INTERIM RECOVERY PLAN NO. 198

# Assemblages of Organic Mound (Tumulus) Springs of the Swan Coastal Plain

## Interim Recovery Plan 2006-2010

January 2006

Department of Conservation and Land Management
Species and Communities Branch, Kensington

DEPARTMENT OF Conservation AND LAND MANAGEMENT
Conserving the nature of WA

Natural Heritage Trust
Helping Communities Helping Australia

## FOREWORD

Interim Recovery Plans (IRPs) are developed within the framework laid down in Department of Conservation and Land Management (CALM) Policy Statements Nos 44 and 50

IRPs outline the recovery actions that are required to urgently address those threatening processes most affecting the ongoing survival of threatened taxa or ecological communities, and begin the recovery process.

CALM is committed to ensuring that Critically Endangered ecological communities are conserved through the preparation and implementation of Recovery Plans or Interim Recovery Plans and by ensuring that conservation action commences as soon as possible and always within one year of endorsement of that rank by CALM's Director of Nature Conservation.

This Interim Recovery Plan replaces plan number 56, 'Assemblages of Organic Mound (Tumulus) Springs of the Swan Coastal Plain', Interim Recovery Plan 2000-2003, by V. English and J. Blyth.

This Interim Recovery Plan will operate from January 2006 to December 2010 but will remain in force until withdrawn or replaced. It is intended that, if the ecological community is still ranked Critically Endangered, this IRP will be reviewed after five years.

This IRP was given Regional approval on 14 December 2005 and was approved by the Director of Nature Conservation on 15 January 2006. The provision of funds identified in this Interim Recovery plan is dependent on budgetary and other constraints affecting CALM, as well as the need to address other priorities.

Information in this IRP was accurate at November 2005.

## IRP PREPARATION

This Interim Recovery Plan was prepared by Rachel Meissner, Val English and John Blyth, Species and Communities Branch, CALM, PO Box 51 Wanneroo, WA 6946.

## ACKNOWLEDGMENTS

The National Reserve System Program of Environment Australia funded the project entitled 'Identifying and conserving threatened ecological communities in the south west botanical province'. The project identified the threatened status of this spring community.

The following people provided valuable advice and assistance in the preparation of this Interim Recovery Plan;

| | |
|---|---|
| Sam Burton | Groundwater Consulting Services Pty Ltd |
| Edyta Jasinska | Previously Zoology Department, University of Western Australia |
| Angus Davidson and Jeff Kite | Previously Water and Rivers Commission |
| Neil Gibson, Greg Keighery, Wes Manson and Peter Speldewinde | CALM, Wildlife Research Centre, Woodvale |
| David Mitchell | CALM's Swan Region |
| Leigh Sage and Lyndon Mutter | CALM's Swan Coastal District |

**Cover photograph** by Mia Morley

## CITATION

This Interim Recovery Plan should be cited as:

Department of Conservation and Land Management (2006). Community of Tumulus (organic mound) springs of the Swan Coastal Plain Interim Recovery Plan 2005-2010. Interim Recovery Plan No. 198. Perth, Western Australia.

**SUMMARY**

**Name**: Community of Tumulus Springs (organic mound springs) of the Swan Coastal Plain.

**Description**: The habitat of this community is characterised by continuous discharge of groundwater in raised areas of peat. The peat and surrounds provide a stable, permanently moist series of microhabitats. Intact vegetated tumulus springs are only found at four locations. There is a high level of heterogeneity of invertebrate fauna assemblages between these sites, but all are associated with a rich, healthy fauna. Groups commonly represented include Ostracoda, Nematoda, Cladocera, Copepoda, Oligochaeta, Tardigrada, Turbellaria and Insecta.

Typical and common native vascular plant species associated with the tumulus springs are the trees *Banksia littoralis*, *Melaleuca preissiana* and *Eucalyptus rudis*, and the shrubs *Agonis linearifolia*, *Pteridium esculentum*, *Astartea fascicularis* and *Cyclosorus interruptus*. The following non-vascular plants have also been located on peat mounds associated with the community: *Lycopodium serpentium* (bog clubmoss), *Riccardia aequicellularis*, *Jungermannia inundata*, *Goebelobryum unguiculatum* and *Hyalolepidozia longiscypha*.

Common weed species include *Isolepis prolifera* and *Pennisetum clandestinum*.

**CALM Region**(s): Swan

**CALM District**(s): Swan Coastal

**Shire(s)**: Swan, Chittering

**Recovery Team**: Swan Region Threatened Flora and Communities Recovery Team (SRTFCRT). Membership: representatives from CALM's Swan Region (Chair), Swan Coastal District, Perth Hills District, Species and Communities Branch (SCB), and Science Division; and City of Gosnells, Botanic Gardens and Parks Authority (BGPA) and World Wide Fund for Nature (WWF).

**Current status**: Assessed 21 November 1995 as Critically Endangered. Also listed as Endangered under the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* (EPCB Act)(Note: community name as listed under the EPBC Act is 'assemblages of plants and invertebrate animals of tumulus (organic mound) springs of the Swan Coastal Plain').

**Habitat requirements**: Some of the fauna species have no dormant stages and depend on the maintenance of a permanent supply of fresh water. Many vascular and non-vascular plant species that inhabit the mounds are also reliant on permanent moisture. The maintenance of hydrological processes in terms of both quality and quantity of water to the mounds is essential to sustain the tumulus spring communities.

**Habitat critical to the survival of the community, and important occurrences:** Comprises the area of occupancy of known occurrences; areas of similar habitat within 200 metres of known occurrences; remnant vegetation that surrounds or links occurrences; and the local catchment for the surface and groundwater that maintain the habitat of the community.

Given that the community is listed as Critically Endangered, it is considered that all occupied habitat is critical to the survival of this community, and all known occurrences are important.

**Benefits to other species/ecological communities:** Recovery actions implemented to improve the quality or security of the community are likely to improve the status of any species within the community. No associated species are separately listed as Threatened under State or Commonwealth legislation.

**International obligations:** This plan is fully consistent with the aims and recommendations of the Convention on Biological Diversity, ratified by Australia in June 1993, and will assist in implementing Australia's responsibilities under that convention. The community is not listed under any specific international treaty, however, and therefore this IRP does not affect Australia's obligations under any other international agreements.

**Role and interests of indigenous people:** An Aboriginal Sites Register is kept by the Department of Indigenous Affairs, and lists one camp site occurring in the vicinity of Occurrence 2, however, indigenous communities interested or involved in the region affected by this plan have not yet been identified. Implementation of recovery actions under this plan includes consideration of the role and interests of indigenous communities in the region.

**Social and economic impacts:** Occurrence 2 is located on private property that is currently under residential development. Negotiations with the private owner resulted in the mound springs and a small area surrounding it to be

set aside as public open space. Negotiations will continue with the land owner to help protect the occurrence.

Occurrence 4 occurs adjacent to private property where an annual four wheel drive gymkhana is held which could have adverse affects on water quality at the springs. Negotiations will continue with the adjacent land managers and regulatory authorities with respect to the future activities and impacts to this occurrence.

The implementation of this recovery plan has the potential to have some social and economic impact, where occurrences are located on and adjacent to private property. Recovery actions refer to continued liaison between stakeholders with regard to these areas.

**Affected Interests:** Occurrences of the Tumulus Springs are within the Local Government Authority of the City of Swan. They occur on land managed by CALM, the WAPC, and on private land. Potentially affected landholders are the developers of land on which Occurrence 2 occurs, and possibly the owners of land adjacent to all occurrences, but Occurrence 4 in particular.

**Evaluation of the plan's performance:** The Department of Conservation and Land Management will evaluate the performance of this IRP in conjunction with the Recovery Team. In addition to annual reporting on progress with listed actions and comparison against the criteria for success and failure, the plan is to be reviewed within five years of its implementation.

**IRP Objective(s)**: To maintain or improve the overall condition of the tumulus springs and the associated fauna and plant community in the known locations and reduce the level of threat, with the aim of reclassifying the community from Critically Endangered to Endangered.

**Criteria for success**:
An increase of 10% or more in the area, and/or increase in the number of occurrences of this community under conservation management.

Maintenance in terms of diversity and basic composition of native invertebrate species (as described in Ahmat 1993; Jasinska and Knott 1994; Pinder 2002) taking account of natural change in the community over time. This will be measured as a loss of no more than 10% of the native invertebrate species in any one spring over the life of the plan.

Improvement in the condition of the habitat, in terms of re-establishment of fringing buffer vegetation, reduction of numbers of exotic species and of other threatening processes as defined in this document. This will be measured as follows:

- a gain in the area of buffer vegetation under conservation management adjacent to the springs of 10% or more,
- reduction of 10% or more in the cover of exotic plant taxa in the springs or buffer areas,
- groundwater levels and quality maintained within the parameters expected as a consequence of natural change, by comparison with monitoring results for the Gnangara Mound in areas remote from development.

**Criteria for failure:**
A decrease of 10% or more in the area covered by the springs, and/or decline in the number of occurrences of this community under conservation management.

A decline in terms of diversity and basic composition of native invertebrate species (as described in Ahmat 1993; Jasinska and Knott 1994; Pinder 2002) taking account of natural change of the community over time. This will be measured as a loss of more than 10% of the native invertebrate species in any one spring over the life of the plan.

Decline in the condition of the habitat, in terms of loss of fringing buffer vegetation, increase in numbers of exotic species and other threatening processes as defined in this document. This will be measured as follows:

- a decline in the area of buffer vegetation under conservation management adjacent to the springs of 10% or more,
- increase in the cover of exotic plant taxa in the springs or buffer area of more than 10%,
- groundwater levels and quality not maintained within the parameters expected as a consequence of natural change, by comparison with monitoring results for the Gnangara Mound in areas remote from development.

**Summary of Recovery Actions**:

| | |
|---|---|
| 1. Coordinate recovery actions | 11. Design and conduct research |
| 2. Map habitat critical to survival | 12. Ensure hygiene conditions near the community |
| 3. Clarify and continue to monitor the extent and boundaries of the community | 13. Continue to monitor dieback |
| 4. Liaise with current land owners, land managers and other interested groups | 14. Monitor and implement weed control |
| 5. Disseminate information | 15. Rehabilitate recharge catchment zones and adjacent wetland areas |
| 6. Monitor water levels and quality | 16. Report on success of management strategies for tumulus springs |
| 7. Manage water quality and quantity | 17. Support reservation of Occurrence 2 and adequate buffer area |
| 8. Monitor the flora and fauna of tumulus springs | 18. Fence Occurrence 2 |
| 9. Develop and implement Fire Management Plans | 19. Ensure visitor access-ways do not impact the tumulus springs |
| 10. Ensure earthworks nears springs do not impact community | 20. Block drain on southeast corner of Neaves Road Nature Reserve |

# 1. BACKGROUND

## 1.1 History, defining characteristics of ecological community, conservation significance and status

The heavy clay soils of the Guildford Formation on the eastern side of the Swan Coastal Plain have been formed through the accumulation of deposits eroded from the hills of the Darling Range to the east. Between Bayswater and Muchea on the eastern extremities of the Bassendean Dune system, the tumulus (Latin meaning 'little mound') springs historically occurred where the sands and clays meet. The Bassendean sands contain the large superficial aquifer known as the Gnangara Mound. This groundwater is forced to the surface at a series of discharge points on the eastern boundary of the aquifer where waters encounter the relatively impervious Guildford clays. Discharge areas form springs, bogs, and swamps.

In the case of the tumulus springs, there is continuous growth of vegetation that causes the formation of peat around the permanent water supply. Water continues to penetrate the increasingly elevated peat layers due to the pressure created by local and regional hydrological forces. Where water finds a 'preferred pathway' or conduit through the soil, water movement is much faster than normal groundwater flow. Such conduits or pipes may carry sand and silt to the surface, where it is deposited as a 'collar' of increasing height, so enhancing the formation of mounds (A. Davidson[1], personal communication).

Historically, the tumulus springs were common within their narrow range. The swamps, lakes, dams and springs form a north - south line parallel to the Darling Scarp, and corresponding to the junction between the Bassendean Sands and the Guildford Clays. Some of these groundwater discharge points are located within the western groundwater catchment of Ellen Brook. The tumulus springs have typically been excavated to create farm dams or cleared and sealed with limestone to provide pasture for horses and cattle.

The remaining vegetated tumulus springs have an overstorey of moisture adapted species including *Melaleuca preissiana*, *Banksia littoralis*, *Agonis linearifolia* and *Eucalyptus rudis*. Common understorey species include *Agonis linearifolia*, *Pteridium esculentum*, *Astartea fascicularis* and *Cyclosorus interruptus*. The following non-vascular plant species have also been located on peat mounds associated with the community (Jasinska and Knott 1994): *Lycopodium serpentium* (bog clubmoss), *Riccardia aequicellularis*, *Jungermannia inundata*, *Goebelobryum unguiculatum* and *Hyalolepidozia longiscypha*. Common weed species associated with the mounds include *Isolepis prolifera* (budding club-rush) and *Pennisetum clandestinum* (kikuyu).

The peat mounds may provide a permanently moist refuge for fauna that historically had a wider distribution. Consequently, relictual species may be protected from climatic changes and survive in these mounds. Some of these species may have no dormant period and would be killed if the mounds dried out (E. Jasinska personal communication[2]). Although there is a high level of heterogeneity in the fauna associated with mounds, common groups include Ostracoda, Nematoda, Acarina, Amphipoda, Cladocera, Copepoda, Decapoda, Oligochaeta, Annelida, Tardigrada, Turbellaria and Insecta.

The significance of the tumulus springs was recognised in the Conservation Through Reserves Committee recommendations (Department of Conservation and Environment 1983) that referred to sites just east and south of reserve 46622 on Faull Street, Muchea. Recommendation C25 referred to the need for survey, discussions with owners and a report on the conservation of the flora, and noted

[1] Dr Angus Davidson, previously Water and Rivers Commission
[2] Dr Edyta Jasinska, previously University of Western Australia

that ways to protect the conservation values should be sought. The same report also recommended that Geological Survey should investigate the hydrology of the area with a view to preventing adverse impact from local groundwater drawdown. None of the recommendations were implemented prior to 1996, and the springs and associated peat mounds have been progressively destroyed by grazing, leveling and packing with limestone, or have dried up (Jasinska and Knott 1994).

The integrated process of updating the 'System 6' Conservation Through Reserves System Recommendations (DEP 1997) and the Ministry for Planning Urban Bushland Strategic Plan, has resulted in Bush Forever (Government of Western Australia 2000). Occurrences 2, 3 and 4 are within the area covered by Bush Forever. While Occurrence 4 was only located and surveyed in 2004, after Bush Forever was published, the spring is contained within a Bush Forever site. Any proposed developments likely to adversely affect those occurrences will need to be assessed under the Bush Forever process (State of Western Australia 2000). Occurrence 1 is outside of the area covered by Bush Forever, but has been purchased as a conservation reserve.

**Table 1 Extent and location of occurrences**

| Occurrence Number | Location | Estimated area of tumulus springs |
|---|---|---|
| Occurrence 1 | Nature Reserve 46622, Faull Street, Muchea | 1.4 ha |
| Occurrence 2 | Private land, Ellenbrook | 2 ha |
| Occurrence 3 | Neaves Rd Nature Reserve, Bullsbrook | 4 ha |
| Occurrence 4 | Bush Forever Site, Bullsbrook | 0.87 ha |

**Table 2 Vesting and tenure of occurrences**

| Occurrence Number | Vesting | Purpose | Tenure |
|---|---|---|---|
| Occurrence 1 | Conservation Commission | Conservation of Flora and Fauna | Crown Reserve – Nature Reserve |
| Occurrence 2 | Multiplex | Freehold – no purpose listed | Freehold – Non CALM Act |
| Occurrence 3 | Conservation Commission | Conservation of Flora and Fauna | Crown Reserve-Nature Reserve |
| Occurrence 4 | DPI/WAPC* | Conservation and Recreation | Freehold, Non-CALM |

* Department for Planning and Infrastructure / Western Australian Planning Commission

**Description of Occurrences**

Intact tumulus springs (uncleared) are only known from four locations; a Nature Reserve on Faull Street in Muchea; Egerton Stud about 2 km south of the junction of Maralla and Halden Roads, Ellen Brook; Neaves Road Nature Reserve; and a Bush Forever site in Bullsbrook that is contiguous with the bushland that contains Neaves Rd Nature Reserve. These four remaining spring areas differ in structure of the mounds, presumably as a result of differences in hydrogeology or history of formation.

Occurrence 1 is in a Nature Reserve on Faull Street in Muchea and contains a series of boggy peat mounds that were historically up to two metres tall. Temporary pools occur where peat has been burnt. Water oozes from the soil, or flows out from discrete vertical channels from the peat mounds. Cattle grazed the area in the past, but have now been excluded by the erection of a fence around the reserve area. This site was previously privately owned, but was purchased in 1996 with joint CALM and Commonwealth funds, and is now a Nature Reserve.

The vegetation composition of the tumulus springs in the Faull Street Nature Reserve is likely to have been altered by grazing, as the area had apparently been intermittently grazed for many years. It is unknown to what extent fire has influenced the present structure or composition of the community. The combination of grazing and fire would almost certainly have increased the

invasion of exotic species such as *Pennisetum clandestinum* and *Isolepis prolifera* into the community.

Occurrence 1 was burnt in a hot fire in 1995 and most of the understorey was destroyed. This created very open areas and led to massive weed invasion. However, monitoring in 2005 indicated that there was again a dense, impenetrable growth of ferns and few weeds in the spring area.

Occurrence 2 consists of a series of permanent springs flowing from a large area of peat mounds. Water oozes from the whole surface of the mounds and from discrete channels (Jasinska and Knott 1994). Low reeds, rushes, liverworts and club mosses cover the mounds. The dune to the west, covered with *Banksia* woodland, is probably part of the catchment. A pine plantation occurs further west again. The water from the springs forms a stream that then feeds into a dam.

The vegetation to the west of Occurrence 2, including the dune, is planned for residential development with approximately 3.6 ha of uncleared vegetation to be left within and surrounding the occurrence. The clearing and possible leveling of the dune may impact the hydrology of the mound springs as it is believed that the dune may currently contribute to the hydraulic pressure of the water flowing to the springs. The mound spring and associated small buffer is intended to be set aside as public land and will, initially at least, be vested with WAPC, and managed by CALM.

Occurrence 3 is located in the southern portion of Bush Forever site 97. It consists of a large series of mainly solid peat mounds with very small patches of bog (about 1 - 4 $m^2$) immediately surrounding some of the more active spring discharges that support tall trees, bracken fern and dense mats of tall sedges. A narrow (1 - 4 m wide) strip of boggy ground provides shallow (1 - 10 cm deep) permanent water near the eastern margin of the spring area. Some of the peat mounds appear to have been burnt through and now occur as deep holes in the line of springs. The catchment is likely to include *Banksia* woodland on a dune to the west (within the Nature Reserve).

Occurrence 4 is located in the northwest corner of Bush Forever site 97. The spring is part of Bush Forever site 97 (immediately north of Neaves Nature Reserve and Occurrence 3). The property has been subdivided into two lots, with Lot 800, containing Occurrence 4, purchased by Western Australian Planning Commission (WAPC) in February 2004. Management of the bushland will be transferred to CALM in the future.

Occurrence 4 is more open and flat than the previous occurrences and contains no ferns. Vegetation consists mainly of *Melaleuca preissiana* over *Agonis linearifolia, Astartea fascicularis, Baumea juncea* and *Baumea articulata*. The bushland that contains occurrence 3 and 4 is contiguous and is contained within the same Bush Forever site.

**Biological and ecological characteristics**

The tumulus springs are permanently moist, and some are also associated with permanent pools and surface water. Many of the invertebrate animals and the vascular and non-vascular plant species present are adapted to this permanent moisture and the areas probably act as refugia from climate change (drying) for certain species (Jasinska and Knott 1994). Some of the invertebrate species do not have dormant stages and would not survive if the peat mounds were to dry out. In particular, Jasinska and Knott (1994) identified an amphipod that is the only known species of a newly discovered genus that is a Gondwanic relic, in the tumulus springs at Egerton. Water quality decline, for example through excessive nutrient input, is also a likely threat to the survival of some of the tumulus spring species.

Species lists, including vascular and non-vascular plants and invertebrates for the remaining intact mound spring areas are at Appendices 1, 2, and 3.

A number of non-vascular plants were historically recorded in Occurrence 1, and have more recently been located in Occurrence 2 (Jasinska and Knott 1994; see Appendices 1 and 2). Some of these taxa are significant as they usually only occur in the far south-west of the State (Jasinska and Knott 1994), but can occur in the spring areas as a result of the permanently moist microenvironment, and possibly due to other specific conditions associated with the sites. These taxa have not been recorded recently from the Faull Street reserve, possibly as a result of too frequent hot fires, grazing and other disturbances.

The presence of *Hibbertia perfoliata* in Occurrences 2 and 3 is of particular significance as it was historically recorded for the Swan Coastal Plain, but until recently was believed to have become extinct in that area (G. Keighery[3] personal communication). It seems the taxon can only survive on the Swan Coastal Plain in permanently wet thickets where disturbance levels are relatively low. Such areas have almost completely disappeared from the Swan Coastal Plain although they are still relatively common in the Jarrah forest - a stronghold of *Hibbertia perfoliata*.

**Hydrology**

Hydrological information on the tumulus springs is somewhat limited as the hydrology has only been investigated in any detail at Occurrence 3. The springs are believed to be fed by a complicated network of conduits whose conformation has been determined by the geology of the stratum where the clays of the Guildford Formation interdigitate with the sands of the Bassendean Dunes. Evidence for the underground flow being in confined conduits is provided by large pieces of material, for example, the carapaces of crustaceans, that bubble up in the spring waters (E. Jasinska personal communication). Also, the pressure required to push water through the peat mounds could presumably only originate from confined flow and not from diffuse groundwater sources (J. Kite[4]; A. Davidson personal communication). The presence of complicated channels is inferred from the fact that springs have apparently dried up and re-emerged some distance away, when spring flow is interrupted. This can occur when springs are excavated (Ahmat 1993). This suggests the springs emanate from a series of channels, and diversion to an alternative path of least resistance can occur (Jasinska and Knott 1994). Also, anecdotal information indicates that during excavation of one spring area the earthworks exposed ‘rabbit burrow-like’ conduits carrying loose sand and water within the Guildford Clay layer.

The top of the Gnangara Mound is located to the west of the springs. Water flows in a number of directions from this point, including eastwards, and supplies the groundwater to the springs. It is essential that the level of the watertable in the Gnangara Mound provides an adequate head of pressure to drive the springs. The local hydrologic pressure created in parts of the aquifer within the dunes adjacent to each of the spring areas is also likely to be significant in terms of maintaining the spring flow (E. Jasinska, A. Davidson personal communication). Rainfall falling on the dunes adjacent to the springs would be involved in recharge of the local conduits feeding the springs (E. Jasinska, A Davidson personal communication). The maintenance of the flora and fauna of the tumulus springs is therefore also likely to depend on maintaining the quality of the water of the Gnangara Mound and of the local water mounds in dunes adjacent to each of the spring areas.

A trend of falling water tables in the general area is evident since around 1976 (Greay 1993). A corresponding decline in annual rainfall since around 1976 has contributed to this lowering of watertables, by contributing to drawdown of the superficial aquifer, the Gnangara Mound to the

[3] Greg Keighery, Senior Principal Research Scientist, CALM, Woodvale
[4] Jeff Kite, previously Water and Rivers Commission

west. The previous owner of the recently gazetted reserve on Faull Street, Muchea noted that some of the springs on the property had dried up in living memory, probably as a result of decline of the water table (Ahmat 1993).

The area in which the tumulus springs occur is characterised by much valued heavy soils, which were historically extensively cleared for agriculture. Clearing is likely to have increased surface runoff and recharge of the groundwater in the localised area and may have acted to counteract drawdown to some extent. The springs on the Faull Street reserve are located on the Muchea townsite lots. There is little uncleared vegetation remaining there, however, so that additional recharge of the superficial aquifer as a result of further clearing for development in the localised area is unlikely. Changes in the level of the water table are very likely to influence the hydrology of these wetlands as they are likely to be almost entirely dependent on groundwater for water supply. This issue is discussed further under threatening processes.

The groundwater supplying Occurrence 1 is likely to flow mainly from the west, and possibly with some contribution of flow from the north (E. Jasinska personal communication). The main water supply for the springs within the reserve is likely to be deep below the surface and from the local water mound in the denuded dune to the west that is also part of the Nature Reserve (A. Davidson personal communication). Land management practices on this land and possibly other land adjacent to the west therefore have the potential to influence the quality and quantity of water supplied to these springs. Deep-rooted vegetation such as trees that originally occurred on the dune in the reserve would probably have drawn relatively large quantities of water from this local groundwater mound. A balance between loss of water through transpiration and gaining water through increased infiltration needs be determined for appropriate management of these dunes. Such hydrologic considerations needs to be considered in planning the revegetation of such dunes.

A line of highly degraded peat mounds occurs to the north of the reserve area that contains Occurrence 1 and links to those on the reserve. A dense area of the non-local tree, *Eucalyptus camaldulensis* (river gum) occurs on these peat mounds and may be drawing larger quantities of water than the original vegetation.

The supply of groundwater to the tumulus springs at Occurrence 2 is likely to be mainly from the west, with the pressure head and recharge being supplied by the dune to the west of the springs (E. Jasinska, A. Davidson personal communication). A seasonal wetland occurs to the east of this dune, with the tumulus springs further east again. Groundwater flowing from the dune is likely to move in the general direction of the wetland in between the springs and the dune, and on towards the springs, confined under clay layers within conduits (E. Jasinska personal communication). Residential development is currently proposed for the area and it is likely that the dune will be leveled or removed. Major earthworks that may sever conduits supplying water to the springs, and abstraction of groundwater in the vicinity of the dune, the seasonal wetland or within the spring area have the potential to severely disrupt water supply to these tumulus springs.

The supply of groundwater to Occurrence 3 appears likely to be mainly from the west. Groundwater abstraction near the springs, or within the springs themselves, has the potential to severely affect flows. Preliminary study by S. Burton[5] (Groundwater Consulting Services 2002) has found that the spring overlies at least 5m of clean quartz sand (Bassendean Sand), which grades into silt of the Guildford Formation in the eastern part of the Reserve. A layer of peat occurs throughout the low lying area, and can be up to 4m thick (but averages 1 to 1.5m thick). Two discrete aquifers occur within the spring area, separated by an unidentified low-permeability unit. High groundwater levels occur to the west in an unconfined sandy aquifer, which is probably recharged by direct infiltration

[5] Sam Burton, Managing Director, Groundwater Consulting Services Pty Ltd

of rainfall, where *Banksia* woodland occurs on a dune (A. Davidson personal communication). This aquifer appears to contribute to spring flow based on groundwater table elevations. Groundwater levels in the east (in the sand aquifer underlying the peat) range from over 1m below ground to 0.3m above ground, and are below the elevation of the spring. Seasonal changes in groundwater levels may induce discharge in other areas (Groundwater Consulting Services 2002).

**Habitat critical to the survival of the community, and important occurrences**

The habitat critical for survival of the Mound Springs community comprises:

- the area of occupancy of known occurrences;
- areas of similar habitat within 200 metres of known occurrences, i.e. areas of continuous discharge of groundwater in raised areas of peat at the junction between the Bassendean Sands and the Guildford clays;
- remnant vegetation that surrounds or links occurrences (this is to provide habitat for pollinators or to allow them to move between occurrences); and
- the local catchment for the surface and groundwater that maintain the habitat of the community (the community would be dependent on maintenance of the local and regional hydrological conditions).

Given that the community is listed as Critically Endangered, it is considered that all occupied habitat is critical to the survival of this community, and all known occurrences are important.

**Benefits to other species/ecological communities**

Recovery actions implemented to improve the quality or security of the community are likely to improve the status of any species within the community. No associated species are separately listed as Threatened under State or Commonwealth legislation.

## International obligations

This plan is fully consistent with the aims and recommendations of the Convention on Biological Diversity, ratified by Australia in June 1993, and will assist in implementing Australia's responsibilities under that convention. The community is not listed under any specific international treaty, however, and therefore this IRP does not affect Australia's obligations under any other international agreements.

**Role and interests of indigenous people**

An Aboriginal Sites Register is kept by the Department of Indigenous Affairs, and lists one camp site occurring in the vicinity of Occurrence 2. Implementation of recovery actions under this plan includes consideration of the role and interests of indigenous communities in the region.

**Social and economic impacts**

Occurrence 2 is located on private property that is currently under residential development. Negotiations with the private owner resulted in the mound springs and a small area surrounding it to be set aside as public open space. Negotiations will continue with the land owner to help protect the occurrence.

Occurrence 4 occurs adjacent to private property where an annual four wheel drive gymkhana is held which could have adverse affects on water quality at the springs. Negotiations will continue

with the adjacent land managers and regulatory authorities with respect to the future activities and impacts to this occurrence.

The implementation of this recovery plan has the potential to have some social and economic impact, where occurrences are located on and adjacent to private property. Recovery actions refer to continued liaison between stakeholders with regard to these areas.

**Affected Interests**

Occurrences of the Organic Mound Springs are within the Local Government Authority of the City of Swan. They occur on land managed by CALM, the WAPC, and on private land. Potentially affected landholders are the developers of land on which Occurrence 2 occurs, and possibly the owners of land adjacent to all occurrences, but Occurrence 4 in particular.

**Evaluation of the plan's performance**

The Department of Conservation and Land Management will evaluate the performance of this IRP in conjunction with the Recovery Team. In addition to annual reporting on progress with listed actions and comparison against the criteria for success and failure, the plan is to be reviewed within five years of its implementation.

**Historical and current threatening processes**

**Clearing**

Clearing for agriculture has been extensive on the heavy soils on the eastern side of the Swan Coastal Plain, with some 97% of all vegetation in the area cleared historically (Keighery and Trudgen 1992; CALM 1990). In particular, the tumulus springs on heavy soils were often perceived as a nuisance to farming practices as they were excessively wet and boggy. Consequently, almost all of these springs have been cleared, leveled, packed with limestone and planted with kikuyu grass, excavated and dammed, or the spring brooks dammed (Ahmat 1993).

Occurrence 1 is now contained within a reserve that is under the care, control and management of the Conservation Commission for 'Conservation of Flora and Fauna'. Occurrence 2 is planned to be set aside as Open Space adjacent to an extensive urban development. Occurrence 3 was purchased with CALM and Commonwealth Government funds and is now part of the Neaves Road Nature Reserve. Occurrence 4 has been purchased by the WAPC as part of a Bush Forever site. It is planned that in future the bushland that contains Occurrence 4 will be managed by CALM.

Dunes of varying sizes occur on the western side of three of the four remaining vegetated tumulus spring areas. Each of these is likely to provide important recharge areas, and to be involved in providing the hydraulic pressure head for the adjacent spring area. In addition, two of the dunes adjacent to spring areas are still vegetated (Occurrences 2 and 3) and vegetation is likely to be important for moisture retention and water percolation into the sands. However, the *Banksia* woodland vegetation on the dune to the west of Occurrence 2 is to be cleared and this may alter the hydrology of the springs, as may the possible leveling of the dune, as mentioned. Vegetation, especially deep rooted plants such as trees, would draw on the local groundwater where roots could tap into this source.

In the case of Occurrence 1 the dune to the west has been largely denuded by a combined process of grazing and possibly dieback deaths and drought. Under normal circumstances, rainfall intersecting the dune surface contributes to recharge of the local groundwater mounds. However, the sands can become hydrophobic when dry and in the absence of vegetation, or following destruction of

vegetation by fire (A. Davidson, E. Jasinska personal communication). In this situation, most of the rainfall would drain off the dune as surface runoff and therefore not contribute to the groundwater recharge. Regrowth of native vegetation may help enhance penetration of rainfall in these circumstances (A. Davidson, personal communication).

Plant species can also contribute to the hydrophobic nature of soils (A. Davidson, personal communication). Introduced grasses, such as Veldt grass (*Ehrharta calycina*) that has established in the reserve containing Occurrence 1, causes soils to repel water and should be kept away from the spring areas themselves and the adjacent dunes.

**Water levels**

The flora and fauna that inhabit the tumulus springs are likely to be entirely dependent on the permanent supply of fresh water (E. Jasinska, personal communication). As mentioned, some of the tumulus springs in reserve 46622 on Faull Street have dried up relatively recently. This is possibly due to local groundwater drawdown, but is probably exacerbated by declining rainfall due to climate change, and an overall decline in the Gnangara Mound that feeds the springs.

There are currently no obvious large groundwater abstraction occurring in the springs' recharge zone (J. Kite, personal communication). Conservation of the discharge areas of each of the springs requires continuing function of the recharge areas to provide adequate water of appropriate high quality (Ahmat 1993). Controls on groundwater abstraction and minimising pollution of the groundwater, exercised through planning and impact assessment, are therefore essential for the conservation of the springs.

As mentioned in the previous section, proposed clearing of vegetation and possible leveling of the dune west of Occurrence 2, as part of a residential development, has the potential to alter the hydrology of this spring area.

Actual groundwater use (i.e. timing and amount of groundwater abstraction), in the vicinity of each of the spring areas needs to be determined. Significant groundwater use close to the springs has the potential to impact the springs as a consequence of groundwater drawdown.

**Water quality**

Where animal droppings and other nutrient sources can contaminate surface or groundwater entering the springs, enhanced nutrient levels are likely to favor weed invasion and possibly alter water quality such that some components of the fauna cannot survive. Nutrient input is most likely to be from very localised areas in the case of surface flow into the springs, so landuse in areas close to the springs may also be very important for conservation of the water quality. On the other hand it may be possible for sources of pollution to enter the groundwater that eventually enters the springs from sources much more distant.

Some activities associated with a four wheel drive Gymkhana event that occurs adjacent to Occurrence 4 have the potential to adversely impact water chemistry. The event involves excavations for water traps, possibly into the shallow groundwater table. The traps are within 45 meters of the boundary of Occurrence 4 and hydrocarbon contamination of the water in these traps is likely to directly affect water quality through hydraulic connection with the groundwater (S. Burton personal communication). Hydrocarbon contamination is possible by driving vehicles with oily engine bays through water traps, washing down of vehicles, refueling and servicing spills or inappropriate disposal or losses through vehicle impact or other damage.

**Grazing**

The tumulus springs of Occurrence 1 have been subject to intermittent grazing, as they were previously located in a paddock that supplied permanent rich pasture. Grazing is likely to have caused alterations to the species composition through the selective grazing of edible species, the introduction of weeds as a consequence of disturbance and increased nutrients from animal droppings, and through general disturbance. This may well have contributed to the decline of non-vascular plants that were recorded historically in Occurrence 1 (refer Appendix 1).

Occurrence 2 does not appear to have been grazed historically (G. Keighery personal communication).

The tumulus springs on Occurrence 3 may have historically been subject to grazing, but no stock are currently kept in the fenced area adjacent to the springs. This spring area is covered in extremely dense vegetation that would be relatively impenetrable to stock. Following fires, however, the dense vegetation cover would have been destroyed, and stock would have been able to graze the area. This occurrence is now fenced from stock.

Occurrence 4 may have been accessible to stock prior to purchase in 2004. Following the purchase of the land, the spring and vegetated buffer were re-fenced in April 2004 to exclude stock.

**Increased weed invasion**

As mentioned above, grazing alters species composition through selective foraging, and causes increased weed invasion. The two major weed species in the tumulus springs in the Faull Street reserve are *Isolepis prolifera* (budding club-rush) and *Pennisetum clandestinum* (kikuyu). The tumulus springs of Occurrence 3 are relatively weed free, but weeds are encroaching at specific points, possibly where levels of disturbance have historically been higher. *Rubus* sp. (blackberry) and *Ficus carica* (fig) occur immediately adjacent to the springs and some *Isolepis prolifera* occurs on the mounds themselves.

A weed control program is necessary to maintain or improve the current condition of occurrences of the community in the long term. Panetta and Hopkins (1991) state that the aims of weed control are to maintain the pre-invasion condition of the habitat (prevention); control or arrest ongoing weed invasion (intervention); and reverse the degraded condition of the habitat where applicable (rehabilitation).

The highest priority will be to control weeds, in the early stages of invasion where possible, that pose the greatest threat to the community, eg *Isolepis prolifera* at Occurrence 3, some perennial grass weeds and *Watsonia*. Appropriate methods of weed control are found in Brown and Brooks (2002) and may include hand weeding or localised application of herbicide.

**Altered fire regimes**

Fires are likely to have a significant effect on vegetation composition in Mediterranean ecosystems (Abbott and Burrows 2003). It is also likely that the fire regime around each of the spring areas has been altered since European settlement, especially those located in agricultural areas (Occurrences 1, 3 and 4). Stratigraphic coring of the peat would help elucidate the fire history of these springs.

The wetland vegetation associated with the springs is likely to be less adapted to very hot fires than upland vegetation as the sites are permanently moist and are unlikely to have burnt as readily. In addition, the build up of peat makes the areas very prone to fires that occur in very dry seasons that

are capable of destroying the peat mounds themselves. An increase in the frequency of hot fires is likely to pose a significant threat to the wetland-adapted flora and fauna.

As this community is not well studied, little is known of the community's requirements in terms of fire regime to maintain plant species composition. As fires can destroy the peat mounds, however, it can be assumed that conservation of the communities depends on hot fires being excluded during seasons when the mounds are drier and are flammable.

The risk of fire is increased by the presence of grassy weeds in the understorey at the Faull Street reserve site (Occurrence 1), as they are likely to be considerably more flammable than the original native species in the understorey.

**Dieback**

It is not known if the community type is susceptible to dieback disease caused by *Phytophthora* species. However, the plants that inhabit the tumulus springs themselves are largely species that are thought not to be sensitive to dieback. In particular, *Melaleuca preissiana* and the sedges that dominate the community are not dieback sensitive (Helyar 1994). *Hibbertia perfoliata* is listed as a dieback indicator on the Swan Coastal Plain by Helyar (1994), however, and therefore may be susceptible to the disease in that area.

*Banksia* woodlands occur on the dunes to the west of Occurrences 1, 2 and 3. As mentioned, these dunes are likely to be important in maintaining the local hydrology of the springs. *Banksia* trees are deep rooted species that are likely to draw on local groundwater. *Banksia* communities are very susceptible to dieback caused by *Phytophthora* species and are often severely affected by its introduction. Loss of *Banksia* and other dieback susceptible species may actually increase local groundwater recharge unless they are replaced with species that increase the hydrophobic nature of the soil, as has occurred at the Faull Street reserve with the introduction of Veldt-grass. Dry, bare sand as occurs in parts of the dune adjacent to Occurrence 1 is also strongly hydrophobic, however. Replacement of the *Banksia* woodlands adjacent to the springs with species that use more water, such as taller trees, may also impact the springs through drawdown of the groundwater table.

The dune to the west of the springs in the Faull Street reserve has been severely degraded, presumably initially through clearing, then from continued loss of juvenile plants through grazing. Dieback may also have impacted the Banksia community by killing mature and juvenile individuals of susceptible species.

Risk of introduction or further spread of disease will be minimised by ensuring good hygiene procedures at all occurrences. This would help ensure that current hydrological regimes are maintained in groundwater in dunes close to the springs. Such hygiene procedures involve washdown of any equipment and footwear prior to undertaking works in the remnant vegetation surrounding the community, as well as within the springs themselves.

**Evaluation of the Plan's Performance**

CALM, in conjunction with the Swan Region Threatened Flora and Communities Recovery Team will evaluate the performance of this Interim Recovery Plan. The plan is to be reviewed within five years of its completion.

### 1.2 Conservation status

The community meets the following criteria for Critically Endangered (CR) ecological communities:

B) Current distribution is limited, and the following apply (i, ii):

i) geographic range and/or number of discrete occurrences, and/or area occupied is highly restricted and the community is currently subject to known threatening processes which are likely to result in total destruction throughout its range in the immediate future (within approximately 10 years);

ii) there are very few occurrences, each of which is small and/or isolated and extremely vulnerable to known threatening processes.

### 1.3 Strategy for recovery

- To identify, and influence the management of, the areas in which the community occurs, so maintaining natural biological and non-biological attributes of the sites and the current area covered by the community.

- To conduct appropriate research into the ecological characteristics of the community to develop further understanding about the management actions required to maintain or improve the condition of the community.

## 2. RECOVERY AIM AND CRITERIA

**Objective**

To maintain or improve the overall condition of the tumulus springs and the associated fauna and plant community in the known locations and reduce the level of threat, with the aim of reclassifying the community from Critically Endangered to Endangered.

**Criteria for success**

An increase of 10% or more in the area, and/or increase in the number of occurrences of this community under conservation management.

Maintenance in terms of diversity and basic composition of native invertebrate species (as described in Ahmat 1993; Jasinska and Knott 1994; Pinder 2002) taking account of natural change in the community over time. This will be measured as a loss of no more than 10% of the native invertebrate species in any one spring over the life of the plan.

Improvement in the condition of the habitat, in terms of re-establishment of fringing buffer vegetation, reduction of numbers of exotic species and of other threatening processes as defined in this document. This will be measured as follows:

- a gain in the area of buffer vegetation under conservation management adjacent to the springs of 10% or more,
- reduction of 10% or more in the cover of exotic plant taxa in the springs or buffer areas,
- groundwater levels and quality maintained within the parameters expected as a consequence of natural change, by comparison with monitoring results for the Gnangara Mound in areas remote from development.

**Criteria for failure**

A decrease of 10% or more in the area covered by the springs, and/or decline in the number of occurrences of this community under conservation management.

A decline in terms of diversity and basic composition of native invertebrate species (as described in Ahmat 1993; Jasinska and Knott 1994; Pinder 2002) taking account of natural change of the community over time. This will be measured as a loss of more than 10% of the native invertebrate species in any one spring over the life of the plan.

Decline in the condition of the habitat, in terms of loss of fringing buffer vegetation, increase in numbers of exotic species and other threatening processes as defined in this document. This will be measured as follows:

- a decline in the area of buffer vegetation under conservation management adjacent to the springs of 10% or more,
- increase in the cover of exotic plant taxa in the springs or buffer area of more than 10%,
- groundwater levels and quality not maintained within the parameters expected as a consequence of natural change, by comparison with monitoring results for the Gnangara Mound in areas remote from development.

## 3. RECOVERY ACTIONS

Note: The responsible authority is frequently listed as the relevant CALM District. This refers largely to initiating and guiding actions. However, in general the relevant CALM District, in cooperation with the Species and Communities Branch (SCB) and the Recovery Team has the primary responsibility for securing funds for recovery actions.

**Future Recovery Actions**

### 3.1 Coordinate recovery actions

The Swan Region Threatened Flora and Communities Recovery Team (SRTFCRT) will coordinate recovery actions for the Tumulus Springs and other TECs and Declared Rare Flora in their Region. They will include information on progress in their annual report to CALM's Corporate Executive and funding bodies.

**Responsibility**: Swan Region Threatened Flora and Communities Recovery Team
**Cost**: $1,000 pa
**Completion date**: Ongoing

### 3.2 Map habitat critical to survival

It is a requirement of the EPBC Act that spatial data relating to habitat critical to survival be determined. Although this habitat is described in Section 1, the areas as described (other than the area of the actual occurrences, see 3.3 below) have not yet been mapped and that will be redressed under this action. If any additional occurrences are located, then habitat critical to survival will also be determined and mapped for these locations.

**Action**: Map critical habitat
**Responsibility**: CALM (Swan Coastal Region, SCB) through the Recovery Team
**Cost**: $2,000
**Completion date**: First year

### 3.3 Clarify and continue to monitor the extent and boundaries of the community

The extent of all known occurrences have been mapped from on-ground survey and aerial photographs.

The extent of occurrences will be monitored every two years. Boundaries can be determined from current aerial photographs and minimal on-site checking. This information will be added to the threatened ecological community database as recommended in English and Blyth (1997).

Likely habitat has been searched extensively for additional occurrences of the community, particularly on the edge of the Commonwealth bombing range, without success (E. Jasinska personal communication). Such areas will be further surveyed for the community on an opportunistic basis.

**Responsibility**: CALM (Swan Coastal District; SCB) through the Recovery Team
**Cost**: $500 every second year
**Completion date**: Ongoing

### 3.4 Liaise with current land owners, land managers and other interested groups to implement recommendations held in this IRP

Owners of land that contains the mound springs were officially informed of the presence of a TEC on their land in March 2005.

Currently, only one of the four existing occurrences of the community is privately owned (Occurrence 2), however, other occurrences may be located on private land. Therefore, the involvement of land managers, local community groups and industry in the recovery of the community wherever possible and practical is essential to the recovery process. Input and involvement will also be sought from any Indigenous groups that have an active interest in areas of the community.

**Responsibility**: CALM (Swan Coastal District; SCB) through the Recovery Team
**Cost**: Costs of all liaison for occurrences of this community $1,000 pa (not including vehicle costs)
**Completion date**: Ongoing

### 3.5 Disseminate information about the community

To seek knowledge of other occurrences, prevent accidental destruction and gain public support for its conservation, information about the community will be provided by local CALM staff to all stakeholders including landholders, and managers of land that contains the community. This would include information from the threatened ecological community database, and maps indicating the location of the community. Information about private land will only be provided to the landholder, unless permission is granted by the landholder to allow wider dissemination of the data. This action is recommended in English and Blyth (1997).

Local CALM staff will ensure regular liaison with owners of land that contains the community to ensure threatened ecological community information is up to date.

A publicity campaign utilising signs on site, and local media and poster displays in prominent areas, will be undertaken to encourage awareness about this threatened ecological community. Information on the community has been included in conservation magazines (Blyth and English 1996; Cresswell *et al*. 1996) and in a brochure on ‘Threatened Ecological Communities of the Swan Coastal Plain Bioregion’.

Visitors to the sites that contain occurrences will be provided information about the impact of dieback and procedures to avoid spreading the disease. This may include the use of signs on site, and interpretive information.

**Responsibility**: CALM (Corporate Relations Division Perth, Swan Coastal District; SCB) through the Recovery Team
**Cost**: $500 pa
**Completion date**: Ongoing

### 3.6 Monitor water levels and quality

The water levels and quality have been monitored since the endorsement of the previous IRP. Water samples were analysed from Occurrence 1, 2, and 3, as part of fauna sampling in 2002 (Pinder 2002). Additional water samples were collected and analysed from Occurrence 4 in October 2004 as part of water quality monitoring before and after a four wheel drive gymkhana was held on adjacent land. Two water samples were taken 1 week before, 1 day and 2 weeks after the event. Levels of hydrocarbon contamination were found to be insignificant in these samples. Monitoring bores have also been installed at Occurrence 3 as part of a shallow hydrogeological study of the spring (S. Burton, personal communication).

Water levels and quality will be monitored regularly for changes that may result in adverse effects on the springs (ie. falling groundwater levels resulting in drying out of springs). Placement of additional bores outside the perimeter of the springs at Occurrences 1 and 3 would supplement other information collected. Groundwater levels are routinely monitored by Department of Environment (DoE, previously Water and Rivers Commission) in specific areas of the Gnangara Mound and data for areas close to the occurrences of the community will be analysed.

**Responsibility**: CALM (Swan Coastal District) in collaboration with DoE, owners of spring areas and adjacent landholders, through the Recovery Team
**Cost**: Costs to be determined
**Completion date**: Ongoing.

### 3.7 Manage water quality and quantity

Any developments or activities that would adversely impact the quality or quantity of the groundwater supply to the spring areas will ideally be avoided. This will require liaison with regard to the maintenance of water supply from the Gnangara Mound itself.

Activities to be avoided include those that would impact on groundwater supply, in particular direct abstraction from conduits supplying the mounds (these are probably mainly to the west, but possibly also to the north of spring areas); avoidance of pollution of groundwater by overuse of fertilisers, herbicides and pesticides on surrounding lands or as caused by inadequate drainage control; prevention of major earthworks that have the potential to sever conduits that carry the groundwater to the mounds; and seeking to help prevent leveling of the dunes to the west of each of the springs to help maintain current hydrological regimes. Developments such as rubbish dumps and petrol stations that may pollute groundwater will ideally also be avoided in catchment areas for the springs.

Continual liaison with organisers of the four wheel drive Gymkhana that is planned as an annual event adjacent to Occurrence 4 is required to help minimize any possible impacts to the water supply to the springs. The quality of water entering Occurrence 4 will be monitored before and after each event.

**Responsibility**: CALM (Swan Coastal District) in liaison with DoE, West Australian Planning Commission (WAPC), surrounding landholders

**Cost**: Costs of liaison included in 3.4; other costs $1,000 pa
**Completion date**: Ongoing.

### 3.8 Monitor the flora and fauna of tumulus springs

Over the last few years, it has been noted that patches of ferns within Occurrence 3 were dying. The deaths were investigated but the cause could not be determined. Possible causes include water drawdown, reduced water quality, herbicide use for weed control, or the impacts of trampling. The fern deaths will be continually checked as part of the monitoring program.

Monitoring data collected will include weed levels, plant species diversity, and species composition of flora and fauna (including macro-invertebrates).

A comprehensive survey of vascular plants or weed levels has not been undertaken for any of the spring areas, and is essential for future comparison. Fauna survey has been conducted on Occurrences 1, 2 and 3 by Jasinska and Knott (1994), Jasinska (1998) and Pinder (2002) (see Appendix 1-4 for species lists). A fauna survey is required for Occurrence 4.

The most recent survey conducted in December 2002, monitored invertebrate fauna, and analysed water quality at Occurrences 1-3 (Pinder 2002). New species were recorded for the springs but a lower number of species were collected compared to Jasinska and Knott (1994) and Jasinska (1998). This was predictable as the springs were only sampled once in the 2002 monitoring, and sampling was undertaken at the beginning of summer when water levels were low.

Occurrences will be monitored every two years to provide information on condition. However, if fauna monitoring appears to be depleting the spring fauna, or damaging vegetation, then this frequency will be decreased. This faunal information will be added to the threatened ecological community database as recommended in English and Blyth (1997).

Floristic plots will be placed in all occurrences (a total of 4 plots). Data on all native and weed species, and density or cover values for each species would be essential for determining changes over time (e.g. as a result of too frequent fire or deaths due to drought). Line intercept and photographic methods may be suitable to monitor these parameters.

**Responsibility**: CALM (Swan Coastal District; SCB); in collaboration with DoE, through the Recovery Team
**Cost**: $3,500 every second year (for flora monitoring - total of 4 plots in the community) for field survey, specimen identification, and databasing for 1 monitoring period. $5,000 in Year 1 for one monitoring period for fauna survey, water analysis and reporting.
**Completion date**: Ongoing

### 3.9 Develop and implement Fire Management Plans that encompass actions 3.9.1 - 3.9.4

#### 3.9.1 Develop fire management plans to ensuring peat mounds do not burn, and to reduce weed invasion

There is a need for research into recovery of the community from wild fires, and to determine the implications of findings for management. For example, Occurrence 1 was burnt in a hot fire in 1995 and most of the understorey was destroyed. There has been no monitoring of flora or fauna at this occurrence since the fire. Information on the recovery of the springs would be useful for future management if fire was to occur in this or other occurrences.

Since the implementation of the first IRP, no fires have occurred within any of the occurrences. No fires will be planned for the springs themselves for the term of this IRP. This will be achieved by appropriate fire management that may include a regime of infrequent cool burns around the perimeter of the mounds to create a buffer of low fuels around the extremely fire sensitive peat mounds. Care will be taken not to further degrade the wooded dune to the west of Occurrences 1-3 as those areas are likely to be important for maintaining the hydrology of the springs.

Currently, a draft fire response plan is being used, however, the full response plan will be completed by the end of 2005. CALM currently responds to fires on or near the reserves as per the Swan Coastal District Standard Operating Procedure.

**Responsibility**: CALM (Swan Coastal District; SCB), WA Fire and Emergency Services Authority, Local Government Authorities, volunteer Bush Fire Brigades, in liaison with all stakeholders, through the Recovery Team
**Cost**: Cost of plan development $2,700
**Completion date**: Ongoing

#### 3.9.2 Ensure maintenance of appropriate strategic firebreaks to help prevent fire spreading to the spring communities

Firebreaks have been established at Occurrences 1, 3 and 4. Strategic firebreaks were constructed around the tumulus springs at Occurrence 3 (~June 1996) with hire of machinery funded by CALM (subsidised by City of Swan), and volunteer labour provided by the Bullsbrook Volunteer Bushfire Brigade.

Firebreak maintenance in the bushland around Occurrence 4 was undertaken in December 2004 however, it was done poorly. The firebreaks were widened unnecessarily, small hill rows remained after maintenance, and spoil was pushed into the bushland. This will be repaired and procedures will be put in place to ensure this does not recur.

Maintenance of existing firebreaks is appropriate where firebreaks are already constructed, unless maintenance is likely to cause spread or intensification of dieback or otherwise degrade the community. Local CALM staff will be involved in planning the construction and maintenance of firebreaks for all occurrences of the community.

No new firebreaks will be constructed or existing breaks upgraded around occurrences of this community on CALM-managed lands unless they are provided for in an authorised fire response.

**Responsibility**: CALM (Swan Coastal District), landholders, through the Recovery Team
**Cost**: Cost of firebreak maintenance $1200 pa; Costs of liaison included in 3.4
**Completion date**: Ongoing.

#### 3.9.3 Liaise with surrounding landholders to ensure strategies for fuel reduction on their lands do not impact the community

In particular, there should be no earthworks to construct firebreaks on degraded mounds to the north of the spring areas in reserve 46622 or adjacent to Occurrence 3 and 4 as such works may sever conduits supplying water to the springs; and controlled burns that may become wildfires in drier conditions and result in the peat mounds being burnt, should be avoided.

**Responsibility**: CALM (Swan Coastal District); liaison with surrounding landholders, through the Recovery Team

**Cost**: Costs of liaison included in 3.4
**Completion date**: Ongoing.

### 3.9.4 Ensure fire suppression strategy does not impact community

CALM is responsible for fire management on land managed by CALM outside the metropolitan gazetted fire district, while Fire and Emergency Services Authority (FESA) is responsible for managing fires in gazetted areas and non-CALM-land.

Fire fighting authorities will be provided information to ensure that they recognise the importance of not constructing new tracks during their operations, including during wildfires in or near these springs. The use of heavy machinery to create new fire breaks, or to upgrade old breaks within the community will ideally be avoided as additional disturbance would encourage further weed invasion and could damage water conduits. Further, retardant chemicals that may be toxic to any part of the community should not be used. Guidelines for appropriate fire suppression actions will be developed.

A fire response plan will be developed for all occurrences under Action 3.9.1, and CALM staff will be present during wildfires and controlled burns in remnants that contain occurrences of the community, to advise on protecting the conservation values of the community.

**Responsibility**: CALM (Swan Coastal District); liaison with local Bush Fire Brigades and FESA, through the Recovery Team
**Cost**: Costs of liaison included in 3.4; additional funds for CALM District staff to attend wildfires in the community $500 pa
**Completion date**: Ongoing

### 3.10 Ensure earthworks near the springs do not impact the community

CALM staff will liaise with relevant landholders to ensure earthworks near the springs and on adjacent lands that may impact the hydrology are avoided. For example, leveling or performing earthworks on adjacent lands, in particular on the denuded mounds to the north of springs on reserve 46622 and north of Occurrence 3 may impact the flow to the mounds.

Existing planning and environmental assessment procedures will be used to ensure no earthworks occur on the peat mounds or in adjacent areas that are likely to contain conduits carrying water to the springs. There will be no clearing of springs or unnecessary clearing in the adjacent remnant vegetation buffers. In the case of Occurrences 2, negotiations will occur as part of Action 3.18.

**Responsibility**: CALM (Swan Coastal District) in liaison with Department of Environment (DoE) and WAPC; liaison with landholders, through the Recovery Team
**Cost**: Costs of liaison included in 3.4
**Completion date**: Ongoing.

### 3.11 Design and conduct research

Considerable research has been conducted on the hydrology of the Gnangara Mound by the Water Corporation and Water and Rivers Commission (now Department of Environment). Such work indicates that the continuing fall in water levels in the Gnangara Mound are a result of interaction between declining rainfall, large pine plantations and water abstraction for public supply and commercial horticulture.

Preliminary hydrological research was conducted by Groundwater Consulting Services (2002). Shallow bores (to a depth of 5 m) were established within Occurrence 3 in 2004 to conduct a shallow groundwater investigation. Groundwater Consulting Services found that this mound spring consisted of two discrete aquifers, however, the hydrology of Occurrence 3 was not fully elucidated and requires additional investigation. If additional bores are required, the damage to the vegetation at the springs will be minimized. Further hydrological work is planned.

Future hydrogeological investigation will be focused on Neaves Nature Reserve, where bores are already *in situ*, as any additional bores at other sites may cause unnecessary disturbance to the other occurrences. Groundwater levels at Occurrence 3 will be monitored regularly using these bores. Placement of additional bores within other occurrences will be avoided as continual traversing into the springs at Occurrence 3 appears to be impacting the vegetation. If additional bores are required, they will be placed outside of the actual spring areas.

Research will be designed to increase the understanding of the biological and ecological characteristics of the community to assist future management decisions. Such research will include:

1. Investigating and assessing the hydrology of Occurrence 3.
2. Investigating the implications of falling water tables of the Gnangara Mound on the hydrology of the mound spring occurrences.
3. Investigating the palaeobiology of tumulus springs through peat studies.
4. Investigation of significant biological processes in the community such as faunal interactions.
5. The potential impacts of water pollution such as pesticides, herbicides and fertilisers on the spring biota.
6. Taxonomic research on invertebrate fauna of the springs.

**Responsibility**: CALM (Swan Coastal District; Science Division; SCB) through the Recovery Team
**Cost**: $10,000 pa to initiate investigations
**Completion date**: To be determined

### 3.12 Ensure hygiene conditions near the community

Risk of introduction or amplification of disease is being minimised by ensuring good hygiene procedures. This involves washdown of any equipment used adjacent to the community, and restricting access by vehicles, machinery and personnel to dry soil conditions.

No vehicles should access bushland areas on or near the community. Standard practice will be for all vehicles using tracks adjacent to occurrences to be free of soil, or plant propagules and for all soil imported into the area to be tested and only dieback free soils used.

Major earthworks are likely to occur in future adjacent to Occurrence 2. Any soil imported into the vicinity of the spring areas including the adjacent *Banksia* woodlands, should be dieback free.

**Responsibility**: All personnel using machinery near occurrences
**Cost**: Costs of all liaison to be undertaken by CALM (Swan Coastal District), is included in 3.4; other costs to be underwritten by user of machinery
**Completion date**: Ongoing

### 3.13 Continue to monitor dieback

Dieback was monitored at Occurrences 1, 3, and 4 in June 2004. Dunes adjacent to Occurrences 1, 2 and 3 are vegetated with *Banksia* woodlands that are commonly very susceptible to dieback caused by *Phytophthora* species. The dune adjacent to Occurrence 1 appears to have been historically denuded, in part at least, by dieback infection.

The dieback fronts adjacent to occurrences will be monitored at least every five years in summer and flagging marking the front replaced regularly. Additional plot information (refer 3.8) would provide useful monitoring data for all sites.

**Responsibility**: CALM (Swan Coastal District) through the Recovery Team, in liaison with landholders
**Cost**: $3,000 in the first and third years
**Completion date**: Ongoing

### 3.14 Monitor and implement weed control

Weed control has primarily been focused at Neaves Road (Occurrence 3). The control of invasive weeds of *Rubus* sp. (blackberry) began in 2001 and has continued as required, with the last weed treatment occurring in April 2004. Weed control at all occurrences will be continued annually.

In 2000, a number of *Eucalyptus* saplings were removed from Occurrence 1 by Green Corps. The saplings were believed to have been *Eucalyptus camaldulensis* but may have been *Eucalyptus rudis* or a hybrid between the two species. No further removal of the *Eucalyptus* species will occur until the taxonomy has been clarified.

Weed invasion in Occurrence 2 appears to be a lesser threat than potential drying of the springs. However, the likelihood of weed invasion will increase with the clearing of adjacent bushland and subsequent residential development.

Weed monitoring (incorporated in Action 3.8) will be used to determine priorities for weed control. Weed populations will be accurately mapped and appropriate manual methods of weed control determined for spring areas. Herbicides will only be used close to spring areas if research indicates they do not have toxic effects on native fauna and flora of the springs.

**Responsibility**: CALM (Swan Coastal District); in liaison with landholders, through the Recovery Team
**Cost**: $1,000 every second year for mapping boundaries of weed species that are high priority for control such as Watsonia, kikuyu and *Isolepis prolifera*. Weed density monitoring will be incorporated into Action 3.8. Weed control - $2,500 pa (springs and buffers - Occurrence 1, 3 and 4)
**Completion date**: Ongoing

### 3.15 Rehabilitate recharge catchment zones and adjacent wetland areas

The dune to the west of the tumulus springs in reserve 46622 will be revegetated with local species that may aid water infiltration and recharge. Heath species, rather than trees would use less water and will be used for rehabilitation of this dune. In addition, revegetating or maintaining healthy vegetation on the dunes adjacent and to the west at each site may help sustain the current hydrological regime of the local recharge zones.

A kikuyu paddock (approximately 0.5 ha in area) occurs within the reserve adjacent to the east side of Occurrence 3. This area will be rehabilitated to local wetland shrubs.

**Responsibility**: CALM (Swan Coastal District), in liaison with landholders, through the Recovery Team
**Cost**: Costs of liaison included in 3.4; Costs to be determined through the Rehabilitation Plan developed under Action 3.15.
**Completion date**: Year 5

### 3.16 Report on success of management strategies for tumulus springs

The success of management strategies will be assessed as part of annual reports prepared by the Recovery Team for CALM's Corporate Executive. The final report will be evaluated as part of the revision of the IRP for this community.

**Responsibility**: CALM (Swan Coastal District; SCB); through the Recovery Team
**Cost**: $1,000 pa
**Completion date**: Year 5.

## SPECIFIC CONSERVATION MANAGEMENT ACTIONS REQUIRED - OCCURRENCE 2

### 3.17 Support reservation of Occurrence 2 and adequate buffer area

Negotiations will be continued to seek reservation of the springs in Occurrence 2, and an adequate buffer of remnant vegetation around the springs. The mound springs and a small buffer are to be vested with WAPC and later managed by CALM. Further negotiations will be required for declaration of the area as Class A reserve for the purpose of 'Conservation of Flora and Fauna' under the care, control and management of the Conservation Commission.

**Responsibility**: CALM (Swan Coastal District, Land Administration Section; SCB), in liaison with DoE, WAPC, landholders, Department of Land Information, through the Recovery Team
**Cost**: Costs of liaison included in 3.4; any costs associated with acquisition to be determined
**Completion date**: To be determined

### 3.18 Fence Occurrence 2

CALM staff will liaise with the landowner to determine the appropriate location for fences to protect the occurrence and a suitable remnant vegetation buffer area.

**Responsibility**: CALM (Swan Coastal District); landholder
**Cost**: Costs of liaison included in 3.4; costs of fencing to be determined
**Completion date**: Year 1

### 3.19 Ensure visitor access-ways do not impact the tumulus springs

Any visitor access-ways including walk/cycle paths and boardwalks will be designed such that they do not impact hydrology around tumulus springs and such that direct disturbance to the springs is minimised.

**Responsibility**: CALM (Swan Coastal District) in liaison with landholder, through the Recovery Team
**Cost**: Costs of liaison included in 3.4

**Completion date**: Ongoing

## SPECIFIC CONSERVATION MANAGEMENT ACTIONS REQUIRED – OCCURRENCE 3

### 3.20 Block drain on south east corner of Neaves Road Nature Reserve

A drain links the springs to adjacent partly cleared land on the eastern edge of the reserve and nutrient enriched water from the adjacent paddock may be able to flow into the springs from this paddock. This drain will be blocked and revegetated.

**Responsibility**: CALM (Swan Coastal District), through the Recovery Team
**Cost**: $2,000 in Year 1
**Completion date**: Year 1

Table 3: Summary of Costs for each recovery action

| Recovery Action | Year 1 | Year 2 | Year 3 | Year 4 | Year 5 |
|---|---|---|---|---|---|
| 1. Coordinate recovery actions | $1,000 | $1,000 | $1,000 | $1,000 | $1,000 |
| 2. Map habitat critical to survival | $2000 | | | | |
| 3. Clarify and continue to monitor extent and boundaries | $500 | | $500 | | $500 |
| 4. Liaise with current land owners, land managers and other interested groups | $1000 | $1000 | $1000 | $1000 | $1000 |
| 5. Disseminate information about the community | $500 | $500 | $500 | $500 | $500 |
| 6. Monitor water levels and quality | To be determined | | | | |
| 7. Manage water quality and quantity | $1,000 | $1,000 | $1,000 | $1,000 | $1,000 |
| 8. Monitor flora and fauna | $5000 | $3500 | | $3500 | |
| 9.Develop and implement Fire Management Plans | $4400 | $1700 | $1700 | $1700 | $1700 |
| 10. Ensure earthworks in area of influence do not impact community | - | | | | |
| 11. Design and conduct research | $10,000 | $10,000 | $10,000 | $10,000 | $10,000 |
| 12. Ensure hygiene conditions near the community | - | | | | |
| 13. Continue to monitor dieback | $3000 | | $3,000 | | |
| 14. Implement weed control | $3500 | $2500 | $3500 | $2500 | $3500 |
| 15. Rehabilitate recharge catchment zones and adjacent wetland areas | To be determined | | | | |
| 16. Report on success of management strategies | $1000 | $1000 | $1000 | $1000 | $1000 |
| 17. Support reservation of Occurrence 2 | To be determined | | | | |
| 18. Fence Occurrence 2 | To be determined | | | | |
| 19. Ensure visitor access-ways do not impact the springs | | | | | |
| 20. Block drain on SE corner of Neaves Road Nature Reserve | $2000 | | | | |
| | | | | | |
| **Total** | 34,900 | 22,200 | 23,200 | 22,200 | 20,200 |

Summary of Costs over five years
Total $122,700

## 5. REFERENCES


Abbott, I. and Burrows, N. (eds) (2003). *Fire in ecosystems of south-west Western Australia: impacts and management.* Bachhuys Publishers, Leiden, Netherlands.

Ahmat, A.J. (1993). *The biology of eight, non-thermal springs along the Ellen Brook Valley*. Unpublished Honours thesis. Department of Zoology, University of Western Australia.

Blyth, J. and English, V. (1996). Endangered - Tumulus Springs. *Landscope*. Vol. 11, Number 3:47.

Brown, K. and Brooks, K. (2002) *Bushland weeds; a practical guide to their management*. Environmental Weeds Action Network (Inc), Western Australia.

Cresswell, I., English, V. and Blyth, J. (1996). Ecological Communities on the Brink. *Conservation Australia*. Number 2: pp 35-36.

Department of Conservation and Land Management (1990). *Data on the Conservation of Vegetation Associations on the Swan Coastal Plain*. Unpublished Report.

Department of Conservation and Environment (1983*). Conservation Reserves of Western Australia. System 6 Part II.* DCE Report 13. EPA. Perth.

Department of Environmental Protection (1997). System 6 update program: unpublished site and area records and analysis. EPA, Perth, Western Australia.

English, V. and Blyth, J. (1997). *Identifying and Conserving Threatened Ecological Communities in the South West Botanical Province*. Project N702, Final Report to Environment Australia. Department of Conservation and Land Management. Perth, Western Australia.

Government of Western Australia (2000). *Bush Forever*. Western Australian Planning Commission, Perth.

Greay, J. (1993). *Yanchep Caves Groundwater Investigation*. Unpublished report for Water Corporation. Perth, Western Australia.

Groundwater Consulting Services (2002) Preliminary Hydrogeological Investigation: Northern Perth Springs Muchea, Bullsbrook and Egerton, Western Australia. Unpublished report prepared for the Department of Conservation and Land Management.

Helyar, K. (1994). *Dieback Interpreters Procedural Manual*. Department of Conservation and Land Management. Perth.

Jasinska, E.J., and Knott, B., (1994*) Aquatic fauna in Gnangara Mound discharge areas of the Ellen Brook catchment, Western Australia*. A report submitted to the Water Authority of Western Australia.

Jasinska, E. J. (1998). *Monitoring of tumulus spring invertebrates. A report to the W.A. Threatened Species and Communities Unit and the Water and Rivers Commission.*

Keighery B.J. and Trudgen, M.E. (1992*). The Remnant Vegetation of the Eastern Side of the Swan Coastal Plain*. Unpublished report to the Department of Conservation and Land Management for the National Estate Grants Program.

Pinder, A. (2002). Report on December 2002 sampling on Gnangara Mound Springs. Unpublished report for WA Threatened Species and Communities Unit, CALM.

APPENDIX 1
SPECIES LIST - OCCURRENCE 1

## VASCULAR PLANTS

**Asteracea**
* *Hypochaeris glabra*

**Cyperaceae**
*Baumea riparia*
* *Isolepis prolifera*

**Droseraceae**
*Drosera macrantha*
*Drosera pulchella*

**Myrtaceae**
*Agonis linearifolia*
*Astartea fascicularis*
* *Eucalyptus camaldulensis*
*Eucalyptus todtiana*
*Melaleuca preissiana*

**Papilionaceae**
*Aotus cordifolia*

**Proteaceae**
*Banksia littoralis*
*Banksia ilicifolia*

**Thelypteridaceae**
*Cyclosorus interruptus*

## NON- VASCULAR PLANTS (From Jasinska and Knott 1994)

*Goelobyrum unguiculatum*
*Hyalolepidozia longiscypha*
*Jungermannia inundata*
*Riccardia aequicellularis*

## INVERTEBRATE FAUNA (From Ahmat 1993)

CHELICERATA
Acarina

CRUSTACEA
Decapoda
*Cherax quinquecarinatus*

Ostracoda

?Hydracarina

Copepoda: Cyclopoida

Copepoda: Harpacticoida

ANNELIDA: Oligochaeta
Oligochaeta
Targigrada
Turbellaria 3
Turbellaria 4
Turbellaria 5

Turbellaria 6

NEMATODA
Nematoda
Flatworm

## INVERTEBRATE FAUNA (From Jasinska 1998)

CHELICERATA
*Lobohalacarus weberi*
*Soldanellonyx monardi* Walter
*Anisitsiellides* sp. nov.
*Trimalaconothrus* sp.

ANNELIDA
*Aeolosoma* sp. 1
*Pristina aequiseta* Bourne
*Pristinella osborni* (Walton)
Enchytraeidae sp. 1
Enchytraeidae (Achaeta) sp. 2

CRUSTACEA
Cladocera
*Ilyocryptus* sp. 1
Macrothricidae sp(p)

Copepoda
*Paracyclops* sp.
*Paracyclops* sp. 2
Harpacticoida sp. 1

INSECTA
Diptera
*Ablabesmyia notabilis* (Skuse)
*Chironomus* aff. *alternans* Walker
*Chironomus* sp. 1
*Paramerina levidensis* (Skuse)
*Polypedilum* (*polypedilum*) aff. K3 "Baroalba"
Ceratopogonidae sp. 1

NEMATODA
*Ironus* sp. 1
*Mesodorylaimus* sp. 1
*Tobrilus* (=*Trilobus*) sp. 1

PLATYHELMENTHES
*Acoela* sp. 1
Prorynchidae sp. 1

ROTIFERA
*Rotifera* spp.

## INVERTEBRATE FAUNA (From Pinder 2002)

CHELICERATA
Oribatid sp. 3 (possibly same as species from Pilbara stygofauna survey)
Astigmata sp. 2 (possibly same as species from Pilbara stygofauna survey)

ANNELIDA
Enchytraeidae immature

CRUSTACEA

Cladocera

Copepoda
*Mixocyclops* sp. (juvenile)
*Australocamptus* sp. 7 (possibly new species)

INSECTA
Diptera
*Culex* (*Culex*) *australicus*
Orthocladiinae (early instar, cannot id further)
*Chironomus* aff. *alternans* (V24)
*Cryptochironomus griseidorsum*

Coleoptera
*Sternopriscus browni*
*Rhantus* sp. larvae
*Paracymus pygmaeus*

NEMATODA
Nematode spp.

ROTIFERA
Rotifer spp.

# APPENDIX 2
# SPECIES LIST - OCCURRENCE 2

## VASCULAR PLANTS

**Dilleniaceae**
*Hibbertia perfoliata*

**Droseraceae**
*Drosera pulchella*

**Lycopodiaceae**
*Lycopodium serpentinum*

**Myrtaceae**
*Agonis linearifolia*

**Papilionaceae**
*Aotus cordifolia*

NON - VASCULAR PLANTS (From Jasinska and Knott 1994)

*Goelobyrum unguiculatum*
*Hyalolepidozia longiscypha*
*Jungermannia inundata*
*Riccardia Aequicellularis*

## INVERTEBRATES (From Jasinska and Knott 1994)

CHELICERATA

Acarina
*Oribatida* sp. s2
*Limnesia* sp. nov.

CRUSTACEA

Amphipoda
Amphipod gen. nov.

Cladocera
*Ilyocryptus* ?*sordidus*

Copepoda: Cyclopoida
*Microcyclops* sp5
*Microcyclops* sp6
*Mixocyclops* sp4
*Paracyclops* sp5
*Paracyclops* sp6
*Paracyclops* sp7
*Paracyclops* sp8

Copepoda: Harpacticoida
*Harpacticoida* spA (gigant)

Decapoda
*Cherax quinquecarinatus* (variant)

Ostracoda
*Darwinula* sp1

NEMATODA
Nematode sp1
Nematode sp3
Nematode sp16

ANNELIDA: Oligochaeta
Oligochaete sp11
Oligochaete sp12
Oligochaete sp13
Tubellaria spp

INSECTA

Diptera
Chironomidae

Coleoptera
Dystiscidae larvae

## INVERTEBRATE FAUNA (From Pinder 2002)

CHELICERATA
Trombidioidea spp.

ANNELIDA

CRUSTACEA
Cladocera
Chydoridae (?Alonella sp.)

Ostracoda
Ostracoda (Unident.)

Copepoda
*Paracyclops* sp. (juvenile, but not same as specimens from King's)
juvenile cyclopoids
*Canthocamptus* sp. 3 (possibly new species)

Decapoda

*Cherax quinquecarinatus* (juvenile)

INSECTA
Diptera
*Clinohelea* sp. 1 (tentative generic id)
Monohelea sp. 4 (tentative generic id)
Tabanidae
*Procladius paludicola*
*Paralimnophyes pullulus*
Orthocladiinae (early instar, cannot id further)
Orthocladiinae S03 sp. A
*Tanytarsus barbitarsis*
*Tanytarsus* sp. C (*bispinosus*)

Hemiptera
*Microvelia* sp. 1 juvenile

Lepidoptera
Lepidoptera (early instar moth larvae)

Odonata
*Austrogomphus lateralis*
*Hemicordulia tau*

Trichoptera
*Oxyethira* sp.
*Ecnomina* F group (sp. A VI8?)
Leptoceridae (early instar)

Coleoptera
*Sternopriscus* sp. larvae
Scirtidae sp. larvae

NEMATODA
Nematode spp.

ROTIFERA
Rotifer spp.

# APPENDIX 3

## SPECIES LIST - OCCURRENCE 3

### VASCULAR PLANTS (identified by G. Keighery during site visit - January 1997)

**Cyperaceae**
*Baumea articulata*
*Baumea vaginalis*
*Cyathochaeta teretifolia*
* *Isolepis prolifera*
*Lepidosperma ?gladiatum*
*Lepidosperma longitudinale*
*Tetraria capillaris*

**Dennstaedtiaceae**
*Pteridium esculentum*

**Dilleniaceae**
*Hibbertia perfoliata*

**Juncaceae**
*Juncus holoschoenus*

**Juncaginaceae**
*Triglochin procera*

**Lobeliaceae**
*Grommatotheca bergiana*

**Myrtaceae**
*Agonis linearifolia*
*Astartea fascicularis*
*Eucalyptus rudis*
*Melaleuca preissiana*

**Papillionaceae**
*Oxylobium linearifolia*

**Poaceae**
* *Pennisetum clandestinum*

**Proteaceae**
*Banksia littoralis*

**Rosaceae**
* *Rubus* sp.

**Thelypteridaceae**
*Cyclosorus interruptus*

## INVERTEBRATE FAUNA (From Jasinska 1998)

CHELICERATA
*Lobohalacarus weberi*
*Soldanellonyx monardi* Walter
Gen. nov. (*Thryptaturus*) sp. nov.

ANNELIDA
*Aeolosoma* sp. 2
*Pristina longiseta* Ehrenberg
Enchytraeidae sp. 1

CRUSTACEA
Cladocera
chydorid carapace were found
Macrothricidae sp(p)

Copepoda
*Paracyclops* sp.
*Paracyclops* sp. 2
*Attheyella* sp.l

Ostracoda
*Candona* sp. 1

INSECTA
Coleoptera
*Platynectes* sp. nov.
Scirtidae sp. (larvae)
*Coelosoma* ?*fabrieii*

Diptera
*Chironomus* aff. *alternans* Walker
*Paralimnophyes pullulus* (Skuse)
*Paramerina levidensis* (Skuse)
*Polypedilum* (*polypedilum*) aff. K3 "Baroalba"

*Polypedilum* (*Polypedilum*) *seorsus*

Odonata
*Synthemis* ?*leachii* Selys

Trichoptera
*Oecetis* sp. 1

NEMATODA
*Ironus* sp. 1
*Tobrilus* (=*Trilobus*) sp. 1

PLATYHELMENTHES
*Gyratrix hermaphroditus* Ehrenberg

ROTIFERA
*Rotifera* spp.

## INVERTEBRATE FAUNA (From Pinder 2002)

CHELICERATA
Mesostigmata

ANNELIDA
Enchytraeidae immature

CRUSTACEA
Copepoda
*Paracyclops* (nr. sp. 2)
*Canthocamptus* sp. 3 (possibly new species)
*Australocamptus* sp. 7 (possibly new species)

INSECTA
Coleoptera

Diptera
*Anopheles atratipes*
*Culiseta atra*
*Paramerina levidensis*
*Paralimnophyes pullulus*
Orthocladiinae (early instar)
*Chironomus* aff. *alternans* (V24)
*Cryptochironomus griseidorsum*

Hemiptera
*Microvelia* sp. 1 juvenile

NEMATODA
Nematoda spp.

ROTIFERA
Rotifera spp.

## VERTEBRATE FAUNA (W. Manson and P. Speldewinde, personal communication)

Mammalia
*Isoodon obesulus*

APPENDIX 4

SPECIES LIST - OCCURRENCE 4

VASCULAR PLANTS

**Cyperaceae**
*Baumea articulata*
*Baumea juncea*

**Myrtaceae**
*Agonis linearifolia*
*Astartea fascicularis*
*Melaleuca lateritia*
*Melaleuca preissiana*