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Catchment Environmental Assessment discussion paper
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ECOLOGICAL SYSTEMS BRANCH
(TERRESTRIAL SECTION)

Memorandum

ATTENTION: Adrian Parker
FROM: Bronwen Keighery/John Dell
DATE: 13th February 2006
SUBJECT: Comment on the Peel Harvey Eastern Estuary Area Catchment
Environmental Assessment Project discussion paper Floa and
Vegetation and Fauna sections of the URS 30.11.05 report

Section 3.4 FLORA AND VEGETATION

Overall the information in this section is very limited and at times incorrect. This information does not adequately describe the diverse flora and vegetation of the general area or any specific area.

3.4.1 Remnant vegetation

The broad descriptions of the three major vegetation systems follow the vegetation mapping by Beard. While this vegetation mapping is useful the standard mapping used in conservation assessments at this scale on the Swan Coastal Plain is the vegetation complex mapping by Heddlé *et al.* (1980) as described in Bush Forever. The percentage remaining in each of the vegetation complexes can then be compared across the entire southern Swan Coastal Plain.

In general the descriptions are insufficiently detailed to adequately discern the values of the vegetation and to compare these values to areas on the remainder of the Plain or to each other.

Specific Comment

Melaleuca hamulosa does not occur on the Swan Coastal Plain.
Jarrah is NOT endemic to the Swan Coastal Plain
Wandoo has not been observed in the study area.

3.4.2 Lake McLarty System

It is unclear as to what constitutes the Lake McLarty System, so no comment can be made here.

3.4.3 Peel-Harvey Estuary

Again, it is unclear what area the document is referring to. However from current studies the majority of the remaining vegetation on the shores of the Peel Inlet has been found to be estuarine fringing vegetation (Vasse complex) and Pinjarra Plain vegetation, not Bassendean vegetation.

There are both threatened species and communities within the entire study area and the Peel-Harvey Estuary area.

3.4.4 Yalgorup Lakes System

This is outside the study area.

Section 3.5 FAUNA

Overall the information in this section is extremely limited and confined to wetlands. This information does not adequately describe the diverse fauna and habitat of the general area. For some reason three areas are selected for description and comment (Lake McLarty System, Peel-Harvey Estuary and Yalgorup Lakes System). One of these areas (Yalgorup Lakes System) is

outside the study area. The other two areas are important areas but there are other important areas such as the Serpentine River that are valuable for fauna.

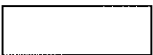
DRAFT REPORT

State of Play Peel Harvey Eastern Estuary Catchment Environmental Assessment discussion paper

Prepared for

Department of Environment

30 November 2005



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LIST OF APPENDICES

1. INTRODUCTION

State of Play represents the first phase of the *Peel Harvey Eastern Estuary Catchment Environmental Assessment* (henceforth “EEEE”), which is part of a Department of Environment strategy stemming from the *Economic Development and Recreation Management Plan for the Peel Waterways* (2000), which found the DoE (formerly Water and Rivers Commission) “should examine and review its requirements for the area between the Peel Highway Deviation and the waterways, so that it can make effective input to the planning process.”

The DoE has sought to clarify the kinds of strategies and guidance for development it needs to have in place to protect and enhance the environment, and to ensure population and development pressures are managed for genuine sustainability in perpetuity. The title for this document seeks to capture the idea of understanding the environment as we find it today, as well as to allude to the human uses and pressures facing the project area must drive environmental policy and strategy.

Consistent with numerous other regional studies, the aforementioned *Peel Waterways* study found that without corrective action, the waterways would not be able to sustain the increased recreational demands of expected population growth. Furthermore, it predicted that the environment would continue to decline unless resources were found for action in the catchment to improve water quality throughout the system, and affirmative action to restore the environment and habitats of the rivers, particularly the Murray and Serpentine.

Therefore, following this first project phase, the EEEA will lead to strategy development aligned to priorities for environmental protection, amelioration and enhancement, plus the establishment of guidance and criteria for land use planning and development. This broader project scope recognises that many studies have been conducted on the environmental values of the Peel region including the area east of the Peel Inlet and Harvey Estuary to the Peel Deviation section of the Proposed Perth to Bunbury Highway, but that greater integration of these with planning processes and assessments is required to attain a balance between environmental, social and economic interests.

Rather than replicate previous environmental studies, producing *State of Play* involved early engagement of some of the best available knowledge and wisdom on the study area. A steering committee comprising government environmental and non-environmental officials, local government, catchment groups and community representation help the project team to “cut to the chase” with respect to identifying priority issues and key pressures. Guidance from the local indigenous community was also received to ensure the project was informed by the long spiritual, cultural and environmental history of the region. The DoE and the project team viewed this as an essential perspective linking the present with the past as a way to guide amelioration priorities reviews and analyses the best available literature on the state of the environment either specifically for the EEEA study area or from relevant regional studies.

2. STRATEGIC PRIORITIES

2.1 ENVIRONMENTAL

[section coming]

2.2 SOCIAL

[section coming]

3. ENVIRONMENTAL ANALYSIS

3.1 SURFACE WATERS (QUALITY, FLOOD RISK, DRAINAGE, SEDIMENTS)

3.1.1 Quality

Section 48 Environmental Review for the Shire of Murray Town Planning Scheme No.4 Amendment No. 104 (Point Grey) (1997) noted that sources within the catchment had delivered high inputs of phosphorous to the estuary, leading to significant problems with algal blooms, odours, weed fouling and insect nuisance. The mechanism identified as most likely responsible for nutrient conveyance was groundwater recharge leading and subsequent discharge to the estuary in shallow groundwater flow. Probable contributing land uses identified were:

- treated effluent disposal by eucalypt woodlot irrigation
- stormwater disposal by soil infiltration
- residential areas – lawn and garden maintenance
- golf course irrigation and fertilization, and
- irrigation and fertilization of grassed playing areas and public landscaped areas.

However, the Review noted that groundwater recharge at the centre of the Point Grey area would take about 100 years to reach the estuary, and that modelling showed the soil profile had a phosphorus storage capacity of at least 160 years. Therefore, assuming similar retention and leaching rates throughout the current EEEA study area with a Spearwood sand profile, it should be expected that the nutrient impacts of human activity in the catchment to date will continue to be observable for at least 160 years, and probably considerably longer, depending on distance to the estuary. The capacity of Spearwood sands to absorb and retain phosphorus was also a beneficial property in terms of future management of phosphorous input to the estuary, inasmuch as limited application of phosphorus products as fertilizers or treated effluent could be managed to meet the EPA catchment target for phosphorous export. The key implication was that, while phosphorous in surface waters should be considered a priority for amelioration and management, it should not be considered a constraint to development provided appropriate application limits and management exist.

3.2 WETLANDS (RAMSAR SITES, CONSERVATION ESTATE, OTHER)

Ramsar

Australia is a contracting party to the Convention on Wetlands, Ramsar, Iran, 1971 ('the Ramsar Convention') and implements these commitments through the Commonwealth's Environmental Protection and Biodiversity Act 1999 (the EPBC Act). The following information is from the Ramsar website.

The Peel-Yalgorup System is a Wetland of International Importance under the Ramsar Convention, and is located partially within the Project Area. It is a joint listing comprising the Peel-Harvey Estuary, Lake McLarty System and Yalgorup Lakes System.

The wetland is listed as the system meets the following four Ramsar criteria:

- contains a representative, rare, or unique example of a natural or near-natural wetland type found within the appropriate biogeographic region

- supports populations of plant and/or animal species important for maintaining the biological diversity of a particular biogeographic region
- regularly supports 20,000 or more waterbirds, and
- supports one per cent of the individuals in a population of one species or subspecies of waterbird.

According to the Ramsar Report for the Peel-Yalgorup System (Ramsar website), the total site area of 26,530 hectares consists of eight different wetland types, of which permanent estuarine waters are dominant. Its biological values include a staging area for migratory waterbird species, a breeding area for waterbirds, importance for fishes and birds, and the presence of endemic flora species.

The current use of the surrounding area and catchment include urban development, settlements, intensive livestock rearing and agriculture. Its main threats are manure pollution, urban development and eutrophication.

The Ramsar site is used for research, education, recreation, commercial and recreational fishing and habitat/ nature conservation. The main threats within the wetland are unspecified disturbance by humans and eutrophication. As these wetlands are also listed as nationally important, they are discussed further in the Section XX.

National

The three systems that constitute the Ramsar Peel-Yalgorup System are also listed individually as nationally significant in the Directory of Important Wetlands in Australia. These are the Lake McLarty System, the Peel-Harvey Estuary and the Yalgorup Lakes System. The following information is provided in the Australian Wetlands Database (DEH):

The Lake McLarty System is located completely within the Project Area. It comprises Lake McLarty, an unnamed swamp, Mealup Lake, Robert Bay Swamp and Carraburmp (Carrabungup) Swamp. The wetlands are seasonal, and most are surface expressions of groundwater with some surface inflow.

Melaleucas and sedges dominate the vegetation of the system. The wetlands generally lack native vegetation buffers, except the unnamed swamp, which has a 100 m buffer. These wetlands therefore represent a potential for enhancement. Flora and vegetation are discussed further in Section XX. Sixty-five species of fauna have been recorded, 23 of which are listed under treaties. The system is a major breeding area for waterbirds, including cormorants, it is a migration stop-over area and a drought refuge area. Fauna are discussed further in Section XX.

The system is used for research, education, conservation, pasture grazing and recreation. There is a management committee for Mealup Lake, the Mealup Lake Preservation Society, which owns most of the lake not vested in CALM. Its past and present threats are eutrophication, algal blooms and exotic plants (the spread of Typha). Potential threats to the wetlands are groundwater extraction, too frequent wildfire and a housing area to be established adjacent to Lake McLarty. These aspects should therefore be prevented or mitigated in order to protect the wetland system.

The Peel-Harvey Estuary is located partially within the Project Area. It comprises the Peel Inlet and Harvey Estuary, their 5 km outlet to the ocean, the tidal lower 1-2 km of the Harvey, Murray and Serpentine Rivers, and the salt marshes around the system. It has a total

catchment area of 11,300 km², is permanently inundated and experiences both tidal and river flow.

Substantial areas of samphire surround the site, which support at least 60 invertebrate taxa, and much of which has been lost in other estuaries in the bioregion. These areas are outside the Project Area, and are currently protected and monitored. However, they still have the potential to be impacted by activities within the Project Area, and should therefore be considered a sensitive area. Melaleucas also dominate the other wetland areas with some eucalypts, casuarinas and sedges. Flora and vegetation are discussed further in Section XX. The far south-east and parts of the north-east have buffers of native vegetation ranging from 200 m to 1,000 m wide. Other areas have patchy buffers, and urban areas generally extend to the water's edge. The vegetated buffers should be protected, and areas with narrow or sparse buffers should be considered for enhancement.

The system is significant to a wide range of fauna, with 86 different species of recorded, the second highest number in Western Australia. It is a principal migration stop-over area and a drought refuge area for waterbirds. It is one of two breeding areas for the Australian Pelican, has major waterbird roost sites and supports moulting ducks. It is a major nursery area for fish and crustaceans (including commercial species). Fauna are discussed further in Section XX.

The system contains a number of Aboriginal sites of cultural value, and these areas should be protected and preserved. The system is currently used for conservation, commercial fishing and recreation. The surrounding area is also used for pasture grazing and has a high human population concentrated in the City of Mandurah.

Eutrophication and algal problems led to the construction of the Dawesville Channel. This enabled circulation between the estuary and the sea, but this has caused the estuary to now resemble a sheltered marine environment. Since then, a pelican breeding site has been lost to inundation, mosquito numbers have increased, the Harvey River Delta (an important waterfowl area) has experienced a decline in vegetation health and there has been an increase in toxic phytoplankton blooms in the Murray and Serpentine Rivers. These negative results could provide enhancement opportunities through activities such as revegetation of the Harvey River Delta. Other disturbances to the system include shoreline development, siltation, dredging and spoil dumping on tidal flats, recreation and mosquito control measures such as ditches and insecticide. Potential threats to the wetlands also include further development near shorelines, increasing disturbances, and possible further adverse impacts of the Dawesville Channel. Disturbances such as shoreline development, dredging and spoil dumping should be considered for action. Past disturbances may be opportunities for enhancement, while future disturbances should be prevented.

The Yalgorup Lakes System is adjacent to the Project Area, and is sensitive to impacts caused by activities within it. The system comprises two main parallel lakes, Lake Clifton and Lake Preston, and a chain of smaller lakes between them: Duck Pond, Boundary Lake, Linda's Lagoon, Lake Pollard, Martins Tank Lake, Yalgorup Lake, Lake Hayward and Lake Newnham.

Lake Clifton's north-eastern shore supports the largest known example of thrombolites in a lake environment in the Southern Hemisphere. Relict (dead) structures are found in some of the other lakes, and Lake Hayward contains diagenetic dolomite (sediments which have altered to become rock). A mucilaginous mat of cyanobacteria lines several of the smaller lakes, restricting exchange with the aquifer. The lakes are all supplied mainly by fresh groundwater and direct rain. The system is considered both interesting and significant as most of the lakes have similar physiognomy and are supplied by the same underground freshwater

aquifer, yet several types of salinity regimes occur. Lake Preston receives additional water via some minor drains. Lake Clifton receives extensive groundwater seepage along the eastern shore, where the thrombolites are found. The groundwater seepage provides the calcium and carbonate ions utilised in mineralisation by cyanobacteria to form the thrombolites. In order to maintain thrombolite growth, it is vital that this inflow of low salinity alkaline groundwater continues. It is therefore imperative that development in the area does not impact the quality or flow of waters into the Yalgorup Lakes System, especially Lake Clifton.

The wetlands are dominated by melaleuca and sedgeland, and the highly saline lakes are also surrounded by samphire. Some of the smaller lakes are completely surrounded by native vegetation, but the eastern extent has little to know buffer. Research suggests that existing buffer zones, especially those less than 50 m wide, are inadequate to limit the input of nutrients into Lake Clifton. Therefore, areas with a substantial buffer should be protected, while the narrow or degraded buffer areas require enhancement/ amelioration. Flora and vegetation are discussed further in Section XX.

The lakes support a total of 40 species of fauna, 10 of which are listed under treaties, but none of which are listed as threatened species. The thrombolites provide a sanctuary for a range of invertebrate fauna and fishes. The system is a major moulting area for the Australian Shelduck, and is the most important drought refuge area for the Musk Duck. Fauna are discussed further in Section XX.

The system is almost completely within the Yalgorup National Park, and is socially valuable for education, research, recreation and aesthetics. It is predominantly used for nature conservation and recreation, with surrounding areas also being used for pasture grazing, rural smallholdings and a low to moderate human population.

The lakes are vulnerable to a number of threats. In 1987 the thrombolite reef was partially covered by an alga with the potential to hinder the thrombolite process. Groundwater extraction, seepage interference and increased nutrients via surface flow all have the potential to change the conditions which currently support thrombolite growth. Human activity on the shoreline of Lake Clifton also has the potential to cause severe damage to the thrombolite reef. Therefore, as human populations in the region increase with development, it is vital that the area is protected from human disturbances.

This view was reinforced in the Federal Minister for Environment and Heritage's consideration of the potential environmental impacts of the proposed Mandurah to Bunbury Highway, which noted that key elements of the Peel-Yalgorup System Ramsar site had suffered acute impacts in the last 20 years. The causes of these may have been related to factors influenced by continued development. One such issue was the extraction of groundwater and interference with seepage near new small-rural holdings, and increased nutrient input (from agricultural fertilisers) as this could change conditions that favour the growth of the thrombolites. Research on the impact of vegetated buffer zones on nutrient inflow into Lake Clifton suggested that existing buffer zones, particularly those classified as small (less than 50 m wide) were inadequate to limit nutrient inputs to the lake.

3.3 CONSERVATION RESERVES

The Environmental Protection Authority's reports and recommendations to the Western Australian Planning Commission on the Peel Region Scheme (2000) and to Main Roads Western Australia on the Perth-Bunbury Highway (Peel Deviation) (2000) both assert the

position that all bushland in good condition and conservation category wetland vegetation in the Peel region should be considered of high conservation value.

This position acknowledges more than 90 per cent of native vegetation in the Peel regional had been cleared for agricultural and urban development.

3.3.1 Conservation reserves

(NOTE some of these may not be within the Project Area- not all are actually named on our maps)

- Peel-Yalgorup System Ramsar Site comprising the Peel-Harvey Estuary, Lake McLarty System and Yalgorup Lakes System (Ramsar website)
- Peel Regional Park (Planned) 6,375 ha surrounding the Peel Harvey waterways, of which 1,984 ha is privately owned (ERM)
- Yunderup National Park – in the delta where the Murray River enters Peel Inlet (
- Austin Bay Nature Reserve, Greenlands Rd, Pinjarra. Eastern shore of Peel inlet, south of South Yunderup. (AHPI, AHD)
- Harvey Estuary Nature Reserve, Herron Point Rd, Coolup (AHPI, AHD)
- Jarrah Forest National Park (proposed), Pinjaraa Williams Rd, Dwellingup (AHPI)
- Nature Reserve 4990, Yunderup Rd South, Pinjarra (AHPI, AHD)
- Nerimba Cay Nature Reserve, Greenlands Rd, Pinjarra (AHPI, AHD)
- Nature Reserve 39404 (CALM proposes to have the remainder of Lake McLarty added) (DEH)
- Nature Reserve 24739 (contains half of the unnamed swamp of the Lake McLarty System and some marshes and fringing scrub/forest of the Peel-Harvey Estuary)(DEH)
- Nature Reserve 6627 (contains most of Mealup Lake)(DEH)
- Lake Mealup Preservation Society land - privately owned sanctuary)
- Gov Water Reserve 7502 (contains most of Robert Bay swamp)(DEH)
- Nature Reserve 2707 (contains Carraburmup Swamp and some marshes and fringing scrub/forest of the Peel-Harvey Estuary)(DEH)
- Nature Reserve 2990 (contains some marshes and fringing scrub/forest of the Peel-Harvey Estuary)(DEH)
- Nature Reserve 23756 (contains some marshes and fringing scrub/forest of the Peel-Harvey Estuary)(DEH)
- Nature Reserve 2738 (contains some marshes and fringing scrub/forest of the Peel-Harvey Estuary)(DEH)
- Nature Reserve 2436 (contains some marshes and fringing scrub/forest of the Peel-Harvey Estuary)(DEH)
- Nature Reserve 4990 (contains some marshes and fringing scrub/forest of the Peel-Harvey Estuary)(DEH)
- Kooljerrenup Nature Reserve – southern end of Harvey Estuary and mouth of Harvey River(ERM)
- Peel Harvey estuary site – a gov planning committee is working on establishing it as a regional park(DEH)
- Yalgorup N P (11710, 22057, 12189, 21271 and 5524, also has proposed extensions) contains most of the Yalgorup Lakes System. Is this N P adjacent to Project Area or is some in Project Area? (AHD, DEH)

Nature Reserves are managed by WADCALM for ~~NPNCA~~ (DEH wetlands)

CCWA

3.3.2 Water birds

The Peel Inlet is a site of international significance for water birds, including migratory species.

3.4 FLORA AND VEGETATION

3.4.1 Remnant vegetation.

Protection of remnant vegetation and biodiversity as well as revegetation should be a priority. The area covered by the Project contains representations of three major vegetation systems, Spearwood, Bassendean and Pinjarra, each with characteristic vegetation and flora.

The **Spearwood System** runs parallel, and close to, to the coast. Minor sections of the Project Area include this system, comprising the SW corner, the Point Grey area and the NW boundary of the Project Area. In the Peel Geographic Perspective, the Peel Development Commission (PDC) describes this as open forest dominated by jarrah (*Eucalyptus marginata*), marri (*Corymbia calophylla*) and tuart (*Eucalyptus gomphocephala*), with an understorey including banksias, peppermints (*Agonis* spp), sheoaks (*Allocasuarina* spp), hakeas and acacias.

Beard describes the Spearwood System as eucalypt woodland interrupted by fresh alkaline lakes overgrown with sedges and bordered by communities of melaleuca or banksia. The eucalypt woodland occurs in two communities: the tuart association, which favours ridges, and the tuart-jarrah association, which favours depressions. In the tuart association, tuart is often the only large tree, with small trees including sweet peppermint (*Agonis flexuosa*), slender banksia (*Banksia attenuata*), firewood banksia (*B. menziesii*) and sheoak (*Allocasuarina fraserana*). There are also grasstrees (*Xanthorrhoea preissii*) and zamia (*Macrozamia riedlei*), with a range of shrubs, low shrubs, creepers and herbs. In the tuart-jarrah association acid tolerant plants such as slender banksia (*Banksia attenuata*), firewood banksia (*B. menziesii*) and sheoak (*Allocasuarina fraserana*) become emphasised and form a more definite understorey. The acid tolerant shrubs, low shrubs, creepers and herbs also persist. Changes also occur from north to south. In the southern areas, including the southern areas of the Project Area, sweet peppermint (*Agonis flexuosa*) is the main understorey tree. Dense low stands of swamp paperbark (*Melaleuca raphiophylla*) often occur between sedges and the tuart (*Eucalyptus gomphocephala*) woodland on dry land. The Peel-Harvey wetland has distinct zones from the water to the shore, comprising *Juncus* marsh, then saltwater paperbark (*Melaleuca cuticularis*) followed by less salt-tolerant *M. hamulosa* and swamp paperbark (*M. raphiophylla*), and finally flooded gum (*E. rudis*) and dry land vegetation.

M. viminea?

The tuart and jarrah are important as they are endemic the coastal plain. Tuart woodland ecosystems particularly require protection as they have been threatened by clearing and an overall decline in tuart health. (PDC)

The **Bassendean System** in the Project Area comprises the NW quarter and the SW corner. In the NW quarter of the Project Area this system extends down to the southern areas of the Peel Inlet and east to an area north of Pinjarra. In the SW corner this system is east of the Spearwood System area, and extends a little into northern vicinity of Kooljerrenup. In the Peel Geographic Perspective, the Peel Development Commission (PDC) describes this as jarrah (*Eucalyptus marginata*)-banksia woodland gradually becoming jarrah (*Eucalyptus marginata*)-marri (*Corymbia calophylla*) towards the east, except where agricultural areas

have been extensively cleared. Swamps and low lying areas contain paperbarks (*Melaleuca* spp), swamp banksia (*Banksia littoralis*), flooded gum (*Eucalyptus rudis*) and bullrushes.

Beard states that in general, the Bassendean System adjoins the eastern, inland side of the Spearwood System, but is divided by the Serpentine and Murray Rivers. The system is a mosaic of vegetation controlled by drainage, dominated by banksia woodland towards the north. In the more southern parts, it becomes jarrah (*Eucalyptus marginata*)-marri (*Corymbia calophylla*) woodland with an understorey which varies from thick banksia to woodland with smaller banksia and casuarina. The freshwater swamps in the area are surrounded by swamp paperbark (*Melaleuca raphiophylla*) and have sedges extending into the water.

The Pinjarra Plain System runs to the east of the Bassendean System, intermittently traversing it to the west and adjoining the Spearwood System. Within the Project Area, it covers the NE corner and central to SE areas. The central to SE area extends north to the wetland areas of the Murray River and also west to the south-eastern shores of the Harvey Estuary. Most of the Plain was cleared as it has the best soils on the coastal plain for pasture development and irrigation. Furthermore, wooded areas would have been selectively culled for trees such as jarrah (*Eucalyptus marginata*) and wandoo (*Eucalyptus* spp) (Beard). According to PDC, only some very small areas of marri (*Corymbia calophylla*) and wandoo (*Eucalyptus* spp) exist today. There are some areas around the foothills east of the Project Area that still support patches of jarrah (*Eucalyptus marginata*) woodland with banksia, sheoak (*Allocasuarina* spp) and grasstrees (*Xanthorrhoea preissii*). (PDC)

The original vegetation would have been paperbark (*Melaleuca* spp) swamp with a range of species, intersected by fringing woodlands or forests of flooded gum (*Eucalyptus rudis*) along natural drainage lines. It is likely that the common small trees would have been Holly-leaved Banksia (*Banksia ilicifolia*) and Christmas Tree (*Nuytsia floribunda*) (Beard).

Therefore, any remnant vegetation within the Pinjarra Plains System should be considered for amelioration and protection.

3.4.2 Lake McLarty System

The Lake McLarty System falls mainly within the Pinjarra Plain System described by Beard, and contains mixed jarrah, marri, tuart and banksia woodlands, with melaleuca and flooded gum flats, large, open reed beds and extensive areas of open water. (LMPS)

According to DEH (Wetlands) it does not include any threatened flora species. Its wetland forests are dominated by *Melaleuca raphiophylla* and other melaleuca species, whereas its wetland scrubs are dominated by melaleuca such as *M. lateritia* and *M. teretifolia*. Fine sedges, likely to be *Baumea* spp, cover significant outer areas around most of the wetlands.

Lake McLarty's sedgeland has extensive *Baumea articulata* and the introduced bulrush *Typha orientalis*. The sedgelands at Mealup Lake and the unnamed lake have extensive populations of *Typha orientalis*.

Parts of Mealup Lake and Carraburmup Swamp support stands of mature Melaleucas, which are considered special communities and should be considered for protection (DEH Wetlands).

3.4.3 Peel-Harvey Estuary

The shores of the Peel Inlet which are located within the Project Area are mainly within the Bassendean Vegetation System described by Beard, except the area around Point Birch on the southern shore, which supports the Pinjarra Plain Vegetation System. The Spearwood Vegetation System covers the Point Grey region at the south-eastern shores of the Peel Inlet, extending almost halfway down the eastern shore of the Harvey Estuary.

According to DEH (Wetlands) it does not include any threatened flora species, and its areas of scrub and forest are most extensive in the far south (Harvey Delta) and north-east. Austin Bay along the east supports significant stands of *Ruppia megacarpa* (underwater flowering plant). (DEH Wetlands). These areas are all located within the Bassendean Vegetation System described by Beard.

In general, the surrounding areas are open forest or scrub, or are cleared. The main wetland trees are Saltwater Paperbark (*Melaleuca cuticularis*), *M. hamulosa*, swamp paperbark (*M. raphiophylla*), flooded gum (*Eucalyptus rudis*) and Swamp sheoak (*Casuarina obesa*). The dominant sedges at the Peel-Harvey Estuary are the Marsh Club-rush (*Bolboschoenus caldwellii*) and Sea Rush (*Juncus kraussii*), and the dominant seagrass is Sea Wrack (*Halophila ovalis*), which is found in the deeper bays. (DEH Wetlands)

Samphire is most extensive in the far north, which is outside of the Project Area. Samphire in the area is important as much has been lost in other estuaries, and the quality and quantity has been decreasing in recent years. Therefore, development in the area must not negatively impact these nearby important areas. (DEH Wetlands)

Erosion of the Murray River has resulted in poor condition that requires revegetation, especially of fringing sedges. (ECB) Therefore, the Murray River should be considered for enhancement and protection.

3.4.4 Yalgorup Lakes System

The Yalgorup Lakes System is not within the Project Area, but are adjacent to the south-western boundary. They are all within the Spearwood Vegetation System described by Beard. According to DEH (Wetlands) it does not include any threatened flora species, and is dominated by *Melaleuca* species and sedgeland. The significance of the Yalgorup Lakes System is the thrombolites, which comprise 8 cyanobacterium (blue-green algae). As discussed in the wetland section, the thrombolites are significant and must not be impacted by developments in nearby areas.

DEH website – EPBC Act Search

3.5 FAUNA

3.5.1 Lake McLarty System

The only threatened species listed under the EPBC Act that has been recorded at Lake McLarty System is the Australasian Bittern (*Botaurus poiciloptilus*). A calling was recorded at Lake McLarty in November 1983, and one was seen at Mealup Lake in February 1984. This bird was once found throughout the Murray-Darling Basin and adjacent coastal areas of Western Australia, as well as across south-eastern Queensland to south-eastern South Australia, including Tasmania. All sub-populations have become confined, and the Western Australian sub-population is now very restricted and concentrated mainly in the Lake Muir

wetlands. The Australasian Bittern has comparatively specialised habitat requirements, so is very sensitive to overall habitat loss or damage, such as that caused by salinisation or drainage. If the Australasian Bittern is present within the Peel-Harvey Region, it is vital for the species that their habitat is not cleared or impacted by development in the area.

There have been 65 species recorded at the Lake McLarty System, 23 of which are under treaties (of 54 that occur in WA). 58 species have been recorded at Lake McLarty, and 44 at Mealup Lake. The 65 species recorded in the system include four darters and cormorants, nine herons and allies, 12 ducks and allies, seven rails and 21 shorebirds.

The Long-toed Stint occurs in the drying sparse sedgeland at Lake McLarty and occasionally at Mealup Lake. The numbers recorded in 1992 were the highest in Australia, emphasising the importance of the wetland to this species. The Pectoral Sandpiper regularly occurs at lake McLarty and in 1986, a count of 12 was probably the highest in Australia. The Ruff (*Philomachus pugnax*) often occurs at lake McLarty, and in 1983 the numbers were the highest in Western Australia.

Seventeen species have been found breeding within the system, including 10 at Carraburmup Swamp and eight at Lake McLarty. Colonies of Little Black Cormorant (*Phalacrocorax sulcirostris*) and Little Pied Cormorant (*P. melanoleucos*) are annually active at Carraburmup Swamp, and are among the largest in the south-west of Western Australia. Black Swans (*Cygnus atratus*) are also known to breed at most of the wetlands, especially in Robert Bay Swamp at the southern parts of the Peel Inlet.

The system of wetlands is used as a migration stopover for 15 migrant shorebirds, nine of them regularly. Lake McLarty supports more than 1% of the known or probable national populations of Red-necked Avocet (*Recurvirostra novaehollandiae*), Wood Sandpiper (*Tringa glareola*), Marsh Sandpiper (*Tringa stagnatilis*), and Pectoral Sandpiper (*Calidris melanotos*), Long-toed Stint (*Calidris subminuta*) and Curlew Sandpiper (*Calidris ferruginea*).

3.5.2 Peel-Harvey Estuary

According to DEH (Wetlands) the Peel-Harvey Estuary does not support any threatened fauna listed in the EPBC Act. There has been a total of 86 fauna species recorded, 34 of which are under treaties (of 54 that occur in WA). The 65 species recorded in the system include five darters and cormorants, 12 herons and allies, 12 ducks and allies, five rails, 35 shorebirds and nine gulls and terns. Nine species have been found breeding at the wetlands, mostly ducks and allies, mostly in salt marshes. The Australian Pelican (*Pelecanus conspicillatus*) sometimes breeds on Nirimba Cay, an island in the south-east of Peel Inlet, and sometimes on some of the other islands in the area. Many roosting sites exist in the system, including high-tide roosts at islands and salt marshes used by shorebirds, the inner edges of exposed mudflats in the north-east used by ducks, small islands in the south used by cormorants, the drain mouth deltas in the south-east Peel Inlet used by ducks, and the sheltered lower reaches, especially at the Harvey River mouth used by ducks and cormorants.

The site supports more than one per cent of the national population of Grey Plover (*Pluvialis squatarola*), Red-capped Plover (*Charadrius ruficapillus*), Black-winged Stilt (*Himantopus himantopus*), Banded Stilt (*Cladorhynchus leucocephalus*), Red-necked Avocet (*Recurvirostra novaehollandiae*), Greenshank (*Tringa nebularia*), Marsh Sandpiper (*Tringa stagnatilis*), Sharp-tailed Sandpiper (*Calidris acuminata*), Red-necked Stint (*Calidris ruficollis*) and Curlew Sandpiper (*Calidris ferruginea*).

At least 55 fishes and more than 20 taxa of benthic invertebrate occur in the system, while the samphires support at least 60 invertebrate taxa.

3.5.3 Yalgorup Lakes System

According to DEH (Wetlands) the Yalgorup Lakes System does not include any threatened fauna listed in the EPBC Act. There have been 40 species of fauna recorded in the system, including 14 shorebirds and four gulls and terns, 10 of which are under treaties. The site supports more than one per cent of the national population of Red-necked Avocet (*Recurvirostra novaehollandiae*). It is a major moulting area for the Australian Shelduck (*Tadorna tadornoides*), and is the most important drought refuge area for the Musk Duck (*Biziura lobata*) and some of the lakes in the system support tortoises.

The thrombolites in Lake Clifton provide habitat for amphipods, isopods, shrimps and fishes, while the area within and near the reef also supports nematodes, polychaetes, copepods, ostracods and sea anemone. The sensitive thrombolites are not only significant as the largest known example of thrombolites in a lake environment in the Southern Hemisphere, they also support a wide range of fauna. These structures rely on the inflow of low salinity alkaline groundwater, and so they must be protected by preventing any potential impacts on groundwater caused by developments in the region.

A search of the Department of Environment and Heritage website for threatened ecological communities listed under *Environmental Protection and Biodiversity Conservation Act 1999* did not identify communities specific to the Study area. However, it did identify sedgelands in Holocene dune swales of the southern Swan coastal plain as threatened. These are likely to occur on the western shores of Lake Preston (Yalgorup System), adjacent to and impacted by land management within the Study area.

3.6 GROUNDWATER (LEVELS, ALLOCATIONS AND AVAILABILITY)

3.6.1 Physiography

The site is situated within the low-lying Swan Coastal Plain, which extends from the coast to the Darling Scarp. The alluvial sediments on the site give rise to an area of generally low relief (Figures 1 and 2). To the west of the site towards the coast there is a series of fixed and active dunes with more varied relief. Beyond the Swan Coastal Plain to the east of the site is the Darling Scarp which is of higher relief and developed in Precambrian rocks along the Darling Fault.

The Swan Coastal Plain in the vicinity of the site area is divided into geomorphic units that are described by McArthur and Bettenay (1960). The physiographic units subparallel the present coastline and from east to west are described below. Figure 3 illustrates the physiographic units of the site area based on their corresponding shallow geology described below.

- Ridge Hill Shelf - lateritic soil forming the foothills of the Darling Scarp, located to the east of the site area.
- Pinjarra Plain - the land falls fairly rapidly from the Ridge Hill Shelf to the Pinjarra Plain, which is essentially flat lying, and consists of alluvial deposits of the Guildford Formation, including the estuarine deposits bordering the Peel Inlet.

- Bassendean Dune System – form low hills, reaching a maximum elevation of about 30m above sea level, in a zone up to 11km wide west of the Pinjarra Plain, and correspond geologically to the Bassendean Sand.
- Spearwood Dune System - west of the Bassendean Dune System intermittently along the western boundary of the site is the Spearwood Dune System which forms a ridge near the coast (up to 60m high in places, although near Mandurah it is fairly low lying and truncated by the Peel Inlet). The system in the vicinity of the site area geologically is the Tamala Limestone consisting of leached and lithified calcarenite and sand.
- Quindalup Dune System - beyond the Spearwood Dune System to the west, and beyond the west boundary of the site area, along the present coastline is the Quindalup Dune System , which comprises recent eolian sand, mostly unconsolidated and consisting geologically of the Safety Bay Sand.

3.6.2 Geology

The site area is situated within the Perth Basin which is a deep elongated sedimentary trough 1000km long bounded on the east by the Darling Fault and the crystalline rocks of the Precambrian Yilgarn Block.

The site area lies in the southern part of the basin where the Mesozoic and Palaeozoic sediments are more than 10,000 m thick. The width of the onshore part of the basin is approximately 30m in this area.

The regional geology is described by Commander (1975, 1982) and Deeney (1989). The Mesozoic sediments are generally covered by Quaternary deposits and do not crop out in the Mandurah-Bunbury area. Information on the subsurface stratigraphy has been gained from oil exploration wells, deep water bores (mostly around the Metropolitan area) and exploratory water-well drilling. Seismic traverses and gravity surveys yield some information on structure.

3.6.3 Stratigraphy

The stratigraphic succession is summarised in Table 1. The formations comprising the Cainozoic succession in the study area are collectively referred to as the superficial formations. They range in thickness from about 12 to 90m and rest of a gentle westerly sloping erosional surface. The superficial formations form a stratigraphically complex sequence and their inferred relationships are shown on Figure 4.

Table 1 Stratigraphic succession

	Age	Stratigraphic unit and lithology		
		West	Central	East
CAINOZOIC	QUATERNARY Holocene	Alluvium, estuarine, lagoonal and swamp deposits (15); (sand, silt, clay and peat)		
		Safety Bay Sand (50) (sand, calcareous and unlithified)	UNCONFORMITY	(a) Colluvium (5) (lithic sand, silt, clay, laterite, laterite debris)
	Pleistocene Middle-Late	Tamai Limestone (90) (limestone, sand, calcarenite, minor clay, minor fossils)		Bassendean Sand (15?); (sand)
			Early-Middle	UNCONFORMITY
	Early	Jandakot beds (25) (sand, silt, clay, minor limestone, fossiliferous)		Guildford Formation sand Member (30) (sand, minor clay, calcareous sand, and fossils)
			UNCONFORMITY	
MESOZOIC	CRETACEOUS Early-Late	Osborne Formation (siltstone and clay)		
	Early	UNCONFORMITY		
		Wanbro Group: Leederville Formation (sand, siltstone, clay, shale) South Perth Shale (sand, silt) Gage Sandstone Member (sand, shale)		
	JURASSIC Early-Middle	UNCONFORMITY		
		Cockleshell Gully Formation (sand, siltstone, clay, shale)		

Notes: (a) Colluvium ranges in age from Tertiary to recent.
 (b) Figures in brackets are estimated maximum thicknesses in metres.
 Source: Deeney (1989) and Commander (1982).

The superficial formations unconformably overlie Mesozoic sediments on the coastal plain, and Precambrian rocks along the Darling Scarp. The Mesozoic sediments do not crop out in the site area. The Mesozoic sediments of the site area comprise mostly the Leederville Formation, except in on the northwest boundary of the site area, near the Peel Inlet/Harvey Estuary, where the superficial formations unconformably overlie the Osborne Formation, and the northeast corner of the site area, where the superficial formations unconformably overlie the Cockleshell Gully Formation (Figure 5). The unconformity surface is irregular and ranges in elevation from 5m AHD to 25m AHD (Figure 5). Two prominent east-west erosional channels in the Mesozoic sediments are located east of and probably beneath the Peel Inlet and at the southern end of the Harvey Estuary.

Deeney (1989) describes the superficial stratigraphical sequence shown on Figure 4, extending east-west across the site area, from Lake Clifton, through the Harvey Estuary and Murray River to the Darling Scarp. Commander (1975, 1982) describes the deeper geological section shown on Figure 4b, near Mandurah.

Cockleshell Gully Formation

The formation is an unconsolidated sand-shale succession, the sands being mostly well sorted coarse-grained quartz with minor feldspar and accessory garnet and pyrite. Thin coal seams are often present. The shale units vary from unlaminated siltstone-mudstones to fissile micaceous shales. The colour is usually dark grey, but near the unconformity there appears to be a weathered zone where mottled red-brown to yellow colours are common. The bedding is very well differentiated. The shale units do not exceed 50m thickness except in the upfaulted block adjacent to the Darling Fault where a shaley sequence over 150m was encountered. The sand and shale units tend to be lens shaped and detailed correlations are not possible except in very closely spaced bores.

Warnbro Group

The Leederville Formation is the main aquifer in the Warnbro Group and consists of interbedded sands and shales. The Leederville Formation extends across most of the site area. The underlying South Perth Shale, which is a succession of interbedded thin sands and silts, is only likely to be present in the northern part of the site, north of the Mandurah area. The Gage Sandstone is at the base of the South Perth Shale and is an alternating sand-shale succession, very similar in lithology to the underlying Cockleshell Gully Formation

Yoganup Formation

The Yoganup Formation consists of white and orange-brown, poorly sorted, subangular to subrounded, fine to very coarse sands and clayey sands. The sands are ferruginized and leached, consist predominantly of quartz with minor amounts of weathered feldspar, and are associated with silts and clays. A basal gravel containing pebbles of granite and laterite up to 2cm in diameter was encountered in some bores in the area. Races of carbonaceous material were sometimes found near the top of the sequence. The samples obtained during drilling generally contained traces of heavy minerals.

The Yoganup Formation rests unconformably on Mesozoic sediments of the Perth Basin and Precambrian rocks of the Yilgarn Block, and is unconformably overlain by the Guildford Formation. The Yoganup Formation adjacent to the Darling Scarp and extends westward beneath the eastern boundary of the site area to interfinger with the Jandakot Beds (Figure 4 and 6). The Yoganup Formation ranges in thickness from 1 to 25m along the eastern boundary of the site; its variable thickness can be attributed to its mode of deposition and the effects of post-depositional erosion. (Figure 6). The Yoganup Formation generally is thickest beyond the eastern boundary of the site area, at the foot of the Darling Scarp.

Jandakot Beds

The Jandakot Beds consist of grey, poorly sorted, subrounded, medium-grained sand to very fine gravel, fine sand, silt, clay, clacarenite, and limestone, generally with abundant fossils. They occasionally contain minor amounts of glauconite, phosphatized shell fragments and phosphatic nodules, and often contain carbonaceous material and traces of heavy minerals.

The Jandakot beds rest unconformably on Mesozoic sediments. They are unconformably overlain by the Guildford formation in the central part of the coastal plain and by the Tamala Limestone in the west (Figure 4). Within the site area the Jandakot beds occur continuously in the subsurface south of Pinjarra.

The Jandakot beds extend from about -30m AHD to +5m AHD and from the contact with the Yoganup Formation, approximately in the middle of the site area, to the west beyond the site

area boundary to within about 7km of the coast. Their thickness ranges from 2.5 m to 25 m, reflecting the influence of pre-depositional topography and post-depositional erosion (Figure 6).

The Jandakot beds generally contain small gastropods and bivalve fragments, echinoid spines, large benthic foraminifers and fragments of brachiopod shells and calcareous marine algae.

The Jandakot beds are considered to be an estuarine to marine facies equivalent of the Yoganup Formation on the basis of their position in the stratigraphic sequence, their depositional environment and their age.

Guildford Formation

The Guildford Formation can be subdivided into a clay member (in the eastern portion of the site area) and a sand member (in the western portion of the site area) that are laterally equivalent (see Figures 2 and 4).

The clay member consists of brown or grey clay and sandy clay together with thin beds of arenaceous gravel. Occasionally, the clays are ferruginized and those occurring close to the Darling Scarp (east of the site area) are often multi-coloured – purple, red-brown, green, yellow and grey.

The sand member consists predominantly of grey, poorly sorted, fine to very coarse-grained quartz sand, together with minor beds of brown or grey clay and clayey sand, and traces of heavy minerals. Generally, a layer of coffee-brown ferruginized (limonitic) sand is present near the water table.

The Guildford Formation unconformably overlies the Jandakot beds, the Yoganup Formation, and east of the site area the granitic rocks of the Yilgarn Block. It is unconformably overlain by the Bassendean Sand and alluvium on the coastal plain, and by colluvium along the Darling Scarp, beyond the site area eastwards (Figure 4). The stratigraphic relationship between the Guildford Formation and the Tamala Limestone is uncertain.

The Guildford Formations extends the entire site area, westwards from the foot of the Darling Scarp to within 10 km of the coast. The clay member, which occurs in the eastern part of the site extends from about -5 m AHD to about +70 m AHD, and generally attains its maximum thickness close to the foot of the Darling Scarp and ranges from 2 m to 27 m thick. The sand and clay members interfinger in the central part of the site. The sand member extends from about -25 m AHD to about +20 m AHD and ranges in thickness from 4 to 30 m.

The lithology, geometry and location of the sediments comprising the clay member suggest that they were deposited as alluvial fans, derived from weathering of the Yilgarn Block. The alluvial fans grade laterally, at their distal end, into the fluvial and shallow-marine sediments of the sand member.

Bassendean Sand

The Bassendean Sand consist of white to pale-grey and occasionally brown, moderately sorted, fine to medium grained quartz sand containing traces of heavy minerals. It unconformably overlies the Guildford Formation.

The Bassendean Sand forms a thin cover over much of the site area east of the Spearwood Dunes and a discontinuous zone of low hills in the central region of the coastal plain (central

region of the site area) (Figures 2 and 4). It may reach a maximum thickness of 15 m and is of eolian origin.

The Bassendean Sand may be of Middle to Late Pleistocene age.

Tamala Limestone

The Tamala Limestone comprises limestone, calcarenite and sand, with minor clay and shell beds.

The Tamala Limestone unconformably overlies Cretaceous sediments in the western portion of the site and the Jandakot Beds along the eastern portion of the site area (Figure 2 and 4). It is unconformably overlain by the Safety Bay Sand in the west and may interfinger with the Bassendean Sand in the east. The nature of the contact between the Tamala Limestone and the Guildford Formation is uncertain. On the basis of its position, lithology and age, the marine sequence in the Tamala Limestone may interfinger with the sand member of the Guildford Formation. The Tamala Limestone occurs on the northwest boundary of the site, between the Peel Inlet and the Harvey Estuary. Along the coast, the Tamala Limestone extends from about -28 m AHD to +70 m AHD, and has a maximum thickness of about 90 m.

Macrofossils recovered from the Tamala Limestone have been assigned a Middle Pleistocene age. The formation is predominantly of eolian origin. However, below approximately +3 m AHD it is composed mainly of marine and lacustrine sediments.

Two bores are located in the Tamala Limestone in the site area, and penetrated a sequence of grey-green and orange-brown clay containing nodules or thin layers of gypsum and dolomite, overlying orange brown calcareous sand and sandy limestone with dolomite, anhydrite and clay. It has been suggested a Middle Pleistocene age for the macrofossil assemblage obtained from one of the bores. The sequence may represent a sabkha-type deposit. These deposits have been tentatively assigned to the Tamala Limestone on the basis of their location and lithology. The sand and limestone are lithologically similar to the marine sequence in the Tamala Limestone, but are also similar to the sand member of the Guildford Formation.

Safety Bay Sand

The Safety Bay Sand consists of unlithified calcareous sand, and unconformably overlies the Tamala Limestone. It forms a narrow strip of stable and mobile dunes along the coastline, beyond the western boundary of the site area, and has a maximum thickness of about 50 m. The Safety Bay Sand is of Holocene age.

Colluvium

The Colluvium consists of fragments of Precambrian rocks and laterite. It overlies the Yoganup formation, the Guildford Formation and Precambrian rocks and laterite, and the grain size ranges from coarse pebbly sand to poorly sorted silty sand and clay.

Deposits of colluvium occur along the Darling Scarp, beyond the eastern boundary of the site area, and the thickness of the deposits varies considerably and may exceed 5 m.

Alluvium, estuarine, lagoonal and swamp deposits

Alluvium, consisting mainly of grey and brown silt and clayey sand occurs along the rivers and their tributaries (Figure 4).

Estuarine and lagoonal deposits comprising black, brown and grey humic sandy clay, silt, marl, clayey sand, sand and calcarenite unconformably overlie the Tamala Limestone and the Guildford Formation. They occur on the floor and margins of the Peel Inlet and the Harvey Estuary within the site area, and the coastal lakes, beyond the western boundary of the site.

3.7 GENERAL HYDROGEOLOGY

The hydrogeology of the area is described by Deeney (1989) and Commander (1975 and 1982) and summarised below.

The superficial formations, which consist predominantly of clay and sand in the eastern part of the site, and of sand and limestone in the western part of the site, form an unconfined aquifer which extend across the site area (Figure 2). In the eastern part of the site, the Guildford Formation clay member forms an important aquitard in the upper part of the aquifer. The water table is generally within 1-2m across the site area, except in the Tamala Limestone, where it can be up to 30m deep. The aquifer is underlain by Mesozoic sediments which generally have low permeability, though locally both upward and downward leakage occurs.

Pumping tests conducted at two groundwater bores in the study area and one just south of the study area (Figure 8) indicate that the superficial formations form an aquifer that is inhomogeneous and anisotropic. The distribution of isopotentials at the end of the pumping, and the variation in lithology indicate that it is a multilayer aquifer which is divisible into aquitards and aquifers. The data indicates the aquifers responded generally in a semi-confined manner. Deeney (1989) provides estimates (based on the solutions of Walton 1962) of transmissivity, hydraulic conductivity and coefficient of elastic storage of the pumped aquifer (Table 2). The calculated values of the hydraulic conductivity of the aquitard provide estimates of the vertical hydraulic conductivity of the sediments overlying and underlying the pumped aquifer, since the direction of flow in these sediments was approximately vertical.

The pumping-test analyses show that the vertical hydraulic conductivity of the superficial formations is lower than the horizontal hydraulic conductivity, and that values may differ by a factor of between 10 and 1000. Generally, this is due to the stratification and variation in lithology. Locally, layers readily identifiable as aquitards are present, and are formed by silts and clays which do not persist laterally.

Deeney (1989) estimated aquifer transmissivities from lithological logs (Table 2), pumping test results (Table 2) and pumping-tests results described by Commander (1988). The transmissivity generally increases from east to west (Figure 8), varies locally and ranges from 50 to 500 m²/day in the vicinity of the site area. The wide range of values obtained reflect the variation in lithology and to a lesser extent the saturated thickness of the aquifer, which is 20-30 m through most of the study area, except where it decreases at the southern margin of the Peel Inlet.

Table 2 Hydraulic Conductivity Values

Lithology	Hydraulic Conductivity (m/d)
Sand	
Fine to very fine gravel	30
Fine to very coarse	30
Medium to coarse	30
Fine to coarse	15
Medium	15
Fine to medium	10
Fine	4
Very fine to fine	2
Very fine	1
Silt	1
Slightly silty/clayey sand	5
Clayey sand	1
Sandy clay	1
Slightly sandy clay	0.5
Clay	0.01
Limestone	50

Source: Freeze and Cherry (1979)

Table 3 Pumping-Test Results

Bore	Pump Rate (m ³ /d)	Drawdown In Observation Bores After 8 h Pumping (m)		Pumped Aquifer	Saturated Thickness (m)	Aquitard	Saturated Thickness (m)	Transmissivity (m ² /d)	Hydraulic Conductivity of Aquifer (m/d)	Hydraulic Conductivity of Aquitard (m/d)	Coefficient of Elastic Storage (Aquifer)
		Water Table	Base of Superficial Formations								
HS15	1095	0.127	2.087	Jandakot beds and Guildford Formation (sand member)	10	Guildford Formation (sand member)	18.5	97	10	3.3x10 ⁻¹	2.4x10 ⁻⁴
HS32	194	0.003	0.932	Jandakot beds	8	Guildford Formation (sand member)	17.5	23	3	2.9x10 ⁻¹	2.7x10 ⁻⁴
HS48	1168	0.220	0.782	Jandakot beds	25	Guildford Formation (sand Member)	9	409	16	1.6x10 ⁻¹	3.2x10 ⁻³

Source: Deeney (1989)

3.7.1 Groundwater Recharge

The superficial formations are recharged directly by rainfall. Recharge rates vary across the coastal plain as a result of variation in lithology, depth to the water table and topographic gradient. Generally, recharge rates are likely to be higher in the central part of the coastal plain than in the east or west because of the low clay content of the sediments, shallow water table and low topographic gradient. Inflow to the superficial formation also occurs locally by upward leakage from the Leederville Formation.

3.7.2 Groundwater Levels and Flow

The water-table elevation generally decreases across the site area from east to west, and generally follows topography (except within the Spearwood Dunes). The presence of water courses, such as the Murray River has resulted in the formation of groundwater divides. Water table contours are shown on Figure 9.

The hydraulic gradient is lower in the central part of the site area, and increases close to the Darling Scarp where the aquifer thickness decreases and the topographic gradient increases, and close to the Peel Inlet and the Harvey Estuary where the aquifer thickness also decreases. There is also a steep hydraulic gradient in the Tamala Limestone close to the contact with the Guildford Formation sand member.

The groundwater flow is indicated in Figure 9. The groundwater flow is in a westerly direction from the Darling Scarp, and in a north-esterly direction from the groundwater divide adjacent and parallel to the Murray River. The saturated thickness of the aquifer in the site area is generally 20-30m, and decreases to 10m along the southern margin of the Peel Inlet. The transmissivity is estimated to be generally less than 200m²/day in the eastern part of the flow system and increases to about 500m²/day in the northwest.

Generally, there is a downward head difference between the water table and the base of the superficial formations of about 0.1-1m, except close to the scarp where it increases to 8m. Locally upward head differences of 0.1-1m are present close to discharge boundaries, and in other areas, as a result of confinement by the Guildford Formation clay member and clays in the Jandakot beds.

The widespread occurrence of significant head differences reflects the vertical anisotropy of the aquifer, and the predominance of downward head differences indicates that regular recharge occurs throughout the area. In the drained area (Figure 9) that covers most of the coastal plain except for the Spearwood and the Quindalup Dunes, much of the water recharged is probably intercepted by the drains before it reaches the lower part of the aquifer.

The water table fluctuates seasonally and intersects the ground surface in many areas during the winter to maintain numerous wetlands (Figure 9). Deeney (1989) indicates that generally the seasonal range in water table level is 1-2m, with the greatest range occurring close to the Darling Scarp and the least range occurring in the Tamala Limestone.

3.7.3 Groundwater Discharge

Groundwater discharges from the superficial formation to the major watercourses, inlets and coastal lakes which form the flow system boundaries, and also to the large number of drains and smaller rivers which are present in the central and eastern parts of the area (refer to surface water section ?). The presence of the Guildford Formation clay member prevents groundwater discharge from the basal section of the aquifer to the rivers and drains which flow across it. The Murray River has completely eroded the Guildford Formation clay member to expose the Yoganup Formation, and groundwater discharges to it.

Significant quantities of groundwater are removed by evapotranspiration from the swamps and areas where the water table is at shallow depth (Figure 9). Groundwater discharge from the Guildford Formation clay member occurs mainly by evapotranspiration.

Discharge to the Mesozoic sediments by downward leakage occurs locally throughout the site area.

3.7.4 Groundwater Throughflow

[section coming]

3.7.5 Groundwater Allocation and Licensing

The DoE implements its water allocation decisions and regulates the use of water through the *Rights Water and Irrigation Act 1914*. The site area groundwater allocation is managed by the DoE Kwinana Office (Kwinana Peel Region).

Groundwater allocation in the site area is managed in accordance with DoE Groundwater Allocation Review Plans, which set the local licensing policy and allocation limits for the local water resources for the area. The groundwater allocation in the site area falls into two groundwater allocation areas: the South West Coastal Area and the Murray Groundwater Area. Each of these areas is divided into numerous sub-areas (Figure 11).

The South West Coastal Area is underlain by a thin lens of superficial aquifer containing generally fresh groundwater overlying the generally more saline Leederville Aquifer. The South West Coastal Area groundwater allocation is usually based on 750 kL/Ha/annum. 99% of the bores in the South West Coastal Area are in the superficial aquifer as the Leederville Aquifer is normally reserved for City of Mandurah bores (i.e. for watering of public open spaced).

The Murray Groundwater Area has a Groundwater Allocation review plan is not as stringent as the South West Coastal Area, and is judged on particular application requirements. It contains areas such as Coolup, Nambeelup, Pinjarra and parts of Waroona.

Groundwater Licencing is managed by the DoE Kwinana Office and applications are assessed based on groundwater abstraction applications. Groundwater licence applications in the area are reviewed taking into consideration protection of the nearby Peel Harvey Catchment.

3.7.6 Groundwater Salinity

[section coming]

3.7.7 Groundwater Contamination

3.8 SOILS

The landforms and soils of the Peel Region have been based on a classification system developed by Churchward and McArthur (1980) and further by the Perth to Albany Map and Explanatory Notes of the Australian Geographical Series. This geographical map series covers the southwest division of Western Australia. Figure XX presents the dominant soils of the study area.

Churchward and McAurther (1980) classified the study site as alternating between soils of the Vasse, Serpentine River, Cottesloe, Bassendean, Southern River, Dardanup and Swan systems.

The Vasse System is typically located along the eastern boundary of the Peel Inlet, at the mouth of the Murray and Serpentine Rivers, and along the southern tip of the Harvey Estuary. The dominant soil profiles varies between sand and mud flats of estuarine and marine alluvium, to upper level sandy terraces and gently undulating beach ridges, to very broad poorly drained plains forming the estuarine deposits which border and partially overly the Pinjarra Plain.

Soils of the Serpentine River tend to be located on the flats of the Pinjarra Plain comprising a fine textured alluvium of deep-to-deep black and grey cracking clays or olive-brown cracking clays with alkaline calcareous subsoils.

Sand plains with low dunes and intervening swamps with iron and humus podzols, peats and clays are characteristic of the Southern River system located between the Cannington and Serpentine River Systems of the study area.

The gently undulating plain of the Cannington system comprises a mix of duplex soils with loamy sand surfaces of variable thickness together with moderately deep to thin veneer topsoil over clays of the Guildford Formation. These major soils do not have a large natural drainage capacity and many swamps occur in uncleared areas

The Bassendean Dune System is generally leached grey, siliceous Pleistocene soils, moderately to well graded and cohesion less, except where it contains minor clay and is located throughout the study site, in particular toward the north of the study site and along the eastern boundary of the Harvey Estuary.. Some reworking of sands close to alluvial and estuarine deposits of the Peel Inlet and Harvey Estuary. Can be consolidated beneath a loose surface cover, which can be remobilised when dry and cleared of vegetation. These soils have low fertility and have a poor ability to hold nutrients.

The soils of Point Grey represent a low hilly landscape with shallow sands over limestone: with yellow sands on hills and brown sands on Karst depressions and on some lower slopes of the Cottesloe System. Additionally there is a small patch of Alluvial fans of medium textured deposits located to the south east of the study site as part of the Dardanup System south of Waroona townsite.

The estuarine and lagoonal deposits are highly variable and generally a poorly sorted soil, low-lying and mostly saturated located along the boundaries of the Peel-Harvey Inlet. Terraces and levees along major rivers consist of red duplex soils and red earths extending along the Murray River from Pinjarra toward the Peel Inlet as part of the Swan System.

4. LAND CAPABILITY

Land Capability of the study region has been based on Soil-Landscape Map Unit Databases (Dept of Agri. 2003) and the Guidelines for Assessing Land Qualities and Determining Land Capability in South-west Australia (Dept of Agri. 2005). The map profile and guidelines are used as the standard assessment, adopted by Agriculture WA, for interpreting land resource mapping and act as base reference for comparison and assessment of land resources across WA.

In Western Australia the capability of land is described as the ability of the land to support a type of land use without causing damage (Austin and Cocks 1978). This was further refined by Dixon in 1986 to include on-site and off-site effects.

Capability of a land is generally assessed and then classed using land use categories dry land cropping, vineyards, grazing, annual and perennial horticulture and septic tanks (for rural residential development) and some consideration of urban land capability.

Wells and King (1989) have classified land use types as very high (Class 1) to very low (Class 5) representing land capability, this mapping technique has been further refined to and is tabulated as follows:

**Table x: Land Capability Classes for Given Land Use Types
(Adapted from Wells and King, 1989)**

Capability Class		General Description
1	Very High	Very few physical limitations present and easily overcome. Risks of land degradation is negligible*
2	High	Minor Physical limitations affecting either productive land use and/or risk of degradation. Limitations overcome by careful planning.
3	Fair**	Moderate physical limitations significantly affecting productions land use and/or risk of degradation. Careful planning and conservation measures required***
4	Low	High degree of physical limitation not easily overcome by standard development techniques and/or resulting in high risk of degradation. Extensive conservation measures and careful ongoing management required
5	Very Low	Severe limitations. Use is usually prohibitive in terms of development costs or the associated risks of degradation

* Few land use developments have no negative effect on land degradation, hence capability Class 1 will not occur for most land uses employing conventional management and development strategies

* Class 3 is often the largest category of land. It is productive agricultural land, which requires improved land management to avoid slowly increasing effects of land degradation associated with conventional land management

**Table x: Grouping of Land Capability Class and Codes
(Departure of Agriculture, 2005)**

Capability Class	Decode	Code
Capability Class 1 & 2	Very high and high capability	A
Capability Class 1&2&3	High and fair capability	B
Capability Class 4&5	Low and very low capability	C

**Table x: Codes Table for Capability
(Departure of Agriculture, 2005)**

Codes for Capability	Decode
A	Most of the land has high capability
A1	>70 % of the area is Class 1 or 2
A2	50-70 % of the area is Class 1 or 2
B	Most of the land has at least fair capability
B1	>70 % of the area is Class 1,2 or 3
B2	50-70 % of the area is Class 1,2 or 3
C	Most of the land has low capability
C1	50-70 % of the area is Class 4 or 5
C2	> 70 % of the area is Class 4 or 5

Land capability has been based on soil type and landforms of the Vasse, Bassendean, Spearwood and Pinjarra systems. The following are classified as subsystems of the Pinjarra System: Serpentine River, Cannington, Southern River, Dardanup and Swan. Cottesloe is a subsystem of the Spearwood System.

Based on these systems the following land capabilities have been summarised. It must be noted that no land capabilities for urban development has been identified. Additionally, land that is classed as fair capability may be highly productive but require extra management to overcome degradation risks.

Table x: Land Systems and Land capability located within Study Area

System	General Location within Study Site	Capability					
		Annual Horticulture	Dry land Cropping	Grazing	Perennial Horticulture	Septic	Vines
Vasse	Eastern Boundary	C1-C2	C1-C2	C1-C2	B1-C2	B1-C2	B1-C2
Bassendean	North Eastern and South Eastern Boundary	B1-C2	B1-C2	B1-C2	B1-C2	A1-C2	B1-C2
Pinjarra-Swan	Murray River	A1-B2	A1-B2	A1-B2	B1-B2	B1-C2	A1-A2
Pinjarra-Cannington	Central to study area	B2-C1	B1-C1	B1	C2	B2	B2-C1
Pinjarra-Serpentine	Harvey River	C2	C2	B1	C2	C2	C2
Pinjarra-Dardanup	South of Waroona	C2	C2	B1	C2	C2	C2
Pinjarra-Serpentine and Southern River	East and adjacent to the Harvey River Drainage Line	C2	C2	B2	C2	C2	C2
Pinjarra	Adjacent and East of Bassenedan and Vasse system	C2	C2	B1	C2	C2	C2
Spearwood-Cottesloe	Pt Grey	B1-C1	B1-C1	B1	A1-C1	B1-C1	A1-C1

Throughout the study area, soils of the Vasse System have been classed as generally low to very low. However, in areas of reworked acidic siliceous Bassendean sands with iron-organic hardpan or deep grey/bleached pale brown siliceous sands, overlying soft shelly limestone the land capability for septic and vines is high to fair. These areas appear intermittently as small pockets along the boundary of the Peel-Harvey Inlet.

While there is evidence of high to fair land capability typically associated with horticulture, septic and vines (and some dryland cropping) of the Bassendean System, it is generally associated with soils that have duplex horizons of extremely low to low relief and only occur sporadically throughout the study area.

The majority of the Bassendean soils encountered within the study area are closed depressions and have poorly defined stream channels, which are poorly to very poorly drained, or have broad poorly, drained sand plains overlying clay subsoils. These soils have relatively low to fair land capabilities and are located in areas flagged as potential high density urban developed in the northern part of the study area.

The Swan is a sub-system of the Pinjarra System and soils are located predominantly along the length of the Murray River grading from flat terraces adjacent to alluvial terraces to low rises contiguous with the Pinjarra Plain. In general these soils are of high land capability that drain relatively well. As the distance from the Murray River becomes greater the capability of the soils become less, in particular septic, which may be related to the depth to clay.

Adjacent to the Swan subsystem, the soils are generally classed as part of the Cannington subsystem, of the Pinjarra System. The duplex soils tend to grade from shallow to moderately deep overlying clay as distance from the River system increases. In general the land capability of the area is high to fair grading to low.

The Serpentine is a sub-system of the Pinjarra System and soils are located predominantly along the drainage line associated with the Harvey River and its associated drainage line. The soils are generally classed as low potential for land capability, while grazing potential is classed as fair to high. The soil profile is generally associated with deep black cracking clays with alkaline subsoils.

The dune ridges of Pt Grey consist of very shallow to moderately deep siliceous sands. The land capability associated with these sands is generally high to very high for the moderately deep sands grading high to fair as the profile becomes shallower.

A relatively distinct area south of Waroona is the Dardanup subsystem. The soil profile has generally imperfect to poor drainage and consists of deep acidic earth and duplex soils with loam to clay loam surfaces. This area is classed as having low to very low capability with the exception of grazing whereby most of the land has high to fair land capability.

The soils profiles of the central part of the study area are predominantly of the Pinjarra System are having a diverse number of soil types with only a few significantly dominant. These dominant soil types and their particular land capabilities have been identified. The most significant profiles include soils located adjacent to the Harvey River drainage line, within the Serpentine River subsystem, which are generally cracking clays with low to very low capability, with some potential for grazing.

The deep alkaline duplex soils, which generally consist of pale sand to sandy loam and overlie clay, are located adjacent to the undulating plains of the Bassendean system to the east of the Peel-Harvey Catchment. These soils are moderately well drained and are characteristically

similar in land capabilities of the soil profiles of this area, low to very low land capability. Additionally, the poorly drained duplex soils surrounding Waroona are moderately susceptible to salinity

In general, it is observed that there is a significant amount of variability within the Eastern Catchment of the Peel Harvey Estuary. In almost all cases careful planning and conservation measures are required to reduce the risk of degradation of the area. It is also observed that soils overlaying the cracking clays have a high degree of limitations in relation to land capability and extensive conservation and ongoing management of these areas will be required.

5. ENGINEERING SUITABILITY

5.1 SANDS

Sands of the Bassendean Dune system are a reasonable foundation material, but its thickness, degree of consolidation, and depth to water table must be established during site investigation. It has fairly high porosity, permeability and void ratio, moderate to high natural density, and is not subject to shrinkage. Drainage disposal is only a problem when underlain with thin layers or mixed with Clays of the Guildford Formation. As a foundation beneath roads, the sand is fair to good. Where thin, the foundation characteristics are those of the underlying foundation.

5.2 GUILDFORD FORMATION

A wide variety of engineering properties can be expected on material of the Guildford Formation due to the variable nature of the sediments. Guildford Formations soils tend to be reactive, shrinking in responses to drying and swell under rewetting.

The Environmental Geology Series mapping identifies possible problems for urbanisation, construction of roads and use of conventional septic tanks on Guildford Formation clays. Drainage is an issue with a high risk of flooding and requiring intervention through drainage works, raised sand pads and similar measures.

Hillman *et al.* observed that as permeability decreases with clay content, drainage disposal becomes difficult and leach drains constructed of permeable aggregate would be required. Low steep cuts are generally stable although slides may result in shallow cuts where seepage occurs. However, Water Corporation is actively requiring underground sewer systems in new subdivisions, and the conversion of old subdivision areas from septic tanks.

The Guildford Formation is generally unsuitable for disposal of roof run-off into soak wells. Roof drainage must generally be connected to the local Council drainage system. Similarly sumps are unlikely to be suitable for the disposal of road-run off in Guildford formation soils

Bitumen roads can be constructed over this formation, but minimum disturbance and side drains to control moisture content are advisable. Pavement thickness design on Guildford Formation subgrades is made more difficult by the high variability of the material and by the issue of selection of design moisture content. The presence of lenses of sand in a predominantly clay area can provide flow paths for water which may bypass subsoil drains.

Water yielding properties range from effectively impermeable in the clays to permeable conditions in sandy lenses. Dewatering of the Guildford Formation may therefore require draining a number of water yielding layers separated by impermeable layers and extending below the base of the zone to be dewatered. Trench slope stability is also at risk from uncontrolled groundwater inflow.

5.3 HOLOCENE MATERIALS

In general, suitability of these materials for specified land uses, such as foundations, road fill, base course, septic tanks and sanitary landfill are undesirable. Current processes include soil moisture changes, flooding and are most likely to be 'high risk' ASS material.

5.4 LAGOONAL AND ESTUARINE DEPOSITS

They are expected to have poor engineering qualities, and because of rapid lateral lithologic changes and will require very detailed individual site investigation.

Swamp Deposits

These deposits would form very poor foundations and cause irregular settlement. The near surface water table would adversely affect excavation, drainage and building stability.

Alluvium

These deposits would form very poor foundations and cause irregular settlement. The sediments could settle under load and the near-surface water table would adversely affect excavation, drainage and building stability.

5.5 TAMALA LIMESTONE

Tamala Limestone is located along Point Grey and is predominantly composed of a mixture of calcarenite and Limesand. The Tamala Limestone includes material ranging from soft to very hard, emphasising the need for individual site examination. Solution cavities, root casts and other zones may be filled with unconsolidated sand leading to severe settlement under load. The majority of the limestone has moderate density, moderate permeability and very low shrinkage. Compressive strength increases with drying after excavation. Steep cuts are commonly stable.

Some settlement can be expected beneath foundations. Subsurface pinnacles and thin sheets of dense hard limestone are common and would increase excavation costs. Drainage disposal characteristics are good.

5.6 ACID SULPHATE SOILS (ASS)

Acid Sulphate Soils (ASS) featured prominently in the reviewed literature and appears to be a significant environmental risk associated with possible development in the study area. Multiple ways exist to trigger ASS into acid generation. ASS is naturally occurring and benign if left saturated and undisturbed, but when exposed to air it is chemically triggered to generate large amounts of sulphuric acid. Dewatering and excavation can expose ASS to oxygen and trigger acidification. Therefore, ASS is an environmental risk either due to direct interference or upstream development activity. Once triggered, ASS can generate acid for hundreds of years causing serious environmental and social impacts. These include:

- acidification of ground and surface water rendering them unsuitable for human uses
- stripping naturally present toxic heavy metals from the soil profile and leaching them into groundwater
- killing ecosystems dependent on affected ground and surface waters, including conservation wetlands and habitat for migratory species
- erosion of sub-surface infrastructure including sewers, concrete footings and sea-walls
- above-ground structural damage to buildings due to sub-surface erosion.

ASS have been classified within the study area as predominantly high to moderate risk with some areas classified as low to no risk. These broad definitions have been defined based on

Planning Bulletin No. 64 (Western Australian Planning Commission, 2004). In addition, the assessment of ASS within the study area has been based on a desktop review of the geology, topography and relative elevation of the area.

Based on this classification system the areas classified as high risk (at depths generally less than 3 m from soil surface) are predominantly located along the boundaries of the Harvey Estuary and Peel Harvey Inlet eastern boundary and associated drainage lines including the Murray, Serpentine and Harvey Rivers and Nambellup Brook (Figure x).

Only a limited number of investigations have been conducted in this region with the most recent conducted by Golder Associates in 2004 along the proposed Peel Deviation alignment. The route of the deviation forms the eastern boundary of the current study area and identified actual and potential ASS along the northern section of the Peel Deviation alignment of the Serpentine River, Nambeelup Brook and Murray River. Of the 138 sites investigated, 15 exceeded the action criteria for ASS. From the results Golder suggested the ASS material was predominantly localised along watercourses and wetlands.

The high-risk areas are predominantly associated with deposits of the Holocene Era and include swamp deposits (peats and clay), lagoonal and estuarine deposits (clay, silt and marl with shell beds), alluvium material (clay, sand and loams) and reworked Bassendean Sands (associated with older stream channels). In particular, along the Harvey Estuary and Peel Inlet boundaries which are associated with river floodplains, estuarine saline flats and beach ridges subject to inundation. The thickness of these deposits may be three to five metres for swamp and lagoonal deposits, and 10 to 15 metres for estuarine, alluvium deposits and reworked Bassendean Sands.

In addition to the above profiles, Golder suggested that the apparently poor acid buffering or neutralizing capacity of surrounding soils was a contributing factor to the level of risk associated with ASS along the Peel Deviation alignment.

The Golder Associates study recommended that further field investigations should be conducted during the construction of the Peel Deviation, especially (but not exclusively) ahead of construction in areas identified as potential ASS sites. The recommendation applied to any area along the alignment where soils will be disturbed at depths greater than one metre.

Additional ASS hotspots have been identified at the mouth of the Serpentine and Murray Rivers and associated floodplain, extending along the eastern most boundary of the Peel Inlet near Yunderup (North and South), Furnissdale, Coodanup, Barragup and Greenfields. It should be noted that these areas have been zoned for further high-density urban development and green belt rural living.

DoE has recognised that insufficient management of ASS along these areas was implemented during the planning stage as there was little understanding of ASS at the time. Such mismanagement is evident through South Yunderup, for example, where there is evidence of infrastructure damage to houses and stormwater drains, acidic runoff into waterways, stormwater drains and high levels of mobilised metals such as aluminium, iron and arsenic leaching into the groundwater and the eastern catchment of the Peel Inlet is present.

Additionally, the desktop review of the study area identified floodways and associated flood fringes along the mouths of the Murray and Serpentine Rivers, crossing through Yunderup (north and south) and along the length of the rivers towards Pinjarra and north along the borders of Furnissdale and Barragup. These areas should also be classified as high risk for ASS material.

Other high-risk areas include swamp deposits, possibly up to five metres thick, at Lake Mealup, Big Lake, and Nine Mile Lake and the Nerimba Nature Reserve and Harvey Estuary Nature Reserve and along the Harvey Delta. Additionally, there are a number of small swampy deposits located intermittently surrounding these lake systems and to the southeast of Nambellup Brook.

The rest of the study area is classified as moderate to low risk of shallow ASS (at depths generally greater than 3 m) except for an area of Tamala Limestone, which is classified as having low or no risk of shallow ASS at depths generally greater than 3 m. This area is located between the Peel Inlet and Harvey Estuary from Pt Grey to Robert Bay on the Northern Point to Mealup Pt along the Southern Boundary.

The areas considered as moderate risk are predominantly associated with materials of the Pinjarra Plain, which comprises a mix of duplex soils with loamy sand surfaces of variable thickness together with moderately deep to thin veneer topsoil over clays of the Guildford Formation. These major soils do not have a large natural drainage capacity and many swamps occur in uncleared areas with profile thickness up to 20 to 30 m.

While such classifications have been developed, it is advised that any works that are intrusive and extend below the water table should be classified as high risk regardless of the above risk classification.

Acid Sulphate Soils (ASS) have been classified within the study area as predominantly high to moderate risk with some areas classified as low to no risk. These broad definitions have been defined based on Planning Bulletin No.64 (Western Australian Planning Commission, 2004). In addition, the assessment of ASS within the study area has been based on a desktop review of the geology, topography and relative elevation of the area.

Based on this classification system the areas classified as high risk (at depths generally less than 3 m from soil surface) are predominantly located along the boundaries of the Harvey Estuary and Peel Harvey Inlet eastern boundary and associated drainage lines including the Murray, Serpentine and Harvey Rivers and Nambellup Brook (Figure x).

These high-risk areas are predominantly associated with deposits of the Holocene Era and include swamp deposits (peats and clay), lagoonal and estuarine deposits (clay, silt and marl with shell beds), alluvium material (clay, sand and loams) and reworked Bassendean Sands (associated with older stream channels). In particular, along the Harvey Estuary and Peel Inlet boundaries which are associated with river floodplains, estuarine saline flats and beach ridges subject to inundation. The thickness of these deposits may be 3 to 5 m for swamp and lagoonal deposits, and 10-15 m for estuarine, alluvium deposits and reworked Bassendean Sands.

Additionally, floodway and associated flood fringes have been identified along the mouths of the Murray and Serpentine Rivers, which cross through Yunderup (north and south) and along the length of the rivers towards Pinjarra and north along the borders of Furnissdale and Barragup and should also be classified as high risk for ASS material. The flood survey was limited in its extent and did not consider the eastern boundary of the Peel Inlet and the Harvey Estuary.

ASS hotspots have been identified at the mouth of the Serpentine and Murray Rivers and associated floodplain, extending along the eastern most boundary of the Peel Inlet near Yunderup (North and South), Furnissdale, Coodanup, Barragup and Greenfields. Department

of Environment have recognised that insufficient management of ASS along these areas was implemented during the planning stage, due to lack of knowledge of ASS at the time, and is evident through South Yunderup for example where evidence of infrastructure damage to houses and stormwater drains, acidic runoff into waterways, stormwater drains and high levels of mobilised metals such as aluminium, iron and arsenic leaching into the groundwater and the Peel Inlet is present.

Other high-risk areas include swamp deposits, possibly up to five metres thick, at Lake Mealup, Big Lake, and Nine Mile Lake and the Nerimba Nature Reserve and Harvey Estuary Nature Reserve and along the Harvey Delta. Additionally, there are a number of small swampy deposits located intermittently surrounding these lake systems and to the southeast of Nambellup Brook.

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The areas considered as moderate risk are predominantly associated with materials of the Pinjarra Plain, which comprises a mix of duplex soils with loamy sand surfaces of variable thickness together with moderately deep to thin veneer topsoil over clays of the Guildford Formation. These major soils do not have a large natural drainage capacity and many swamps occur in uncleared areas. The profile thickness may be up to 20 to 30 metres.

While such classifications have been developed, it is advised that any works that are intrusive and extend below the water table should be classified as high risk regardless of the above risk classification.

5.7 CONTAMINATION

Limited information is currently available with respect to land contamination. The Department of Environment currently holds files in relation to acid sulphate soil investigations in the Yunderup area, and a former pesticide formulation facility in Pinjarra is also listed. *[A request under Freedom of Information was unsuccessful as we were advised the current data base requires specific location and lot numbers to be cited for searches, i.e. regional searches are not possible at this stage]*

6. SOCIAL ANALYSIS

6.1 EXISTING LAND USE

6.1.1 Mining

The Peel region continues to be an important mineral producing area. The main minerals are bauxite and mineral sands and limited gold production. While no mining tenements are within the study area there is potential for growth as significant titanium deposits are located to the north of Amarillo and south of Coolup. Future excavations should be sited remote from population centres and highways.

6.1.2 Agriculture

The bulk of the agricultural economy is derived from keeping livestock and is based primarily around dairy and beef cattle. Peel Sustain (2002) predict that while over 94 per cent of present farmers have been farming for over 10 years, there are few young farmers and as a result many farmers are now concerned about succession planning. Additionally, as urban sprawl expands, the fringe activities are changing with a trend to subdivide large properties

However there is the potential for other industries to develop in these areas such as wine, vegetables, wool, pigs, eggs, flowers, grains, and poultry, which are also produced successfully in considerable quantities in the Jarrahdale-Serpentine region.

It is worthy to note the implications of agriculture to the Peel-Harvey Catchment prior to management of the Catchment. The flat coastal plain was originally a series of winter swamps with only the Murray having a well-defined course. As it was cleared for agriculture, drains were dug to flow into the estuary and other rivers were connected to the estuary. Much of the soil east of the estuary was poor leaching sands, and it was phosphorus deficient so artificial fertilisers were heavily used. Clearing deep-rooted hinterland vegetation has caused increasing salinity. Heavy winter rains have washed increasing sediment loads into the estuary. Added to this are an increasing population and the establishment of intensive animal industries.

Peel Sustain (2002) is integrating strategies, in conjunction with the Peel-Harvey Catchment Council, Land Conservation District Committees (LCDC) and other local groups to focus on actively attracting investors and new agri-based enterprises within the region as well as working with and educating existing landholders.

6.1.3 Timber Production

Based on figures supplied by Peel Sustain (2002) Timber production from plantations and State forests was valued at \$11.0 million during 2002-03 for Western Australia. Production in the region accounted for 17.4 per cent of the State's total mass of hardwood. Timber production within the study area is limited to the southern corner near Myalup. However, soil profiles conducive to Pine and Tasmanian Blue Gum plantations are significant within the rural regions indicating a potential area of growth.

6.2 CURRENT ZONINGS

Figure X was developed as part of the Inner Peel Region (1997) Final Structure Plan and outlines the current zonings and the current land use patterns for the area. Town planning schemes for the study area were identified, but not referred to in the analysis as the data replicated the Final Structure Plan, but in a detail which was not required.

The water body of the Peel Inlet and Harvey Estuary is used extensively for public recreation, especially fishing. The Yalgorup lakes (Lake Mealup and Lake Mclarty), located within the Yalgorup-Peel National Park, are used only for passive recreation associated with their natural values.

The current dominant land use is rural, principally for cattle farming, within the central and western part of the study area. This provides for the sustainable use of land for agriculture and provides the potential for a distinctive rural landscape setting for carefully planned rural living developments. The rural land to the north of Paterson Road has groundwater protection strategies implemented.

The eastern boundary of the Peel Inlet is currently zoned nature conservation, recreation, urban (residential-greenbelt rural living), and high human population (mainly at north- north-east sides of estuary).

The majority of high-density urban development is located along the buffer zone of the Serpentine and Murray River, nearby existing facilities and within the Pinjarra townsite. Potential development (urban and peri-urban) would essentially extend from these regions along the river systems adding significant pressure to environmentally sensitive areas.

Current and future industrial land has been isolated to the north-east side of the estuary along Lakes Road in the Murray Shire, the extent of which borders Amarillo to the north of the study area. Future developments propose Amarillo a 'new city' of major commercial and high urban density concentration. There are allocated areas for drainage and water catchment throughout Amarillo and the proposed Industrial sites to the south.

Mining tenements are regionally situated outside the study area to the east however, there is potential for Titanium deposits likely to be found to the south of Coolup,

A buffer of native vegetation (above high water mark) a few 100 to 1000 m wide occurs in the far south-east, parts of the north-east and patchily elsewhere. Adjoined to this buffer is an area allocated regional open space, which, under the scheme, is reserved for public purposes and is predominantly located in environmentally sensitive areas. There are a number of greenbelt rural living areas within these allocations.

Ramsar listed and CALM protected wetlands are addressed in Section XX, however it is note worthy that they commonly coincide with zones allocated as regional open space. Further, access to the eastern boundary of the Peel Inlet, via the Pinjarra bypass, may increase recreational pressure on environmentally sensitive areas surrounding the Peel Inlet and Harvey Estuary.

Throughout the study area there is one significant state forest located in the southern tip of the study area surrounding Myalup. Some marshes and fringing scrub/forest in the south and north-east are in the relatively small Nature Reserves 2990, 23756, 24739, 2738, 2707, 2436 and 4990 and Yunderup National Park; Nature Reserve 28087 covers the far south-east waters of Peel Inlet.

The section of Point Grey bordering the Harvey Estuary is regional open space, however the Environmental Protection Authority (EPA) has deferred assessment of potential, existing and future tourist allocations and will require resolution of any environmental and planning requirements prior to further zoning allocations by the Western Australian Planning Commission (WAPC).

Additionally, the EPA (2000) deferred assessment of vegetation and wetlands of areas zoned rural and assessment of site contamination of all land within the Peel Region Scheme. Future developments within these zones will be reassessed to ensure future local government scheme amendments; subdivisions or development proposals provide sufficient information for assessment. Additional deferred areas are the vegetation and noise assessment of the Pinjarra Bypass and vegetation wetlands noise and vibration assessment for the rapid transit corridor.

6.3 EXISTING INFRASTRUCTURE

6.3.1 Access

The Peel region has good road access with three major highways crossing its boundaries. The Kwinana Freeway from Perth currently extends as far as Baldivis. Planning is continuing for the extension of the Kwinana Freeway south, towards Mandurah.

The Peel Development Commission is currently working in conjunction with the South West Development Commission, Main Roads WA and other stakeholders for the construction of the Perth-Bunbury Highway. This route would extend from the southern end of the Kwinana Freeway to take traffic south of Mandurah, via the eastern edge of the Peel-Harvey Estuary, to link with the Old Coast Road, on to Bunbury in the South West Region.

The South West Highway is also being upgraded and a series of major road works will be undertaken over the next few years. On the eastern boundary of the Peel region, the Albany Highway provides an alternative access to the region via Boddington. Most minor roads in the region used by tourists are sealed.

Further Fishermans Road, Greenlands Road and Patterson Road are proposed major upgrades, which will allow more access routes to Pinjarra from the proposed Perth-Bunbury Highway and to the South Western Highway. Gordon Road will also be upgraded as the main arterial from Mandurah to the proposed Perth-Bunbury Highway. Access will further improve with the development of the Perth to Mandurah urban rail network, scheduled to be completed in 2007.

These major projects will promote increased transient and permanent access to the Peel Region and are expected to facilitate significant economic benefits. There is a clear need to manage pressures on the environment due to increased development to ensure the valuable environmental assets of the region that make development highly marketable are protected for the economic and lifestyle benefit of future generations, and for the intrinsic value of the environment itself.

In July 2005, the Federal Minister for Environment and Heritage deemed Perth to Bunbury Highway a controlled action under the Commonwealth *Environmental Protection and Biodiversity Conservation Act 1999* (EPBC Act). This meant a full formal environmental impact assessment process would be required before construction of the highway could begin.

However, under a bilateral agreement under Section 45 of the EPBC Act allows for accreditation of certain State environmental assessment processes.

Background information on the referral of the highway proposal to the Minister for Environment and Heritage was provided to the Minister for the Environment, and the following commentary is extracted from this advice.

Public submissions stated that the proposal should be a controlled action because of potential significant impacts on listed threatened and migratory species and Ramsar wetlands. Also, adverse impacts on the hydrological regime of the Peel-Yalgorup System wetland were cited.

The submissions asserted that the southern portion of the route would cross the Harvey River and require excavation of an area between 100 metres and 200 metres wide and to a depth of 10 metres to provide a proportion of the 500,000 cubic metres of limestone and the 1,000,000 cubic metres of sand needed for the construction of the freeway.

A further submission raised concerns that a remnant vegetation patch near the southern extremity of the mapped road transect was potential habitat for the Western Ringtail Possum. The submission was concerned about the degradation and loss of habitat for this species in the face of further development.

Key issues influencing the Minister's decision to deem the highway proposal a controlled action related to potential impacts on significant wetlands and listed or threatened migratory bird species. Specifically, background information to the decision noted that the project area, at its closest point, passes one kilometre east of the Peel-Yalgorup System Ramsar site. The Peel-Yalgorup System comprised the most important area for waterbirds in south-western Australia.

It identified that the proposed highway could impact on the ecological character of the wetland in a number of ways unless adequate mitigation measures were in place. These were:

- During construction
 - increased volumes of run off containing higher contaminant and sediment loads,
 - diversion of water flows,
 - disturbance of potential acid sulphate soils, and
 - disturbance of soil profiles including importing/exporting of fill and therefore risks of spread of invasive species.
- During operation
 - increased volumes of run off containing higher contaminant loads,
 - noise and airborne contaminants, and
 - increased visitation to Ramsar wetlands and adjacent areas.

Another potential consequence of the highway during construction was thought to be higher levels of contaminants entering wetlands due to large areas of exposed earthworks, and during operation due to vehicle by-products. This was particularly the case where the road crosses the Serpentine, Murray and Harvey River drainage systems. Potential acid sulphate soils were considered a risk for long term impacts such as altering pH conditions and releasing contaminants from soil to groundwater systems if exposed.

The advice noted that Main Roads has prepared a Wetland Compensation package to off-set the road's impact on wetlands. The package was being negotiated with CALM and, if

approved, would result in the addition of 77 hectares of native vegetation and wetland to the eastern side of the Kooljerrenup Nature Reserve, which abuts the Peel Harvey estuary. However, it concluded that significant impacts to Ramsar sites within the scope of the proposed action could not be discounted.

The potential for indirect/facilitated impacts was considered to be high, particularly along the currently undeveloped eastern shoreline of the Peel-Harvey System.

Construction of the highway was considered to pose potential for impacts on several listed threatened species, particularly the endangered Carnaby's Black-Cockatoo, the vulnerable Baudin's Black-Cockatoo, Western Quoll and Western Ringtail Possum. Three listed endangered ecological communities also were acknowledged within the vicinity of the proposed highway - the *Xanthorrhoea preissii* woodlands and shrublands of the Swan Coastal Plain, Sedgeland in Holocene dune swales of the southern Swan Coastal Plain and the *Kingia Australia* woodlands on heavy soils of the Swan Coastal Plain.

Further consideration was given to consequential pressures likely to be associated with increased traffic and access through the Peel region. The highway was viewed as conducive to accelerated and heterogeneous development and increased human interaction with the landscape.

Specifically, increased urban development facilitated by the highway and improved southern access to Rockingham and Perth was considered a risk factor for increased clearing of habitat for listed species particularly within the catchment of the nearby Peel-Yalgorup System Ramsar system.

Potentially greater disturbance to waterbirds and damage to habitat due to increased recreational use of the Peel-Harvey estuary, causally associated with increased access resulting from development of the highway, was considered. The highway was considered likely to accelerate development of the eastern hinterland for both urban and peri-urban (hobby farms, horticulture) uses.

Other issues were potentially significant impacts on downstream wetlands due in particular to groundwater usage, changes to infiltration patterns and runoff events, and consequent impact on water temperature and salinity fluctuations. The project was considered likely to facilitate further coastal development, resulting in further loss of surrounding habitat and encroachment on sensitive areas of the wetland, the introduction of feral and domestic pet species, the spread of garden pest species and higher nutrient levels in runoff due to fertilizers.

6.3.2 Air

Murray field Airpark, on Lakes Road in the Shire of Murray, has a 1,300 metre sealed airstrip. It services the Mandurah-Pinjarra communities and is used as a pilot training facility. Plans exist for the construction of a hotel and a golf course. Murray field Airpark is being considered as the alternative airport to Jandakot (Perth) for light aircraft movements.

6.3.3 Industrial Land

Industrial Land There is light industrial area in Pinjarra and North Mandurah. The sites in Pinjarra are being reviewed for further expansion. A large general commercial site is being

investigated in the Nambelup area in the Shire of Murray while another is being assessed in the Shire of Waroona.

6.3.4 Water Supply

Most residents within Peel are supplied from the Integrated Water Supply Scheme. Within the study area this scheme supplies Waroona, Mandurah, Park Ridge, Ravenswood, Pinjarra, and North Dandalup. The water is sourced from major dams in the Darling Range. Water sourced is supplemented by the Ravenswood Water Treatment Plant, Paganoni Water Reservoir, Meadow Springs Reservoir and Karnup Reservoir and Water Treatment Plant.

6.3.5 Wastewater

Within the study area wastewater services are provided at Ravenswood and Pinjarra. It is proposed that the Yunderup wastewater treatment plant will be closed and an additional waste water treatment plant will be opened between Patterson Road and the Perth to Bunbury Highway (West Murray Regional).

All plants treat wastewater to secondary or tertiary levels. The Pinjarra WWTP includes a 100 per cent re-use scheme in association with the ALCOA Pinjarra Refinery. While some of the soils in the Region are suitable for septic effluent disposal in smaller estates, all major residential developments require sewerage. The level of sewerage infrastructure available will impact on urban density development.

Concern has been raised by key stakeholders in the Study about the appropriateness of deep sewerage in areas affected by acid sulphate soils. Analysis of available maps and previous studies concerning ASS concurs with the principle concern that excavation in areas affected by ASS for the purpose of constructing sewerage and other infrastructure is unwise due to the high risk of long term ecological impacts, and the future high cost of repairing damaged infrastructure. The alternative method of "vacuum sewerage" was believed by some stakeholders to be a better option for sensitive areas, and appears consistent with the broader finding of this study that avoiding further disturbance of ASS is essential.

6.3.6 Energy

Western Power is currently upgrading power facilities in the Peel Region. In 1997/98, Western Power undertook a \$4.6 million network reinforcement, which included the construction of 26 kilometres of underground cable from the Mandurah Substation to developments around the Dawesville Cut (west coast).

A 22 kV feeder from the Mandurah substation has improved the quality of power to the area north east of Mandurah through to Pinjarra. Western Power is also working on (improving the capacity) of a 22kV feeder from the Mandurah substation, at a cost of \$550,000, to the Halls Head area. Planning is in progress to provide additional capacity to the area north of Mandurah and to the Mandurah Ocean Marina area in preparation for future development. Natural gas is supplied to the Region via the Dampier to Bunbury Natural Gas Pipeline (DBNGP), which is owned and operated by Epic Energy.

Alinta Gas provides distributed natural gas services to the town of Pinjarra and the Mandurah coastal area. The gas pipeline network extends northward past Madora and in 2002 crossed

the Dawesville Channel to the south. Alinta Gas continually monitors demand for natural gas and it is anticipated the gas network expansion will continue to follow the land development front to the south.

In 2002, Alinta Gas entered into a Memorandum of Understanding with Alcoa World Alumina Australia to build up to 10 co-generation power units at each of Alcoa's three refinery sites. The first unit will be built at the Pinjarra refinery. Alcoa will use all of the steam output from the co-generation units in its refinery processes and Alinta Gas will sell cheaper electricity into the retail market to consumers on the South West Interconnected System (SWIS).

6.4 KNOWN DEVELOPMENT PROPOSALS

The Peel Regional Scheme provides the statutory basis for implementing the Inner Peel Region Structure Plan (WAPC,1997) to ensure that regional facilities such as regional open space and regional roads are provided. It includes regional reservations and broad land use zones. It identifies sufficient future urban land for the next 25 to 30 years and about 15 years supply of industrial land, as well as the region's future transport network and regional open space system. The PRS will enable land reserved for purposes such as Regional Open Space (ROS) to be purchased, which will include land for conservation purposes. Current Infrastructure projects such as the Kwinana Freeway Extension and the Perth to Mandurah Railway are both funded by the State Government

The Shire of Murray Town Planning Scheme No.5 Draft Local Planning Strategy foreshadows considerable expansion of existing urban and rural residential areas, with the specific objective to maximise opportunity for growth. This appears to be both in response to demand reflected in the popular subscription of new land development releases in the coastal areas of the Peel region, and as a strategy to glean economic and social benefits from accommodating a bigger population.

The Pinjarra town site itself is the subject of an urban expansion strategy with consideration to four distinct areas adjacent to and within the town centre. Murray River Country Estate to the north west of the town site has been created with a potential site area of 211 hectares and a potential population of about 6,000 people. A large portion of the estate is affected by the Murray River floodway and is proposed to be used for a golf course and drainage compensating basins.

The Draft LPS identifies an area immediately to the north of the town site for potential special residential development bordering the Murray River and Patterson Road to the east. An area further north again is earmarked for rural residential development between the river, Patterson Road and the railway line. An area to the north east of Pinjarra town site land between the railway line and South Western Highway has potential for urbanisation to link up with North Pinjarra. An additional 180 hectares is identified for potential urban expansion subject to the application of water sensitive design principals and a range of lots sizes. West of the existing town centre integration of service infrastructure and the need to address the low lying nature of the land, including water sensitive drainage design principals, results in this area being deemed a longer term proposition for urban development.

Opportunities for growth south of town were considered limited due to flood plain constraints and the proximity of the western and eastern bypass routes. In terms of providing a more vibrant town centre, the urban expansion strategy report recommended expansion of the Town

Centre zoning so as to increase flexibility in mixed land uses and avoid ribbon commercial development along the Pinjarra Road and South West Highway frontages.

A major regional recreation facility site was identified in the Inner Peel Region Structure Plan to the east of Fiegerts Road and adjoining the proposed Peel Highway deviation. Potential exists for an increased urban area to border this regional recreation facility and provide an increased urban catchment to cater for regional sporting and recreation needs. Further structure planning will be necessary over this area to demonstrate how the land can be integrated into the predominately rural environment.

The Furnissdale Structure Plan included limited expansion of the Furnissdale townsite with an R15 residential code density and retention of the balance of the area for Rural Residential purposes (Refer to Plan 8).

The Strategy Plan for South Yunderup/Murray Lakes identified 358 hectares of existing and future urban land in South Yunderup with a population potential of about 10,000. The concept plan for the Murray Lakes Golf Course Estate identifies a golf course within the floodway, a local neighbourhood centre and approximately 1500 dwelling units.

The Structure Plan for the North Dandalup Townsite noted an area on the eastern fringe of town within 800m radius of the railway line proposed for rural residential purposes.

The Shire of Murray's Local Rural Strategy of July 1994 detailed several changes to zoning categories within Town Planning Scheme No 4. A more recent review took into account major road infrastructure proposals reflected in the Peel Region Scheme, but Council's broader planning policy remained largely unchanged.

Key features relevant to this Study are zoning changes that allow for smaller lot sizes within the catchment, specifically:

- Farmlet Zone – generally lot sizes in the 10 to 40 hectare range to satisfy demand primarily for hobby farming and equestrian uses.
- Special Rural Zone – (nominally located within 3 km of existing townsite areas) generally two to four hectare sized lots to satisfy demand for lifestyle rural-residential lots with land use and management restrictions due to potential impacts on the Peel-Harvey Estuary system and
- other waterways.
- Special Residential Zone – lot sizes in the range of 2000 metres square to one hectare to satisfy
- demand for larger residential lots with limited livestock potential and strict land use controls.

An area either side of the Perth to Bunbury Highway was earmarked as having potential for diversified agricultural pursuits such as hydroponics, organic farming or aquaculture type uses.

Smaller lot subdivisions in the five to 10 hectare lot size category were envisaged in this area as

variations to the 40ha minimum lot size, provided certain environmental conditions including water availability and nutrient management were addressed by proponents.

Rural Smallholdings development to cater for larger lot sizes in the 10 to 20 hectare category were identified in the North Dandalup locality and Ravenswood precinct to the east of the proposed Peel Highway Deviation. The Pinjarra plain southern precinct situated to the east of the Peel Highway Deviation is intended to remain primarily rural zoned with

potential for some smaller lot subdivision down to 20 hectares subject to water availability and land capability analysis.

A new 'Agricultural Diversification' area has been identified in the south western portion of the Shire either side of the Peel Highway Deviation. Council is keen to see this area promoted and developed for hydroponic and other associated value added agricultural pursuits, not only to add to the economic base but also to protect rural properties from being developed for residential and semi-rural purposes adjacent to the future highway alignment.

The Shire of Murray LPS flags that the Point Grey/Birchmont area is likely to face pressures for further rural residential development between the Perth to Bunbury Highway and the Harvey Estuary and earmarks areas for this purpose. It notes Council support for urban development in addition to tourist and rural residential land uses on Point Grey – a departure from the Inner Peel Regions Structure Plan intent for light tourist activity only. However, it is also acknowledged that this area needs special attention as acknowledged in the Peel Waterways Recreation Management and Economic Development Plan which recommends specific policy guidelines be prepared to deal with development pressures and environmental management measures.

The predominantly canal developments of North and South Yunderup are flagged for further urban development. Among principal objectives for these areas, the LPS identifies:

- provision for alternative residential lifestyles and tourism facilities based on the canal development theme, without detriment to the precinct's natural environment; and
- provision for expansion of North Yunderup urban area and consolidate South Yunderup urban growth potential whilst recognising conservation value of adjoining reserves.

On face value this appears problematic given issues already noted in this Study with respect to acidification of soils and waters associated with the existing canals developments. The LPS itself acknowledges that acid sulphate soils in South Yunderup Spoil Disposal area must be appropriately managed and rehabilitated, but does not identify the issue as a constraint. Rehabilitation of acid sulphate soils is acknowledged as the high risk, high cost alternative to disturbance avoidance as the front line mitigation strategy. The LPS also allows for the consideration of a Marina Development adjacent to Serpentine River, but with deference to stringent environmental assessment and feasibility studies.

6.5 ABORIGINAL HERITAGE

[section coming]

6.6 EUROPEAN HERITAGE

The Pinjarra Heritage Precinct Planning Study prepared in 1996 provides a number of key recommendations that focuses on enhancing the attributes of Pinjarra as an attractive alternative to metropolitan and coastal locations for lifestyle, cultural, economic reasons. A review of heritage places is presently being conducted by a working group and heritage and

design guidelines are to be prepared so as to assist landowners and developers for sites within the Pinjarra Heritage Precinct planning study area.

[more coming]

6.7 RECREATION

[section coming]

7. CONSTRAINTS MAPPING

7.1 ENVIRONMENTAL CONSTRAINTS

[figures coming aligned with section 8]

7.2 SOCIAL CONSTRAINTS

[figures coming aligned with section 8]

8. FUTURE MANAGEMENT

8.1 PROTECTION PRIORITIES AND OPPORTUNITIES

[To be completed when missing sections inserted]

8.1.1 Environmental

The Economic Development and Recreation Management Plan for the Peel Waterways (2002) found conservation of bush land, wetlands, foreshores, fringing vegetation, lakes and marshes was a priority for land use policy. It also found rehabilitation and the establishment of ecological buffers was required, and these are addressed in sections 6.2 and 6.3. Consistent with EPA reports and recommendations, the current Study also found conservation of intact environmental values was a priority due to extensive clearing and other causes of degradation to date meaning the local ecology and any potential recreational and tourist-oriented development was already threatened.

8.1.2 Social

8.2 ENHANCEMENT PRIORITIES AND OPPORTUNITIES

8.2.1 Environmental

8.2.1.1 Conservation

The Economic Development and Recreation Management Plan for the Peel Waterways (2002) identified enhancement of the environment east of the estuary as a strategic priority to complement protection of intact environmental values. Specifically, it cited the need to encourage large scale reforestation and revegetation on public and private lands, along the rivers and as buffers around remnant vegetation areas.

8.3 SOCIAL

Riparian zones are heavily degraded either as a consequence of clearing and incompatible adjacent land use, or of residential development on land marketed at a premium due to access to the water body. Any serious measures to protect and enhance surface water quality must involve conservation of riparian vegetation, and rehabilitation wherever possible. This implies a departure from a key selling point for residential developments within the study area, and the Peel region generally, where water frontage is prized. The environment shows signs that the current direction in land use and development will compromise the health and quality of the environment to a point that defeats its own purpose – to build lifestyles around enjoyment of a wonderful environment.

8.4 AMELIORATION PRIORITIES AND OPPORTUNITIES

8.4.1 Environmental

8.4.1.1 Surface and groundwater quality

The *Economic Development and Recreation Management Plan for the Peel Waterways* (2002) identified net reduction of nutrients in surface and ground waters entering the estuary as a “main thrust” for strategic direction. The current Study also found amelioration of nutrient input would be necessary to address established ecological problems, and more so to accommodate projected regional population growth particularly in the Study area. An opportunity exists to address a long-standing issue with nutrient input to the estuary from groundwater sources, which has been strongly associated with diminished ecological and amenity values in the Study area.

Discharge of nutrients to the Peel-Harvey Estuary has been linked to nutrient-laden shallow groundwater flow following recharge events, and contributing land uses. Interventionist management options such as dewatering to inhibit the discharge of groundwater to the estuary would interfere with natural hydrogeological attributes, and potentially expose sub-strata of ASS to oxygen thereby causing acidification of groundwater.

Therefore, point source strategies and guidance dealing with human activities linked to nutrient export are strongly indicated. However, this should be viewed as a step towards long-term ecological sustainability, given the expected conveyance period for groundwater recharge to the estuary of at least 100 years. Successful amelioration of groundwater quality and consequential conditions in the estuary would enable further beneficial uses of the groundwater resources and social values of the estuary for future generations. Improvements in water quality within a shorter period of time through vegetation and engineering interventions also could be explored.

The *Economic Development and Recreation Management Plan for the Peel Waterways* (2002) identified the establishment of substantial nutrient detention basins of wetlands within the Study area as an important strategy for ameliorating excessive nutrients in ground and surface waters for ecological reasons as well as for sustainable and safe social/recreational uses of the waterways.

8.4.2 Social

Amelioration of the waterways is a priority also in terms of beneficial and recreational human interactions with the environment. The Peel Inlet and Harvey Estuary continue to experience periods where intervention is required to maintain water quality within safe limits for human exposure. Toxic algal blooms occur on a regular basis and poor catchment management in the face of increasing development pressures risks ruining the very asset that continues to attract market interest.

9. REFERENCES

[references to be added]

Ramsar website

DEH website - Australian Wetlands Database

DEH The action Plan for Australian Birds 2000.

<http://www.deh.gov.au/biodiversity/threatened/action/birds2000/cont.html>

DEH - <http://www.deh.gov.au/biodiversity/threatened/communities/>

DEH website – EPBC Act Search

AHPI – Australian heritage Places Inventory search results

AHD – Australian Heritage Database search results (The database includes places in the World Heritage List, the National Heritage List, the Commonwealth Heritage list and the Register of the National Estate.)

Yalgorup national park management plan

LMPS Lake Mealup Preservation Society <http://www.green.net.au/ppg/lakemealup.html>

ERM Environmental Resources Management Australia Pty Ltd. Peel Regional Park Plan Working Paper Final Report for the Western Australian Planning Commission March 2005

ECB Everall Consulting Biologist Economic Development and Recreation Management plan prepared for the Water and Rivers Commission

PDC Peel Development Commission Peel Geographic Perspective Oct 2003

Beard J S 1979 Vegetation Survey of Western Australia The Vegetation of the Pinjarra Area of Western Australia

Geological Survey of Western Australia, 1980. Australia 1:250,000 Geological Series. Pinjarra. Sheet SI 50-2 and part of Sheet SI 50-1.

Commonwealth of Australia, 1979. National Topographic Map Series 1:100,000. Pinjarra Sheet 2032.

McArthur, W.M. & Bettenay, E., 1960. The development and Distribution of the Soils of the Swan Coastal Plain, W.A. CSIRO Soil Publication No. 16.

Commander, D.P., 1975. Hydrogeology of the Mandurah - Pinjarra area, Perth Basin, Western Australia: Western Australia Geological Survey, Record 1975/3.

Commander, D.P., 1982. An outline of the groundwater resources of the Mandurah-Bunbury Region: Western Australia Geological Survey, Hydrogeology Report 2412.

Deeney, A. C., 1989. Geology and groundwater resources of the superficial formations between Pinjarra and Bunbury, Perth Basin: Western Australia Geological Survey, Professional Papers, Report 26, p. 31 - 57.

Walton, 1962, W.C. Selected analytical methods for well and aquifer evaluation: Illinois State Water Survey, Bulletin 49.

Peel Development Commission (2003) Peel Geographic Perspective, Government of Western Australia, October 2003

Western Australian Planning Commission (WAPC) (2003) Planning Bulletin No 64 Acid Suphate Soils,

McAurther. W.M. (1991) Reference soils of South-Western Australia, D.A.W. Johnston and L.J.Snell, Information Branch, Department of Agriculture

McAurther. W.M. & Bettenay. E. (1974) The Development and Distribution of the Soils of the Swan Coastal Plain, Western Australia, Soil Publication No.16, Commonwealth Scientific and Industrial Research Organisation, Melbourne

Peel Sustain (2002) Strategic Plan for the Future of Agriculture in the Peel Region in Western Australia, April 2002 Draft

Western Australian Tourism Commission (2003) Peel Region: Tourism Product and Infrastructure Development Plan 2004-2013, Government of Western Australia.

Northcote. K.H., Bettenay.E, and Churchward. H.M. (1967) Atlas of Australian Soils, Explanatory data for Sheet 5. Perth-Albany-Esperance Area. Commonwealth Scientific and Industrial Research Organization, Australia, Melbourne University Press.

10. LIMITATIONS OF REPORT

URS Australia Pty Ltd (URS) has prepared this report in accordance with the usual care and thoroughness of the consulting profession for the use of Department of Environment and only those third parties who have been authorised in writing by URS to rely on the report. It is based on generally accepted practices and standards at the time it was prepared. No other warranty, expressed or implied, is made as to the professional advice included in this report. It is prepared in accordance with the scope of work and for the purpose outlined in URS Proposal No. 3021241.

The methodology adopted and sources of information used by URS are outlined in this report. URS has made no independent verification of this information beyond the agreed scope of works, and URS assumes no responsibility for any inaccuracies or omissions. No indications were found during our investigations that information contained in this report as provided to URS was false.

This report was prepared between [*Insert Dates*] and is based on the conditions encountered and information reviewed at the time of preparation. URS disclaims responsibility for any changes that may have occurred after this time.

This report should be read in full. No responsibility is accepted for use of any part of this report in any other context or for any other purpose or by third parties. This report does not purport to give legal advice. Legal advice can only be given by qualified legal practitioners.

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DRAFT

1.1 Existing Surface Water GIS

The source of the GIS data reviewed for this study is the WA Department of Environment and included surface water catchment data, stream flow data and water quality data.

Catchment Data

The GIS catchment data available included polygons for:

- Hydrographic division with the project area located in the south west division. (*hydrographic_divisions.dbf*);
- Hydrographic basins, includes the two basins that form part of the south west division and include the Harvey River and the Murray River (*hydrographic_basins*);
- Hydrographic catchments that include the Harvey River basin with the exception of a southern portion and the Murray River basin with the exception of a northern portion (*hydrographic_catchments*); and
- Hydrographic sub-catchments that include all of the Harvey River hydrographic catchment (*hydrographic_subcatchments*).

Stream Flow Data

The GIS stream flow data available was point data associated with licenses and stream gauging and included:

- Licenses to remove surface water. The information included the licensee, details of the property, the location of the property, whether the license was in force, as well as the start and end dates of the current license. (*wrl_surfacewater_licenses_property*)
- Details of the drawdown points to remove surface water for the licensees. The information included basic details of the resource where the drawdown is occurring (name of river, tributary or brook), dam storages (heights and capacities) and location of the drawdown point. (*wrl_surfacewater_licenses_drawpoints*)
- Details of the Department of Water and Rivers stream gauging stations. This information included the water resource being gauged, the station name, the gauging station location, the upstream catchment, the start and end dates of monitoring, the most recent water level, the most recent salinity (Total Dissolved Solids) concentration and a URL (internet address) to download additional information for each of the gauging stations. (*win_surface_water_sites_stream_gauging_(dewcp)*)
- The URL for each of the stream gauging stations includes the following stream flow data:

-
- Details of the gauging station cross section (current and historical);
 - Total monthly and mean monthly discharges in mega litres and associated statistics;
 - Total annual discharge in mega litres (data and graphically); and
 - Total annual rainfall in millimetres (graphically).
- Details of the Water Corporation and the Metro Water Authority dam sampling. This information included the dam being gauged, the dam name, the dam location, the upstream catchment, the start and end dates of monitoring, some site included a recent water level, and some site included the most recent salinity (Total Dissolved Solids) concentration.
(win_surface_water_sites_other_(non_dewcp))

Water Quality Data

The GIS water quality data available was point data and included:

- Stream gauging stations: The dates that water sampling commenced and ceased at the station and the most recent salinity (Total Dissolved Solids) concentration.
(win_surface_water_sites_stream_gauging_(dewcp));
- Dams: The dates that water sampling commenced and ceased at the station and the for some sites the most recent salinity (Total Dissolved Solids) concentration.

1.2 Data Gaps

Data gaps identified that would be recommended to be addressed to enable surface water resources to be considered in a more systematic manner when assessing development applications. The data gaps identified included the following:

- No current land use data within the catchment. Of specific interest would be rural land use, urban areas, impervious areas (roof areas and roads), residential land use, commercial land use and industrial land use.
- Little or no water quality data being available. Typical contaminants of concern for:
 - Rural catchments include pH, dissolved oxygen, suspended solids, turbidity, salinity (total dissolved solids) and nutrients particularly nitrogen and phosphorus and biological parameters (such as E. Coli).
 - Urban catchments include pH, dissolved oxygen, suspended solids and turbidity, nutrients particularly nitrogen and phosphorus, total organic carbon, heavy metals (particularly lead and zinc) and biological parameters (such as E. Coli).

-
- Monitoring of salinity (total dissolved solids) throughout the catchment would also assist in classification of sections of streams and river as either fresh or estuarine.
 - No data on groundwater users within the catchment was included. This data including location, water quality and usage would be useful for assessing potential impacts. These users will have a potential impact on surface water resources within the catchment.
 - Addition of information of areas with vegetation (including vegetation type and species name) fringing the waterways with conservation value would assist in highlighting areas with existing conservation value that require protection and also areas of possible degradation that require rehabilitation. It could also identify areas which are significantly altered.
 - Addition of information of areas with fauna (such as native fish and birds including species name) with conservation value particularly in estuarine portions of the catchment would assist in highlighting areas with existing conservation value that require protection and also areas of possible degradation that require rehabilitation. It could also identify areas which are significantly altered.

This data should be collected on a regular basis to establish baseline data within the catchment and allow changes in the catchment to be highlighted.

KEIGHERY Bronwen

From: Parker Adrian
Sent: Monday, 19 December 2005 12:54 PM
To: KEIGHERY Bronwen; WHISSON Gary; RICHARDSON Andrew; OLEJNIK Craig
Subject: FW: 42905942 EEEA incomplete draft



R1157 Deliverable Section Version 1 42905924.pdf
EA invento... 14 December ...

Hi All,

Attached please find incompleated PRELIM DRAFT of the Stage 1 deliverable Discussion Paper for the EEEA project. It's pretty rough at this stage and I hope to receive the mapping and appendices later this week from the consultancy team. Most of the vegetation info seems to have been lifted from the Peel Development Commission's Peel 2020 document which is a little surprising. Anyhow I just thought I would circulate this amongst you to get a feel as to the progress the project has made with the consultants and the huge amount of work remaining. If you have any feedback on the discussion paper please let me know preferably by January 20th, 2006, however we will be aiming at community consultation in February 2006 and you shall all receive an invite.

Many thanks and merry xmas.

Adrian Parker
A/Program Manager
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Kwinana-Peel Region
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-----Original Message-----

From: Paul_McLeod@URSCorp.com [mailto:Paul_McLeod@URSCorp.com]
Sent: Wednesday, 14 December 2005 5:17 PM
To: Parker Adrian
Cc: Ian_LeProvost@URSCorp.com
Subject: 42905942 EEEA incomplete draft

Hi Adrian,

As requested, attached is a copy of the incomplete draft EEEA document. Some sections are still being finalised and will be available for a more complete draft on Monday. Some additional material on groundwater has just arrived (attached with a map as requested), Aboriginal heritage is coming, Bronwyn Keighery's section is not yet available, and inferential sections (i.e. strategic discussion based on other content) will be finalised as the missing bits are dropped in. There are some other gaps and these are noted in the copy. As mentioned our GIS person has been ill so we're stuck for other maps for now but should be able to get at least some for Monday.

Just bear in mind that this is unedited and incomplete, and hasn't been through our standard QAQC. It should not be considered a draft for distribution...this will be laid out with maps and photos and formatting etc in January. However, if it'll give you and other steering committee members an early look at where we're headed so people can give some thought to matters for discussion on Monday.

In terms of agenda items for Monday, I suggest the following...

Peel Harvey Eastern Estuary Catchment Environmental Assessment steering committee meeting
DoE Mandurah, 2pm to 3pm

2pm Overview of report
2:20 Strategic priorities and hierarchy (i.e. protection, enhancement, amelioration)
2:40 Outstanding issues (i.e. work to be completed)
2:45 Discussion

I will be in early tomorrow morning so let me know if there's anything further you need for tomorrow. Will send you the more complete version ahead of Monday if humanly possible.

Regards
Paul

(See attached file: R1157 Deliverable # EA inventory 1st Draft 30 Nov 05.doc) (See attached file: Section Version 1 14 December 05.doc) (See attached file: 42905924.pdf)

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