Department of
Environment and Conservation

Our environment, our future

Resource Condition Report for a Significant Western Australian Wetland

Desert Queens Baths

2009

Figure 1 – Desert Queens Baths (A. Pinder, DEC).

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Contents

1. Introduction

This Resource Condition Report (RCR) was prepared by the Inland Aquatic Integrity Resource Condition Monitoring (IAI RCM) project. It describes the ecological character and condition of Desert Queens Baths, a series of permanent spring fed rock pools in a tributary of the Rudall River in the Pilbara Region.

Desert Queens Baths were selected as a study site in the current project because they are representative of arid zone rock pools. They are also a drought refuge for native fauna and a popular camping spot for travelers on the Canning Stock Route.

1.1. Site Code

Pilbara Biological Survey, Pilbara Surface Water Survey (DEC): PSW027.

Inland Aquatic Integrity Resource Condition Monitoring Project (DEC): RCM007.

1.2. Purpose of Resource Condition Report

The objective of the RCR is to provide a summary of information relevant to the ecology of Desert Queens Baths. This information is then used to describe the drivers of, and threats to, the ecosystem. The resultant 'snapshot' of ecological character will provide context for future monitoring of the wetlands and assist with gauging the effectiveness of management planning and actions at the site.

1.3. Relevant Legislation and Policy

This section provides a summary of international agreements and important legislation that are relevant to the management of Desert Queen Baths.

Western Australian state policy

Wildlife Conservation Act 1950

This Act provides for the protection of wildlife. All fauna (animals native to Australia) in Western Australia is protected under section 14 and all flora (plants native to Western Australia) are protected under section 23 of the *Wildlife Conservation Act 1950*. The Act establishes licensing frameworks for the taking and possession of protected fauna, and establishes offences and penalties for interactions with fauna.

Conservation and Land Management Act 1987

This Act is administered by the State Department of Environment and Conservation (DEC) and applies to public lands. It sets the framework for the creation and management of marine and terrestrial parks, reserves and management areas in Western Australia, and provides protection for flora and fauna within reserve systems.

Aboriginal Heritage Act 1972

The purpose of this Act is to protect Aboriginal remains, relics and sites from undue interference, and to recognise the legitimate pursuit of Aboriginal customs and traditions. Under the Act, it is an offence for a person to excavate, destroy, damage or alter any Aboriginal site. The Act applies to all objects which are of sacred, ritual or ceremonial significance to persons of Aboriginal descent, or which are or were used for any purpose connected with the traditional cultural life of the Aboriginal people and the places where such objects are found. It also protects any sacred, ritual or ceremonial site, which is of importance and special significance to persons of Aboriginal descent. Finally, the Act states that, where a representative body of persons of Aboriginal descent who usually live subject to Aboriginal customary law has an interest in a place, that place shall be available to that body for purposes sanctioned by the Aboriginal tradition relevant to that place.

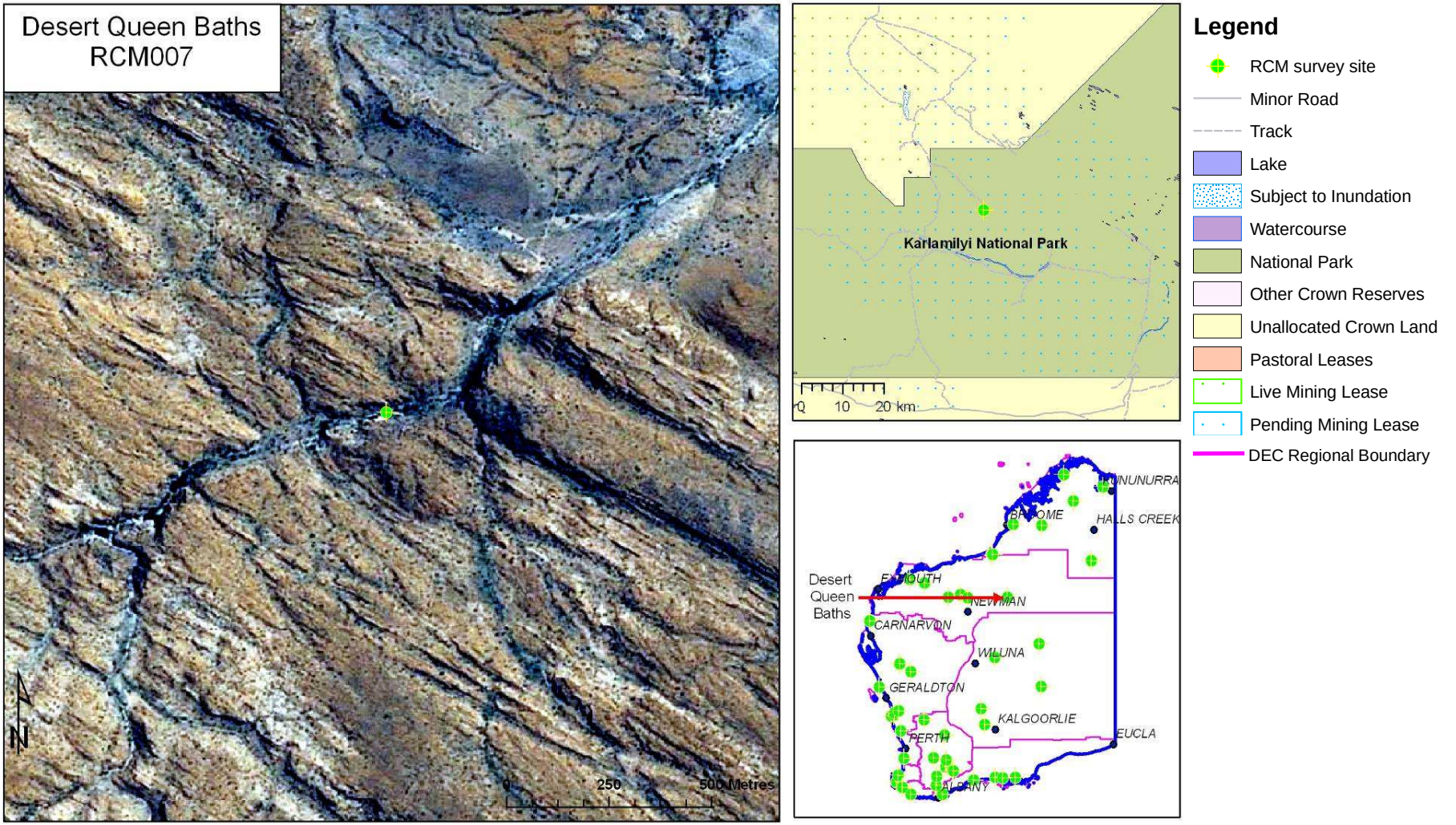

Figure 2 – Aerial photograph showing the location of the survey site at Desert Queens Baths. The upper insert shows the location of the survey site relative to Rudall River National Park (Karlamilyi). The lower insert shows the location of the site relative to the project's other survey sites and the state of Western Australia.

2. Overview of Desert Queens Baths

2.1. Location and Cadastral Information

Desert Queens Baths are located within Rudall River National Park (Karlamilyi to the Martu people), approximately 500 km south of Broome (Figure 2). They are found within a gorge known as Rooney Creek, which is a tributary of the Rudall River. Rudall River is the largest national park in Western Australia and the only national park in Australia that encompasses an entire seasonal river system in the arid zone (Kendrick 2001). It lies at the junction of the Great Sandy and Little Sandy Deserts.

2.2. IBRA Region

Desert Queens Baths lies within the Rudall (LSD1) subregion of the Little Sandy Desert Interim Bioregionalisation of Australia (IBRA) region. The subregion comprises protozoic hill country of the Throssell, Mount Sears, Broadhurst and Harbutt Ranges. It also includes the headwaters and course of the Rudall River and its terminal point - Lake Dora. The vegetation consists primarily of sparse shrub-steppe over *Triodia basedowii* on stony hills, with River Gum communities and bunch grasslands on alluvial deposits in, and associated with, ranges (Kendrick 2001).

2.3. Climate

The nearest Bureau of Meteorology weather station to Desert Queens Baths is at Telfer, 85 km to the north (Bureau of Meteorology 2009). Records have been kept at Telfer since 1974. Climatic conditions at Desert Queens Baths would not differ appreciably from those at Telfer.

Telfer experiences an arid climate. It receives a mean annual rainfall of 366.5 mm with precipitation falling on an average of just twenty-nine days per year (Figure 3). Annual evaporation at Telfer is approximately 4,100 mm.

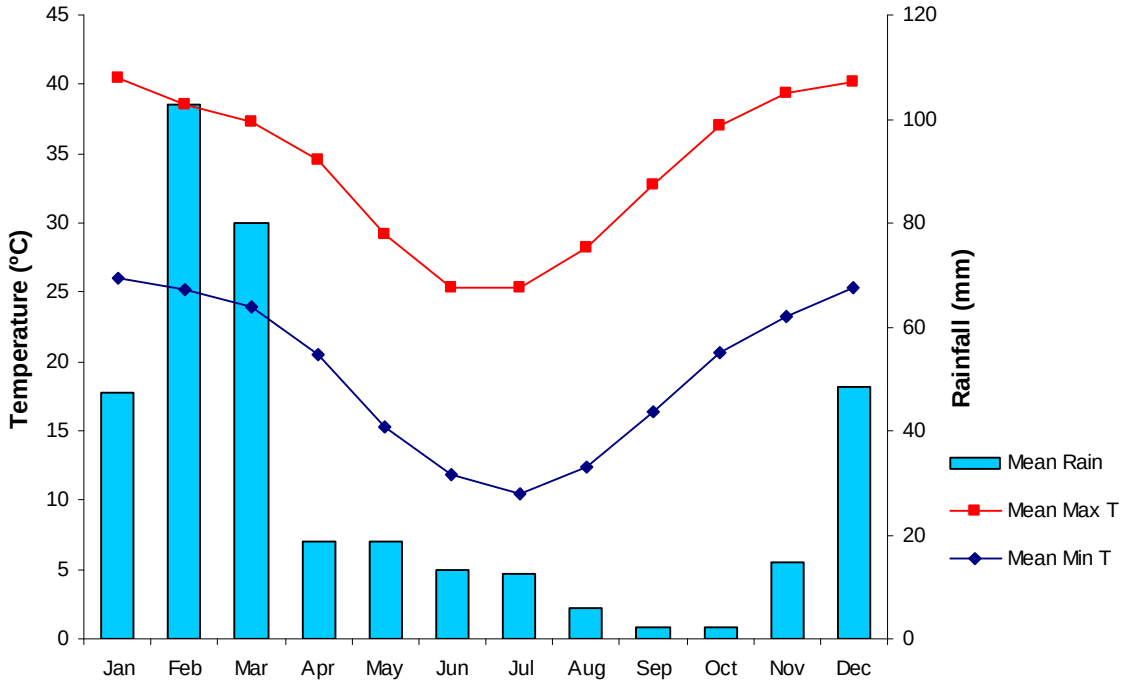

Figure 3 – Climatic means for Telfer, approximately 85 km north of Desert Queens Baths.

Desert Queens Baths were surveyed by the IAI RCM project on the 12th of May 2008. In the six months preceding the survey, Telfer received 123.2 mm of rain. The majority of this (55.8 mm) fell during February and no rain fell after the 2nd of April 2008.

2.4. Wetland Type

Desert Queens Baths are a series of permanent, spring fed freshwater rock pools, which are part of Denny Creek. Denny Creek is a tributary of the Rudall River.

2.5. Values of Desert Queens Baths

Values are the internal principles that guide the behaviour of an individual or group. Value systems determine the importance people place on the natural environment and how they view their place within it. Divergent values may result in people pursuing different objectives in relation to nature conservation, having different reasons for desiring a commonly agreed outcome, or favouring different mechanisms to achieve it. Because of this, it is important to be explicit about the values that are driving conservation activities at a wetland.

The Conceptual Framework for Managing Natural Biodiversity in the Western Australian Wheatbelt (Wallace 2003) identified eight reasons that humans value natural biodiversity:

a. Consumptive use

Consumptive use is gaining benefit from products derived from the natural environment, without these products going through a market place, for example, the collection and personal use of firewood or 'bushtucker'. There are two Aboriginal communities within the Rudall River National Park: Parnngurr and Punmu (Kendrick 2001). These people would be likely to value the consumptive use of the various rock pools found throughout the Park, including Desert Queens Baths, as a source of water.

b. Productive use

Productive use values are derived from market transactions involving products derived from the natural environment. For example, firewood may be collected and sold or exchanged for another commodity or commercial cattle may be grazed on native grasses. It is possible that Desert Queens Baths provided productive uses for local Aboriginal people in the past. However, there are no known productive use of the baths in the present day.

c. Ecosystem services

There are many naturally occurring phenomena that bring enormous benefit to mankind. For example, plants generate oxygen, insects pollinate food crops and wetlands mitigate floods by regulating water flows. The term 'ecosystem services' is used as a broad umbrella to cover the myriad of benefits delivered, directly or indirectly, to humankind by healthy ecosystems. Desert Queens Baths, in itself, would make a relatively small contribution to the ecosystem services delivered by the broader catchment of the Rudall River. That said, given the parlous state of the global environment, every small contribution is important.

d. Amenity

Amenity describes features of the natural environment that make life more pleasant for people, for example, pleasant views, shade and wind shelter from a stand of trees. It is difficult to quantify the amenity value of a remote site such as Desert Queens Baths, but it is certainly valued by the local Aboriginal communities and visitors to the Rudall River National Park for the amenity it provides.

e. Scientific and educational uses

Parts of the natural environment that remain relatively unmodified by human activity represent great educational opportunities. Such sites allow us to learn about the changes that have occurred to the natural world. They are also 'control' sites that allow us to

benchmark other, altered habitats. Desert Queens Baths are a mostly unmodified freshwater wetlands that may present opportunities for advancing the science of wetland ecology.

f. Recreation

Many recreational activities rely on the natural environment (bird watching, canoeing, wildflower tourism, etc.) or are greatly enhanced by it (hiking, cycling, horse riding, etc.). Recreation may deliver economic benefit derived from tourism and also delivers spiritual and physical health benefits to the recreator. Desert Queens Baths are approximately 18 km from the Canning Stock Route, and provides a welcome camp site for travellers in such a remote and harsh environment.

g. Spiritual/philosophical values

People's spiritual and philosophical reasons for valuing natural environment are numerous and diverse. One commonly cited is the 'sense of place' that people derive from elements of their environment. This is evident in many Aboriginal and rural Australians, who strongly identify themselves with their natural environment. Many people also believe that nature has inherent value or a right to exist that is independent of any benefit delivered to humans. A sense of spiritual well-being may be derived from the knowledge of healthy environments, even if the individual has no contact with them. Permanent fresh water in an otherwise arid region is an important resource. The Rudall River system most certainly would have been utilised by Aboriginal people historically and is likely to be of cultural significance.

h. Opportunities for future use

Not all uses for the natural environment may be apparent at present. The potential for future benefit from the natural environment is maximised by maintaining the greatest possible biodiversity. Every lost taxa or ecosystem represents a lost opportunity. Desert Queens Baths may support endemic or rare taxa. Such unique features would increase the potential for future opportunities.

The intent of nature conservation is usually to maintain the ecosystem services, scientific and educational uses and opportunity value at a given site. Doing so is likely to have positive effects on the amenity, recreational potential and spiritual/philosophical values to which the site's natural environment contributes. Consumptive and productive uses of the natural environment are not usually considered, as these are often incompatible with nature conservation. That said, the Desert Queens Baths may be esteemed for their consumptive uses by Aboriginal people who reside in nearby communities. These conflicting value sets should be considered when attempting to implement conservation management at the site.

3. Critical Components and Processes of the Ecology of Desert Queens Baths

The objective of the Desert Queens Baths RCR is to compile information relevant to the ecology of the wetlands' ecosystems. By doing so, it is possible to identify the critical components and drivers of the system. These components and processes determine the site's ecological character and are the variables that should be assessed in any ongoing monitoring.

Climate and geomorphology are the most important drivers of wetland ecosystems. Between them, these factors determine the position of a wetland in the landscape and the type and hydrological regime of that wetland. In turn, a wetland's position, type and hydrology exert a strong influence on its biota and biochemical properties and processes.

A summary of Desert Queens Baths critical ecosystem components follows, along with a detailed description of the results of the IAI RCM 2008 survey. Relevant information from previous studies conducted on these wetlands is also provided.

Table 1 – Summary of critical ecosystem components at Queens Desert Baths.

Component	Summary description
Geomorphology	Situated in a u-shaped valley, which is gouged into glacial palaeotopography that is preserved over Coolbro sandstone.
Hydrology	Fed with fresh water from a series of permanent springs. Flooded occasionally when the Rudall River flows.
Water Quality	Fresh (0.3 mS/m); pH 7.0.
Phytoplankton	Five species of freshwater algae previously recorded in the Rudall River National Park, none recorded at Desert Queens Baths.
Benthic Plants	*Marsilea exarata* was recorded.
Littoral Vegetation	*Eucalyptus* sp. and *Acacia* sp. over *Typha domingensis* and grasses.
Invertebrates	72 species (in 29 families) recorded during IAI RCM survey; a total of 199 species have been recorded in all surveys at the site.
Fish	None recorded.
Birds	More than 90 species of bird have been recorded in the Rudall River National Park; the Pilbara Biological Survey recorded 1 species of bird at Desert Queens Baths in 2003.

3.1. Geology and Soils

Desert Queens Baths are situated within the Yeneena Group - a thick, marine carbonate sequence, comprising shales, siltstones and dolomite assemblages, as well as sandstones, shales, conglomerate and dolomite.

Sediments at the Baths are dominated by bedrock and boulders (90%), with small amounts of pebble/cobble (5%) and gravel/sand (5%).

3.2. Hydrology

Desert Queens Baths are fed with fresh water from a series of permanent springs. These springs are a result of groundwater percolating through permeable sandstone and emerging where underlying impermeable shale intersects the surface (Muir 1982).

3.3. Water Quality and Sediments

In addition to the 2008 IAI RCM survey, Desert Queens Baths were surveyed by the Pilbara Biological Survey in September 2003 and May 2004. The series of interconnected pools that comprise Desert Queens Baths are fresh and permanent, being maintained by inflow from springs. They are circum-neutral, with low turbidity and colour. Nutrient concentrations were low in 2003 and 2008, but well in excess of ANZECC/ARMCANZ guidelines in 2004 (Table 2). The reason for this is unknown, as there was no obvious source of nutrients, other than some decaying carcasses.

Table 2 - Water quality parameters measured at Desert Queens Baths during the IAI RCM survey and the Pilbara Biological Survey.

	Pilbara Survey PSW027		IAI RCM Survey RCM 007
	Sep 03	May 04	May 08
pH	6.91	7.41	7.00
Alkalinity (mg/L)	85	110	60
TDS (g/L)	0.21	0.43	0.23
Turbidity (NTU)	1.3	1.6	4.1
Colour (TCU)	2.5	32	3
Total nitrogen (µg/L)	-	-	200
Total phosphorus (µg/L)	-	-	10
Total soluble nitrogen (µg/L)	70	3100	180
Total soluble phosphorus (µg/L)	5	50	5
Chlorophyll (µg/L)	3	2	11
Na (mg/L)	36.8	89.2	31
Mg (mg/L)	17.5	25.3	12.7
Ca (mg/L)	7.6	11.6	5
K (mg/L)	8.1	12.5	6.3
Cl (mg/L)	59	150	52
SO_4 (mg/L)	21.6	33	16.5
HCO_3 (mg/L)	104	134	73
CO_3 (mg/L)	1	1	0.5

3.4. Phytoplankton

Muir (1982) collected five species of freshwater algae in the Rudall River National Park. However, the Desert Queens Baths was not surveyed as part of that study. No algae has been collected from Desert Queens Baths.

3.5. Benthic Plants

The aquatic plant, *Marsilea exarata*, was recorded on the vegetation transect during the IAI RCM survey.

3.6. Littoral Vegetation

Most of the soaks that are found in the Rudall River National Park are surrounded by dense, tall, *Acacia* thickets that are conspicuous in this desert environment. The Desert Queens Baths are surrounded by *Eucalyptus* and *Acacia* species over *Typha domingensis* and grasses and sedges.

A 40 m transect of eight consecutive 5 m x 5 m quadrats was established at Desert Queens Baths on the 12th May 2008 (Figure 4). Percentage cover was recorded for all species occurring within the quadrats (Table 3).

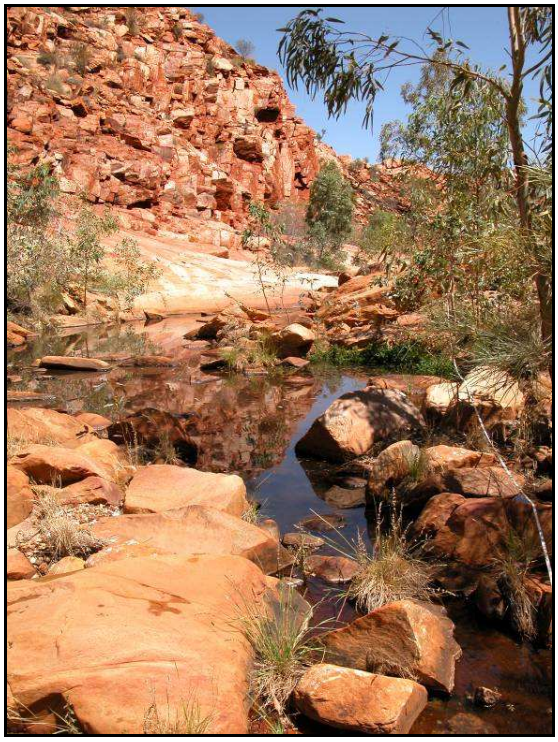

Figure 4 – Vegetation transect at Desert Queens Baths.

Table 3 – Percentage cover per taxa on the riparian vegetation transect at Desert Queens Baths.

Species	Quadrat (m) / % layer cover							
	0-5	5-10	10-15	15-20	20-25	25-30	30-35	35-40
Acacia tumida var. *tumida*	2	2	0	0	2	2	0	0
Centipeda minima subsp. *macrocephala*	0	0	5	5	1	1	0	0
Cyperus cunninghamii subsp. *cunninghamii*	1	1	1	1	0	0	1	1
Eragrostis cumingii	2	2	1	1	1	1	0	0
Eucalyptus sp.	5	5	10	10	2.5	2.5	0	0
Eulalia aurea	5	5	1	1	5	5	5	5
Marsilea exarata	0	0	0	0	1	1	0	0
Pluchea dentax	1	1	1	1	1	1	0	0
Poaceae sp.	1	1	0	0	0	0	0	0
Seedling sp.	1	1	0	0	0	0	0	0
Triodia pungens	0	0	5	5	1	1	0	0

According to the National Vegetation Information System (NVIS), the vegetation community may be described as (ESCAVI 2003):

U1+^*Eucalyptus* sp.\tree\?7\r; M1 ^*Acacia tumida* var. *tumida*\shrub\4\r; G1 ^*Eulalia aurea*, *Cyperus cunninghamii* subsp. *cunninghamii*, *Triodia pungens*, *Eragrostis cumingii*\grass, sedge\1\r.

There were no weeds found on the transect or in surrounding vegetation. There was no evidence of recent disturbance across the site by either fire or grazing. Pathogen attack on vegetation was negligible, some leaves with insect damage were observed. The ground was largely rocky, and the only evidence of erosion was limited to a track and was a result of trampling by visitors to the Baths.

3.7. Aquatic Invertebrates

The location surveyed for aquatic macroinvertebrates was actually immediately downstream of the Desert Queens Baths. Samples of aquatic macroinvertebrates were collected within three habitats at the location:

1. Macrophyte: Typha
2. Sediment: Pool with bedrock
3. Sediment: Pool with boulders

Family and species macroinvertebrate richness was lower at the time of the IAI RCM survey than during the Pilbara Biological Survey at this site (Table 4). This may be due to the much lower water depth at the time of the IAI RCM survey: 30 to 40cm in 2008 versus 80 to 95 cm in 2003-2004. The lower water level means less diversity of habitat, including smaller areas of submerged macrophytes and larger areas of *Typha*. This does not necessarily indicate declining condition at the site, as arid zone wetlands are extremely variable and responsive to recent rainfall. Several groups were noticably less rich in 2008 than on earlier occasions, particularly ceratopogonid midges, chironomid midges and Hemiptera.

Twenty-six species collected during the RCM work were not recorded during the Pilbara Biological Survey. These include several species of odonates (*Neurothemis stigmatizans stigmatizans*, *Austrogomphus turneri*, and *Austroagrion watsoni*) and a whirligig beetle (*Dineutes australis*). This brings the total number of invertebrate taxa recorded from this site to 199. A complete list of invertebrate taxa recorded during the 2008 IAI RCM survey may be found in the attached Appendix.

Table 4 – Summary of the results of aquatic invertebrate surveys at Desert Queens Baths in 2003, 2004 and 2008.

Diversity measure	Pilbara Survey Sep 2003	Pilbara Survey May 2004	RCM Survey May 2008
Total invertebrate species richness	114	118	-
Macroinvertebrate species richness	108	83	72
Total invertebrate family richness	56	55	-
Macroinvertebrate family richness	46	40	29

3.8. Fish

No fish were observed at the Desert Queens Baths during the IAI RCM survey and none have been recorded previously.

3.9. Birds

More than ninety species of bird have been recorded in the Rudall River National Park (Gough 1997). Bush Stonecurlew (*Burhinus grallarius*, Priority 4 fauna) and a Peregrine Falcon (*Falco peregrinus*) have previously been sighted at Desert Queens Baths. The Pilbara Biological Survey

recorded one species of waterbird, an Australasian Grebe (*Tachybaptus novaehollandiae)* at Desert Queens Baths in 2003. The IAI RCM survey recorded no birds at the site in May 2008.

3.10. Terrestrial Vertebrates

A quantitative survey of fauna has not been undertaken in the Rudall subregion of the Little Sandy Desert (Kendrick 2001). Fauna records for the area are sporadic and the result of opportunistic collections. Six amphibian species, fifteen mammal species and thirty-six reptile species have been recorded in the Rudall River National Park.

4. Interactions between Ecological Components at Desert Queens Baths

An appreciation of the interactions between the elements of a wetland ecosystem is essential to understanding the condition of the system. Although the ecological components and processes of a wetland are often monitored and managed as discrete entities, they exist as nodes in a complex ecological web. Documenting the full extent of the interactions that occur at a wetland would be impractical. However, it is essential to identify key interactions that define the system's ecological character.

The key features of Desert Queens Baths that contribute to its outstanding ecological character are:

- The characteristics that make the site a good example of a wetland type occurring within a biogeographic region in Australia: *Desert Queens Baths are a good example of a series of permanent freshwater pools that feed into an entire seasonal river system, a rarity in the arid zone.*
- The contribution the site makes to the ecological or hydrological functioning of the wetland system/complex. *The springs that form the Desert Queens Baths also provide water for the entire Rudall River system.*
- The animal taxa that utilise the site as habitat at a vulnerable stage in their life cycles, or as a refuge when adverse conditions such as drought prevail; and the characteristics of the site that allow it support these populations. *Desert Queens Baths are a significant drought refuge area for birds and other fauna in the bioregion. These rock pools have been known to support waterbirds such as the Australasian Grebe (Tachybaptus novaehollandiae), as well as other birds and terrestrial vertebrates.*
- The site's outstanding historical and cultural significance. *Permanent fresh water in an otherwise arid region is an important resource and the pools and surrounds would likely have been utilised by Aboriginal people historically.*

Furthermore, Desert Queens Baths and the surrounding Rudall River National Park have been sparsely-surveyed for biological diversity. The area is likely to support endemic or rare taxa, due to the presence of permanent fresh water in an arid environment.

Table 5 summarises the interactions between key components and processes at Desert Queens Baths. The table lists the components that are directly responsible for the provision of each service or benefit of the wetland and the biotic and abiotic factors that support or impact these components. Also listed are the key threats that may affect the components or processes. These are discussed in Section 5.

Table 5 – The relationship between the services and benefits delivered by Desert Queens Baths and the key components and processes that support them.

Benefit or Service	Component	Factors Influencing Component		Threats and Threatening Activities
		Biotic	Abiotic	
Consumptive Value Bush tucker	Palatable plants and animals	Plant pollinators Animal food sources	Hydrological regime Fire regime Habitat requirements	Altered fire regimes Grazing and predation by introduced animals
Opportunity Value Potential future use of unique flora and fauna	Endemic flora Endemic fauna	Pollinators Food sources	Habitat extent and distribution Hydrological regime Fire regime Water quality	Grazing and predation by introduced animals Altered fire regimes
Ecosystem Service Value It is a good example of a wetland type occurring within a biogeographic region in Australia	A series of permanent freshwater pools that feed into an entire seasonal river system	Vegetation communities	Hydrological regime Geomorphology	Grazing by introduced animals Erosion and deposition
Ecosystem Service Value It is a wetland which plays an important ecological or hydrological role in the natural functioning of a major wetland system/complex	Rudall River that flows into Lake Dora	Vegetation communities	Soils and sediments Hydrological regime	Grazing by cattle or introduced animals Erosion and sedimentation
Ecosystem Service Value It is a wetland which is important as the habitat for animal taxa and provides a refuge when adverse conditions such as drought prevail	Australasian Grebe Other birds and terrestrial vertebrates	Invertebrate populations (food source) Phytoplankton (food source) Benthic plant biomass	Soils and sediments Nutrient concentrations Water salinity and pH Groundwater level	Grazing by introduced animals Altered fire regimes Excessive nutrient inputs from camels Predation of fauna

Benefit or Service	Component	Factors Influencing Component		Threats and Threatening Activities
		Biotic	**Abiotic**	
Recreational Value Bird watching Picnicking Camping Bush walking	Landscape amenity Bird populations Vegetation communities Significant flora Significant fauna	Invertebrate populations (food source) Phytoplankton (food source) Benthic plant biomass	Soils and sediments Nutrient concentrations Water salinity and pH Groundwater level	Grazing by introduced animals Altered fire regimes Predation of fauna Erosion and deposition
Spiritual Value The wetland is of outstanding historical or cultural significance	Geomorphology of the pools and surrounds Native flora and fauna communities Association with early explorers	Flora and fauna populations Pollinators and food sources for above	Soils and sediments Hydrology Water quality	Grazing by introduced animals Altered fire regimes Predation of fauna Erosion and deposition

5. Threats to the Ecology of Desert Queens Baths

The ambition for management at Desert Queens Baths is to maintain those elements of the system that are the primary determinants of its ecological character. These are the geomorphologic, hydrologic and water quality factors that ensure the pools provide water to the river system and make them a suitable refuge site for native flora and fauna. These factors are influenced by, and exert an influence on, the vegetation communities that surround the water body, the aquatic invertebrate and benthic vegetation communities that inhabit it and the threatening processes that could impact on all of these. Also of importance are the elements of the system that contribute to its cultural and scientific value.

Threats to Desert Queens Baths must be considered in relation to their likelihood of causing the failure of the above management goal for the wetland. An assessment is made of the probability that goal failure will result due to the impacts of each threatening process identified at the site, or potentially acting there. The results of this assessment are presented in Table 6. In summary, failure to achieve the management goal for Desert Queens Baths is most likely to occur from the impacts of exotic flora and fauna, and alteration to natural fire regimes. Climate change may also be a significant threat and the potential impacts of more extreme events (drought and flood) should be considered.

Camels (*Camelus dromedarius*) and Buffel Grass (*Cenchrus ciliaris*) are considered to be significant threats to rockhole wetlands of the inland Pilbara and to the semi-permanent pools along the course of the Rudall River (Kendrick 2001). Camels have the potential to significantly impact on an area by trampling and grazing native vegetation. They can also deplete or foul water. These impacts have a negative flow on effect on the native fauna that rely on those water points for refuge in hot weather (DEC 2008). At the time of the IAI RCM survey there was no evidence of camels at Desert Queens Baths, but their presence may be seasonal or occasional.

No weeds were recorded during the site visit in April 2008. However, weeds may establish at the site in the future and should be carefully monitored. Buffel grass is a particular concern as it grows best along creek lines and is capable of invading an area and replacing native grasses. Its presence increases the severity of fires, with further impacts on native species (CSIRO 1995). It is difficult to implement weed control in wetland environments. The fragility of these systems, and the movement of water through them, can make chemical weed control inappropriate. Mechanical control is often complicated by difficulty in accessing infestations. These factors make early detection of infestations essential to successful control.

Altered fire regimes are a major threat to biodiversity across the Pilbara region. Inappropriate fire regimes have the potential to facilitate the establishment of weed species, expose soils to erosion, cause the loss of fire-sensitive flora and negatively impact on fauna. Late dry season fires are particularly problematic because the availability of fuels is greatest at that time. It is very difficult to manage fire in a setting such as Rudall River due to the size and remoteness of the park.

The CSIRO predicts that climate change will make the north-western area of Australia a significantly warmer and slightly drier place in the future (CSIRO 2001). Periods of aridity are likely to be longer and the rainfall events that end them more extreme. Some of the potential effects of these changes include the replacement of plant communities with more drought-resistant assemblages, and the occurrence of more intense fires with longer post fire recovery times for vegetation. A reduction in rainfall, combined with hotter days leading to higher evaporation rates, could make the Rudall River and its tributaries a drier system overall. This would have a detrimental impact on the fauna species that rely on the wetlands as habitat. Algal blooms are also expected to become more frequent and widespread as a result of rising temperatures.

Although the rate of human visitation to the Desert Queens Baths is low, it does create a risk that visitors could carry seed propagules, plant pathogens or even exotic fauna to the site. Tourism also increases the risk of wildfire due to deliberate ignition or the failure to properly extinguish campfires.

Table 6 – Threat assessment for Desert Queens Baths, including the perceived likelihood of goal failure resulting from the impacts of each identified threat category.

Goal: to maintain the geomorphology and hydrology of Desert Queens Baths, thus ensuring they remain a suitable drought refuge for flora and fauna and retain their cultural and scientific values.

Threat category	Management issue	Probability (%) that threat will cause goal failure with:		Assumptions underlying initial probability assessment and explanatory notes
		Existing management	Extra management	
Altered biogeochemical processes	Carbon cycle and climate change	.05	.05	Predicted rises in temperature in the Pilbara (as much as 7^0C) would lead to higher evaporation rates and water consumption. Changes to rainfall are expected to be fairly minor in the Pilbara, perhaps as little as 1% over the next 50 years, but may lead to slight increases in stream flow (CSIRO 2001).
Impacts of introduced plants and animals	Environmental weeds	.05	0	No weeds were recorded during the site visit in April 2008. There is a risk of future colonisation of the site by invasive plants.
	Herbivory and trampling by introduced species	.10	.05	No impacts from introduced animals were present. However, camels are known to be present in the area and they may utilise the site at other times of the year.
Impacts of problem native species	Overgrazing by native species	0	0	No impacts evident.
Impacts of disease	Plant pathogens	0	0	No impacts evident.
Detrimental regimes of physical disturbance events	Fire regimes	.10	.05	Altered fire regimes are a major threat to biodiversity across the Pilbara region. In the context of the Rudall River, its tributaries and Lake Dora, fire has the potential to facilitate the establishment of weed species, expose soils to erosion, cause the loss of fire sensitive flora taxa and negatively impact on fauna. Late dry season fires can also have significant impacts on soil loss, loss of nitrogen in smoke, increased greenhouse gas emissions, and impacts on air quality and human health. It is very difficult to manage fire in a setting such as Rudall River due to the size and remoteness of the area.

Threat category	Management issue	Probability (%) that threat will cause goal failure with:		Assumptions underlying initial probability assessment and explanatory notes
		Existing management	Extra management	
	Drought	.05	.05	Rainfall projections for the Pilbara show that climate change may result in warmer weather with less but more intense rainfall (CSIRO 2001). The impacts of this on the ecology and geomorphology of the Desert Queens Baths are difficult to predict. It is possible that it may lead to some alteration in the composition of flora and fauna at the site.
	Flood	.05	.05	Alteration to rainfall and hydrological fluxes associated with global climate change may impact on the vegetation of Desert Queens Baths and associated wetlands. The nature of the impacts is not clear and should be monitored.
Impacts of pollution	Herbicide, pesticide or fertiliser use and direct impacts	0	0	No impacts evident or likely.
Impacts of competing land uses	Recreation management	.01	0	Recreational usage of Desert Queens Baths is low impact and unlikely to have any deleterious impacts.
	Nutrient enrichment of the water body	.05	.01	Camels accessing the pools may cause nutrient enrichment of the water body. Future control measures may prevent this.
	Urban and industrial development	0	0	The remoteness of the area makes it an inappropriate site for any urban or industrial development.
	Consumptive uses	0	0	Any consumptive use of Desert Queens Baths by local Aboriginal people is most probably sustainable in the long-term.
	Illegal activities	0	0	No evidence of any threat.
	Mines and quarries	0	0	Possible mineral potential but no plans for exploitation of resources at present.
Insufficient ecological resources to maintain viable populations	Habitat, genetic exchange	.01	.01	The Desert Queens Baths and associated wetlands are well connected to extensive areas of natural or near natural environment. Populations are likely to be self-supporting in this setting. Off-site impacts on any native fauna could potentially reduce their population size to unsustainable levels, but this could not be addressed at a site level.

6. Knowledge Gaps and Recommendations for Future Monitoring

Rudall River National Park has not been adequately surveyed for flora and fauna. In 1982, a resource inventory was completed in the park by a team lead by ecologist B. Muir (1982). However, no recent surveys have been undertaken, probably due to the remoteness of the area. There is currently no management plan for the park.

The IAI RCM survey did not find any evidence of degradation at Desert Queen Baths. Feral camels and weeds probably represent the greatest potential threats to the site and periodic monitoring should be conducted to ensure that neither are becoming established in the area.

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Appendix

Table 7 – Aquatic invertebrate species recorded at Desert Queens Baths during the IAI RCM 2008 survey.

Class	Order	Family	Lowest ID	Habitats*
Gastropoda	Basommatophora	Lymnaeidae	*Austropeplea lessoni*	1,2,3
		Planorbidae	*Glyptophysa* sp. P1 (RCM)	2,3
			Gyraulus sp.	1,2,3
Oligochaeta	Tubificida	Naididae	*Allonais pectinata*	1,2
			Allonais paraguayensis	1
Arachnida	Acariformes	Limnesiidae	*Limnesia parasolida*	3
		Unionicolidae	*Unionicola neoaffinis*	3
		Arrenuridae	*Arrenurus tricornutus*	3
Insecta	Coleoptera	Dytiscidae	*Laccophilus sharpi*	2
			Hydrovatus opacus	1
			Hydrovatus sp.	1,3
			Hydroglyphus orthogrammus	2
			Hydroglyphus leai	2
			Hydroglyphus grammopterus (=*trilineatus*)	3
			Limbodessus compactus	1
			Tiporus lachlani	2
			Megaporus ruficeps	3
			Platynectes decempunctatus var. *decempunctatus*	3
			Rhantaticus congestus	2
			Cybister sp.	1
		Gyrinidae	*Dineutes australis*	2,3
			Macrogyrus gibbosus	2,3
		Hydrophilidae	*Berosus* sp.	2
			Regimbartia attenuata	1
			Paranacaena horni	1
			Helochares tatei	1
			Paracymus pygmaeus	1,3
		Hydraenidae	*Hydraena barbipes*	1
		Scirtidae	Scirtidae sp.	1
		Hydrochidae	*Hydrochus interioris*	1
			Hydrochus sp. P1 (PSW)	3
	Diptera	Culicidae	*Anopheles* sp.	3
			Culex (Culex) *annulirostris*	1,3
		Ceratopogonidae	*Bezzia* sp.	1,2,3
			Monohelea sp.	1,3
			Atrichopogon sp.	1
		Tabanidae	Tabanidae	1,3

Class	Order	Family	Lowest ID	Habitats*
Insecta	Diptera	Stratiomyidae	Stratiomyidae	1,2,3
		Chironomidae	*Procladius paludicola* P1 (no U-claws)	1,2,3
			Ablabesmyia hilli	1,3
			Ablabesmyia notabilis	1
			Ablabesmyia aff *notabilis*	2
			Paramerina sp C (PSW)	2
			Larsia albiceps	1,2
			Tanytarsus fuscithorax/semibarbitarsus	1,2,3
			Stenochironomus watsoni	1,3
			Dicrotendipes sp. K4 (RCM)	1,2,3
			Polypedilum leei	1,2
			Polypedilum convexum	3
			Zavreliella marmorata	1,2,3
			Skusella subvittata	2,3
	Ephemeroptera	Baetidae	*Cloeon* sp.	1,2,3
		Caenidae	*Tasmanocoenis arcuata*	1,2,3
			Tasmanocoenis sp. M (PSW)	2
	Hemiptera	Gerridae	*Limnogonus luctuosus*	1,2
		Nepidae	*Laccotrephes tristis*	2
			Ranatra dispar	1
		Corixidae	*Micronecta lansburyi*	1,2
		Notonectidae	*Anisops elstoni*	2
			Anisops occipitalis	2
			Anisops paraexigerus	1
			Anisops stali	2
	Odonata	Coenagrionidae	*Austroagrion watsoni*	1,2,3
		Aeshnidae	*Aeshna brevistyla*	1,2,3
			Hemianax papuensis	1,2,3
		Gomphidae	*Austrogomphus turneri*	2
		Libellulidae	*Diplacodes haematodes*	3
			Neurothemis stigmatizans stigmatizans	2
			Orthetrum caledonicum	2,3
			Trapezostigma stenoloba	1,2,3
	Trichoptera	Ecnomidae	*Ecnomus pilbarensis*	1,2,3
		Leptoceridae	*Oecetis* sp.	1,2,3
			Triplectides ciuskus seductus	1

* Habitats:
1. Macrophyte: Typha
2. Sediment: Pool with bedrock
3. Sediment: Pool with boulders