Biodiversity of Metropolitan Melbourne

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BIOREGIONAL CONTEXT

Australia can be divided into broad geographical regions known as ‘bioregions’. These share common physical and biological features, such as climate, soils and vegetation. This classification aims to capture ecological characteristics and patterns in the landscape. There are 28 bioregions recognised in Victoria, of which six occur in the Victorian Environmental Assessment Council’s (VEAC) Metropolitan Melbourne Investigation Area (Figure 1), hereafter referred to as the ‘investigation area’. Bioregions are used as a broad framework for conservation planning and management in Victoria (Platt and Lowe 2002). The major bioregions in the investigation area are the ‘Victorian Volcanic Plain’, ‘Gippsland Plain’, and ‘Highlands - Southern Fall’, with smaller patches of ‘Otway Plain’ and ‘Central Victorian Uplands’ and ‘Highlands - Northern Fall’ (Figure 2).

The climate of the investigation area is temperate and variable with a measurable rainfall gradient that ranges from less than 500 mm in the west of Metropolitan Melbourne to some 1100 mm to the east (Bureau of Meteorology and Walsh 1993, Brown-May and Swain 2005). Temperatures range from a mean of around 25^{o}C in summer and between 13^{o}C-14^{o}C in winter. In inner Melbourne temperatures below freezing have not been recorded in 20 years, while the outer suburbs commonly drop below freezing on winter mornings. For a variety of reasons, Melbourne’s mean temperature has been rising over the past 50 years at a rate of 0.14^{o}C per decade and scientists predict it will continue to rise due to the effects of global climate change (Climate Change Task Force 2008). The impacts of these changes on Melbourne’s biodiversity are discussed later in Chapter 2 under ‘Threats to Biodiversity’.

The **Victorian Volcanic Plain Bioregion** is an area of flat to undulating basaltic plains, characterised by large areas of open grassland vegetation and small open woodland patches. The landscape contains peaks from long-extinct volcanoes, stony rises created by old lava flows, and many large, shallow lakes (DPI 2008a). On the higher fertile plains, soils range from acidic, heavy clay soils rich in iron to porous larval rock (scoriaceous) material. The vegetation in these areas includes Plains Grassy Woodland and Plains Grassland. On the intermediate plain, soils range from alkaline, clay soils high in sodium to relatively deep well drained soils. The low plains contain what is called ‘shrink and swell’ clay that can exhibit deep cracking during dry hot summers. These soils support Stony Knoll Shrubland, Plains Grassy Woodland and Plains Grassy Wetland. On the volcanic outcrops soils are well drained stony earths that support Stony Rises Herb-rich Woodland, Basalt Shrubby Woodland and Herb-rich Foothill Forest (DSE 2008a).

Within the investigation area, Victorian Volcanic Plain Bioregion predominates to the west of the Yarra and Plenty Rivers (Figure 2). More broadly, the bioregion extends west to the South Australia border, south to Colac and north to Beaufort (DSE 2008a) (Figure 1). The Victorian Volcanic Plain experienced relatively early European settlement (i.e., 1830s onward), partly due to ease of access to open grassland areas for sheep grazing (Taylor *et al.* 2003) and is almost entirely privately owned. It has experienced extensive impacts including clearing, mainly for agriculture. The eastern portion of the bioregion covered by the investigation area is more densely populated by humans (DSE 2008a). The native vegetation of the Victorian Volcanic Plain is some of the most depleted in Victoria, with only 4.5% native vegetation cover remaining and less than 1.2% in conservation reserves (Taylor *et al.* 2003; Williams *et al.* 2005b). Across the entire bioregion, eleven species are thought to be extinct, and 171 species are considered rare or threatened including 90 plants, 54 birds, 4 reptiles, 1 amphibian, 9 fish and 4 invertebrates (Taylor *et al.* 2003).

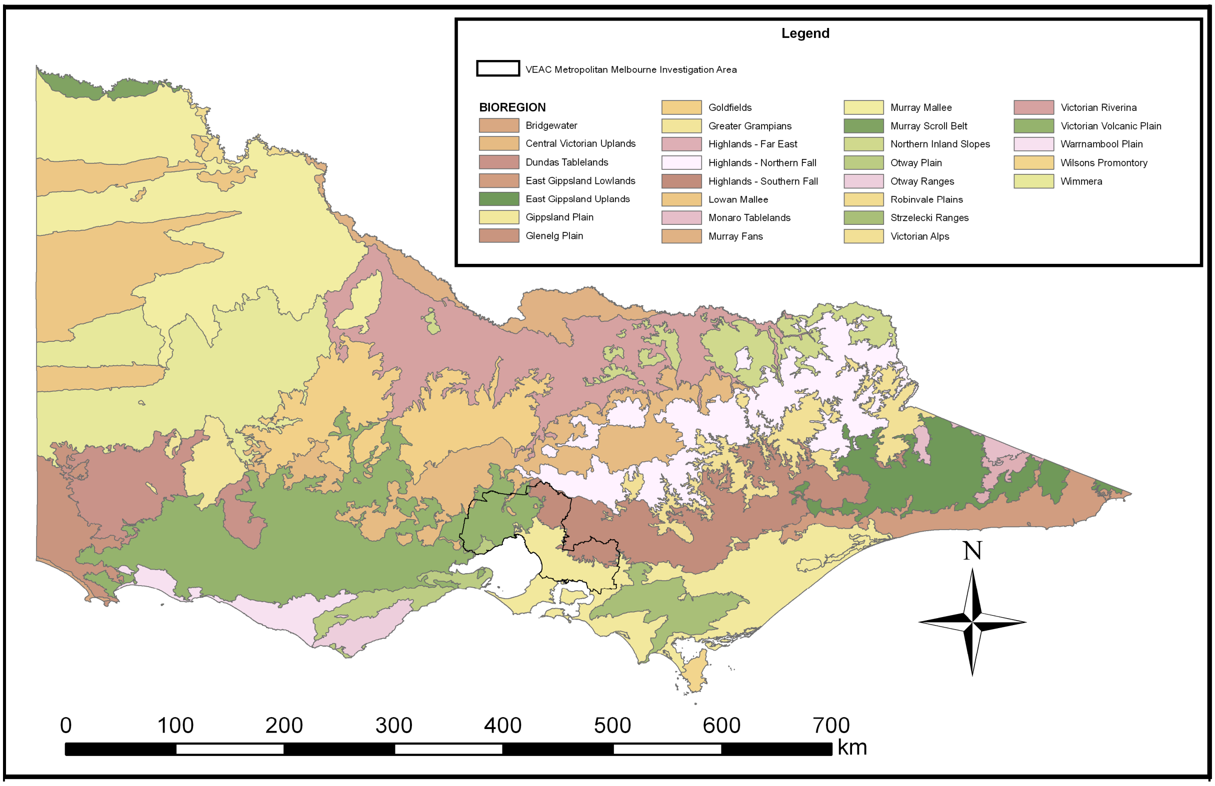

Figure 1. A map of Victoria showing bioregions. The black outlined area is the investigation area. Data Source: 'Victorian Bioregions mapped at 1:100,000 (version 3.0 May 2004)', © The State of Victoria, Department of Sustainability and Environment

The **Gippsland Plain Bioregion** consists of flat to gently undulating, low-lying, coastal and alluvial plains. The terrain includes dunes, floodplains and swampy flats. Dunes typically have deep well drained sandy soils and support Heathy Woodland and Damp Sands Herb-rich Woodland vegetation. The floodplains and swamps have more fertile earths and pale yellow and grey texture contrast soils. These regions contain Swamp Scrub, Plains Grassy Woodland, Plains Grassland and Gilgai Wetland. The higher areas of the bioregion are typically characterised by Lowland Forest ecosystems on a gradient of soils from textured clays with moderate to high sodium content exhibiting an abrupt increase in clay with depth to moderately deep low sodium fertile soils (DPI 2008b).

The Gippsland Plain Bioregion dominates the south-eastern part of the investigation area, from the Melbourne CBD and along the coast to the east (Figure 2). The bioregion continues east as far as Lakes Entrance, and from Foster in the south to Moe in the north (Figure 1). This makes it the most populated bioregion in Victoria, and it includes the demographic centre of Melbourne (i.e., eastern suburbs) (Wallis *et al.* 2003). High human population has altered the landscape considerably within the metropolitan area. Whilst remnant native vegetation in the whole of the Gippsland Plain Bioregion is more intact than many bioregions in Victoria (most of the Gippsland Plain experienced later human settlement than other areas of Victoria (post-1840)), settlement occurred earlier in the parts of the bioregion close to Melbourne. For the bioregion as a whole, approximately 18% of the native vegetation cover remains, with 8.2% of this located in conservation reserves (Wallis *et al.* 2003). Within the investigation area, the bioregion experiences pressure from development and recreation, leaving only fragmented remnants of native vegetation. Some areas remain as green corridors, typically along creeks and rivers. The investigation area also includes farmland areas used mainly for cattle grazing to the east beyond the suburban fringe (Wallis *et al.* 2003). In the Gippsland Plain Bioregion, six species are thought to be extinct (3 plants and 3 mammals), and 184 are considered rare or threatened. This includes 77 plants, 12 mammals, 66 birds, 6 reptiles, 2 amphibians, 11 fish and 8 invertebrates (Wallis *et al.* 2003).

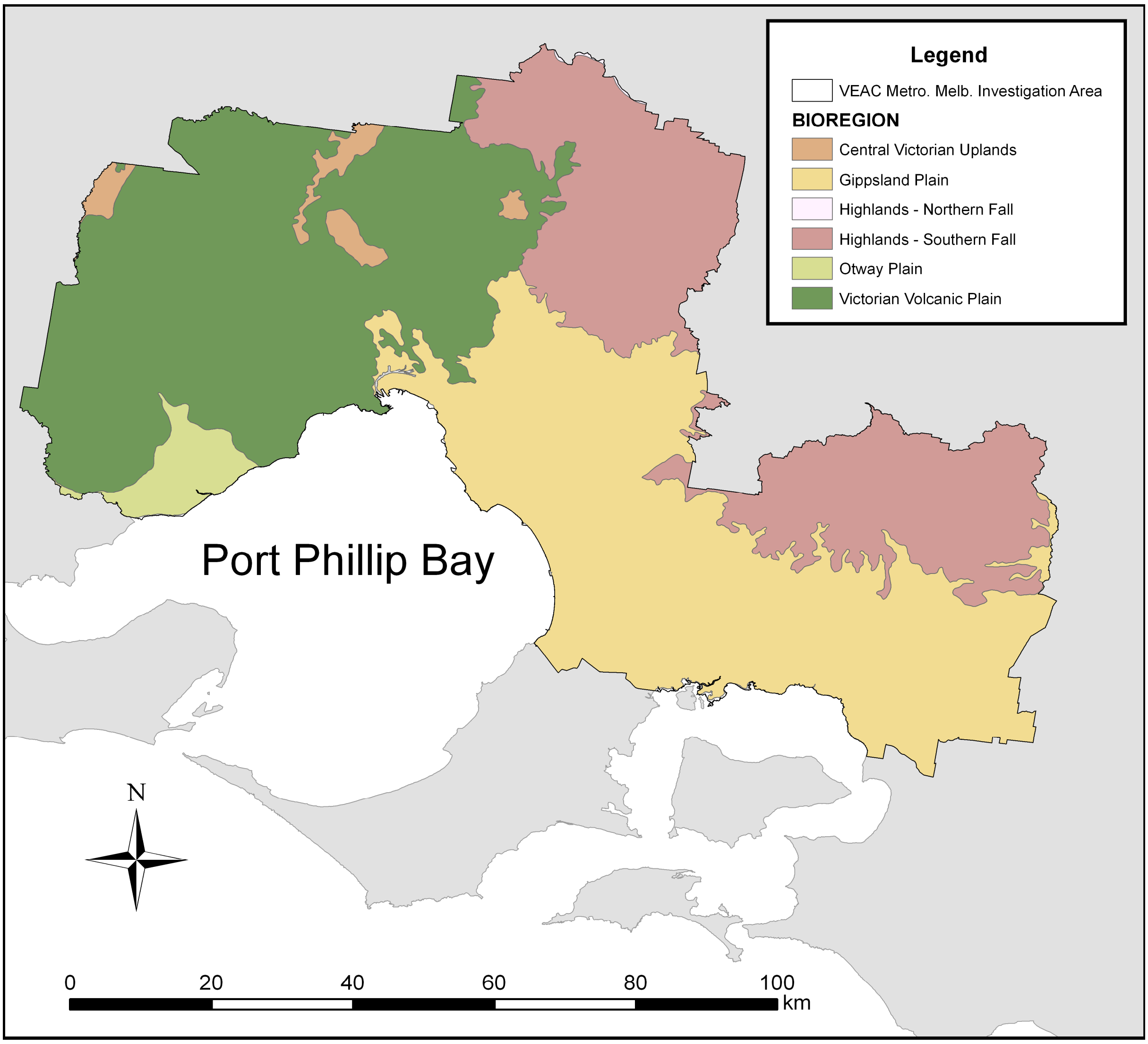

Figure 2. Bioregions within the investigation area. Data Source: 'Victorian Bioregions mapped at 1:100,000 (version 3.0 May 2004)', © The State of Victoria, Department of Sustainability and Environment

The **Highlands - Southern Fall Bioregion** is the southern part of the Great Dividing Range in Victoria, extending from Melbourne to near Omeo (Figure 1). Large patches of the bioregion occur in the northeast of the investigation area. 'Highlands - Southern Fall' includes dissected uplands, with moderate to steep slopes, high plateaus and alluvial flats along the valleys. Yellow and red texture clay soils occur in the valleys, with brown and red moderately well drained fertile soils in the higher regions. The vegetation is dominated by Shrubby Dry Forest and Damp Forest ecosystems on the slopes, with Wet Forest in the valleys. Cool Temperate Rainforest occurs in the more protected gullies. Higher altitudes support Montane Dry Woodland, Montane Damp Forest and Montane Wet Forest (DPI 2008c).

Victorian Highland regions generally contain a relatively low human population density. Parts of the Highlands - Southern Fall have been cleared for agriculture and settlement (DSE 2008b). Settlement is generally limited to the fringes of the region, such as those included in the investigation area. The Highlands - Southern Fall bioregion as a whole has close to 30% of its area protected in conservation reserves (Parks Victoria 2000).

An area of the **Otway Plain Bioregion** occurs in the Werribee region of the investigation area (Figure 2). The majority of this bioregion is found further west, from just east of Princetown to the Bellarine Peninsula (Figure 1). The Otway Plain consists of coastal plains and dunes, foothills with river valleys, and lowland swamps. The Werribee area has clay soils that are higher in fertility than the rest of the Otway Plain (Duffy *et al.* 2002). The vegetation of the Otway Plain includes Lowland Forest, Heathy Woodland, Grassy Woodland and Plains Grassy Woodland (DPI 2008d). European pastoral settlement of Werribee first occurred in the 1830s. Market gardens, poultry farms and orchards developed in the early 1900s. Many farms were set up at Werribee South after World War I, and further immigration and growth occurred after World War II (Duffy *et al.* 2002). The Otway Plain is now 70% privately owned and there has recently been strong sub-division and residential development around places such as Werribee. The region includes a large sewage treatment facility, and recreation is also a significant landuse (Duffy *et al.* 2002). The Otway Plain Bioregion as a whole has 31% native vegetation cover remaining, with less than 15% in conservation reserves. It contains areas of significant wetland habitat, and examples of most original vegetation types. Two species of the region are thought to be extinct (2 mammals), and 165 species are considered rare or threatened. This includes 94 plants, 10 mammals, 52 birds, 4 reptiles or amphibians, 3 fish and 2 invertebrates (Duffy *et al.* 2002).

In the west of the investigation area, the **Central Victorian Uplands Bioregion** occurs in a few small patches within a matrix of Victorian Volcanic Plain (Figure 2). The rest of the Central Victorian Uplands Bioregion extends from the Grampians and Ararat in the west, to Porepunkah in the east, and from the You Yangs and Lara in the south to Lurg in the north (Anderson *et al.* 2003) (Figure 1). The landscape of the Central Victorian Uplands consists of rugged to gently undulating terrain, with the vegetation being mainly dry forests. Ecosystems of the bioregion include Grassy Dry Forest, Heathy Dry Forest, Herb-rich Foothill Forest, Shrubby Foothill Forest, Valley Grassy Forest and Plains Grassy Woodland (DPI 2008e).

The bioregion as a whole has retained 28% of its native vegetation cover, with 8.5% of the bioregion in conservation reserves. The patches within the investigation area are subject to agriculture and urban development, with the majority of remaining native vegetation found in the westernmost patch (Anderson *et al.* 2003). Five species from the bioregion are known to be extinct (2 plants and 3 mammals), and 129 species are considered rare or threatened. The latter includes 60 plants, 10 mammals, 46 birds, 3 reptiles, 1 amphibian, 5 fish and 4 invertebrates (Anderson *et al.* 2003).

Within the investigation area, the **Highlands - Northern Fall Bioregion** occurs only in tiny patches in the far north (Figure 2). The bioregion extends further to the northeast, following the northerly aspect of the Great Dividing Range (Figure 1) (DPI 2008f). 'Highlands - Northern Fall' consists of dissected uplands with moderate to steep slopes, high plateaus and alluvial flats along the valleys. Soils consist of yellow and red texture clay soils in the valleys, with brown and red moderately deep well drained fertile soils in the higher regions (DPI 2008f). The bioregion supports Grassy Dry Forest and Valley Grassy Forest in the valleys, and Montane Dry Woodland and Heathy Dry Forest ecosystems on the plateaus and upper slopes. The lower slopes contain Herb-rich Foothill Forest and Shrubby Dry vegetation (DPI 2008f). Approximately 20% of the bioregion is protected in parks and reserves (Parks Victoria 2000).

BIOGEOGRAPHY AND LANDSCAPE STRUCTURE OF THE METROPOLITAN MELBOURNE INVESTIGATION AREA

The investigation area includes a range of environments. The Melbourne Central Business District (CBD) is located on the northern tip of Port Phillip Bay, and urban developments cover a large proportion of the region, particularly to the east of the CBD. Urban growth corridors are developing to the southeast (Cranbourne and Pakenham), North (Hume, Epping North and Plenty Valley), and West (Caroline Springs and towards Werribee) (State of Victoria 2002, Melbourne 2030: a planning update Melbourne @ 5 million). The western part of the investigation area also includes smaller areas of urban development centred around the towns of Melton and Sunbury.

Coastal environments occur adjacent to Port Phillip Bay, southeast and southwest of the Melbourne CBD. The Yarra River Valley extends from the CBD through the northeast of the region. Several tributaries flow into the Yarra from the north, including Maribyrnong River, Merri Creek, Darebin Creek and Plenty River. The majority of Greater Melbourne has relatively flat terrain, with the Dandenong Ranges rising to the east.

Melbourne has a moderate, coastal climate. Between 1855 and 2009, Melbourne's regional weather station has recorded a mean maximum annual temperature of 19.8 °C and mean annual minimum temperature of 10.2 °C (Bureau of Meteorology 2009b). Mean annual rainfall was 648.5 mm over the same period, distributed relatively evenly throughout the year but with highest rainfall in October (Bureau of Meteorology 2009b). Greater Melbourne has an east to west rainfall gradient, with average falls of less than 500 mm per year in the outer west, ranging to almost 1100 mm per year to the east (Bureau of Meteorology 2009a).

The basic geology of the investigation area consists of basaltic lava flows to the west of the CBD; siltstone, sandstone and claystone to the east; and sand, clay, gravel, silt, limestone and marl to the southeast along Port Phillip Bay (McAndrew and Marsden 1973). The west of the investigation area consists of hard alkaline duplex soils, with red clay subsoils. Grey cracking clays are found to the north, and coastal sandy soils to the southeast. The northeast and east have hard acidic duplex soils with yellow clay subsoil (Arnold 1964).

The current landscape structure of Melbourne and the surrounding region has been greatly influenced by State and local government planning policies. In the late 1960s, the Victorian Government planning policies focused on concentrating development along growth corridors while also preserving areas between the growth corridors as non-urban land (Buxton and Goodman 2003). This non-urban land has been referred to as Melbourne's green wedges. It is the remnants of these green wedges that contain a large proportion of the native vegetation still present within the inner section of the investigation area. The size and shape of Melbourne's green wedges have changed significantly over the last 30 years as both local and State governments rezone sections of the green wedges to allow for development. The *Melbourne 2030* report was released in 2002 and it promotes the increase in urban density, but limits urban expansion through the creation of an Urban Growth Boundary (UGB) (State of Victoria 2002). It has been criticised for failing to assess the biodiversity or sustainability of green wedges, or the biodiversity values of planned urban growth corridors (Buxton *et al.* 2006). In May 2009, a new document was released entitled "Melbourne 2030: a planning update @ 5 million report' that addresses the new growth projections for Melbourne. Indeed, Melbourne's population is projected to increase by 1 million from 3.7 million people in 2006 to 4.7 million people in 2026 (Victoria in the Future 2008). This new plan proposes extensions to the Urban Growth Boundary and a new outer metropolitan ring road and regional rail link (Melbourne 2030: a planning update Melbourne @ 5 million).

Three categories of land tenure were considered during this investigation: Conservation Reserve Public Land[1] (Public-conservation reserved), Other Public Land (Public-other) and Private Land. The first two categories consist of the land parcels within the investigation area that are of direct interest to VEAC as they are either parcels of Crown land, or are land held by other public authorities, and therefore have the opportunity for coordinated management and decision making with a few key agencies. The remainder of the investigation area is considered to be private land and is outside the scope of VEAC's investigation.

Appendix 1 details the methods used to analyse biodiversity data from the investigation area. The Highlands - Northern Fall Bioregion represents a very small proportion of the investigation area (less than 1%), and as such was not included in the analysis.

[1] The conservation reserve system refers to a network of protected public land. Within the investigation area, this land includes reference areas, national and state parks, marine sanctuaries, nature conservation reserves and some natural features reserves.

BIODIVERSITY OF THE METROPOLITAN MELBOURNE INVESTIGATION AREA

Sites With Important Biodiversity Value

Of the 2028 sites of public land in the investigation area as a whole, 1057 sites have been recognised as containing biodiversity values (Appendix 1). Of these 1057 sites, some 114 (11%) are protected within conservation reserves. The majority of conservation reserves are located in the Highlands - Southern Fall and Gippsland Plain bioregions, reflecting a large number of sites in total (699) in these areas. The Victorian Volcanic Plain also covers a large proportion of the investigation area, and has 279 important sites recognised. However, only 27 of those are conservation reserves. Of the 37 and 42 sites of public land with biodiversity values identified in the Central Victorian Uplands and the Otway Plain, seven and none are in reserves (respectively).

Within the investigation area, the **Gippsland Plain** bioregion includes 981 sites of public land, of which 426 sites are considered to have important biodiversity values (total area over 18,600 hectares). Thirty-one of these sites are in conservation reserves.

Within the investigation area, the **Highlands - Southern Fall** bioregion includes 310 sites of public land, of which 273 are considered to contain important biodiversity values. Forty-nine of these sites are located in conservation reserves.

Within the investigation area, the **Victorian Volcanic Plain** bioregion includes 640 sites of public land, of which 279 sites are considered to have important biodiversity values. Only 27 of these sites are located in conservation reserves.

Species Present Within the Investigation Area

Within the investigation area as a whole some 1864 species of indigenous flora have been recorded, of which 178 are considered threatened (ARCUE 2009). In addition, 520 indigenous fauna species have been recorded, 136 of which are considered threatened.

The species types recorded within each bioregion are described in more detail below. It should be noted that small organisms, such as invertebrates and fungi, have often been poorly surveyed and as a result the number of species recorded is thought to be significantly lower than the number actually present.

Within the investigation area, the **Central Victorian Uplands** bioregion contains 375 species of indigenous flora, of which 9 species are considered threatened. Six species of cryptograms have also been recorded in the region, all of which occur within reserves. The bioregion also contains 231 species of indigenous fauna, including 14 amphibian species, 160 bird species, 3 invertebrate species, 21 mammal species and 19 reptile species. The Central Victorian Uplands contains 24 threatened fauna species (3 amphibians, 16 birds, 1 invertebrate, 1 fish, 2 mammals and 1 reptile).

Within the investigation area, the **Gippsland Plain** bioregion contains 1256 species of indigenous flora, of which 57 species are considered threatened. The region also includes 146 species of cryptograms and 326 fungal species. All but two of these were recorded outside reserves, mostly on private land. The bioregion also includes 440 species of indigenous fauna, including 16 amphibians, 292 birds, 61 fish, 7 invertebrates, 34 mammals, and 30 reptiles. One hundred and three of these fauna species are considered threatened (3 amphibians, 77 birds, 12 fish, 7 mammals and 4 reptiles). The total number of butterfly species recorded in the Gippsland Plain bioregion is 72.

Within the investigation area, the **Highlands - Southern Fall** bioregion contains 1344 indigenous flora species, of which 87 species are threatened. Fifty-five cryptograms and 229 fungi have also been recorded in the region, mostly on private land. Within the bioregion, 383 species of indigenous fauna species have been recorded, including 18 amphibians, 247 birds, 28 fish, 11 invertebrates, 43 mammals and 36 reptiles. Eighty-three of these fauna species are considered threatened (3 amphibians, 51 birds, 7 fish, 4 invertebrates, 12 mammals and 6 reptiles). Sixty-nine butterfly species have been recorded within the Highlands - Southern Fall part of the investigation area.

Within the investigation area, the **Otway Plain** bioregion contains 139 indigenous flora species, of which 2 are considered threatened. Within the bioregion, 271 species of indigenous fauna have been recorded, including 8 amphibians, 198 birds, 35 fish, 17 mammals and 13 reptiles. Of these fauna species, 48 are considered threatened (1 amphibian, 44 birds, 2 mammals, and 1 reptile). Seven butterfly species have also been recorded in the region.

Within the investigation area, 83 threatened flora species have been recorded from the **Victorian Volcanic Plain** bioregion out of a total of 1072 species. Additionally, 240 cryptogram species and 108 fungal species have been recorded, mostly from private areas. The region contains 408 indigenous fauna species, including 16 amphibians, 275 birds, 47 fish, 9 invertebrates, 31 mammals and 30 reptiles. Within the region, 98 indigenous fauna species are considered threatened (2 amphibians, 75 birds, 8 fish, 2 invertebrates, 6 mammals and 5 reptiles). A total of 43 butterfly species has also been recorded from this region.

Ecological Vegetation Classes (EVCs)

Vegetation in Victoria has been classified into Ecological Vegetation Classes (EVCs). EVCs are a type of native vegetation classification that is described through a combination of floristic, life form and ecological characteristics (DNRE 2002).

Approximately 300 EVCs are recognised in Victoria (DSE 2009). Over 80 EVCs occur within the investigation area, covering nearly 145,500 ha (Appendix 2). Most of the EVCs are on private land (66%) while only 19% are on Conservation Reserved Public Land and 16% are on Other Public land. EVCs are used as surrogates for biotic communities and, consequently, as a key unit for conservation planning and biodiversity management. Many EVCs are currently poorly represented or unrepresented in the conservation reserve system. Appendix 2 shows the number and bioregional conservation status of EVCs within each bioregion.

Within the investigation area, 18 EVCs occur within the **Central Victorian Uplands**. Eight of these EVCs are considered endangered, and five are vulnerable Two EVCs are considered depleted, with the remaining three EVCs of least concern.

Within the investigation area, 62 EVCs occur within the **Gippsland Plain**. Thirty-one of these EVCs are considered endangered, and 18 are vulnerable. Two EVCs are considered rare, and six depleted. The remaining five EVCs are of least concern.

Within the investigation area, 34 EVCs are found within the **Highlands - Southern Fall** bioregion. Eleven of these EVCs are considered endangered, ten are vulnerable, and three depleted. The nine remaining EVCs are of least concern.

Within the investigation area, nine EVCs are found within the **Otway Plain** bioregion, all of which are considered endangered.

Within the investigation area, 43 EVCs are found within the **Victorian Volcanic Plain** bioregion. Thirty of these EVCs are considered endangered, eight are vulnerable, and three depleted. One remaining EVC is of least concern and the other is not categorised.

Chapter 2. Threats to and Management of Biodiversity in the Metropolitan Melbourne Investigation Area

THREATS TO BIODIVERSITY ASSOCIATED WITH URBAN ENVIRONMENTS

Humans have (to some extent) influenced environments throughout the world (McDonnell *et al.* 2009), although anthropogenic modification of the landscape is particularly obvious in built environments such as cities and towns. Human landscape modification and building occurs for a wide range of purposes, including residential, commercial, industrial and recreational developments. Anthropogenic modifications alter the physical, chemical and biological environment. Several of these alterations are described further in 'Threats to Biodiversity' below and other less obvious human impacts on biodiversity in Melbourne are described by McDonnell and Holland (2008). Economic, cultural, social and environmental land uses compete for space within the investigation area.

By global standards, Australian cities such as Melbourne develop via low-density urban sprawl, and there remains a high reliance on cars for transport. Dramatic changes to the environment have caused many local extinctions of the indigenous biodiversity (Hamer and McDonnell 2008; Hamer and McDonnell in press; van der Ree and McCarthy 2005). Remnant or planted habitats are subject to multiple land uses in addition to conservation, such as recreational use, leading to additional pressure on species remaining in these areas.

A range of urban and peri-urban environments exist within the investigation area. Peri-urban areas are those immediately surrounding densely-populated metropolitan centres. They contain a mosaic of urban, rural and remnant native areas, and are subject to expanding urban development. The conservation of native biodiversity in close proximity to a large and dense human population is a challenge that relies on planning and active management.

Open space persists within the anthropogenic landscape in a variety of forms, including remnant patches of native vegetation, planted native vegetation, planted non-indigenous parks and gardens (both public and private), and recreational spaces (e.g. sports fields, golf courses) (Leary and McDonnell 2001). These areas vary in habitat quality and the species they support. While remnant native habitat is most commonly considered in biodiversity management, human created systems can also provide habitat. In Melbourne, the designed and planted Fern Gully at the Royal Botanic Gardens was a preferred habitat for a large mob of Grey-headed Flying-Foxes (*Pteropus poliocephalus*) (van der Ree et al. 2005). In cities around the world, golf courses often provide important habitat for biodiversity (Colding and Folke 2009).

Native biodiversity differs in its tolerance to human disturbance and landscape modification. Some species within the Melbourne region persist only in high quality or larger reserves. For example, the Southern Brown Bandicoot (*Isoodon obesulus*) once occupied much of the southeastern suburbs of Melbourne, but the only remaining large, productive population is thought to be in the Royal Botanic Gardens Cranbourne (Mornington Peninsula and Western Port Biosphere Reserve Foundation 2008; Southwell *et al.* 2008). The species is thought to be sensitive to threats in urban areas, including predation by foxes, cats and dogs, and road mortality. Management to ameliorate these threats such as reducing predator numbers and creating landscape corridors is required to maintain species such as bandicoots within the investigation area.

Populations of some native plant species, particularly those with long lived individuals such as trees, may persist in urban remnants for long periods of time (i.e., 50 - 100 years), but due to changing conditions new individuals cannot survive and grow into the canopy. These new recruits are required for the species to persist long-term into the future. When natural processes of plant recruitment and growth no longer occur in urban environments, populations of plants can only persist through active management.

Despite the often detrimental impacts of landscape modification on plants and animals, many species prosper in urban environments. Examples of species that have increased in abundance within the investigation area include Rainbow Lorikeets (*Trichoglossus haematodus*) and Grey-headed Flying-Foxes. These are highly mobile species, and are able to utilise resources from across a large landscape, including planted fruiting and flowering plants (Shukuroglou and McCarthy 2006; Williams *et al.* 2006a). Human practices may provide increased food resources for wildlife, both unintentionally (e.g., tree planting and refuse) and intentionally (e.g. bird feeders, Chase and Walsh 2006). They may also create increased safety for some species, such as reduced populations of natural predators.

An additional challenge to preserving biodiversity within a densely human-populated landscape is managing the potential conflicts between humans and native species. Examples include possums nesting in roof spaces (Harper *et al.* 2005), and the noise and destruction of vegetation caused by large camps of flying-foxes (van der Ree *et al.* 2005). At the same time, urban biodiversity provides a significant opportunity to educate people and allow them to connect with and value nature.

The investigation area includes large areas of built environments, including roads, buildings and paved areas. These environments are commonly considered unsuitable for biodiversity, but built-up and highly modified environments remain relevant to biodiversity in the region. Species utilise additional resources in the landscape surrounding vegetated areas, and may need to pass through built areas when travelling between habitat patches. For example, Brushtail Possums (*Trichosurus vulpecula*) often live in native remnants, but also forage in the surrounding residential landscape (Harper 2005). Additionally, the environment surrounding remnant vegetation or other patches of habitat will also influence the biodiversity within the patch. For example, local extinction of native grassland plants is more strongly related to the urbanisation of the surrounding landscape than to factors such as remnant patch size (Williams *et al.* 2006b).

Managing threatening processes is critical to biodiversity conservation, and to uphold the aims of the *Flora and Fauna Guarantee Act 1988* and the Commonwealth *Environmental Protection and Biodiversity Conservation Act 1999*.

Land clearing and development lead to habitat loss and contribute to local extinctions of native species. In the investigation area, significant habitat loss has occurred as a result of urbanisation. Habitat loss is considered the most important cause of species decline worldwide (Sih *et al.* 2000).

In Melbourne's inner city only approximately 1.6% of the original native vegetation remains, while in the outer suburbs nearly 16% remains (McDonnell and Holland 2008). Habitat loss is a continuing process, with much remaining land in private ownership and threatened by future urban development. In highly modified landscapes, the consequences of small incremental habitat losses are increased (Tilman *et al.* 1994). This makes remnant habitat in the investigation area an ever more valuable resource for maintaining biodiversity.

In addition to direct habitat loss, remaining native areas face potential loss of habitat quality through a range of degrading processes including invasions of non-indigenous species, air, soil and water pollution, changes to hydrologic flows and climate change (McDonnell and Holland 2008).

The **invasion of non-indigenous species** is considered a large threat to native ecosystems (Groves and Willis 1999; Williams and West 2000; Mack *et al.* 2000). Urban areas such as Melbourne contain an abundance of introduced species (e.g. planted non-native gardens), leading to significant opportunity for these species to invade more natural areas. Additionally, human activities and travel aid the spread of species (Hobbs and Humphries 1995). It is also expected that some invasive species will be favoured by predicted global climate change, leading to greater impacts on native ecosystems (e.g. Dukes *et al.* 2009).

Non-indigenous species threaten native biodiversity in multiple ways, including direct competition for resources, altering habitat conditions, hybridisation with native species, herbivory, and predation (Simberloff *et al.* 2005). For example, introduced Common Mynas (*Acridotheres tristis*) compete aggressively with other species, and dominate nest box and hollow use, required by many native species for reproduction and daytime shelter (Harper *et al.* 2005). Foxes are common in the investigation area (Marks and Bloomfield 1999) and have a broad, opportunistic diet (White *et al.* 2006), meaning they will potentially feed on a wide range of native animals.

Pollution and nutrient additions alter the air, water and soil of native ecosystems, changing suitability for biodiversity. Air pollution is known to alter the distribution of species in urban regions (e.g. Giordani *et al.* 2002). Wet and dry deposition of elements, including nitrogen and phosphorus, occurs at high levels in urban areas due to use of motor vehicles and other burning of fossil fuels. Increased nutrient levels alter the structure and functioning of ecosystems, thereby reducing biodiversity (Singh and Tripathi 2000). For example, weeds may be better able to compete with native species following nutrient enrichment, as has been demonstrated in remnant native woodlands in urban Melbourne (Bidwell *et al.* 2006), and for grassland species present in the region (Badgery *et al.* 2005).

The **climatic conditions** in cities are altered from those of the surrounding region. The 'urban heat island effect' means city centres are typically warmer than the surrounding landscape (Coutts et al. 2007, 2008). This occurs due to a variety of interacting factors, including buildings and roads absorbing heat during the day and releasing it during the night (Landsberg 1981; Oke *et al.* 1999). Morris and Simmonds (2000) detected an urban heat island of up to 2 °C in Melbourne, on 75% of days between 1973 and 1991. This difference is sufficient to impact organisms and ecosystem processes. Increased temperatures increase suitability for some species, and have been implicated in the expansion of the year-round range of Grey-headed Flying-Fox into Melbourne (Parris and Hazell 2005). Urban heat islands can also alter species phenology (the timing of biological cycles, such as seasonal flowering or migration). For example, plants in urban areas may begin flowering earlier in the year than in surrounding areas (Ho *et al.* 2006; Roetzer *et al.* 2000).

In addition to increased temperatures, some areas may have higher effective precipitation than would otherwise occur due to supplemental watering. Parris and Hazell (2005) suggest that parks and gardens in Melbourne may receive an additional 590 mm (95% Confidence Interval: 450 - 720 mm) per year. Changing temperature and water availability have implications for wildlife food resource availability, such as the abundance of flowers and fruits.

Hydrology in urban regions is altered due to the replacement of natural flows by the construction of impermeable surfaces (e.g. roads, pavement) and artificial drains. Urban river water quality and sediments are affected by storm and waste water drainage, and pollution inputs (Gurnell *et al.* 2007). Urban rivers tend to be degraded due to the extent of change to catchment form and function (Gurnell *et al.* 2007). Studies conducted on the Yarra River have shown that the stream invertebrates present are strongly related to the proportion of the catchment covered by impervious surfaces (Walsh *et al.* 2007). Reducing the impact of urbanisation through dispersed, low-impact drainage schemes has been recommended for improving stream biodiversity (Walsh *et al.* 2007).

Global climate change is also predicted to have impacts on biodiversity in the investigation area. Over the last 100 years, Australia as a whole has warmed approximately 0.8 °C, in line with global trends (Hughes 2003). In southeastern Australia, recent conditions have been hotter and drier than previously, and this trend is expected to continue (Department of Climate Change 2007; Murphy and Timbal 2008). Table 2.1 shows the predicted climatic change for Melbourne. Bioclimatic analysis predicts that climate change in Australia will result in fragmentation and contraction of species ranges (Hughes 2003).

Table 2.1. Predicted climatic changes for Melbourne.

Year	2002	2030	2070
Annual average max. temperature (°C)	19.8	20.8 ± 0.7	22.8 ± 2.2
Dec-Feb days over 35 °C	8	10.5 ± 1.5	15 ± 5
Annual rainfall (mm)	657	630 ± 50	580 ± 155
Source: (CSIRO and AGO 2002)			

Human use of the landscape leads to a variety of other impacts on native biodiversity. Recreational activities can lead to degradation of parks and reserves. Stenhouse (2004a) found that for reserves in Perth, those closer to the CBD experienced more trampling and rubbish dumping, and contained a higher abundance of exotic species, bare patches and erosion. Damage may also be caused by trail bikes or cars, children's play, or vandalism (Stenhouse 2004b). Human rubbish provides additional food supplies for some species (Chase and Walsh 2006), thus altering species abundance and competitive interactions. Noise and light pollution represent disturbances with potential impacts on species physiology and behaviour (Ditchkoff *et al.* 2006; Rich and Longcore 2006). Noise can have a masking effect that makes communication between animals (such as mating calls, or alerting others to the presence of predators) more difficult (Warren *et al.* 2006). Little Penguins (*Eudyptula minor*) at St Kilda in Melbourne nest preferentially in areas with restricted human access, presumably to avoid anthropogenic disturbances (Giling *et al.* 2008). Road mortality of wildlife can have consequences for population viability (e.g. swamp wallabies in peri-urban Sydney; Ramp and Ben-Ami 2006).

Maintaining appropriate **disturbance regimes** is also important to biodiversity conservation. Many Australian landscapes evolved with fire as a common disturbance. The fire frequency, intensity and season are important to Australian vegetation communities (Bradstock *et al.* 2002). Fire suppression is common in urban areas, including the investigation area. This has known detrimental effects on the biodiversity of grassland and heathland communities, where many plants rely on fire, for example, to create open areas for seedlings to germinate, or to stimulate seed release (Lunt and Morgan 1999; Phelan 2000).

Fragmented native ecosystems experience altered community and landscape dynamics (Laurance 2002). Examples include mortality and recruitment rates, and fluctuations in the population of individual species. In Sydney, higher levels of invertebrate herbivory on eucalypts has been observed in urban remnants compared to continuous forest, possibly due to nutrient enrichment and lack of insect predators (Christie and Hochuli 2005).

Genetic and reproductive processes are influenced by landscape fragmentation and isolation of populations. Fragmentation leads to lower genetic diversity, particularly in landscapes that have been fragmented for a long time (Aguilar *et al.* 2008). Genetic diversity is important for the ability of species to adapt to changing environments. Additionally, low levels of genetic diversity may lead to inbreeding depression, which lowers survival or reproduction rates (Young *et al.* 2006). Plant-pollinator interactions are threatened by habitat fragmentation and other human alterations to the landscape. The conservation of these processes is important to maintaining biodiversity (Kearns *et al.* 1998).

As mentioned in Chapter 1, the implementation of the 'Melbourne 2030: a planning update @ 5 million' report will have a profound impact on the investigation area. It is estimated that the expansion of the Urban Growth Boundary will open some 40,000 ha of land currently included in the green wedges to development. Those bioregions under the greatest threat within the investigation area include Victorian Volcanic Plains, Gippsland Plain and Highlands-Southern Fall.

SPECIFIC THREATS IN THE METROPOLITAN MELBOURNE INVESTIGATION AREA

Ten major threats to biodiversity were specifically investigated for the 1057 Public Land sites containing biodiversity values within the investigation area. Threats to the Public land sites with biodiversity values were compiled to provide information to VEAC on where biodiversity values may be most at risk within the investigation area. The measures used are considered to be the most appropriate for quantifying threats based on the current scientific literature in this area and the spatial information available at the time of the study. A description of the threats and the methods used to calculate them can be found in Appendix 1.

Table 2.2 provides a summary of sites with biodiversity values that are likely to be impacted by selected threats associated with human modified landscapes. As shown, the majority of sites with biodiversity values on public land are likely to be impacted by internal fragmentation effects. Seventy-eight percent of Conservations Reserve sites and 91.5% of sites on Other Public Land have been identified as potentially having high levels of internal fragmentation. Internal fragmentation effects are processes which occur within the patch boundaries. This effect is distinct from the landscape fragmentation effects represented by Edge Effects, which are acting at the scale of the entire patch (see discussion below). The second greatest threat to sites is the presence of a major road within 500 m of the edge of the site. Over half the sites in the investigation area are close to a major road, and could therefore be considered to be at a high risk of eventually being lost due to demands on these areas for development into alternative uses (Williams et al. 2005a). Threats such as urban effects (e.g. the 'heat island effect' and pollution) and human impacts (e.g. trampling and rubbish) are also prominent threats at sites with biodiversity values within the investigation area. The prevalence of these threats is unsurprising considering the highly urbanised nature of the investigation area. The proportion of sites at high risk from weeds (greater than 50% of the site contains weeds) is relatively low on both Conservation Reserves and Other Public Land. However, the proportion of such sites would be much greater if sites of low and medium risk from weed impacts were included. The number of sites likely to be impacted by proposed roads is relatively small, but for those sites where a proposed road is present, the risk of eventual habitat destruction could be considered particularly high.

Relatively few sites have been identified as at high risk from edge effects. This is likely to be due to the interactions between Perimeter: Area Ratio (the measure used to determine edge effects in this study), and the area of a site. Small sites (less than 5 ha in size) are not likely to have a distinct interior area, as the entire site is likely to be affected by the processes associated with edge effects in fragmented landscapes. Therefore they will not be considered to be at risk of edge effects, based on the Perimeter: Area Ratio. Over 70% of all sites of public land, regardless of biodiversity status, are less than 5 ha in size. The main sites that are being picked up by this study as having a high risk of edge effects are the long linear patches that are greater than 5 ha in size. These are the sites where a distinct difference may be found in the conditions at the edge of the site, compared to the interior, but the extent of edge conditions is much greater than if the site had a more compact shape.

In general, the prevalence of threats in Conservation Reserves is roughly equivalent to or notably lower than the proportion of sites with biodiversity values in Other Public Land. For example, the percentage of Conservation Reserves at high risk from urban effects is much lower than the percentage of sites in Other Public Land (15.8% compared to 38.6%). The exception to the above is the likely risk of predation by dogs, cats and foxes, which is higher than expected in conservation reserves. This is likely to be more of a reflection of the data used to assess this threat, with greater efforts at recording indigenous and introduced species likely to occur within conservation reserves. If anything, predation pressure may actually be lower within Conservation Reserves if they are undertaking active control measures to manage predator numbers.

Table 2.2. Summary of the number and proportion of sites with biodiversity values that are likely to be impacted by some of the main threats associated with human modified landscapes.

Threat	Sites with Biodiversity Values Likely to be Impacted by Selected Main Threats				
	% of Total Number of Sites on Public Land	Number of sites in Conservation Reserves	% of Total Number of sites in Conservation Reserves	Number of sites in Other Public Land	% of Total Number of sites in Other Public Land
High Levels of Internal Fragmentation	90.1%	89	78.1%	863	91.5%
High Risk of Site Loss Due to Proximity to Major Road	54.2%	48	42.1%	525	55.7%
High Risk of Urban Effects (e.g. heat island, pollution)	36.1%	18	15.8%	364	38.6%
High Risk of Human Impacts (e.g. trampling, rubbish)	27.6%	31	27.2%	261	27.7%
Likely to be Impacted by Proposed Roads	13.4%	10	8.8%	132	14.0%
High Risk from Introduced Plant Species (> 50% site)	11.5%	8	7.0%	114	12.1%
Likely Risk of Predation by Dogs, Cats and Red Foxes	11.0%	26	22.8%	90	9.5%
High Risk from Edge Effects	2.3%	0	0%	24	2.5%
Sites with Biodiversity Values	100.0%	114	100.0%	943	100.0%

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Appendix 1. Methods: Spatial Data Sources and Methodology

SPATIAL DATA SOURCES

Bioregions

Information about the extent of bioregions occurring within the investigation area was obtained from the Department of Sustainability and Environment's (DSE) VBIOREG100 layer (version 3.0, May 2004), which is part of the national framework the Interim Biogeographical Regionalisation for Australia (IBRA). IBRA represents a landscape based approach to classifying the land surface of Australia and consists of two datasets: IBRA bioregions (85 of which have been delineated) is a larger scale regional classification of homogenous ecosystems, and sub-regions (405 of which have been delineated) are more localised. Each bioregion is a large geographically distinct area of similar climate, geology, landform, vegetation and animal communities and reflects a unifying set of major environmental influences which shape the occurrence of flora and fauna and their interaction with the physical environment. This data source is derived from the native vegetation modelled for 1750 (NV1750_EVCBCS) and expert interpretation, and is contained within a vector polygon layer where the data the data are accurate to at least 1:100,000.

Public Land Parcels Database

The sites of public land used in this analysis were those provided by VEAC on 15 May 2009 as the shapefile 'metparcv22vg94_vicroads_20090515_arcue.shp', in conjunction with the lookup table 'landtemp_20090515.dbf'. In consultation with Paul Peake (VEAC), the records that did not have value for LUNAME, CATNAME or RESERVE were assigned a name by joining text from other fields within the shapefile as described in Table M1.

Table M1. Description of the methods used to populate the three new fields created by ARCUE in 'metparcv22vg94_vicroads_20090515_arcue.shp'.

Field	Value
LUNAME_arc	Combination of values from the LUNAME field, and where those values were missing, a new LUNAME was created by combining the fields SOURCE, LANDCAT and LANDMAJCAT.
CATNAME_arc	Combination of values from the CATNAME field, and where those values were missing, a new CATNAME was created by combining the fields LANDCAT and LANDMAJCAT.
RESERVE_arc	Combination of values from the RESERVESYS field, and where those values were missing, the value was designated as 'other'.

The 'metparcv22vg94_vicroads_20090515_arcue.shp' was then combined with the Bioregions theme (VBIOREG100) within the extent of the investigation area. This created a theme that covered the entire investigation area, and assigned a bioregion to all areas of public and private land. This theme will be referred to as '**metparc_bioreg100.shp'** in the remainder of this document. As the bioregion Highlands – Northern Fall represented a very small area on the fringe of the investigation area, these polygons were reclassified as Highlands – Southern Fall so that the biodiversity values could be considered as part of the larger Kinglake National Park land unit.

Fauna

Records of fauna within the investigation area were obtained from the Atlas of Victorian Wildlife (AVW). The AVW incorporates data from various sources including faunal surveys conducted by the State of Victoria Department of Sustainability and Environment (DSE), professional zoological consultants, field naturalist groups and incidental sightings by members of the general public, along with Museum of Victoria specimens. FAUNA100 is a geographically-registered, relational database of the AVW containing data on the distribution of faunal species within the State of Victoria administered by the DSE. This dataset is a point layer, but the points can represent data at various accuracies depending on data source though generally 100m accuracy is achieved. A subset of this database containing records for Cats, Dogs and Red Foxes was used to calculate predation pressure within the different sites on public land.

The AVW data was supplemented by additional data sources held for specific purposes by other custodians. These include the Melbourne Water Frog Census records (2002-2007); Butterfly records from Melbourne Museum's Bioinformatics database; fish records from DSE's Aquatic Fauna database; and the Birds Australia Bird Atlas.

Flora

Records of flora within the investigation area were obtained from the Victorian Flora Information System (FIS). The FIS contains records of floral species, sub-species, varieties, forms, hybrids and undescribed taxa of plants (vascular and non-vascular) gathered from ecological surveys carried out by the DSE, herbarium specimens, professional botanical consultants, competent field naturalists and botanical literature. Also administered by the DSE, FLORA100 is a spatially-referenced, relational database of the FIS containing data on the distribution of floristic records across the State of Victoria. This dataset is a point layer, but the points can represent data at various accuracies depending on data source though generally 100m accuracy is achieved. A subset of this database containing introduced species was used to calculate the weed pressure within the different sites of public land.

Data for Fungi, Mosses, Lichens, Liverworts and Hornworts were obtained from the Royal Botanic Gardens Melbourne MELISR database. These records provide additional floristic information to supplement the information contained in the FIS database.

Threatened Fauna and Flora

Subsets of both the AVW and the FIS are available from the DSE that contain records pertaining to the distribution of Victorian Rare or Threatened Species (THFAU100 and THFLO100 respectively). Both the threatened flora and fauna datasets contain only those species defined in the DSE Threatened Species Advisory Lists, or listed under the Victorian *Flora and Fauna Guarantee Act 1988* (FFG Act) or the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* (the EPBC Act).

Native Vegetation

Spatial datasets describing the extent of native vegetation types in Victoria are managed by the DSE. Ecological Vegetation Classes (EVCs) are the standard unit for classifying vegetation types in Victoria. Native vegetation is classified through a combination of floristics, life forms and ecological characteristics, and through an inferred fidelity to particular environmental attributes. Each EVC includes a collection of floristic communities that occur across a biogeographic range and have similar habitat and ecological processes operating. Mapping of the current extent of native vegetation across Victoria was recently revised by the DSE, and the bioregional conservation status of each EVC updated. Previous mapping had been done using a variety of subjective techniques at different times over the last decade whereas the new approach takes advantage of advances in Geographic Information Systems by using time-series satellite imagery to model the current extent of native vegetation. As EVC coverages differ between the old (EVC100) and new (NV2005_EVCBCS) datasets, both were used to map the extent of native vegetation within the investigation area. The new EVC data source (NV2005_EVCBCS) is contained within vector polygons that are mapped at a scale of 1:100,000. The old EVC data source (EVC100) is contained within vector polygons that are mapped at a scale of 1:25,000 for most of the investigation area, and at 1:100,000 for the remainder of the area.

The Bioregional Conservation Status of EVCs was calculated from the NV2005_EXTENT, and NV19750_EVC themes. Therefore the Bioregional Conservation Status was not considered to be applicable to the superseded EVC100 database. The EVC100 database was summarised on its own merit, as it is considered to better represent remnant vegetation in some of the urban areas due to the methodologies used to create the different layers.

Planning Zone

Planning zones in Victoria are designated by individual Local Government Areas (LGAs) and on a weekly basis are compiled into a statewide database held by Department of Sustainability and Environment. This database contains polygon features representing different planning schemes, which can vary in their level of complexity between LGAs. This layer is mapped at 1:25,000 and its spatial accuracy is verified against the Vicmap Property database. The subset of this database used for this analysis were those records with values of "Residential" for the field Plan_cod_1.

Roads

The road network within the investigation area has been mapped at 1:25,000 (TR_ROAD25) and is held by Department of Sustainability and Environment. This dataset contains all road features digitized as polyline features representing the centre of the roadway.

DATA SCREENING

All spatial data were extracted from their respective sources in May 2009 and entered into ArcGIS (*ESRI, Inc., USA*). All data were viewed in geographic co-ordinates (e.g. lat/long), however polygon datasets (i.e. EVCs) were projected into an Albers Equal-Area Conical projection when determining the area of their extent. Flora and fauna records were filtered to ensure a minimum standard for all records. Only records of fauna and flora occurring after 1985 were used for analysis to ensure that the species lists compiled were based on recent information, rather than historical records. Records where the date of observation was missing were deleted from the dataset before analysis, as were any duplicate records. Other records that were omitted from analysis were those where the location was obviously incorrect (e.g. terrestrial species occurring in marine environments), and those of non-native species that were introduced after initial European settlement (with the exception of cats *Felis catus*, dogs *Canis lupis* and red foxes *Vulpes vulpes*) based on data about species' origin that are contained within both the AVW and FIS lookup tables Faunaspp_lut.dbf and Floraspp_lut.dbf.

DATA MANIPULATION

Bioregional species lists of flora and fauna were generated by assigning the point datasets (FAUNA100 and FLORA100) to a bioregion (VBIOREG100) by spatial join. Data were exported to MS Excel (*Microsoft Inc. USA*) and pivot tables were then used to summarise both the number of records, and the year of the most recent record, for each species per bioregion. Similarly, bioregional lists of threatened flora and fauna species (THFLO100 and THFAU100) were compiled; however threatened flora and fauna records were first assigned to a single land use unit (**'metparc_bioreg100.shp'**) so that the number of records, and year of most recent record, of each threatened species could be reported grouped by land unit type and bioregion. Assigning species records to land units also allowed the summary of the number of threatened species occurring within Conservation Reserved Public Land, Other Public Land and Private Land.

Due to potential duplication of some records between of the additional data sources with records in the AVW database and FIS database, each data sources was analysed separately to determine species recorded within the parcels of public land (‘**metparc_bioreg100.shp’**). However, the data were combined and summarised together to compile ‘**ARCUE_Appendix17_SummaryBiodivThreats_summarisefortext_20090702.xls’**

The extents of both of the EVC data layers (EVC100 and NV2005_EVCBCS) were separately overlaid with the extents of the land unit layer (‘**metparc_bio100reg.shp’**) using a union geoprocessing operation. The extent of each EVC type occurring within each land-unit within each bioregion could then be summarised using pivot tables. The total extent of each EVC type occurring within each bioregion was reported to allow comparison with the proportion of each EVC-bioregion combination occurring within a particular land-unit. The extent of each EVC-bioregion combination occurring within or outside of public reserves and other public land was determined, along with the number of land-units containing that EVC-bioregion combination.

A summary of the ecological content of each land-unit parcel was compiled by consolidating data contained in the pivot tables previously created for summarising flora, fauna and EVC data. Land-units were first grouped bioregion, then the number of threatened flora and fauna species and different EVC types (from both EVC data sources) contained within that land-unit were determined. Finally the total extent of each land-unit was determined along with the extent of which was native vegetation (again using both EVC data sources). As this was a desktop study, we were restricted to characterising biodiversity in terms of existing data sets. Sites were considered to have biodiversity value if they contained any records of indigenous flora, indigenous fauna, butterflies, fungi, cryptograms or EVCs from either EVC data source. This provided the broadest definition of “biodiversity value” possible, to ensure that the widest range of sites with potential biodiversity were identified for more detailed analysis by VEAC.

Equivalent analyses were conducted to calculate the threats to each site, by substituting the biodiversity layer with a threat layer. The Perimeter to Area Ratio of the sites of public land were calculated based on the polygons in ‘metparcv22vg94_vicroads_20090515_arcue.shp’, as this provided a more realistic definition of patch size compared to the somewhat artificial polygons created by intersecting the VBIOREG100 theme- which occasionally split polygons where they were located at the boundary of two or more bioregions. As this was a desktop study, we were limited to quantifying threats using simple measures and existing spatial data sources. The following ten measures represent many of the general threats identified in Chapter 2.

Reserve System. The formal designation of the Land Unit as a reserve serves to protect that Land Unit from future changes to the purpose that land is used for. Therefore, sites which are not conservation reserved are potentially at risk of changes to the land-cover and land-use of that site.

Edge Effects. Small sites and linear sites that are long and narrow are most likely to experience disturbances associated with edge effects. Edge effects are changes in species composition, physical conditions or other ecological factors at the boundary between two ecosystems. The Perimeter to Area Ratio (P/A) of the site is an indication of the shape of the site, with very large values of the ratio indicating long, narrow, linear sites. Sites with a Perimeter to Area Ratio of more than 0.5 are considered to be at a high risk from edge effects. Sites with a Perimeter to Area Ratio of 0.25-0.50 were considered to be at moderate risk, and sites with a Perimeter to Area Ratio of less than 0.25 were considered to be at low risk.

Introduced Plant Species. Introduced plant species and other weeds have the potential of changing the ecological value of a site through competition, exclusion and other degrading processes. The risk posed by weed species at a site has been measured as the proportion of introduced plant species recorded at the site (FLORA100, Department of Sustainability and Environment). Sites with more than 50% introduced species where considered to be at high risk from the effects of weeds. Sites with 25-50% introduced species were considered to be at moderate risk, and sites with 0-25% introduced species were considered to be at low risk.

Human Presence. Human use of a site is often accompanied by impacts such as trampling, dumping of rubbish and green waste, and the arrival of new plant species. The intensity of human use at a site was calculated as the proportion of a 100 m buffer around the site that is comprised of residential planning zone. Sites where more than 50% of the area within the surrounding 100 m of the site consisted of Residential Planning Zone land were considered to be at the highest risk from visitation from humans and the disturbances associated with their use of the site. Sites where 25-50% of the area within the surrounding 100 m of the site consisted of Residential Planning Zone land were considered to be at moderate risk, and sites with 0-25% were considered to be at low risk.

Proximity to Major Road. A study of native grassland patches in the investigation area found that grassland sites close to major roads were more likely to be destroyed than sites located at a greater distance from major roads (Williams *et al.* 2005a). The likelihood of sites being destroyed was measured by the presence of freeways, highways or arterial roads within a 500 m buffer of the site. Sites that are not conservation reserved, and have a major road within 500 m of the site were considered to be potentially at a relatively high risk of changes to the land-cover and land-use of that site. Sites were designated as “High Risk” if they contained a major road within 500m of the site, as they were considered to be at relatively high risk of other changes to the site associated with being in proximity to major roads (such as reduced opportunities for prescription burning). Sites without a major road within the surrounding 500 m were designated as “Low Risk”.

Urban Effects. Changes to the landscape associated with urbanisation often result in changes to the site through the heat island effect, pollution, changes in moisture availability and other impacts. The density of roads is a commonly used measure of urbanisation that can provide an index of urbanisation for a site (McDonnell and Hahs 2008; McIntyre *et al.* 2000). In this investigation, the density of all roads from freeways to 4WD tracks was calculated for a 500 m buffer around each site. Sites with a density of roads of more than 0.01 m/m^2 were considered to be the most urban, and therefore at highest risk from disturbances associated with urban land-use in the surrounding landscape. Sites with a density of roads between 0.005-0.01 m/m^2 were considered to be at moderate risk from urban effects, and sites with a density of roads less than 0.005 m/m^2 were considered to be at relatively low risk.

Predation. Predation by cats, dogs and foxes has the potential to create a large impact on populations of native animals. In urban areas the large availability of supplemental water and food sources, as well as the large number of households with pets, contributes to potentially high populations of these introduced predators. Within the investigation area, most sites are likely to experience some level of predation. However to identify sites where predation is potentially a major threat, we have calculated the number of records of cats, dogs and foxes within each site based on the data in the FAUNA100 database (Department of Sustainability and Environment 2008). Any sites where one of these predators has been observed and formally recorded is considered to be highly likely to be at risk from predation pressure. All other sites are considered to have a possible risk of predation.

Internal Fragmentation. The presence of roads within a site may affect biodiversity through mortality associated with vehicle collisions, noise and chemical pollution from the traffic, and internal edge effects (van der Ree 2009). The greater the density of roads within a site, the greater the area of the site that is likely to experience these effects. The density of roads (freeways to 4WD tracks) within each site was calculated, and sites with a density of roads greater than 0.01 m/m^2 were considered to have a high risk of disturbances associated with internal fragmentation. Sites with a density of roads between 0.005-0.01 m/m^2 were considered to be at moderate risk from urban effects, and sites with a density of roads less than 0.005 m/m^2 were considered to be at relatively low risk.

Proposed roads. Similar to the risk associated with the proximity of major roads, those sites which are traversed by a proposed road are likely to be affected by the construction process and change in land-cover that eventuates when the proposed road is finally built. Any site which had a proposed road through the site is considered to be at high risk of experiencing the land-cover change and other disturbances associated with the construction of the new road. Sites without a proposed road through the site were considered to be at low risk.

GAPS AND BIASES

The information on biodiversity presented within this report is based on a desktop study conducted using existing data sources. The information is therefore only as good as the data sources that were available at the time of the investigation. When the spatial coordinates for the survey information are not accurate enough, the records may not fall within the parcels of land investigated here. This is particularly relevant to small linear parcels of land, but also includes some larger parcels such as Bradshaw Reserve in Parkdale ([Multipno] = P360750), where the records in the FLORA100 database fall just outside the reserve boundary. Similarly, some parcels of land may not have had a biodiversity survey associated with them, and therefore their biodiversity values will not be captured by the existing data sources.

Estimating the number of land parcels that have been missed due to these biases has not been undertaken. Efforts have been made to minimise these gaps by: 1) including the superceded EVC100 layer in this analysis; 2) combining fauna data from multiple sources, including Birds Australia, Melbourne Museum, Melbourne Water Frog Census, and the DSE Aquatic Fauna databases; and 3) using the most up to date versions of each dataset. While it may have been possible to identify duplicate records in between the FAUNA100 database and the data from Melbourne Museum, Melbourne Water and DSE Aquatic fauna, the Birds Australia data contained over 300,000 records and could not be quickly reconciled with the FAUNA100 database. Therefore, each database was analysed separately, and then pooled to create the database: VEAC_Indigfauna_Metparcbio100_combineddatasources.xlsx. For this reason, the number of records reported for a species may be artificially inflated due to potential duplication of records between databases.

The methods used to provide a LUNAME for each parcel also contributes to a potential bias within the investigation. Some of the LUNAME_arc labels do not correspond with commonly used terms to describe a site. For example, Brens Drive in Royal Park is a well documented remnant patch of *Eucalyptus camaldulensis* woodland, but in the current database it is labelled as "Manningham unknown". Similarly, some of the LUNAME_arc's are non-descriptive but very frequently used e.g. "VM CL Parcels". Due to the methods used to summarise biodiversity at a site level using the LUNAME_arc field to define the site, some of the LUNAME_arc classes represent very generic land uses, where the biodiversity is associated with only a handful of parcels within that LUNAME_arc. An example of where this occurs is in a parcel of Melbourne Water land 500 m south of Mt Derrimut Grassland Conservation Reserve in Derrimut ([Multipno] = Q008313) used as a drainage line. This parcel of land is a good quality example of Creekline Tussock Grassland vegetation (EVC 654) containing a number of regionally rare herb species (Nick Williams, personal communication). However, the scale at which the EVC layers have been mapped are too coarse to capture this area of important vegetation. In addition, this parcel of land will not be directly identifiable from the other parcels with the LUNAME_arc "Melbourne WaterWater and sewerage servicesServices and Utilities" in the current investigation. For this reason, additional work will be required when examining the distribution of biodiversity values within the sites where the LUNAME_arc field is a generic term, and also for sites where there may be multiple names used to label the site.

An additional characteristic of the data to be aware of is that due to the way that two themes were unioned to create the '**metparc_bioreg100.shp'**, some sites may be present in more than one bioregion. For example, the majority of Bundoora Park is within the Victorian Volcanic Plains bioregion, but also contains some areas within the Gippsland Plain bioregion. This is something to be aware of when considering the full biodiversity value of the site, as it may mean that information for that site is held under two (or potentially more) bioregions.

Appendix 2. Ecological Vegetation Classes (EVCs) within the Metropolitan Melbourne Investigation Area

Table 1. Area (hectares) of EVC in three categories of land tenure within the Investigation Area.

EVC	Conservation Reserved Public Land	Other Public Land	Private Land	Total Area EVC (ha)
Aquatic Herbland	26.1	29.7	11.6	67.4
Berm Grassy Shrubland	0.0	4.3	8.9	13.2
Blackthorn Scrub	11.7	0.2	0.4	12.3
Box Ironbark Forest	387.9	667.3	1493.0	2548.3
Brackish Grassland	0.0	39.5	8.6	48.1
Brackish Lake Aggregate	0.0	10.5	1.8	12.4
Brackish Wetland	0.0	45.2	2.3	47.5
Cane Grass Wetland	0.0	14.0	138.1	152.1
Clay Heathland/Wet Heathland/Riparian Scrub Mosaic	1365.0	24.0	250.3	1639.3
Coast Banksia Woodland	0.0	3.1	1.7	4.7
Coast Banksia Woodland/Coastal Dune Scrub Mosaic	0.0	43.3	3.7	47.1
Coast Banksia Woodland/Swamp Scrub Mosaic	0.0	26.8	9.1	35.9
Coastal Alkaline Scrub	22.1	37.4	1.7	61.2
Coastal Dune Scrub	0.0	7.8	0.9	8.7
Coastal Dune Scrub/Coastal Dune Grassland Mosaic	0.0	12.5	0.4	12.9
Coastal Headland Scrub	0.0	0.7	0.7	1.4
Coastal Headland Scrub/Coast Banksia Woodland Mosaic	0.0	54.7	5.0	59.6
Coastal Saltmarsh	409.3	1036.9	490.4	1936.6
Coastal Saltmarsh/Coastal Dune Grassland/Coastal Dune Scrub/Coastal Headland Scrub Mosaic	0.0	5.1	0.5	5.6
Coastal Saltmarsh/Mangrove Shrubland Mosaic	12.3	118.8	26.0	157.2
Cool Temperate Rainforest	181.8	68.1	0.1	250.0
Creekline Grassy Woodland	15.1	110.4	415.9	541.3
Creekline Herb-rich Woodland	66.3	242.0	1955.2	2263.5
Damp Forest	5239.4	1612.9	4233.0	11085.3
Damp Heathy Woodland	2654.0	767.5	1750.1	5171.6
Damp Sands Herb-rich Woodland	3.6	36.9	41.5	82.0
Damp Sands Herb-rich Woodland/Heathy Woodland Complex	0.0	0.4	2.9	3.4
Damp Sands Herb-rich Woodland/Heathy Woodland Mosaic	16.6	15.9	66.8	99.3
Escarpment Shrubland	56.4	343.7	476.6	876.7

EVC	Conservation Reserved Public Land	Other Public Land	Private Land	Total Area EVC (ha)
Estuarine Flats Grassland	6.9	27.5	56.0	90.4
Estuarine Wetland/Estuarine Swamp Scrub Mosaic	0.0	6.6	12.8	19.4
Floodplain Riparian Woodland	22.2	486.4	793.7	1302.2
Floodplain Wetland Aggregate	0.0	18.5	19.6	38.1
Granitic Hills Woodland	0.0	0.0	27.2	27.2
Grassy Dry Forest	917.0	1971.8	10231.0	13119.7
Grassy Forest	187.5	448.2	1961.3	2597.0
Grassy Riverine Forest	0.0	15.0	34.7	49.8
Grassy Woodland	94.5	596.7	3458.3	4149.5
Grassy Woodland/Damp Sands Herb-rich Woodland Mosaic	2.8	1.8	11.0	15.5
Grey Clay Drainage-line Aggregate	41.6	5.6	77.9	125.1
Gully Woodland	75.9	63.6	189.9	329.5
Heathy Dry Forest	2402.5	578.5	627.3	3608.4
Heathy Woodland	330.7	464.3	2608.0	3403.0
Heathy Woodland/Sand Heathland Mosaic	<0.1	1.5	6.9	8.4
Herb-rich Foothill Forest	2425.6	1606.3	4956.2	8988.1
Hills Herb-rich Woodland	20.1	407.7	302.7	730.4
Lignum Swamp	0.0	0.0	17.3	17.3
Lowland Forest	2818.6	1391.8	7301.9	11512.3
Mangrove Shrubland	25.4	119.5	11.9	156.8
Mangrove Shrubland/Coastal Saltmarsh/Berm Grassy Shrubland/Estuarine Flats Grassland Mosaic	27.9	10.7	0.4	39.0
Plains Grassland	587.9	1155.0	21201.6	22944.5
Plains Grassland/Plains Grassy Woodland Mosaic	0.0	98.2	946.3	1044.5
Plains Grassy Wetland	8.8	188.8	419.8	617.3
Plains Grassy Woodland	225.7	1216.5	6036.5	7478.7
Plains Grassy Woodland/Swamp Scrub/Plains Grassy Wetland Mosaic	0.0	13.0	23.2	36.1
Plains Sedgy Wetland	0.0	25.8	95.4	121.2
Plains Woodland/Plains Grassland Mosaic	28.3	71.0	904.3	1003.7
Red Gum Swamp	0.0	0.0	15.4	15.4
Reed Swamp	0.0	0.7	4.0	4.7
Riparian Forest	1131.3	1038.0	1782.4	3951.7
Riparian Scrub	7.7	32.7	117.1	157.5
Riparian Scrub/Swampy Riparian Woodland Complex	22.4	97.5	937.0	1056.8
Riparian Thicket	9.7	49.9	333.8	393.4
Riparian Woodland	4.3	57.0	147.8	209.2
Rocky Chenopod Woodland	7.9	5.8	20.8	34.5
Sand Heathland	65.2	10.2	31.3	106.7
Scoria Cone Woodland	0.0	0.0	9.2	9.2
Sedgy Swamp Woodland	0.0	0.0	1.0	1.0
Shrubby Dry Forest	115.0	1.4	0.1	116.5
Shrubby Foothill Forest	1364.1	415.1	2462.0	4241.2
Stream Bank Shrubland	43.5	129.7	610.0	783.2

EVC	Conservation Reserved Public Land	Other Public Land	Private Land	Total Area EVC (ha)
Swamp Scrub	54.0	317.5	2182.6	2554.1
Swamp Scrub/Plains Grassy Forest Mosaic	0.0	0.0	9.7	9.7
Swampy Riparian Complex	43.5	213.1	2524.6	2781.2
Swampy Riparian Woodland	126.1	691.3	1032.4	1849.8
Swampy Riparian Woodland/Swamp Scrub Mosaic	0.0	104.9	86.5	191.4
Swampy Woodland	33.2	447.6	1393.0	1873.7
Valley Grassy Forest	819.6	811.7	6248.2	7879.4
Valley Grassy Forest/Herb-rich Foothill Forest Complex	0.0	0.1	53.7	53.8
Valley Heathy Forest	5.3	332.0	758.2	1095.6
Wet Forest	2869.9	1500.5	883.1	5253.5
Wet Verge Sedgeland	0.0	0.1	0.9	1.0
Wetland Formation	15.0	0.1	16.2	31.2
Grand Total	27455.0	22626.8	95391.6	145473.4

Data source: 'Native Vegetation - Modelled 2005 Ecological Vegetation Classes (with Bioregional Conservation Status)'.

Table 2. Area (hectares) of EVCs within the Central Victorian Upland bioregion within the Investigation Area.

EVC	EVC Threatened Status	Conservation Reserved Public Land	Other Public Land	Private Land	Total Area EVC (ha)
Box Ironbark Forest	Vulnerable	374.7	251.2	439.3	1065.2
Creekline Grassy Woodland	Endangered	0.0	29.9	6.2	36.1
Escarpment Shrubland	Endangered	0.0	0.1	34.7	34.8
Granitic Hills Woodland	Depleted	0.0	0.0	26.5	26.5
Grassy Dry Forest	Depleted	39.0	18.2	162.5	219.7
Grassy Woodland	Endangered	0.0	83.7	631.4	715.1
Heathy Dry Forest	Least Concern	152.9	5.2	43.4	201.5
Hills Herb-rich Woodland	Vulnerable	20.1	386.3	278.2	684.5
Plains Grassland	Endangered	0.0	0.0	1.2	1.2
Plains Grassy Wetland	Endangered	0.0	0.0	2.9	2.9
Plains Grassy Woodland	Endangered	0.9	1.5	88.4	90.9
Plains Woodland/Plains Grassland Mosaic	Endangered	<0.1	0.0	9.9	9.9
Riparian Woodland	Endangered	0.1	0.9	77.5	78.5
Rocky Chenopod Woodland	Vulnerable	5.0	0.0	0.0	5.0
Shrubby Dry Forest	Least Concern	115.0	1.4	0.1	116.5
Shrubby Foothill Forest	Least Concern	11.0	0.0	0.4	11.4
Stream Bank Shrubland	Vulnerable	5.8	27.9	202.6	236.2
Valley Grassy Forest	Vulnerable	0.0	0.0	17.7	17.7

Data source: 'Native Vegetation - Modelled 2005 Ecological Vegetation Classes (with Bioregional Conservation Status)'. © The State of Victoria, Department of Sustainability and Environment.

Table 3. Area (hectares) of EVCs within the Gippsland Plain bioregion within the Investigation Area.

EVC	EVC Threatened Status	Conservation Reserved Public Land	Other Public Land	Private Land	Total Area EVC (ha)
Berm Grassy Shrubland	Endangered	0.0	4.3	8.9	13.2
Box Ironbark Forest	Vulnerable	0.0	10.4	4.2	14.6
Brackish Grassland	Endangered	0.0	39.0	8.4	47.4
Brackish Lake Aggregate	Rare	0.0	10.5	1.8	12.4
Brackish Wetland	Endangered	0.0	45.2	2.3	47.5
Clay Heathland/Wet Heathland/Riparian Scrub Mosaic	Depleted	0.0	2.2	60.3	62.5
Coast Banksia Woodland	Vulnerable	0.0	3.1	1.7	4.7
Coast Banksia Woodland/Coastal Dune Scrub Mosaic	Vulnerable	0.0	40.4	3.0	43.4
Coast Banksia Woodland/Swamp Scrub Mosaic	Vulnerable	0.0	26.8	9.1	35.9
Coastal Dune Scrub	Depleted	0.0	7.8	0.9	8.7
Coastal Dune Scrub/Coastal Dune Grassland Mosaic	Depleted	0.0	12.5	0.4	12.9
Coastal Headland Scrub	Depleted	0.0	0.7	0.7	1.4
Coastal Headland Scrub/Coast Banksia Woodland Mosaic	Vulnerable	0.0	54.7	5.0	59.6
Coastal Saltmarsh	Least Concern	86.5	462.5	270.3	819.4
Coastal Saltmarsh/Coastal Dune Grassland/Coastal Dune Scrub/Coastal Headland Scrub Mosaic	Endangered	0.0	0.4	0.0	0.4
Coastal Saltmarsh/Mangrove Shrubland Mosaic	Vulnerable	12.3	90.5	21.3	124.1
Creekline Grassy Woodland	Endangered	12.2	16.6	19.4	48.2
Creekline Herb-rich Woodland	Endangered	0.0	0.4	1.6	1.9
Damp Forest	Endangered	0.0	1.8	23.2	25.0
Damp Heathy Woodland	Vulnerable	0.6	4.7	66.3	71.5
Damp Sands Herb-rich Woodland	Vulnerable	3.6	36.9	41.5	82.0
Damp Sands Herb-rich Woodland/Heathy Woodland Complex	Vulnerable	0.0	0.4	2.9	3.4
Damp Sands Herb-rich Woodland/Heathy Woodland Mosaic	Vulnerable	16.6	15.9	66.8	99.3
Escarpment Shrubland	Endangered	0.0	12.2	12.0	24.2
Estuarine Flats Grassland	Endangered	6.9	27.5	56.0	90.4
Estuarine Wetland/Estuarine Swamp Scrub Mosaic	Depleted	0.0	6.6	12.8	19.4
Floodplain Riparian Woodland	Endangered	0.0	281.6	350.8	632.4
Floodplain Wetland Aggregate	Endangered	0.0	18.5	19.6	38.1
Grassy Dry Forest	Least Concern	5.7	3.5	19.8	29.0

Grassy Forest	Endangered	10.9	10.3	175.0	196.1
Grassy Woodland	Endangered	67.8	319.7	1957.7	2345.2
Grassy Woodland/Damp Sands Herb-rich Woodland Mosaic	Endangered	2.8	1.8	11.0	15.5
Gully Woodland	Endangered	0.0	<0.1	3.3	3.3
Heathy Woodland	Least Concern	330.7	464.3	2608.0	3403.0
Heathy Woodland/Sand Heathland Mosaic	Least Concern	<0.1	1.5	6.9	8.4
Herb-rich Foothill Forest	Vulnerable	1.9	4.3	47.9	54.1
Lowland Forest	Vulnerable	1.4	13.2	655.3	669.9
Mangrove Shrubland	Least Concern	25.4	109.3	8.5	143.2
Plains Grassland	Endangered	0.0	<0.1	0.2	0.2
Plains Grassland/Plains Grassy Woodland Mosaic	Endangered	0.0	93.0	940.2	1033.3
Plains Grassy Wetland	Endangered	8.7	162.1	126.5	297.3
Plains Grassy Woodland	Endangered	111.4	172.0	358.9	642.4
Plains Grassy Woodland/Swamp Scrub/Plains Grassy Wetland Mosaic	Endangered	0.0	13.0	23.2	36.1
Reed Swamp	Endangered	0.0	0.7	4.0	4.7
Riparian Forest	Vulnerable	1.4	48.2	93.9	143.5
Riparian Scrub	Vulnerable	7.7	26.5	47.7	81.9
Riparian Scrub/Swampy Riparian Woodland Complex	Vulnerable	0.0	1.3	3.8	5.0
Riparian Thicket	Vulnerable	0.0	<0.1	0.4	0.4
Riparian Woodland	Endangered	0.0	36.5	6.6	43.1
Sand Heathland	Rare	65.2	10.2	31.3	106.7
Sedgy Swamp Woodland	Endangered	0.0	0.0	1.0	1.0
Swamp Scrub	Endangered	54.0	271.2	2074.2	2399.3
Swamp Scrub/Plains Grassy Forest Mosaic	Endangered	0.0	0.0	9.7	9.7
Swampy Riparian Complex	Endangered	0.3	25.8	107.3	133.4
Swampy Riparian Woodland	Endangered	45.1	511.7	862.7	1419.5
Swampy Riparian Woodland/Swamp Scrub Mosaic	Endangered	0.0	104.9	85.9	190.8
Swampy Woodland	Endangered	29.4	422.0	1177.7	1629.1
Valley Grassy Forest	Vulnerable	0.6	12.3	40.9	53.8
Valley Grassy Forest/Herb-rich Foothill Forest Complex	Vulnerable	0.0	0.1	25.2	25.2
Valley Heathy Forest	Endangered	2.9	326.9	699.7	1029.5
Wet Forest	Depleted	0.0	2.4	<0.1	2.4
Wetland Formation	Endangered	0.0	0.0	11.4	11.4

Data source: 'Native Vegetation - Modelled 2005 Ecological Vegetation Classes (with Bioregional Conservation Status)'.

Table 4. Area (hectares) of EVCs within the Highlands Southern Fall bioregion within the Investigation Area.

EVC	EVC Threatened Status	Conservation Reserved Public Land	Other Public Land	Private Land	Total Area EVC (ha)
Blackthorn Scrub	Least Concern	11.7	0.2	0.4	12.3
Box Ironbark Forest	Vulnerable	13.2	313.4	760.7	1087.3
Clay Heathland/Wet Heathland/Riparian Scrub Mosaic	Depleted	1365.0	21.8	190.0	1576.8
Cool Temperate Rainforest	Endangered	181.8	68.1	0.1	250.0
Creekline Grassy Woodland	Endangered	0.0	0.7	3.3	4.1
Creekline Herb-rich Woodland	Vulnerable	66.3	230.0	1951.7	2248.0
Damp Forest	Least Concern	5239.4	1611.1	4209.7	11060.3
Damp Heathy Woodland	Depleted	2653.4	762.9	1683.8	5100.1
Escarpment Shrubland	Endangered	9.4	159.0	47.7	216.1
Floodplain Riparian Woodland	Endangered	14.2	4.2	99.2	117.6
Grassy Dry Forest	Least Concern	872.3	1918.2	9748.8	12539.3
Grassy Forest	Vulnerable	176.6	437.9	1786.3	2400.9
Grassy Riverine Forest	Not Applicable	0.0	13.3	17.8	31.1
Grassy Woodland	Depleted	11.4	146.0	304.9	462.3
Gully Woodland	Vulnerable	75.9	63.6	186.6	326.2
Heathy Dry Forest	Least Concern	2249.4	536.1	443.0	3228.5
Herb-rich Foothill Forest	Least Concern	2423.7	1602.0	4908.3	8934.0
Lowland Forest	Least Concern	2817.2	1378.6	6646.6	10842.4
Plains Grassland/Plains Grassy Woodland Mosaic	Endangered	0.0	<0.1	2.3	2.3
Plains Grassy Woodland	Endangered	1.7	152.4	172.7	326.9
Riparian Forest	Least Concern	1129.9	989.8	1688.5	3808.2
Riparian Scrub/Swampy Riparian Woodland Complex	Vulnerable	20.0	90.7	892.2	1002.9
Riparian Thicket	Vulnerable	9.7	49.9	333.4	393.0
Shrubby Foothill Forest	Least Concern	1353.2	415.1	2460.1	4228.4
Swamp Scrub	Endangered	0.0	46.4	106.5	152.9
Swampy Riparian Complex	Endangered	43.3	165.0	2390.2	2598.4
Swampy Riparian Woodland	Vulnerable	81.0	179.6	169.7	430.3
Swampy Riparian Woodland/Swamp Scrub Mosaic	Endangered	0.0	0.0	0.6	0.6
Swampy Woodland	Endangered	3.7	24.4	185.6	213.7
Valley Grassy Forest	Vulnerable	819.0	783.9	6117.9	7720.7
Valley Grassy Forest/Herb-rich Foothill Forest Complex	Vulnerable	0.0	0.0	28.6	28.6
Valley Heathy Forest	Vulnerable	2.5	5.1	58.6	66.1
Wet Forest	Least Concern	2869.9	1498.1	883.0	5251.1
Wetland Formation	Endangered	0.0	0.1	4.2	4.3

Data source: 'Native Vegetation - Modelled 2005 Ecological Vegetation Classes (with Bioregional Conservation Status)'.

Table 5. Area (hectares) of EVCs within the Highlands Otway Plain bioregion within the Investigation Area.

EVC	EVC Threatened Status	Conservation Reserved Public Land	Other Public Land	Private Land	Total Area EVC (ha)
Coastal Alkaline Scrub	Endangered	0.0	26.8	0.0	26.8
Coastal Saltmarsh	Endangered	0.0	52.6	22.5	75.1
Coastal Saltmarsh/Mangrove Shrubland Mosaic	Endangered	0.0	28.4	4.7	33.0
Creekline Grassy Woodland	Endangered	0.0	9.6	19.8	29.4
Floodplain Riparian Woodland	Endangered	0.0	74.9	68.6	143.5
Plains Grassland	Endangered	0.0	6.4	14.2	20.7
Plains Grassy Wetland	Endangered	0.0	0.0	<0.1	<0.1
Plains Grassy Woodland	Endangered	0.0	187.9	68.5	256.4
Plains Sedgy Wetland	Endangered	0.0	25.8	0.0	25.8

Data source: 'Native Vegetation - Modelled 2005 Ecological Vegetation Classes (with Bioregional Conservation Status)'.

Table 6. Area (hectares) of EVCs within the Victorian Volcanic Plain bioregion within the Investigation Area.

EVC	EVC Threatened Status	Conservation Reserved Public Land	Other Public Land	Private Land	Total Area EVC (ha)
Aquatic Herbland	Endangered	26.1	29.7	11.6	67.4
Box Ironbark Forest	Depleted	0.0	92.4	288.8	381.2
Brackish Grassland	Endangered	0.0	0.5	0.3	0.7
Cane Grass Wetland	Vulnerable	0.0	14.0	138.1	152.1
Coast Banksia Woodland/Coastal Dune Scrub Mosaic	Vulnerable	0.0	2.9	0.8	3.7
Coastal Alkaline Scrub	Endangered	22.1	10.6	1.7	34.4
Coastal Saltmarsh	Vulnerable	322.8	521.7	197.6	1042.1
Coastal Saltmarsh/Coastal Dune Grassland/Coastal Dune Scrub/Coastal Headland Scrub Mosaic	Endangered	0.0	4.7	0.5	5.2
Creekline Grassy Woodland	Endangered	2.9	53.4	367.2	423.5
Creekline Herb-rich Woodland	Endangered	0.0	11.6	1.9	13.5
Damp Sands Herb-rich Woodland	Vulnerable	0.0	0.0	<0.1	<0.1
Escarpment Shrubland	Endangered	47.0	172.4	382.2	601.6
Floodplain Riparian Woodland	Endangered	8.0	125.8	275.1	408.8
Granitic Hills Woodland	Endangered	0.0	0.0	0.7	0.7
Grassy Dry Forest	Depleted	0.0	31.9	299.9	331.7
Grassy Riverine Forest	Not Applicable	0.0	1.7	17.0	18.7
Grassy Woodland	Endangered	15.2	47.3	564.3	626.8
Grey Clay Drainage-line Aggregate	Endangered	41.6	5.6	77.9	125.1
Heathy Dry Forest	Least Concern	0.2	37.2	140.9	178.3
Hills Herb-rich Woodland	Vulnerable	<0.1	21.4	24.5	45.9
Lignum Swamp	Endangered	0.0	0.0	17.3	17.3
Mangrove Shrubland	Vulnerable	0.0	10.2	3.4	13.6
Mangrove Shrubland/Coastal Saltmarsh/Berm Grassy Shrubland/Estuarine Flats Grassland Mosaic	Endangered	27.9	10.7	0.4	39.0
Plains Grassland	Endangered	587.9	1148.5	21186.0	22922.4
Plains Grassland/Plains Grassy Woodland Mosaic	Endangered	0.0	5.1	3.8	8.9
Plains Grassy Wetland	Endangered	<0.1	26.7	290.5	317.2
Plains Grassy Woodland	Endangered	111.6	702.6	5348.0	6162.2
Plains Sedgy Wetland	Endangered	0.0	0.0	95.4	95.4

Plains Woodland/Plains Grassland Mosaic	Endangered	28.3	71.0	894.4	993.8
Red Gum Swamp	Endangered	0.0	0.0	15.4	15.4
Riparian Scrub	Endangered	0.0	6.2	69.4	75.6
Riparian Scrub/Swampy Riparian Woodland Complex	Endangered	2.4	5.5	41.0	48.8
Riparian Woodland	Endangered	4.3	19.6	63.7	87.6
Rocky Chenopod Woodland	Vulnerable	3.0	5.8	20.8	29.5
Scoria Cone Woodland	Endangered	0.0	0.0	9.2	9.2
Shrubby Foothill Forest	Depleted	0.0	0.0	1.5	1.5
Stream Bank Shrubland	Endangered	37.7	101.9	407.4	547.0
Swamp Scrub	Endangered	0.0	<0.1	1.9	1.9
Swampy Riparian Complex	Endangered	0.0	22.3	27.1	49.4
Swampy Woodland	Endangered	0.0	1.2	29.7	30.9
Valley Grassy Forest	Vulnerable	0.0	15.5	71.7	87.2
Wet Verge Sedgeland	Endangered	0.0	0.1	0.9	1.0
Wetland Formation	Endangered	15.0	0.0	0.6	15.5

Data source: 'Native Vegetation - Modelled 2005 Ecological Vegetation Classes (with Bioregional Conservation Status)'.