Technical Surveys of the Dawesville to Binningup Region

CONTENTS

APPENDICES (CD)

Geology
VCSRG-DEC October 2009 Report Geology of SCP Dawesville to Binningup

Hydrology
Rockwater Hydrology Study 09-001a

Coastal Geomorphology
The Yalgorup Coast Report FINAL

Flora and Vegetation
Final Dawesville to Binningup Flora and Veg Report Sept 2009

Fauna reports
Binningup Bat Survey 2009 – Report 22 June
Herpetofauna of Dawesville-Binningup June 2009
Natural values vertebrate fauna of Dawesville-Binningup 150909
Non volant mammals of Dawesville-Binningup 210909
Report Birds of Dawesville-Binningup

Cover page: View of Lake Clifton, looking south (Photograph, G Whisson).

Department of
Environment and Conservation
Our environment, our future

1 SUMMARY

The coastal region between Mandurah and Bunbury is coming under increasing pressure for rural and residential development, tourist facilities, and intensive horticulture. The area includes a major coastal reserve (Yalgorup National Park), and coastal wetlands; the latter are part of the Peel-Yalgorup wetland system which is recognised as a "wetland of international importance" under the Ramsar Convention. Important biological features include thrombolite communities (similar to stromatolites), regionally significant fauna populations, and coastal vegetation such as Tuart forest which is largely degraded on much of the Swan Coastal Plain.

In May 2009, the Environmental Protection Authority (EPA) released Environmental Protection Bulletin No. 4 - Dawesville to Binningup advising that it was undertaking a review to clarify the environmental values of the region and the state of current knowledge and scientific data about these values. This information was considered necessary to identify additional areas of conservation significance, and areas that may have potential for development and land use that are compatible with the environmental values. It is envisaged that the review will result in strategic advice from the EPA to guide future directions for both environmental protection and planning for development in the area.

The study area is bounded by Tims Thicket Road to the north, the Old Coast Road to the east, Buffalo Road to the south, and the coastline to the west. It covers 286 km^2 and contains the coastal settlements of Preston Beach, Myalup and Binningup. The only major road is the Old Coast Road, although smaller roads lead from the highway to the coastal settlements.

The compilation of the technical reports aims to provide a regional assessment of the values of the study area to inform the EPA's strategic advice to the Minister for the Environment. The following subsections provide a summary of each of the technical reports prepared within the study area.

All summary and recommendation information below is direct extraction from the technical reports. Full reports are included in pdf format on a CD and provide more detailed information.

1.1 Geology

The landforms that comprise the Swan Coastal Plain have been generally formally named, though not all of the landforms that are the surface expression of the sedimentary units have been formally named. Those that have been formally named are:

1. The alluvial fans and (in part) desert dunes along the Darling Scarp = the Ridge Hill Shelf
2. The alluvial sediments on the eastern part of the Plain = the Pinjarra Plain
3. The Pleistocene desert dunes of quartz sand = the Bassendean Dunes
4. The Pleistocene coastal dunes (now limestone) = Spearwood Dunes
5. The Pleistocene coastal marine to dune deposits (now limestone) = the Yalgorup Plain and Eaton-Mandurah Ridge, and subdivided into smaller scale units (see later)
6. The Holocene coastal dunes = Quindalup Dunes

Some of the stratigraphic units have no expression at the surface on the Swan Coastal Plain, i.e., they are wholly subsurface formations, and so axiomatically have no formal landform nomenclature (e.g., the Becher Sand).

In the Study Area, the following stratigraphic units and their corresponding surface expression as landform units have been recorded (Semeniuk 1997):

1. The easternmost unit is the Eaton Sand that underlies the Mandurah-Eaton Ridge.
2. The next western unit is the upward shoaling limestone system referred to the Tims Thicket Limestone that underlies a Pleistocene landform termed Youdaland.
3. The next western unit is a quartz shoestring deposit referred to the Myalup Sand that underlies a Pleistocene landform termed Myalup Sand Ridge and Myalup Sand Shelf.
4. The next western unit is the upward shoaling limestone system referred to the Kooallup Limestone that underlies a Pleistocene landform termed Kooallupland.

5. The most western unit is the barrier dunes of the Safety Bay Sand that forms the seafront of the Study Area.

In a regional context, the entire package of stratigraphic units and landform units listed above occur within a broad scale low-amplitude embayment or plan concavity cut into the Bassendean Dunes, and demarcated by the broadly arcuate form of the Mandurah-Eaton Ridge. The broad concavity was the Western Australian coat line for four Pleistocene sedimentary episodes, and was anchored between the Bunbury Basalt to the south and the Limestone rocky shore of Halls Head to the north. The Pleistocene to Holocene sedimentary units over the interval of five interglacial sedimentary periods have progressively filled the broad concavity along the coast.

In the marine near-shore environment, the Study Area is comprised of a limestone pavement shelf, comprised of lithified Pleistocene marine shelf sediments, with veneers of sand, and encrustations of hard bottom communities (Collins 198x; Searle & Semeniuk 1985). In the marine near-shore environment, north of the Study Area, there are two marine limestone ridges, the (outer) Five fathom Bank, and the (inner) Garden Island Ridge (Searle & Semeniuk 1985), the latter variably emergent above the water level (ranging from submerged rock reefs, to submerged rocky reefs and small islands, to large Islands like Garden Island). The southern extension of the Garden Island Ridge (Searle et al 1987) intersects the coast at Halls Head (Semeniuk 1995). The southern extension of the ridge of the Five Fathom Bank (Searle et al 1987) forms the Bouvard Reefs and intersects the coast just south of the Bouvard Reefs (Semeniuk 1995). Further south of the Bouvard Reefs, the Western Australian coast is offshore barrier-free and exposed directly to swell and wind waves resulting in the development of a barrier dune system along the shore (the Preston-Leschenault Barrier).

As such, for the tract of coast between Halls Head and Bunbury, the coast is relatively bathymetrically simple between Bunbury and the Bouvard Reefs, and bathymetrically complex in the near-shore in the region of the Bouvard Reefs. The bathymetrically complex near-shore environment had implications in the Holocene history in this part of the coast.

Various types of wetlands have been developed in the Study Area, ranging from lakes to water logged basins. The majority of the wetlands have been developed along the interfaces between the major stratigraphic units. However, some of the wetlands have been developed as perched types on calcreted limestones, some as karst features and some as intra-dune in a Pleistocene beach ridge terrain. Note that in the Study Area there is a general lack of fluvial drainage.

1.2 Hydrogeology

The study area is underlain by the superficial formations which overlie Cretaceous-age sedimentary strata of the Leederville and Osborne Formations at elevations of about -25 m AHD. Groundwater resources which support the surface environmental features in the study are contained in the superficial aquifer, which is the shallow (mainly unconfined) aquifer of the area. The aquifer contains local groundwater flow systems which discharge to the main lake systems (Lake Clifton, Lake Preston and Lake Yalgorup chain of lakes), Harvey Estuary, Leschenault Inlet or the ocean. The lakes are groundwater sinks.

The superficial formations comprise several juxtaposed lithological units and, consequently, the superficial aquifer is hydrogeologically complex as a result of variations in the hydraulic properties of the various lithologies: predominantly sand, limestone and clay. Additionally, thin calcrete sheets, formed by diagenesis, may extend subhorizontally across stratigraphic boundaries. The existing hydrogeological data provide a regional-scale picture of the hydrogeology which is useful for regional management of groundwater resources but is not suitable for investigations of the hydrogeology on a more local scale.

Ecosystems associated with the lakes may be dependent on local-scale influences such as low-permeability layers which may control the locations of groundwater discharge zones. Groundwater discharge to the lakes will vary according to local variations in the hydraulic properties of the superficial aquifer. In some cases, a small fall in the level of the water table, for example from above to below a low-permeability layer, may cause a substantial change in the location of the zone where groundwater discharge is occurring. This could displace such a discharge zone from where it supports a local ecosystem.

Groundwater levels range in elevation from 3 to 5 m AHD in the southeastern part of the study area but lie below sea level near some lakes, due to the higher density of the underlying hypersaline water. Seasonal variations are up to 2 m but mainly less than 1 m and reflect the seasonality of rainfall recharge. Groundwater levels in most monitoring bores in the area have shown overall reductions over the last about 30 years, but by less than one metre. This is mainly attributed to reductions in rainfall but groundwater extraction has probably influenced water levels locally. A few drains, designed to reduce water logging, are located west of Lake Preston and north of Leschenault Inlet. These may slightly reduce groundwater levels but would decrease evapotranspiration and, consequently, may reduce salinity in the local groundwater. It is unlikely that the Dawesville Cut is having an influence on groundwater levels in the study area.

The flow systems contain low-salinity groundwater occurring as lenses which lie above hypersaline water associated with the lakes, or as fresh-water bodies overlying saline water wedges adjacent to the Harvey Estuary and the coast. Low-salinity or fresh groundwater extends to the base of the aquifer only in the southern and eastern sectors, where there is groundwater throughflow from further to the east. The aquifer is recharged by rainfall and provides discharge to the lakes, (from where is water is lost by evapotranspiration), estuaries, and the ocean. Groundwater salinity at the water table varies from less than 500 mg/L TDS to about 2,000 mg/L TDS. The groundwater contains nutrients at suitably low levels for maintaining the thrombolite communities along the eastern shore of Lake Clifton. Higher levels of nutrients in lake water can favour the growth of algae, reducing light penetration, potentially affecting microbialite formation, and increasing the potential for eutrophication. Most of the nutrients in the groundwater are derived from natural sources; however, fertilisers and grazing activities are sources of locally higher nutrient concentrations.

Groundwater in the study area provides a source of domestic and stock water supplies for small landholders, and irrigation water supplies for horticulture The study area is in the South West Groundwater Area where there is a total available allocation in subareas that overlap the study area of 72,500,000 kL/a of which about 35,000,000 kL are currently allocated. The larger groundwater users, accounting for about half of the total allocations, are in the south, where there is considerable irrigation usage; there are many small supplies for domestic and stock purposes in the north. Current allocations are either above or approaching the DoW allocation limits in the south.

Groundwater resources in the superficial aquifer support important environmental features, such as the Yalgorup lakes and the Lake Clifton thrombolite communities. Investigations have shown that these features can be particularly sensitive to changes in groundwater level which are reflected by changes in the quality and quantity of discharge to the lakes. Groundwater discharge to Lake Clifton provides a source of carbonate and bicarbonate ions, low-level nutrient concentrations, and appropriate salinities for the thrombolite communities. Monitoring of Lake Clifton by DEC since 1985 indicates trends of falling lake water depth, rising salinity and, possibly, slightly falling pH. These trends suggest that groundwater inflow to the lake could be reducing and signify potential threats to the viability of the thrombolite communities. Nutrient concentrations in the lake water appear stable. Groundwater also provides a source of low-salinity water for vegetation around the lake system. It is unlikely that the slightly lowered water table levels have affected the vigour of tuart forests in the area.

There is an extensive network of DoW groundwater monitoring bores which are monitored frequently for water levels; however, groundwater quality data are available only from samples taken when the bores were installed. Additional groundwater quality monitoring should be instigated to allow assessments of any changes that may be occurring. This monitoring may involve the installation of new bores to target specific monitoring objectives. A database of groundwater extraction volumes would reflect actual extraction rather than licensed allocations and allow historical data to be assessed.

1.3 Coastal Processes

Five sediment cells (Myalup, Lake Preston South, Preston Beach, Lake Clifton North and White Hills Road) are nested along the Yalgorup Coast and within a coastal compartment extending between Binningup and

Cape Bouvard. In turn this coastal compartment is part of a large primary compartment extending from cape Naturaliste to Rottnest Island.

At a geological scale, the primary coastal compartment has provided topographic control for formation of the Leschenault - Yalgorup Barrier as it evolved during the past 10,000 years. Barrier evolution is continuing at present as sediment is moved along and across the shore. Phases of dune activity associated with fluctuations in the intensity and duration of metocean processes continue to contribute to development of the dune ridge through the formation of foredunes, blowouts and nested parabolic sand dunes as the barrier migrates landwards.

Medium time scales are relevant to barrier changes occurring over decades and centuries. In this context, recurrence of the cycle of dune formation and migration on the Leschenault – Yalgorup Barrier is ultimately dependent on sediment supply from offshore and alongshore. At present the alongshore component of littoral sediment transport between Binningup and Cape Bouvard is critical to coastal stability and future evolution of the barrier. The ramifications of this are that the future medium-term stability of the Yalgorup Coast will potentially be affected by any updrift interference with the coastal sediment transport between Cape Naturaliste and Cape Bouvard as well as by natural variability and change to metocean processes. At sub-decadal time scales, interaction of modern metocean processes with the inherited geologic framework has two ramifications. First, it produces localised reversals of the overall northerly littoral drift pattern. Alongshore variation in beach erosion, foredune formation and dune development occurs as a result of the interaction, with the most unstable reaches of coast in commonly in close proximity to shoreline salients and extensive rock outcrops. Second, it invalidates application of the Bruun Rule (Bruun 1988) that has been widely applied in the calculation of setback to development on mixed sandy and rocky coast in Western Australia (WAPC 2003).

Three sets of Holocene dunes have been described foredunes, primary dunes and secondary dunes. Low, discontinuous, hummocky dunes are common in the southern two cells (Myalup and Lake Preston South) in which the dune barrier is narrowest. They are higher in the Preston Beach cell (Cell 3) especially near the northern boundary where they have formed along the seaward margin of a large deflation basin. Foredune morphology is more variable in the northern cells, Lake Clifton North and White Hills Road. Some sections of the northern cells lack foredune and others landwards of rock platforms have erosion scarps. In contrast to the eroded foredunes, a narrow foredune plain is apparent as an inset at the southern end of the White Hills Road cell (Cell1).

Other dunal features of the barrier include fields of nested blowouts and/or parabolic dunes comprising the main ridge; coalescing blowouts where several mobile dunes are in the process of combining; mobile sand sheets where the combined dunes are moving freely as a single landform; and deflation basins which are extensive hollows remaining where sand sheets and/or coalescing blowouts have become detached from the shore. All are present as vegetated (stable) and unvegetated (mobile) forms.

Active blowouts and tracts of partially vegetated dunes, those with approximately less than 50% cover, occur in all sediment cells. The most extensive areas are landward of deflation basins in the northern sectors of Lake Preston South (Cell 4) and Preston Beach (Cell 3), on the southern flanks of the salients at the cell boundaries. Other active blowouts in the primary dunes occur close to beach access tracks in Cell 2 – Lake Clifton North as well as near the outlet of the Harvey Drain and as small individual or coalescing blowouts in Cell 5 – Myalup.

1.4 Flora and Vegetation

The Dawesville to Binningup Region, also referred to as the "study area", is located in the south west of Western Australia. The northern boundary is approximately 13 kilometres south of the Mandurah townsite and approximately 80 kilometres south of Perth. The study area is defined by Tim's Thicket Road forming the northern boundary, Old Coast Road forming the eastern boundary (the exception being an east-west linkage across to the Peel Harvey Estuary at Lot 2 Old Coast Road, Bouvard), the southern boundary at Buffalo Road and the Indian Ocean forming the western boundary.

The study area comprises approximately 28,616 hectares of land (82%) and 5175 hectares of water (18%) held in various tenure including privately owned land, National Park, Regional Open Space and supporting a variety of uses including hobby farms, broad-acre agriculture, conservation, public purposes, water and resource extraction. Yalgorup National Park reserves 46% of the study area. The Yalgorup National Park is 13,137 hectares in area with 61% of the area being terrestrial and 38% of the area being water.

The study area is located on the Swan Coastal Plain. The Swan Coastal Plain is a series of geomorphic entities running parallel to the coastline, is generally flat, approximately 20-30 kilometres wide (east/west) and abruptly bordered by the Darling Scarp to the east. Beard (1990) describes dominant soils of the Swan Coastal Plain as recent sands or swamp deposits within a low-lying coastal plain with sandhills. The Dawesville to Binningup Region characterizes the Coastal Belt, comprising of the Quindalup and Spearwood geomorphological systems.

Trudgen (1991) states that the Quindalup Dune System (in the northern study area) consists of a complex pattern of parabolic dunes directly overlaying Tamala Limestone. Within the study area, the Quindalup system forms the primary dune system adjacent to the Indian Ocean. The Spearwood Dune System is the dominant landform in the study area, occurring in a wide band and encompassing the Vasse System that defined the lakes and wetland of the study area. Wetland units with the Spearwood Dunes are discussed below.

Three upland vegetation units and four wetland vegetation units were described within the Quindalup Dunes. Seven Swan Coastal Plain Floristic Communitiy Types (SWAFCTs) have been determined from 11 survey quadrats/ relevés. Most quadrats are located in the Yalgorup National Park. Three SWAFCTs have been analysed or inferred from these points and/or field observations. SWAFCT29a and SWAFCT29b are listed as Priority 3 ecological communities.

Three upland vegetation communities and nine wetland vegetation communities were described within the Spearwood Dunes. As the study area is dominated by the Spearwood Dunes which supports a number of different plant communities, the majority of the quadrats are located within this unit. SWAFCTs have been identified from 16 survey quadrats/relevés. The majority of the quadrats/relevés are located within Yalgorup National Park, located in a number of areas. Four SWAFCTs have been analysed or inferred from these quadrats:

Fourteen SWAFCTs have been analysed or inferred from the study area with a number of wetland communities undescribed and likely to represent new SWAFCTs. A number of TEC and PECs have been identified in the study area with the potential for more occurrences with future targeted survey.

The amalgamation of the information from the plots and bushland areas resulted in a list of 658 taxa, 522 native taxa (74%) and 136 weeds (26%) for the study area. The listing of 522 native taxa contains many members of the groups outlined below:

- Monocotyledons - the most well represented families are: Orchidaceae (46 taxa), Cyperaceae (28 taxa), Poaceae (18 taxa), Anthericaceae (13 taxa), Haemodoraceae (9 taxa), Restionaceae (10 taxa) and Juncaginaceae (7 taxa), reflecting the large number of annually renewed plants in the flora of the study area.
- Dicotyledons - the most well represented families are: Asteraceae (36 taxa), Myrtaceae (36 taxa), Proteaceae (24 taxa), Epacridaceae (23 taxa), Papilionaceae (22 taxa), Apiaceae (20 taxa), Stylidiaceae (14 taxa), Chenopodiaceae (12 taxa), Goodeniaceae (13 taxa), Mimosaceae (12 taxa) and Droseraceae (8 taxa).

When taxa are considered according to conservation status, 108 are considered significant flora in the Study area. Of these, 3 are listed as DRF and 12 are listed as priority taxa: one Priority 1, two Priority 2, six Priority 3 and three Priority 4. Seventeen taxa are endemic to the Swan Coastal Plain and one of these is endemic to the Yalgorup National Park (*Hakea* sp. Yalgorup).

A series of species of conservation significance generally confined to Quindalup Dunes are found in the study area including: *Bromus arenarius*, mallee Tuart and Peppermint, and *Stylidium maritimum.* Of particular interest are the large populations of a variety of increasingly rare species of Quindalup Dune communities such as the grasses *Poa poiformis* var. *poiformis*, *Austrostipa flavescens, A. pycnostachya*, *Bromus arenarius*, *Stylidium maritimum* and *Leptorhynchos scaber.*

Much of the vegetation in the study area is in Excellent condition. In general the areas in best condition are in public lands. However from limited ground survey, roadside observations and aerial photograph interpretation there are substantive areas in Excellent condition in private lands, especially within the Quindalup Dunes of the study area. Twenty six percent (135 taxa) of the study area's flora is weeds. Dominant families are Asteraceae (16 taxa), Poaceae (29 taxa), Caryophyllaceae (11 taxa) and Papilionaceae (11 taxa).

Regionally significant ecological linkages identified in the Greater Bunbury Region Scheme (EPA 2003) recognised Yalgorup/Riverdale Road/Yarloop ecological linkage as a significant east-west linkage. Both with the north-south linkages, east-west linkages degrade in the south of the study area, as more extensive clearing and disturbance is encountered. A strong north-south linkage is present in the north of the study area where the grouping of Yalgorup National Park tenure is greatest. The vegetated area bordering the Peel-Harvey estuary forms an east-west linkage at the north of the study area. An additional east-west linkage exists south of Preston, generally along remnant vegetation associated with Johnson Road and Riverdale Road, through Myalup State Forest.

1.5 Fauna and Habitat

The Department of Environment and Conservation on behalf of the EPA considered that a series of fauna surveys should be undertaken to determine the fauna values of the Dawesville to Binningup study area. Due to limited resources not all fauna groups could be surveyed, so only herpetofauna, avifauna and mammals were identified for survey. Of those fauna groups identified for study, groups more easily sampled and considered able to provide better information on natural values of the study area were selected for detailed sampling.

The Department of Environment and Conservation commissioned the Western Australian Museum to undertake a herpetofauna survey (How *et al*. 2009) and Bat Call WA to undertake an echolocation-based survey of bat (volant mammals) activity (Bullen 2009). The herpetofauna and bat surveys were funded by the South West Catchment Council (WALGA) and Enviro Planning (Department of Planning and Infrastructure) respectively. Other fauna groups studied were avifauna (Dell and Hyder 2009) and non-volant mammals (Hyder and Dell 2009). The overall objective of the surveys was to assist in providing technical advice to the EPA on the natural values of the area and to enable the EPA to determine the likely impact of development on the biodiversity values of the region.

The vertebrate fauna values of the Dawesville to Binningup study area are provided in a series of reports covering herpetofauna (How *et al*. 2009), avifauna (Dell and Hyder 2009), non-volant mammals (Hyder and Dell 2009) and bats (Bullen 2009). The study area is bounded by Tim's Thicket Road to the north, Buffalo Road to the south, and from the coast inland to the Old Coast Road. The study area includes Yalgorup National Park including major internationally significant lakes (Lake Clifton and Lake Preston) and other wetlands, regionally significant Tuart woodlands, as well as patches of uncleared vegetation, semi-cleared farmlands and the coastal townships of Preston Beach, Myalup and Binningup.

1.5.1 *Herpetofauna*

The terrestrial herpetofauna assemblage of the Dawesville to Binningup study area is surprisingly rich and diverse and comprises at least 8 frogs and 39 reptiles comprising one freshwater turtle, 3 geckoes, 5 legless lizards, 2 dragons, 16 skinks, 2 monitors, one blind snake, one python and 8 front-fanged snakes. One gazetted species of Specially Protected Fauna, the Carpet Python (*Morelia spilota imbricata*) and one DEC

Priority 4 listed species, the Perth Lined Lerista (*Lerista lineata*), are recorded from the study area. A number of species are regionally significant as they are known to be at or near the southern limits of their distribution. These include the Side-barred Delma (*Delma grayii*), Western Heath Dragon (*Rankinia adelaidensis*), Perth Lined Lerista (*Lerista lineata*), Line-spotted Robust Lerista (*Lerista lineopunctulata*), Reticulated Whip Snake (*Demansia psammophis reticulata*). The population of *Ctenotus labillardieri* in the study area is likely to be genetically distinct from populations on the Darling Scarp and Range and is more likely to be the Schedule 1 Threatened Lancelin Island Skink (*Ctenotus lancelini*). The Ticking Frog (*Geocrinia leai*) represents the most northerly known population on western side of the Swan Coastal Plain.

Although the survey was conducted outside the optimal season, it recorded 24 species of reptile and 5 amphibians of the 8 frogs and 39 reptiles known from the region. It is likely that further species will be recorded from the study area when additional sampling is undertaken at a time of the year more conducive to herpetofauna activity.

It is highly probable that the reptile and frog fauna of the study area represent important contiguous distributions of populations that have been subjected to major fragmentation, alteration and extinctions further north on the Swan Coastal Plain. Suitable habitats of sufficient size and spatial representation remain within the study area. Retention of these areas will enable species to survive major perturbations such as fire and to persist in the longer-term.

1.5.2 *Avifauna*

The Dawesville to Binningup study area has a rich and diverse avifauna comprising at least 174 species which includes 124 species of non-passerines in 31 families, and 50 species of passerines in 21 families. Among the non-passerines the most species-rich families are those associated with wetland habitats, viz. 11 species of ducks, 7 species of herons and egrets, 7 species of crakes and rails, 10 species of plovers and dotterels, and 17 species of sandpipers. Other rich non-passerine families are the eagles, kites and hawks with 11 species and the parrots and cockatoos with 6 species. Among the passerines the most species-rich family is the honeyeaters with 11 species. Small insectivorous families are well-represented with several species of fairy-wrens, thornbills and whistlers.

The study area is Internationally significant for wetland and shore birds. The wetlands are part of the Ramsar Peel-Yalgorup System, one of the largest and most diverse estuarine/wetland complexes in Western Australia. These areas are internationally important as a habitat and refuge site for waterbird species protected by JAMBA, CAMBA and ROKAMBA agreements. Over one hundred wetland dependent species of birds have been recorded making this the most regionally significant wetland site for birds in Western Australia.

The extensive natural vegetation in the study area is also of National and State significance for bushland birds including four Nationally and State listed species, three DEC Priority listed species, and 45 regionally conservation significant species which have reduced distributions or populations on the Swan Coastal Plain.

The richness and diversity of the avifauna of the study area is exemplified by the fact that the total of 174 species comprises more than half of the 311 species known from the entire Swan Coastal Plain between the Moore River and Dunsborough. Such a rich and diverse assemblage of regionally significant bushland bird species has not been documented anywhere else on the Swan Coastal Plain. The study area is the most significant area known on the Swan Coastal Plain for the conservation of wetland and bushland bird species with International, National and State significance.

1.5.3 *Mammals*

Seven insectivorous microbat species were recorded within the study area including one Priority 4 species Western False Pipistrelle (*Falsistrellus mckenziei*). The presence of this species is significant considering its apparent recent range contraction. The continuing presence of this species in the study area is considered to

be closely linked to the combination of healthy and extensive open woodland stands in conjunction with permanent fresh water sources.

Seven native non-volant mammal species have recently been recorded within the study area. Of these three species are of conservation significance: Western Ringtail Possum Vulnerable (EPBC Act 1999), Schedule 1; Western Brush Wallaby DEC Priority 4 and Quenda DEC Priority 5. Fifteen other native non-volant mammal species are known from or likely to occur in the study area most of which are regionally significant; it is likely that a comprehensive survey would record some of these species.

2 CONCLUSIONS AND RECOMMENDATIONS

The conclusions and recommendations of the technical studies are summarised below.

2.1 Geology

The key geoheritage features of International, National and State-wide significance are assessed in below according to the criteria developed by Brocx & Semeniuk (2007). The case has been made in the Geology report that this area of the Yalgorup Plain is an Internationally significant classroom, not only for one geological feature, but for a range of features, and for a ranges of geological features that are interrelated. Urbanisation and other types of development will impact on the natural values of this region. For instance, any urbanisation or other types of development on the Pleistocene stratigraphy, landforms and history will adversely impact on the natural values of a feature that has International significance. Land clearing associated with urbanisation or other types of development clearly will compromise the nature landscape features of the Pleistocene landforms, and groundwater alteration will affect the diagenetic "wilderness" of the limestone system.

Similarly, because there is a south to north variation in the Holocene barrier dune that is in parcels, land clearing associated with urbanisation or other types of development will affect the interrelated integrity of the barrier. The Holocene barrier history, as preserved in the stratigraphic record, is a subsurface feature, and if the terrain is not markedly modified by landscaping this international feature would still be present. However, the effect of this stratigraphy on groundwater and vegetation is unknown, and needs to be rigorously investigated to determine whether merely leaving the stratigraphy intact but clearing the land will affect and destroy vegetation that is linked geochemically and hydrologically to the complex subsurface stratigraphy. The same argument applies to the stratigraphy and landforms record a sea rising into a bathymetrically complex coast during the early Holocene, and the response of this complex coast to a variable sea level record. This geological, stratigraphic and geomorphic ensemble is an outstanding feature of global importance, and should not be compromised by any development.

The wetlands in the region, while they would not be directly built upon or developed, are targets of altered hydrology and hydrochemistry. Any urbanisation or other types of development where they alter groundwater patterns or carry risk of contributing contaminants such as nutrients, need to be constrained or avoided. The impacts would be on the water quality of the wetlands, the water regime of the wetlands, and the peripheral vegetation of the wetlands.

Aspects of altered natural cycles may be:

1. urbanisation on a dune system will carry with it contamination of the groundwater with nutrients and other contaminants;
2. there will be export of nutrients and other contaminants towards the Lake and specifically to the peripheral vegetation;
3. the peripheral vegetation will be altered in floristics and structure; and
4. these effects will be within a Ramsar site, that is obligated to be protected by International Treaty

This rationale of avoiding the alteration of hydrology and hydrochemistry applies also the areas where there is clear linkage of stratigraphy to hydrology, as this feature is a aspect of geoheritage significance. Finally, as with the wetlands, the stromatolites/thrombolites are sensitive ecological/geological features, and alteration of groundwater regimes in terms of flow rates and rising and falling of the hinterland groundwater table, and any alteration of hydrochemistry (such as contribution of contaminants such as nutrients) runs risk of affecting and damaging these internationally significant features.

It appears that the wetlands of the Study area are, as an *ensemble*, unique globally because the style of development of landforms with Quaternary progradation of the limestone and quartz sand terrain appear to be globally unique. As such, globally, the wetlands of the Study Area are important, and at the National level very significant.

2.2 Hydrogeology

The following recommendations were provided in regards to improving understanding of hydrogeology in the study area:

- In the eastern parts of the Island Point and Lake Clifton Subareas of the South West Coastal Groundwater Area, limit or curtail activities that may cause reductions in the quantity or deterioration of the quality of the groundwater discharge that supports the Lake Clifton thrombolite communities.
- Request that the Department of Water include the actual extraction volumes associated with groundwater licences in the South West Coastal Groundwater Area in their database so that the actual draw on the aquifer can be assessed. Metering of all bores should be considered.
- Request DoW to compile historical groundwater licence allocations for the area to assist in the analysis of trends in groundwater monitoring data.
- Ensure that groundwater resource allocations are within the allocation limits calculated through groundwater resource assessment studies. Update the resources assessments for the northern subareas of the South West Coastal Groundwater Area.
- Establish groundwater quality monitoring at selected sites in the area. If existing bores are unsuitable, establish bores at new sites to target specific monitoring objectives, such as the quality of groundwater upstream of discharge zones to the lakes and the effects of irrigated horticulture on the groundwater.
- Ensure fertiliser applications for irrigated horticulture are managed so that nutrient concentrations in the underlying groundwater remain below acceptable levels agreed with the DoW for the holder of the groundwater extraction licence and no adverse trends of change are apparent.
- Undertake detailed geological and hydrogeological investigations to describe the processes and quality of groundwater discharge in the complex hydrogeological system at selected sites of the Yalgorup lakes, such as in the vicinity of the Lake Clifton thrombolite communities. Any investigations should be carefully targeted to meet specific objectives.

2.3 Coastal Processes

Analysis of the Yalgorup coastal stability has primarily been conducted with reference to historic behaviour, as a means of identifying the processes active along this section of coast. However, it is relevant to recognise that the coastal climate is subject to considerable variability, both due to natural causes and anthropogenic factors, with the latter most strongly linked to those caused by increased Greenhouse gas emissions (IPCC 2007; CSIRO 2007). Both natural and anthropogenic climate variations are subject to uncertainty, with increasing significance when considered over longer time scales. Consequently, coastal management within the region should be undertaken within a framework that recognises this uncertainty.

Despite the lack of detailed morphostratigraphic and chronologic information, the following general observations about coastal change and stability can be summarised from the available data:

1. Bathymetry in Cells 4 and 5 (Lake Preston South and Myalup) has only a narrow section of shallow water (0 – 10 metres) before deepening to 10 – 20 metres. This coincides with the dominantly erosive environment immediately north of the rocky pavement off Binningup in the southern part of Cell 5 (Myalup).
2. Cells 1 and 2 (Myalup and Lake Preston South) have a broad area of shallow inshore water, coinciding with a more depositional inshore environment. The inshore waters of Cell 3 (Preston Beach) appear to be transitional with the narrow, shallow section of the southern cells beginning to deepen.
3. Comparison of changes to the vegetation line along the beach backshore from 1955 to 2006 indicate the coast between Binningup and Cape Bouvard is being eroded in the southern sector and accretion, albeit discontinuous, is more commonly occurring to the north. This is consistent with the prevailing SW winds, exposure to the SW swell regime and northerly littoral drift.
4. Although the barrier is widest in the northernmost cell (Cell 1 - White Hills Road), erosional features coincide with the rock platform occurring on the beach. Platforms and narrow inshore channels also coincide with the location of scarping or eroded foredunes elsewhere along the barrier.
5. Shoreline movement, indicated by changes to the vegetation line, in the two northern cells (Lake Clifton North and White Hills Road) is a reversal of the overall pattern between Binningup and Cape Bouvard, with the northern flank of salients undergoing accretion and the northern ends of the cells

erosion. This is a short to medium term process associated with localised migratory behaviour of sediment around the smaller salients under weak to moderate SW wind conditions, such as periods of prolonged sea breeze activity. It is also associated with higher landform variability than elsewhere along the barrier.

6. The deflation basin, a large erosional feature at the northern end of Cell 3 (Preston Beach) is located in a section with a prograding foredune and small localised blowouts (depositional features). This is apparently due to beach recovery following loss of sediment from the beach system but is consistent with the general erosional character of this part of the coast described in Point 5 above.
7. Stable and/or accreting foredunes occur dominantly in the northern half of the Yalgorup Coast; namely with sections in Cell 1 (White Hills Road) as well as along the southern half of Cell 2 (Lake Clifton North) and continuing into the northern part of Cell 3 (Preston Beach).

Observations of the Yalgorup coast over the historic period show that the coast responds to a range of coastal climate parameters, including sea level, wave direction and wave energy. These parameters are subject to considerable variability and uncertainty, both natural and anthropengenic and their effect is likely to be strongly influenced by exposure of the lithified basement which underlies the Leschenault-Yalgorup barrier. Coastal climate variation over the historic period is generally larger than the predicted anthropogenic forcing over the next 30 years. Consequently, the natural variability may either mask or exacerbate the effects of climate-change induced trends, depending upon the active phase. Due to the apparent sensitivity of the Yalgorup coast to different coastal parameters, interpretation of the effects of climate variability, including anthropogenic change, should consider a range of possible scenarios, with variation of winds, wave conditions and water levels.

Preliminary estimates of the wind climate are consistent with a southwards latitudinal shift of the weather bands, with a mild weakening of median winter winds and a slight strengthening of summer median winds (CSIRO 2007). These changes are small (<5%), and the range of uncertainty associated with the modelling is apparently larger than the trend. Projected changes to the southwest region wave climate have not presently been downscaled from global climate models (Hemer *et al*. 2008). Interpretation of the existing wave climate and projected change to wind fields suggests that there would be a general decline of background swell, with a slight increase to summer winds. The effect on alongshore sediment transport is uncertain.

Coastal climate variation over the historic period is generally larger than the predicted anthropogenic forcing over the next 30 years (Eliot & Pattiaratchi 2006; CZM & Damara WA 2008). Consequently, the natural variability may either mask or exacerbate the effects of climate-change induced trends, depending upon the active phase. Due to the apparent sensitivity of the Yalgorup coast to different coastal parameters, interpretation of the effects of climate variability, including anthropogenic change, should consider a range of possible scenarios, with variation of winds, wave conditions and water levels.

2.4 Flora and Vegetation

The Dawesville to Binningup Region supports a suite of natural values related to vegetation and flora. The presence of the largest coastal reserve on the southern Swan Coastal Plain in the study area provides opportunities to consolidate the substantive values of the coast, dune and wetland environments in what is the only opportunity for a consolidated reserve with potential for a coastal ‘wilderness” experience readily accessible to the major population centres of Western Australia.

The extensive, diverse suite of naturally vegetated landforms in the study area supports plant communities from grasslands to forests, containing a native flora of more than 520 native taxa including 108 significant taxa. These features and their relationship with the major landforms are summarised below together with reference to their conservation significance.

2.4.1 *Consolidation and Enhancement of the Yalgorup Wilderness Area*

The Yalgorup National Park forms the core of a 'wilderness' type area located between two major regional centres (Bunbury and Mandurah), within 150kms of the capital city (Perth). The outstanding mixture of landscapes and scenery with extensive, seemingly remote beaches, rolling coastal dunes with grasslands and shrublands, Tuart Forest/Woodland, *Banksia* Woodlands, limestone ridges with Heaths and mallees and a huge variety of wetlands supporting extensive Sedgelands, Shrublands and Low Forest as well as a series of aquatic communities. These varying landforms and plant communities form a vast array of habitats for fauna, and in the past an important area for the Aboriginal people.

Together these features establish a sense of remoteness for visitors to the area. Development interests in the area have the capacity to impact adversely on these features of the Park and region. There is a need to consolidate and buffer the Park to enhance and complement these features from development. At present Yalgorup National Park has an extremely tenuous shape with a very long (~50 kms) boundary and very little core area that is remote from private land and potential development.

Two overall priorities should be noted:

1. Buffering of native vegetation, in particular the wetland areas of Lake Clifton and Lake Preston
   The buffer will need to be determined from the water requirements of both the lakes and the vegetation. At times the areas included as buffer will be degraded. The vegetation of these areas would then require enhancement that is the areas be revegetated with local native species to mimic the structure of vegetation before clearing. Ramsar wetlands and Critically Endangered TECs and PECs are dependent on maintenance of groundwater quality.
2. Public usage managed.
   The ability of the Yalgorup National Park to both protect biological diversity and serve as access to natural environment for the growing regional population centres and Perth will required consolidation of the park boundaries to enhanced the core area and reduce impact from other landuses around the edges of the park.

2.4.2 *Conservation of Significant Communities and Flora*

The conservation of significant communities and flora identified during this study has been approached at a landform scale due to the high level of clearing in land outside the National Park and lack of complete survey coverage in the area.

Quindalup Dunes

Uplands

All vegetation in Good or better condition should be protected, priorities for protection in this category are:

- vegetation contiguous with wetland areas vegetation in Good or better condition;
- strand vegetation where the frequency of weed grasses introduced for stabilisation are is low;
- vegetation contiguous with Spearwood Dune vegetation in Good or better condition; and
- vegetated parabolic dunes.

Wetlands

All wetlands with vegetation in Good or better condition should be protected (these wetlands would meet the criteria for being classified as Conservation Category wetlands).

Spearwood Dunes

Uplands

All vegetation in Good or better condition should be protected, priorities for protection in this category are:

- areas of the three Limestone ridges;
- vegetation contiguous with wetland areas vegetation in Good or better condition;
- Tuart woodland/forest where the Tuart has not declined;
- vegetation contiguous with Quindalup and/or Spearwood Dune vegetation in Good or better condition;
- is part of a ecological linkage; and

- vegetated parabolic dunes.

Wetlands
All wetlands with vegetation in Good or better condition should be protected (these wetlands would meet the criteria for being classified as Conservation Category wetlands).

2.5 Fauna and Habitat

The vertebrate fauna within the Dawesville to Binningup study area is regionally significant and dependent on the remnants and wetlands that were once part of a vegetation continuum that covered the study area. The fauna requires particular habitat types of sufficient size, spatial replication and connectivity across the region. Further fragmentation or loss of vegetation will result in the reduction of the abundance, diversity, geographic distribution and productivity and hence the long-term survival of fauna throughout the study area.

Habitats within the Dawesville to Binningup study area are of regional significance for mammals, particularly for those species and assemblages that have greatly reduced distributions or have declined in abundance elsewhere on the Swan Coastal Plain. These habitats also have values for potential reintroductions of species which have become locally or regionally extinct. This is exemplified by the successful reintroduction of Western Ringtail Possums in the northern part of the study area.