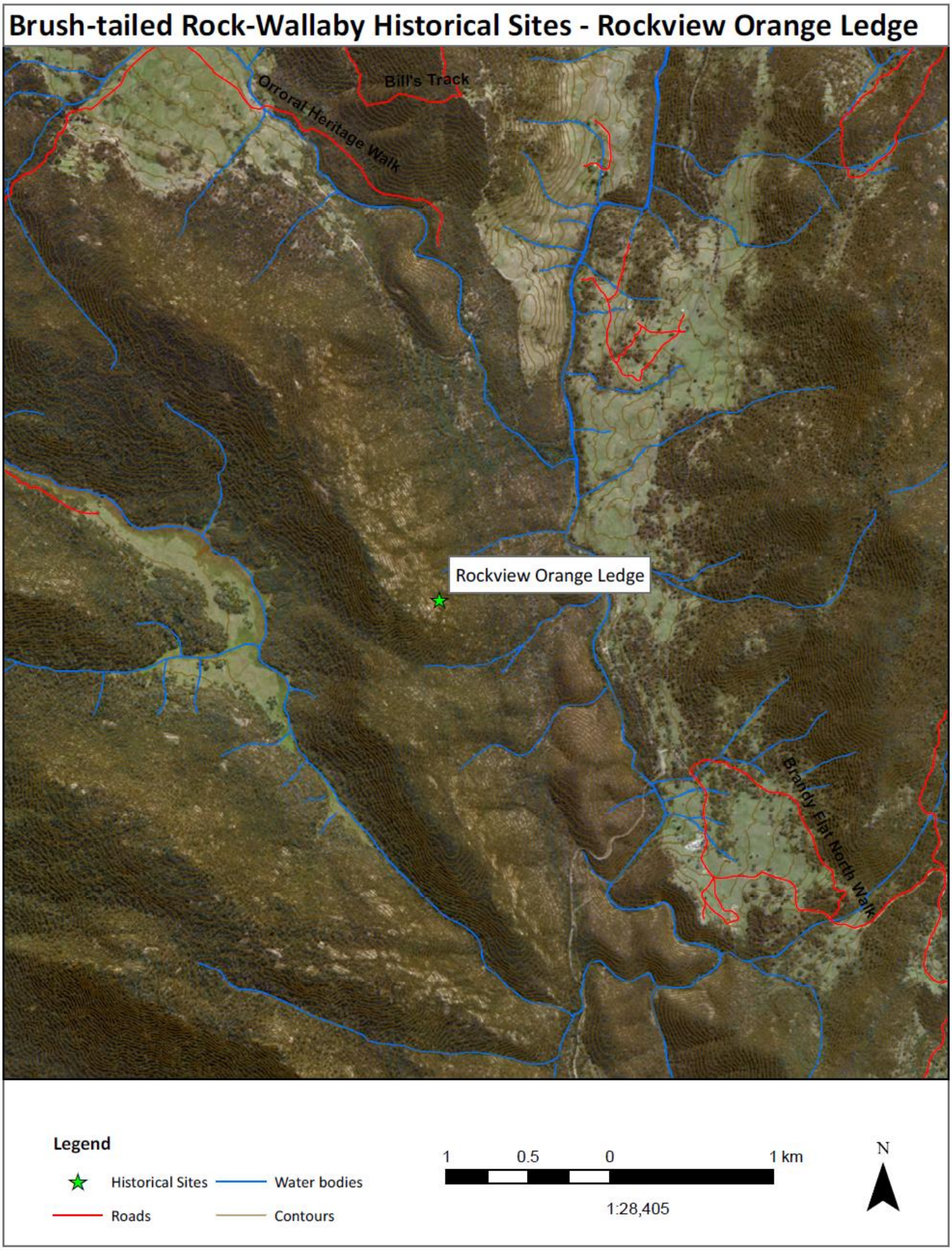


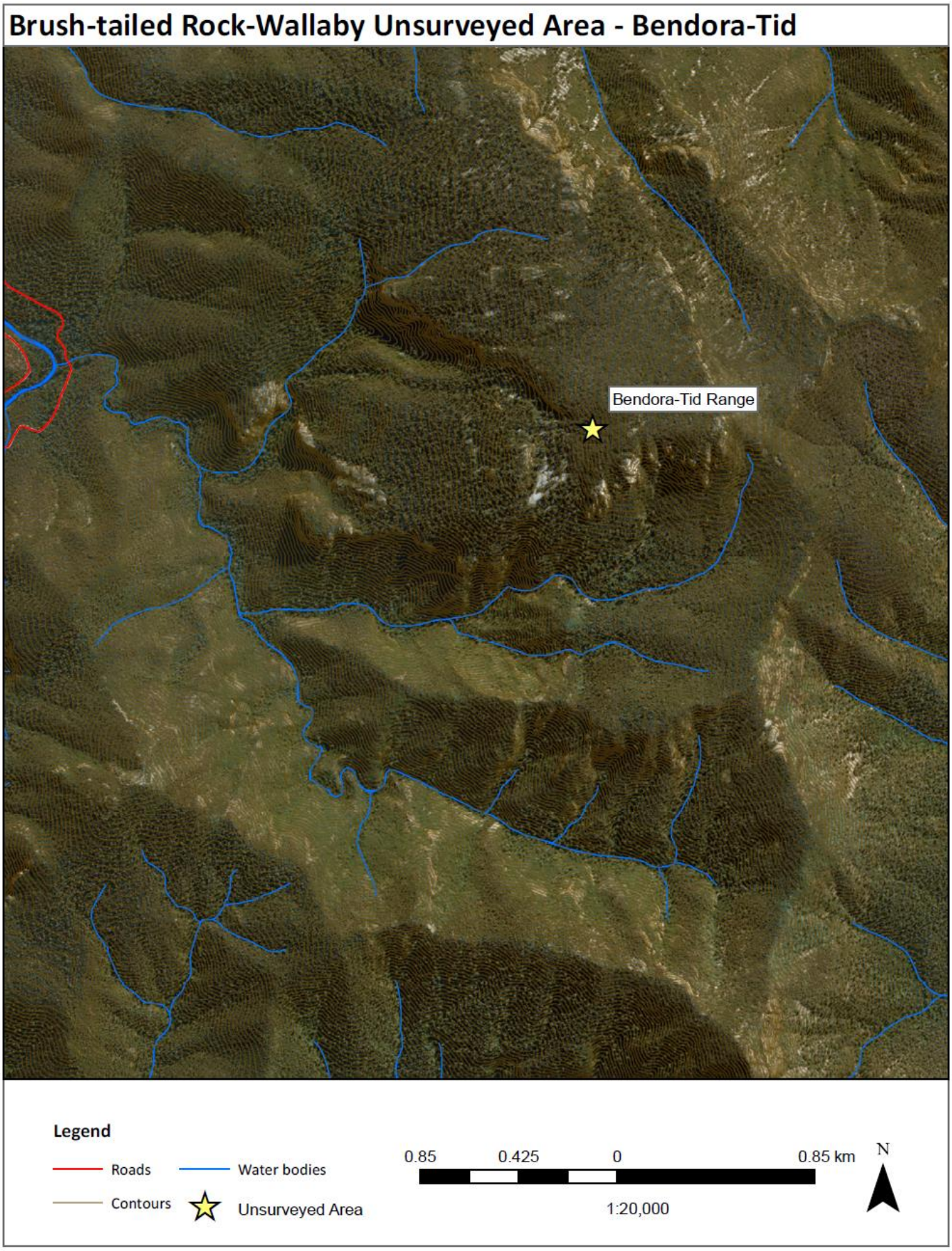

Brush-tailed Rock-Wallaby Historical Sites - Gibraltar
Gibraltar
Legend
Historical Sites
Water bodies
Roads
Contours
0.4
0.2
0
0.4 km
1:10,000
N

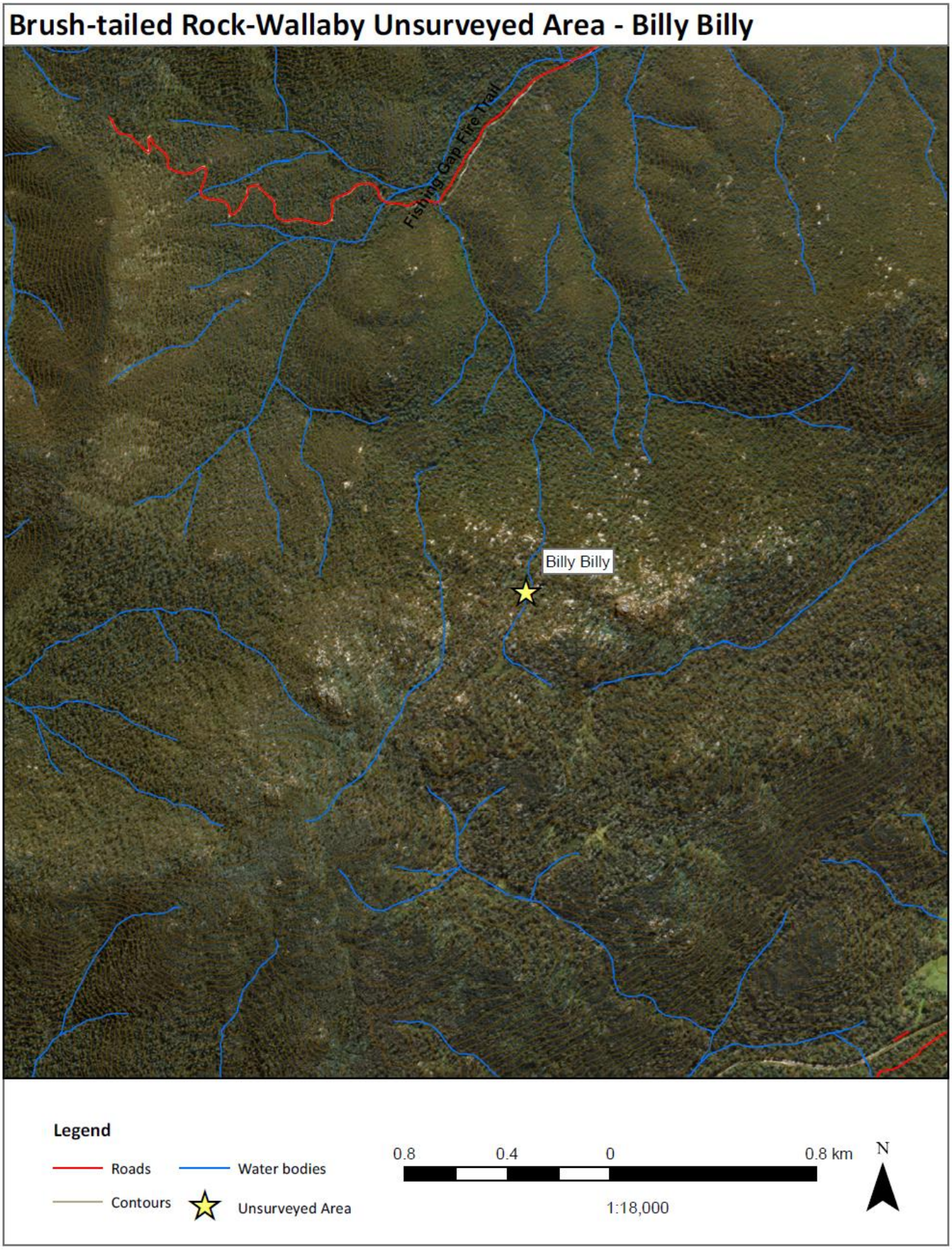

Brush-tailed Rock-Wallaby Historical Sites - Square Rock
Square Rock
Square Rock Walk
Stockers Trail
Legend
Historical Sites
Water bodies
Roads
Contours
0.4
0.2
0
0.4 km
1:10,000
N

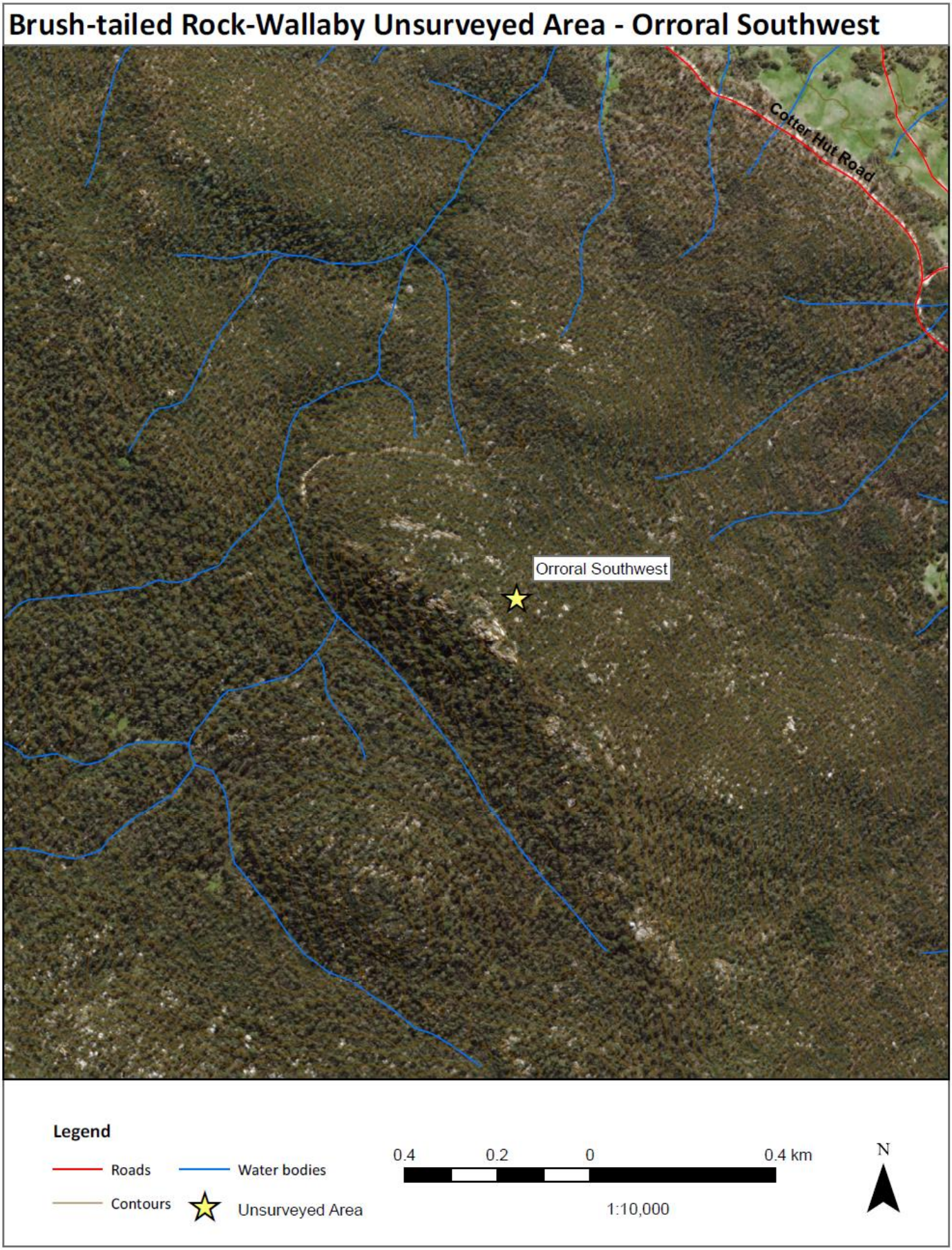

Brush-tailed Rock-Wallaby Historical Sites - Mt Tennent/Booroomba
Booroomba Stn (E)
Booroomba Stn (W)
Mt Tennent
Bushfold Flats Fire Trail
Mount Tennent Fire Trail
Booroomba Rocks Walk
Legend
Historical Sites
Water bodies
Roads
Contours
1.5
0.75
0
1.5 km
1:40,000
N

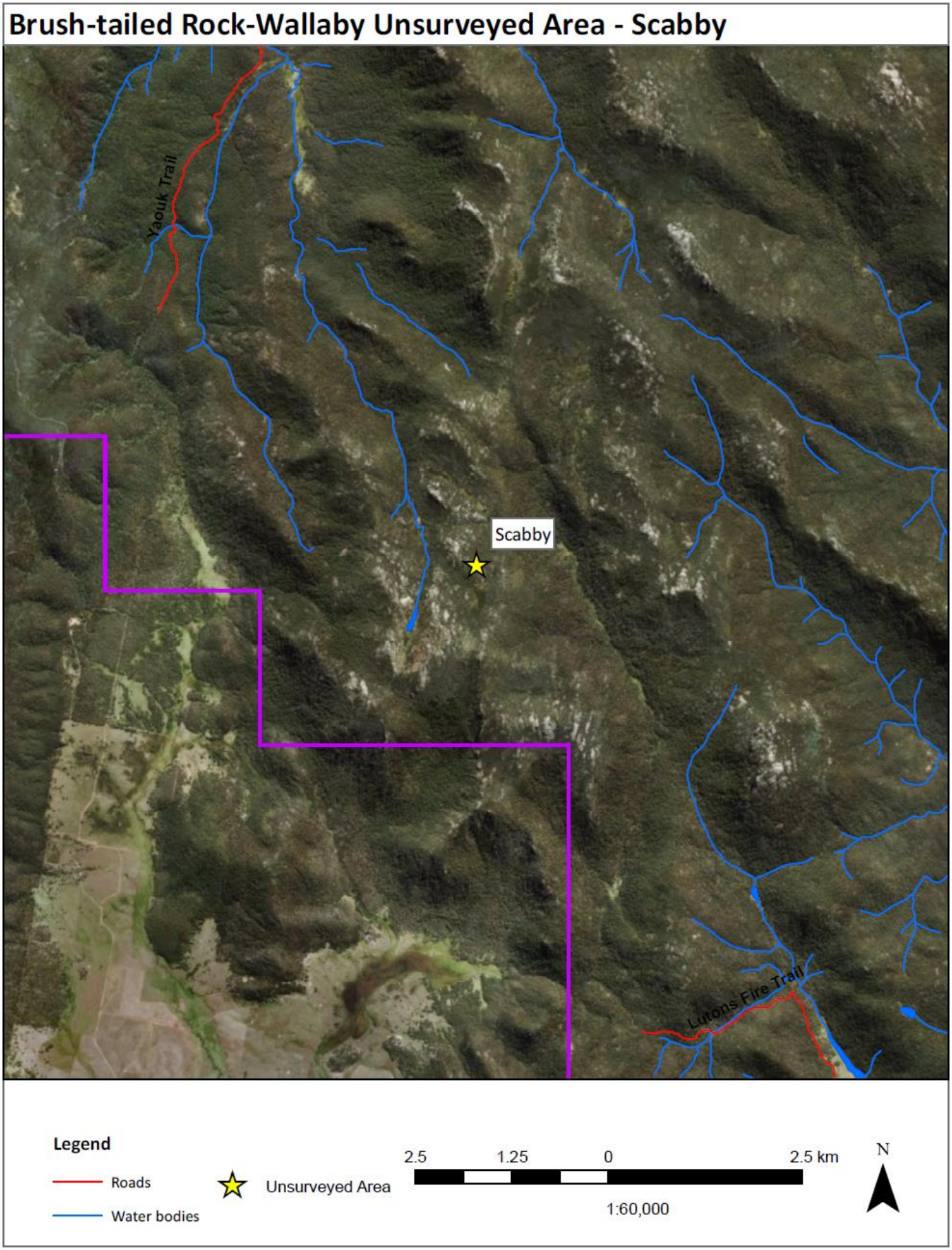

Brush-tailed Rock-Wallaby Historical Sites - Orroral Complex
Orroral Ridge (north A)
Orroral Ridge (north B)
Honeysuckle Walk
Honeysuckle Crag
Legoland
Honeysuckle Crag
Orroral Ridge Road
Orroral (SE Belfry)
Orroral (N. White whitches)
Orroral Ridge (south)
Orroral Valley Walking Trail
Link Road
Cotter Hut Road
Link Road
Legend
Historical Sites
Water bodies
Roads
Contours
1
0.5
0
1 km
1:25,000
N


Brush-tailed Rock-Wallaby Historical Sites - Rockview Orange Ledge
Bill's Track
Orroral Heritage Walk
Rockview Orange Ledge
Brandy Flat North Walk
Legend
Historical Sites
Water bodies
Roads
Contours
1
0.5
0
1 km
1:28,405
N


Brush-tailed Rock-Wallaby Unsurveyed Area - Bendora-Tid
Bendora-Tid Range
Legend
Roads
Water bodies
Contours
Unsurveyed Area
0.85
0.425
0
0.85 km
1:20,000
N


Brush-tailed Rock-Wallaby Unsurveyed Area - Billy Billy
Fishing Gap Fire Trail
Billy Billy
Legend
Roads
Water bodies
Contours
Unsurveyed Area
0.8
0.4
0
0.8 km
1:18,000
N


Brush-tailed Rock-Wallaby Unsurveyed Area - Orroral Southwest
Cotter Hut Road
Orroral Southwest
Legend
Roads
Water bodies
Contours
Unsurveyed Area
0.4
0.2
0
0.4 km
1:10,000
N


Brush-tailed Rock-Wallaby Unsurveyed Area - Scabby
Yaouk Trail
Scabby
Lutons Fire Trail
Legend
Roads
Water bodies
Unsurveyed Area
2.5
1.25
0
2.5 km
1:60,000
N