MINDEROO WATER RESOURCES STUDY

VEGETATION AND FLORA SURVEY

Prepared for:

WORLEY PTY LTD

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TABLE OF CONTENTS

ABBREVIATIONS

AHD	Australian Height Datum	
ANZECC	Australian and New Zealand Environment and Conservation Council	
ARMCANZ	Agriculture and Resource Management Council of Australia and New Zealand	
CALM	Conservation and Land Management (Department of)	
CD	Chart Datum	
DEP	Department of Environmental Protection	
DME	Department of Minerals and Energy	
DO	Dissolved Oxygen	
DOLA	Department of Land Administration	
DPA	Dampier Port Authority	
E	East	
EMP	Environmental Management Program, or Environmental Management Plan	
EMS	Environmental Management System	
EPA	Environmental Protection Authority	
FTU	Formazin turbidity unit (equivalent to nephelometric turbidity unit, NTU)	
GL	Gigalitre	10^6 m^3
GPS	Geographical Positioning System	
Ha	Hectare	10^4 m^2
kL	Kilolitre	1 m^3
Km	Kilometre	
kPa(a)	Kilopascal absolute	
kPa(g)	Kilopascal gauge	
M	Metre	
m^3	Cubic metre	1 kL
mg/L	Milligrams per litre	
ML	Megalitre	10^3 m^3
ML/d	Megalitre per day	
MRWA	Main Roads of Western Australia	
MSDS	Material Safety Data Sheet	
N	North	
NWQMS	National Water Quality Management Strategy	
PAH	Polycyclic Aromatic Hydrocarbons	
Psu	Practical salinity unit (part per thousand mass/mass)	
S	South	
Salinity	An indication of the dissolved solids content of the water	
TBT	Tributyltin	
W	West	

NOTES.

All GPS readings presented in this report have been recorded using Australian map Grid AMG 84 datum.

Worley Pty Ltd

MINDEROO WATER RESOURCE STUDY VEGETATION AND FLORA SURVEY

1 INTRODUCTION

1.1 BACKGROUND

In order to supply water for the irrigation of fodder crops during extended periods of drought, Murion Pastoral Company (Murion) proposes the construction of a 'riffle' in the Ashburton River on Minderoo Station, approximately 40 km SSE of Onslow. Murion proposes to construct the riffle on a natural high in the riverbed approximately 1 km upstream of Minderoo Bridge. Engineering design work and simple storage modeling undertaken by Worley Pty Ltd (Worley) indicates that construction of the proposed riffle to a maximum height of 3 m would provide capacity storage of up to 0.36 GL. Constructed to this maximum height it is expected that the water impounded by the riffle would create a pool extending approximately 8 km upstream. A detailed description of the proposed riffle design and associated features is provided in the accompanying report (Worley 2003).

In addition to the modeling and engineering design works already undertaken, an assessment of the environmental impacts associated with the proposed development is also required. This is aimed at ensuring that all sensitive features within the project area are identified and that any impacts associated with the proposed construction are minimized. Preliminary correspondence with the Waters and Rivers Commission (WRC) (16/7/99) identified impacts on riparian vegetation in response to the proposed construction as a feature of primary concern. More specifically, the potential for mortality of upstream vegetation in response to increased water levels and an altered hydraulic regime was identified. This report offers a detailed description of the vegetation and flora features within the study area. It also provides an assessment of the potential for impact on these features as a result of the proposed construction.

1.2 STUDY AREA

The area of investigation for this report includes all vegetation and flora features along the riverbanks of the Ashburton River 10 km upstream and 2 km downstream of the proposed riffle location. The location of the proposed riffle construction was recorded using a handheld GPS as 50K 0297435E 7567552N (AMG84). Considering that the maximum height to which the proposed riffle will be built is 3 m, this investigation is particularly focused on all vegetation and flora to 3 m above the riverbed at the proposed construction location as well as the upstream extent of water at that height, tapering out at approximately 8 km.
In order to obtain information from a regional perspective, all database searches were conducted on areas containing, yet beyond the immediate confines, of this study area.

1.3 SCOPE

The scope of work for this document is to provide a review of the vegetation and flora features within the study area. More specifically it is to include:

- A search of all relevant databases for Rare, Endangered and/or Priority Species and Ecological Communities.
- Results of a vegetation and flora survey extending beyond the maximum area of impact (i.e. 10 km upstream and 2 km downstream of the proposed riffle location).
- An assessment of the impacts arising from the altered hydrologic regime

1.4 THIS REPORT

This document reports the results of a desktop review and field survey of the Ashburton River study area. It specifically offers:

- A review of the Biogeographic classification, regional vegetation classification and known Rare and Priority Flora distributions for the study area;
- A description of the vegetation and flora features observed during the field survey;
- Identification of any unique or significant vegetation and/or flora features within the study area; and
- An assessment of the proposed riffle construction on vegetation within the Ashburton River.

2 METHODS AND LIMITATIONS

2.1 PRELIMINARY INVESTIGATIONS

A preliminary vegetation and flora survey involving an extensive literature review and desktop study was undertaken prior to the commencement of the field survey. This included:

- Searches for all recorded taxa within the project area and surrounds using CALM's Florabase
- Searches of the Department of Conservation and Land Management (CALM) Reserve list flora species
- Review of published literature, relevant environmental reports, environmental data and maps
- Consultation with CALM staff experienced with vegetation and flora in the region
- Examination of aerial photographs of the project area

2.2 FIELD DATA COLLECTION

A field survey of the proposed riffle construction site was conducted between the 12th and 13th of September 2003. The survey focused on the vegetation and flora along the riverbanks at the proposed riffle location, as well as all areas stretching 10 km upstream and 2 km downstream of the proposed construction site. Vegetation in the area was described using the vegetation classification system of Specht, as modified

by Aplin (1979). All species present along the riverbanks were recorded, along with their height and foliar cover (expressed as a %). Additional notes included a description of landform, soil, disturbance, Priority or significant species, weed species, and collection numbers and notes for any plants collected. Those plants not immediately identified in the field were collected for later identification and confirmation using the Western Australian Herbarium Reference Collection. Considering the general uniformity of vegetation along the banks of the river, data was collected wherever there was a distinct change in channel structure, in-channel features or bedforms. Photographs were taken at all sample locations along the river.

2.3 LIMITATIONS

The proposed inundation level had not been pegged during the survey, so this had to be estimated upstream from the riffle. To be conservative, a 3 m height up from the riverbed was considered for the entire survey but deeper, localized water depths may occur.

Many of the plant species collected were annuals which were not yet flowering or seeding, making positive identification difficult. In addition, there has been very few collections and little vegetation mapping of the Ashburton River making regional significance comparisons impossible. As too little is known about the flora in the area due to the lack of botanical survey work, no Priority species are included on the CALM database for the area.

3 EXISTING ENVIRONMENT

3.1 BIOGEOGRAPHY

The Interim Biogeographic Regionalisation of Australia (IBRA) is an Australian Nature Conservation Agency system of classification (Environment Australia 2000). It is aimed at delineating nationally recognised biogeographical boundaries for the assessment of conservation values.

The study area is located in the north-eastern corner of the Carnarvon biogeographic region, an area typified by Quaternary alluvial, aeolian and marine sediments overlying Cretaceous strata. The Carnarvon Region consists of a mosaic of saline alluvial plains with samphire and saltbush low shrublands, Bowgada (*Acacia ramulosa / Acacia linophylla*) low woodland on sandy ridges and plains, Snakewood (*Acacia xiphophylla*) scrubs on clay flats, and tree to shrub steppe over hummock grassland on and between red sand dune fields. Limestone strata with *Acacia startii / Acacia bivenosa* shrublands also outcrop in the north, where extensive tidal flats in sheltered embayments support Mangal. The Carnarvon region coincides broadly with the geological Carnarvon Basin and is thus situated upon sedimentary rocks to the west of the Western Shield (Beard 1990).

3.2 CLIMATE

The study area lies within the southern portion of the arid, subtropical coastline of the Pilbara region of W A. The region experiences low, erratic rainfall, high evaporation and day temperatures which vary from

warm in the winter to very hot in the summer. Weather is dominated by dry anticyclonic high pressure cells throughout the year and occasional tropical cyclones in the summer.

The summer season is characterized by prolonged periods of hot, dry conditions created by anticyclonic activity to the south. The mean daily maximum summer temperature for the nearby town of Onslow is 35.5°C, but temperatures exceed 40°C on an average of 17 days each year (Bureau of Meteorology, 2001). The maximum recorded temperature is 48.3°C in February. Further inland, maximums increase, with Nyang, some 80 km from the coast, experiencing a mean monthly summer maximum of 40.3°C

During winter, the anticyclonic belt is usually centred about the latitude of the Ashburton River and conditions are fine and warm in the day, and cool at night The average maximum winter temperature recorded at Onslow is 25 6°C and at Nyang 26.0°C (Bureau of Meteorology, 2001)

Rainfall is low and erratic, averaging approximately 277 mm near the coast and 313 mm at Nyang. Rainfall is generally very low between September and November averaging only 3.4 mm over this entire 3 month period at Onslow and 7 9 mm at Nyang. In summer, thunderstorms may develop as a result of convectional activity producing localized falls of rain. Cyclones, which usually occur between the months of January and April, often bring heavy rains and are the major source of precipitation In winter, rain bearing depressions from the south or the interaction of southern depressions with middle level disturbances moving through the tropics can result in quite high rainfall.

Mean monthly evaporation figures are very high, often exceeding 400 mm in summer and varying between 150 mm and 200 mm in winter. The mean annual evaporation at Onslow is 3,166 mm Humidity inland is generally low (15% to 25%), increasing in the winter months, but at the coast it is higher (50% to 60%) and shows less variation.

4 VEGETATION AND FLORA

4.1 REGIONAL OVERVIEW

The proposed riffle construction is located in the north-western portion of the Eremaean Province as defined by Beard (1979). More specifically it is situated in the north-eastern corner of the Carnarvon Botanical District and in close proximity to the western boundary of the Pilbara Botanical District. The Carnarvon Botanical District is typified by *Acacia* scrub and woodland becoming tree and shrub steppe in the north and with halophytes along the lower river courses (Beard 1990).

No Threatened Ecological Communities (TEC's) are present within the study area

4.2 VEGETATION

As a result of the proposed riffle construction impacting on only a single habitat type (i.e. the banks of the river, and more specifically the lower banks of the river), and considering the general uniformity of vegetation structure within that habitat, only a single vegetation association was described during the current survey.

The predominant vegetation within the study area was therefore recognised as a:

> Low Woodland of *Eucalyptus camaldulensis / Melaleuca argentea* (generally 10-30% but sometimes 30-70%; <5m) over mixed open Herbland (2-10%) over mixed open *Cynodon dactylon* tussock Grassland (generally 2-10% but sometimes 10-30% or locally higher).

Despite only a single vegetation association being described, distinct zonation within that vegetation was evident up the vertical extent of the bank. *Melaleuca argentea* was generally restricted to the lower section of the bank, typically starting at approx. 1.5 – 2.0 m above the channel base (it was rarely observed lower than this level). Most *M. argentea* extended approximately two thirds of the way up the bank, with decreasing density higher up. *Eucalyptus camaldulensis* typically dominated the upper portion of the bank, with most trees starting approximately 3 - 4 m from the channel base. At most locations within the river, the density of *E. camaldulensis* increased up the vertical extent of the bank.

Despite this general zonation a distinct overlap between the two vegetation dominants was present throughout the majority of the mid-section of the bank. The degree of overlap within the higher and lower sections of the bank was shown to vary considerably at a local extent. Despite being primarily dominated by *M. argentea*, *E. camaldulensis* did occur on the lower section of the bank at some locations.

Eucalyptus victrix was also sometimes present on the upper section of the bank. This species in general, however, became a more dominant feature of the vegetation as the riverbanks gave way to floodplain.

Although vegetated in-channel structures occurred very rarely throughout the extent of the study area, a number of features of note were observed during the current survey. Details of each of these features upstream of the proposed riffle construction site are given in Section 4.1, while those downstream of the proposed riffle construction site are discussed in Section 4.2. Vegetation inhabiting the channel itself was recorded at only one location. This consisted of two *M. argentea* trees growing within the middle of the channel approximately 5 km upstream from the proposed riffle location (50K 0297103E 7565121N) (Plate 1).

Plate 1: Two *Melaleuca argentea* trees approximately 5 km upstream of the proposed riffle location represented the only stand of in-channel vegetation within the study area.

4.3 FLORA

A search was undertaken for information on rare flora in an area containing, yet greater than, the Ashburton River study area, between the co-ordinates of 21° 55' – 22° 03' S and 115° 00' – 115° 03' E. This included a search of CALM's *Threatened (Declared Rare) Flora* database (CALM, 2000), the *Western Australian Herbarium Specimen* database and the CALM *Declared Rare and Priority Flora List*. The CALM *Threatened (Declared Rare) Flora* database and the *Declared Rare and Priority Flora List* (CALM 2000) identify species that are considered to be under threat of extinction and prioritizes these species based on the degree of that threat. The *Declared Rare and Priority Flora List* is covered under the *Wildlife Conservation Act, 1950*.

No Declared Rare or Priority Flora are currently listed by CALM for the survey area. Nevertheless, three CALM listed Priority species have previously been identified within the Onslow / Ashburton River region. Details for each of these species are given in Table 1 below.

Table 1: Priority Flora Species known for the Onslow / Ashburton River Region, Pilbara

4.3.1.1 Species / Taxon	Conservation Code	Description
Abutilon uncinatum	Priority 1	Small herb, 0.2–1 m high, with grey foliage and spined pods. Occurs on red sands and flat plains. Recorded from Onslow.
Mimulus clementii	Priority 1	Small herb, 0.1–0.2 m high, with leaves 10–20 mm long and 3–5 mm wide. Recorded between the Ashburton and De Grey Rivers.
Goodenia pascua	Priority 3	An ascending to erect yellow flowered herb to 0.5 m high. Occurs on red sandy soils and basaltic plains. Recorded from Onslow.

Priority 1 Species are taxa which are known from one or a few (generally <5) populations which are under threat. Priority 3 species are taxa which are known from several populations, and the taxa are not believed to be under immediate threat. Although there is currently no statutory restriction on the destruction of Priority species[1] (apart from regulations imposed as an environmental condition under the *Environmental Protection Act, 1986*), a set procedure for the destruction of any populations of Priority Flora species must be followed. This involves counting and recording all occurrences of Priority and Rare flora within proposed development areas and reporting the numbers to CALM. Vouched specimens should also be lodged with CALM where possible.

Survey Results

A total of 22 taxa were recorded in the study area during the field survey. These taxa represented 13 families and 20 genera (Appendix 1). The most commonly recorded family was the Myrtaceae with 4 species in 2 genera. Seven families were represented by only a single taxon.

No Declared Rare or Priority Flora currently listed by CALM were found within the survey area.

5 ASSESSMENT OF THE IMPACTS ON VEGETATION

Impacts on the vegetation as a result of the proposed riffle construction can be broadly classified as either:

- Those impacts associated with the actual construction of the proposed riffle; or
- Those impacts arising from an altered hydrologic regime as a result of placement of the riffle in the river.

The latter of these impacts can be further divided into those occurring as a result of increased inundation upstream of the proposed riffle, and those occurring as a result of a reduction in downstream flow.

An assessment of the relative effect on the vegetation in the Ashburton River study area as a result of each of these impacts is given below.

5.1 CONSTRUCTION OF THE RIFFLE

The proposed location for construction of the riffle is on a natural high in the riverbed approximately 1 km upstream of the Minderoo Bridge. Both the eastern and western banks at this location contain fairly open mixed low woodland of *Eucalyptus camaldulensis / Melaleuca argentea*, a vegetation type well represented along the upstream and downstream extent of the river within the study area. Photographs of the eastern and western banks at the proposed location are given in Plates 2 and 3 respectively.

[1] This differs from the situation with Declared Rare Flora whereby Ministerial consent is required before disturbance to identified populations can occur.

Plate 2: The eastern bank of the river at the proposed riffle location. Note the small cluster of *Melaleuca argentea* trees upstream (right side of photo) and directly adjacent to the proposed construction location.

Plate 3: The western bank of the river at the proposed riffle location. Note the low *Melaleuca argentea* tree downstream (right side of photo) of the proposed construction is at a height of approximately 1.5m above the riverbed.

The river channel at the proposed riffle location has a flat bed structure and contains no major in-channel features or vegetation. Recruitment of vegetation within the channel bed itself is obviously constrained by the frequency of flow. Although both of the banks of the river at the proposed riffle location are fairly steep sided, it is the lower toes of the bank in particular (i.e. those areas that are subject to more frequent flows) that remain the steepest. This steepness on the lower sections, and most probably the frequency of flows at this height, has restricted the potential for vegetation establishment. As a result, the lower section of the bank at the proposed riffle location is largely devoid of any perennial vegetation.

The open structure of the vegetation at the proposed riffle location means that no active clearing of vegetation would be required as a result of the proposed construction. Nevertheless, considering their proximity to the proposed riffle location, it is possible that some of the isolated *M. argentea* directly adjacent to the proposed riffle (see Plate 2) could be either directly or indirectly damaged during the construction process. Although the loss of these trees could potentially result in a decrease in bank stability in the area, the proposed riffle has been designed in such as fashion so as to minimise any risk of bank erosion (Worley 2003).

5.2 UPSTREAM IMPACTS ON VEGETATION

Considering the nature of the vegetation along the riverbanks, the primary impact occurring as a result of construction of the proposed riffle will be the potential loss of perennial vegetation through increased inundation upstream. This localised mortality of riparian vegetation, in turn, increases the potential for riverbank erosion.

Substitution of a variable-flooding pattern with a more permanent one will undoubtedly result in the mortality of some of the trees currently inhabiting the lower portions of the bank. Indeed the senescence of floodplain eucalypts as a result of prolonged flooding has been reported extensively in the scientific literature (Smith and Smith 1990; Walker and Thoms 1993; Thorton and Briggs 1994; Kingsford 2000) and even recorded locally in the nearby Cane River wetlands (Astron 2003). Nevertheless, the degree to which mortality occurs as a result of the proposed construction will largely be dependent on the length of inundation, a feature that is intrinsically linked to the relative height of the vegetation on the riverbank.

On completion of the proposed riffle, pool capacity would be achieved after the occurrence of a significant rainfall event and (if constructed to a maximum height of 3m) would extend upstream, albeit with decreasing depth, for a distance of approximately 8 km. After capacity is reached, and assuming no further rainfall events in the interim, steady reductions in the volume of the pool would occur as a result of evaporation, leakage and water usage. Historical records from flow in the Ashburton, however, suggest that a baseflow can be maintained in the river for periods of up to 9 months (R. Doherty - WRC pers. comm.). This being the case, it is possible that all vegetation below the upstream extent of the maximum capacity water level of the riffle will be subject to prolonged periods of inundation.

Despite this, it is that vegetation currently inhabiting the lower portions of the bank (i.e. less than 3 m) and closest to the proposed riffle location (where the impounded water would be at its deepest), which is most likely to suffer extended periods of inundation. Therefore, it can generally be accepted that the lower the vegetation is with respect to the upstream extent of the maximum capacity water level and the closer that vegetation is to the riffle, the greater its risk of mortality

It is also expected that the degree of mortality will be somewhat dependent on the species of trees being inundated. Considering the zonations of vegetation on the vertical extent of the bank, *M. argentea* is expected to be more tolerant of prolonged periods of inundation in comparison to *E. camaldulensis*. Indeed field observations made at other locations within the Pilbara tend to support this claim. The observed mortality of eucalypts in the north-eastern extent of the Cane River Wetland in response to increased inundation, yet the persistence of *Melaleuca*'s at the same site, certainly suggests this. Additionally, the survival of *Melaleuca*'s subject to prolonged periods of inundation has also been observed at Miaree Pool, west of Karratha (J. Kruger pers. obs.).

As stated in Section 4.1 above, the higher frequency of flow means that the lowest portions of the bank are typically the most steep, and as a corollary, remain poorly vegetated. This is typically the case for the majority of the river upstream of the proposed riffle location. Nevertheless, vegetation does periodically inhabit the lowest sections of the bank, and was frequently recorded at heights below the proposed level of inundation. A summary of those areas identified during the field survey as being most prone to increased inundation upstream as a result of the proposed riffle location is given below. All sites are listed as starting from the proposed riffle location and moving upstream away from this site.

Location 1: Riffle – 50K 0297435 7567552

The lowest perennial vegetation on the banks of the river at this location and directly upstream (*Melaleuca argentea*) occurs approximately 1.5 m – 2.0 m above the river base (Plate 4). The density of *Melaleuca* trees at and near this height on each riverbank directly upstream of the riffle location was estimated to be no greater than two per 100 m. The density of Eucalyptus trees at this height was considerably less than this. It is expected that this typical level of inundation would continue upstream before slowly tapering out with increased distance away from the proposed riffle location.

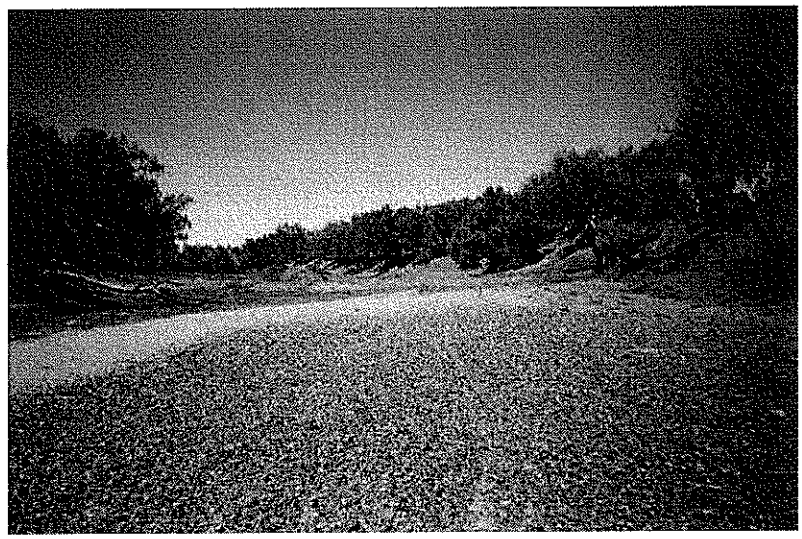

Plate 4: A view of the river directly upstream of the proposed riffle location. Note the typical height of the vegetation and the general lack of vegetation on the lower portion of the bank.

Location 2 – 50K 0297657 7567364

Flow dissecting the toe of the outer bank at this corner, situated approximately 350 m upstream from proposed riffle location, has almost created a mid-channel bar structure (Plate 5). The bar contains a small population of mixed *Melaleuca* species (*M. argentea* and *Melaleuca glomerata*) over a mixed Herbland. A small pool is present on the in-channel toe of the dissected bar. Considering the location of this structure it is likely that it will be subject to periods of extensive inundation if the pool is maintained at capacity over a prolonged period.

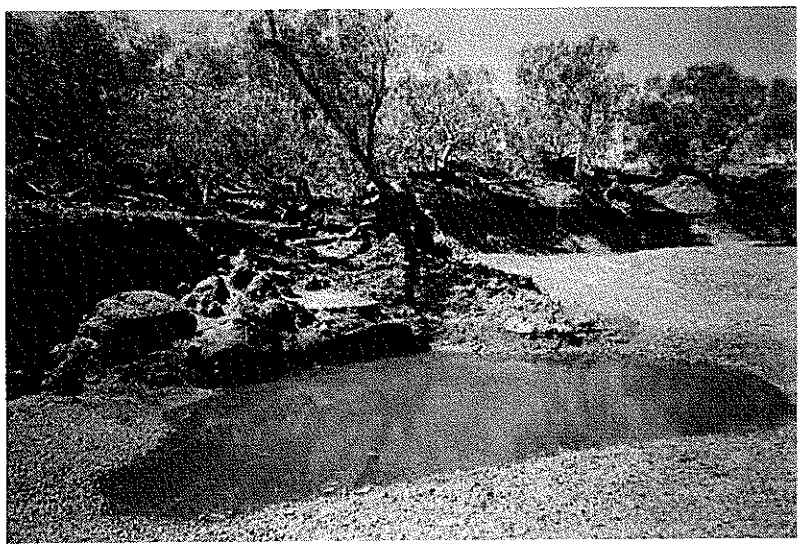

Plate 5: Mid-channel bar structure containing a mixed *Melaleuca* woodland. Note the relative height of the vegetation on the bank in the background.

Location 3 – 50K 0297729 7567256

These co-ordinates identify the northern extent of a pool located approximately 500 m upstream of the proposed riffle location (Plate 6). Although the lower extent of the bank at this site is poorly vegetated, a distinct line of *M. argentea* and dense couch grass (*Cynodon dactylon*) is present on what would most probably mark the top of the pool under current base flow conditions. It is likely that the lower of these trees would be subject to prolonged periods of inundation on construction of the proposed riffle.

Plate 6: Photo of the pool at Location 3 taken from the northern end looking upstream towards the south. Note dense couch grass (*Cynodon dactylon*) and a line of *Melaleuca argentea* of equal height along the edge of the pool area on the eastern bank.

Location 4 – 50K 0297616 7566937 through to Location 5 - 50K 0297356 7566564

Situated approximately 900 m upstream from the proposed riffle location, the toe of the western bank at this site has been slightly dissected, almost to a point where it has created an in-channel feature (Plate 7). This feature contains a number of large *M. argentea* trees over a mixed sparse Herbland over a sparse *C. dactylon* tussock grassland. It extends upstream for several hundred meters until Location 5 (Plate 8).

Considering the general height of the vegetation along this stretch, it is likely that most of these trees would be subject to prolonged periods of inundation after construction of the proposed riffle.

Plate 7: Downstream extent of the dissected western bank feature at Location 4. Note the relatively low status of the *Melaleuca argentea* in respect to the riverbed along this western bank.

Plate 8: Upstream extent of the dissected western bank feature at Location 5. Note the elevated riverbed level in the foreground.

Location 6 – 50K 0297563 7566053

Moderate channel widening at this site has resulted in the steepening of the eastern bank and has caused the deposition of old bank vegetation (*M. argentea*) within the river channel (Plate 9). Some regeneration *M. argentea* is also present near the base of the eroded bank. The lower trees within the channel will most probably be inundated as a result of the proposed riffle construction.

Plate 9: The channel widening recorded at Location 6 Note the regenerating *Melaleuca argentea* in the foreground, as well as some of the *M argentea* from the old bank deposited within the channel

Location 7

A number of low Melaleuca are present along the eastern bank approximately 300 m upstream from Location 6 (Plate 10). Although the trees along this bank appear to be very close to the riverbed, the significant pebble/sediment build-up around the trees suggests that the riverbed is somewhat elevated at this point. Nevertheless, it is expected that some of the lower trees along this eastern bank will be subject to prolonged inundation as a result of the proposed riffle construction.

Plate 10: The row of low *M argentea* along the eastern bank at Location 7.

Location 8 – 50K 0297103 7565121

Two *M argentea* trees were found growing within the channel at this location (see Plate 1). The build-up of the heavy gravel bedload around these trees again suggests an elevated riverbed at this site. Being located within the channel itself, however, it is highly likely that these trees would be subject to prolonged periods of inundation after construction of the proposed riffle.

In spite of the potential for tree mortalities as a result of inundation, it is highly likely that the proposed construction will greatly increase the density of vegetation along the riverbanks. The increased availability of water throughout the year will most probably result in locally higher levels of recruitment and survival, which in turn will lead to a greater rate of plant establishment along the riverbanks. The favourable growth conditions afforded by the proposed pool construction will most likely favour the establishment of the smaller *Melaleuca* species over the larger eucalypts (at least in the shorter term), and potentially result in the introduction of macrophytic species. It is likely that the increased level of bank stability afforded by this greater density of vegetation will offset any reductions in bank stability as a result of localised tree mortalities. Even if mortalities did occur, the dead trees would still provide a level of stability to the banks, long enough for the higher density vegetation to establish.

5.3 DOWNSTREAM IMPACTS ON VEGETATION

Another impact occurring as a result of the proposed riffle construction is the potentially deleterious impact on downstream vegetation as a result of reductions in flow. A significant reduction in flow to downstream vegetation communities has the potential to result in vegetation mortalities, which in turn can lead to a loss of bank stability and subsequent higher rates of erosion.

The vegetation located downstream of the proposed riffle location is typical of that recorded elsewhere along the river within the study area. Both the eastern and western banks downstream of the proposed riffle contain a mixed low woodland of *E. camaldulensis* and *M. argentea* over a mixed open herbland / tussock grassland (Plate 11). The majority of the vegetation is situated higher on the banks, with the very toe of the banks being steep at most locations. No in-channel vegetation is present within the area 2 km downstream of the proposed riffle location. At the time of survey a significant pool was located approximately 400 m downstream of the proposed riffle location. This pool extended discontinuously downstream beyond Minderoo Bridge.

Plate 11: The river channel directly downstream of the proposed riffle location. Note the general height of vegetation along the banks.

Results of modeling undertaken by Worley suggest that downstream reductions in flow would be minimal under the proposed design (Worley 2003) Specifically, the construction of the riffle would see a moderate reduction in low flows when water levels within the river are low.

Of the two main perennial species present along the banks of the river it is likely that the *Melaleucas*, being smaller trees and having a less extensive root structure than the eucalypts, will be more susceptible to reductions in flow. Nevertheless, most of the *Melaleucas* along the downstream stretch of the river are quite large trees and are likely to have extensive root systems that utilize the existing water table conditions. Considering the high seasonality of flow that already exists plus the current variation in vegetation heights along the bank (indicating that some natural variation in distance away from the water table is already tolerable), it is unlikely that the minimal reduction in flow, as is planned for the riffle construction, would have a significant deleterious impact on downstream vegetation.

It is also worth noting that the impact of leakage from the proposed pool may also result in locally higher levels of groundwater. This may prove beneficial to the downstream vegetation by providing a more sustained groundwater level throughout the duration of the year (i.e a lower degree of fluctuation), which, on average, may be at a level higher than that which currently occurs. The degree to which this influences the vegetation, however, is solely dependent on the rate of leakage from the proposed pool.

6 CONCLUSION AND RECOMMENDATIONS

Based on the vegetation and flora survey and desktop review undertaken as part of the Minderoo Water Resource Survey, the following conclusions and recommendations can be made.

6.1 CONCLUSIONS

1. The type of vegetation and flora that will be potentially impacted by the proposed riffle construction is well represented along the Ashburton River. No unique or significant vegetation or flora features will be impacted as a result of the proposed development.

2. The proposed riffle construction will result in prolonged periods of inundation for vegetation upstream and only a minor reduction in flow downstream. However, due to the intermittent nature of rainfall in the region, evaporation, leakage and water usage, construction of the riffle will not result in the permanent inundation of all the upstream riparian vegetation.

3. Substitution of a variable-flooding pattern with a more permanent one will undoubtedly result in the mortality of some of the trees currently inhabiting the lower portions of the bank. At present, however, the degree of tolerance to inundation afforded by the two dominant perennials along the bank can only be speculated.

4. Construction of the proposed riffle will offer favourable growth and establishment conditions for vegetation, which in turn will see an increase in vegetation density higher on the riverbanks. It is likely that the increased level of bank stability afforded by this greater density of vegetation will offset any reductions in bank stability as a result of localised tree mortalities. Even if mortalities did occur, the dead trees would still provide a level of stability to the banks, long enough for the higher density vegetation to establish.

5. Considering the high seasonality of flow that already exists, plus the current variation in vegetation heights along the bank, it is unlikely that the minimal reduction in flow occurring as a result of the proposed riffle construction would have a significant deleterious impact on downstream vegetation. It is possible that leakage from the proposed pool may result in locally higher levels of groundwater, which in turn may prove beneficial to the downstream vegetation by providing a more sustained groundwater level for the duration of the year.

6.2 RECOMMENDATIONS

Although the current survey assessed the impact of constructing a riffle to a maximum height of 3 m, construction of the riffle to an interim height of 2.5 m would offer a better basis for assessing and managing vegetation mortalities. At 2.5 m high the riffle would provide approximately 0.25 GL of water storage and would create a pool stretching approximately 6 km upstream of the construction. Based on the current assessment, the portion of the bank between 0 - 2.5 m is generally less densely vegetated than the remainder of the bank above this height. Subsequently the potential for vegetation mortalities would increase significantly with increasing height of the riffle constructed. Nevertheless, reductions in pool volume via evaporation, leakage and water usage would mean that the more densely vegetated upper sections of the bank would experience lesser rates of inundation in comparison to those areas lower on the bank. It may therefore be that the degree of inundation imposed on the vegetation on the higher portion of the banks is tolerable and as a result might not cause 'blanket' mortalities. We therefore make the following recommendations:

1. Because the degree to which riparian vegetation and flora is impacted by the proposed riffle is intrinsically linked to the height of the riffle constructed, and the effect of inundation on vegetation mortality increases with water depth, a staged development is recommended. Constructing the riffle to 2.5 m initially is the best method of ensuring that vegetation mortalities occurring as a result of inundation upstream are managed appropriately.

2. The raising of the riffle to 3 m should occur reasonably soon after the initial instruction, all being well, to ensure that new vegetation does not establish in the 2.5 m to 3 m zone, only to be later inundated.

3. In any case, vegetation along the river banks should be monitored at 6 monthly intervals for 2 years after riffle construction, to determine what effect inundation has on riparian species. Annual monitoring should continue for some time after this initial period until a stable ecosystem is achieved.

4. If broadscale vegetation mortalities occur as a result of inundation and vegetation establishment failed to eventuate, then pro-active planting or stabilization measures should be undertaken in order to ensure overall channel stability.

5. Active measures should be taken to eliminate all weed species from the area of proposed construction and within the proposed pool boundaries. Although not observed during the current survey *Parkinsonia acuelata* is known to occur along the banks of the river channel. All known occurrences of *Parkinsonia* should be eradicated prior to construction of the riffle. Additionally, measures should be undertaken to ensure that the smothering vine *Passiflora foetida* is not introduced to the vegetation along the banks of the proposed pool. *Passiflora foetida* is an aggressive invasive species with the ability to completely smother larger riparian trees and vegetation. It occurs commonly throughout the Kimberley and Pilbara and was observed downstream of the proposed riffle location at nearby Scotties Weir.

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APPENDIX 1

FLORA SPECIES RECORDED WITHIN THE PROPOSED RIFFLE CONSTRUCTION AREA, ASHBURTON RIVER - MINDEROO STATION.

FAMILY	FAMILY NAME	SPECIES
31	Poaceae	*Cenchrus ciliaris* *Cyndon dactylon* *Eragrostis tenellula*
32	Cyperaceae	*Cyperus vaginatus*
105	Chenopodiaceae	*Chenopodium melanocarpum var leucocarpum*
106	Amaranthaceae	*Alternanthera nodiflora* *Amaranthus pallidiflorus*
165	Papilionaceae	*Sesbania cannabina* *Vigna lanceolata*
185	Euphorbiaceae	*Euphorbia australe* *Phyllanthus maderaspatensis*
221	Malvaceae	*Sida fibulifera*
273	Myrtaceae	*Eucalyptus camaldulensis* *Eucalyptus victrix* *Melaleuca argentea* *Melaleuca glomerata*
307	Convolvulaceae	*Ipomoea muelleri*
315	Solanaceae	*Nicotiana occidentalis*
316	Scrophulariaceae	*Stemodia viscosa*
341	Goodeniaceae	*Goodenia lamprosperma*
345	Asteraceae	*Centipeda minima* *Pluchea rubelliflora*