ntepa Northern Territory Environment Protection Authority

ENVIRONMENTAL QUALITY REPORT

BIODIVERSITY OF THE HOWARD SAND PLAINS SITE OF CONSERVATION SIGNIFICANCE

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Version 0.2

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Acknowledgement

The NT EPA acknowledges the assistance provided by Northern Territory Government departments of Land Resource Management and Mines and Energy in developing this Environmental Quality Report.

Figures

Tables

Abbreviations

CCNT	Conservation Commission of the Northern Territory
DLPE	Department of Lands, Planning and Environment
DLRM	Department of Land Resource Management
DME	Department of Mines and Energy
EPBC Act	*Environment Protection and Biodiversity Conservation Act 1999 (Cth)*
Endangered	Species listed as in danger of extinction under the TPWC Act and/or the EPBC Act
FFD	Flora and Fauna Division of DLRM
ML/yr	Megalitres per year
NRETAS	Department of Natural Resources, Environment, the Arts and Sport
NT EPA	Northern Territory Environment Protection Authority
NT EPA Act	*Northern Territory Environment Protection Authority Act*
NTG	Northern Territory Government
SOC	Site of Conservation Significance
Threatened species	A species listed under the TPWC Act or EPBC Act as vulnerable or endangered
TPWC Act	*Territory Parks and Wildlife Conservation Act*
Vulnerable	Species listed under the TPWC Act or the EPBC Act as vulnerable to extinction

Units

cm	Centimetre
ha	Hectare
km	Kilometre
km^2	Square kilometre
m	Metre
mm	Millimetre
tpa	Tonnes per annum

Executive summary

The Northern Territory Environment Protection Authority (NT EPA) is of the opinion that unless something is done to prevent it, rapidly increasing threats to the biodiversity of the Howard sand plains Site of Conservation Significance (SOC) (Figure 1) will result in the extinction of what seems likely to be the most significant area of biodiversity in the Darwin region. The threats are primarily caused by long term extraction of sand and gravel, and adjacent expansion of urban and rural developments. The information and assessments that led the NT EPA to this conclusion are documented in this report.

The report is an environmental quality report under section 28 of the *Northern Territory Environment Protection Authority Act* (NT EPA Act) and will provide a basis for advice to the Minister for the Environment (the Minister) under section 25 of the NT EPA Act.

The objectives of this report are to document:

- the significance of the biodiversity of the Howard sand plains SOC
- the vulnerabilities of the threatened biodiversity to potential disturbance
- threatening processes impacting on the biodiversity of the Howard sand plains
- the absence of, and improbability of finding techniques to effectively rehabilitate the sand plains' biodiversity
- a preferred design for securing the protection of areas that may provide security for the threatened biodiversity and possibly 10 species of near threatened plant, 13 species of plant for which there are too few data to be able to determine their conservation status, and two species of threatened animal
- the need for additional information to ensure the preferred protected area option, with future modification as necessary, will provide risk averse security for the threatened biodiversity.

The objectives of the report are compatible with the environmental objectives of the Northern Territory Government's Framework for the Future policy. The preferred protected area would also be in keeping with the Northern Territory government being signatory to the National Strategy for Ecologically Sustainable Development and Australia's Biodiversity Conservation Strategy.

Findings

1. The Howard sand plains SOC contains a community of carnivorous plants, bladderworts of the genus *Utricularia* that is of international significance.
2. The vulnerable carnivorous bladderwort, *Utricularia dunstaniae,* is found in the Howard sand plains and is of Northern Territory significance.
3. The endangered plant, *Typhonium taylori,* is found only on the Howard sand plains, and is of national and Northern Territory significance.

4. The endangered Darwin palm, *Ptychosperma macarthurii,* is found in the Howard sand plains and lower Adelaide River floodplain, and is of Northern Territory significance.

5. The vulnerable Howard toadlet, *Uperoleia daviesae*, is primarily found on the Howard sand plains and small areas along the Elizabeth River floodplain, and is of Northern Territory and likely national significance.

6. The area has the only known Northern Territory record and location of an endangered orchid species (*Habenaria rumphii*).

7. Of lesser significance is the presence of an additional plant species vulnerable to extinction, ten species of near threatened plant, 13 species of plant for which there are too few data to be able to determine their conservation status, and two additional species of threatened animal.

8. The bladderwort community, *Utricularia dunstaniea, T. taylori* and the Howard toadlet are found in habitats provided by sand sheet heath vegetation; occupying approximately 2 259 ha of the seasonally inundated/saturated flood plains.

9. *P. macarthurii* is dependent on habitat provided by spring-fed monsoon rainforests.

10. The biodiversity of the sand plains is vulnerable to:

    - alteration of the distribution and abundance of sand sheet heaths and monsoon rainforests across the north-south and east-west extents of the flood plains (land clearing)
    - spatial and temporal alteration of ground water tables, and surface water flows across the the entire wetland system in relation to ground water seepage, spring flows, patterns of Wet season inundation/saturation and Dry season water availability
    - alteration of topographic and micro-topographic features relevant to maintaining existing patterns of surface water flows, inundation and water logging.

11. Approximately 31.8% of the SOC is occupied by existing urban and rural development on lands around the low plateau margins of the plains. Urban/rural development over much of the remaining land is constrained by seasonal saturation and inundation.

12. Abstraction of ground water from over 3000 domestic bores in the adjacent rural residential area, and bores for the supply of water to the Darwin area have lowered the late Dry season water table by up to 15 m and possibly more in some areas, with a less extreme lowering spread into the sand plains.

13. Approximately 3.5% of the SOC is subject to farming/forestry, with 4.1% having been subject to disturbance from extractive mining, the vast majority of which is in the seasonally wet areas of the floodplain.

14. 75% of the area's extractive industry on the flood plains occurs within the area's sand sheet heaths, with 502 ha (22.2%) of it subjected to extractive mining as of 2013.

15. There are no known techniques capable of rehabilitating sand sheet heaths to a state that would allow for the preservation of the threatened species or community. Nor are there likely to be such techniques.

16. Knowledge of the biology of the threatened biodiversity, other than *P. macarthurii,* is rudimentary, largely limited to distributional records obtained from low intensity quadrat sampling or informal searches.

17. Sand sheet heaths are the core habitat for the *Utricularia* community, *U. dunstaniae, T. taylori* and the Howard toadlet.

18. Monsoon rainforest provides core habitat for *P. macarthurii.*

19. Land clearing and extractive mining have had a significant impact on the spatial distribution and abundance of sand sheet heath habitat across the Howard sand plains.

20. Knowledge of the hydrology of the sand plain is essentially non-existent at a scale relevant to the habitat requirements of the threatened biodiversity, being limited to casual observations during natural history studies and informal searches.

21. There has been no hydrological investigation of the impacts of extractive mining on the area's hydrology, the habitats of the threatened biodiversity, or the interaction between the impacts of mining and abstraction of ground water.

22. The limited state of knowledge of the sand plains and its biodiversity necessitate a risk averse, precautionary approach to ensuring the future of the threatened biodiversity.

23. The lowest risk, preferred option for protection of the threatened biodiversity is to establish a protected area over the entire seasonally inundated and water logged area of the sand plains (Option 1).

24. This preferred option would allow for maximum possible protection of the biodiversity from threats, although full transition of land use would take some time. It would provide for the closest possible achievement of the outcomes required of a risk averse protected area. It would protect:

    - all that is left of the apparent north-south and east-west variation in the occurrence of *Utricularia* species
    - all that is left of the range of micro-habitats that are the basis of habitat specialisation among the *Utricularia* species and the broad distribution of species rich *Utricularia* communities across the majority of vegetation types
    - the known populations of *U. dunstaniae*, and all that is left of habitat types that may contain additional populations if any

- the few known populations of *T. taylori* and all that is left of habitats that may contain additional populations if any
- the two populations of *P. macarthurii*
- all the remaining area, allowing possible maintenance of viable populations of the many species that have small and widely dispersed subpopulations
- all remaining areas with habitats that provide or are likely to provide for all life history stages of the threatened biodiversity
- all that is remaining of the metapopulation dynamics of the threatened species, and minimise future deterioration
- to greatest extent possible, hydrological conditions across the the entire wetland system, as well as providing the best opportunity for remediation of hydrological conditions
- the Howard sand plains with a protected area design that facilitates future management of external threats and the protected area
- the best possible protection for possibly 10 species of near threatened plant, 13 species of plant with too few data to be able to determine their conservation status, and two species of threatened animal.

25. Approaches based on definition and protection of core habitats and surrounding buffers with or without linkage areas are found to be risk prone, cause potential uncertainty in the extractive mining industry, and should not be implemented.
26. Protection of some of the upper Howard River catchment (south of Gunn Point Road) (Option 2) has the capacity to provide the threatened biodiversity with some level of security. It would have risks (higher than Option 1) associated with maintenance of the hydrology and the absence of linkage between the east and west of the sand plains.
27. Options 3, 4 and 5 pose a potentially high risk to the future of the Howard sand plains' biodiversity and should not be implemented.
28. All five options involve a potentially significant economic cost. All involve reduction in the abstraction of ground water from the sand plains. All involve transition of the extractive mining industry away from the sand plains. The costs of the latter would vary depending on the possible future extent of mining in the sand plains, and the duration of the required transition. The greater the extent and duration of mining activity, the greater the threat to the threatened biodiversity.
29. Implementation of an effective protected area is a good first step to rectify a long standing neglect.

1 Introduction

The Northern Territory Environment Protection Authority (NT EPA) is of the opinion that unless something is done to prevent it, rapidly increasing threats to the biodiversity of the Howard sand plains will result in the extinction of what seems likely to be the most significant area of biodiversity in the Darwin region. The threats are caused by long term extraction of sand and gravel, and adjacent expansion of urban and rural developments. The information and assessments that led the NT EPA to this conclusion are documented in this report.

The Howard sand plains Site of Conservation Significance (SOC) (Figure 1) has been designated as one of 67 Northern Territory SOCs (Harrison *et al.,* 2009). The designation is based on the presence of:

- bladderwort communities (carnivorous plants of genus *Utricularia*) of global significance
- a species of bladderwort (*U. dunstaniae*) listed as vulnerable to extinction in the Northern Territory
- a herb (*Typhonium taylori*) listed as endangered under Australian and Northern Territory legislation and found nowhere else in the world
- the only Northern Territory populations of the endangered Darwin palm (*Ptychosperma macarthurii*), found on the Howard sand plains and adjacent western floodplain of the Adelaide River
- the vulnerable Howard toadlet (*Uperoleia daviesae*), a frog found primarily in the Howard sand plains and small areas of sand plain along the adjacent Elizabeth River.

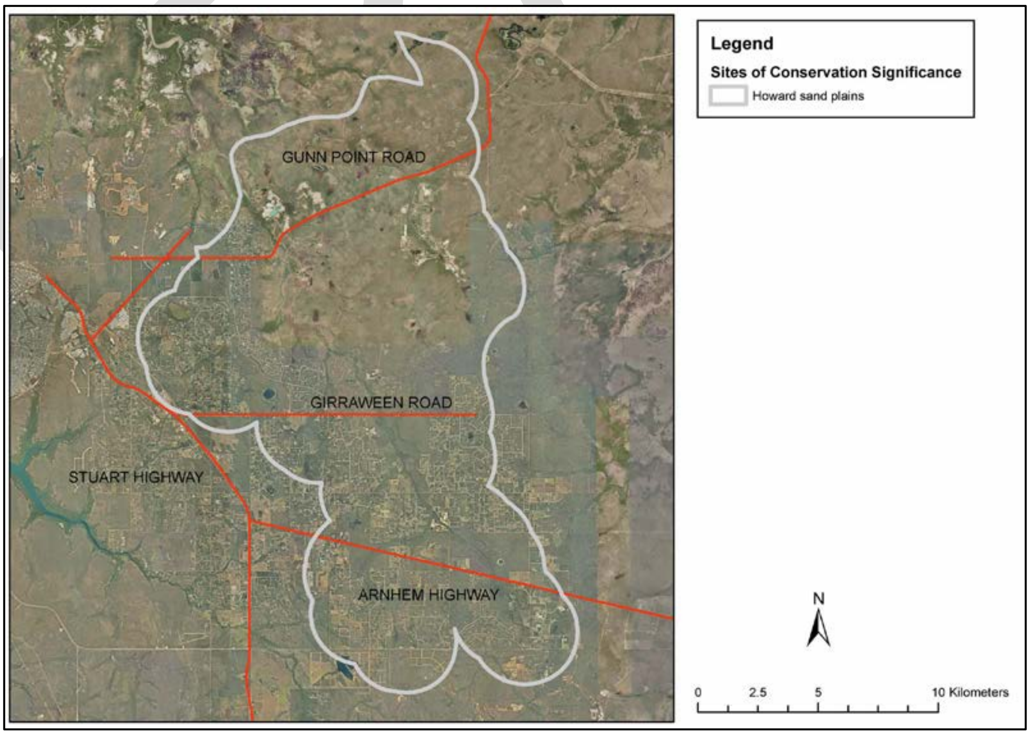

Figure 1: The Howard sand plains Site of Conservation Significance (mapping of SOC NTG, DLRM)

The area is the only known Northern Territory record and location of an additional endangered plant species (*Habenaria rumphii*), 10 species of near threatened plant, 13 species of plant for which there are too few data to be able to determine their conservation status, and two additional species of threatened animal.

This report is an environmental quality report under section 28 of the *Northern Territory Environment Protection Authority Act* (NTEPA Act) and will provide a basis for separate advice to the Minister for the Environment (the Minister) under section 25 of the NT EPA Act.

1.1 Objectives

The objectives of this report are to document:

- the significance of the biodiversity of the Howard sand plains SOC
- the vulnerabilities of the threatened biodiversity to potential disturbance
- threatening processes impacting on the biodiversity of the Howard sand plains
- the absence of, and improbability of finding techniques to effectively rehabilitate the sand plains' biodiversity
- a preferred design for securing the preservation of areas that may be sufficient to provide security for the threatened biodiversity, and possibly 10 species of near threatened plant, 13 species of plant for which there are too few data to be able to determine their conservation status, and two species of threatened animal.

To meet the above objectives, the NT EPA has:

- reviewed available literature on the biodiversity of the Howard sand plains
- made particular use of research conducted over many years by the Flora and Fauna Division (FFD) of the Department of Land Resource Management (DLRM)
- examined the adequacy of available information for understanding the nature and extent of threatening processes on the Howard sand plains
- examined options and determined a preferred design for preservation of the sand plains' threatened biodiversity.

2 The Howard sand plains environment

2.1 Site location

The Howard sand plains SOC is located within 30 km to the east of Darwin. It occupies an area of approximately 264 km^2, approximately 27 km north to south and 16 km east to west. The area consists of areas of fine sand along river flood plains surrounded by gravelly rises. It is the plains of fine sand, referred to in this document as the Howard sand plains, that are the particular focus of this report.

The landscape is underlain by Proteozoic (2 500 to 542 million years ago) alluvium and gravels, overlain by lower Cretaceous (146 to 66 million years ago) alluvium and gravels, later overlain by a thinner layer of recent late Tertiary (16 to 2.58 million years ago) sediments (Wells and Harrison 1978). These strata have eroded to form low plateaus with low foothills surrounding floodplains and incised stream lines. The floodplains contain seasonally saturated/inundated white sand plains with a basal lithology (gross character of a geological formation) of brown clay with quartz clasts (small rocks/grains resulting from breakdown of larger rocks), or in some cases ferricrete (sediments cemented together by iron oxides) (Doyle 2011). Clayey sands predominate along the streamlines. The sand plains are the largest in the Northern Territory (Harrison *at al.,* 2009). Shallow depressions have formed on the surface of some more elevated areas.

The area is underlain by a seasonally recharged aquifer hosted in Koolpinyah dolomite. The Power and Water Corporation managed Howard East Borefield accesses the ground water to provide water for Darwin. Numerous springs emerge from the edges of the floodplain during the Wet season (Cook *et al.,* 1998; Vanden Broek 1980).

2.2 Biodiversity of the Howard sand plains

2.2.1 Bladderwort communities of global significance

Bladderworts (genus *Utricularia*) are small herbaceous plants found in aquatic, semi-aquatic and moist terrestrial habitats in most countries of the world; especially in tropical and sub-tropical areas. Some species are epiphytes growing on other plants. The bladderwort's structure is unusual among flowering plants in that there are no clearly defined roots, stems or leaves. Stems (stolons) usually remain below the water or soil surface. The flowers are often the only parts of a bladderwort visible above the surface of soil or water. All bladderworts have bladders or traps attached to the stolons below the surface. The bladders trap small organisms such as protozoans (single celled organisms) and rotifers among terrestrial species, or water fleas, nematodes, and insect larvae among aquatic species. Some bladderworts produce leaf-like photosynthetic shoots at the surface of the soil or water.

Flowers are asymmetrical and can be colourful. Flowers may be either self-pollinating or pollinated by insects. Little is known of pollination biology of the *Utricularia.* Wasps, flies and butterflies have been observed visiting flowers (Taylor 1989). The timing and duration of flowering of the sand plains' *Utricularia* varies according to species, and the availability of water in micto-habitats used (Cowie 2002). Seeds are small (less than 1 mm) and may be dispersed by water, adherence to water birds or other animals, or in the case of epiphytic species, by wind.

Taylor (1989) first drew attention to the exceptional species richness of the Howard sand plains' communities of bladderworts in a taxonomic assessment of the world's bladderworts (genus *Utricularia*). He reported up to 14 species of bladderwort in an area of no more than 0.1 ha. He noted that more species may have been present as an additional five were found within a few kilometres. This compares to Taylor's (1989) report that the island of Trinidad has exceptionally high species richness i.e. 16 species in 276 ha, or 19 species on the entire island. More recent work by the FFD and the Northern Territory Herbarium has found up to 12 bladderwort species in a single 20 m by 20 m plot, 16 species in a single vegetation type and a total of 26 species identified from the Howard sand plains (DLRM 2015).

The global significance of the Howard sand plains' bladderwort communities is reinforced by information gathered to determine centres of bladderwort species richness in the Northern Territory. Liddle *et al.,* (2013) analysed species richness of bladderwort communities in 253, 20 m by 20 m plots across regions in the Northern Territory, and at a broad geographic scale (25 km by 25 km quadrats).

Results indicated that the centre of bladderwort species richness in the Northern Territory is in the Darwin area incorporating the Howard sand plains. Species richness was highest in the Howard sand plains. Only 2% of samples contained greater than seven species; all were in the Howard sand plains.

Liddle *et al., (*2013) found species of *Utricularia* in 18 of the 21 vegetation communities present in areas of the Howard sand plains subject to annual inundation or water logging. Eight of the communities had a maximum number of species per plot of five or more. The highest maximum number of bladderwort species per plot and the highest average number of species per plot were recorded from *Grevillea pteridifolia* and *Melaleuca nervosa* low open woodland with or without *Pandanus spiralis* and *Veriticordia cunninghamii* low scattered trees or heath, and *Dapsilanthus spathaceua* mid-open sedgeland understory (Liddle *et al.,* 2013 community 4b). Three other communities with a similar species composition and structure (4a, 4c, 4d) had five or greater bladderwort species. Community 3a (*M. nervosa, P. spiralis* low open woodland with a *Sorghum intrans, Eriachne triseta* grassland) had six species per plot. Communities 9, 12 and 13 recorded maximums of five species per plot (*P. spiralis* +/- *M. viridiflora* low open woodland with a mid tussock grassland/sedgeland ground story; *Lophostemon lactifluus* +/- *Banksia dentate* and *G. pteridifolia l*ow open woodland over *D. spathaceus* and mid sedgeland understory with heath shrubs and tussock grasses; and low tussock grassland with isolated *M. nervosa* respectively).

Twelve plant communities had recorded numbers of bladderwort species of ten or more. Communities 4a, 4b, 4c, 4d, 3a and 3b all recorded greater than ten species each. Community 3b (M. nervosa, G. pteridifolia low open woodland with D. spathaceus low open sedgeland) (Figure 2) had the highest number (16 species). Community 4c, along with communities 10 and 13, had 14 species each. Communities 10 and 13 exhibited a plant species composition that overlapped with those of the 3 and 4 community groupings.

Communities 3 and 4 with high numbers of species of bladderwort are known as sand sheet heath, and are referred to by this name throughout the report.

The broad presence of bladderwort species in the Howard sand plains across the majority of all vegetation types and high species numbers in most types are influenced by vegetation existing as mosaics of types, with small un-mappable areas of one or more vegetation types occurring within a larger mapped matrix on another vegetation type.

Figure 2: Sand sheet heath community 3b (NTG, Photograph D. Liddle)

2.2.2 The vulnerable *Utricularia dunstaniae*

U. dunstaniae is listed under the *Territory Parks and Wildlife Conservation Act* (TPWC Act) as being vulnerable to extinction (Kerrigan and Cowie 2007a) (Figure 3). The species is endemic to Australia and is found in the Mitchell Plateau in Western Australia, and in the Northern Territory. The species is recorded from the Howard sand plains, Jabiru (Taylor 1989), once from the McMinns Lagoon area, once from the Adelaide River floodplain and more recently the Cobourg Peninsula, near Murgenella and near the Finniss River.

The species is an annual, terrestrial bladderwort that produces a solitary yellowish flower at the end of the Wet season or early Dry season (April to May (Cowie 2002)). The lower petals form two erect spikes with filamentous like appendages up to 4 cm long. *U. dunstaniae* is one of four northern Australian bladderwort species to produce flowers with insect-like appearances. The others are *U. dunlopii, U. capilliflora* (both found in the Northern Territory) and *U. antennifera* (which is only found in Western Australia).

All four species may mimic a female insect, attracting males to "mate" with the flower and so transferring pollen from one mimic plant to the next. The possible pollinator remains unknown but size and morphology of *U. dunstaniae* and the other apparently mimic species suggest a winged insect capable of moving over reasonable distances. Solitary wasps with wingless females fulfil this role for orchids with flowers that mimic insects, and may do the same for *U. dunstaniae.*

U. dunstaniae grows in microhabitats that are wetter than those used by some other bladderworts species in the area. Its small and isolated populations are often found where water percolates from the ground (Cowie 2002).

Figure 3: ***Utricularia dunstaniae* (NTG, Photographer D. Liddle)**

Liddle *et al.*, (2013) found *U. dunstaniae* in sand plain heath vegetation communities 4a, 4b, and 4d. It was also found to occur in an isolated area of sand sheet heath within vegetation community 12 (*Lophostemon lactifluus, Banksia dentata and G. pteridifolia* low open woodland over *D. spathaceus* mid-high sedgeland with heath shrubs and tussock grasses).

The total population of the species is estimated to be less than 1 000 individuals scattered across seven sites (Kerrigan and Cowie 2007a), with only eight records from the sand plains.

2.2.3 The endangered *Typhonium taylori*

The small, seasonal herb *T. taylori* was discovered in 1996 and scientifically described in 1997 (Figure 4). *T. taylori* is found in several places scattered over an area of approximately 43 km^2 of the Howard sand plains area. The total habitat occupied is only 0.28 km^2 (Liddle and Trikojus 2010). It occurs nowhere else in the world (Kerrigan and Cowie 2007b).

The species is listed as endangered under the Australian Government's *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) and the Northern Territory's TPWC Act.

Figure 4: *Typhonium taylori* (NTG, Photographer D. Liddle)

*T. taylori i*s a tuberous plant that lies dormant during the Dry season. During the Wet season (late December to February in particular) plants push up leaves as long as 45 mm and grow to an average height around 22 mm. The above ground growth of the plant survives into the early Dry season, with no significant growth from the time of first emergence to the time of senescence (dying of above ground parts). An average of only 2.2 leaves is produced by each plant (Liddle and Trikojus 2010). Insect damage to leaves increases gradually through the growth season with some leaves lost entirely (Liddle and Trikojus, 2010). Leaves lost to insects are not replaced during the growth season in which the leaves are lost.

Flowering occurs in association with production of the first leaf during the early Wet season. Flowers are of a brownish purple colour and last one or two days and are rarely observed. A solitary inflorescence (a complex of flowers) emerges to about 7.5 cm, with an entirely underground stalk. An approximately 6.5 cm long spathe (a modified sheath-like leaf) partially encloses the inflorescence. It is closed at the bottom and open at the top with a maximum width of 5.5 mm. The spathe is two chambered with the lower 1.5 cm underground. The spathe semi-encloses a spadex (a spike like structure) about 5.5 cm long, 1 cm wide at its base and extending beyond the top of the semi-enclosing spathe. The top pointed portion of the spadex has no flowers. Below this portion is a zone of male flowers (3.5 mm long), followed by a naked zone (1 mm), then a zone of modified sterile flowers (6 mm) and finally a zone of female flowers (1 mm).

The female flowers are likely to be pollinated by beetles, as with other species of *Typhonium* (Broderbauer *et al.,* 2012).

Rove beetles (Staphylinidae), dung beetles (Scararabaeidae), and other beetle groups that favour carrion, dung or decaying vegetation pollinate *Typhonium* species. The beetles are attracted to the *Typhonium* by odours emitted from the zone of modified sterile flowers. On entering the beetles slip down into the bottom chamber of the inflorescence (because of specialised slippery cells lining the inner surface of the spathe). The entering beetles are trapped by the spathe twisting and closing the entrance to the bottom chamber. This separates the upper male flowers (inactive at this stage) from the lower female flowers (active at this stage) in the lower chamber. Entry of the beetles is facilitated by the spadex tilting forward, and then becoming erect at closure of the bottom chamber. Pollen on the beetles is transferred to the female flowers, which then cease to be receptive to pollen. The slippery cells on the spathe surface cease to be slippery and the male flowers produce pollen. The spathe twists and opens, releasing the beetles carrying a newly acquired load of pollen. Exit is facilitated by the spadex tipping forward for a second time. The spathe then closes again and the spadex resumes an erect posture. The colour of the spathe gradually changes from reddish to brown during the process.

There is no reported observation of the fruit of *T. taylori.* It might be expected to be a small berry as with other species of *Typhonium*. There is no knowledge of the mechanism of fruit dispersal; although an animal agent is likely to be involved.

Liddle *et al.*, (2013) found *T. taylori* in sand sheet heath vegetation communities 4a, 4b, 3a and 3b along with a presence in five other communities, i.e. nine vegetation types. The two largest know populations occur in community 3a, with the third largest located in community 3b.

Liddle and Trikojus (2010) conducted a survey of the Howard sand plains SOC and located a total of 10 populations out of 12 sites examined. The three largest populations had recorded observations of 574, 508 and 58 individuals. An additional population had been recorded by the Northern Territory Herbarium during earlier work.

T. *taylori* is small and difficult to see making population estimates difficult. The three largest populations were additionally sampled using distance methods along straight line transects to obtain more quantitative estimates of population size. The estimates were 28 222, 35 577, and 2 638 individuals in each population respectively. The numbers of plants seen in each of the populations during sampling were 159, 355 and 33 respectively. The difficulty with the quantitative estimates is that, as is often the case with estimates of population abundance of wild populations, the level of confidence in the estimates is low. The lack of precision is reflected in Liddle and Trikojus' (2010) estimate of the total known population as being somewhere between 34,000 and 131,000 individuals. The reliability of the estimates is yet to be investigated.

Numbers of *T. taylori* seen in the remaining seven populations of the ten population studied by Liddle and Trikojus (2010) were 30, 29, 11, three populations with two individuals and two populations with one individual each.

2.2.4 The endangered Darwin palm (*Ptychosperma macarthurii*)

The Darwin palm (Figure 5) was formerly known as *P. blesserii.* It is a slender palm with "feather-like" fronds with 30 to 40 leaflets either side of a midrib. It has a clumping growth form. Flowering occurs between May and December, with fruits between August and December. The pendulous inflorescences contain separate male and female flowers, with males ceasing to produce pollen before female flowers become active (Essig 1973). Pollinators are likely to be bees and flies. Fruits are red and dispersed by birds.

Figure 5: The Darwin palm (*Ptychosperma macarthurii*) (NTG, Photographer D. Liddle)

The species is known in the Northern Territory from eight populations on the Howard sand plains and adjacent western floodplain of the Adelaide River. The species is found in monsoon rainforests forests associated with springs. The species in total occupies less than one square kilometre of habitat and has a known population of 1037 plants. Over 70% of individuals occur in a single population at Crocodile Creek (Liddle *et al.,* 2006).

The TPWC Act lists the Darwin palm as endangered with extinction.

The Darwin palm occurs as two populations in the Howard sand plains. Both populations occur in the same vegetation type; spring fed monsoon rainforest forest (Figure 6) (Liddle *et al.,* 2013; community 16).

The Darwin palm is found in northern Queensland where it is not threatened by extinction (Kerrigan *et al.,* 2007).

Figure 6: Spring fed monsoon forest (Community 16) (NTG, Photographer D. Liddle)

2.2.5 The vulnerable Howard toadlet (*Uperoleia* daviesae)

Discovered in 2000, the Howard toadlet is listed under the TPWC Act as endangered with extinction (Ward 2007) (Figure 7). Its distribution is largely confined to the Howard sand plains and minor areas of habitat in the floodplains of the adjacent Elizabeth River (near Noonamah and the proposed city of Weddell). There is a record from near Berry Springs and a population in the Sunday Creek area extends just south of the SOC (Reynolds and Gattidge 2013)

The toadlet is small (less than 23 mm long) and has an orange-red groin with a narrow yellow to pale red mid-vertebral stripe. The dorsal surface is black with numerous pale brown tubercles (bumps). The ventral side is cream. Toes are not fringed and have little webbing.

Little is known of the species' natural history. Individuals emerge, call, mate, lay eggs and grow from tadpoles to adult form during the Wet season. Habitats used are largely inundated sand sheet heaths or areas adjacent to *Melaleuca* (paperbark) woodlands. These sites are shallowly inundated situations receiving flows from more elevated areas. Males call in small numbers. The call has 22 pulses and is raspy (Young *et al*., 2005; Fisher *et al*., 2005). Males often call from small mounds creatred by earthworms around *Diptapsilanthus spathaceus,* other sedges and perennial grasses. Males may call from a small cavity dug from the side of the mound (Reynolds and Grattidge 2013). Call sites are adjacent to water usually less than 3 cm depth (Reynolds and Grattidge 2013).. The inhospitable conditions of the Dry season likely force the Howard toadlet into inactivity; similar to what occurs for most individuals of other Northern Territory species of this genus. The locations and habitats used to survive the Dry season are not known.

Figure 7: The Howard toadlet (*Uperoleia daviesae*) (NTG, Photographer S. Young)

The majority of records from the Howard sand plains are from community 3 grouping (sand sheet heaths) as identified by Liddle *et al.* (2013) (64%, N=25). The additional 36% of records were 12% from eucalypt woodland; 8% from community 7 (*Acacia plectocarpa, A. latescens* low open woodland with a low open grassland understorey), and 1% from each of community 2a (*M. viridiflora* mid open woodland with mid open tussock grassland), community 6 (*Lophostemon +/- M. viridiflora* mid open woodland with tall tussock grassland), community 9 (*P. spiralis +/- M. viridiflora* low open woodland with mid tussock grassland/sedgeland) and community 13 (tussock grassland with scattered *M. viridiflora*). Records from eucalypt woodland are of interest given the absence of information on habitats the Howard toadlet uses to pass the Dry season.

Additional records from disturbed habitats included two from residential areas and 20 from disturbed sites. Records from disturbed sites were associated with past extractive mining.

Assessment of the species habitat preference is made difficult by the somewhat haphazard nature of sampling efforts. This contrasts with the clearly defined sampling programs used in assessing *Utricularia* spp., and *T. taylori* (Liddle and Trikojus 2010; Liddle *et al.,* 2013). Biased sampling seems to have been inevitably caused by sampling being restricted to tracks allowing access during the Wet season when the toadlet is active. Although this deficiency prevents the conduct of a rigorous assessment of the Howard toadlet's habitat preference, it is clear that it has a preference for sand sheet heath vegetation with the sedge *D. spathaceus* in the ground layer vegetation and for habitats with an open canopy.

2.3 Land use in the Howard sand plains

2.3.1 Rural and urban development and expansion

Lands subject to rural residential development, and farming and forestry cover 31.8% and 3.5% respectively of the seasonally inundated or water logged lands of the Howard sand plain SOC (Liddle *et al.,* 2013). These data are current as of the date of the imagery used to conduct the mapping (2010). The developments are largely restricted to the more upland surrounds of the flood plain, with the seasonally water logged/inundated sand plains constraining development. Rural and urban “infill” and/or “densification” is likely to continue into the future.

Rural development around the western rim of the sand plain is not expected to have caused significantly enhanced levels of nutrients and toxicants in, or enhanced flows of storm water to and through the flood plain. Rural land use would not be expected to cause the levels of enhanced run-off and elevated nutrients and toxicants associated with urban development (Skinner *et al.,* 2009).

Further expansion of rural residential and urban development south into the Hughes-Noonamah and Noonamah Ridge will inevitably alter of the quality and quantity of stormwater flows through the Elizabeth River. In the longer term these impacts will be enhanced by development of the City of Weddell further downstream. These stormwater changes are important because the flood plain areas of the Elizabeth River are the only other area where the Howard toadlet is found. This flood plain may also provide habitat for the threatened *U. dunstaniae.* Significantly increased volumes and rates of flow through the Elizabeth River during storm events will impact negatively on the floodplain and riparian habitats and any threatened species present. The impacts would include erosion, scouring and sedimentation detrimental to the topographic and micro-topographic features essential to maintenance of existing biodiversity. The degradation of Mitchell Creek, Palmerston, following urban expansion provides an example of the impacts of improperly managed stormwater. It would be inappropriate to depend on the relatively small, Elizabeth River flood plain and riparian habitats for the long term preservation of the sand plain biodiversity.

Rural and urban development on the sand plain has been associated with a significant lowering of the late Dry season water table in some areas; especially following Wet seasons with low rainfall. Haig and Townsend (2003) demonstrated that water abstraction from rural domestic, agricultural and municipal bores in the McMinns and Girraween Lagoon area following low rainfall Wet seasons caused a lowering of the late Dry season water table. This was 8 to 10 m greater than the average 10 m reduction in areas the Howard River catchment not affected by abstraction. Wet season rainfall replenishes the aquifers and brings the water table to or close to the surface.

Yin Foo (2004) modelled the McMinns/Howard East groundwater system in response to increasing demand for abstraction from the aquifer. Modelling compared the outcomes of scenarios of the natural condition, the situation as it existed in 2004, and what might occur with implementation of the first two stages of a five stage development plan for additional municipal abstraction. He found that the 2004 scenario resulted in a doubling of recharge to the Layer 2 aquifer (Layer 1 is near the surface, Layer 2 is deeper and is used for abstraction). The 2004 scenario was associated with significant lowering of discharge to streams, springs, swamps and wetlands from Layer 1 compared to the natural scenario. There was a late Dry season draw down of 10 m under the rural residential area. The first two stages of the development were predicted to cause no increase in the depth of the draw down, but would expand the area of the draw down into the area of the sand plains. The projected future development would increase drawn down in the rural residential area to 15 to 21 m with further expansion of the drawdown area. Evapotranspiration would be reduced by 43% (the estimates of evapotranspiration did not include the effects of extractive mining (section 5.3.3). Flows to the Howard River would be 40% of that received under natural conditions. The NT EPA does not possess monitoring data that may confirm these results.

The Power and Water Corporation is in the process of equipping four of the Howard East Bore Field's bores to provide additional emergency water supplies for Darwin (PowerWater undated). The McMinns-Howard East Bore Field is theoretically capable of supplying Darwin with 20% of its water needs. Limitations to infrastructure limit this potential supply to 15%. Current Power and Water Corporation abstraction is less than 20% of the abstraction from the bore field, most being accounted for by domestic bores. The Power and Water Corporation is licenced to abstract up to 8 420 ML/yr from the six bores in the area. Equipping the bores is designed to allow the Power and Water Corporation to provide emergency supplies should there be an infrastructure or water quality failures at Darwin River Dam. It will also allow the Corporation to access its total licenced abstraction to meet a current shortfall in supply of 2 420 ML/yr. The shift is also proposed to reduce the risk associated with ground water contamination from rural and mining activities (PowerWater undated).

The move to increase abstraction from the eastern portion of Howard East Bore Field, and increase abstraction from the entire bore field, seem likely cause a larger Dry season lowering of the water table, and expand the zone of influence to the east of its current significant extent.

2.3.2 Land use planning under the Northern Territory Planning Scheme

The draft of the Darwin Regional Land Use Plan 2014 (the Plan) provides a map of the location of the Howard sand plains SOC, and describes it as part of a natural area. It also provides maps of the locations of threatened vegetation communities. The draft Plan describes the Howard sand plains as follows:

> *Howard Sand Plains – extensive seasonally inundated wetlands with shallow lagoons and swamps and sandy substrates that provides habitat for communities of carnivorous plants (bladderworts) that are internationally significant because of their species richness, a nationally threatened plant species (*Typhonium taylori*) found nowhere else in the world, a threatened palm found nowhere else in the Northern Territory (*Ptychosperma macarthurii*), a threatened species of bladderwort (*Utricularia dunstaniae*), and a threatened species of frog (the Howard toadlet (*Uperoleia daviesae*) found nowhere else in the world. The future survival of this centre of unique biodiversity is dependent on the*

identification and establishment of areas capable of ensuring their long term protection. The Plan notes that:

Darwin Harbour, Shoal Bay, the Howard Springs Sand Plains, Finniss River and Adelaide River Coastal Floodplains and Fogg Bay are all recognised as being of national and international significance. Key Environment and Heritage Objectives in the Regional Context and Policy section of this plan establish a framework to ensure more detailed planning and assessment of development occurs in the context of appropriate identification and protection of areas of conservation significance.

A key Objective of the Plan is to:

Protect and maintain the significant biodiversity and habitats (natural landscapes) of the region, including the threatened plants and animals under the Territory Parks and Wildlife Conservation Act 2013 (NT) and the Environment Protection and Biodiversity Conservation Act 1999 (Cth).

The Howard sand plains SOC received a similar designation in the current land use plan.

2.3.3 Mining of extractive minerals in the Howard sand plains

Demand and uses of extractive minerals

The Howard sand plains are a major source for the supply of fine sand, coarse sand and gravel to the construction industry in the Darwin Region (Doyle 2001). Total Darwin region extraction of these extractives plus crushed rock for the four years to 2001 was 1.3 million tonnes, which was approximately 50% of the Northern Territory usage (Doyle 2001). Northern Territory production of sand in 2000-01 was 328 725 tonnes (Department of Mines and Energy (DME)), with sand production in 2013-14 reported by the DME to be 753 663 tonnes. This is greatly in excess of Doyle’s (2001) predicted 500,000 tonnes of sand likely to be produced in 2020. The rapid increase in mining of extractives is associated with recent demand from urban expansion and development along with the INPEX gas plant and other developments on Darwin Harbour.

Fine sand is used for land fill in new land developments, housing pads, piping bedding sand, sanitary land fill and mortar and plaster (Doyle 2001). In these applications the sand needs to be free of vegetable matter and is neither screened nor washed. Washed fine sand is used in manufacture of pavers and as an additive for concrete in paving slabs, pipes, and bridge beams. Washing to reduce silt and clay content is required for these purposes.

Coarse sand is used as concrete aggregate and in the manufacture of concrete blocks. Natural gravel is primarily used as road base, fill material and as decorative stone. High quality gravel is used for road base-course, with lower quality gravel used as shoulder and sub-base material. Natural gravel does not have the strength of manufactured crushed rock. Crushed rock must be used in urban areas, greatly reducing demand for the natural equivalent (Doyle 2001).

Extraction of superficial deposits of fine sand

Superficial fine sand deposits occur across the Howard sand plains. These are located at the surface on top of a superficial lateritic layer, or may have accumulated in stream channels where the laterite has leached away. On average the sand is 1 m in thickness and contains generally less than 10% clay and silt (Doyle 2001).

Extraction is a relatively simple process involving no more than removal of the native vegetation, stripping away the upper 100 mm to remove the organic content, followed by stripping of the sand to a depth, on average, of 50 cm (but up to 2 m), and stockpiling, screening and washing depending on clay and silt content and projected end uses. Stripping depths are usually defined by a need to cease stripping above underlying laterite in order to avoid contamination with clays, an underlying layer of ferricrete, or as defined by the depth of the water table during the Dry season (Figure 8). The pits cover areas of land limited by the boundaries of extractive licences and permits, and the area covered by economically viable deposits of sand.

Figure 8: Sand mining in the Howard sand sheet (NT EPA, Photographer C. Smith)

Extraction of coarse sand deposits

Coarse sand deposits have been identified and are being exploited in areas adjacent to and/or on the Howard sand plains. ‘Sand deposits are generally located within a 2 km wide corridor either side of the river and are 0-15 m below the current topographic surface’ (Doyle 2001). Depths are generally shallower at lower topographies to the west and east of the Howard River. Exploitable deposits in the Howard River area are on average about 12 m thick. Extraction of coarse sand involves (Doyle 2001) removal of sand sheet vegetation, removal of an average 2 m of lateritic gravel and clay/claystone, excavation of overburden and coarse sand to the depth of the Dry season water table (about 10 m below the surface) and dredging of coarse sand below the Dry season water table to depths of up to at least 20-25 m. The extractives are screened, washed and products stock piled (gravel, coarse sand and fine sand).

Bucket excavation has been used although this limits the depth of extraction to about 6 m compared to 20-25 m or possibly more using dredging.

Extraction of gravel

Natural gravel is sourced from erosional remnants of lateritic, hard mineral crust near or at the top of the soils in the Darwin region, which are extensive. Most gravel sources close to Darwin are largely exhausted. For example areas near Girraween Road west and east of the Howard River and near Gunn Point Road were largely depleted by 2001 (Doyle 2001).

Lateritic gravel is stripped from shallow pits, screened to remove oversize material and stockpiled (Doyle 2001).

2.3.4 Extent of mining extractive minerals on the Howard sand plains

Lands subject to mining disturbance cover 4.1% of the Howard sand plain SOC (Liddle *et al.,* 2013). These data are current as of the date of the imagery used to conduct the mapping (2010).

Mining of extractive minerals in the Howard sand plains has altered and continues to alter the extent and distribution of sand sheet heaths across the north-south and east-west extents of the flood plains. Sand sheet heath habitats occupy approximately 38% (2259 ha) of the SOC. As of 2013, 21% (502 ha) of the sand sheet heaths had been subject to mining (Liddle and Fisher 2014). The sand sheet heaths accommodate approximately 75% of the extractive industry activities in the region. Permit and licence areas are distributed across the north-south and east-west axes of the sand plains, other than where there are reservations from mining associated with water abstraction bores, or where there are areas that may be difficult to access or do not contain viable sand resources (Figure 9).

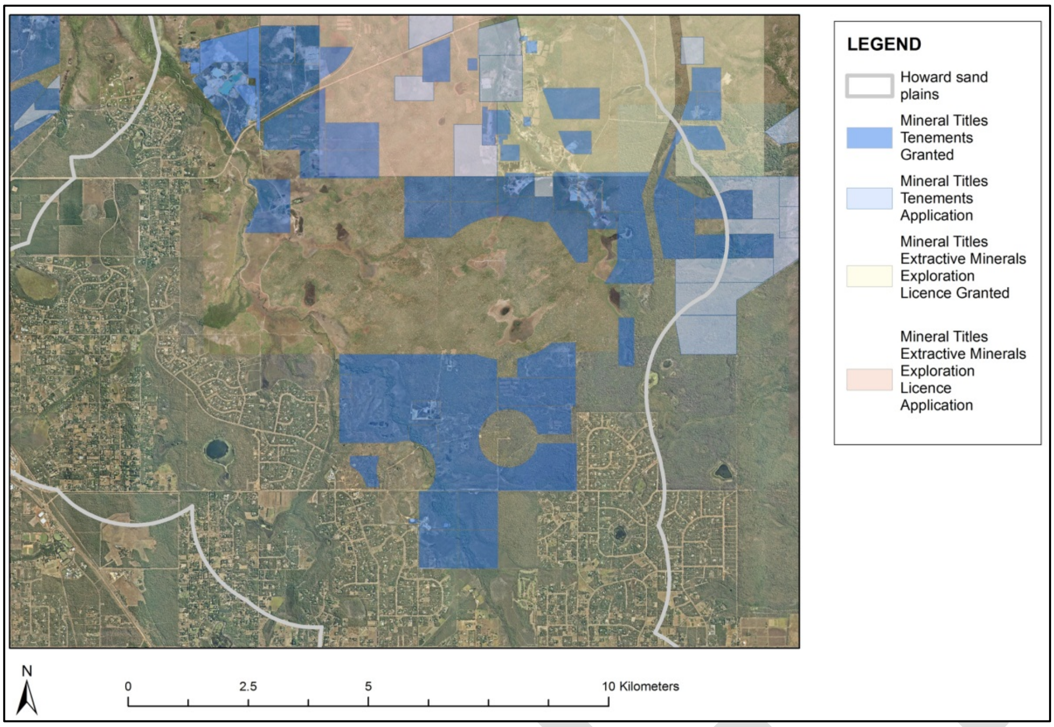

Figure 9: Mineral titles across the Howard sand plain (NTG, DME)

2.3.5 Rehabilitation of the Howard sand plains following disturbance

Two studies of rehabilitation of extractive sites have been completed. Additional work is being undertaken by Charles Darwin University in collaboration with the Extractive Industry Association, Greening Australia, Power and Water Corporation (http://www.greeningaustralia.org.au/project/howard-sand-plains).

Tayler (2004) undertook a review of the extractive industry's rehabilitation performance in relation to Australian best practice in mined land rehabilitation. He found that the rehabilitation of extractive sites had historically been poor in the Northern Territory.

Rehabilitation of extractive sites was first addressed in the 1970s by the then Commonwealth Department of Northern Australia. The agency recommended even re-spreading of top soil with the pit floor ripped along the contour. Direct application of seed prior to the Wet season was recommended with use of fertiliser as appropriate.

The Conservation Commission of the Northern Territory provided guidance on the rehabilitation of borrow pits in 1983 (Applegate 1983). These recommendations included deep ripping of pit floors, stockpiling of top soil, recommended pit sizes and buffers between pits and from drainage lines, and a maximum pit depth of 1.5 m. These recommendations and those of the Commonwealth were used by DME in developing guidelines for the extractive industry in 1985. These guidelines did not differ greatly from those of the previous recommendations. None of the recommendations dealt with the consequences of differing vegetation or soils, or a need for monitoring success of the rehabilitation.

Current DME recommendations for rehabilitation for the extractive industry are generic and relate to all mining operations. It consists of a Commonwealth 2006 publication by the Department of Industry, Tourism and Resources titled:

'Leading practice sustainable development for the mining industry: mine rehabilitation'. This provides high level generic advice for the entire mining industry, together with case studies. None of the case studies relates to the extractive industry. DME provides an advisory note: *'Mining Management Plan (MMP) structure for the extractive operations'.* This includes recommendations for rehabilitation, largely limited to advising the inclusion in the MMP of information on 'infilling, replacement of top soil, revegetation techniques and ripping/scarification etc'.

The paucity of advice on rehabilitation of extractive sites, particularly sand extraction sites, seems likely to reflect the absence of consensus on the goals of such rehabilitation, and the absence of techniques likely to provide for rehabilitation of sites to allow protection of the sand plains' biodiversity.

Price *et al.,* (2005) conducted an intensive study of the effectiveness of rehabilitation of extractive sites for fine sand and gravel in the sand plains and other areas adjacent to Darwin. They assessed recovery of woody vegetation and found that:

- mined sites recovered about 50% of the stem count and canopy
- mined sites recovered about 10% of the basal area and mature tree count
- time since mining had no influence on recovery, even after 27 years
- deeper mines had poorer recovery
- gravel mines did not recover as well as sand mines
- only 35% of expected woody species were present on sand mined sites
- only 41% of expected woody species were present at gravel mined sites.

No attempt was made to assess the effectiveness of rehabilitation in terms of *Utricularia* or other herbaceous species.

The authors concluded that there was a need to improve the standard of rehabilitation, and that the capacity to rehabilitate to a level that could support the area's threatened species was problematic.

These conclusions were endorsed by Grattidge (2013) when developing guidance for rehabilitation following sand mining in the Howard sand plains. The detailed guidance largerly reflected procedures and processes widely used in rehabilitation of shallow mining sites. These remain largely untested and of necessity include procedures and processes that remain hypothetical. Grattidge (2013) did not claim that the proposed processes would or necessarily could result in rehabilitation of the sand plains' biodiversity.

Recent work involving Charles Darwin University, the Extractive Industry Association, Greening Australia and the FFD has focused more specifically on rehabilitation for effective re-colonisation by species of *Utricularia.* While these studies are ongoing, there has been little success in providing for colonisation by the rarer and often microhabitat specific species (Herath 2014). The nature of *Typhonium'*s and the *Utricularia*s' microhabitat specialisations e.g. location of *U. dunstaniae* in areas of water percolating from the ground and the importance of worm mounds to this and other species, may well preclude appropriate rehabilitation at the bottom of a pit (often under water), or on an artificially sloped rehabilitation.

There is no known way in which to rehabilitate the Howard sand plains biodiversity. The nature of the sand plains and the biology of its biodiversity are likely to preclude effective rehabilitation in the long term.

3 Threats to the biodiversity of the Howard sand plains

Potential threats to the sand plains' biodiversity are associated primarily with urban and rural development, and the activities of the extractive mining industry. The impact of a development/threatening process on any species or ecological community is a function of the vulnerability of that species/community to the disturbance (as determined by its habitat requirements and life history), the extent and severity of the disturbance, and the adequacy of any mitigation or rehabilitation applied during and following the disturbance.

This section describes the potential vulnerabilities of the threatened community and threatened species to potential sources of threat, and assesses the extent and nature of the threats.

3.1 Vulnerability of the Howard sand plains' biodiversity to threats

The vulnerabilities of the species rich bladderwort community, the vulnerable *U. dunstaniae*, the endangered *T. taylori*, the endangered *P. macarthurii* and the vulnerable Howard toadlet to habitat disturbance are assessed using an analysis of known habitat requirements, and where appropriate, knowledge of other vulnerabilities (e.g. fire and weeds). The vulnerabilities of the Howard sand plains biodiversity are expressed in terms of the habitat or other features that are critical to its continued existence.

3.1.1 Vulnerabilities of the bladderwort communities of global significance

The patterns of distribution of *Utricularia* species vary across the Howard sand plain vegetation types and across the flood plain (Cowie 2002). Some species are found predominantly in the west and north of the floodplains, some in the north eastern area, and another group of species is more likely to occur in the southern parts of the area. These difference are likely to be influenced the micro-habitat requirements of the various species.

Taylor (1989) was the first to report significant differences among the micro-habitat requirements of bladderwort species on the sand plains. He found that *U. gibba* occurred in deeper pools, anchored to the bottom or margins, while *U. leptoplectra* was found on the pool margins, but extended away from the pools into wetter areas among hillocks/hummocks. In contrast *U. circumvoluta, U. capilliflora, U. dunstaniae, U. holtzie, U. hamiltonii, U. kamienskii, U. lasiocaulis* and *U. quinquedentata* occurred in shallower water (a few millimetres to a few centimetres deep) between hillocks. *U. caerulea, U. chrysantha, U. odorata and U. subulata* (cliestogamous form only i.e. bears closed flower buds that self-pollinate) occurred towards the edge of surrounding woodlands among taller grasses and sedges.

Hillocks play a significant role in providing a diverse habitat capable of maintaining many species of bladderwort (Cowie 2002). Earth worms (likely to be species of *Diplotrema*, G. Dyne *pers. comm.*) build low hummocks of soil a few centimetres or more in height around the bases of the sedge *D. spathaceus* or grass tussocks. It is thought the mounds allow worms to remain above water level during the Wet season. The mounds provide the hillocks and depressions noted by Taylor (1988). Cowie (2002) noted that *U. capilliflora, U. dunstaniae, U. holtzie, U. hamiltonii,* and *U. lasiocaulis* occupied the shallow water in depressions while *U. caerulea, U. chrysantha, U. kamienskii, U. odorata* and *U. quinquedentata* inhabit the dryer mounds (or moist sand in areas that started to dry out). The proportion of mound dwelling species increased as these habitats dried out.

Other habitat requirements noted by Cowie (2002) included:

- *U. limosa* – tolerant of stagnant water
- *U. caerulea* (small white form) – ephemerally moist areas in *Eucalyptus* woodland
- *U. kimberleyensis* – seasonally water logged *E. alba* woodland
- *U. caerulea* (large form) and *U. odorata* – seepage areas that remain waterlogged for most of the year
- *U*. chrysantha and *U. odorata* – tend to peak after water has receded, with *U. odorata* found on sites with more grass
- *U. leptoplectra* – found in finer textured soils down slope, with prevalent grasses, deeper surface water and no ground water seepage.

These examples are likely to be only some of the intricacies of habitat partitioning among species of *Utriculia* on the sand plains. Maintenance of these micro-habitat features and the capacity for partitioning of micro-habitats through time, in association with changing hydrological conditions, are likely to be critical in maintaining the species rich communities.

The ecology of the species rich bladderwort communities suggests vulnerability to:

- alteration of the distribution and abundance of sand sheet heaths across the north-south and east-west extents of the flood plains (i.e. habitat removal)
- spatial and temporal alteration of ground water tables, and surface water flows across the the entire wetland system in relation to ground water seepage, spring flows, patterns of Wet season inundation/saturation, and Dry season water availability
- alteration of topographic and micro-topographic features relevant to maintaining existing patterns of surface water flows, inundation and water logging.

There is no available information concerning the vulnerability of the bladderwort community to fire, weeds or feral animals.

3.1.2 Vulnerabilities of the vulnerable *Utricularia dunstaniae*

The habitat requirements of *U. dunstaniae* are not documented beyond the species having requirements for sand plain heath vegetation and wetter environments than some associated bladderwort species. It is often associated with water percolating from the ground. There is no detailed information on the species growth period, or the nature and duration of hydrological conditions necessary for growth and reproduction. The species is distributed in very small populations over what may include areas distributed over the north-south extent of the sand plain (Kerrigan and Cowie 2007a; Liddle *et al.,* 2013). The habitat requirements for maintaining effective pollination over the small and widely dispersed populations remain unknown.

The habitat requirements and the little that can be surmised indicate vulnerability to:

- alteration of the distribution of sand sheet heaths across the north-south and east-west extents of the flood plains (i.e. land clearing)
- spatial and temporal alteration of ground water tables, and surface water flows across the entire wetland system in relation to ground water seepage, spring flows, patterns of Wet season inundation/saturation, and Dry season water availability
- alteration of topographic and micro-topographic features relevant to maintaining existing patterns of surface water flows, inundation and water logging.

Nothing is known about the potential impacts of fire, weeds and feral animals on *U. dunstaniae.*

3.1.3 Vulnerabilities of the endangered *Typhonium taylori*

Known *T. taylori* populations are restricted to sand sheet heath vegetation located in the western, north to south portion of the Howard sand plain. In this habitat it is restricted to areas of water logged soils and inundation in areas of flowing water such as adjacent to springs arising from neighbouring gravelly rises. Plants may become submerged. Timing of plant emergence in the Wet season varies among sub-populations according to timing of increasing water availability. Additional plants may initiate growth as late as May if water availability lasts. This may occur when the above ground parts of plants in other subpopulations are in senescence (Liddle and Trikojus 2010).

The critical nature of water availability is well demonstrated by the growth patterns of plants in three populations studied by Liddle and Trikojus (2010). The differences in growth pattern were attributed to the differing effects of different human infrastructure on surface water hydrology.

One population studied had a bitumen road 100 m upstream of the site, a bitumen road along one edge of the site and was adjacent to a water production bore. This was the driest site studied. It exhibited a relatively rapid increase in plant senescence and hence apparent population decline from March to May (Liddle and Trikojis 2010). By May there was little water left on the site even though it was present across the floodplain upstream of the nearby road.

A second site had less infrastructure intrusion (a series of vehicle tracks that did not impede water flow) and the plants exhibited an in general longer survival of the above ground parts, and limited apparent population decline between March and May.

A third population was in the vicinity of roads, tracks and old mining areas; with the site upstream of impediments to the flow of water. It seemed the wettest site. This site exhibited continued appearance of new plants throughout the period January to May.

These limited observations are likely to be indicative of the sensitivity of *T. taylori* to changes in hydrology and potential impacts from development on the sand sheet. The observations do not provide detailed information on particular plant responses to particular infrastructure or changes in hydrology. Nor do they provide critical information on the likely effects of infrastructure on the plants' growth, survival or reproductive output; all critical to population growth and survival.

The habitat requirements for enabling effective pollination by rove, scarab or other beetles over the small and widely dispersed populations remain unknown.

T. taylori is vulnerable to:

- alteration of the distribution of sand sheet heaths across the north-south and east-west extents of the flood plains (land clearing)
- spatial and temporal alteration of ground water tables, and surface water flows across the the entire wetland system in relation to ground water seepage, spring flows, patterns of Wet season inundation/saturation, and Dry season water availability
- alteration of topographic and micro-topographic features relevant to maintaining existing patterns of surface water flows, inundation and water logging.

Little is known of the potential impacts of fire, weeds and feral animals on *T. taylori.* The introduced pasture grass *Brachiaria humidicola* can form dense monocultures on the sand plains and should be regarded as a significant threat (Liddle and Trikojus 2010).

3.1.4 Vulnerabilities of the endangered *Ptychosperma macarthurii*

P. macarthurii, along with the monsoon rainforests in which it is found, is dependent on the presence of a spring fed-water supply. Elimination or reduction in the water supply, ground water or surface water, could be expected to impact negatively on the palm. Reduction in water supply to the monsoon rainforest could potentially result from lowering of the water table as a result of abstraction, topographic disturbance to recharge zones in adjacent upland eucalypt forests/ woodlands or topographic disturbance adjacent to the monsoon rainforest. Liddle *et al.,* (2006) found that apparently localised lowering of the water table late in the Dry season was associated with increased risk of fire. Fires were instrumental in lowering the abundance of adult *P. macarthurii* in Whitewood Jungle (located in the west of the Howard sand plain), by 60% over the years 1990 to 2000. *P. macarthurii* is known to be vulnerable to:

- potential clearing of monsoon forest habitat
- spatial and temporal alteration of ground water tables, and surface water flows across the entire wetland system in relation to ground water seepage, spring flows, patterns of Wet season inundation/saturation, and Dry season water availability
- alteration of topographic and micro-topographic features relevant to maintaining existing patterns of surface water flows, inundation and water logging.

Fire, possibly exacerbated by the invasion of introduced grasses, is known to negatively impact on *P. macarthurii.* Feral animals have significant negative impacts on *P. macarthurii* (Liddle *et al.,* 2006; Barrow *et al.,* 1993).

3.1.5 Vulnerabilities of the vulnerable *Uperoleia daviesae*

Little is known about the vulnerabilities of the Howard toadlet to various forms of potential impact. In particular there are no data in relation to critical life history staging habitats such as where eggs are laid, where tadpoles grow to maturity, or where the juvenile and adult toadlets spend the Dry season.

The available information is that the Howard toadlet is found primarily in the Howard and Elizabeth River catchments, and has a preference for sand sheet heath vegetation. It has been found in other open habitats, and rarely in eucalypt forest adjacent to sand sheet heaths.

Reynolds and Grattidge (2013) recoded an instance where a Howard toadlet population was transected by the development of a road and a drain. The drain intercepted flows across area, making part of it no longer suitable for the Howard toadlet.

U. daviesae is potentially vulnerable to:

- alteration of the distribution and abundance of sand sheet heaths across the north-south and east-west extents of the flood plains (land clearing)
- spatial and temporal alteration of ground water tables, and surface water flows across the entire wetland system in relation to ground water seepage, spring flows, patterns of Wet season inundation/saturation, and Dry season water availability
- alteration of topographic and micro-topographic features relevant to maintaining existing patterns of surface water flows, inundation and water logging.

3.1.6 Summary vulnerabilities of the threatened sand plain biodiversity

The threatened community of bladderworts, the threatened plant species and threatened Howard toadlet are all subject to largely the same vulnerabilities to threats. These involve the known effects of clearing and mining in removing habitat, changes to surface and ground water hydrology, and aspects of topography and micro-topography that are either related to maintenance of the spatial and temporal characteristics of the hydrology, or to specific aspects of the biology of particular organisms.

Known and potential vulnerabilities to fire, weeds and feral animals cannot be effectively assessed from available information; other than for *P. macarthurii*. It is recognised that the other threatened sand plain biodiversity are or could be vulnerable to these threats, that the impacts of these threats may be increased by various developments, and that the threats are likely to require management as part of any proposal for preserving the sand plain biodiversity.

In summary, the biodiversity of the threatened Howard sand plains is vulnerable to:

- alteration of the distribution and abundance of sand sheet heaths and monsoon rainforests across the north-south and east-west extents of the flood plains (land clearing)
- spatial and temporal alteration of ground water tables, and surface water flows across the entire wetland system in relation to ground water seepage, spring flows, patterns of Wet season inundation/saturation and Dry season water availability
- alteration of topographic and micro-topographic features relevant to maintaining existing patterns of surface water flows, inundation and water logging.

3.2 Threats to the sand plain biodiversity

The major, immediate sources of threat to the sand plain biodiversity are rural and urban development and expansion, and the extractive mining industry.

3.2.1 Threats to sand sheet heath distribution and abundance

The major current threat to the distribution and abundance of sand sheet heaths is the clearing of land associated with extractive mining, including clearing to establish pits, stock piles, sand washing and screening, office and facilities, roads and tracks.

As noted in section 2.3.4, 21% of the sand sheet heath has been subject to mining and extractive mineral approvals are widely scattered across the sand plain. None of the areas subject to extractive mining has been or can be effectively rehabilitated to allow subsequent recovery of the threatened biodiversity.

In addition there are lesser levels of clearing associated with roads and sites for urban development, and ground water abstraction and delivery.

On this basis it is reasonable to conclude that land clearing has had and will continue to have increasingly significant impacts on sand sheet distribution and abundance. All elements of the threatened sand sheet biodiversity are similarly likely to have experienced significant alteration in habitat distribution and abundance, fragmentation and lowered interconnection among populations. This is likely to increase with ongoing land clearing, especially from extractive mining which is largely focused on this habitat.

The spring fed monsoon rainforest habitats have not suffered any known impact from land clearing although there is potential for the rainforests and *P. macarthurii* to have suffered indirect consequences in relation to water availability. Any future clearing of these habitats would result in a significant impact on the two *P. macarthurii* populations in the sand plains, and on the species in the Northern Territory as a whole.

3.2.2 Threats to seasonal patterns of water tables, inundation and saturation

Threats to hydrology are known to be related to impacts of rural and urban development and extractive mining.

Threats related to rural and urban development are ground water abstraction leading to documented significant lowering of Dry season water tables (section 2.3.1) and undocumented but likely impacts of human recreational activities. Human recreational activity causing development of tracks, hollows and compaction of the ground from machinery have unassessed impacts on patterns of surface water flows through the sand plain habitats. They are also likely to alter topographic and micro-topographic features, including those manufactured by earthworms, which provide a hydrological basis of microhabitat selection among wetland plants.

Potential threats from mining involve:

- pits and excavations reducing ground water flows to areas of percolation and springs causing altered patterns of surface water flows and availability
- pits and excavations enhancing drainage from areas of ground water percolation and springs
- impoundment of surface water flows in pits and other mining activity caused depressions intercepting, reducing and altering surface flow volumes and patterns
- impoundments in pits and excavations enhancing Dry season evaporation of ground water and earlier lowering of the water table (especially in areas with high hydraulic capacity)
- impoundment in pits and excavations enhancing infiltration to ground water, causing earlier raising of the water table to its maximum
- abstraction of water for use or pit de-watering causing enhanced rates of lowering of water tables in the Dry season.

The potential threats from mining are not independent of each other. For example there are interactions between the water table lowering effects of enhanced evaporation from a pit and the raising of a water table by early Wet season rains. These are difficult to measure and assess (e.g. Arnold *et al.,* 2002). The outcomes however are likely to vary according to timing and quantities of early rains, and the late Dry season weather. Whatever the outcomes of interactions in any particular year, the pattern of outcomes across years seem unlikely to conform to those prior to mineral extraction.

Increasing areas for shallow and deep pits intersecting the water table, increasing numbers of stockpiles and other infrastructure, increasing lengths of roads and tracks and pit dewatering will inevitably cause significant change in the spatial and temporal patterns of surface water flows and availability of ground water. The impact of these changes with expansion of the extractive industry cannot be predicted with precision. It is reasonable to conclude that change to surface and ground water is likely to have a negative influence on the quality of habitat for the threatened species and community.

3.2.3 Impacts on the threatened biodiversity

The *Utricularia* (including *U. dunstaniae*), *T. taylori* and *P. macarthurii* have high levels of known habitat or microhabitat specialisation. These are largely defined by seasonal and spatial patterns of water flow, depth and duration of inundation and waterlogging. Change to the seasonal and spatial patterns caused by interactions between abstraction and the hydrological impacts of mining would inevitably impact on the availability of micro-habitats, and in consequence the threatened biodiversity.

Mining and other infrastructure is known to impact *T. taylori* by altering temporal and spatial patterns of surface water flow (Liddle and Trikojus 2010).

Low rainfall wet seasons and associated lowering of water tables may alter the temporal pattern and availability of surface flows, ground water percolation and spring flows critical to growth and longer term survival of the species rich *Utricularia* communities and *U. dunstaniae.* As with *T. taylori,* these seem vulnerable to disruption of water flows by mining excavations, roads, etc., with consequent reduction in micro-habitat diversity, and negative impacts on the species. Negative impacts on the hummock building earthworms would exacerbate microhabitat loss.

Liddle *et al.,* (2006) documented a dramatic 65% reduction in the number of adult *P. macarthurii* in Whitewood jungle (on the western edge of the sand plain). This was attributed to fire associated with drying of the monsoon rainforest during a period of low rainfall Wet seasons, exacerbated by significant lowering of the water table caused by abstraction. The level of abstraction of water from the sand plains has increased since that time (Yin Foo 2004; Yin Foo (as quoted in Woodward *et al.,* 2008)), and is likely to increase in the near future.

It is reasonable to assume that altered patterns of ground and surface water hydrology would also impact the Howard toadlet. Impacts would particularly relate to altered temporal and spatial availability of habitats that provide it with opportunities for Wet season breeding and feeding activities.

Lowering of water tables caused by abstraction interacting with the effects of disturbance from mining have impacted on ground water and surface water hydrology across the entire Howard sand plain wetland system, and has had recorded impacts on the threatened biodiversity.

4 Conservation of the Howard sand plains' biodiversity

Urban and rural development and the extractive mining industry in the Howard sand plains area are impacting negatively on the area's biodiversity. The impacts relate to documented vulnerabilities of the sand plain's threatened community and species. The impacts cannot be rehabilitated.

The objective of this section is to provide a lowest risk option for preservation of an area/s of the Howard sand plains that will allow for the long term persistence of the Howard sand plain's threatened biodiversity, and that can be implemented in the near term.

This section documents the strengths and weaknesses of our knowledge of the Howard sand plains, identifies the objectives of establishing a protected area and the specific requirements to meet these objectives, discusses options for a risk averse approach to the design of a protected area/s that takes account of the strengths and weaknesses of existing knowledge of the sand plains, and outlines a risk averse final lowest risk option for the protected area. Appropriate design parameters are determined, and evaluated in relation to the positive and negative consequences of changes to those parameters.

4.1 Limitations to knowledge of the sand plains

4.1.1 Limitations to knowledge of biodiversity

Knowledge of the Howard sand plains biodiversity is limited to sampling of the sand plains to determine:

- the species richness of *Utricularia* in various plant communities on the sand plains, and the distributions of individual *Utricularia* species (including *U. dunstaniae*) (formal quadrat survey and less structured searches)
- the distribution of *T. taylori* in relation to the sand plains and vegetation types (formal survey of 11 quadrats in likely environments and less structured searches)
- extensive searches and evaluation of *P. macarthurii* populations (many years of information)
- records of *U. daviesae* from informal sampling
- casual natural observations.

The survey data on the species rich *Utricularia* communities and *U. dunstaniae* are constrained by the number of plots sampled for plants (only 69). Nearly half the vegetation types were sampled from only one or two plots. The highest number of plots for a vegetation type was seven, and this was used in only two cases (Liddle *et al.,* 2013) (Figure 10). The sampling intensity is low.

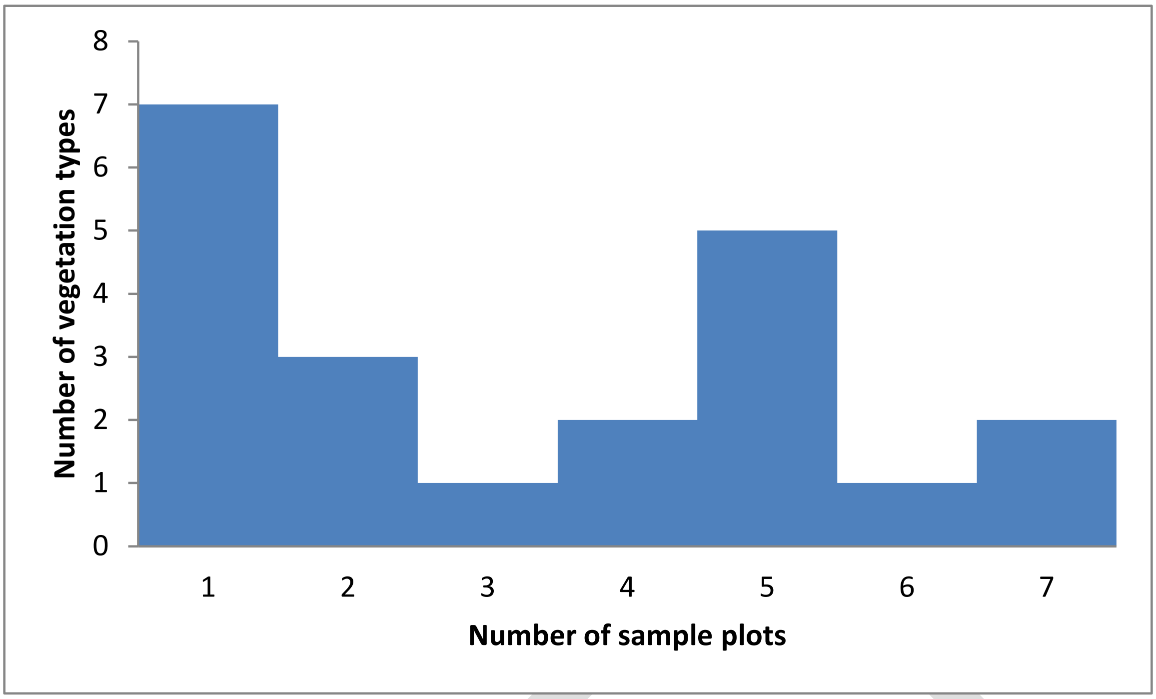

Figure 10: Numbers of vegetation types in relation to number of sample plots used

If it is assumed the 26 *Utricularia* species recorded from the area are all the species present (there may be an additional species (e.g. Wakabayashi (2010) described a species of *Utricularia* not previously known to science)), then the formal sampling failed to locate seven species, and may have provided underestimates of the number of *Utricularia* species in vegetation types (Figure 11). It may also have influenced understanding of the distribution of *U. dunstaniae.*

Sampling of *T. taylori* may have been similarly deficient. Eleven plots is a very small number of plots. Plots were located in areas thought to provide appropriate habitat. No indication was provided as to the presence or extent of similar habitats in other parts of the sand plains.

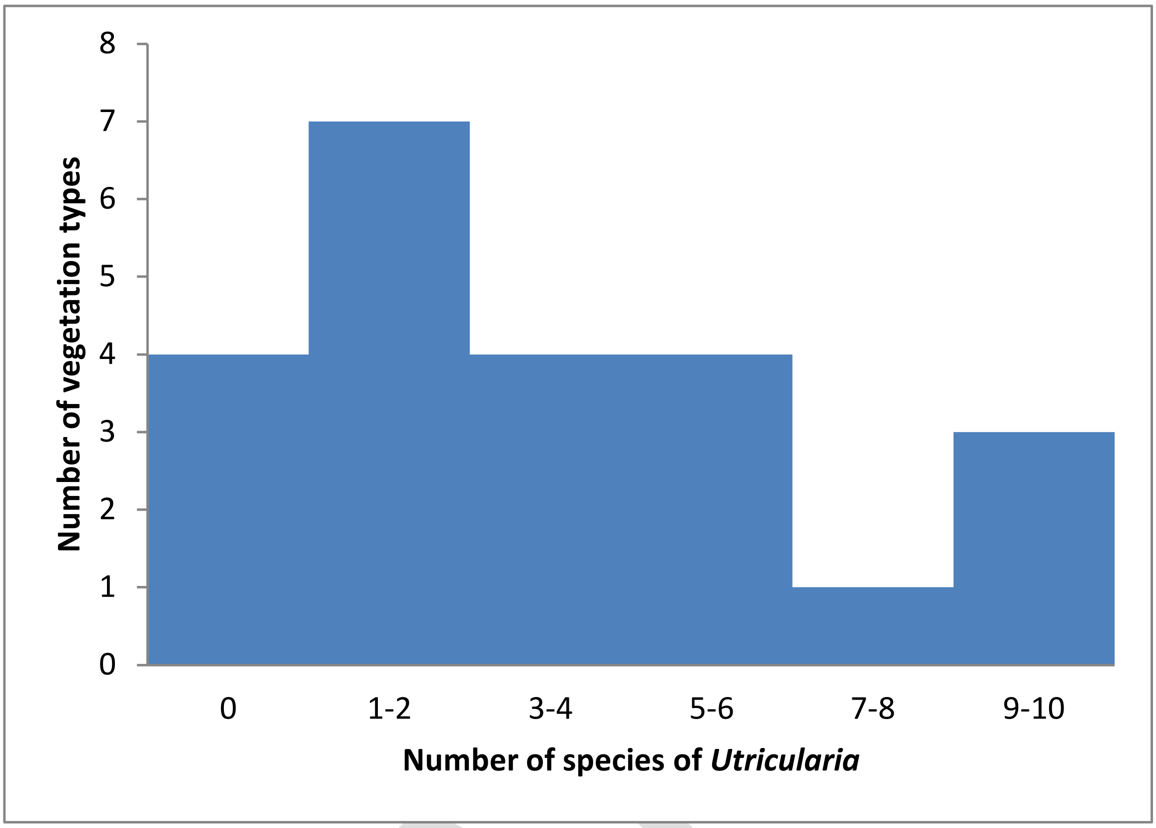

Figure 11: Number of vegetation types in relation to number of species of *Utricularia* recorded

Documented knowledge of the life histories, natural histories and ecology of the species rich *Utricularia* communities*, U. dunstaniae,* and *T. taylori* are limited to the distributional and habitat data listed above, and a brief natural history account of *T. taylori's* seasonal growth cycle. Data on population sizes are limited to unreliable estimates for three *T. taylori* populations. There are no data on pollination or fruit dispersal of these species.

P. macarthurii has been relatively well studied producing useful data of species distribution, population sizes, habitat requirements, pollination, fruit dispersal and population genetics. There is also a good understanding of the effects of changing water tables, fire, and feral animals on populations of *P. macarthurii.*

The *U. daviesae* data are biased by sampling having been constrained by the difficulty of accessing the wetlands during the Wet season. Sampling is largely limited to access via roads and tracks, leaving large areas of the sand plains not sampled, few records to assess (N=47), and providing a limited capacity to assess habitat preferences. There is little known of the species' biology or level of population fragmentation on the sand plains.

Limitations to the understanding of the Howard sand plains biodiversity are summarised in Table 1: Understanding of Howard sand plains biodiversity

	Utricularia community	*U. dunstaniae*	*T. taylori*	*P. macarthurii*	*U. daviesae*
Distribution	North-south & east-west species distributions across plains, sample bias	Few identified, sample bias	Some populations identified, sample bias	Adequate	Inadequate data, biased sampling
Habitats	Many vegetation types, ranked by species richness, sample bias	Vegetation types described, sample bias	Vegetation types described, possible sample bias	Adequate data, possibly dated	Inadequate data, biased sampling
Population size / abundance	No population data	No population data	Unreliable population data	Adequate data, possibly dated	No population data
Population fragmentation	No data	Few, dispersed small populations, sample bias	Few, dispersed, small populations, sample bias	Dispersed, adequate data	No population data
Seasonal growth, reproductive cycle	Little known	Little known	Basic description	Adequate data	Basic description
Pollination / fruit dispersal / dispersal / population genetics	Unknown	Unknown	Unknown	Adequate data	Unknown

Table 1: Understanding of Howard sand plains biodiversity

4.1.2 Limitations to knowledge of hydrology

Knowledge of the hydrology of the Howard sand plains is biased by the imperative of providing Territorians with a water supply. There has been no investigation of the intricacies of the surface water-ground water interaction at a scale appropriate to understanding the needs of the threatened biodiversity. There has been no investigation of the local hydrological impacts of extractive mining on surface and ground water flows across the Howard sand plain wetland system. There is no understanding of the cumulative impacts of abstraction and mining on the hydrology at any scale, and there is no appropriately detailed understanding of the hydrological requirements of the threatened species. Nor are there any records of how, or in what ways, abstraction and mining have impacted the hydrological environments of the threatened biodiversity, other than for the historical impacts of abstraction on *P. macarthurii*.

4.2 Required outcomes of a protected area on the Howard sand plains

The limited knowledge of the biology of the threatened biodiversity and the hydrology of the sand plains greatly reduces the certainty of success that any protection framework might provide for the security of the biodiversity of the Howard sand plains.

Certainty can only be increased by using a risk averse approach to the design of the protected area. That approach needs to make best use of the biological information that exists. It also needs to take a precautionary approach in relation to shortcomings in the available biological information, and to determining parameters to mitigate the threats of mining and urban development.

The key outcomes of a risk averse protected area design are to:

- preserve the apparent north-south and east-west variation in the occurrence of *Utricularia* species
- preserve the range of micro-habitats that are the basis of habitat specialisation among the *Utricularia* species and the broad distribution of species rich *Utricularia* communities across the majority of vegetation types
- preserve the known populations of *U. dunstaniae*, and if possible habitat types that may contain additional populations
- preserve all or at least the vast majority of the few known populations of *T. taylori*
- preserve the two populations of *P. macarthurii*
- preserve the majority of known *U. daviesae* locations in the sand plains
- preserve sufficient area to maintain viable populations of the many species that have small and widely dispersed subpopulations
- preserve habitats that provide or are likely to provide for all life history stages of the threatened biodiversity
- preserve the metapopulation dynamics of the threatened species
- protect hydrological conditions across the entire wetland system
- provide a design that facilitates future management of threats and the protected area.

These outcomes are compatible with the environmental objectives of the Northern Territory Government's Framework for the Future policy. The protected area would also be in keeping with the Northern Territory Government being signatory to the National Strategy for Ecologically Sustainable Development and Australia's Biodiversity Conservation Strategy.

4.3 Risk averse protection of wetland biodiversity

The approach to development of the lowest risk option for a protected area is based on recognition that the Howard sand plains is a wetland system, and that the sand sheet heaths are wetlands often bordered by other wetland types. There are a number of definitions of wetland. The simplest is that provided by the Macquarie Dictionary (Yallop 2005 (ed.)): 'an area in which the soil is frequently or permanently saturated with or under water'. There are many other definitions, such as that provided in Article 1 of the Ramsar Convention on wetlands (UNESCO 1994). The Macquarie Dictionary definition is sufficiently encompassing to accommodate the higher level of detail included in this and other definitions.

Design of wetland preservation areas can be based on identification of habitat areas of primary significance (core habitat) that are sufficient to sustain the wetland areas that are to be preserved, and the designation of surrounding areas (buffers) to provide a risk averse approach to ensuring that species and populations are adequately included in the protected area, to ensure all life history stages and population and community processes of the species of concern are catered for with appropriate habitat, and to protect the area and its species/communities from external threats (e.g. Water and Rivers Commission 2000; Semlitsch and Bodie 2003; DERM 2011).

All such guidelines require detailed evaluation of the wetland to be preserved (e.g. DERM 2011). This can only be undertaken with certainty if there is substantial knowledge and understanding the systems to be preserved, and the threats to the systems. The fundamental requirement is that each situation be examined according to its characteristics, conservation needs and current understanding; with guidelines tailored to suit the individual circumstance (DERM 2011).

Preservation of the metapopulation dynamics of species is a key consideration in the design of wetland protected areas. The ecology of metapopulation dynamics is well understood and potentially applies to any organism. All populations have a finite probability of going extinct. The probability of extinction is influenced by population size (the smaller the population the higher the probability of extinction), and the rate at which the population is colonised by individuals from adjacent populations (the higher the rate of colonisation, the lower the probability of extinction). Some species populations may naturally occur as multiple entities whose survival depends on colonisation (i.e. dispersal among populations). Other species' populations may become fragmented by development activities, with the survival of the fragments then depending on dispersal among populations. Fragmentation can also cause disruption of gene flow (genes in dispersing animals, seeds in dispersed fruit, or pollen), between subpopulations and have significant impacts on genetic diversity. The threatened biodiversity of the sand plains exists with many species having naturally small, widely dispersed subpopulations (e.g. many *Utricularia, T. taylori*), and most are vulnerable to fragmentation from mining and infrastructure.

Size of a protected area has a direct bearing on the vulnerability of an area to outside threats, and the capacity to manage the area. Smaller, fractured areas have smaller area to circumference ratios than would a single area of similar total area. This effectively increases the level of exposure of the protected area to outside impacts (e.g. hydrological impacts caused by mining, unpredictable pollution events) and exacerbates the future difficulty of managing the preserved area/s (e.g. fire management).

4.3.1 Core habitats

Core habitat is easily defined in many wetland systems as being the high water mark, the edge of a swamp, or a river bank with its riparian vegetation. Using this definition of core habitat would require the entire area of seasonally inundated and saturated wetlands of the Howard sand plain to be defined as core habitat (i.e. the entire area mapped by Liddle *et al.,* (2013)) (Figure 12).

Liddle and Fisher (2014) choose to define core habitats, focusing on habitats containing larger numbers of records of the threatened community and species. This entailed defining one or more wetlands types as core habitats from among other contiguous wetland types in a single wetland system. There are no available guidelines that address this approach. They used the vegetation mapping and quadrat data of Liddle *et al.,* (2013) to identify habitat types that could be viewed as core habitats. The determinations were made for bladderwort communities and for each of the threatened species as follows.

Determination of core habitats for species rich *Utricularia* communities, and *U. dunstaniae* were conducted together. Priorities were based on the presence of *U. dunstaniae*, levels of maximum species richness of *Utricularia* in quadrats, and levels of average *Utricularia* species richness for vegetation types. The core habitats for *Utricularia* are vegetation communities groups 4a, 4b, 4c and 4d. These communities maintain many of the richest areas of bladderworts, and the recorded presence of *U. dunstaniae.* All core habitats are sand sheet heaths.

Core habitats of *T. taylori* were determined as the vegetation type with the greatest abundance of *T. taylori* in the three largest populations, the vegetation type with the second greatest abundance of *T. taylori* in the three largest populations, and vegetation types with other occurrences. The core habitats were the vegetation community groups 3a and 3b. Both core habitats are sand sheet heaths.

Core habitats determined for *P. macarthurii* were the only two areas of the vegetation type where the species occurs, i.e. spring-fed monsoon forest, vegetation type 16.

Core habitats determined for the Howard toadlet were the primary natural vegetation type occupied by the species: vegetation community group 3a and 3b. Both core habitats are sand sheet heaths.

Where possible Liddle and Fisher (2014) avoided including areas of mining disturbance (i.e. avoided 21% of the former sand sheet heaths).

The core areas would allow for protecting the known locations of 20 species (all records, Liddle *et al.,*(2013)) of *Utricularia*, *Utricularia* habitats across the north-south and east-west dimensions of the sand plain, many of the vegetation types known to maintain the most species rich *Utricularia* communities, all known eight records of *U. dunstaniae* in the sand plains, the three largest of the known 11 populations of *T. taylori*, both populations of *P. macarthurii,* and the locations of 28 of the 139 sand plain records of *U. daviesae.*

DLRM (2014c) subsequently made minor refinements to the mapping, and applied a slightly modified process for selecting habitats type. The results are essentially the same (DLRM 2015).

4.3.2 The need for buffer zones

The defined core habitats go a long way to providing a basis for designing a protected area for the sand plains. The conservation deficiencies of the core habitats need to be meet by buffer zones that provide some probability of including the remaining six *Utricularia* species known in the area, an increased number of known *T. taylorii* populations, unknown populations and increased overall population sizes of *U. dunstaniae,* other *Utricularias* and *T. taylori*, and a higher proportion of known locations of *U. daviesae.*

An additional need is for the buffers to link as many of the core habitats as practical into a very few, larger manageable units that provide for metapopulation dynamics. Buffers also need to provide a risk averse approach to mitigating the lack of knowledge of population sizes, distributions and life cycle requirements, as well as protection from outside threats.

The buffer zones are necessarily multipurpose. For example, the vegetation survey by Liddle *et al.* (2013) yielded four non-core *Utricularia* vegetation types with five or more species of *Utricularia,* compared to the six core *Utricularia* vegetation types all of which had greater than or equal to five species of *Utricularia*. The survey also found, having used a similar numbers of quadrat samples, the non-core habitat included more species than the core habitat, with six species not included in the core habitat (Table 2). This underlines the uncertainties associated with low levels of biased sampling, and the multi-parameter importance of a proposed buffer zone. Liddle and Fisher's (2014) designation of core habitats also included data from informal searches for which there are no indications of relative effort among vegetation types. These data are also likely to be biased.

	Core habitats	**Non-core habitats**
Number of samples	**33**	**36**
Number of *Utricularia* species	**13**	**16**
Number of species not found in the other habitats	**3**	**6**

Table 2: **Sampling of vegetation types for species of *Utricularia* by Liddle *et al.* (2013). Core *Utricularia* habits are defined as vegetation types in groups 3 and 4.**

4.4 Buffer zone design

The design of a buffer zone guaranteed to overcome the inadequacies described in section 4.3.2 would require detailed biological and hydrological knowledge of the Howard sand plains, and the impacts of mining and urbanisation.

The review of the threats of mining to the sand plain biodiversity provides clear understanding of the way in which the sand plain hydrology is being or is likely to be impacted. It provides no understanding of the width of a buffer zone that would meet the requirement to protect the habitats from hydrological change. The issue is compounded by unknown interactions between the impacts of mining and those of abstraction.

A brief literature review of buffers and inferences that can be made from what is known of the distributions and biology of the threatened biodiversity are used to guide determination of appropriate buffers in the absence of detailed information. This relates particularly to determination of a risk averse width for buffer zones and provision of interconnectedness between populations that would allow for metapopulation dynamics.

There is a large number of buffer zone widths proposed for the protection of wetlands (e.g. Water and Rivers Commission 2000; DERM 2011; DLRM 2014a). These recommendations are highly varied, and often do not provide sound data based justifications for the recommendations. All relate primarily to providing protection from land clearing.

The buffer recommendations in the documents cited relate to a wetland surrounded by terrestrial habitat, often riparian vegetation. The wetland is the core habitat, and is protected by a buffer of terrestrial vegetation often viewed as also protecting core habitat for terrestrial biodiversity (i.e. vegetation types, species) that requires proximity to wetland, as well as protecting the core wetland habitat from external threats. The buffer’s primary function is to stop land clearing close to wetlands. In some cases the recommendation includes a buffer to protect the buffer (e.g. DERM 2011).

These recommendations do not necessarily apply to the situation on the Howard sand plains. The Howard sand plains situation is one of a core wetland habitat often surrounded by additional wetland; both of which may have been exposed to land clearing, mining into the water table and the effects of abstraction. Areas outside a proposed buffer would likely continue to be cleared and mined, with the core habitat continuing to be affected by abstraction and possibly increasing hydrological impact from mining. The necessary buffer width required to avoid hydrological impacts on core habitat in the sand plains under these circumstances cannot be predicted. It is not simply a land clearing issue.

The approach taken in evaluating a possibly effective buffer width necessarily focuses on what can be gleaned from the literature. The NT EPA is unaware of any study on buffers appropriate to maintaining species rich communities of bladderworts, species of bladderwort or species of *Typhonium.*

There are data on recommended buffer widths for frogs. There are also data on the nature and importance of the metapopulation dynamics of frogs, and buffer widths that may be important to maintaining frog metapopulation dynamics. It is emphasised that as with the clearing guidelines discussed above, buffer widths proposed specifically for frogs relate to retention of terrestrial vegetation around a wetland; not land clearing and mining in, along with abstraction of water from wetlands.

The literature on buffers appropriate to frogs, and the metapopulation dynamics of frogs are briefly reviewed to provide a basis for determining an option for a buffer width that might apply to a protected area in the Howard sand plains. The result is reviewed in terms of what is known and can be inferred from the biology of *U. dunstaniae* and *T. taylori,* the general distributions of *Utricularia* species and

T. taylori, and Northern Territory recommendations on buffers to protect rainforests from the effects of land clearing (DLRM 2014b).

Frogs, metapopulations and buffers

Buffers around wetlands to protect frogs have been developed for two purposes, and have used data from a variety of different species. The purposes are to provide advice on buffers of terrestrial habitat around wetlands sufficient to provide for the every-day activities and life histories of frogs, and/or buffers that are sufficient to allow for juvenile dispersal and associated metapopulation dynamics.

Observations of frog movement during every-day activities provide a recommended buffer of 159 to 290 m (Semlitsch and Bodie 2003). A similar recommendation (100 to 400 m) was derived for seven frog species in the one region using frog species presence and absence data in wetlands (Ficetola *et al.,* 2009). The wide range within the recommendations emphasises the significance of variation among frog species.

There are numerous studies documenting the nature and impacts (e.g. genetic) of disruption of dispersal on frogs (e.g. Vos *et al.,* 2001; Ficetola *et al.,* 2009; Heard and McCarthy 2012; Yu Wang *et al.,* 2012). These studies generally demonstrate various human developments (e.g. roads, urban development, railways) that disrupt dispersal, often leading to genetic differentiation among populations in different wetlands. Ficetola *et al.,* (2012) differed in that they used their results to encourage consideration of the landscape aspects of metapopulations in determining the scale at which connectedness (capacity of frogs to disperse) among populations is managed. As well as recognising that roads etc., caused significant blocks to dispersal, they recommended that a spatial scale of 300 to 1500 m be used in determining buffers.

Investigations into the metapopulation dynamics of the Australian endangered growling grass frog (*Litoria raniformis*) are used as an example where there has been detailed assessment of the metapopulation dynamics, along with provision of recommendations for appropriate buffer widths (Heard *et al.,* 2012, Heard and McCarthy 2012; Heard *et al., 2*013). The growling grass frog is threatened by urbanisation on the fringes of Melbourne. Disruption of dispersal among the fragmented populations is considered to be a significant contributor to population extinction. Populations were recorded as going extinct and estimates made of the rates of dispersal. The probabilities of extinction and colonisation were modelled in relation to landscape features. Heard and McCarthy (2012) were able to determine that narrow buffers of riparian habitat (100 m or less both sides of the river) were associated with a relatively high probability of extinction over a 30 year period (53%). Increasing the buffer to 200 to 300 m both sides of the river reduced the probability of extinction over 30 years to 27%. The probability of extinction over a 30 year period was reduced further to 9% when a 400 to 750 m buffer was used each side of the river. They recommended the use of buffers greater than or equal to 400 m on both sides of a river.

The situations of the growling grass frog and the Howard toadlet are not directly comparable, The growling grass frog (80 mm) is larger than the Howard toadlet (<23 mm). The growling grass frog is likely to be able to move more quickly than the Howard toadlet, and travel longer distances during any given period of time. This does not necessarily imply that dispersal between fractured populations of the Howard toadlet would be any less significant than it is between fractured populations of the growling grass frog, and may in fact be the reverse, i.e. the effects of fracturing populations may become apparent with less habitat disturbance. It may be that *U. daviesae* populations are more vulnerable to fracturing than are those of *L. raniformis.* The size difference may be significant in determining the size of buffers for every-day activities; but an every-day use function is dependent of the locations of habitats in which the Howard toadlet is able to pass the Dry season. This is unknown but likely to be eucalyptus woodlands which occur at variable distances from the identified core habitats.

The two situations also differ in that the growling grass frog is known to exhibit patchily distributed populations whose survival is directly associated with the connectedness of the populations. Too little is known of the distribution of the Howard toadlet to make a determination on the potential importance of metapopulation processes under natural circumstances, or the likelihood of mining, water abstraction and urban development having caused fragmentation. Continued mining of extractives, increased abstraction and urban development have the potential to cause fragmentation, or enhance any existing fragmentation of the species' populations.

An equally significant difference between the two situations is the differing roles of buffers in species preservation. The buffers for the growling grass frog are designed to ensure preservation of habitat suitable for dispersal; and this is related largely to avoiding infrastructure development and preventing land clearing. The role of buffers in the Howard sand plains is more complex, involving preservation of vegetation, and maintenance of appropriate hydrology in wetlands when adjacent wetlands are subject to impacts from abstraction of water, diversion of ground and surface water flows, mining and the development of mining and urban infrastructure, e.g. roads.

Buffers and the threatened plant community and species

The design of appropriate buffers for the sand plains is simplified by the core habitat of the Howard toadlet often coinciding with that of the threatened plant community and the threatened species other than *P. macarthurii.*

An appropriate design for the Howard toadlet may provide a similarly appropriate solution for *Utricularia* and *T. taylori.* The effectiveness of a buffer for the toadlet in insuring the future security of the threated plant biodiversity is dependent on the core habitats and buffer providing a solution to the inadequacies of the core habitat in achieving the key outcomes of a risk averse protected area design specified in section 4.2.

The first seven concerns are partially accommodated by preservation of the core habitats for the plants and the toadlet. The adequacy of buffers designed on the basis of requirements for frogs and the biology of the Howard toadlet would depend on the capacity of the buffers to provide protection for threatened community and plant populations and species that may not be appropriately protected in the core habitat. The adequacy of such protection may be preliminarily determined using distributional data and previous studies. The inadequacies of the distributional, population and life history information would necessitate a precautionary approach to determining an appropriate buffer on this basis.

The few known populations of *U. dunstaniae* and *T. taylori* are small and widely dispersed. Mining and other infrastructure has the potential to exacerbate the level of fracturing of the populations. The major issue associated with the existing population distributions and the effects of development on plants are those associated with maintaining gene transfer between populations via pollination and fruit dispersal.

U, dunstaniae has a specialised flower. This is likely to be related to the need to provide for pollination among widely dispersed populations of few individuals. The pollinator is unknown. The pollinator would likely need to be an insect capable of flying over considerable distances. Provision of buffers linking the widely dispersed populations may be essential to ensuring pollination of this annual plant. Nothing is known of the dispersal of *U. dunstaniae* seeds.

T. taylori likewise has a specialised pollination system that is likely to allow for long distance pollination. Rove and dung beetles are among the likely pollinators. These night-flying, unwitting pollinators are noted to be strong fliers able to cover long distances and rapidly locate new carrion or dung deposits (e.g. Bornenissza 1957; Roolin 2006). The relatively small size of the plant and its flowers indicate that the pollinator is likely to be relatively small (e.g. some rove beetles down to 1 mm or less long, and some dung beetles down to 2 mm long). Retention of buffers linking populations may be critical in maintaining gene flow in the long term. The fruit is unknown although it may be a small berry dispersed by some animal agent.

The core habitats of *P. macarthurii* are located immediately adjacent to core habitats of the other threatened biodiversity. *P. macarthurii* exhibits remarkably little genetic variation within and among populations (Shapcott 1998). Pollination is by generalised pollinators (Essig 1973). Given the wide separation between populations, pollination is likely to be localised and unlikely to benefit from provision of corridors linking populations.

Fruit dispersal is likewise generalised to cater for a number of bird species. Detailed studies have found that the frugivores can be sustained by retaining sufficient native vegetation within a 10 km radius of a rainforest to provide the birds with food during the Dry season (Bach and Price 1999; DLRM 2014(b)).

The core habitats of *P. macarthurii* would be included as core habitat in any design. The buffer provided for frogs should be extended to protect the monsoon rainforest; possibly using the DLRM (2014b) advice for rainforest buffers in upland areas. The DLRM advice is seemingly designed to avoid disruption of the supply of water to rainforest. The basis of this recommendation is not readily available.

4.4.1 Options for buffers around core habitats in the Howard sand plains

A 500 m wide buffer

Fisher and Liddle (2014) provided a draft design for buffers around identified core habitats in the Howard sand plains. The draft proposed a 500 m buffer around core habitats (Figure 12). A 500 m buffer is compatible with recommendations on buffers that provide for the every-day activity of frogs. It may also compatible with existing knowledge of frog dispersal requirements, and may provide some but an unknown level of security in terms of maintaining appropriate hydrology in core habitats, and possibly areas within at least some of the buffer.

Preservation of the designated areas of core habitat and the associated 500 m buffer zones would (Liddle and Fisher 2014):

- preserve the most important remaining areas of the richest known carnivorous bladderwort communities (550 ha, 91% of total of these habitats)
- preserve the three largest populations of the endangered *Typhonium taylori* (3 of 11 locations)
- preserve the known locations (8 of 8 records) of the threatened *U. dunstaniae* in the Howard sand plains
- preserve two of the eight populations (25%) of the threatened Darwin palm (the remaining six occur outside the Howard sand sheet)
- preserve the majority (62%) of the recorded locations of the Howard toadlet in the Howard sand plains
- provide some protection for the other threatened, near threatened and data deficient species in the area.

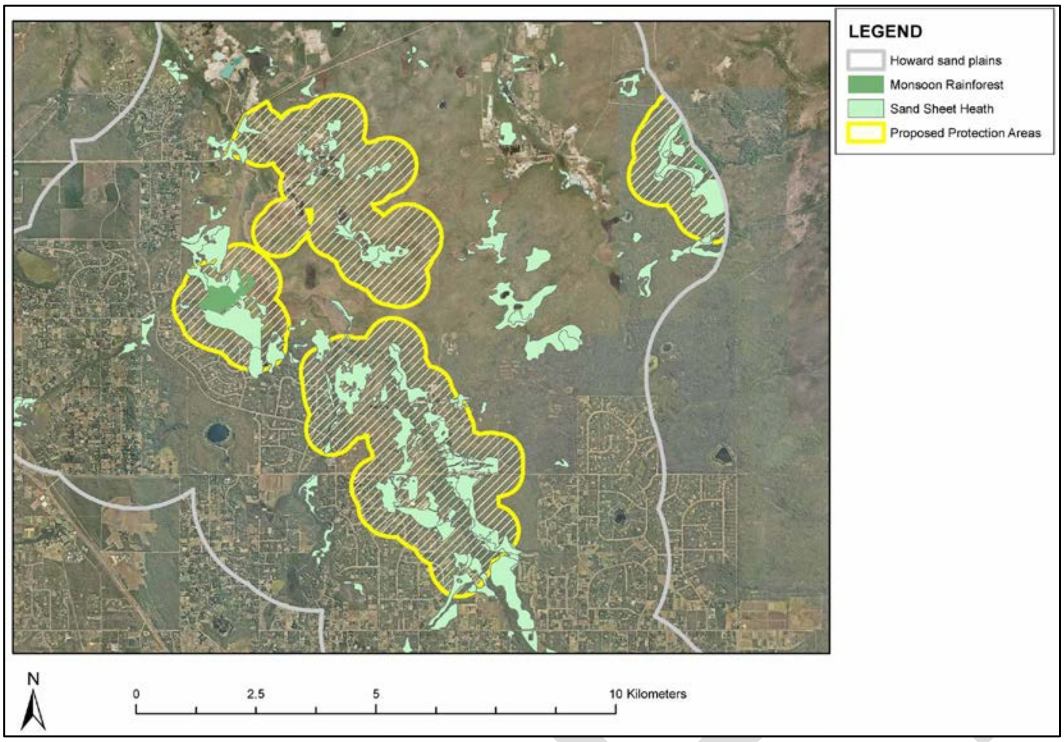

Figure 12: Core habitats and a 500 m buffer (NTG, Liddle and Fisher 2014)

Liddle and Fisher's (2014) draft design needs to be enhanced by modification of the buffer surrounding the *P. macarthurii* monsoon forest in the north east of the area. It is currently defined as 500 m in areas within the sand plain, but is essentially non-existent in areas to the monsoon forest's immediate east and north east, which is outside the sand plain. A buffer of at least 500 m would need to be provided in this area.

The use of a 500 m buffer up the ground water gradient from a core habitat area may be insufficient. For example the Western Australian guideline (Water and Rivers Commission 2006) provides for a 2 km buffer in this circumstance. The Queensland guideline makes reference to this guideline but makes no recommendation in this regard (DERM 2011). The Northern Territory guideline for monsoon forest is 500 m, and makes no distinction according to ground water gradient (DLRM 2014b). This guideline does however recommend retention of sufficient native vegetation within 10 km of a monsoon forest so as to ensure a food supply for frugivorous birds during the Dry season. The issue of an appropriate buffer to protect ground water flows to monsoon forest would benefit from additional knowledge.

A weakness of the 500 m buffer is that it allows for the creation of four separate areas of protected habitat without provision of habitat linkage, potentially leading to fracturing of populations, limitation on dispersal among populations of the Howard toadlet and potential constraints on pollination of the threatened *U. dunstaniae* and the threatened *T. taylori.*

Each of the four areas would have a smaller area to circumference ratios than would a single area of similar total area. This effectively increases the level of exposure of core habitat and buffer areas to outside impacts (e.g. hydrological impacts caused by mining, unpredictable pollution events) and exacerbates the future difficulty of managing the preserved area/s (e.g. fire management).

A 250 m buffer

DLRM (2014c) provided Figure 13 showing a protected area with core habitats and 250 m buffers as a preferred alternative to the protected area design proposing a 500 m buffer in Liddle and Fisher (2014). The DLRM (2014c) option was created using minor changes to vegetation mapping and selection of core habitats. This option and the 500 m buffer option would protect approximately the same known major areas of species rich *Utricularia* communities, the same known *U. dunstaniae,* the same number of *T. taylori* populations, the same two populations of *P. macarthurii,* and the same number of *U. daviesae* locations. The two options were developed using the same data, designated essentially the same habitats and have areas within the buffer that broadly overlap. The options would be expected to produce similar results, but the 250 m option would not necessarily provide for all outcomes required of risk averse design for the protected area.

A direct consequence of the 250 m buffer is subdivision of the protected areas into six generally smaller areas compared to the four that arise when a 500 m buffer is applied. These areas would have increased area to circumference ratios and be more difficult to manage, and more vulnerable to mining and hydrological disturbance and other external threats. These effects would be exacerbated by a 250 m buffer providing for continuation of a larger extractive mining enterprise than would a 500 m buffer. It would allow for development of mining excavation, roads and other infrastructure in zones between the smaller preservations area.

A 250 m buffer would not be in accordance with buffer widths appropriate for ensuring frog dispersal between populations, and may limit appropriate access to Dry season refuges by the Howard toadlet. Nor is a 250 m buffer compatible with the DLRM (2014b) advice of buffer widths around monsoon rainforests. It would also enhance negative impacts on pollination and toadlet dispersal. It guarantees fracturing of populations and impeded dispersal and pollination while ensuring greater vulnerability to external threats.

Compared to a 500 m buffer the 250 m option would inevitably reduce the sizes of populations preserved, and given the limitation of sampling, may lower the probability of preserving additional species of *Utricularia,* additional *U. dunstaniae,* or additional *T. taylori.* Preserving just three populations of an endangered species, *T. taylori,* is not risk averse conservation.

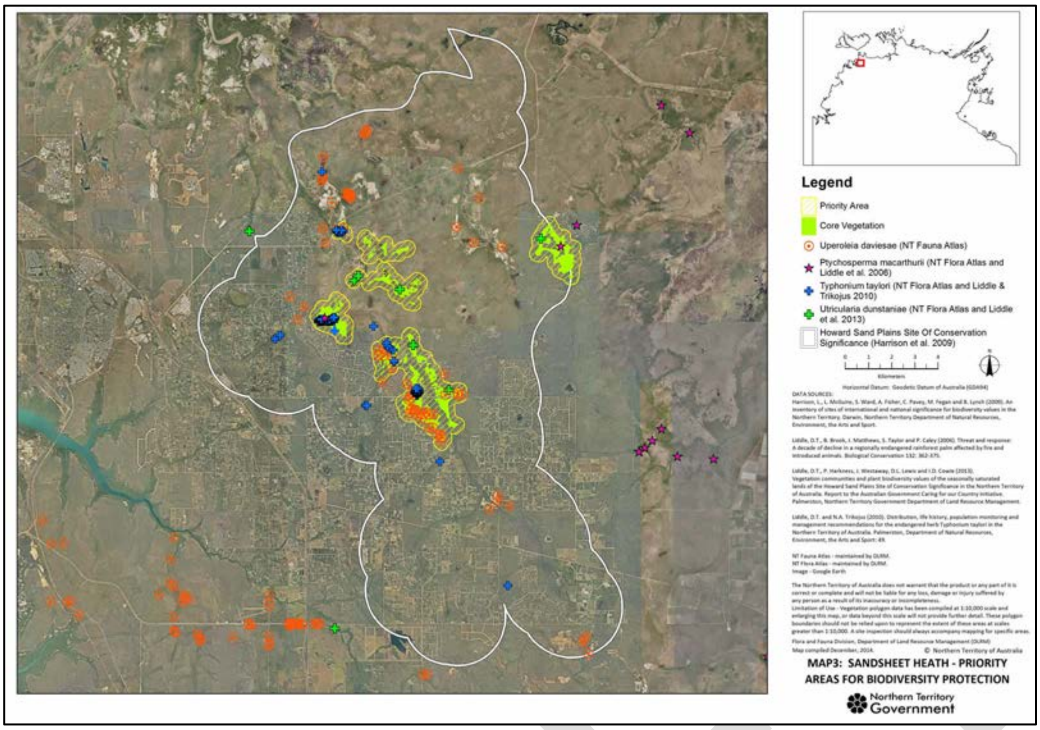

Figure 13: A protected area of core habitat with 250 m buffer zones (NTG, DLRM 2014c) (Option 5)

5 Evaluation of options for a protected area in the Howard sand plains

5.1 Option 1 – The entire, seasonally inundated and saturated area of the Howard sand plains as a protected area

Defining the entire area of seasonal inundation and water logging as the protected area would, given the paucity of information available on the sand plains, provide the lowest risk option for a protected area (Figure 14). The option would necessarily include an additional 500 m buffer around the non-sand plains portion of the north eastern spring fed monsoon rainforest to protect its water supply. This option would provide for the best possible achievement of the outcomes required of a risk averse protected area. It would protect:

- all that is left of the apparent north-south and east-west variation in the occurrence of *Utricularia* species
- all that is left of the range of micro-habitats that are the basis of habitat specialisation among the *Utricularia* species and the broad distribution of species rich *Utricularia* communities across the majority of vegetation types
- the known populations of *U. dunstaniae*, and all that is left of habitat types that may contain all additional populations, if any
- the few known populations of *T. taylori* and all that is left of habitats that may contain all additional populations, if any
- the two populations of *P. macarthurii*

- all the area remaining area, allowing possible maintenance of viable populations of the many species that have small and widely dispersed subpopulations
- all remaining areas with habitats that provide or are likely to provide for all life history stages of the threatened biodiversity
- all that is remaining of the metapopulation dynamics of the threatened species, and minimise future deterioration
- to greatest extent possible, the hydrological conditions across the entire wetland system, as well as providing the best opportunity for remediation of hydrological conditions
- the Howard sand plains with a protected area design that facilitates future management of external threats and the protected area.

It would also provide the best possible protection for possibly 10 species of near threatened plant, 13 species of plant with too few data to be able to determine their conservation status, and two species of threatened animal.

This lowest risk approach is the preferred approach, if the threatened biodiversity is to be preserved. It would require cessation of sand mining throughout the protected area, and reduction in the abstraction of water as alternative supplies become available. These requirements would impose significant economic costs, and would require time. If implemented, the transition in land use should begin immediately. The SOC boundary would provide a zone free from mining, with the managed protected area being defined by removal of urbanised and rural living areas.

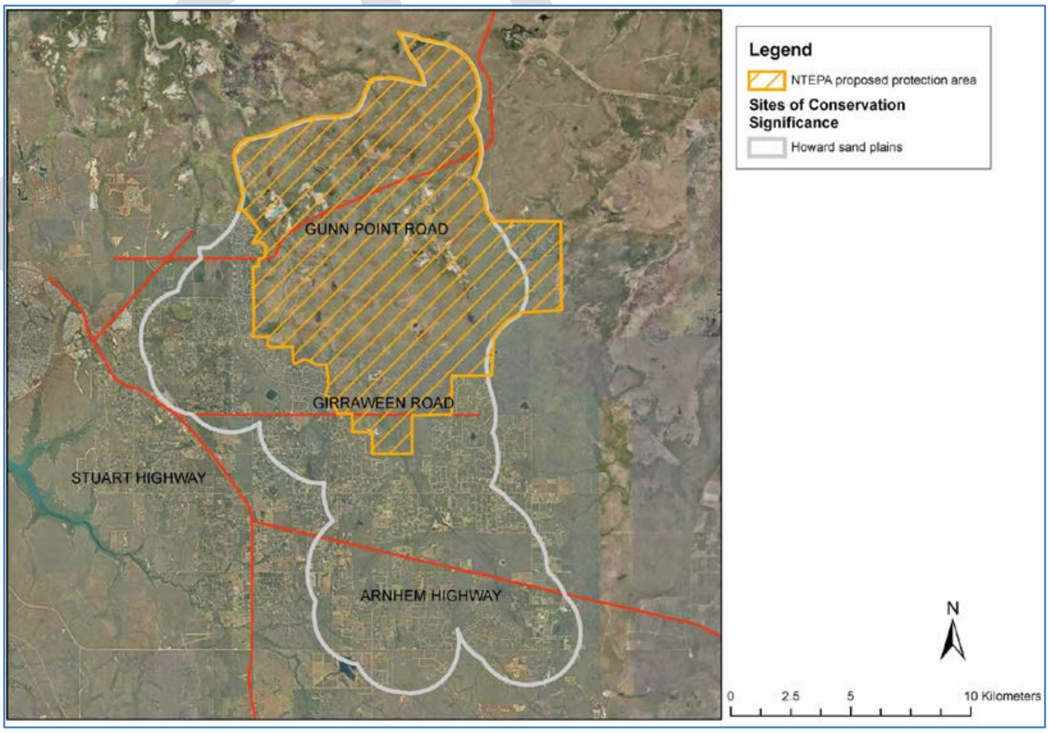

Figure 14 Option 1 – Protection of the entire, seasonally inundated and saturated area of the Howard sand plains

5.2 Option 2 – Protection of the upper Howard River catchment

This option provides for a clearly defined, manageable, single protected area in the western side of the sand plains south of the Gunn Point Road. It would protect the course of the Howard River in the area and much of its immediate catchment. A separate, smaller protected area would be required in the north east to cater for the second population of *P. macarthurii,* associated sand plain areas and a portion of the catchment area (Figure 15). It is not possible in this option to provide an appropriate linkage between this area and the protected area in the west. The drainage system in the east drains north of Gunn Point Road. The design is focused on the areas known to maintain the highest proportion of the threatened biodiversity. It treats the need to protect the biodiversity in a holistic manner that does not rely on possibly misleading distinctions as to the relative importance of particular wetland types that may jeopardise protection from hydrological impacts and maintenance of metapopulation dynamics. It would protect:

- all that is left of the apparent north-south and east-west variation in the occurrence of *Utricularia* species (does not include species occurring north of Gunn Point Road) (less than Option 1, better than Options 2, 3 and 4)
- all that is left of the range of micro-habitats that are the basis of habitat specialisation among the *Utricularia* species and the majority of the areas of species rich *Utricularia* communities
- the known populations of *U. dunstaniae*, and much of all that is left of habitat types that may contain additional populations, if any
- four of the few known populations of *T. taylori* and most of the remaining habitat that may contain additional populations, if any
- the two populations of *P. macarthurii*
- an area sufficient to allow for possible maintenance of viable populations of the many species that have small and widely dispersed subpopulations
- a range of habitats that provide or are likely to provide for all life history stages of the threatened biodiversity
- all that is remaining of the metapopulation dynamics of the threatened species and minimise future deterioration (in the eastern area south of Gunn Point Road)
- the hydrological conditions across the protected area, including the course of the upper Howard River and associated wetland system, as well as providing an opportunity for remediation of hydrological conditions in the protected area
- the Howard sand plains with a protected area design that facilitates future management of external threats and the protected area.

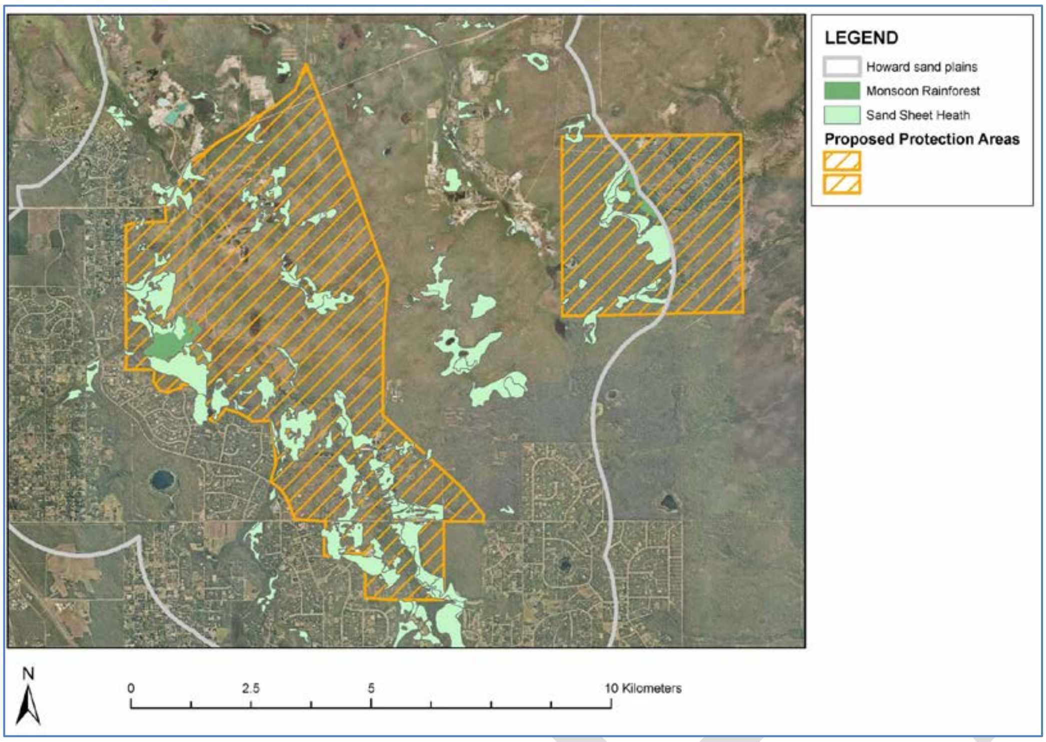

Figure 15: Option 2 – Protection of the upper Howard River catchment (core habitats NTG, Liddle and Fisher 2014)

It would also provide a reasonable opportunity to protect the possibly 10 species of near threatened plant, 13 species of plant with too few data to be able to determine their conservation status, and two species of threatened animal.

This is a medium to high risk option. Its major failings are the lack of linkage between the eastern and western areas of interest, and less than Option 1's capacity to protect the area's hydrology and biodiversity other than *P. macarthurii*.

5.3 Option 3 – Core habitats, 500 m buffers and linkage areas

Option 3 is based on the Liddle and Fisher's (2014) core habitats and 500 m buffers, as modified by adding an additional 500 m buffer around the entirety of the north eastern monsoon rainforest boundary, and providing for linkage areas between the three of the four areas of core habitat and buffers (Figure 16). The linkage areas are in keeping with the recommendations of Heard and McCarthy (2012b) concerning frogs.

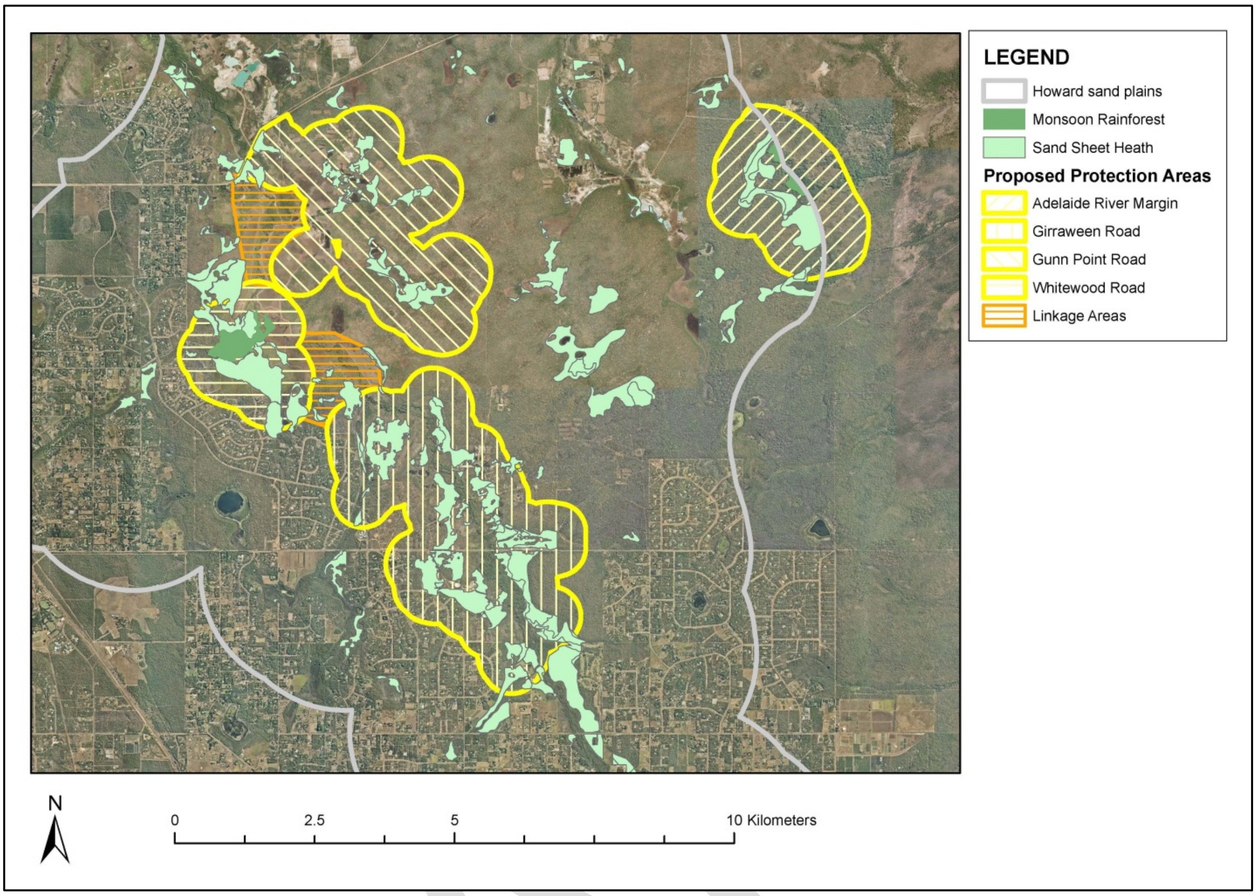

Figure 16: Option 3 – Core habitats, 500 m buffers and linkage areas (core habitats and 500 m buffers NTG, Liddle and Fisher (2014))

The linkage areas proposed are designed to link the three areas of core habitat and buffers in the west of the sand plains. The more northerly linkage is designed around the course of the Howard River, and contains areas of wetlands 3a, 6, 9, 10, 11 and 12. These wetland types are known to contain at least 11, 11, ten, 14, four and ten species of *Utricularia* respectively (Liddle *et al.,* 2013 (all species records)). The more southerly linkage also follows the course of the Howard River and contains areas of wetlands 2a, 3a, 3b, 4d, 8, 9, and 12. These wetland types maintain three, 11, 16, 12, 4, ten species of *Utricularia* respectively (Liddle *et al.,* 2013 (all records)). Liddle *et al.,'s* (2013) survey data recorded wetland type 6 as having three species recorded only once or twice in the survey, wetland type 9 having two such species, and wetland types 4d and 12 having one such species (Liddle *et al.,*2013), The linkages provide a boost to the potential for protection of viable populations of *Utricularia* as well as fostering metapopulation dynamics.

Inclusion of the two linkages would likely add to the size of the overall preserved populations of *Utricularia* species found in the linkage areas, and possibly improve the number of species adequately protected. The more southerly linkage includes a known location of *T. taylori.* Choice of largely wetland areas for linkages of areas of wetand fauna and flora would provide appropriate habitat for dispersal and likely pollinators. This seems more appropriate than using linkages composed of more elevated eucalyptus woodland.

This option would protect:

- a portion of what is left of the apparent north-south and east-west variation in the occurrence of *Utricularia* species (does not include species north of Gunn Point Road)
- a portion of what is left of the range of micro-habitats that are the basis of habitat specialisation among the *Utricularia* species and the broad distribution of species rich *Utricularia* communities across the majority of vegetation types
- the known populations of *U. dunstaniae*, and a slightly increased proportion of what is left of habitat types that may contain some additional populations, if any
- four populations of *T. taylori* and a portion of what is left of habitats that may contain some of the additional populations, if any
- the two populations of *P. macarthurii*
- a larger area allowing possible maintenance of viable populations of some the many species that have small and widely dispersed subpopulations
- a portion of the remaining areas with habitats that provide or are likely to provide for all life history stages of the threatened biodiversity
- habitat allowing for possibly maintenance of metapopulation dynamics of the threatened species in the western portion of the sand plains
- to a limited extent hydrological conditions across the entire wetland system, as well as limited opportunity for remediation of hydrological
- an area that is inherently difficult to manage, and vulnerable to external threats.

Compared to Options 1 and 2 the 500 m buffer and linkage design would necessarily provide a lower level of protection for the possibly 10 species of near threatened plant, 13 species of plant with too few data to be able to determine their conservation status, and two species of threatened animal.

Too little is known of the biology of the community and species, and the potential impacts of ground water abstraction and mining on the threatened biodiversity to assume that implementation of this option would provide for the long term security of the threatened biodiversity. It would not allow for adequate remediation of the existing and future hydrological conditions. Implementation of this option would need to include opportunities to increase knowledge of the sand plains and modify the design through time in response to new understanding of the Howard sand plains. The need for adaptive changes to the design as knowledge improves through focused research would cause uncertainty to the mining industry, and not provide timely responses to threats.

This Option has a higher risk than Options 1, and 2.

5.4 Option 4 – Core habitats, 500 m buffers

A design for a protected area based on core habitats and 500 m buffers (Liddle and Fisher 2014) is provided in Figure 17.

This option would provide a lower level of achievement of the outcomes than is required of a risk averse protected area. It would protect:

- what is left of the apparent north-south and east-west variation in the occurrence of *Utricularia* species (does not include species north of Gunn Point Road)
- a large portion of what is left of the range of micro-habitats that are the basis of habitat specialisation among the *Utricularia* species and the broad distribution of species rich *Utricularia* communities across the majority of vegetation types
- the known populations of *U. dunstaniae*, and a large portion of what is left of habitat types that may contain some additional populations, if any
- three populations of *T. taylori* and a significant portion of what is left of habitats that may contain some of the additional populations, if any
- the two populations of *P. macarthurii*
- a portion of the area remaining allowing possible maintenance of viable populations of some the many species that have small and widely dispersed subpopulations
- a portion of the remaining areas with habitats that provide or are likely to provide for all life history stages of the threatened biodiversity
- no habitat allowing for maintenance of metapopulation dynamics of the threatened species in the western portion of the sand plains, and would promote deterioration
- to a limited extent , hydrological conditions across the the entire wetland system, as well as limited opportunity for remediation of hydrological
- an area that is inherently difficult to manage and vulnerable to external threats.

Compared to protecting the entire area and Options 2 and 3, the 500 m buffer option would necessarily provide a lower level of protection for the possibly 10 species of near threatened plant, 13 species of plant with too few data to be able to determine their conservation status, and two species of threatened animal.

Too little is known of the biology of the community and species, and the potential impacts of ground water abstraction and mining on the threatened biodiversity to assume that implementation of this option would provide for the long term security of the threatened biodiversity. It would leave the protected areas vulnerable to the hydrological and land clearing effects of continued mining. Nor would it provide a practical management option. Implementation of this option would need to include opportunities to increase knowledge of the sand plains and modify the design through time in response to new understanding of the Howard sand plains. The need for adaptive changes to the design as knowledge improves through focused research would cause uncertainty to the mining industry, and not provide timely responses to threats.

This is a higher risk than Options 1, 2 and 3.

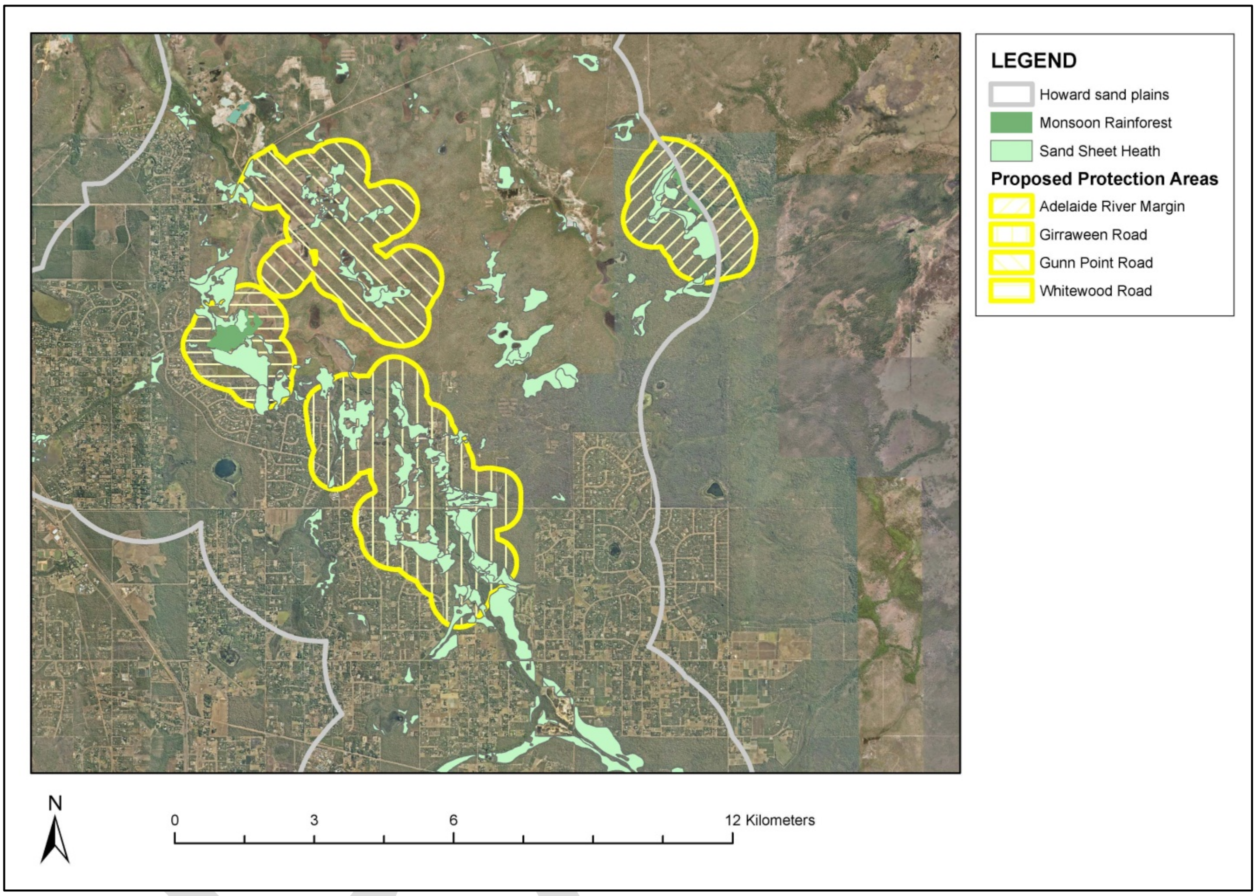

Figure 17: Option 4 – Core habitats with 500 m buffers (core habitats and 500 m buffers NTG, Liddle and Fisher (2014))

5.5 Option 5 – Core habitats, 250 m buffers

The 250 m buffer option design is provided in Figure 13. This option would provide a lowest level of achievement of the outcomes required of a risk averse protected area. It would protect:

- a small, patchy portion of what is left of the apparent north-south and east-west variation in the occurrence of *Utricularia* species (would not include species north of Gunn Point Road)
- a small portion of what is left of the range of micro-habitats that are the basis of habitat specialisation among the *Utricularia* species and the broad distribution of species rich *Utricularia* communities across the majority of vegetation types
- the known populations of *U. dunstaniae*, and a lower probability of protecting any additional populations if any, that may exist in appropriate habitat in the sand plains

- three populations of *T. taylori* and a lower probability of protecting any additional populations, if any, that may exist in appropriate habitat in the sand plains
- the two populations of *P. macarthurii*
- a smaller portion of the area remaining allowing possible maintenance of viable populations of some the many species that have small and widely dispersed subpopulations
- a smaller portion of the remaining areas with habitats that provide or are likely to provide for all life history stages of the threatened biodiversity
- no habitat allowing for maintenance of the remaining metapopulation dynamics of the threatened species, and would enhance future deterioration
- to a minimal extent, the hydrological conditions across the entire wetland system, as well as providing minimal opportunity for remediation of hydrological conditions an area that is inherently difficult to manage, and vulnerable to external threats. Compared to Options 1, 2, and 3, this option would necessarily provide a very low level of protection for the possibly 10 species of near threatened plant, 13 species of plant with too few data to be able to determine their conservation status, and two species of threatened animal.

This option has the highest risk of failure.

6 Conclusions

The Howard sand plains maintain a biodiversity that is of international, national and Northern Territory significance. Central to this significance are an internationally significant species rich community of carnivorous bladderworts, the nationally endangered perennial plant, *T. taylori*, the Northern Territory vulnerable annual carnivorous plant, *U. dunstaniae*, the Northern Territory endangered Darwin palm, *P. macarthurii*, and the Northern Territory endangered Howard toadlet, *U. daviesae.* The threatened community and threatened species other than the Darwin palm occur primarily in sand sheet heath vegetation. The biology of the sand plains biodiversity is poorly known.

The threatened community and species are all vulnerable to negative, complex, interacting impacts imposed by urban expansion, abstraction of ground water, and the mining of extractive minerals. Habitat removal and hydrological impacts are of particular significance. The impacts of many of these threatening processes are incompletely understood, and little is known of the surface and ground water hydrology at a scale that is relevant to the threatened biodiversity. There is no known way of rehabilitating disturbed sand plains habitats to allow the biodiversity to re-establish.

There is too little known of the biodiversity and the hydrology of the area to effectively provide for preservation with a high level of certainty. The best that can be achieved is to use existing knowledge and information from the literature to implement an as risk averse as possible protected area design.

The preferred, lowest risk option is to protect the entire seasonally inundated and water logged area of the sand plains (Option 1). Implementation of the option would necessarily involve potentially significant economic cost in transition of the extractive industry to other areas, and in reducing the abstraction of ground water.

A design based on protecting the more significant part of the upper Howard River catchment (Option 2) has the capacity to provide the threatened biodiversity with some level of security. It would have risks (higher than Option 1) associated with maintenance of the hydrology, the absence of linkage between the east and west of the sand plains, and failure to include species of *Utricularia* north of Gunn Point Road. The economic cost of transitioning the extractive industry would be significant although less than for Option 1. The economic costs of reducing ground water abstraction would not be altered by adoption of this option. The level of threat to the threatened biodiversity is such that the preferred protected area design should be implemented immediately.

Approaches (Options 3, 4, and 5) based on definition and protection of core habitats and surrounding buffers with or without linkage areas are found to be risk prone (compared to Options 1 and 2) and should not be implemented.

References

Applegate, R. J. 1983. *Guidelines for effective rehabilitation of borrow pits in the top end*. Technical Report No. 13. Conservation Commission of the Northern Territory, Darwin.

Archer, M. J. 2003. Annual variation in arrival and departure times of carrion insects at carcasses: implications for succession studies on forensic entomology. *Australian Journal of Zoology* 51: 564-576.

Boggs, D. L., L. Hutley, P. G. Cook, D. T. Liddle and L. P. Ellliott. 2008 *Department of water use and water sources of spring-fed monsoon vine forest ecosystems*. In *Biophysical modelling of water quality in a Darwin rural area groundwater dependent ecosystem*. D. T. Liddle, D. Boggs, L. Hutley, D. Yin Foo, G. Boogs, D. Pearson, P.G. Cook and L. P. Ellliott (eds.). Report to Natural Resource Management Board (NT), NHT Project 2005/133. Department of Natural Resources, Environment, the Arts and Sport, Northern Territory Government: 60-78.

Bornenissza, G. I. 1957. An analysis of arthropod succession in carrion and the effect of its decomposition on the soil fauna. *Australian Journal of Zoology* 5:1-12.

Bach, C., and O. Price. 1999. *Fruit season, frugivore movement and landscape scale conservation in monsoon rainforests of northern Australia*, *in* G. Gorman (ed), Australian Wildlife Management Society, Darwin Conference.

Broderbauer, D., A. Diaz, and A. Weber. 2012. Reconstruction of the origin and elaboration of insect-trapping inflorescences in the Araceae. *American Journal of Botany* 99: 1666-1679.

Conservation and Natural Resources Group. 2002. *Litchfield Shire remnant vegetation*. Department of Infrastructure, Planning and Environment. Northern Territory Government, Darwin.

Cook, P. G., T. J. Hatton, D. Eamus, L. Hutley and D. Pidsley, 1998. *Hydrological investigations at Howard East*, NT. Technical Report 41/1998, CSIRO Land and Water, Urrbrae,

Council of Australian Governments. 1992. *National strategy for ecologically sustainable development of Australia. www.environment.gov.au/about-us/esd*

Cowie, I. D. 2002. *Preliminary report on a survey of Utricularia (LENTIBULARIACESE) in the Howard River – Shoal Bay area*. NT Herbarium, Department of Infrastructure, Planning and Environment, Northern Territory Government, Darwin.

Department of Industry, Tourism and Resources (2006). *Leading practice sustainable development for the mining industry: mine rehabilitation.* www.nt.gov.au/Minerals/Energy/Content/File/Forms_Guidelines/Mine_Closure_and_Comlpetion.pdf. Accessed 14/2/15.

DLRN. 2011. *Queensland wetland buffer planning guide*. Queensland Department of Environment and Resource Management, Brisbane.

Dixon, D., I. Cowie and R. Kerrigan. 2003. *Ptychosperma macarthurii or P. blesseri? The taxonomic status of P. blesseri reconsidered*. The Beagle, Records of the Museums and Art Galleries of the Northern Territory 19: 81-86.

DLRM. 2013. *Sensitive vegetation in the Northern Territory, Sandsheet Heath*. Department of Land Resource Management, Northern Territory Government.

DLRM. 2014(a). *Native vegetation buffers and corridors*. Department of Land Resource Management, Northern Territory Government, Palmerston, NT.

DLRM. 2014(b). *Sensitive vegetation in the Northern Territory: monsoon rainforest*. Department of Land Resource Management, Northern Territory Government, Palmerston, NT.

DLRM. 2014(c). *Sandsheeet heath in the Howard sand plains and greater Darwin area: Identification of priority areas for biodiversity protection.* Department of Land Resource Management, Northern Territory Government, Palmerston, NT.

DLRM. 2015. *Protection of sand sheet heath and threatened species in the Howard sand plain area. Comparison of DLRM final (2015) recommendation and initial (2014) proposal.* Department of Land Resource Management, Northern Territory Government, Palmerston, NT.

Doyle, N. 2001. *Extractive minerals within the outer Darwin area*. Northern Territory Geological Survey, Report 14.

DME 2015. *Mining Management Plan (MMP) structure for the extractive operations.* www.nt.gov.au/Minerals/Energy/Content/File/Forms_Guidelines/Small_Mine_MMP_Structure_Guideline.pdf. Accessed 14/2/15.

Essig, F. B. 1973. Pollination in some New Guinea palms. *Principles* 17:75-83.

ESCAVI. 2003. *Australian vegetation attribute manual: National Vegetation Information System Version 6.0*. Executive Steering Committee for Australian Vegetation Information. Department of Environment and Heritage, Canberra.

Ficetola, G. F., E. P. Schioppa and F. De Bernardi. 2008. Influence of landscape elements in riparian buffers on the conservation of amphibians. *Conservation Biology* 23: 114-123.

Foggarty, P. J., B. Lynch and B. Wood. 1984. *The land resources of the Elizabeth, Darwin and Black more Rivers*. Conservation Commission of the Northern Territory, Darwin.

Forsyth, A., and J. Alcock. 1990. Female mimicry and resource defence polygyny by males of a tropical rove beetle, *Leistotrophus versicolour* (Coleoptera: Staphylinidae). *Behavioural Ecology, and Sociobiology* 26:325-330.

Grattidge, A. 2013. *Assessment framework for rehabilitation sand mining Howard sand plains Site of Conservation Significance*. EcOz Environmental Services .

Harris, H., and S. Townsend. 2008. *An understanding of the groundwater and surface water hydrology of the Darwin Harbour Plan of Management area*. Proceedings of the Darwin Harbour Presentations – February 2003.

Harrison, L., McGuire, L., Ward, S., Fisher, A., Pavey, C., Fegan, M. and B. Lynch. 2009. *An inventory of sites of international and national significance for biodiversity values in the Northern Territory*. Department of Natural Resources, Environment, The Arts and Sport, Darwin, NT.

Heard, G. W., M. P. Scroggie and B. S. Malone, 2012(a), Classical metapopulation theory as a useful paradigm for conservation of an engendered amphibian. *Conservation Biology* 148: 156-166.

Heard, G. W., and M. McCarthy. 2012(b). *Metapopulation viability of the growling grass frog in Melbourne's urban growth area*. Prepared for the Biodiversity and Ecosystems Division, Department of Sustainability and Environment, Melbourne.

Heard, G. W., G. W. Heard, K. Smith, K. Parris, J. Austin, M. Kearney and J. Melville. 2013. Structure and fragmentation of growling grass frog metapopulations. *Conservation Genetics* 14: 313-322.

Hempel, C. J. 2003. *The application of Landsat imagery to land cover mapping in the greater Darwin region*. Darwin, Biodiversity Unit, Department of Infrastructure, Planning and Environment: 39.

Herath, Y. 2014. *Rehabilitation of* Utricularia *and framework species after sand extraction at the Howard sand plains*. Honours thesis, School of Environment, Charles Darwin University.

Holmes, J., D. Bisa, A. Hill and B. Crase. 2005. *Threatened and data-deficient plants in the Litchfield Shire of the Northern Territory*. WWF-Australia, Sydney.

Kerrigan, R., and I. Cowie. 2007a. *Utricularia dunstaniae.* In *Lost from our landscape; threatened species of the Northern Territory*. J. Woinarski, M. A. J. Williams, R. E. O'Farrall and J. R. McAlpine (eds.). Melbourne, CSIRO.

Kerrigan, R., and I. Cowie. 2007b. *Typhonium taylori.* In *Lost from our landscape; threatened species of the Northern Territory*. J. Woinarski, M. A. J. Williams, R. E. O'Farrall and J. R. McAlpine (eds.). Melbourne, CSIRO.

Kerrigan, R., and I. Cowie and D. Liddle. 2007. *Darwin palm, Ptychosperma macarthurii*. In *Lost from our landscape; threatened species of the Northern Territory*. J. Woinarski, M. A. J. Williams, R. E. O'Farrall and J. R. McAlpine (eds.). Melbourne, CSIRO

Liddle, D. T., B. Brook, J Mathews, S. M. Taylor, and P. Caley. 2006. *Threat and response. A decade of decline in a regionally significant rainforest palm affected by fire and introduced animals*. Biological Conservation 132: 62-375.

Liddle, D. T., and N. A. Trikojus. 2010. *Distribution, life history, population monitoring and management recommendations for the endangered herb Typhonium taylori in the Northern Territory of Australia*, Department of Natural Resources, Environment, the Arts and Sport, Darwin.

Liddle, D. T., P. Harkness, D. L. Lewis, and I. D. Cowie. 2013. *Vegetation communities and plant diversity of the seasonally saturated lands of the Howard sand plains Site of Conservation Significance in the Northern Territory of Australia*. Report to the Australian Government Caring for our Country initiative, Liddle, D., and A. Fisher. 2014. *Sandsheet heath and identification of priority areas for biodiversity protection in Howard sand plains (draft).* Flora and Fauna Division, Department of Land Resource Management, Palmerston.

Natural Resource Management Council. 2010. *Australia's Biodiversity Conservation Strategy 2010-2030*. Australian Government, Department of Sustainability, Environment, Water, Population and Communities, Canberra.

PowerWater. Undated. *Darwin region water supply strategy*. Power and Water Corporation, Darwin.

Price, O., D. Milne and C. Tynan. 2005. Poor recovery of woody vegetation on sand and gravel mines in the Darwin region of the Northern Territory. *Ecological Management and Restoration* 6: 118-122.

Reynolds, S., and A. Grattidge. 2013. *Howard CfoC surveys for Howard River toadlets* (Uperoleia daviesae). EzOz Environmental Services.

Roolin, T. 2000. Dung beetle movement at two spatial scales. *Oikos* 91:323-335.

Semlitsch, R. D., and J. R. Bodie. 2003. Biological criteria for buffer zones around wetlands and riparian habitats for amphibians and reptiles. *Conservation Biology* 24: 1219-1228.

Shapcott, A. 1998. The genetics of *Ptychosperma blesserii*, a rare palm from the Northern Territory. *Biological Conservation* 85:1-2.

Skinner, L., S. Townsend and J. Fortune. 2009. *The impact of urban land use on total pollutant loads entering Darwin Harbour.* Report 06/2008D, Aquatic Health Unit, Department of Natural Resources, Environment, the Arts and Sport, Darwin.

Tayler, K. T. 2004. *The Northern Territory extractive industry – A review of industry performance against Australian standards of best practice in mined land rehabilitation*. 40 Credit Point Thesis, Master of Tropical Environment Management, Charles Darwin University, Darwin.

Taylor, P. 1989. *The genus Utricularia – a taxonomic monograph*. *Kew Bulletin additional series* XIV.

UNESCO. 1971. *Convention on wetlands of international significance especially as waterfowl habitat: as amended by the protocol of 3.12.1982 and the amendment of 28.5.1987. www.ramsar.org*

Ward, S. 2007. *Howard River Toadlet. Uperoleia daviesae.* In *Lost from our landscape: threatened species of the Northern Territory*. J. Woinarski, M. A. J. Williams, R. E. O'Farrall and J. R. McAlpine (eds.). Melbourne, CSIRO: 71-94.

Wakabayashi, H. 2010. *Utricularia linearis* (Lentibulariaceae), a new species from the Howard Springs, Northern Territory, Australia. *Journal of Insectivorous Plant Society* 61: 88-92.

Woodward, E., Jackson, S., and A. Stranton. 2008. *Water resources of the Howard River region, Northern Territory: A report on the social and cultural values and stakeholder assessment of water use scenarios.* CSIRO Sustainable Ecosystems, Darwin, 175 pages.

Vanden Broek, P. H. 1980. *Engineering geology of Darwin East*, NT. Bulletin 203, Bureau of Mineral Resources, Geology and Geomorphology, Australian Government Publishing Service, Canberra.

Vos, C. C., A. G. Antonisse, P. W., Goedhart and M. M. Smulders. 2001. Genetic similarity as a measure for connectivity between fragmented populations of the moor frog (*Rana arvalis*). *Heredity* 86: 598-608.

Water and Rivers Commission. 2000. *Wetland buffers*. Water Notes WN4. Water and Rivers Commission, Western Australia.

Wells, M. R., and C. J. Harrison. 1978. *Land units of the Howard Springs-Humpty Doo area*. Land Conservation Unit, Territory Parks and Wildlife Commission, Darwin.

Yallop, C. 2005. *Macquarie dictionary* (4^{th} edition). The Macquarie Library Pty Ltd.

Yin Foo, D. 2004. *Modelling of the McMinns/Howard East groundwater system*. Report 26/20004D. Department of Infrastructure, Planning and Environment, Darwin.

Yu Wang. 2012. Sex-biased dispersal of a frog (*Odorrana schmackeri*) is affected by patch isolation and resource limitation in a fragmented landscape. *PLos* 7: e47683.