Government of **Western Australia**
Department of **Water**

Baigup Reserve remediation and management plan

Looking after all our water needs

March 2010

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Prepared by Ecoscape (Australia) Pty Ltd

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Department of Water
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1 Introduction

1.1 Purpose

Baigup Reserve is one of the few remaining bushland areas on the Swan Estuary. It is recognised as a regionally significant bushland reserve through its listing as Bush Forever site 313. It also forms part of a regionally significant potential bushland/wetland linkage (**Figure 8**) and is included in Greenways 24 (Government of Western Australia 2000).

In 2006 the Department of Water was allocated funding to develop an action plan for remedial works at Baigup Reserve, which aimed to achieve the following:

1 Contain and treat ponded surface waters at the reserve

2 Determine the impact of discharging acidic groundwater to the Swan-Canning estuary

3 Implement a community awareness program communicating the current status of the reserve and the nearby estuary

4 Develop an environmental management and remediation plan

5 Implement and continue to assess the groundwater remediation plan.

In 2007 Ecoscape was commissioned to develop the environmental management and remediation plan in cooperation with the Department of Water, URS and CSIRO, which have conducted hydrogeological surveys and water quality sampling, and assessed acid sulfate soils and surface water and groundwater quality. Monitoring was conducted in the reserve, Bayswater catchment and immediate receiving environment (Swan River).

1.2 Study area location and extent

Baigup Reserve is located 6.5 km from Perth's central business district on the northern foreshore of the Swan River. It is approximately 1 km long (from Garrett Road Bridge in Bayswater to Kelvin Road in Maylands), 200 m wide, 15 ha leading back from the river and is bisected by a bicycle path.

shows the study area's location.

1.3 Land tenure and vesting

Baigup Reserve is currently reserved for parks and recreation under the Metropolitan Region Scheme 1963 and was created under the *Land Administration Act 1993* (WA) under the control of the Department of Planning. The remaining freehold land within the boundary (**Figure 9**) is owned by the Western Australian Planning Commission and is to be transferred to the State of Western Australia with the aim to establish a Crown reserve vested with the City of Bayswater (Regeneration Technology Pty Ltd 2004).

1.4 Background

Baigup Reserve once supported market gardens and remains the receiving point for drainage from the surrounding catchment, which includes roads and urban and industrial areas. Despite the multiple human impacts, the reserve is still considered an important wetland on the Swan River because it supports diverse wildlife species and is a summer refuge for migratory birds. The reserve is listed as Bush Forever site 313, identified as M51 under the System 6 classification, and listed in the *Directory of important wetlands in Australia*. It is also subject to protection under the *Environment Protection and Biodiversity Conservation Act 1999* (Cwlth).

The reserve has been the subject of many studies over the years, including a management plan by Regeneration Technology (1994) with input from a variety of stakeholders and community representatives. This plan was designed to guide the management and rehabilitation of the reserve to enable the City of Bayswater to take over the reserve's long-term management. In 2004, the City of Bayswater commissioned Regeneration Technology to update the 1994 management plan. The updated plan's purpose was to provide an 'umbrella' document to guide works within the reserve. In 2006, the North Metro Conservation Group undertook a Perth Biodiversity Project natural area assessment to identify vegetation communities and condition, fauna and other environmental aspects.

In conjunction with this remediation and management plan, the Department of Water, CSIRO and URS have undertaken additional works to determine the water quality at Baigup Reserve and whether actual acid sulfate soils are present and what impact they could have on the Swan River environment. These results and consequent recommendations have been included in this plan.

1.5 Reserve values

Baigup Reserve's previous management plans identified a number of environmental, cultural, landscape and recreational values. Some of these include:

- the diversity of habitat supporting a high diversity of fauna
- the historic use of the reserve as market gardens from the late 1800s until the 1970s
- it remains one of the few places along the Swan River that has retained its natural appearance and its landscape has not been significantly altered
- it provides a range of recreational opportunities due to its location and public accessibility.

2 Method

2.1 Ecoscape assessment

Desktop assessment

Two management plans have been written for Baigup Reserve along with additional environmental surveys for vegetation and water quality, which include management recommendations. This information has been reviewed and collated for inclusion in this remediation and management plan.

The following documents were reviewed as part of this plan:

- Regeneration Technology Pty Ltd 1994, *Baigup Wetland Reserve management plan 1994–1999*
- Regeneration Technology Pty Ltd 2004, *Baigup Wetland Reserve (incorporating Hinds Reserve) management plan 2004–2014*, prepared for the City of Bayswater
- North Metro Conservation Group 2006, *Baigup Reserve natural area initial desktop assessment and initial Field A assessment*, Perth Biodiversity Project
- City of Bayswater 2004, *Birds and reserves of the City of Bayswater*, Birds Australia Western Australia Inc
- Bading, R 2005, *Baigup Reserve acid sulfate soil material investigation report*, prepared for the Department of Environment, Swan River Trust and City of Bayswater
- Department of Environment 2005, *Fish kill – Baigup Reserve to Riverside Gardens, Bayswater*, unpublished report
- Department of Environment 2006, *Ecological impacts of acidic drainage from Baigup Reserve on the Swan River Estuary – preliminary investigations*, Department of Environment, Aquatic Branch
- Patterson, BM et al. 2007, *Baigup field assessment report series*, CSIRO
- URS 2008, *Baigup Reserve hydrogeological survey – soil and water quality sampling and hydrogeological conceptual modelling*, prepared for the Department of Water, Perth, Western Australia.
- Douglas, G, Patterson, B, Davis, G, Wendling, L, Coleman, S & Furness, A 2008, *Assessment of acid sulfate soils and surface water and groundwater quality at Baigup Reserve*, National Research Flagships, Water for a Healthy Country, CSIRO, Western Australia.

Field assessment

As part of the Perth Biodiversity Project, the North Metro Conservation Group (2006) mapped vegetation communities and condition. These were groundtruthed and updated where required by Ecoscape in 2008.

Vegetation communities

Vegetation was classified on the basis of vegetation structure according to methods used by Keighery (1994, adapted from Muir 1977 & Aplin 1979) (**Table 1** and **Figure 10**).

Table 1 Classification system used to describe vegetation structure (Keighery 1994)

Life form and height class	Canopy cover (%)			
	100 – 70	70 – 30	30 – 10	10 – 2
Trees over 30 m	Tall Closed Forest	Tall Open Forest	Tall Woodland	Tall Open Woodland
Trees 10–30 m	Closed Forest	Open Forest	Woodland	Open Woodland
Trees under 10 m	Low Closed Forest	Low Open Forest	Low Woodland	Low Open Woodland
Tree Mallee	Closed Tree Mallee	Tree Mallee	Open Tree Mallee	Very Open Tree Mallee
Shrub Mallee	Closed Shrub Mallee	Shrub Mallee	Open Shrub Mallee	Very Open Shrub Mallee
Shrubs over 2 m	Closed Tall Scrub	Tall Open Scrub	Tall Shrubland	Tall Open Shrubland
Shrubs 1 – 2 m	Closed Heath	Open Heath	Shrubland	Open Shrubland
Shrubs under 1 m	Closed Low Heath	Open Low Heath	Low Shrubland	Low Open Shrubland
Grasses	Closed Grassland	Grassland	Open Grassland	Very Open Grassland
Herbs	Closed Herbland	Herbland	Open Herbland	Very Open Herbland
Sedges	Closed Sedgeland	Sedgeland	Open Sedgeland	Very Open Sedgeland

Bushland condition

Bushland condition is a measure of the degree to which vegetation has been degraded. This measure is based on the proportion of weeds and the degree to which structure (i.e. height and density of vegetation layers) has been modified.

For bushland condition mapping, Ecoscape used the Keighery (1994) standardised scale shown in **Table 2** and **Figure 10**.

Table 2 Criteria used for bushland condition assessment (Keighery 1994)

Keighery condition scale (Keighery 1994)	Description
Pristine	No obvious signs of disturbance.
Excellent	Vegetation structure intact, disturbance only affecting individual species and weeds are non-aggressive species.
Very Good	Vegetation structure altered, obvious signs of disturbance e.g. repeated fires, aggressive weeds, dieback, logging and grazing.
Good	Vegetation structure altered and obvious signs of disturbance. Retains basic vegetation structure or ability to regenerate it. The presence of very aggressive weeds at high density, partial clearing, dieback, logging and grazing.
Degraded	Basic vegetation structure severely impacted by disturbance. Requires intensive management. The presence of very aggressive weeds at high density, partial clearing, dieback, logging and grazing.
Completely Degraded	Vegetation structure is no longer intact and the area is completely or almost completely without native flora. Often described as 'parkland cleared'.

Macroinvertebrate survey

This survey aimed to provide a 'snapshot' of macroinvertebrate populations within Baigup Reserve. Two different habitat types were identified: emergent vegetation and open water. A minimum of three sweeps covering these habitats was undertaken with seven sites sampled overall. All macroinvertebrates found were collected and preserved in 70 per cent ethanol for identification in the laboratory.

There was only one sampling period for this survey, which was conducted in summer (19 December 2007).

2.2 Hydrogeological survey and water quality sampling

Department of Water

The Department of Water's Water Science Branch has conducted and commissioned numerous studies (biological, surface water and groundwater, sediment and soils) throughout Baigup Reserve, the local catchment and the Swan River (the receiving environment). This includes two major studies conducted by URS and CSIRO described later in this section.

Monitoring programs conducted within the scope of the Baigup Reserve action plan, along with a number of preliminary investigations conducted by the Department of Water and its external contractors, have included:

- 2003: surface water and sediment analysis in the drainage network of Bayswater catchment (Department of Environment)
- 2003: analysis of metal content in estuarine fish tissues in the Swan River (Department of Environment)
- 2004: surface water quality assessment of ponded waters adjacent to culverts in Baigup Reserve (Swan River Trust)
- 2004: ecotoxicological assessments (invertebrates, fish larvae, bacteria) in ponded water adjacent to culverts in the reserve
- 2004: surface water quality assessment in Swan River adjacent to the reserve and one site above and below it (Maylands Peninsula; Ron Courtney Island)
- 2004–05: groundwater assessments through two transects across the Swan River (10 sites) in both the middle of the reserve and at Garrett Road bridge
- 2005: fish-kill response within the Swan River (adjacent to reserve)
    - 100 fish (trumpeter and bream species) adjacent to reserve
    - included associated water quality assessment
- 2006: analysis of groundwater, surface water and sediment (nutrients, metals, physico-chemical) in bores and drainage network of the Bayswater catchment
- 2006: groundwater assessed in 20 shallow bores (~4 m) within City of Bayswater
    - parameters assessed included nutrients, physicals, Redox, total acidity, metals, SO_4^{-2}, Cl^-, F^-
- 2006: analysis of surface water in West Lake and Swan Lake Main Drain, Baigup Reserve and Bayswater catchment (Swan River Trust)
- 2006–07: surface water and sediment tested at inflow point from Swan Lake Main Drain
- 2007: soil samples collected from the reserve and analysed by CSIRO
- 2007: analysis of macroinvertebrate assemblages in the reserve's lakes by Ecoscape

- 2007–08: within the Swan River (adjacent to reserve) fortnightly samples taken of estuarine water quality (surface and bottom water)
    - parameters included dissolved and total metals, physico-chemical parameters, nutrients and acid sulfate soil parameters
- 2005–09: groundwater quality logged every 15 minutes in three shoreline bores along the reserve
    - parameters tested were ORP, TEMP, DO, COND, pH
- ongoing data collection: fortnightly monitoring of estuarine water quality (surface and bottom)
    - parameters include dissolved and total metals, physico-chemical parameters, nutrients and acid sulfate soil parameters
- ongoing data collection: pH in Bayswater Main Drain recorded every few minutes
- 2007: the reserve was included in a larger study examining contaminants (metals, pesticides, PAHs) throughout the Swan-Canning estuary
    - this study characterised and prioritised sections of the estuary
- monitoring of water and sediment within a number of estuarine systems in south-west Western Australia including the reserve.

The results of these studies are summarised in Section 3 of this report.

URS

Hydrogeological survey

In February 2008 URS began a program that involved monitoring water quality from selected surface water sites, installation and monitoring of a series of bores, and soil assessment. The groundwater installation program aimed to characterise the reserve's hydrogeological and geochemical properties, map groundwater and surface water properties and collect data on the reserve.

Between 3 to 7 December 2007 a total of 19 monitoring bores were installed, which comprised 17 shallow (2–5.5 m bgl) and two deep (~10 m bgl) bores along the reserve's length. A further three bores were installed on 24 January 2008 by hand auger (URS 2008).

A total of 17 soil bores, at depths ranging between 2 m and 10 m bgl in line with the proposed depths of groundwater monitoring wells, were also extracted. In addition to these, eight 'hotspot' locations based on known historical disturbance and/or current visual indicators of a deteriorating wetland, were hand augured to depths of approximately 2 m bgl or to the watertable. The aim of the additional soil sampling was to characterise the subsurface profile along the length of the reserve.

All soil samples were analysed for a suite of parameters, detailed in the *Baigup hydrogeological survey – water quality sampling report* (URS 2008).

Initial surface water survey

An initial surface water survey was conducted at 17 locations on a weekly basis between 13 December 2007 and 3 January 2008. The survey's aim was to determine the hydraulic and chemical properties of the reserve's surface water.

As a result of this survey, five surface water locations were identified for monthly water quality and analytical testing as part of the proposed groundwater and surface water monitoring program.

Groundwater and surface water monitoring program

The groundwater and surface water monitoring program was implemented in February 2008. In situ water quality parameters including pH, dissolved oxygen (DO), electrical conductivity (EC), redox potential (Eh), calculated turbidity, depth to groundwater and temperature were determined on a monthly basis. Groundwater and surface water samples were submitted to ALS laboratory for analytical tests.

The chemical suites included:

- dissolved and total metals
- general parameters
- nutrients
- acid sulfate soil parameters.

Heavy rain conditions on 16 and 17 April 2008 enabled an additional opportunistic sampling event; thus the chemical characteristics of the area during a 'first flush' event were recorded.

A surface flow survey of the largest open waterbody in the reserve was undertaken. This involved taking flow-meter readings at grid locations across the lake. Measurements were taken from 28 sites at varying depths. Physical parameters (DO, temperature, pH and EC) were also recorded at each sampling site and at each depth.

Monthly groundwater and surface water monitoring was completed in September 2008 (URS 2008).

CSIRO

Soils

A total of 69 surface soils were collected at Baigup Reserve either by CSIRO Land and Water or by Murdoch University Marine and Freshwater Research Laboratories under the direction of CSIRO Land and Water. The Department of Water also collected 71 soil samples consisting of seven surface and 62 subsurface soil samples in a complementary sampling exercise. Soil samples were taken primarily to assess actual and potential acidity at the reserve (Douglas et al. 2008).

Three separate phases of soil sampling were undertaken at the reserve. The first phase was undertaken along the edge of the Swan River, while the second was

based on surface soil pH distribution in regions of low pH to better delineate areas of potentially active acid generation. The third phase was undertaken in areas identified previously by Bading (2005) as having actual acid sulfate soils (Douglas et al. 2008).

Surface water and groundwater

Surface water and groundwater samples were collected approximately monthly between December 2006 and June 2007. Surface water quality was determined from water samples collected from the following:

- seeps located on the northern boundary
- the two lakes in the reserve
- scald locations (shallow depressions with iron staining) showing periodic surface water (Douglas et al. 2008).

Spear probing

Spear probing was used to identify where groundwater discharges into the river from the reserve and to assess its quality. Spear probes were inserted into the riverbed (to various depths) to locate a sandy horizon below the clayey riverbed for water sample collection (Douglas et al. 2008).

3 Physical environment

3.1 Geomorphology and soils

Baigup Reserve is situated within the Bassendean Dune system – the oldest series of dunes on the Swan Coastal Plain – consisting of poorly sorted, fine to medium grained quartz sand (Biggs, Leech & Wilde 1980). The reserve is low lying, which means most of the soil types are alluvial in origin with areas of peat clay, swamp and river deposits. Peat is found closest to the river's foreshore and in the swamps, while the typical porous Bassendean grey sands occur in the reserve's most elevated sections (Regeneration Technology Pty Ltd 1994; 2004).

3.2 Hydrology and hydrogeology

The Baigup wetland was originally an expression of groundwater with numerous freshwater springs and creek lines feeding into the reserve. The hydrology was altered in 1984 when the Dampier to Perth gas pipeline was constructed through the reserve and a limestone access track (now a bicycle path) was constructed alongside the pipeline (Douglas et al. 2008). Water is discharged across the reserve and to the wetland area via pipes beneath the bicycle path at eight locations (**Figure 14** and the contour feature map in **Appendix E**).

The path through the middle of the reserve has a significant influence on the area's hydrology. The Baigup wetland receives fresh water year-round from springs in the north. The water from the springs originally flowed unconstrained into the Swan River but is now landlocked, which has created permanent woodland swamps (Regeneration Technology Pty Ltd 2004). On the river side of the path, the hydrology is influenced by heavy rainfall and the Swan River's high tides, resulting in the wetland being flushed with brackish river water. The landward side is now a shallow freshwater swamp that is flushed by stormwater outlets and seepage.

The watertable in the reserve is at or within 1 m of the surface and in some areas forms lagoons and natural swamps. A number of subsurface springs occur throughout the reserve. Most of the reserve lies between 0.5–1 m above sea level.

Two artificial lakes (primary and secondary –

) were built in the reserve in 2000 and 2001 in an effort to:

- improve the quality of water entering the riverside vegetation communities and the Swan River
- enhance the reserve's aesthetic value
- establish open water habitats for endemic fauna (particularly birds) and flora
- reduce fire risk by decreasing the fuel load.

The primary artificial lake at the reserve's north-eastern end was constructed in April 2000. It has a total water surface area of 0.3 ha (when the water level is at 0 m AHD) and a minimum level of -1 m AHD (Regeneration Technology Pty Ltd 1994). The

balance of inflows (Swan Lake Main Drain, rainfall, groundwater) and outflows (surface water to the Swan River, evaporation, groundwater) controls the lake's water levels.

Water from the lake passes under the cycleway through culverts, which ensures the hydraulic connection between the river and the lake is adequate to prevent inland surcharging (Regeneration Technology Pty Ltd 1994).

The secondary lake at the reserve's western end is on the landward side of the cycleway. It was designed to improve drainage by controlling the pooling of water and eliminating vast tracts of weeds. It was constructed in the most degraded section of the reserve which had originally been used for market gardens. There was very little endemic vegetation in the area, with the exception being stands of *Schoenoplectus validus* among the *Typha* (Regeneration Technology Pty Ltd 1994).

Construction of the secondary lake began in March 2001. It has a total area of 0.9 ha, with a minimum level of -1 m AHD grading to the natural surface between 0.5 m AHD and 2 m AHD. A number of minor runoffs send surface water into the lake but it was designed with no direct inflow or outflow of surface water. The lake's water level is an extension of the groundwater table. Its water balance consists of two main flow paths, rainfall, evaporation and groundwater inflow and outflow. No hydraulic structures (inlet or outlet structures) were required for this lake (Regeneration Technology Pty Ltd 1994; 2004).

The URS (2008) study concluded that Baigup Reserve is a closed system because of the cycle path, which acts as a hydraulic barrier to the necessary river-water flush and stormwater runoff. A saline groundwater wedge was identified, associated with the Swan River, which may also act as a hydraulic barrier to the necessary seepage into the river. These processes may have significant impacts on the reserve's hydrology and water quality. Because the wetlands and groundwater systems are closed systems, chemical components in the groundwater (e.g. nutrients and metals) may be recycling in the groundwater, pond and swampy sediment (URS 2008), affecting the reserve's water quality.

3.3 Acid sulfate soils

Actual acid sulfate soils are generally naturally occurring soils containing sulfides that have reacted with oxygen to produce acids. Potential acid sulfate soils contain sulfides that have not reacted with oxygen (usually because they are permanently waterlogged). They produce acids when exposed to air by excavation, filling, creation of artificial watercourses, or groundwater abstraction/dewatering.

Throughout Baigup Reserve potential acid sulfate soils were found to be underlying and shallow. However, based on information that the Department of Water, CSIRO and URS have gathered, there is limited evidence to support the reserve's classification as a site with significant actual acid sulfate soils (Department of Water 2009). Previously reported environmental concerns have included acid scalds, dying vegetation, low pH and high acidity. These symptoms have significantly reduced in

extent, severity and frequency over recent years and were presumably a result of previous soil disturbance and oxidation events associated with hydrological disturbance, such as construction of the two lakes (Department of Water 2009).

In terms of connectivity with the receiving environment, no evidence was found of recent acidity being transferred into the adjacent Swan River. However, there is evidence to suggest that iron is discharging to the river along the shoreline (most evident in the reserve's east), probably due to a thin lens of groundwater flow. These volumes of groundwater discharge are likely to be small and intermittent and surface flows into the estuary may also periodically carry some dissolved iron (Department of Water 2009).

3.4 Water and sediment quality

Baigup Reserve's water quality is affected by nutrients, heavy metals and pesticides (Regeneration Technology Pty Ltd 1994) coming from the surrounding catchment. Environmental concerns are centred on elevated nutrient and metal concentrations, especially iron (Fe), aluminium (Al), copper (Cu), zinc (Zn) and lead (Pb), as well as the presence of sulfidic materials including monosulfidic black ooze. Nutrient levels and metals exceeded ANZECC & ARMCANZ (2000) guidelines for both sediment and water. However, it is thought that these concerns are more likely to be related to ongoing inputs from the surrounding environment rather than a function of acid sulfate soil activity in the reserve. This is supported by metal concentrations recorded in the reserve being comparable with those found in the local catchment (Department of Water 2009; URS 2008).

The presence of monosulfidic black ooze in the reserve has the potential to reduce pH, deplete dissolved oxygen and cause the release of metals and metalloids. Although monosulfidic black ooze forms naturally in many wetland areas along the Swan River and throughout Australia, the rate of formation can be accelerated by increased inputs of iron (by groundwater or surface water inflows) and eutrophication. However, no significant deposits have been found in the reserve (Department of Water 2009).

4 Biological environment

4.1 Vegetation and flora

Native vegetation

The vegetation at Baigup Reserve has changed since European settlement. The naturally low-lying floodplains would have originally supported sedgelands such as the wide expanse of *Juncus kraussii* present in the reserve's east. The permanently wet areas would have supported *Melaleuca rhaphiophylla* woodland with an understory of sedges including *Lepidosperma tetraquetrum, Baumea juncea, B. articulata, B. preissii, B. vaginalis, B. rubiginosa* and *Schoenoplectus validus.* The area closer to the river at either end of the reserve, where the floodplain narrows, would have supported a taller *Eucalyptus rudis* community, while the reserve's upland areas would have supported *Banksia-Marri* woodland (Regeneration Technology Pty Ltd 2004). The reserve's vegetation, as mapped by Heddle et al. (1980), consists of Fringing Woodland of *E. rudis* and *M. rhaphiophylla* with localised occurrences of Low Open Forest of *Casuarina obesa* and *M. cuticularis* (**Figure 8**).

Baigup Reserve's existing vegetation consists of a mixture of estuarine and freshwater swamp communities, which are becoming rare along the Swan River. The tidal components of the wetlands consist largely of shore rush (*Juncus kraussii)* sedgelands, with a fringe of swamp sheoak *(Casuarina obesa)* along the river's edge. In places there are belts of marsh club rush (*Bolboschoenus caldwellii)* and stands of freshwater paperbark (*Melaleuca rhaphiophylla)* (North Metro Conservation Group 2006; Regeneration Technology Pty Ltd 2004). The vegetation communities identified in the reserve are summarised in **Table 3** and shown on **Figure 10**.

Table 3 Vegetation communities in Baigup Reserve

	Vegetation community	Area (ha)
1	*Typha orientalis*/*Baumea articulata*/*Schoenoplectus validus* Sedgeland over a Very Open Herbland of **Cotula coronopifolia* with scattered *Melaleuca rhaphiophylla*	2.07
2	*Melaleuca rhaphiophylla* Tall Open Scrub over a *Bolboschoenus caldwelliii*/*Juncus kraussii* Sedgeland	4.28
3	*Eucalyptus rudis* Open Woodland over an Open Shrubland of **Lathyrus tingitanus*, over a Very Open Herbland of **Rumex* sp. and *Typha orientalis* Very Open Sedgeland over a mixed exotic Closed Grassland	0.47
4	*Melaleuca rhaphiophylla* Open Woodland over a Very Open Herbland of **Cotula coronopifolia* and a *Typha orientalis*/*Baumea articulata*/ *Schoenoplectus validus* Sedgeland	0.22

	Vegetation community	Area (ha)
5	*Pteridium esculentum* community over a **Cynodon dactylon*/**Pennisetum clandestinum* Closed Grassland	1.5
6	*Melaleuca rhaphiophylla*/*Eucalyptus rudis* Closed Forest over a Very Open Herbland of *Centella asiatica* and a *Bolboschoenus caldwellii*/**Carex divisa* Closed Sedgeland	0.62
7	*Melaleuca rhaphiophylla* Open Woodland over a Very Open Shrubland of *Sarcocornia quinqueflora* and a Closed Sedgeland of *Juncus kraussii*	2.3
8	*Casuarina obesa*/*Melaleuca rhaphiophylla* Woodland over *Bolboschoenus caldwellii*/*Juncus kraussii* Closed Sedgeland	0.99
9	Mixed exotic Closed Grassland with scattered *Melaleuca rhaphiophylla*	0.76
10	*Eucalyptus rudis* Open Woodland over an Open Shrubland of *Melaleuca rhaphiophylla*, *Typha orientalis*/*Baumea articulata*/*Schoenoplectus validus* Sedgeland	0.76
11	*Eucalyptus rudis* Open Woodland over mixed exotic Closed Grassland	0.27
	TOTAL	14.24

** indicates introduced species*

Introduced species

Many weed species are present in Baigup Reserve: the most dominant is bulrush (*Typha orientalis).* In 2003 Regeneration Technology Pty Ltd wrote a weed control and rehabilitation plan that identified and mapped the reserve's weed species. A total of 45 species were identified, of which 12 were ranked as a threat to the reserve's ecology. A flora species list is in **Appendix C**.

The diversity of invasive weed species at the reserve is a result of historic clearing for market gardening, dairy farming, installation of the gas pipeline and construction of the dual purpose pathway. These areas came to be dominated by weeds (Regeneration Technology Pty Ltd 1994). However, the weed community (including *Typha orientalis*) has declined during the past 10 years, with the river side of the cycleway being the major focus of weed control efforts. Virtually all *Typha* has now been removed from the area. Expanses of *Typha* have also been removed from the landward side of the cycleway through manual and chemical weed control methods. Large areas of weeds were also removed during construction of both artificial lakes (Regeneration Technology Pty Ltd 2004).

4.2 Fauna

Baigup Reserve is of regional conservation significance. It provides protection for species affected by urban development and acts as a major corridor for bird and other faunal movement along the Swan River and nearby wetlands (Regeneration Technology Pty Ltd 1994).

The area is characterised by extensive and contiguous belts of indigenous sedges and reeds, paperbarks, flooded gums and sheoaks, which comprise an excellent diversity of habitat types. Due to the combination of extensive wading areas, woodland and dense herbaceous cover – together with saline to freshwater zones – the reserve is an important area for waterbirds and other wetland fauna. Two species of waterbird (great egret and Caspian tern) and one land bird (rainbow bee-eater) that visit the area are protected under the Japan-Australia Migratory Bird Agreement (JAMBA) and China-Australia Migratory Bird Agreement (CAMBA). Part of the reserve is also categorised as a conservation category wetland (DEC 2004) due to the presence of rare fauna habitats, as well as its high-value natural and human-use attributes. A species list of fauna identified within the reserve is in **Appendix D**.

Birds

The Swan-Canning estuary (including Baigup Reserve) is a significant waterbird habitat. The diversity of birds is similar to what is found in adjacent foreshore areas (e.g. Maylands Peninsula), and confirms the reserve's value for breeding, feeding and wading. The high diversity of invertebrates in woodland areas also provides a good food source for both waterbirds and fringing woodland species (Regeneration Technology Pty Ltd 1994).

In 2004 Birds Australia and the Perth Biodiversity Project conducted a bird survey: they recorded 66 species, of which 33 were water-dependent. Of these, 10 were listed as significant under Bush Forever (Gole 2004) – five water birds and five bush birds. The most abundant water-dependent species were the pacific black duck and grey teal. It is thought the reserve may represent an important habitat for some water-dependent species such as the buff banded rail and crake, due to the presence of tidal mudflats and marshes (Gole 2004). However, the reserve does not appear to support small insectivorous species. This is most likely because of the existing habitat types rather than how the reserve is managed (Gole 2004).

Reptiles and amphibians

Six frog species were recorded in the reserve, including two of *Crinia,* two of *Litoria,* the bonking frog (*Limnodynastes dorsalis)* and the whooping or moaning frog (*Heleioporus eyrie)*. The number of reptiles in the area was reported to have been declining since 1991 (Regeneration Technology Pty Ltd 2004).

Mammals

The native water rat (*Hydromys chyrogaster)* – a nocturnal animal that lives in fringing shore vegetation – has been recorded in the reserve. No other native

mammals have been recorded. The southern brown bandicoot may once have occurred at this site but is likely to have been predated by foxes (Regeneration Technology Pty Ltd 2004). There have been no recent mammal surveys in the reserve.

Invertebrates

The reserve has a relatively high diversity of invertebrates, particularly in the paperbark woodlands (*Melaleuca rhaphiophylla)* (Regeneration Technology Pty Ltd 1994).

The main stormwater drain was sampled in 1994 and found to be virtually absent of aquatic invertebrates. This could be due to poor water quality or a lack of habitat. Ecoscape also conducted aquatic invertebrate sampling in 2007 with similar results; that is, few individuals were recovered from the samples (Ecoscape 2008).

Introduced species

Anecdotal evidence suggests that foxes are present in the area (Regeneration Technology Pty Ltd 1994). Foxes and cats exact a heavy toll on native animals and pose a direct threat to mammals, reptiles and birds within the reserve.

It is also likely that black rats (*Rattus norvegieus)*, brown rats (*Rattus rattus*) and house mice (*Mus musculus)* are present in the area (Regeneration Technology Pty Ltd 1994).

5 Social environment

5.1 Aboriginal heritage

Aboriginal people have a broad association with and highly value the Swan River. Pre-European settlement it offered the basic requirements of fresh water and food and would thus have been used regularly by the local people.

There are no records of sacred sites within Baigup Reserve, but the existence of freshwater springs means it is highly probable that parts of the reserve were used for camp sites. It is also possible that mythology is associated with the area. The word Baigup is a Nyoongar term for rushes (Regeneration Technology Pty Ltd 1994).

5.2 European history

The river was an important source of transport in the early years of European settlement. Boats were used to ferry people from Garratt Road Bridge to what was then known as the Perth Racecourse. The first bridge was opened on 1 January 1935, and the second section of the bridge completed in 1972 (Regeneration Technology Pty Ltd 1994).

Because of its fertile soils, Baigup Reserve was used for market gardens between the late 1800s and the 1970s. Remnants of this activity remained after the current reserve was established, including a cobbled access road at the western end of the secondary lake.

In the late 1970s the area was obtained for parks and recreation as part of the Metropolitan Region Scheme. In 1986 the Dampier to Perth gas pipeline was constructed through the reserve and a raised limestone track was paved, which created a cycle path through the reserve (**Figure 14**). In the 1970s another access track was built on the reserve's northern boundary (near residential areas) to enable the Water Corporation to lay pipework for the infill sewerage program (Regeneration Technology Pty Ltd 2004).

Baigup Reserve is one of the few areas in this section of the Swan River with minimal man-made alterations. Up and down stream of the reserve the river has been straightened: riverbanks have been replaced with artificial walls and embankments as well as the Garret Road Bridge (Regeneration Technology Pty Ltd 2004).

6 Plan for management

6.1 Introduction

The City of Bayswater has used Regeneration Technology Pty Ltd's 2004 management plan as an 'umbrella' document to guide the management objectives for Baigup Reserve. So that the plan could be implemented, goals for each major part of the plan were set and objectives to achieve these goals were identified. This document identifies these principal goals and includes the following:

1 *Conservation*: protect, conserve and enhance the reserve's biota as well as its physical, cultural and landscape resources

2 *Recreation:* manage recreation by providing opportunities that are compatible with the protection of conservation values in the reserve

3 *Research and monitoring:* seek a better understanding of the natural, cultural and social environments and the impacts of human use and reserve management

4 *Community relations*: promote informed appreciation of the reserve's natural environment, conservation values and recreation (e.g. bird watching).

This remediation and management plan aims to be consistent with these goals and to provide further guidance on the long-term vision for the reserve, which is:

> … a quality wetland supporting a diversity of habitats. As a conservation reserve it will be a successful example of a self sustaining natural ecosystem within an urban environment, providing a natural refuge for native flora and fauna and the community.

A wealth of information has been gathered on Baigup Reserve via previous surveys: this has been reviewed and collated for inclusion in this plan.

Management zones

From the field assessment, Ecoscape divided the reserve into six management zones, which have been based on natural and man-made boundaries, such as vegetation communities, vegetation condition and access paths. These zones were set up to facilitate and prioritise management practices for the reserve. By separating the reserve into manageable zones, the City of Bayswater will be able to organise and monitor works' programs in a structured manner. **Table 4** below lists the ecological communities and the area in each condition class for each management zone. **Figure 11** illustrates the management zones identified in this management plan.

Table 4 Management zones of Baigup Reserve

Zone	Veg #	Communities	Vegetation condition					Zone area (ha)
			Excellent	Very Good	Good	Degraded	Completely Degraded	
1	n/a	Parkland Cleared	–		–	–	0.25	**0.25**
2	6	*Melaleuca rhaphiophylla/ Eucalyptus rudis* Woodland over *Bolboschoenus caldwellii*						
	7	*M. rhaphiophylla* Open Woodland over Very Open Shrubland of *Sarcocornia quinqueflora* and Closed Sedgeland of *Juncus kraussii*			0.34			**0.34**
3	7	*Melaleuca rhaphiophylla* Open Woodland over a Very Open Shrubland of *Sarcocornia quinqueflora* and Closed Sedgeland of *Juncus kraussii*						
	8	*Casuarina obesa/ M. rhaphiophylla* Woodland over *Bolboschoenus caldwellii/J. kraussii* Closed Sedgeland						
	2	*M. rhaphiophylla* Tall Open Scrub over a *B. caldwellii/J. kraussii* Sedgeland	2.0	3.2				**5.2**
	10	*Eucalyptus rudis* Open Woodland over an Open Shrubland of *M. rhaphiophylla*, *Typha orientalis/Baumea articulata/Schoenoplectus validus* Sedgeland						
	11	*E. rudis* Open Woodland over mixed exotic Closed Grassland						
4	4	*Melaleuca rhaphiophylla* Open Woodland over a Very Open Herbland of **Cotula*			0.45	3.55	0.05	**4.05**

Zone	Veg #	Communities	Vegetation condition					Zone area (ha)
			Excellent	Very Good	Good	Degraded	Completely Degraded	
		coronopifolia and a *Typha orientalis/Baumea articulata/ Schoenoplectus validus* Sedgeland						
	5	*Pteridium esculentum* community over a **Cynodon dactylon/*Pennisetum clandestinum* Closed Grassland						
	2	*M. rhaphiophylla* Tall Open Scrub over a *Bolboschoenus caldwellii/Juncus kraussii* Sedgeland						
	3	*Eucalyptus rudis* Open Woodland over an Open Shrubland of **Lathyrus tingitanus*, a Very Open Herbland of **Rumex* sp., a *T. orientalis* Very Open Sedgeland and a mixed exotic Closed Grassland						
5	2	*Melaleuca rhaphiophylla* Tall Open Scrub over a *Bolboschoenus caldwellii/Juncus kraussii* Sedgeland						
	3	*Eucalyptus rudis* Open Woodland over an Open Shrubland of **Lathyrus tingitanus*, a Very Open Herbland of **Rumex* sp., a *Typha orientalis* Very Open Sedgeland and a mixed exotic Closed Grassland		0.05	1.0	0.2	0.05	**1.30**
	7	*M. rhaphiophylla* Open Woodland over a Very Open Shrubland of *Sarcocornia*						

Zone	Veg #	Communities	Vegetation condition					Zone area (ha)
			Excellent	Very Good	Good	Degraded	Completely Degraded	
		quinqueflora and a Closed Sedgeland of *J. kraussii*						
6	1	*Typha orientalis/Baumea articulata/Schoenoplectus validus* Sedgeland over a Very Open Herbland of **Cotula coronopifolia* with scattered *Melaleuca rhaphiophylla*				3.1		**3.1**
	9	Mixed exotic Closed Grassland with scattered *M. rhaphiophylla*						
	11	*E. rudis* Open Woodland over mixed exotic Closed Grassland						
		Total area of bushland in each condition class	**2.0**	**3.25**	**1.79**	**6.85**	**0.35**	**14.24**

** indicates introduced species*

6.2 Acid sulfate soils

Objectives

The management objectives for acid sulfate soils are to:

- ensure land containing acid sulfate soils is managed to minimise potential adverse effects on the natural and built environment
- protect the hydrological balance and stability of the reserve's vegetation communities
- manage surface water and groundwater to maintain the reserve's biological and social values
- protect and maintain the reserve's existing geomorphologic and soil associations
- manage water regimes affecting the reserve in a manner that complements Department of Water policies and enhances the reserve's conservation and recreational values.

Background

In recent years the issue of acid sulfate soils has emerged, particularly in relation to developments in tidal and floodplain zones in Western Australia. The resulting disturbance of soils and alteration of water tables/regimes can lead to the oxidation of prone soils and the release of heavy metals and acid into the environment. This can lead to a detrimental shift in the ecology of lakes and wetlands. If acid sulfate soils are detected, a number of management options are available to minimise or prevent their long-term effects.

Previous surveys of acid sulfate soils in Baigup Reserve show it is relatively stable. However, disturbance of these soils remains a management issue, as does monosulfidic black ooze mobilisation and other potential problems arising from the reserve's altered hydrology. Although there may be some surface water and possibly shallow groundwater connectivity between the reserve and the Swan River (based on findings of previous studies), there is no evidence of site specific impacts from the reserve (Department of Water 2009).

Most of the issues discussed in the following section appear to be consistent with characteristics of other aquatic systems in the area. For example, the concentrations of metals found in the reserve are typical of the Swan River and all have the potential to be exposed, disturbed and oxidised through a number of causes, both natural and anthropogenic (Department of Water 2009).

Strategy

The following strategy options were outlined in the Department of Water's *Baigup Reserve action plan position statement* (2009).

Maintenance of the current condition

This is a relatively low-risk option, although future acid sulfate soil/monosulfidic black ooze problems in the reserve cannot be discounted. However, in the absence of any significant hydrological changes occurring, most of the residual acid sulfate soil problems and any potential monosulfidic black ooze accumulation would most likely be localised and have little impact on the Swan River.

Minimal disturbance of topsoil during weed control

Some degree of disturbance of topsoils is required in the reserve for weed control and other site management. Any disturbance must be minimised and carried out in accordance with best management practices for appropriate risk mitigation and site rehabilitation. Information collected to date provides the basis for determining which areas contain potential acid sulfate soil materials close to the surface (between depths of 0–1 m) and where monitoring of acidity and treatment of this should be undertaken if disturbance occurs (**Figure 13**). Surface water and groundwater should be monitored after any such disturbance to ensure mitigation strategies are sufficient. Monitoring requirements depend on the size of the disturbance and should be examined on a case-by-case basis – but would likely involve a network of groundwater monitoring bores down-gradient of the disturbance.

This approach might produce initial impacts should shallow potential acid sulfate soils be disturbed, yet the situation can be readily managed through appropriate mitigation strategies (staged responses to weed control and on-going condition monitoring to minimise impacts).

Heavy disturbance to remove the causeway

The causeway dividing the reserve is acting as a hydraulic barrier, which significantly constrains tidal flushing. The high culvert height results in water being retained inland of the causeway, while only permitting occasional inflows of tidal water. Increased pooling of water in the reserve appears to have reduced exposure of acid sulfate soils to the atmosphere, although seasonal drying of pools still occurs. The current situation is relatively stable and immediate attention is not required. However, factors such as decreased rainfall may lead to increased drying of sediments in the reserve's up-slope areas.

It may be feasible to replace sections of the causeway (that Alinta Gas no longer requires for access) with a raised bike path to enable tidal exchange between the two sides of the path. Further investigations are required.

It is likely, however, that the causeway's removal and replacement with an elevated pathway would produce significant risks to the reserve because of acid sulfate soil disturbance while the works were carried out. An alternative option might include installation of several large culverts beneath the existing causeway. This would require a detailed hydrological assessment of where these would be sited for maximum tidal exchange. Given careful management and monitoring of acid sulfate soils, the disturbance associated with both alternatives should be relatively controllable. Removing the causeway or installing the culverts would need to be carried out in stages.

It is difficult to determine when the long-term benefits of this scenario would be realised. Ideally it could result in rapid reinstatement of a healthy system whereby inflow water achieves regular neutralisation of any periodic incidences of soil or water acidity. However, the scenario would require an initial intensive level of management to ensure that flushing of accumulated iron flocculent and any future monosulfidic black ooze to the estuary did not occur while the system was reaching equilibrium. Equilibrium would be achieved when inflow alkalinity neutralises acidity generated by residual natural and other low-level disturbance in the reserve.

Lakes as sinks

This recommendation is not directly related to this plan's scope, however the potential for contaminants to build up in the reserve's lakes is significant in terms of its general environmental condition. Runoff from the adjoining urban area flows directly into the primary lake, carrying with it contaminants similar to those associated with sulfidic materials in the reserve, and thus creating a risk that the lakes will accumulate and potentially become sources of contaminants. Rates of contaminant accumulation are critical and require long-term assessment. This issue is more a general consideration for all lakes within acid sulfate soil areas in the Swan-Canning

catchment receiving urban drainage. Advice from the Department of Environment and Conservation should be sought on this issue as it comes under their jurisdiction.

As part of the issue of contaminant build-up, the quantity of iron flocculent in the reserve's ponded water is important because it directly affects aquatic biota, predominantly invertebrates. This issue is not considered a high priority for the reserve, given the ponded waters (where flocculent is concentrating) are not natural and that the iron levels appear to be characteristic of the region. However, it does deserve attention if the lakes' ecology is to be valued. Increased iron concentrations might also promote monosulfidic black ooze formation in shallow peats and sands, assuming sulfate and anoxic conditions are not limiting. If flocculated iron accumulates to the extent that management action is needed, it would likely involve monosulfidic black ooze removal or stabilisation or filling-in of the lake systems, both of which would require disturbance of acid sulfate soils.

Recommendations

Acid sulfate soils	Priority
Surface water and groundwater should be monitored following any site disturbance, e.g. weed control, rehabilitation, installation of infrastructure	High
Disturbance should be conducted in a staged approach to minimise and better manage the outcomes	High
Conduct a disturbance test site to determine the possible extent of impacts before large disturbance works	High
Retain pooling of water within the lakes to reduce exposure of acid sulfate soils to the atmosphere	High
Install several large box culverts allowing for increased exchange between the two sides of the path	Med
Depending on the level of access required by Alinta Gas to maintain the pipeline, investigate replacing sections of the bike path with a raised walkway to enable exchange between the two sides of the path	Low

6.3 Weed control

Objectives

The objectives for weed control are to:

- identify and control existing weeds with the highest priority for control
- prevent introduction of additional weed species
- prevent further encroachment of weeds into bushland areas
- minimise any detrimental effects of the weed control program on the native biota
- integrate the weed control program with bushland restoration programs
- minimise disturbance of acid sulfate soils during weed control practices.

Background

Environmental weeds are plants that establish themselves in natural ecosystems and modify natural processes, resulting in the decline of the natural communities they invade. Impacts on ecosystem functions by environmental weeds include:

- resource competition, as weeds often out-compete native species
- prevention of seedling recruitment of native species
- alteration to geomorphological processes, such as increased erosion
- changes to soil nutrient status
- alteration of the fire regime, usually through increased fire frequency
- changes to the abundance of indigenous fauna due to reduced habitat diversity
- loss of genetic diversity
- loss of species diversity
- changes to the structure of vegetation communities, often by the removal of the shrub layer or native groundcovers.

The presence of weeds is a serious problem in the reserve. Past land uses, altered hydrology and the dumping of garden waste has resulted in an extensive weed invasion. Weeds are a major threat to the reserve's conservation values and it is important that ongoing management focuses on reducing this impact to control the degradation process (Regeneration Technology Pty Ltd 2004).

Strategy

Integrated management

Integrated weed management involves control options that create sustainable and effective management systems. Reliance on one control process will generally not

succeed; for example, the continual use of herbicides can result in some weed species developing herbicide resistance. In natural areas, integrated weed management involves the use of manual, chemical and biological systems coupled with an appropriate restoration (revegetation) process to increase ecosystem resilience and long-term sustainability.

Priority ratings of weed species

The priority ratings of weeds species recorded during the 2004 survey are listed in **Table 5**. Seven weed species were classified as High Priority weeds. For site preservation, immediate targeted strategies are required to control these weeds. Thirteen weed species were rated as Moderate Priority threats: for site enhancement these should be targeted after the High Priority weeds.

A table indicating the priority weeds and ways to manage them is located in **Appendix A**.

Table 5 Priority ratings of weeds identified at Baigup Reserve

Scientific name	Common names	Mapping frequency
High Priority weed species – targeted control required for site preservation		
Ehrharta calycina	Perennial veldt grass	Annually
Euphorbia terracina	Geraldton carnation weed	
Ipomoea cairica	Morning glory	
Lagurus ovatus	Hares tail grass	
Paspalum dilatatum	Paspalum	
Pelargonium capitatum	Rose pelargonium	
Moderate Priority weed species – target once High Priority weeds are controlled for site enhancement		
Avena fatua	Wild oat	Every 2 years
Conyza albinia	Tall fleabane	
Conyza bonariensis	Fleabane	
Cortaderia selloana	Pampas grass	
Cynodon dactylon	Couch	
Juncus microcephalus		

Scientific name	Common names	Mapping frequency
Paspalum distichum	Water couch	
Pennisetum clandestinum	Kikuyu	
Ricinus communis	Castor oil	
Rorippa nasturtium aquaticum	Water cress	
Rubus fruticosus	Blackberry	
Schinus terebinthifolius	Japanese pepper	
Zantedeschia aethiopica	Arum lily	

Weed control action plan

Mapping vegetation condition in conjunction with weed species distribution and abundance has enabled a general weed management action plan to be formulated for the reserve (**Table 6**). It is provided as a general guide for determining the priority for weed control activities. This action plan is based on three methods of control:

- species-led
- site-led
- cause-led.

Species-led control

Generally it is recommended that species-led control be undertaken before site-led control. Weed species are placed in this category if they:

- have small populations
- are relatively easy to remove
- have high potential to spread and therefore become a problem in the future.

Site-led control

Generally it is recommended that site-led control be undertaken after species-led control. Weed species are placed in this category if they:

- have widespread and well-established populations
- require concentrated and/or long-term efforts to remove them
- are highly detrimental to the ecological functions of bushland if left unchecked.

Weed species should be tackled on a weed-by-weed basis, using the guiding principles listed above.

Cause-led control

If a source or cause of weed infestation can be identified, cause-led control can be used. This is suitable where the cause or source can be eliminated or reduced. An example is weed species that spread from enrichment plantings from adjacent parklands and urban developments.

Action plan for high priority weeds

As the reserve is relatively large and varies considerably in condition and levels of weed infestation, the most appropriate course of action is to conduct a **site-led** control strategy across the entire area. Weeds in *low* weed infestation areas should be controlled first, followed by those in *moderate*, *high* and *extreme* weed infestation areas respectively. Priority weeds should be targeted when controlling each area, and non-priority weeds should be opportunistically controlled if resources allow it.

Action plan for non-priority weeds

Weeds not on the list of High Priority species should be included in any weed control program as 'species to be controlled if resources allow', but they would not be classed as a priority at that particular stage.

As weed control of priority species progresses, other weed species that were previously not rated as highly may become more significant. Therefore, it is important to keep weed control programs flexible and updated according to monitoring data, so that as bushland condition and weed species dominance changes, control activities are adjusted accordingly.

The priority status of an individual weed species should be used as the basis for its control, along with factors such as its abundance and distribution. For example, weed species with a lower weed ranking (see Appendix A for more detailed explanation) , but which has a limited distribution within the site, should be controlled if resources allow – rather than left to spread and become a bigger problem. See **Appendix A** for priority status of weeds.

In general:

- species rated High Priority should be targeted first
- species rated Moderate Priority should be controlled opportunistically if resources allow after targeted control of High Priority weeds
- species rated Low Priority should be controlled opportunistically if resources allow after control of Moderate Priority and High Priority weeds.

However, the situation needs to be assessed in context with other species and resource availability.

Table 6 General weed control action plan

Priority	General recommendations
Priority 1 Start with species-led control	**Species-led control:** 1 Select weeds for control on a species basis according to time of year and available resources 2 For each weed species, use weed infestation distribution maps to: – start control efforts in areas of *low* weed infestation – move to areas of *moderate* weed infestation – move to areas of *high* weed infestation – move to areas of *extreme* weed infestation The above represents primary weed control. Secondary weed control and long-term monitoring of weed populations will also need to be undertaken.
Priority 2 Move to site-led control	**Site-led control:** 1 Select sites suitable for site-based control 2 Use weed infestation distribution maps to: – start control efforts in areas of *low* weed infestation – move to areas of *moderate* weed infestation – move to areas of *high* weed infestation – move to areas of *extreme* weed infestation Depending on resources and the time of year, it may be necessary to undertake control of different site-led species before moving to other areas. Again, the above represents primary weed control. Secondary weed control and long-term monitoring of weed populations will also need to be undertaken.

Priority	General recommendations
Priority 3 Move to cause-led control	**Cause-led control:** 1 Select sites suitable for cause-based control 2 Use bushland condition and weed distribution maps to: – start control efforts in areas of *low* weed infestation – move to areas of *moderate* weed infestation – move to areas of *high* weed infestation – move to areas of *extreme* weed infestation Again, the above represents primary weed control. Secondary weed control and long-term monitoring of weed populations will also need to be undertaken.

Control methods

A variety of control methods for each weed species has been provided in **Appendix A**. Weed management recommendations are based on information from Moore and Moore (2008) *Herbiguide*, Brown and Brooks (2002) *Bushland weeds*, and Dixon and Keighery (1995) *Recommended methods to control specific weed species.*

Details of the different options are described below.

Physical removal

Some degree of disturbance of topsoils in the reserve is required for weed control. Because there are potential acid sulfate soils at the site, any disturbance must be minimised and carried out in accordance with best management practices for appropriate risk mitigation and site rehabilitation (Department of Water 2009). From the information collected by URS, CSIRO and the Department of Water, the areas that contain potential acid sulfate soil materials near the surface (between depths of 0–1 m) have been identified (**Figure 13**). Acidity needs to be monitored and treatment undertaken if these soils are disturbed during weed control efforts.

The process of physically removing weeds should follow the Bradley method of bush regeneration. The Bradley method's aim is the systematic removal of weeds to allow native plants to re-establish themselves when and where they choose. This method does not involve replanting – simply the gradual removal of weeds so that no large openings are made. This makes the Bradley method ideal for many situations, such as those where native plants can colonise the site by seeds or vegetative means, areas sensitive to erosion and areas likely to be over-used.

The Bradley method process is detailed in **Appendix B**.

Spot spraying

Various herbicides have been recommended for controlling each weed species where appropriate. It is up to the party responsible for weed control to decide which herbicide is the most appropriate to use, depending on the nature of the environment, costs and availability of the herbicides. Recommended dosages for each herbicide have been calculated for a 10 L knapsack.

Herbicides

Any application of herbicides must be in accordance with labelling requirements or the manufacturer's materials safety data sheet (MSDS). Personnel must be trained in the use of herbicide chemicals. The application of any herbicide for purposes not specified on the labelling requires an off-label permit from the Australian Pesticides and Veterinary Medicines Authority in Canberra.

The application of herbicides must also be in accordance with water catchment restrictions. Chemical-based weed control strategies in particular must recognise potential adverse impacts on water resources such as lakes, wetlands, streams, rivers and dams.

The timing for targeting specific weeds is an estimate only, as it can vary according to factors such as what time of year fire occurs and the impact of fire on native vegetation and the soil seed bank.

It should also be noted that the herbicide treatments are a suggestion only and many application rates have been adapted from rates for large-scale agriculture. The types of herbicides and application rates should be verified by a qualified weed scientist before any such methods are used in the study area.

As the site contains wetlands, surfactants should not be used with the herbicide treatments. Many common herbicides such as Roundup® contain NPE surfactants that are known to affect the development of amphibian species such as frogs, leading to a decline in or even loss of such fauna species (Mann 2000). Herbicides not containing NPE surfactants, such as Bioactive®, are strongly recommended.

Details of herbicides recommended for controlling weeds at Baigup Reserve are provided in **Appendix A**. It should be noted that the preferred approach to weed control for the reserve is manual control; however, where other factors prohibit manual control (such as high-risk areas for potential acid sulfate soils) then chemical control via wiping is preferred to spraying.

Monitoring data

Monitoring data is used to determine the success of weed control activities and to plan them from year to year. Monitoring data is only useful if it is fed back to the managing agencies to ensure efforts are being focused where they are most needed and each is aware of the others' activities.

Weed mapping

To monitor previous weed control efforts, the distribution of High Priority weeds should be mapped annually and Moderate Priority weeds every two years. To consolidate knowledge of all weeds within the site, two weed species not previously mapped should be mapped each year. This does not need to be a major undertaking every year, as some weeds will have very limited distributions. Weeds with higher priority ratings should be mapped first. No frequency for mapping such weeds is suggested, because not all the weeds need to be mapped.

Recommendations

Weed control	Priority
Conduct a comprehensive weed survey to prioritise weeds for control	Low
Use **Table 5** to undertake immediate removal of the six identified High Priority weeds at Baigup Reserve	High
Ensure application of any herbicides is in accordance with the material safety data sheets and Department of Water (2000) water catchment restrictions	High
Implement monitoring program to assess changes in weed species and distribution in the study area and adapt weed strategies accordingly	Med
High disturbance weed control (e.g. removal of *Typha*) should be conducted in a staged approach in potential acid sulfate soil areas (**Figure 13**) to minimise and better manage the outcomes	High

6.4 Rehabilitation and revegetation

Objectives

The objectives for rehabilitation are to:

- minimise the impact of activities that may result in degradation to vegetation communities by using appropriate management strategies
- improve the overall condition of vegetation communities within the reserve
- optimise the use of resources by prioritising areas for rehabilitation
- reinstate indigenous flora and vegetation communities
- ensure that vegetation communities are self-sustaining and capable of natural regeneration.

Background

Aspects of bushland management are interrelated, but in this plan the strategies have been separated into the following categories:

- **rehabilitation**: identifying priority areas in which assisted natural regeneration and reconstruction should be undertaken
- **revegetation**: identifying techniques for reconstruction.

Rehabilitation involves restoring vegetation and habitats by way of reinforcing and reinstating the system's ongoing natural regenerative processes. This involves reducing or eliminating disturbance factors, removal of inhibitors to natural regeneration such as weeds, and the reconstruction of the ecosystem in highly disturbed areas where the potential for natural regeneration has been markedly reduced or lost and involves:

- **assisted natural regeneration** through reducing or eliminating disturbance factors and removal of inhibitors to natural regeneration, such as weeds
- **reconstruction** of the ecosystem in highly disturbed areas where the potential for natural regeneration has been markedly reduced or lost.

Bushland condition (**Table 7**) can help determine restoration strategies given that:

- maintaining better condition bushland is often more cost effective and sustainable than improving poor condition bushland
- weed control is generally most critical in better condition bushland and revegetation is usually only considered in very poor condition bushland.

Table 7 Bushland condition at Baigup Reserve, Keighery scale (1995)

Condition rating	Area (ha)	Percentage of bushland
Pristine	0	0%
Excellent	1.9	13.5%
Very Good	3.4	24.3%
Good	1.9	13.6%
Degraded	6.3	45%
Completely Degraded	0.5	3.6%

To improve Baigup Reserve's condition, the main issues to be addressed are assisted natural regeneration in the form of weed control and reconstruction in the form of strategic and targeted revegetation. The appropriate situations for applying these two techniques are detailed in **Table 8**. These zones are illustrated on **Figure 10**.

Table 8 Situations for applying alternative bushland rehabilitation techniques

Term	Description of applicable areas	Applicable areas in terms of bushland condition	Percentage at Baigup Reserve	Actions
Assisted natural regeneration	Remnants retain regenerative capacity or where a reconstructed community regains its regenerative capacity.	Good to Very Good or Excellent	51.4%	Remove weeds and disturbance factors.
Reconstruction	Remnants are seriously depleted – e.g. where only some overstorey is left or there is no remnant vegetation left.	Degraded to Completely Degraded	48.6%	Replant, spread topsoil and direct seed. Ensure weeds aren't present in topsoil.

Assisted natural regeneration following the Bradley method (**Appendix B**) is to be undertaken in bushland in Good to Very Good condition or better, which is about 50 per cent of the reserve's bushland.

Replanting and **reconstruction** is required in the Degraded to Completely Degraded condition bushland because the exclusion of further disturbance alone will not lead to adequate regeneration in these areas.

Therefore the priority areas for assisted natural regeneration (weed control in good condition bushland) and reconstruction (revegetation of poor condition bushland) will not coincide. In general, maintaining good condition bushland should be a higher priority than revegetation of poor condition bushland. However, considerations such as creating linkages between bushland, improving amenity or consolidating areas of bushland may justify variances to this rule.

Social and environmental factors considered in setting priorities for rehabilitation are outlined in **Table 9**.

Table 9 Considerations in prioritising rehabilitation

Priority	Social factors	Environmental factors
Low	No or limited public access Not visible from accessible areas No views from site Little or no opportunities for interpretation	Vegetation not degrading or unlikely to degrade either due to no degrading impacts or poor condition of bushland Vegetation common in study area and region
Medium	Limited public access Limited interpretation opportunities Non-focal point in public area Moderate visibility Moderate views from site	Vegetation is degraded or may degrade slowly Good to Very Good condition bushland Vegetation common in study area
High	High degree of public access Highly visible Focal point of public area Extensive views from site Public liability risks Provides protection for infrastructure (e.g. coastal erosion) or public (e.g. industry buffer)	Good to Excellent condition bushland Flora, fauna or vegetation uncommon in study area Rare or significant species at regional scale Significant degrading factors present (e.g. disease, changes in hydrology, noxious weeds, large perimeter to area ratio, adjacent areas in much poorer condition) Significant degrading activities present (e.g. informal tracks being used)

Note: All the factors for setting a particular priority level are not expected to coincide at any one site.

Table 10 below indicates the zones for assisted natural regeneration, which are areas in Good to Very Good or better condition; and zones for reconstruction, which are areas in Degraded to Completely Degraded condition. The assigned priority rating is based on a zone's environmental and social attributes, such as those identified in **Table 8**. These zones are illustrated on

.

Table 10 Priority zones for assisted natural regeneration (ANR) and reconstruction

Zone	Area in Good to Very Good (or better) condition (ha)	Area in Degraded to Completely Degraded condition (ha)	Total zone area (ha)	Priority	
				ANR	Reconstruction
2	0.34		0.34	High	
3	5.20		5.20	Mod	
4	0.45	3.60	4.05	Low	Mod
5	1.0	0.31	1.31	High	Low
6		3.10	3.10		High

Strategy

Zone 1

Zone 1 is situated within cleared parkland, and has not been identified as an area requiring rehabilitation. However, the boundary of this zone requires weed control to reduce the chance of parkland grasses invading the reserve.

Priorities for assisted natural regeneration

Assisted natural regeneration follows the basic principles of the Bradley method (1988). This method involves selective weeding around native species to decrease competition, increase the size and number of native plants and gradually improve the condition of the bushland. The underlying principles of this method are to:

1. Work from areas in good condition to areas in poor condition. Start regeneration work in areas with the least disturbance to increase their resilience and then gradually work into areas with a greater density of weeds.
2. Minimise disturbance to soils and trampling of plants while working. This is important so that regeneration work does not simply create conditions favourable for weed invasion.
3. Let the rate of natural regeneration determine the rate of weed removal. This can be important, as over-weeding will leave large bare areas that can be reinvaded by more or different weeds.

Assisted natural regeneration following the Bradley method should be undertaken in bushland in Good to Very Good condition or better, which is just over 50 per cent of the reserve.

Zone 2

This zone is in Good condition and abuts part of the reserve that is in Excellent condition. It has also been identified as having potential acid sulfate soils near the surface (between 0–1 m). Maintaining and improving this zone's vegetation is important to protect the status of the Excellent condition vegetation as well as to enhance the reserve's visual aspect (this section is highly visible and the reserve's entrance). This zone is therefore a high priority for assisted natural regeneration.

Figure 1 Management zone 2

Zone 3

This zone consists of *Melaleuca rhaphiophylla* Open Woodland over Sedgeland of *Juncus kraussii* and *Bolboschoenus caldwellii* in Very Good to Excellent condition. There are very few weeds throughout the zone; however, poorer condition areas on the edges could affect this area if left unattended. It is a moderate priority area for assisted natural regeneration.

Figure 2 Management zone 3 – Swan River side

Figure 3 Management zone 3 – lakes' side

Zone 4

Zone 4 consists of Good condition *Melaleuca rhaphiophylla* Tall Open Scrub over a *Bolboschoenus caldwellii* and *Juncus kraussii* Sedgeland. Only some weeds were observed, *Typha orientalis* in particular, which is encroaching on the north-eastern section of the zone. Because of weed pressure from the zone's surrounding areas and its accessibility from both the cycle path and central reserve path, this zone has

been assigned a high priority for assisted natural regeneration. It should be noted that potential acid sulfate soils have been identified in the western portion of this zone (**Figure 13**).

Figure 4 Management zone 4 – facing east from centre track

Priorities for reconstruction

Zone 5

This area is degraded predominantly due to weed invasion. Situated in the reserve's north-eastern section, this zone backs onto residential properties. It has been given a low priority for regeneration but a moderate priority for reconstruction – because it is an important link to the Good to Excellent condition vegetation to the south. It is also a highly visible location for residents and visitors and reconstruction would improve its aesthetic value.

Figure 5 Management zone 5 – from property boundary facing south

Figure 6 Management zone 5 – from bicycle track facing north

Zone 6

This area is severely impacted by weeds, particularly *Typha orientalis* and *Ipomoea cairica*. This zone has been assigned a high priority for reconstruction because it abuts Excellent condition bushland and is highly visible. It also contains a high density of the weeds affecting the reserve and is thus a significant source of seed disbursement into other areas of the reserve.

Figure 7 Management zone 6

Revegetation

Site preparation

Weed control

The most important factor in a successful revegetation program is weed control. The vast majority of revegetation projects fail due to poor weed control. Experience from revegetation sites has shown that unless weed control is excellent, revegetation – particularly direct seeding – will fail. Weed control should follow the guidelines outlined in this plan for each priority species. For best results, two applications should be made: the first at the recommended timing outlined in **Appendix A** before planting or sowing, and the second one week before planting or sowing. Adequate ground preparation is important for good plant establishment.

Mulch

Thick layers of mulch can help retain soil moisture for seedlings while denying weed seeds access to light and thereby restricting their growth. After the manual and herbicide controls have been applied, weed-free mulch can be spread around seedlings in bare areas to help reduce weed growth. When sourcing the mulch, care must be taken to ensure it is not contaminated with weed seeds or disease.

Mulch is less effective in areas that are damp or flooded in winter, because it will rot quickly or be washed away. However, if initial weed control is carried out in spring, the mulch will still prevent germination of weeds over the first summer.

Timing of planting

To maximise survival rates, the seedlings must be disease-free, sun-hardened, have well-developed roots, not be root bound, and be planted to the correct depth.

Upland plants should be planted in late autumn to early winter. It is preferable for planting to occur as early after the break-of-season as practicable, when the soil is thoroughly moist and follow-up rain is expected. The longer the plants have to establish an adequate root system in the ground before the first summer, the better the success rate.

Seedlings planted in areas prone to inundation should be planted in spring as water recedes.

Species selection

Ideally the species used for revegetation would comprise the entire suite of plants that naturally occur at the site. A comprehensive species list from the site and surrounding area is required; a species list for the reserve is presented in **Appendix C**. This can be used in conjunction with the vegetation map (

) to select appropriate species for restoration sites.

In developing revegetation lists, consideration should be given to:

- the fact that not all species can be commercially propagated
- impact on access and views.

Plants should preferably be grown from seeds or cuttings collected within the study area or surrounding areas of similar vegetation type. All of the propagated plants should be grown by accredited *Phytophthora*-free (dieback-free) nurseries, preferably those specialising in contract growing of revegetation species.

Plant establishment

Seedling planting

Native seedlings should be planted in late autumn and early winter to ensure good establishment from beneficial winter rains. They should only be planted after initial winter rainfall has thoroughly moistened the soil and further rain is expected. Seedlings that have grown beyond the post-emergent stage (around four to nine months, depending on species growth rates) in square plastic pots (e.g. 75 x 75 x 100 mm or similar) are considered most suitable for planting. Nevertheless mature stock, although less suitable, makes an obvious statement to the public that a regeneration program is underway and is useful in some places. Native seedlings should include a range of ground strata, middle strata and upper strata species with a view to achieving the floristic and structural composition of the original vegetation community.

Adequate ground preparation is important for good plant establishment. A small area approximately 50 cm in diameter should be cleared of weeds by using a weed mat, manual hoeing or herbicides, as thick layers of mulch can deny weed seeds access

to light and thereby restrict their growth. After manual and herbicide controls have been applied, weed-free mulch can be spread around revegetated seedlings to help reduce weed growth. As discussed previously, care must be taken to source mulch that is not contaminated with weed seeds or disease. It is not necessary to water plants on planting as long as they are well watered beforehand and the planting precedes further rains.

A number of techniques can be used in association with the planting of seedlings, such as the use of tree guards and mulch, but these should be considered on a site-by-site basis.

Generally no fertilisers should be used at the time of planting. Seedlings should not be staked for support because free-standing plants become more durable and strong. Care should also be taken to ensure that plants are not evenly spaced or planted in rows. Seedlings should be randomly clumped or spaced to achieve a natural effect.

Direct seeding

Direct seeding can be a useful technique in reconstruction areas where the level of weeds is low. The areas requiring reconstruction within Baigup Reserve have significant levels of weeds and this method is not considered appropriate – except perhaps in areas where a blanket application of a broad spectrum knockdown herbicide can be used or the soil is scalped (i.e. the top layer contains weeds and weed seed is removed).

Recommendations

Rehabilitation and revegetation	Priority
Maintain the Good to Excellent condition bushland through assisted natural regeneration in zones 2, 3 and 4	Zones: 2 & 4 – High 3 – Med
Focus reconstruction efforts within Zone 6	High
Develop an annual monitoring program to assess vegetation condition through the success or failure of weed control and rehabilitation	Med
Use only local provenance plants for rehabilitation	High

6.5 Fire

Objectives

Fires have the potential to destroy the native ecology, both directly (through burning the vegetation) and indirectly (such as allowing weed invasion). It also threatens human life and adjacent properties.

Therefore the objectives for fire management are to:

- protect lives, properties and assets
- preserve the reserve's conservation values
- maintain the risk posed by wildfire to adjoining properties at an acceptable level
- preserve ecological and evolutionary processes
- conduct the monitoring necessary to ensure that the four above aims are achieved.

There is no single optimal fire regime for balancing all these requirements and fire management must always consider local conditions.

Background

Wildfires are a significant threat to Baigup Reserve. Within wetlands frequent fires will prevent the establishment of *Melaleuca* (paperbark) communities and can lead to a dominance of weed species, in particular *Typha orientalis*. This is because weed species can regenerate at a much faster rate than many native species (Regeneration Technology Pty Ltd 2004).

It has been recognised in previous management plans that the risk of fire is potentially high in the reserve due to:

1 The extent of weed growth in certain sections, which is a fire hazard for adjacent landowners and adjacent parts of the reserve

2 The peaty nature of the soil, which can hold heat and cause fires to re-ignite after the initial fire has been extinguished (Regeneration Technology Pty Ltd 1994).

General impacts of fires on the biological environment

Both the immediate and cumulative impacts of fires on biological values are of major concern given they can reduce the biodiversity of natural areas. Fires can affect the natural vegetation by:

- promotion of weed growth
- alteration of species composition
- threatening the viability of rare, endangered or geographically restricted species
- threatening the viability of obligate seeder species (which cannot resprout).

Fires at intervals more frequent than the inherent regenerative capacity of the vegetation can promote the spread of exotic weeds by creating favourable conditions such as:

- increased light penetration because of a burnt-out overstorey
- reduced competition from native perennial species
- increased availability of nutrients.

Increased weed growth, particularly annual grassy weeds, greatly increases the fire risk in a number of interrelated ways, including:

- forming a fine-textured fuel that is highly flammable
- producing a high fuel load annually, depending on climate and growth rate (native plants take much longer to reach the same fuel levels)
- forming a continuous fuel bed, permitting a fire to spread quickly (native plants usually have gaps between them which act to slow down the spread of fire)
- creating a very hot fire at ground level.

This situation leads to a cycle of increased weed growth and a resulting higher fire risk, leading to increased intensity and frequency of fires, which in turn leads to increased weed growth. The effect of this situation on natural communities is profound and can quickly lead to a greatly reduced diversity of flora and fauna.

Although fire is a natural part of the reserve's ecology, its current environmental conditions are very different to those of its natural situation, due to a number of factors including:

- the isolated nature of the study area within an urban context
- the greatly increased risk of fire ignition due to arson.

Assets requiring protection

Natural assets

Natural assets that require protection include:

- fire-sensitive species
- rehabilitation sites
- Very Good to Excellent condition bushland.

Rehabilitation sites should be protected from fire to prevent the loss of all seedlings. The best condition vegetation within the reserve is on the south side of the bicycle path adjoining the Swan River. A fire in this area would lead to the invasion of weeds and degradation of the bushland.

Infrastructure

Infrastructure within and adjacent to the reserve that needs protection from fire includes:

- adjacent houses
- bicycle path
- public utility
- boardwalk at the reserve's north-eastern end.

These can be seen in **Figure 14**.

Strategy

The proposed fire management plan has three core elements:

- hazard reduction
- fire suppression
- post-fire recovery and incident analysis.

The fire management plan's purpose is to reduce the frequency of ignitions, either accidental or deliberate, and to minimise the extent of fires within the bushland. A further aim is to minimise adverse environmental impacts of any fires that do occur.

Hazard reduction

Hazard reduction involves fuel and ignition reduction.

Fuel reduction

Strategic or controlled burns in urban bushland such as Baigup Reserve are **not** recommended. Given the small, fragmented and degraded nature of the reserve, the urban nature of the study area and its proximity to local residents, the risks associated with controlled burns outweigh any benefits gained from this activity. Furthermore, the high incidence of arson-related burns means that regeneration of some species is being adversely affected by the short interval between fires. As such, the minimum fuel loads required before controlled burns are initiated (8 tonnes/ha) are unlikely to be reached.

Instead fuel reduction activities should be focused on weed control and careful placement of low fuel zones (e.g. fire breaks and use of specific plants).

Control of grassy weeds and *Typha orientalis* should be undertaken in the reserve. This needs to be done in conjunction with revegetation activities. Spraying with Fusilade before revegetation will yield good results. If no revegetation is planned immediately after control, slashing or mowing may at times be appropriate. However, this is often not favoured due to the adverse impact on any native seedlings that have the potential to establish.

Ignition reduction

A significant portion of fires in urban bushland are deliberately lit. This study area is no exception, with arson being the primary cause of fires in Baigup Reserve.

Throughout the reserve, particularly in areas of high public use, interpretative signs could be installed that refer to the dangers of wildfires to human life and property, and the destructive cumulative effects of frequent fire on flora and fauna. The message should focus on the risk of accidental fire lighting and the need for the public to be vigilant against arsonists. Education programs should also emphasise the importance and vulnerability of the reserve's flora and fauna, as well as outline methods to prevent and control the spread of wildfire and ensure human safety in the event of a major fire in the reserve.

Fire suppression

Fire suppression involves fighting fires once they have started and taken hold. The Fire and Emergency Services Authority is the peak fire-fighting body in Western Australia. The authority administers the *Fire and Emergency Services Authority of Western Australia Act 1998*; *Fire Brigades Act 1942*; *Bush Fires Act 1954* and *Emergency Services Levy Act 2002*.

Post-fire recovery and incident analysis

Bushland is in a highly sensitive condition following fire. The soil is left bare and sensitive to erosive processes, such as vehicle and foot movements, heavy summer rain and wind.

After a fire in Baigup Reserve, the potential for further encroachment or movement of weeds into bare ground should be assessed. Access control measures should be put in place as soon as possible after the fire. Access to any burnt areas should be limited to management purposes only for the first six to 12 months.

Following fire, weed species have an opportunity to increase in density and abundance. Weed control measures will need to be implemented if a fire occurs. The post-fire environment is susceptible to further damage, and weed control works should be timed to give bushland the greatest chance of successful regeneration.

Fire-fighting operations have the potential to cause damage by trampling of vegetation, water erosion and small-scale clearing. While this cannot be entirely avoided, it can be minimised where possible through appropriate training of fire fighters. Trained bush regenerators should be used to repair damage of this nature.

Post-fire incident analysis is an important facet of fire management, enabling fire fighters and fire-control authorities to review procedures, strategies and tactics and revise them in light of experience. It is crucial that accurate records be kept to facilitate future fire and bushland management. A database should be set up in which details of all fires in the reserve are recorded. Maps of the fire extent should also be developed.

Recommendations

Fire management	Priority
Develop fire-response plan to assist the fire-fighting response	Med
Educate the community to increase awareness of the damaging effects of fire, particularly through school education programs	High
Regularly maintain fire breaks and keep tracks clear of weeds	High
Reduce fuel loads through control of weeds such as perennial veldt grass and bulrush	High
Revise weed control works after any fires to ensure potential damage by works are minimised and efficiencies are maximised	High

6.6 Fauna

Objectives

The objectives for fauna management are to:

- protect the diversity and abundance of native fauna species
- maintain the suite of native animals present through habitat preservation and supplementation
- extend surveys of fauna so that comprehensive lists can be compiled and management decisions tailored accordingly
- minimise predation and competition pressure on native animals
- minimise grazing pressure on native plants and seedlings by rabbits.

Background

Fauna was originally surveyed at Baigup Reserve for the 1994 management plan. In addition to this, avifauna was surveyed on a monthly basis from January to May in 2003 by Birds Australia (Gole 2004; Regeneration Technology Pty Ltd 2004). No formal surveys of other fauna had been undertaken until recently, when an aquatic invertebrate survey was conducted for baseline data and as a water quality indicator. Fauna lists from the 1994 report and other surveys can be seen in **Appendix D**.

The loss of native habitat surrounding the reserve has isolated it from other local bushland and wetlands. Without a continual green link between bushlands along the river, only the most mobile fauna such as large birds, amphibians and reptiles will be able to recolonise in the reserve. On the other hand, an overall improvement in the reserve's vegetation would likely see native species become more abundant and diverse (Regeneration Technology Pty Ltd 2004).

Strategy

Habitat preservation and supplementation

The most critical factor for native fauna is to maximise habitat and protection by minimising fires, maintaining water quality, improving bushland condition and managing feral animals, which may compete with or predate upon them. Maintaining a healthy vegetation buffer around the lake will also maximise the habitat requirements for many fauna species.

Introduced fauna

Controls need to be put in place when feral animals are reported. Specific control options are discussed below.

Foxes

Pindone is the only poison that may be considered for use at Baigup Reserve because 1080 poison cannot be used in urban areas (DAFWA 2005). Consideration also needs to be given to off-target poisoning (e.g. pets). The urban setting of the reserve means that shooting of feral animals is not an option due to public safety concerns.

The removal of shelter for foxes is not necessarily effective. A fox may have numerous resting sites within its home range and therefore the destruction of any one shelter is less critical (Thompson 2000). Foxes rest during the day in dens or sheltered sites such as rock piles, hollow logs or thickets (Thompson 2000).

The construction of exclusion fences may not be deemed appropriate for small urban bushland areas because of the visual impact and/or the financial burden. The construction and maintenance of fencing capable of excluding foxes is expensive, reportedly costing anywhere between $18 000 to $50 000/km (Environment Australia 1999b).

Animal Pest Management Services (2005) suggests that trapping and fumigation of dens may be the only suitable and effective methods to control foxes in urban areas. Yet when foxes are removed from a particular area, an influx of new individuals is likely to occur afterwards. This is because foxes tend to occupy distinct areas, from which they exclude other foxes; if one group is removed, another is able to move in.

Therefore the best way to mitigate the negative impacts of foxes is to reduce their foraging efficiency. In environments with dense vegetation, steep topography, rocky crevices or extensive wetlands, foxes are less likely to catch prey. As such, provision of a continuous canopy and thick understorey of shrubs reduces the risk of fox predation upon native animals (Environment Australia 1999b)

Cats

The issue of controlling cats in urban bushland is complicated by three different categories of cats, and not being able to distinguish between these categories when

attempting to control them. The Biodiversity Group of Environment Australia (Environment Australia 1999a) defines these as such:

- *Feral cats* are those that live and reproduce in the wild (e.g. forests, woodlands, grasslands and wetlands). They survive by hunting or scavenging and none of their needs are satisfied intentionally by people. (Feral cats differ little in appearance from their domestic counterparts except that they are generally more robust when in good condition (Department of Natural Resources Mines and Energy 2003).
- *Stray cats* are those found in and around cities, towns and rural properties. They may depend on some resources provided by humans, but are not owned.
- *Domestic cats* are those owned by individuals, households, businesses or corporations. They depend on their owners for most of their needs.

The home ranges of feral cats can vary from 4 to 8 km^2, depending on the availability of suitable den sites and food availability (NRME 2003). On this basis there is an assumption that stray and domestic cats will be in greater numbers and have a greater impact on the native animals in urban bushland such as Baigup Reserve.

The *Threat abatement plan for predation by feral cats* (Environment Australia 1999a) states that:

> The responsibility for managing domestic cats ultimately rests with their owners. State, territory and local governments are supporting initiatives aimed at encouraging responsible pet ownership, including developing appropriate legislation, education and awareness programs, and management plans to address local problems with domestic and stray cats. Victoria has enacted the *Domestic (Feral and Nuisance) Animals Act 1994* which requires cat owners to register their animals and gives councils the power to set fees and take remedial action when landowners experience problems with wandering cats. New South Wales has initiated the development of legislation to promote responsible ownership and improved welfare of companion animals.

Trapping and baiting of cats has limited effectiveness (and would be politically undesirable). Fencing is the only feasible method of control when special areas need protection from cats (NRME 2003). However, as with fox control, fencing to exclude cats may not be deemed appropriate for small urban bushland areas due the visual impact and/or the financial burden.

Providing a continuous canopy and a thick understorey of shrubs may also be the most effective method to reduce the impact of predation upon native animals. Cat owners should also be encouraged to keep their cats at home at night, while a cat curfew within a 200 m buffer of the reserve could also be considered.

Dogs

Dogs should remain on a leash throughout all areas of Baigup Reserve to avoid the following:

- destruction of native habitat and newly established seedlings
- soil disturbance, which may promote weed invasion
- threats to native fauna safety, breeding cycles and health (diseases may be passed onto these species through excrement)
- spoiling of native vegetation, which may interfere with the territorial behaviour of native fauna.

The provision of plastic bags and bins at appropriate locations around the reserve will enable dog owners to dispose of dog waste, which will help to minimise the impact of dogs on the environment.

Recommendations

Fauna	Priority
Use signs and interpretative information to inform the community about the adverse effects of pets on native fauna	High
Ensure dogs are on a lead and under effective control at all times	High
Provide more plastic bags and bins around the reserve for dog owners to dispose of waste responsibly	High
Trap and remove the European fox and discourage adjacent landowners from dumping garden refuse in the wetland to help reduce rat and mouse populations	Med
Investigate the implementation of a cat curfew within a certain buffer of the reserve to minimise predation on the native fauna by domestic cats	Low
Encourage landowners to restrict the free movement of pet cats and dogs in the reserve to reduce negative effects on native birds and mammals	High
Undertake an initial fauna survey of amphibians, reptiles, mammals and invertebrates to gather baseline information of the species present	High
Undertake routine sampling of fauna to determine changes in diversity and population size	High

6.7 Access, recreation and infrastructure

Objectives

The objectives for access, recreation and infrastructure are to:

- allow for a range of passive recreation activities without compromising or conflicting with the reserve's conservation values
- minimise human impact on fragile environments.
- provide safe and convenient access within the reserve.

Background

The reserve's major focus is conservation. Recreation opportunities are limited to more passive pursuits. The preference of more passive recreation within a conservation reserve will dictate the types of facilities that can be situated in it.

Access to the wetlands within the reserve is limited to the cycleway that runs east-west through the reserve and a limestone track between the two lakes (**Figure 14** and contour map in **Appendix E**). There is also a limestone access track at the rear of the houses on Stone Street that the Water Corporation created for the infill sewerage program.

At present there is no access to the wetlands, although boardwalk access has been planned. Informal tracks have been created for access to the wetlands and the river foreshore, which contributes to shoreline erosion – especially where vegetation is trampled and access requires scrambling from higher more-stable ground to the sandy foreshore.

Strategy

Access

Access should be restricted to the formal paths within the reserve: these include the central path running east-west and the limestone track between the wetlands. The entrances to these paths are already restricted to pedestrian and cycle use with steel bollards to prevent unauthorised vehicle access.

Formal paths

The formal paths within the reserve are adequate but should be periodically inspected to ensure they are maintained to a standard that does not expose the City of Bayswater to a risk in terms of public liability.

Recreation sites and facilities

There have been a number of proposals for facilities in the past including:

- a lookout at the Kelvin Street end of the reserve
- boardwalk access to the wetlands and lakes

- picnic tables and seating at either end of the reserve, at its midway point and at the beach.

If any of these go ahead, the emphasis should be on well designed and constructed facilities such as furniture, boardwalks and lookouts that don't detract from the reserve's natural and conservation values (Regeneration Technology Pty Ltd 2004).

Visitor safety

Safety is an issue for all public spaces. The random nature of natural settings presents numerous hazards – many of which will never be identified. For management purposes all reasonable and practical efforts should be taken to minimise risks to visitors. These management actions should be consistent with the values of the reserve and not intrude unduly on the experience of visitors. Safety is an integral component, especially for the development of new facilities within the reserve (Regeneration Technology Pty Ltd 2004). At present warning signs in the reserve advise visitors not to swim in the wetlands and identify the location of the gas pipeline.

Lighting of the reserve would be another way to improve visitor safety. However, if soil disturbance is required to install lighting options, then it should be avoided.

Recommendations

Access, recreation and infrastructure	Priority
Restrict access to the limestone access track at the rear of Stone Street properties	High
Ensure all new boardwalks and platforms are designed to Australian design standards to allow access for all	High
Allow access for emergency response vehicles	High
Prepare and plan for suitable and safe facilities guided by Australian standards	Low
Develop facilities and structures in a manner that is sympathetic with the surrounding landscape	Med
Provide information to visitors that identifies potential hazards and hazardous activities	High

6.8 Cultural heritage, interpretation and education

Objectives

The objectives for cultural heritage, interpretation and education are to:

- identify, protect and appropriately manage sites with Aboriginal and European heritage significance within the reserve
- increase awareness of the environment and cultural significance of the reserve
- improve interpretive educational activities
- promote educational awareness and appreciation of the reserve.

Strategy

Aboriginal use and association

As part of any management strategy for Baigup Reserve, management obligations need to be fulfilled according to the *Aboriginal Heritage Act 1972* (WA) and the *Native Title Amendment Act 1998* (Cwlth) before any planning or public works takes place.

Signs

The four types of signs erected in reserves are:

- directional (provide information as to where facilities etc. are located)
- regulatory (inform the public about what activities are permitted)
- interpretative (provide information about animals, birds and history etc.)
- entrance (such as the reserve's name and the managing authority).

In the reserve at present are signs identifying the reserve, pointing to the location of the gas pipeline, warning of dangers (e.g. swimming in the lakes) and providing information about rehabilitation. There is no interpretive signage within the reserve linking it to the significance of the Swan River to Aboriginal people or providing information and education about the natural features or social history of the site.

Signs on-site create the opportunity to inform and inspire the public. This could be in the form of information shelters and/or interpretative signs along walk trails.

Information shelters could include permanent panels (with information that does not need to be changed frequently such as a map or the values of the reserve) as well as panels to be periodically updated with information.

In positioning signs along paths, careful consideration should be given to their location. Signs should be located near to what they are describing or significant views, and/or places of historical interest or educational significance. The text could be accompanied with images and diagrams.

Interpretation helps to meet the demand for educational visitor experiences and encourages people to care about the places they visit. It should build on the experiences in and interests of the area, in order to enhance an understanding and enjoyment of the place.

Recommendations

Cultural heritage, interpretation and education	Priority
Develop an interpretation plan for the reserve to facilitate a coordinated plan for interpretation and education	Med
Establish interpretive signage along the walk trail	Med
Develop a signage standard/scheme such that all signs are consistent in materials, dimensions, colours etc.	Med
Liaise with other authorities (e.g. Alinta Gas and Bikewest) to ensure consistency of signs (or sign placement) within the reserve	Med

7 Implementation program

7.1 Introduction

To implement this *Baigup Reserve remediation and management plan*, the actions identified in the management issues section are presented in **Table 11** and assigned a priority. An opinion on the probable cost of bushland revegetation is also provided in this section.

To ensure the reserve's successful management, on-going liaison is required between management bodies such as the City of Bayswater, Department of Water, Department of Environment and Conservation and other stakeholders such as the Water Corporation and Alinta Gas.

7.2 Action plan

Table 11 below summarises all the recommendations previously listed in this plan.

The priority ranking assigned to each action is defined as follows:

High	Recommendation should be initiated within the next year
Medium	Recommendation should be initiated within three years
Low	Recommendation should be initiated within five years depending on budget constraints

Table 11 Baigup Reserve action plan

Recommendation	Priority
Acid sulfate soils	
Surface and groundwater should be monitored following any site disturbance, e.g. weed control, rehabilitation, installation of infrastructure	High
Disturbance should be conducted in a staged approach to minimise and better manage the outcomes	High
Conduct a disturbance test site to determine the possible extent of impacts before large disturbance works	High
Retain pooling of water within the lakes to reduce exposure of acid sulfate soils to the atmosphere	High
Install several large box culverts allowing for increased exchange between the two sides of the path	Med

Recommendation	Priority
Depending on the level of access required by Alinta Gas to maintain the pipeline, investigate replacing sections of the bike path with a raised walkway to enable exchange between the two sides of the path	Low
Weed control	
Conduct a comprehensive weed survey to prioritise weeds for control	Low
Use **Table 3** to undertake immediate removal of the six identified High Priority weeds at Baigup Reserve	High
Ensure application of any herbicides is in accordance with the material safety data sheets and Department of Water (2000) water catchment restrictions	High
Implement monitoring program to assess changes in weed species and distribution in the study area and adapt weed strategies accordingly	Med
High disturbance weed control (e.g. removal of *Typha*) should be conducted in a staged approach in potential acid sulfate soil areas (Figure 13) to minimise and better manage the outcomes	High
Rehabilitation and revegetation	
Maintain the Good to Excellent condition bushland through assisted natural regeneration in zones 2, 3 and 4	Zones: 2 & 4 – High 3 – Med
Focus reconstruction efforts within Zone 6	High
Develop an annual monitoring program to assess vegetation condition through the success or failure of weed control and rehabilitation	Med
Use only local provenance plants for rehabilitation	High
Fire management	
Develop fire-response plan to assist fire-fighting response	Med

Recommendation	Priority
Educate the community to increase awareness of the damaging effects of fire, particularly through school education programs	High
Regularly maintain fire breaks and keep tracks clear of weeds	High
Reduce fuel loads through control of weeds such as perennial veldt grass and bulrush	High
Revise weed control works after any fires to ensure potential damage by works are minimised and efficiencies are maximised	High
Fauna	
Use signs and interpretative information to inform the community about the adverse effects of pets on native fauna	High
Ensure dogs are on a lead and under effective control at all times	High
Provide more plastic bags and bins around the reserve for dog owners to dispose of waste responsibly	High
Trap and remove the European fox and discourage adjacent landowners from dumping garden refuse in the wetland to help reduce rat and mouse populations	Med
Investigate the implementation of a cat curfew within a certain buffer of the reserve to minimise predation on the native fauna by domestic cats	Low
Encourage landowners to restrict the free movement of pet cats and dogs in the reserve to reduce negative effects on native birds and mammals	High
Undertake an initial fauna survey of amphibians, reptiles, mammals and invertebrates to gather baseline information of the species present	High
Undertake routine sampling of fauna, to determine changes in diversity and population size	High
Access, recreation and infrastructure	
Restrict access to the limestone access track at the rear of Stone Street properties	High

Recommendation	Priority
Ensure all new boardwalks and platforms are designed to Australian design standards to allow access for all	High
Allow access for emergency response vehicles	High
Prepare and plan for suitable and safe facilities guided by Australian standards	Low
Develop facilities and structures in a manner that is sympathetic with the surrounding landscape	Med
Provide information to visitors that identifies potential hazards and hazardous activities	High
Cultural heritage, interpretation and education	
Develop an Interpretation Plan for the reserve to facilitate a coordinated plan for interpretation and education	Med
Establish interpretive signage along the walk trail	Med
Develop a signage standard/scheme such that all signs are consistent in materials, dimensions, colours etc.	Med

7.3 Opinion of probable cost for bushland revegetation

The opinion of probable cost (OPC) given in **Table 12** is based on the full commercial costs of restoring bushland in an urban setting. The cost of maintaining Very Good to Excellent condition bushland can vary significantly between sites: larger remnants being less expensive per m^2 than maintaining small or fragmented remnants. The cost of establishment and maintenance of the Completely Degraded sites is less variable, given that most of the cost is absorbed by seedlings. It is assumed that seedlings will be bought at a cost of approximately $1.75 each and that two to three seedlings will be planted per m^2 in Degraded to Completely Degraded sites. Once the bushland is in Very Good to Excellent condition, the annual maintenance costs should stabilise at approximately $0.02/$m^2$. The cost of restoration is higher than maintenance because costs of propagules such as seedlings do not have to be borne.

While it is a useful exercise to gauge the full costs of restoring Baigup Reserve's vegetation, funds available for bushland management are likely to vary annually and implementation will need to be adjusted accordingly. Staff and volunteer labour can significantly reduce costs, particularly for the maintenance of higher quality bushland where a greater proportion of costs is labour. Costs can also be reduced by

extending works over a longer period of time by staggering revegetation within the site.

Table 12 Cost of professional restoration per m^2

Condition	Very Good to excellent	Good	Degraded	Completely degraded	Burnt areas
Establishment	NA	NA	$5.00	$6.00	NA
After 1st year	$0.02	$0.25	$2.00	$3.00	$0.25
After 2nd year	$0.02	$0.05	$1.00	$1.20	$0.05

On the basis of the bushland condition mapping and **Table 12** above, the probable cost for restoring and maintaining Baigup Reserve to Very Good condition over five years is given in **Table 13** below for each management zone.

Table 13 Estimate of cost of professional restoration for each management zone

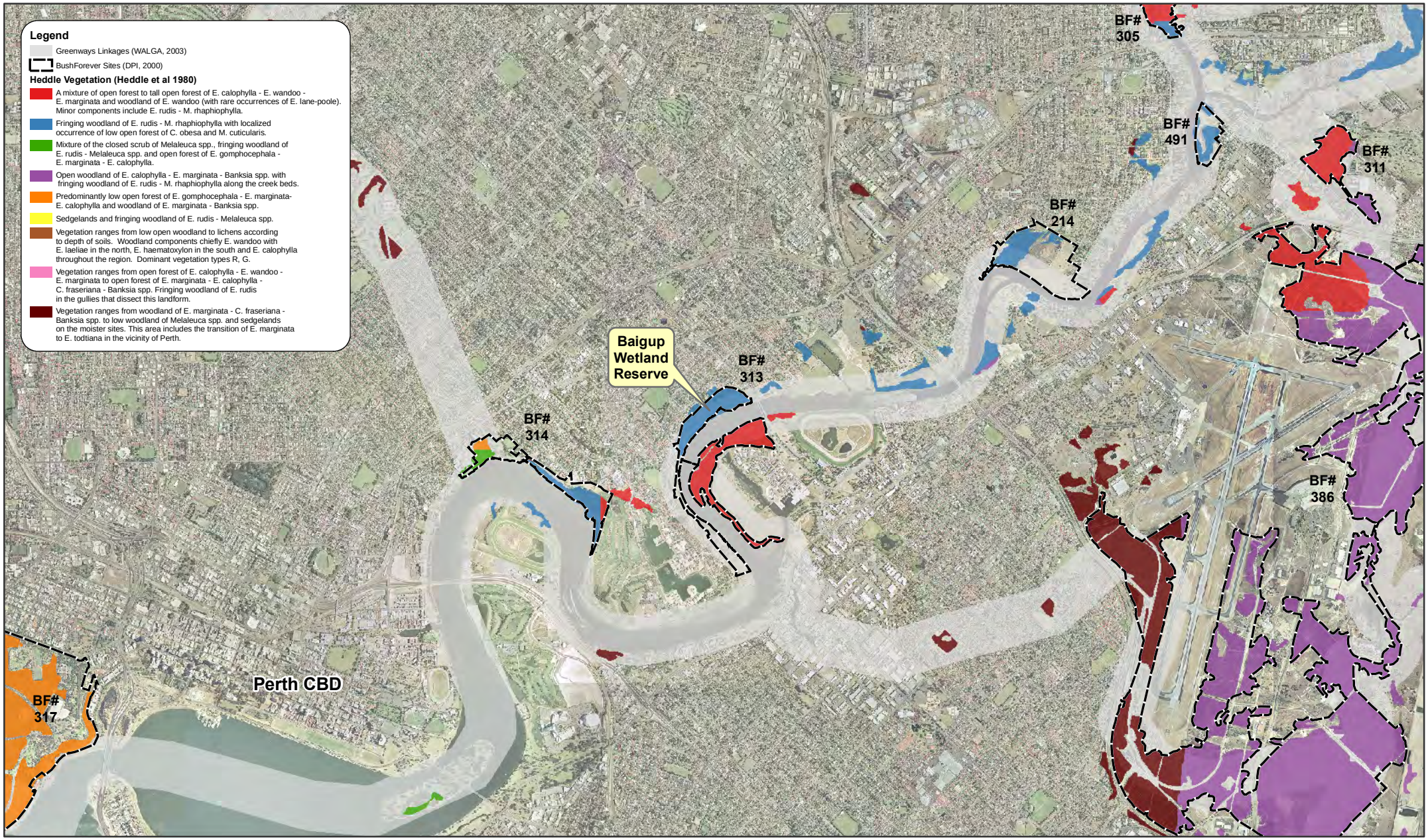
Zone	Priority	Area (m^2)	OPC over five-year period
2	High	3400	$272
3	Mod	52 000	$4160
4	Mod	40 500	$277 180
5	Mod	13 100	$10 034
6	High	31 000	$264 120
	TOTAL	**140 000**	**$555 766**

Table 14 Indicative costs for various management activities

Action	Cost	Unit
Restoration		
Weed control barrier	$12.00	linear metre
Supply and install plant guards	$1.60	each
Supply and install organic mulch	$7.00	square metre

Action	Cost	Unit
Supply and install treated timber bollards	$50.00	each
Supply and install fencing	$30.00	linear metre
Supply and install brushing	$25.00	square metre
Formal path installation	$15.00	
Rabbit baiting per 500 m^2	$100.00	station
Composite wood decking	$20.00	linear metre
Supply and install boardwalk sub-structure	$400.00	square metre
Supply and install basic sign	$250.00	each
Supply and install basic park bench	$1500.00	
Miscellaneous labour	$30.00	hour
Maintenance (per year)		
Landscape maintenance	$3.50	
Fencing maintenance	$3.00	linear metre
Brushing maintenance	$2.50	square metre
Formal path maintenance	$1.50	
Rabbit baiting per 500 m^2	$100.00	station
Miscellaneous labour	$30.00	hour

8 Maps



Map 1

Aug 2009

Baigup Reserve Remediation and Management Plan

Figure 8 Regional Context

prepared for Department of Water

0 0.5 1 1.5 2 Kms

1:50,000@ A4

Project No. 1831-07

ecoscape

Map 2

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Baigup Reserve Remediation and Management Plan

Figure 9 Site Location and Tenure

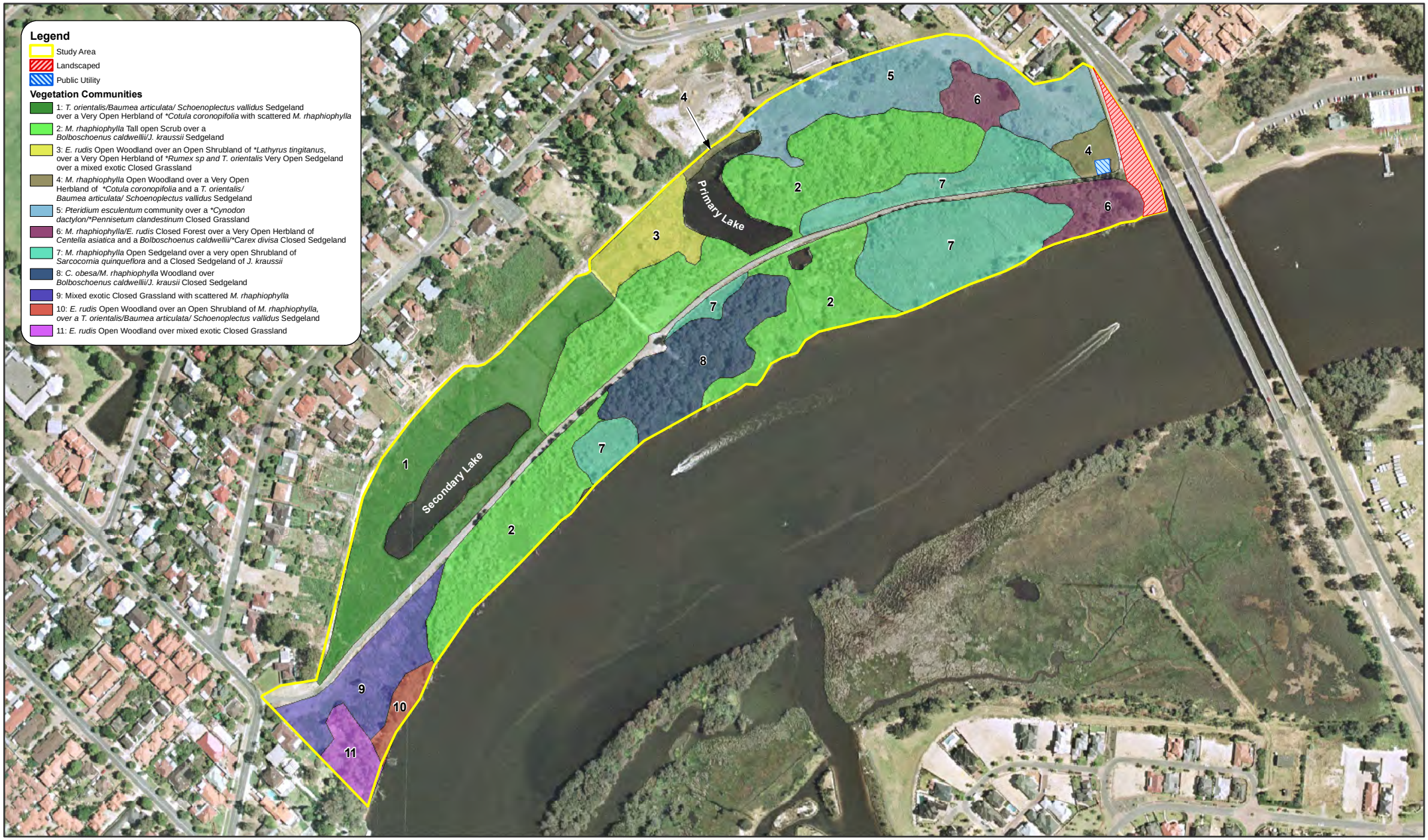
prepared for Department of Water

0 50 100 150 200 250 Meters

1:6,000 @ A4

Project No. 1831-07

ecoscape



Map 3

Aug 2009

Baigup Reserve Remediation and Management Plan

Figure 10 Vegetation Communities

prepared for Department of Water

0 50 100 150 200 250 Meters

1:4,500 @ A4

Project No. 1831-07

ecoscape

Map 4

Aug 2009

Baigup Reserve Remediation and Management Plan

Figure 11 Bushland Condition

prepared for Department of Water

0 50 100 150 200 250 Meters

1:4,500 @ A4

Project No. 1831-07

ecoscape

Map 5

Aug 2009

Baigup Reserve Remediation and Management Plan

Figure 12 Management Zones

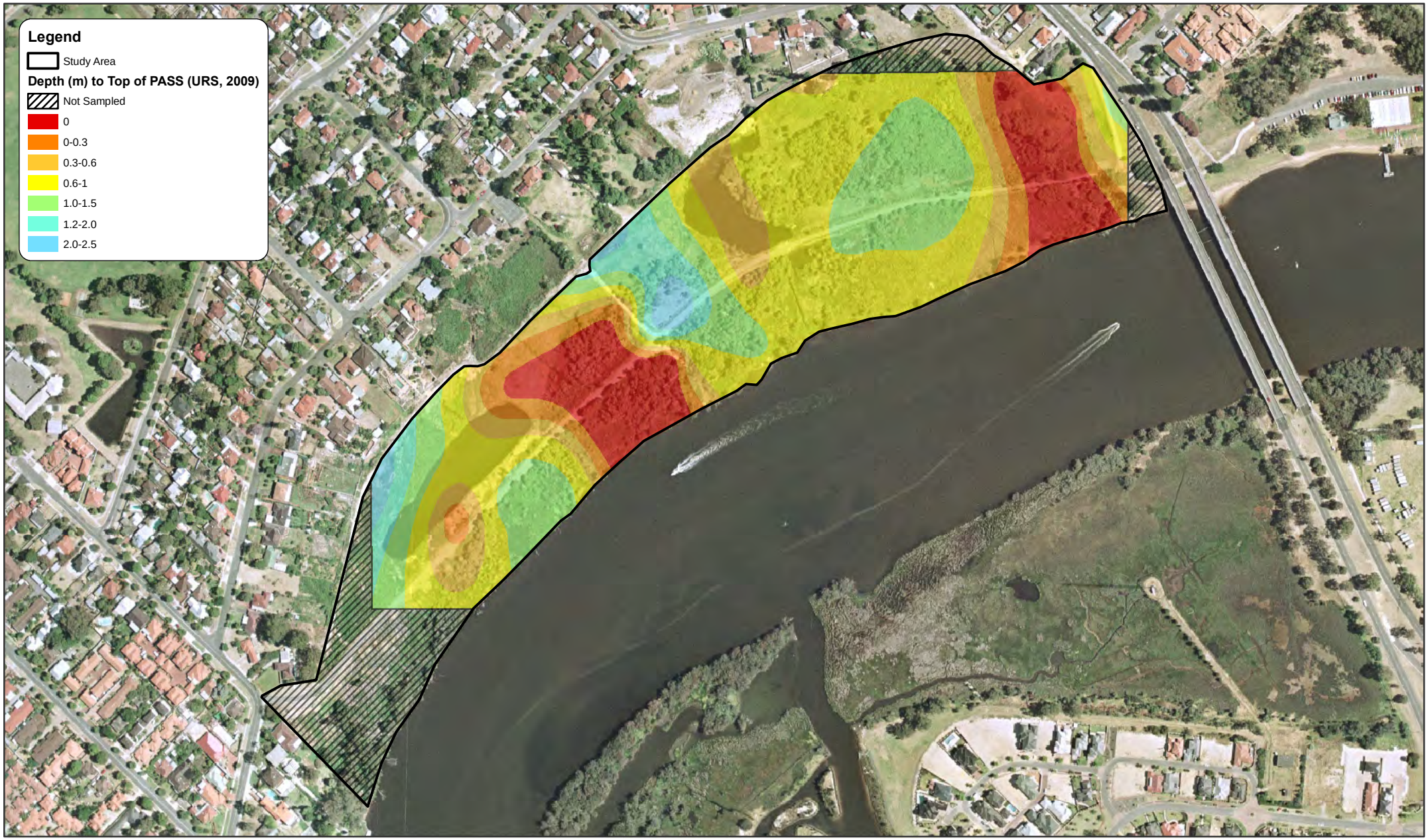
prepared for Department of Water

0 50 100 150 200 250 Meters

1:4,500 @ A4

Project No. 1831-07

ecoscape



Map 6

Aug 2009

Baigup Reserve Remediation and Management Plan

Figure 13 Acid Sulfate Soils

prepared for Department of Water

0 50 100 150 200 250 Meters

1:4,500 @ A4

Project No. 1831-07

ecoscape

Map 7

Aug 2009

Baigup Reserve Remediation and Management Plan

Figure 14 Recreation Sites and Facilities

prepared for Department of Water

0 50 100 150 200 250 Meters

1:4,500 @ A4

Project No. 1831-07

ecoscape

Appendices

Appendix A – Weed priority and control methods

Table 15 Priority of species recorded at Baigup Reserve

Weed species		Prioritisation					
Species	**Common name**	**EWSWA rating**	**Dixon and Keighery rating**	**Final rating**	**Priority**	**Visual prominence of species**	**Baigup Reserve priority**
Arundo donax	Giant reed	Unrated	2	4	Mod	Low	Low
Avena fatua	Wild oat	Mod	1	5	High	Mod	Mod
Carex divisa	Divided sedge	Mod	3	3	Mod	Low	Low
Conyza albinia	Tall fleabane	tba	3	2	Low	Mod	Mod
Conyza bonariensis	Flaxleaf fleabane	Low	3	2	Low	Mod	Mod
Cortaderia selloana	Pampas grass	High	1	6	High	High	Mod
Cotula coronopifolia	Water buttons	Low	1	1	Low	Low	Low
Cynodon dactylon	Couch	Mod	1	5	High	Low	Mod
Cyperus involucratus		Low	1	1	Low	Low	Low
Ehrharta calycina	Perennial veldt grass	High	1	6	High	Low	High
Euphorbia terracina	Geraldton carnation weed	High	1	6	High	Mod	High
Hypochaeris glabra	Flat weed	Mod	3	3	Mod	Low	Low
Ipomoea cairica	Morning glory	Mild	3	2	Low	High	High
Lagurus ovatus	Hares tail grass	High	2	5	High	Low	High
Lathyrus tingitanus	Tangier pea	Low	3	2	Low	Low	Low
Lolium rigidum	Ryegrass	Mod	3	3	Mod	Mod	Low
Paspalum dilatatum	Paspalum	Mod	2	4	Mod	Low	High

Weed species		Prioritisation					
Species	Common name	EWSWA rating	Dixon and Keighery rating	Final rating	Priority	Visual prominence of species	Baigup Reserve priority
Paspalum distichum	Water couch	Mod	2	4	Mod	Low	Mod
Pelargonium capitatum	Rose pelargonium	High	1	6	High	Mod	High
Pennisetum clandestinum	Kikuyu	Mod	1	5	High	Low	Mod
Raphanus nasturtium-aquaticum	Wild radish	Mild	3	2	Low	Low	Low
Ricinus communis	Castor oil	Low	3	2	Low	Low	Mod
Rorippa nasturtium-aquaticum	Water cress	Mod		4	Mod	Low	Mod
Rubus fruticosus	Blackberry	Low		6	High	Low	Mod
Salix babylonica	Weeping willow	Low	3	2	Low	Low	Low
Schinus terebinthifolius	Japanese pepper	Unrated	1	1	Low	Low	Mod
Typha orientalis	Bulrush	High	1	6	High	High	High
Zantedeschia aethiopica	Arum lily	High	1	6	High	Low	Mod

Priority weeds

Weed significance

The priority rating of each recorded weed species, above, was determined after examining:

- its rating in the *Environmental Weed Strategy of Western Australia* (EWSWA) by the Department of Conservation and Land Management (CALM 1999)
- the rating in Dixon and Keighery's *Recommended methods to control specific weed species* (1995)
- whether it was listed in the *Agricultural and Related Resources Protection Act 1976* (ARRPA)

- whether it was listed as a *Weed of National Significance* (WONS) (Australia 2008)
- its local significance to natural areas.

The role of the weed strategy is to highlight which weed species pose significant environmental risk to Western Australia. The EWSWA rating provides a basis for determining which weeds are most critical to control. The three characteristics used for determining an EWSWA rating are:

- *Invasiveness.* Ability to invade bushland in good-to-excellent condition, and waterways.
- *Distribution.* Wide current or potential distribution, including consideration of a known history of wide distribution elsewhere in the world.
- *Environmental impacts*. Ability to change the structure, composition and function of ecosystems, in particular to form a monoculture in a vegetation community.

EWSWA weed species were rated accordingly:

- *High.* Have all three of the characteristics.
- *Moderate*. Have two of the characteristics.
- *Mild*. Have one of the characteristics.
- *Low*. Not deemed to have any of the characteristics.

The system used by Dixon and Keighery (1995) classified all weeds according to the threat they pose to bushland in the Perth Metropolitan region. The three classifications used were:

- *Priority 1*. Major weeds, which are the most serious weeds within their ecosystem, often affecting many reserves or habitats in ways likely to permanently degrade them.
- *Priority 2*. Nuisance weeds, which are generally found only in a few locations or ecosystems, usually in disturbed areas.
- *Priority 3.* Minor weeds, which have little known effect and occur in smaller numbers or are less competitive than priority 2 weeds.

The type of control for ARRPA-declared weed species are listed below:

- *P1*. Prohibits movement of plants or their seeds within the state. This prohibits the movement of contaminated machinery and produce including livestock and feed.
- *P2*. Eradicate infestation to destroy and prevent propagation each year until no plants remain. The infested area must be managed in such a way that prevents the spread of seeds or parts of plants in or on livestock, fodder, grain, vehicles and/or machinery.
- *P3*. Control infestation in such a way that prevents the spread of seed or plant parts within and from the property in or on livestock, fodder, grain, vehicles and/or machinery. Treat to destroy and prevent seed set in all plants.

- *P4* – Prevent the spread of infestation from the property in or on livestock, fodder, grain, vehicles and/or machinery. Treat to destroy and prevent seed set in all plants.

In 1999 WONS was jointly declared by the Minister for Forestry and Conservation, the Minister for Agriculture, Fisheries and Forestry and the Minister for The Environment as part of the *National Weeds Strategy*. The four characteristics used for determining whether the species was of national significance were:

- invasiveness
- impacts
- potential for spread
- socioeconomic and environmental values.

Ranking priority weeds

The above sources were used to rank the recorded weed species in **Table 15**, also above, in order of priority for control. Both EWSWA (CALM 1999) and Dixon and Keighery (1995) were used because they allowed most weeds identified in the study area to be assigned a rating and thereby be ranked. If only one source had been used, many weed species would have not been assigned a rating score.

For the purposes of this study, the Dixon and Keighery (1995) ratings of priority 1 and priority 2 were deemed equivalent to the EWSWA high and moderate ratings, respectively. The Dixon and Keighery (1995) priority 3 rating was considered equivalent to the EWSWA mild and low ratings. Species that were only rated with one system were assumed to have an equal rating in the other system. For example, a species that had a high rating in EWSWA but was not rated in Dixon and Keighery (1995) was assumed to have a priority 1 rating in Dixon and Keighery (1995).

The use of two rating systems resulted in some conflict when assigning a ranking for a weed species. To overcome this issue, a scoring system was developed to enable the ranking of the weed species. This system is summarised in the table below and had the following characteristics:

- EWSWA rates were scored as follows: high (3 points), moderate (2 points) and mild/low (1 point). Mild and low in EWSWA were considered equal.
- Dixon and Keighery rates were scored: priority 1 (3 points), priority 2 (2 points) and priority 3 (1 point).
- If a weed was not rated, by both EWSWA and Dixon and Keighery, it was given a score of 1.

In addition, as weed species listed under either ARRPA or WONS are required by legislation to be controlled, any of these listed weed species recorded were automatically given a rating of 6.

The calculated ratings were adjusted according to whether the species were more or less of a threat, or dominant in the local native areas. Species with low ratings that posed a greater threat or were already highly dominant had their ratings increased.

In contrast, species with high ratings that were not considered to be a local threat had their ratings lowered accordingly.

The priority of each weed species was then classified by the final rating (**Table 15**):

- species given a rating of 5 or 6 were high priority weeds.
- species with a final rating of 3 or 4 were moderate priority weeds
- species with a rating of 1 or 2 were low priority weeds.

Table 16 Calculated rating of priority weeds

EWSWA rating	Dixon & Keighery (1995) rating	Score	Priority
High	Priority 1		
High	TBA	6	
TBA	Priority 1		High
High	Priority 2	5	
Moderate	Priority 1		
High	Priority 3		
Moderate	Priority 2		
Moderate	TBA	4	
Mild/Low	Priority 1		Moderate
TBA	Priority 2		
Moderate	Priority 3	3	
Mild/Low	Priority 2		
Mild/Low	Priority 3	2	
Mild/Low	TBA		
TBA	Priority 3		Low
TBA	TBA	1	

Note: TBA = To Be Assessed (weed species which have not been priority rated)

Table 17 Management recommendations for weed species recorded in study area

Weed species				Control recommendations				
Scientific name	**Common names**	**Life form**	**Comments**	**Manual control**	**Wicker wipe/ cut stump**	**Spot spray @ 10 L water**	**Blanket spray per ha**	**Herbicide timing**
Arundo donax	Giant reed	Perennial	Mainly found in disturbed areas. Difficult to control. Serious weed.	Cut down or burn, spray regrowth when 0.5–1.0 m high.		Thoroughly wet foliage using Glyphosate 360, 100 mL in 10L water + wetter (dilution 1 per cent). Repeat application may be necessary.		All year
Avena fatua	Wild oat	Annual	Mainly in highly disturbed areas. Competes with natives. Fire hazard.	Prevent seed set for 3–5 years. This may be achieved by manual removal, regular mowing, grazing or spraying.			Spray at 3–5 leaf stage with Fusilade® 10 mU 10 L (500 ml/ha) + wetting agent; repeat over following 2 years.	
Carex divisa	Divided sedge	Perennial	Only in disturbed wetlands, forms dense colonies, smothers native sedges.	Difficult to dig out. No specific information on herbicide control.		Suggest high rates of glyphosate/ Roundup plus Pulse, when actively growing. A pre-burn or slash to encourage new growth may make control easier.		Sep–Dec
Conyza albinia	Tall fleabane	Annual	It is a common weed of roadsides and disturbed bushland in Perth. Produces large numbers of seed therefore difficult to control. Native to South America. A major problem in disturbed sites. Produces large numbers of seed therefore difficult to control. Summer annual, in poor seasons can flower when only a few cm high.	Planting perennial species to increase ground cover and shade will help reduce reinfestation. Hand pulling after stem elongation is effective on loose soils, but on heavier soils a weed fork is required to prevent the plant breaking and regrowing from the base. Manually remove small populations before they spread.	Wicker wipe with 1:2 Roundup® to water.	• 100 mL Roundup Bioactive® • 70mL Agroxone® + 10 mL Jaguar® • 5 mL Lontrel® • 100 mL Agriliance® • 50 mL Tordon® 75-D • 5 mL Lontrel® • 100 mL Grazon® • Spraying 50–75 mL glyphosate per 10 L water		Sep–Dec

Weed species				Control recommendations				
Scientific name	**Common names**	**Life form**	**Comments**	**Manual control**	**Wicker wipe/ cut stump**	**Spot spray @ 10 L water**	**Blanket spray per ha**	**Herbicide timing**
Conyza bonariensis	Flaxleaf fleabane	Annual	A common weed of roadsides and disturbed bushland in Perth. Produces large numbers of seed therefore difficult to control. Native to South America. A major problem in disturbed sites. Produces large numbers of seed therefore difficult to control. Summer annual, in poor seasons can flower when only a few cm high.	Planting perennial species to increase ground cover and shade will help reduce reinfestation. Hand pulling after stem elongation is effective on loose soils, but on heavier soils a weed fork is required to prevent the plant breaking and regrowing from the base. Manually remove small populations before they spread.	Wicker wipe with 1:2 Roundup® to water.	• 100 mL Roundup Bioactive® • 70 mL Agroxone® + 10 mL Jaguar® • 5 mL Lontrel® • 100 mL Agriliance® • 50 mL Tordon® 75-D • 5 mL Lontrel® • 100 mL Grazon® • Spraying 50–75 mL glyphosate per 10 L water		Sep–Dec
Cortaderia selloana	Pampas grass	Perennial	A garden escape, it is naturalised in sunny, swampy sites from Perth to Albany. Potentially a serious weed of wetlands and its wind-blown seeds are capable of long-distance dispersal. Native to South America.	Cut out small plants, do not leave uprooted plants lying on ground – they can resprout; remove flower heads.	Wicker wipe with 1:2 Roundup® to water. Wipe both sides of leaf.	Selective control • 10 mL Fusilade® • 10 mL Targa® • 10 mL Verdict® • 5 mL Sertin® Non-selective control • 100 mL Roundup Bioactive®		Oct–Dec
Cotula coronopifolia	Water buttons	Perennial	A fleshy, hairless annual or perennial found in damp situations.	n/a	n/a	n/a	n/a	n/a

Weed species				Control recommendations				
Scientific name	**Common names**	**Life form**	**Comments**	**Manual control**	**Wicker wipe/ cut stump**	**Spot spray @ 10 L water**	**Blanket spray per ha**	**Herbicide timing**
Cynodon dactylon	Couch	Perennial	Competes with native species. Mainly in highly disturbed areas. It is widely planted as a lawn grass and it invades wetlands and river edges in southern Western Australia. It is native to the Kimberley and the tropics worldwide.	Shade out with black plastic during spring and autumn.		Selective control • 50 mL Fusilade® • 50 mL Targa® • 50 mL Verdict® • 20 mL Sertin ® Non-selective control • 100 mL Roundup Bioactive® • Ally® • Brushoff® • Glean®	• 4 L Fusilade® • 4 L Sertin® • 4 L Targa® • 1.5 L Verdict®	Oct–Nov April–May
Cyperus involucratus			A garden ornamental found in some wetlands around Perth. It has a similar growth habit to the other species, except that it is tall and the stems are cylindrical.	n/a	n/a	n/a	n/a	n/a
Ehrharta calycina	Perennial veldt grass	Perennial		Manually remove small populations before seeding.	Wicker wipe with 1:2 Fusilade®, Sertin®, Targa® or Roundup® to water.	Selective control • 50 mL Targa® • 50 mL Sertin® • 50 mL Fusilade® • 20 mL Verdict® Non-selective control • 100 mL Roundup Bioactive®		Aug–Sep
Euphorbia terracina	Geraldton carnation weed	Annual/ perennial	Common and serious weed of grazing land, road verges, coastal heath and tuart woodlands from Geraldton to Esperance. Native to the Mediterranean.	Manually remove small populations.	Try 1:2 glyphosate for wicker wiping.	Spray seed 200,10–15 mL in 10 L water + 0.25% wetter, in early winter.	Spray large populations with 15 mL Spray-seed 200 plus 25 mL surfactant in 10 L water.	May–June

Weed species				Control recommendations				
Scientific name	**Common names**	**Life form**	**Comments**	**Manual control**	**Wicker wipe/ cut stump**	**Spot spray @ 10 L water**	**Blanket spray per ha**	**Herbicide timing**
Hypochaeris glabra	Flat weed	Annual/ perennial	Common	Use a weed fork to extract the taproot if hand pulling. Use 2–3 L/ha glyphosate (450 g/L) on road shoulders to reduce the spread of seed in traffic slipstreams. In bushland situations, 500 mL/ha of Lontrel is fairly selective.	Try 1:2 glyphosate for wicker wiping	Glyphosate/Roundup 100 mL in 15 L water, knapsack, or use weeding wand higher rate. Apply when rosettes are fully developed at the early flower stage.	Spray large populations with 100 ml Roundup or 50 mL Tordon®75-D + 25 mL surfactant in 10 L water	Aug–Nov
Ipomoea cairica	Morning glory	Perennial	A glabrous perennial vine with tuberous roots. The young stems are red and the leaves ovate in outline, but with 5–7 finger-like lobes. Flowers are funnel-shaped, mauve-pink.	Manual removal recommended.	Wicker wipe with 1:2 Roundup® to water.	Non-selective control • 100 mL Roundup Bioactive®		All year
Juncus microcephalus		Perennial	Creek lines, competes with natives			Non-selective control • 100 mL Roundup Bioactive®		Nov–Feb
Lagurus ovatus	Hares tail grass	Annual	Competes with native plants. A common weed of sandy soils, especially near the coast. Native to the Mediterranean.	Manually remove individuals. Prevent seed set for 2–3 years by mowing, grazing or cultivation.	Wicker wipe with 1 2 Roundup® to water.	Selective control • 10 mL Fusilade® • 10 mL Targa® • 10 mL Verdict® • 5 mL Sertin® Non-selective control • 100 mL Roundup Bioactive®		Jun–Sep
Lathyrus tingitanus	Tangier pea	Perennial	Smothers native plants. Usually in highly disturbed areas.	Prevent seed set – hand pull or spray with grass selective herbicide 4–6 weeks after opening rains.			No specific information on herbicide control. Suggest high rates glyphosate/Roundup when actively growing.	

Weed species				Control recommendations				
Scientific name	**Common names**	**Life form**	**Comments**	**Manual control**	**Wicker wipe/ cut stump**	**Spot spray @ 10 L water**	**Blanket spray per ha**	**Herbicide timing**
Lolium rigidum	Ryegrass	Annual	Common especially in disturbed areas. Some of the selective grass herbicides are far better than others in controlling this species.			Spray with 5 mL Select® (or Fusilade® 212) plus 100 mL spray oil in 10 L water in winter when the grass has 2–8 leaves.	Spray with Targa, Sertin and similar herbicide at 2–4 L/ha before flowering.	
Paspalum dilatatum	Paspalum		Use Fusilade or similar herbicide 4 L/ha on young growth, 3–6 leaves. Two applications may be necessary on old plants. Also controlled by Roundup/Glyphosate 360 150 mL in 15 L water applied to plants actively growing in the early head stage.	Manual control is usually very difficult.	Wipe with 10% glyphosate or spray adult plants 10 mL/L Fusilade +wetting agent	100 mL glyphosate (450g/L) plus 25 mL Pulse® in 10 L of water applied when the grass is actively growing.		
Paspalum distichum	Water couch		Easy to control, but may need two applications. Use 4 L/ha Fusilade or similar herbicide. Spray spring–autumn when actively growing, plants must not be under stress.			Controlled by Glyphosate 360/Roundup spray Feb–March when actively growing, knapsack 200 ml/15 L water. Spray with glyphosate 1%, 2–3 sprays over single growing season. Plant weed break to block spread into risk habitats.		July–Oct
Pelargonium capitatum	Rose pelargon-ium	Perennial	Smothers small native plants. Colonises natural bare sandy areas, therefore destroys natural habitat of burrowing snakes etc.	Difficult to control. Pull plants in autumn/winter when soil is damp. Plant will reshoot if stem is broken at or below ground level. Secondary weeding is important but good control can be achieved.			No specific data for herbicide control. Suggest Ally/Brush 5 g/ha. Glyphosate 1 in 100 in early Sept gives some control – add wetting agent. Try with wick applicator. Repeat applications may be necessary.	July–Sept

Weed species				Control recommendations				
Scientific name	**Common names**	**Life form**	**Comments**	**Manual control**	**Wicker wipe/ cut stump**	**Spot spray @ 10 L water**	**Blanket spray per ha**	**Herbicide timing**
Pennisetum clandestinum	Kikuyu grass	Perennial	Occurs mainly in highly disturbed areas. Smothers native plants.	Rake and remove as much of the kikuyu thatch as possible. Cover the remaining kikuyu in June/July with black plastic held down with rocks or pegs. In summer remove the black plastic, control any live kikuyu runners and seed or plant area with native species.		Selective control • 10 mL Fusilade® • 10 mL Targa® • 10 mL Verdict® • 5 mL Sertin® Non-selective control • 100mL Roundup Bioactive®		All year round
Raphanus raphanistrum	Wild radish	Annual	Found on offshore islands and in disturbed sites, especially along firebreaks.	Remove small populations by hand. No specific information for herbicide control.		Suggest spot spraying with glyphosate		All year round
Ricinus communis	Castor oil	Perennial	Common in disturbed sites. Has been successfully controlled in Walunga National Park by slashing before flowering.	Remove small populations by hand. For larger plants use the cut stump method with glyphosate. For large populations of seedlings spot spray with glyphosate 1 in 80.				Dec–May
Rorippa nasturtium-aquaticum	Water cress		Found in disturbed wetlands, drains, seepages and creeks from Geraldton to Albany. Introduced from Europe, probably for use of its astringent leaves in salads.	-	-	-	-	-

Weed species				Control recommendations				
Scientific name	**Common names**	**Life form**	**Comments**	**Manual control**	**Wicker wipe/ cut stump**	**Spot spray @ 10 L water**	**Blanket spray per ha**	**Herbicide timing**
Rubus fruticosus	Blackberry		Are all Declared Plants and Priority Plants to be eradicated.	Mechanical control is difficult and most of the root system must be removed for effective control. Repeat as new growth appears. Trounce® (a mixture of glyphosate and metsulfuron) plus Pulse® is also effective.		100 mL Glyphosate in 10 L water provides reasonable control and can be used in sensitive areas. Repeat as new growth appears. Trounce® (a mixture of glyphosate and metsulfuron) plus Pulse® is also effective.	Three annual, summer applications of 100 mL of Grazon® plus 25 mL of Pulse® in 10 L of water has provided eradication on 30% of sites when assessed 10 years later. On large infestations, 1 g metsulfuron (600 g/kg) plus 25 mL Pulse® in 10 L water, applied in summer when the blackberry is actively growing, provides a cheaper option to reduce the size of the infestation before Grazon® is used. Grazon will damage most broad-leaved species but is the only chemical that has provided reliable eradication. It has little effect on grasses so the area is not left bare and this also helps reduce seedling establishment.	
Salix babylonica	Weeping willow	Perennial		Remove small plants by hand. No specific information for herbicide control. Suggest cut stump method with glyphosate. Failing this, try garlon.				All year round
Schinus babylonica	Japanese pepper			Remove small plants by hand. No specific information for herbicide control. Suggest cut stump method with glyphosate. Failing this, try garlon.	n/a	n/a	n/a	All year round

Weed species				Control recommendations				
Scientific name	**Common names**	**Life form**	**Comments**	**Manual control**	**Wicker wipe/ cut stump**	**Spot spray @ 10 L water**	**Blanket spray per ha**	**Herbicide timing**
Typha orientalis	Bulrush	Perennial	Native to eastern Australia but not to Western Australia. It is an aggressive coloniser of disturbed wetlands and competes with native *Typha (T. domingensis)* and other native plants. Fire hazard.	Difficult to dig out even small populations and reinfestation can be rapid. Ensure all the rhizomatous root is removed. Remove flowers, seed source. Cut stems below water level in summer or just before recharge of wetland – plants then rot. Repeated cuttings in growing season (summer) will kill plants. Remove cut material.		100 mL Roundup Bioactive® after the male flowers have opened and before the female flowers have expanded. Better results when not stood in water, wait if possible for water level to recede.		Nov–Feb Sep–Nov
Zantedeschia aethiopica	Arum lily		A widespread and conspicuous weed from the Dandaragan area southwards. Primarily found in wet, swampy habitats.		Several applications may be necessary. Can also use Glean Ally/Brushoff. Difficult to dig out in most sites. On dry sites use a Peter lever. Glean 20 g/ha (1 g in 50 L water) plus wetter.	Spot spray from April–Nov when plants are 8–12 cm high. Respray 2 months later to get missed growth. Try to spray before flowering to stop seed set. In wetland areas use glyphosate without a surfactant to avoid problems with frogs and tadpoles etc. The herbicide will form a pool at the leaf base and be absorbed into the plant.		June–Oct and April–Nov

Appendix B – Bradley method of bush regeneration

The aim of bush regeneration by the Bradley method is the systematic removal of weeds to allow native plants to re-establish themselves when and where they choose. This method does not involve replanting – simply the gradual removal of weeds so that no large openings are made. This makes the Bradley method ideal for many situations, such as where native plants are able to colonise the site by seeds or vegetative means, areas sensitive to erosion and areas likely to be over-used.

Underlying principles

1 *Always work from areas with native plants towards weed-infested areas.*
This makes good ecological sense. If you are relying on natural regeneration then choose areas that will contain the maximum number of existing native plants and native plant seeds, and minimal weed seeds and vegetative reproductive organs of weeds.

2 *Make minimal disturbance.*
Application of this principle depends on the native species to regenerate. Many plant communities (both weeds and native) need disturbed and sunlit soil for successful regeneration. However, by following the first principle above, any weed regeneration should be minimised. Any soil that is disturbed should be returned in its original layers, thus ensuring that any native seed stored in the soil will still be on top. This principle also applies to the application of natural plant mulch in the work area – where a gap is left as a result of weeding, it is recommended that mulch from surrounding areas be added to the gap. This helps to minimise weed regeneration.

3 *Let native plant regeneration dictate the rate of weed removal.*
The ability to follow this principle may depend on the amount of time and money committed to a particular project. If few weeds and many native plants regenerate, or if the ground remains weed free, little time will need to be spent re-weeding a site, allowing time to be spent on other sites. If masses of weeds regenerate then a lot of time will be required re-weeding so that regenerating native plants can flourish.

Developing work plans

1 *Prevent deterioration of good areas.*
Start by removing weeds scattered through otherwise clean bush. Practically no follow-up work will be needed, but it should be checked once or twice a year.

2 *Improve the next best area.*
Once you are confident you have prevented deterioration of better condition bush, you can start work on thicker patches of weed. Choose a place you can visit easily and often, where thick native growth is pushing up against weeds, preferably no worse than one weed species to every two native plant species. Start with a strip approximately 12 feet wide and no longer than can be managed with monthly weeding days. If the area to be cleared of weeds runs up a slope that may erode, clear a number of smaller patches instead.

3 *Hold the advantage gained.*
Resist the temptation to push deeper into the weeds before regenerating natives have stabilised each cleared area. The natives do not need to be very tall, but they usually need to form an almost complete ground cover. Weeds will nearly always keep germinating until this is achieved. These newly regenerated areas are most vulnerable to weed reinvasion and so must be re-weeded as required. If weeding occurs adjacent to the regenerating area before sufficient new cover, light from adjacent cleared patches can affect the regeneration of natives.

4 *Cautiously move into the really bad areas.*
When new growth coming up consists almost entirely of native plants with only a few weeds among them, it is safe to move deeper into the weeds. Keep working along the regeneration boundary, making new clearings smaller as the weeds get denser.

Weeding techniques

1 *Disturb the soil as little as possible.*
All tools used for weeding programs should be small, such as a broad boning knife, trowel, secateurs, pliers (for pulling roots), lopper, hatchet and small saw. This recommendation is based on the belief that using small tools will cause minimum soil disturbance and minimal damage to the roots and shoots of nearby native plants.

2 *Sweep back the mulch surface.*
Any weeding will disturb the ground litter and soil will be exposed. Repair the damage as you go, by pushing back as much mulch as possible. It is often helpful to sweep aside mulch before removing large plants, so that it can easily be redistributed when you have finished removing the plant.

3 *Mulch with the weeds themselves.*
Removed weeds can be used to add to existing mulch. In dry areas leaving the weed with its roots exposed will be sufficient to kill it. In moist areas, hanging the weeds on nearby native vegetation will allow them to dry out and die. Some items are unsuitable for mulch and should be removed from the site. Such items include bulbs and tubers, plants that root at every node and free-seeders with ripe seed.

4 *Watch where you put your feet.*
Be careful how you move through the bush. A small weeding party moving through thick bush single-file can open up a track. Efforts should be made not to walk on the same paths all the time, and to watch where you walk to ensure you are not trampling native vegetation.

Appendix C – Flora species list

Species	Common name
**Arundo donax*	Giant reed
**Avena fatua*	Wild oat
**Carex divisa*	
**Conyza albinia*	Tall fleabane
**Conyza bonariensis*	Flaxleaf fleabane
**Cortaderia selloana*	Pampas grass
**Cotula coronopifolia*	Water buttons
**Cynodon dactylon*	Couch
**Cyperus involucratus*	
**Ehrharta calycina*	Perennial veldt grass
**Euphorbia terracina*	Geraldton carnation weed
**Hypochaeris glabra*	
**Ipomoea cairica*	Morning glory
**Juncus microcephalus*	
**Lagurus ovatus*	Hares tail grass
**Lathyrus tingitanus*	Tangier pea
**Lolium rigidum*	Ryegrass
**Paspalum dilatatum*	Paspalum
**Paspalum distichum*	Water couch
**Pelargonium capitatum*	Rose pelargonium
**Pennisetum clandestinum*	Kikuyu

** indicates introduced species*

Species	Common name
**Raphanus raphanistrum*	Wild radish
**Ricinus communis*	Castor oil
**Rorippa nasturtium aquaticum*	Water cress
**Rubus fruticosus*	Blackberry
**Salix babylonica*	Weeping willow
**Schinus babylonica*	Japanese pepper
**Typha orientalis*	Bulrush
**Zantedeschia aethiopica*	Arum lily
Acacia saligna	Orange wattle
Baumea arthrophylla	
Baumea articulata	Jointed rush
Baumea juncea	Bare twigrush
Baumea preissii	
Bolboschoenus caldwellii	Marsh club-rush
Carex appressa	Tall sedge
Carex fascicularis	Tassel sedge
Carex inversa	Knob sedge
Casuarina obesa	Swamp sheoak
Centella asiatica	
Corymbia calophylla	Marri
Eucalyptus rudis	Flooded gum
Ficinia nodosa	Knotted club-rush
Gastrolobium ebracteolatum	

** indicates introduced species*

Species	Common name
Juncus kraussii	Sea rush
Juncus pallidus	Pale rush
Juncus planifolius	Broadleaf rush
Lepidosperma longitudinale	Pithy sword sedge
Lepidosperma tetraquetrum	
Melaleuca rhaphiophylla	Swamp paperbark
Persicaria sp.	
Sarcocornia quinqueflora	Beaded samphire
Samolus repens	Creeping brookweed
Schoenoplectus validus	Lake club-rush
Taxandria linearifolia	
Viminaria juncea	Swishbush

Appendix D – Fauna species list

Lists from Regeneration Technology's 1994 management plan and Birds Australia 2004.

Bird list

Common name	Common name
Australasian grebe	Crested tern
Australasian shoveler	Darter
Australian magpie	Dusky moorhen
Australian pelican	Eurasian coot
Australian raven	European goldfinch*
Australian ringneck	Fan-tailed cuckoo
Australian shelduck	Galah
Australian white ibis	Great cormorant
Baillon's crake	Great egret
Black swan	Grey fantail
Black-faced cuckoo-shrike	Grey teal
Black-fronted dotterel	Hardhead
Black-shouldered kite	Hoary-headed grebe
Black-winged stilt	Collared sparrowhawk
Blue-billed duck	Common sandpiper
Brown goshawk	Crested tern
Brown honeyeater	Darter
Buff-banded rail	Dusky moorhen
Caspian tern	Eurasian coot
Clamorous reed-warbler	European goldfinch*

Common name	Common name
Collared sparrowhawk	Fan-tailed cuckoo
Common sandpiper	Galah
Great cormorant	Red wattlebird
Great egret	Red-kneed dotterel
Grey fantail	Rufous whistler
Grey teal	Sacred kingfisher
Hardhead	Silver gull
Hoary-headed grebe	Silver gull
Kookaburra	Silvereye
Laughing turtle-dove*	Singing honeyeater
Little black cormorant	Spotless crake
Little grassbird	Spotted turtle-dove*
Little pied cormorant	Striated pardalote
Little wattlebird	Tree martin
Magpie-lark	Welcome swallow
Mistletoe bird	Western gerygone
New Holland honeyeater	White-cheeked honeyeater
Pacific black duck	White-faced heron
Purple swamphen	White-winged triller
Rainbow bee-eater	Willie wagtail
Rainbow lorikeet*	Yellow-billed spoonbill

** indicates introduced species*

Reptile list

Scientific name	Common name
Ctenotus labillardiera	
Demansia affinis	Dugite
Egernia kingii	King skink
Egernia lactuosa	Mourning skink
Leiolopisma trilineatum	
Morethia obscura	
Notechis scutatus	Western tiger snake

Amphibian list

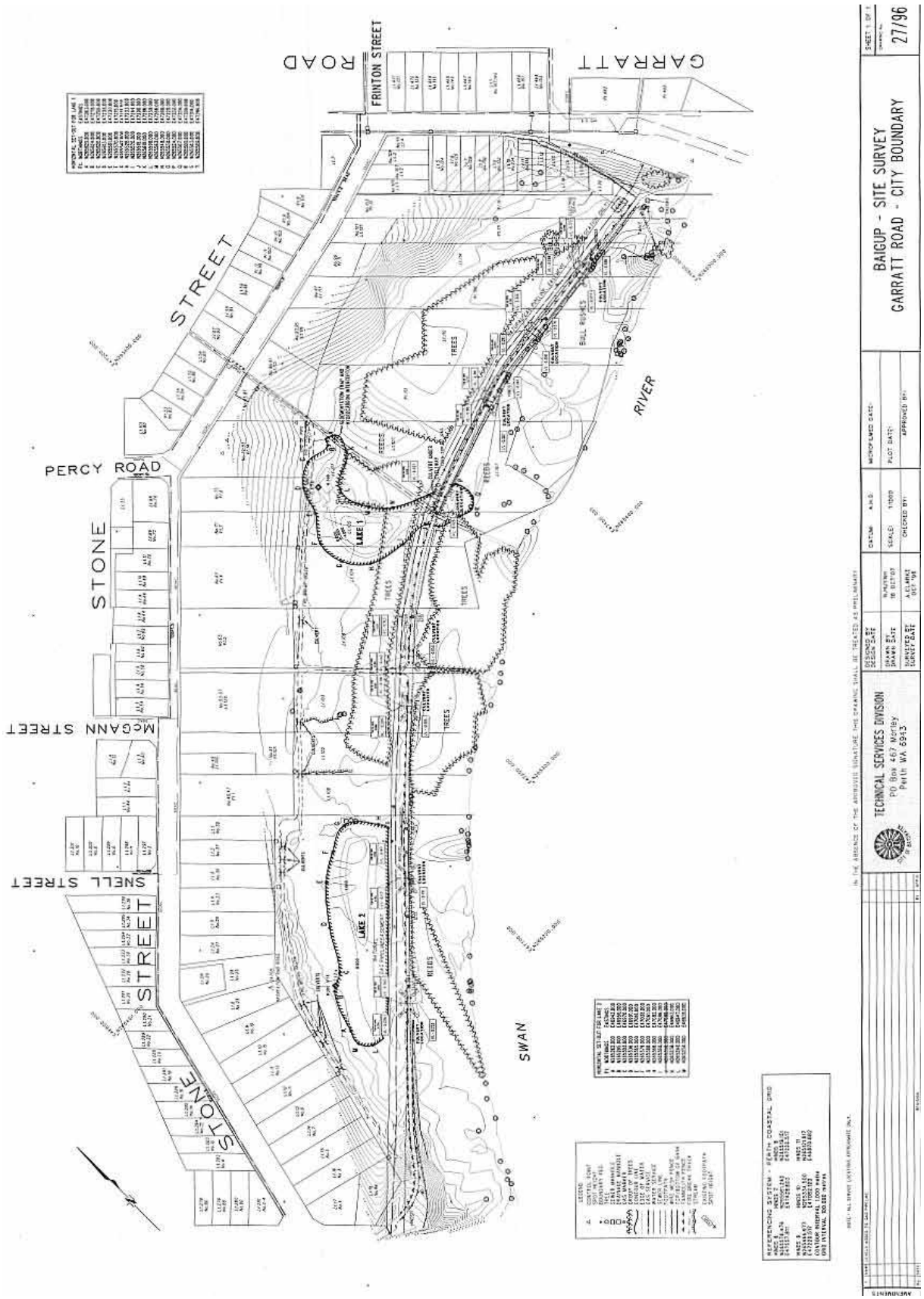
Scientific name	Common name
Crinea georgiana	
Crinea glauteri	
Heleioporus eyrei	Moaning frog/whooping frog
Limnodynastes dorsalis	Bonking frog
Litoria adelaidensis	
Litoria moorii	Western green frog

Mammal list

Scientific name	Common name
Hyromus chrysogaster	Water rat
Mus musculus	House mouse*
Rattus norvegicus	Brown rat*
Rattus rattus	Black rat*
Vulpes vulpes	Fox*

** indicates introduced species*

Appendix E – Contour and feature survey



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