7. Environmental and Social Impact Assessment

This chapter describes the material impacts of the project on the existing environment. Compass will endeavour to minimise the adverse effects and maximise the beneficial aspects of its operation wherever possible. This involves evaluating each impact to assess its significance, establish mitigative or ameliorative measures and present environmental and socio-economic safeguards.

The prediction and evaluation of the key impacts are based on a knowledge of the existing environments likely to be affected, the results of specific investigations, surveys and monitoring programs, identification of site-specific issues, experience gained from mining projects in comparable environmental settings, reviews of scientific literature and professional judgement.

Residual environmental impacts are those that remain after avoidance, management and mitigation measures have been applied. For some impacts, quantitative predictions can be made and subsequent monitoring need only be minimal to validate the predictions. For impacts where accurate predictions are not possible, based on currently available information, a correspondingly greater emphasis will be placed on monitoring, as described in Chapter 9.

7.1 Terrestrial Flora

A flora impact assessment for the Browns Oxide Project was undertaken by Judy Egan, Botanical Consultant, and is included as Appendix 5A. This assessment built on the previous flora assessment of the broader project area by Metcalfe in 2002 (Appendix 5B). This section summarises the findings of these assessments.

7.1.1 Background

The composition, structure and diversity of flora species in the project area is based on a desktop review of vegetation mapping and aerial photography, and field surveys undertaken in May 2002 and August 2005.

The 2002 survey sampled an area of 37.5 km^2 (3,750 ha) in and around the project area, while the 2005 survey focussed on the 1.75 km^2 (175 ha) project area and selected surrounding vegetation types.

Egan (Appendix 5A) mapped preliminary vegetation community boundaries based on aerial photographs of the project area, and compared them to those prepared by Metcalfe (Appendix 5B). In general, a high level of correlation between the two maps is apparent. From this, Egan (Appendix 5A) selected 20 sites across a range of vegetation communities for ground truthing. Of these, 17 were assessed using 20 m x 20 m quadrats (400 m^2) and the following characteristics were recorded:

- Vegetation structure (height of upper, mid and ground stratum species).
- Species composition and dominance.
- Percentage canopy cover for each species.
- Presence or absence of introduced species (weeds).
- Level of disturbance (including fire, feral animal and anthropogenic impacts).
- Environmental features including landform, aspect, soils and drainage patterns.

Three of the 20 locations selected by Egan (Appendix 5A) were not fully assessed due to the level of disturbance at two of the sites that was caused by fire several weeks prior to assessment, and the degraded nature of one area of riparian vegetation. A species list only was compiled for these locations.

Unknown plant species were collected and pressed for botanical identification utilising Northern Territory herbarium resources.

7.1.2 Existing Conditions

Summary

Native vegetation distribution in the project area closely reflects the interplay of topography and soils, and the influence of seasonal fluctuations in fresh water supply and drainage. Consequently, the pattern of vegetation broadly corresponds to major topographic contours.

Most of the project area (approximately 50%) comprises dryland savannah vegetation on gentle lower slopes and foothills that support eucalyptus-dominated communities. These communities comprise various formations ranging from open woodland to woodland.

The central and eastern sections of the project area are highly disturbed and dominated by weeds and introduced grasses. The remaining vegetation in the project area comprises riparian, floodplain and vine forest communities with varying degrees of weed infestation. In general, the plant species recorded within the project area are common and widespread in the region. There are no vegetation communities of declared conservation significance, at either the Commonwealth or territory level, in the project area. Similarly, there are no plant species of conservation significance listed under the EPBC Act in the project area, nor do records exist of any rare or endangered plant species. The only protected species found or likely to occur in the project area is the cycad *Cycas armstrongii*, which is listed as threatened under the *Territory Parks and Wildlife Conservation Act.* This species is present within several vegetation communities in the project area.

Vegetation Communities

Appendix 5B identified 10 major vegetation communities (VC) – in addition to previously mined or disturbed areas – within the 3,750 ha survey area. A total of seven of these vegetation communities (VC 1, 2, 3, 5, 6, 7, 10) were found within the smaller 175 ha project area (Appendix 5A). In addition, a further three communities (VC 12, 13 and 14) have been identified in the 175 ha project area as a result of the more detailed mapping in Appendix 5A. Appendix 5B also includes an additional vegetation classification

(VC 11) to reflect the presence of the highly disturbed areas. The vegetation communities present within the project area are summarised in Table 7.1 and described in detail below, and shown in Figure 7.1.

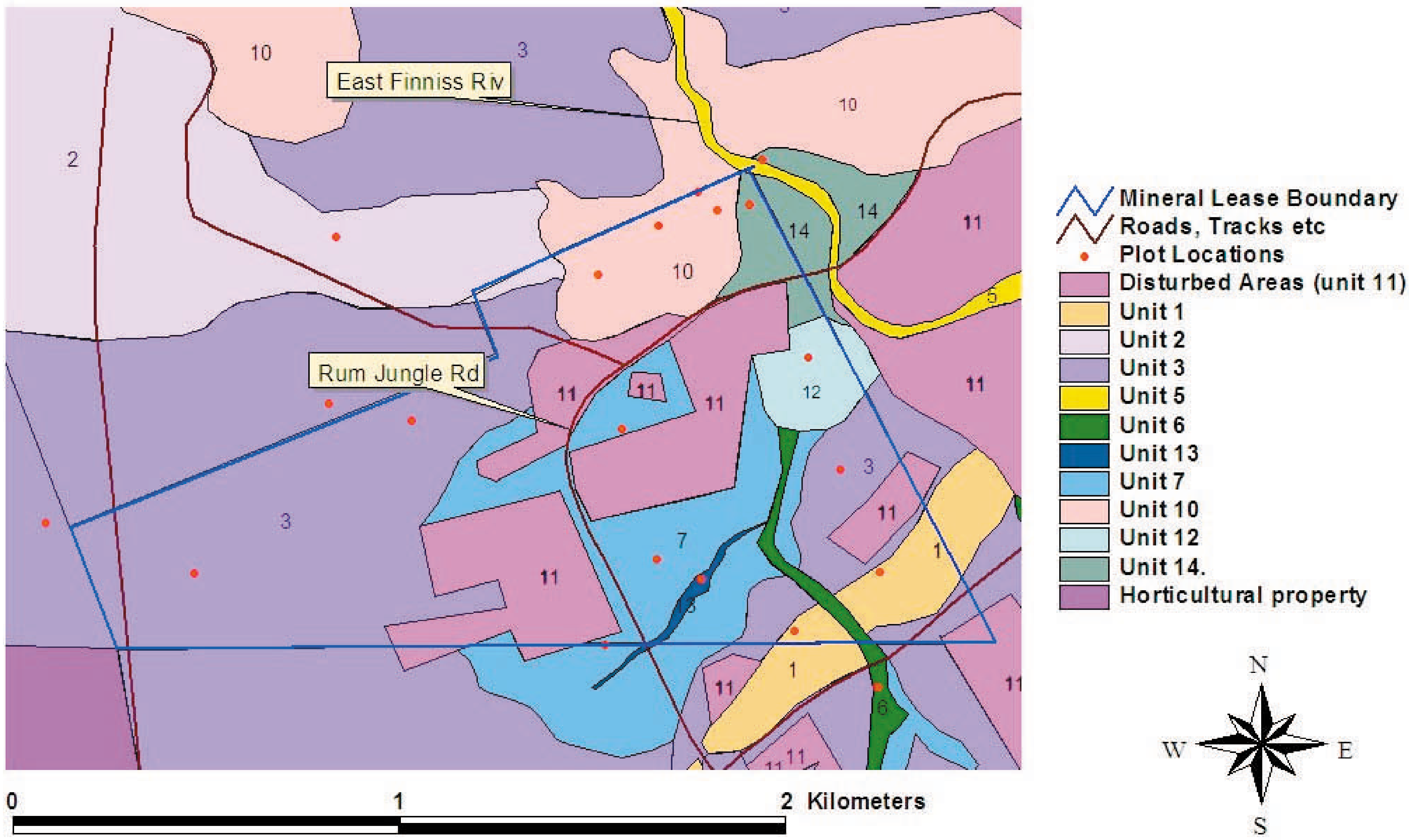
Table 7.1 Vegetation communities within the project area

Unit	Vegetation Community	Mean Species Richness		Approx. Area (ha)	% Project Area
		2002	2005		
1	*Eucalyptus phoenicea/Corymbia bleeseri* Open Woodland.	17	35	6.5	3.7
2	*Eucalyptus tetradonta/ Eucalyptus miniata/ Erythrophleum chlorostachys* Tall Open Forest to Woodland.	31	35	1	0.6
3	*Eucalyptus tetrodonta/E. miniata* Open Woodland.	28	30	65	37.1
5	Riparian corridor.	26	27	0.5	0.3
6	*Lophostemon* community Open Woodland to Grassland.	20	18	2.3	1.3
7	*Eucalyptus papuana/Corymbia foelscheana/ Melaleuca* spp. Open Woodland to Grassland.	17	21	28	16
10	*Acacia auriculiformis* community Woodland to Open Forest.	31	31	13	7.4
11	Disturbed areas – including old mines, borrow pits, rehabilitated areas and recent exploration activities.	N/A	N/A	41	23.4
12	*A. auriculiformis/Melaleuca dealbata/Lophostemon* Forest, with exceptionally heavy weed infestation.	N/A	30	5.7	3.3
13	*Pandanus spiralis* Woodland over *Imperata cyclindrica*.	N/A	12	1	0.6
14	Extensively degraded *Erythrophleum/A.auriculiformis* Woodland with dense weed infestation.	N/A	23	4	2.3

N/A: Not Assessed.

VC 1 – **Eucalyptus phoenicea/Corymbia bleeseri** *Open Woodland (6.5 ha, 3.7%)*

This community has a limited distribution in the project area, occurring on the rocky crests of several low hills in the southeastern section. The dominant species, *Eucalyptus phoenicea*, is typically a mid-height, multi-trunk Eucalypt characteristic of rocky habitats, ridges and hills, that forms an open woodland formation to 8 m with a sparse mid and ground stratum. Common species in this vegetation community are listed in Table 7.2; no introduced species were recorded.



Source: Appendix 5A

Job No: 836	Compass Resources NL	Vegetation map	Figure No: 7.1
File No: 836_08_F7.01_HB	Browns Oxide Project		

Table 7.2 Common species in VC 1

Vegetation Structure		
Upper Stratum	**Middle Stratum (to 4 m)**	**Ground Layer**
• *Corymbia bleeseri* • *Eucalyptus miniata* • *Erythrophleum chlorostachys* • *Eucalyptus tetrodonta*	• *Xanthostemon paradoxus* • *Owenia vernicosa* • *Acacia* spp. • *Livistona humilus*	• Dense annual grasses (*Heteropogon contortus, Themeda triandra, Sorghum* spp.) • Juvenile Eucalypts • Herbs (*Bonamia* sp., *Sauropus glaucus, Gomphrena* spp., *Pachynema* spp.) • Sub-shrubs including *Petalostigma quadriloculare and Grevillea dryandrii*. • *Cycas armstrongii*

VC 2* – Eucalyptus tetrodonta/E. miniata/Erythrophleum chlorostachys *Tall Open Forest to Woodland (1.0 ha, 0.6%)

This vegetation community comprises well-developed, tall open forests on deeper soils of low plateau surfaces, upper hill slopes and rises, and is found to the far north of the project area. An extensive area of this vegetation community occurs to the northwest outside of the project area. Open woodland formations are common where this vegetation community merges with the eucalypt-dominated savannah woodland habitat. A few introduced species (occurring at low densities) were recorded in this vegetation community.

The dominant upper stratum species of *Eucalyptus tetrodonta, E. miniata* and *Erythrophleum chlorostachys* (ironwood) form a moderate to dense upper stratum to 15 m high. Ironwood is an outstanding and typically large, ubiquitous tree throughout this community. Table 7.3 lists other common species in this community.

Table 7.3 Common species in VC 2

Vegetation Structure			
Upper Stratum	**Dense Understorey (to 6 m)**	**Middle Stratum (in areas of seasonally elevated soil moisture)**	**Ground Layer**
• *Eucalyptus confertiflora* • *Syzygium suborbiculare* • *Alstonia actinophylla* • *Acacia auriculiformis*	• *Buchanania obovata* • *Flueggia virosa* • *Persoonia falcata* • *Livistona humilus*	• *Exocarpus latifolius* • *Petalostigma pubescens* • *Acacia auriculiformis* • *Ficus opposita*	• *Sorghum spp.* • *Themeda triandra* • *Chryspogon latifolius* • *Eriachne spp.* • *Cycas armstrongii*

VC 3* – Eucalyptus tetrodonta/E. miniata *Open Woodland (65 ha, 37%)

This vegetation community largely comprises eucalypt-dominated open woodlands with minor areas of denser woodland habitat. The introduced tall grass *Andropogon gayanus* (gamba grass) is abundant, mainly in disturbed areas such as roadsides. Table 7.4 lists common species in this community.

Table 7.4 Common species in VC 3

Vegetation Structure		
Upper Stratum (12 to 20 m)	**Middle Stratum (2 to 6 m)**	**Ground Layer**
• *Eucalyptus miniata* • *E. tetrodonta* • *E. confertiflora* • *Erythrophleum chlorostachys*	• *Acacia* spp. • *Cycas armstrongi* • *Brachychiton megaphyllus* • *Calytrix exstipulata* • *Petalostigma pubescens* • *Gardenia megasperma*	• Grasses, including *Sorghum* spp., *Eriachne* spp., *Chrysopogon latifolius* and *Heteropogon contortus* • Introduced grasses, including *Andropogon gayanus and Pennisetum* spp. • *Flemingia lineata* • *Fleuggia virosa* • *Distichostemon hispidulus* • *Waltheria indica* • *Ampelocissus* spp. • *Cycas armstrongii*

The dominant species varies locally with changing topographic conditions and associated variations in drainage and soil type:

- On the well-drained upland areas and low foothills of the survey area, the dominant species is characteristically *Eucalyptus miniata* (Darwin woollybutt), with *E. tetrodonta* either alone or in co-dominant stands; *E. confertiflora* may be locally abundant.
- *Eucalyptus miniata* is the most widespread dominant tree on the shallower, yellowish soils of the upper slopes. In these areas, *Eucalyptus tetrodonta* may also be present, with occasional *E. tectifica* (especially in rockier areas and on low crests).
- On the lower slopes, and particularly where this community intergrades with alluvial flats and low-lying areas, *E. confertiflora*, *Coymbia polycarpa* and *E. papuana* may become locally common.
- Other species including *Corymbia grandifolia* and *Erythrophleum chlorostachys* may become abundant towards drainage areas.

VC 5 – Riparian Corridor (0.5 ha, 0.3%)

Riparian vegetation exists along the corridor of the East Finniss River in the far northeast of the project area. Although this riparian vegetation shows obvious signs of degradation, it currently supports a reasonable density and diversity of riparian species, with common species being listed in Table 7.5.

Table 7.5 Common species in VC 5

Vegetation Structure		
Semi-aquatic		
• *Phragmites vallatoria* • *Psedoraphis spinescens*	• *Pitrogramma colmelanos* • *Eleocharis geniculata*	• *Cyperus aquatilis* • *Hygrophila angustifolia*
Terrestrial		
Upper Stratum (12 to 20 m)	**Middle Stratum**	**Ground Layer**
• *Acacia auriculiformis* • *Melaleuca* spp. • *Terminalia carpentariae* • *Corymbia polycarpa*	• *Pandanus spiralis* • *Barringtonia acutangula* • *Leptospermum longifolium*	• *Ischaemum australe* • *Imperata cylindrica* • Weeds, including *Mimosa pigra, Stachytarpheta spp., Hyptis suaveolens* and *Andropogon gayanus.*

VC 6 –* Lophostemon *(2.3 ha, 1.3%)

The small, linear drainage line that drains the southeast of the project area supports a narrow but dense woodland community in which *Lophostemon lactifluus* is dominant. A second species, *Lophostemon grandiflorus*, also forms monospecific stands in localised areas of the broad drainage way flanking Rum Jungle Creek and the Finniss River floodplain system, outside the project area. Weeds are present in highest densities along creek banks and levees. Table 7.6 lists the common species associated with this community.

Table 7.6 Common species in VC 6

Vegetation Structure		
Upper Stratum	**Middle Stratum**	**Ground Layer**
• *Lophostemon lactifluus* • *Lophostemon grandiflorus* • *Eucalyptus papuana*	• *Melaleuca viridiflora* • *Pandanus spiralis* • *Planchonia careya* • *Corymbia polycarpa*	• *Eriachne burkittii* • *Paspalum scrobiculatum* • *Themeda triandra* • *Ischaemum* spp. • *Fimbristylis pauciflora* • *Sporobolis pyramidalis* • *Limnophila fragrans*

VC 7 –* Eucalyptus papuana/Corymbia foelscheana/Melaleuca *Open Woodland to Grassland (28 ha, 16%)

This community is highly variable, both floristically and structurally, and commonly occurs on the seasonally flooded flats surrounding the major drainage lines. Common species are listed in Table 7.7. Ten weed species occur in this community and introduced grasses may form dense infestations on river levees, particularly where seasonal flooding and/or feral animals have disturbed the native vegetation. Previous clearing and grazing has also encouraged the weed proliferation.

Vegetation varies with local variations in the soils and especially drainage across floodplain areas. Typically:

- Ghost gums (*Eucalyptus papuana)* are ubiquitous in lowland and floodplain areas and generally occur as scattered trees above dense grassland (open woodlands).
- Toward upland areas with greater site drainage, *Corymbia foelscheana* can become locally abundant to dominant.
- In more swampy areas of the floodplain *Melaleuca* spp. becomes locally prevalent.
- A distinctive corridor of grassland, in which *Ischaemum australe* forms dense monospecific stands, characteristically flanks the riparian vegetation fringing the drainage line in the southeast of the project area.

Table 7.7 Common species in VC 7

Vegetation Structure	
Upper Stratum	**Ground Layer**
• *Eucalyptus papuana* • *Corymbia foelscheana* • *Lophostemon grandiflorus* • *Melaleuca dealbata* • *Acacia auriculiformis*	• *Ischaemum australe* • *Andropogon gayanus* • *Stachytarpheta spp.* • *Hyptis suaveolen*

VC 10 –* Acacia auriculiformis *Woodland to Open Forest (13 ha, 7.4%)

Although these habitats are floristically rich and support a suite of species not associated with other more widespread eucalypt woodland habitats, the *Acacia auriculiformis* (Darwin black wattle) communities typically represent degraded or regenerating vine-forest habitats within the north of the project area, where forest appears to be recovering from the impacts of disturbance (e.g., clearing, fire and mining). Many vine-forest species are frequently fire-sensitive and may become restricted to habitats associated with permanent water or to fire-protected rocky outcrops.

Vegetation structure reflects the lack of perennial water supply, with open forest and woodland structural formations more common than closed canopy forests. Table 7.8 lists common species for this community.

Table 7.8 Common species in VC 10

Vegetation Structure		
Upper Stratum	**Middle Stratum**	**Ground Layer**
• *Acacia auriculiformis* • *Erythrophleum chlorostachys* • *Terminalia microcarpa* • *Ficus virens* • *Alstonia actinophylla*	• Vines, including *Tinospora smilacina, Parsonsia velutina, Smilax australis* and *Abrus precatorius*	• *Hypoestes floribunda* • *Cheilanthes nitida* • Weeds, incuding *Hyptis suaveolens*, *Sida acuta*, *Senna obtusifolia* and *Pennisetum polystachion* • Vines, including *Cardiospermum halicacibum*, *Passiflora foetida* and *Calopogonium mucunoides*

VC 11 – Disturbed Areas (41 ha, 23.4%)

Significantly disturbed areas include old mine pits, borrow pits, rehabilitated areas and recent exploration areas. Disturbed areas were not fully assessed in the surveys undertaken for the project. Much of the disturbed land in the centre of the project area appears to have previously been *Eucalyptus papuana/Corymbia foelscheana/Melaleuca* open woodland to grassland (VC 7), although a considerable proportion of these areas is now heavily infested with weed species.

VC 12 – **Acacia auriculiformis/Melaleuca dealbata/Lophostemon grandiflorus** *Forest with Exceptionally Dense Weed Infestation (5.7 ha, 3.3%)*

This community is restricted to an area immediately adjacent to the East Finniss River in the east of the project area. The moister, southerly fringes of this vegetation community contain native grasses and sedges, although there is evidence of ongoing weed invasion. Common species found in this community are listed in Table 7.9.

Table 7.9 Common species in VC 12

Vegetation Structure		
Upper Stratum (18 to 20 m)	**Middle Stratum**	**Ground Layer**
• *Acacia auriculiformis* • *Melaleuca dealbata* • *Lophostemon grandifloru* • *Timonius timon*	• *Lophostemon grandiflorus* • *Acacia auriculiformis* • *Flueggea virosa* • *Jasminum aemulum*	• Weeds, including *Andropogon gayanus, Calopogonium mucunoides* and *Pennisetum spp*.

At the time of the assessment much of the herbaceous material had dried and withered, with some areas being patchily burnt. During the growing (wet) season, the percentage cover of these areas by weed species is estimated to approach 100%, forming an impenetrable mass that would smother any germinating seedlings of other species.

VC 13 – **Pandanus spiralis** *Woodland over* **Imperata cylindrica** *(1.0 ha, 0.6%)*

This vegetation type occupies drainage channels to the south of the project area. Common species are listed in Table 7.10. The lack of apparent diversity in this community is likely to be at least partly attributable to the time of year (late dry season) when the flora assessment was conducted. Many more seasonally perennial or annual species could be expected to occur in the same habitat throughout the wetter times of the year.

Table 7.10 Common species in VC 13

Vegetation Structure		
Upper Stratum (to 6 m)	**Middle Stratum**	**Ground Layer**
• *Pandanus spiralis* • *Melaleuca dealbata* • *M.viridiflora*	• Juvenile *Pandanus spiralis* • *Flemingia lineata* • *Grewia asiatica*	• *Imperata cylindrica* • *Themeda triandra* • *Ischaemum australe*

VC 14 – Extensively Degraded Erythrophleum/Acacia auriculiformis *Woodland with Dense Weed Infestation (4 ha, 2.3%)*

This degraded woodland community (where common species are listed in Table 7.11) is found immediately next to the East Finniss River and links with the adjacent *Acacia auriculiformis* community (VC 10). Due to its position close to the river and bridge crossing, it is likely to have had a long history of disturbance and of being burnt each dry season. This community is considered to be the extensively degraded remnants of open forest akin to that of *Eucalyptus tetrodonta/E. miniata*, combined with the outer intergrading margins of the adjacent *Acacia auriculiformis* community.

Table 7.11 Common species in VC 14

Vegetation Structure		
Upper Stratum	**Middle Stratum**	**Ground Layer**
• *Erythrophleum chlorostachys*	• Absent due to fire	• *Petalostigma quadriloculare* • *Persoonia falcata* • *Jasminum molle* • Weeds, including *Andropogon gayanus, Pennisetum* spp. and *Hyptis suaveolens.*

The area had been burnt about four weeks prior to the site assessment, and virtually no mid stratum remained. All shrub or tree species other than the emergent *Erythrophleum* trees were present only as resprouting shoots from lignotubers or rootstocks. The ground stratum had also been burnt.

Vegetation Communities of Conservation Significance

In general, the plant species recorded within the project area are common and widespread in the region. There are no vegetation communities of declared conservation significance, at either the Commonwealth or territory level, in the project area.

The locally and regionally important evergreen monsoon vine forest is not present within the project area. The *Acacia auriculiformis* vine thicket community (VC 10), restricted to the northeast of the project area, is recognised as being of high plant diversity with a distinct floristic assemblage providing food and habitat for native fauna. The project area contains approximately 13 ha of the relatively intact *Acacia auriculiformis* vegetation community (VC 10), with another 5.7 ha of extensively degraded habitat of this general type (VC 12). The 13 ha patch of forest abuts a larger area of approximately another 40 ha outside the project area.

Plant Species of Conservation Significance

There are no plant species of conservation significance listed under the Commonwealth EPBC Act in the project area.

No rare or endangered plant species have been recorded in the project area. There is also an absence of plant communities of restricted distribution or vegetation types known to contain significant numbers of rare species.

A high proportion of Northern Territory plant species from the Orchidaceae and Cycadaceae families have significant status, and these groups are generally regarded as having some intrinsic ecological value due to their relatively restricted distribution (Cowie, cited in Appendix 5B). The cycad *Cycas armstrongii*, which is endemic to the Northern Territory and is a common understorey species within Eucalypt-dominated woodlands, is listed as a threatened species under the *Territory Parks and Wildlife Conservation Act.* This plant is present within VCs 1, 2, 3 and 14, although its distribution and density are both variable across the eucalypt woodland savannah regions of the project area. These vegetation communities occupy approximately 50% of the total project area, with the estimated mean density of *Cycas armstrongii* within these communities being about 130 individuals per hectare.

Three additional protected species (*Habenaria elongata* (Orchidaceae), *Helicteres* sp*. 'Glenluckie Creek'* (Steruculiaceae) and *Indigofera schultziana* (Fabaceae)) have been investigated for their potential presence in the project area. It has been determined unlikely that *Helicteres* sp*. 'Glenluckie Creek'* or *Indigofera schultziana* are present and there is no evidence of *Habenaria elongata* in the project area, nor is there any substantial area of its preferred habitat.

7.1.3 Potential Issues

Clearing of Vegetation

About half of the vegetation within the 175 ha project area will be cleared to accommodate project infrastructure such as access roads, plant site, pit, tailing storage facility, stockpiles and sedimentation traps. Measures to minimise vegetation loss during the design of the project infrastructure layout are discussed in Section 7.1.4.

The clearing of vegetation will remove individual plants from the broader regional population. This has the potential to impact on the distribution, dispersal and genetic diversity of populations of species in the region. The removal of vegetation also has the potential to further fragment and reduce the area of habitat available for fauna species dependent on it for resources. The consequences of habitat fragmentation for fauna species are discussed in Section 7.2.4.

Patches of remnant vine forest (VC 10) and degraded vine forest (VC 12) will potentially be cleared. These vegetation communities have ecological significance largely due to the general scarcity of perennial water and the frequency and extent of annual burning. Vine forest communities are characteristically fire sensitive (i.e., killed by fire) and are fire restricted, and typically occur as small disjunct patches in a 'sea of savannah' (Appendix 5b). They contain a distinct and diverse flora, and their scattered and relatively restricted distribution in the region present challenges for their adequate conservation.

Weed Density and Distribution

Vegetation clearing can lead to a change in the environmental conditions along vegetation corridors (such as increased light, wind and temperature). This can often favour the establishment and spread of 'edge' species, which are usually exotic, leading to a shift in vegetation community composition. A total of 33 introduced plant species have been recorded in the total survey area, with several of these such as gamba grass and mission grass being of particular concern.

Project-related vehicles and equipment (especially earth-moving equipment) also have the potential to introduce and/or spread weed species within the project area.

Increases in weed density and distribution have the potential to further reduce the available local habitat for fauna species that are dependent on specific vegetation communities. Several weed species also have the potential to alter the extent and intensity of fire in the project area.

Fire

Fire is a natural, annual event in the landscape of northern Australia, with up to 50% or more of the region burnt each year (Williams 1995, cited in Appendix 5b). Early-season, low intensity fires are common, although project-related activities have the potential to alter fire frequency, intensity and timing in the region. For example, gamba and mission grass both form extremely dense clumps of vegetation 3 to 4 m tall and are capable of supplying large fuel loads that can create fires up to eight times as intense as those in native grasses (Rossiter et. al., 2003, cited in Appendix 5a). These altered fire regimes can lead to further changes in vegetation structure and composition.

7.1.4 Avoidance, Mitigation and Management Measures

Avoidance, management and mitigation measures will be developed to minimise the impact of the project on the flora, and specifically vegetation communities, of the area. The primary impacts to flora relate to vegetation clearing and the potential for increased weed density and distribution in vegetation communities surrounding the project area.

The on-going implementation of the site-specific Biological and Land Management Plan (Section 9.8.3) will ensure that impacts to vegetation communities and threatened species are managed in a sensitive manner.

Clearing of Vegetation

The extent and amount of vegetation to be cleared in the project area will be dependent on the final design and layout of the project components. Measures designed to avoid, mitigate and manage the clearing of vegetation include:

- Appropriate siting of project components by specifically considering the following:
  - Retaining vegetation in the southeast of the project area containing the threatened species, *Cycas armstrongii*, to reduce the total number of individuals removed.
  - Minimising clearing of vine forest vegetation in the north of the project area.
  - Retaining *Eucalyptus miniata* and *E. tetrodonta* +/- *E. chlorosachys* open forest to woodland, as this vegetation supports the highest diversity of fauna in the

project area, including the northern quoll, the red goshawk and the brush-tailed phascogale (see Section 7.2). Near-threatened fauna species are also found in this habitat.

- Severing of riparian corridors will be avoided where possible.
- Use of previously disturbed and modified areas will be maximised in preference to clearing intact habitat.
- Areas to be disturbed will be subject to written clearance authority and will be clearly defined and identified.

Weed Density and Distribution

Measures designed to avoid, mitigate and manage the density and distribution of weeds in the project area include:

- A focus on the control of recognised problem weed species such as gamba grass and mission grass, and the prevention of their spread during the life of the project.
- Targeted application of weed control measures.
- Regular monitoring of areas with a high potential for, or susceptibility to, weed invasion, such as along roadsides, in recently cleared areas, and the vine forest vegetation communities to the north of the project area.
- Control and/or prevention of weed infestations in topsoil stockpiles to minimise the likelihood of weed introduction during respreading of topsoil.
- Wash down units for vehicles and project equipment moving on or off the project area.

Fire

The planning and management of fire within the project area will play a significant role in managing impacts on the diversity and composition of vegetation communities in and around the project area. Management measures to control fire are described in the Fire Management Plan (Section 9.8.2) and will include:

- Implementation of a controlled burn regime that takes into account the requirements of vegetation communities and flora species within the project area.
- Procedures to avoid, control and regulate potential unplanned fires.
- Controlling the spread of weeds such as gamba grass in the project area.

7.1.5 Residual Impact Assessment

Clearing of Vegetation

The vegetation to be cleared contains common and widespread vegetation types of no declared conservation significance within the local and regional contexts (Appendix 5B).

The terrestrial vegetation communities within the project area are typical of eucalypt forest and woodland of the 'Top End' and comprise part of an extensive bioregion i.e., the Pine Creek bioregion that covers 30,404 km^2. Thus, in the regional context, the conservation value of the terrestrial flora found in the project area is not significant and clearing represents a minor vegetation loss in an area where disturbance and other impacts from past mining, clearing, fires, roads and tracks, and the introduction of weeds, have impacted on the condition and structure of vegetation communities. The nearby Litchfield National Park contains at least comparative, if not greater, composition and diversity of species in an undisturbed area. Additionally, approximately 43% of the Pine Creek bioregion is currently reserved, predominantly for conservation purposes (Woinarski, Connors and Oliver, 1996, cited in Appendix 5b).

Natural regeneration of vegetation, and ultimately rehabilitation, will compensate for vegetation lost during clearing (apart from areas such as the pit).

In terms of specific species, the *Eucalyptus tetrodonta/E. miniata* open woodland is the dominant vegetation community in the project area, occupying 37% of the land. Most of this vegetation community within the project area will be cleared during construction. The significant species *Cycas armstrongii* is found within this and other eucalypt woodland vegetation communities in the project area, and Egan (Appendix 5a) has estimated that approximately 10,200 individuals of this species could be removed. *Cycas armstrongii* is present as part of a widespread, and relatively common, population in the region and is represented in a range of conservation reserves, including the Litchfield National Park. The retention of about 22 ha of eucalypt woodland in the southeast of the project area will significantly reduce the number of *Cycas armstrongii* to be cleared.

The removal and/or fragmentation of minor areas of riparian, floodplain, *Lophostemon* and melaleuca communities associated with drainage lines in the project area will be avoided where possible. These are of no declared conservation significance but have local and regional ecological importance since they support a distinct fauna composition, and are fire sensitive. Management and mitigation measures will be implemented to minimise the impact to these vegetation communities.

Weed Density and Distribution

Vegetation clearing and other project-related activities have the potential to accelerate the spread of gamba grass over the project area and into adjacent woodlands and forests. This species is capable of spreading into undisturbed bushland, although its easiest and most rapid mode of spreading is along roads and cleared corridors. Mission grasses (*Pennisetum* spp.), *Mimosa pigra* and *Grewia asiatica* are also examples of species with the potential for expansion in distribution as a result of vegetation clearing.

Clearing of the fragmented *Acacia auriculiformis* vine forest communities in the north of the project area has the potential to increase the rate of invasion of weed species into the surrounding vine forest community. The southeastern edge of this vegetation community has been extensively infiltrated by gamba grass, mission grass and other weed species. The design and layout of project infrastructure will include consideration of minimising the area of this vegetation community that will require complete removal.

The implementation of the Biological and Land Management Plan (Section 9.8.3) will mitigate the risks associated with an increase in the density and abundance of weed species in the project area. Active weed management will reduce the density and extent of weed distribution, thereby leading to an improvement in the composition and structure of remnant vegetation communities.

Fire

The impact of a large-scale wildfire on vegetation communities would be extensive, notwithstanding the fact that the pit, haul roads and site access road will form a natural fire break against fire coming from the north and northwest. Implementation of appropriate measures is expected to satisfactorily manage the risk of smaller-scale fires with respect to flora species and vegetation communities, with these smaller fires having the potential to increase diversity and reduce weed infestation across the project area.

7.2 Terrestrial and Aquatic Fauna

A fauna impact assessment for the Browns Oxide Project was undertaken by Ecological Management Services Pty Ltd (EMS) and is included as Appendix 4. This section summarises the findings of the assessment.

7.2.1 Background

Description of the type, number and density of fauna species in the project area is based on a desktop review and field surveys undertaken during the dry season of 2002 and the wet season of 2005 (see Appendix 4).

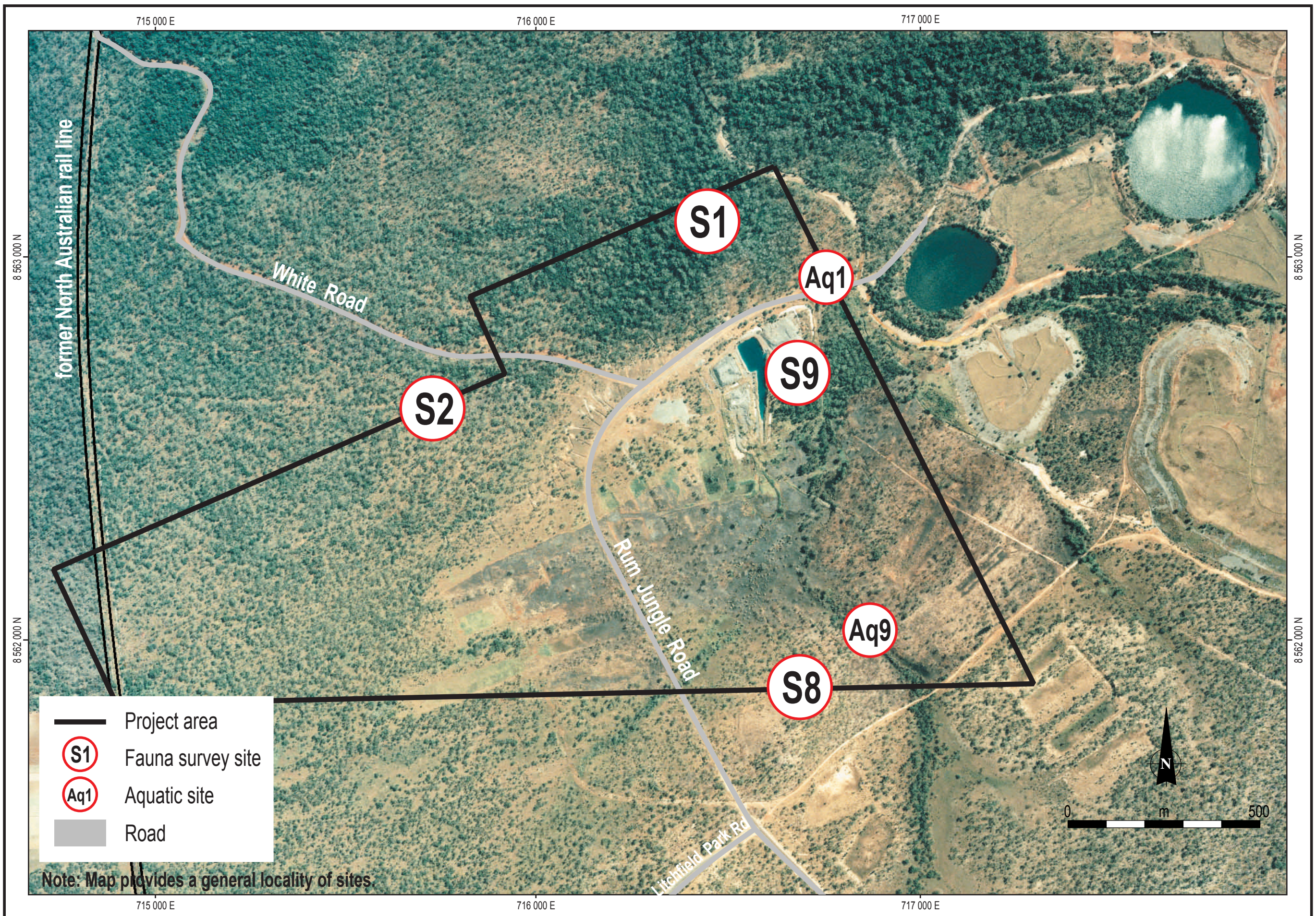
The dry season survey sampled a study area of 37.5 km^2 (3,750 ha) in and around the project area, while the wet season survey focused on the 1.75 km^2 (175 ha) project area and surrounding selected habitat types.

Eight terrestrial, 8 aquatic and 12 herpetofauna sites were systematically surveyed during the 2002 dry season, while 4 terrestrial and 2 aquatic sites were systematically sampled during the 2005 wet season (Figure 7.2). A summary of the fauna survey methods is given in Table 7.12.

7.2.2 Existing Conditions

Summary

The project area and immediate surrounds support a range of fauna species including 18 amphibians (including the cane toad [*Bufo marinus*] which has only arrived to the area during the latest wet season), 38 reptiles, 120 birds and 33 mammal species (29 native and 4 introduced).



Source: Appendix 4 figures 3 and 2

enesar people and place	Job No: 836	Compass Resources NL	Fauna survey sites (2002 dry season / 2005 wet season)	Figure No: 7.2
	File No: 836_08_F7.02_HB	Browns Oxide Project		

Table 7.12 Fauna survey methods

Type of Survey	Site Number		Method of Survey
	2002 Dry Season	2005 Wet Season	
Terrestrial Fauna	S1 – S7	S1, S2, S8, S9	Hair funnels
	S1 – S8	S1, S2, S8, S9	Tree-mounted traps
	S1 – S8	S1, S2, S8, S9	Elliot Type A traps
	S1 – S8	S1, S2, S8, S9	Elliot Type B traps
	S1 – S8	S1, S2, S8, S9	Wire cage traps
	S1 – S7	S1, S2, S8, S9	Pitfall trap
	S1 – S8	S1, S2, S8, S9	Timed area bird survey
	S1 – S8	S1, S2, S8, S9	Nocturnal call playback
	S1 – S8	S1, S2, S8, S9	Timed active area search (diurnal)
	S1 – S8	S1, S2, S8, S9	Timed active area search (nocturnal)
	S1 – S8	S1, S2, S8, S9	Spotlight survey
	S1 – S8, Aq1/Aq2, Aq5 – Aq8	S1, S2, S8, S9	Bat call detection (fixed point)
Aquatic Fauna	Aq1 – Aq8	Aq1, Aq9	Semi-aquatic vertebrates
	Aq1 – Aq8		Turtle trapping
Additional Reptile Search	H3 – H5, H9		Timed area search (rock outcrops)
	Aq6 – Aq8		Timed area search (riverine habitat)
	H2 – H6 – H7		Timed area search (upland Eucalypt habitat)
	H1 – H11 – H12		Timed area search (vine-forest habitat)
	Av1 – Av2		Timed area bird survey
Additional (Non-standard) Surveys	S1, S2, S4, S6, Aq5	S1, S2, S8, S9	Harp trap
			Vehicle spotlighting
			Bat roost searches
			Collection of scats and or skeletal remains

Three species listed as vulnerable or endangered under the EPBC Act are present, or potentially present, within the project area:

- Northern quoll (*Dasyrus hallucatus*).
- Partridge pigeon (*Geophaps smithii*).
- Red goshawk (*Erythrotnorchis radiatus*).

Additional species listed as vulnerable or near threatened under the TPWC Act that are present, or potentially present, within the project area are:

- Northern death adder (*Acanthophis praelongus*).
- Yellow-spotted monitor (*Varanus panoptes*).
- Brush-tailed phascogale (*Phascogale tapoatafa*).

- Bush stone-curlew (*Burhinus grallarius*).
- Black-footed tree rat (*Mesembryiomys gouldi*).
- Arnhem Land pebblemound mouse (*Pseudomys calabyi*).
- Pale field-rat (*Rattus tunneyi*).
- Arnhem sheathtail bat (*Taphozous kapalgensis*).

Amphibians

The number and abundance of amphibian species in the region is consistent with that of the wider 'Top End' of the Northern Territory, with diversity comparative to that of the nearby Litchfield National Park. Seventeen native amphibian species were observed during the combined dry and wet season surveys. To date the cane toad (*Bufo marinus*) is present in low numbers, having arrived in the area within a few weeks or months prior to the 2005 wet season (Earthrowl, pers. com., 2005 cited in Appendix 4).

During the dry season, amphibian species such as the bilingual frog (*Crinia bilingua*) and Tornier's frog (*Litoria tornieri*) are unlikely to exist in areas other than the major river systems and spring-fed streams in the region, including Rum Jungle Creek, the main Finniss River channel and the East Finniss River. This pattern of amphibian diversity and abundance within the project area is likely to be similar to that observed within adjacent areas of Litchfield National Park, where streams and drainage depressions support a high proportion of the frog fauna during the dry season (Griffiths *et al.*, 1997 cited in Appendix 4).

During the wet season, amphibians are found in greater abundance and diversity across the project area due to an expansion in suitable habitat. During and following rainfall events, amphibian species are often found in typically drier habitat types (including upland eucalypt forest, monsoon vine thicket and rocky habitats), with species including *Limnodynastes ornatus*, *Litoria tornieri* and *Uperoleia inundata*.

Significant Species. There are no species of amphibian recorded in the project area that are listed as rare or threatened under the relevant legislation (TPWC Act, EPBC Act). However, many amphibian species in the region have been listed as data deficient under the TPWC Act due to the potential impact of the cane toad.

Reptiles

A high diversity of aquatic and terrestrial reptile species occurs in and around the project area.

The aquatic and semi-aquatic reptile species found in the region include the northern yellow-faced turtle (*Emydura tanybaraga*), estuarine crocodile (*Crocodylus porosus*), freshwater crocodile (*Crocodylus johnstonii*), Merten's water monitor (*Varanus mertensi*) and Macleay's water snake (*Enhydris polyepis*). The common tree snake (*Dendrelaphis punctulata*) and small litter-dwelling skink species (*Carlia gracilis* and *Carlia rufilatus*) are also commonly associated with riparian and aquatic habitat in the area.

Reptile species richness is high in the dry rock outcrops and scree areas, with common species including the bar-shouldered ctenotus (*Ctenotus inornatus*, dark vertebral stripe form), northern spotted rock dtella (*Gehyra nana*) and olive python (*Liasis olivaceus*). The open forest habitat supports a high diversity of skinks and lizards, while the acacia regrowth/monsoon vine-forest habitat and the open drainage areas support a reduced reptile diversity and abundance.

One species of snake, the northern small-eyed snake (*Rhinoplocephalus pallidiceps*), was recorded during the dry season 2002 survey in vine-forest and is not listed in regional fauna databases. It has not been previously recorded in the local area, including Litchfield National Park (Griffiths *et al*., 1997 cited in Appendix 4).

During the wet season, reptile species appear to be less abundant in the region than during the dry season, although this may be due to difficulties in observing reptiles in the dense exotic and native grasses that dominate the landscape after rain. Species present only during the wet season 2005 survey included the frilled lizard (*Chlaydosaurus kingii*), ornate snake-eyed skink (*Notoscincus ornatus*) and the slender blind snake (*Ramphotyphlops nema*).

Significant Species. Habitats within the project area support reptile species that are generally common in the region, and none of the taxa recorded are considered to be endangered or vulnerable by relevant conservation authorities. Two 'near threatened' (under the TWPC Act) reptile species were noted (Table 7.13), although the listing of these two species is due primarily to the threat posed by lethal toxic ingestion of cane toads. Many reptile species in the region have been listed as data deficient under the TPWC Act due to the potential impact of the cane toad.

Table 7.13 Significant reptile species

Scientific Name	Common Name	Listing	Habitat	Location and Season
Acanthophis praelongus	Northern death adder	Near threatened, TPWC Act	Upland eucalypt	S2 (dry)
Varanus panoptes	Yellow-spotted monitor	Near threatened, TPWC Act	Drainage areas	S5 (dry)

Birds

There are approximately 120 bird species in and around the project area, and this is about half the number of species in surrounding areas, including Litchfield National Park. The majority of species are widely distributed in the open forest/woodland habitats, with the remaining species usually associated with wetlands or freshwater habitats; a limited number occur primarily in riparian forests or vine thickets.

Birds that have restricted ranges during the dry season occur in broader habitat types during the wet season, when dense grasses support species such as the masked finch (*Poephila personata*) and the tailed finch (*Poephila acuticauda*). Migratory species such as the dollarbird (*Eurystomus orientalis*), channel-billed cuckoo (*Scythrops novaehollandiae*), and the fork-tailed swift (*Apus pacificus*) are present in the project area during the wet season, when waterbirds are also more common than in the dry season.

Significant Species. Three significant bird species occur in the study area, all of which are listed under the TWPC Act, with two of them also being listed under the EPBC Act (Table 7.14) (Figure 7.3).

Table 7.14 Significant bird species

Scientific Name	Common Name	Listing	Habitat	Location and Season
Burhinus grallarius	Bush stone-curlew	Near Threatened, TPWC Act	Upland eucalypt forest, rocky rises	S8 (dry)
Erythrothrichochis radiatus	Red goshawk	Vulnerable, EPBC Act Vulnerable, TPWC Act	Upland eucalypt woodland, riparian corridors	S3, S4, S8 (dry) S2 (wet)
Geophaps smithii	Partridge pigeon	Vulnerable, EPBC Act Near Threatened, TPWC Act	Upland eucalypt forest, rocky rises	S2, S8, S9 (wet)

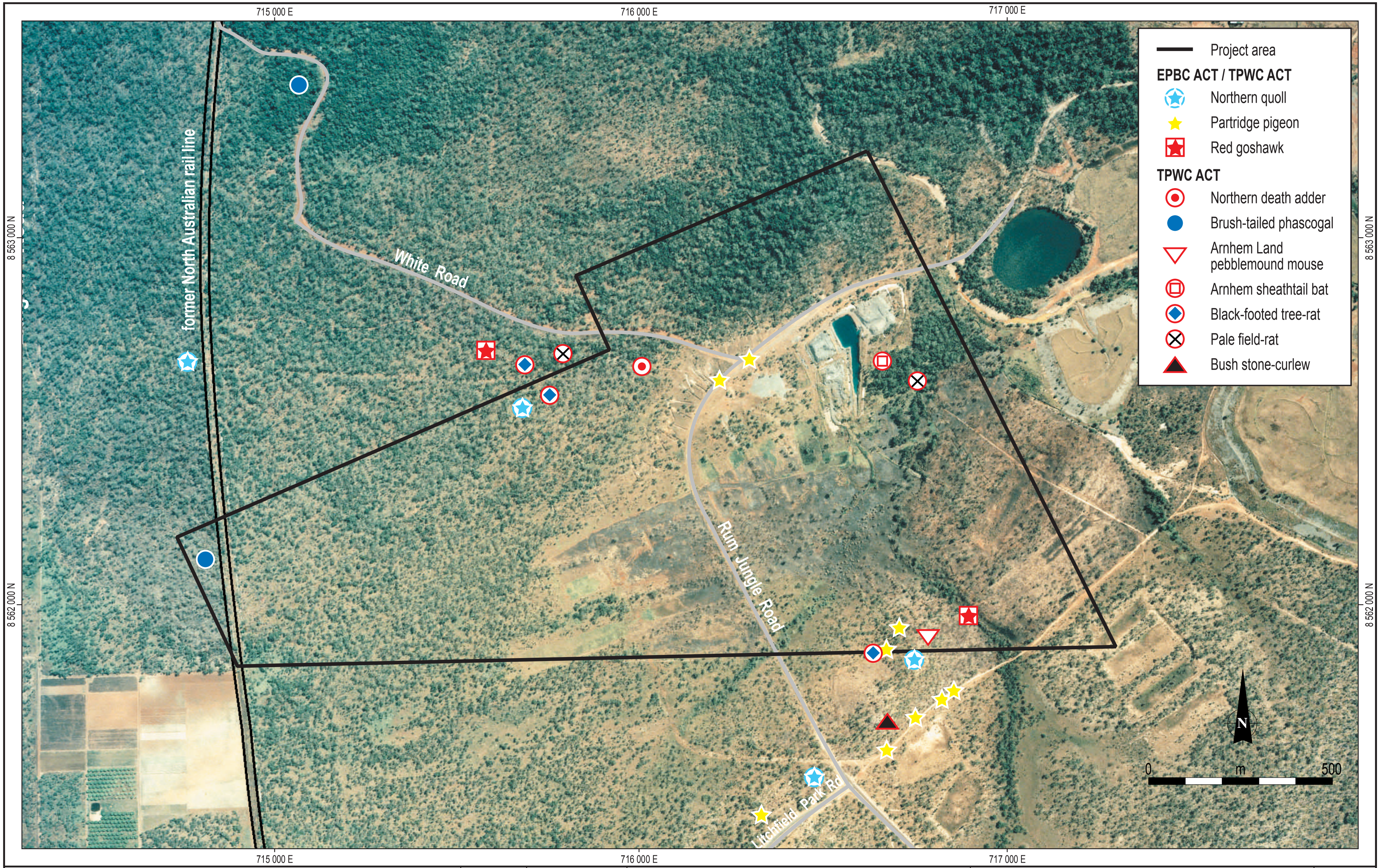
The bush stone-curlew is relatively common in northern Australia and is at times very common in Litchfield National Park (Price and Barker, 2003 cited in Appendix 4). Predation by feral cats, land clearing and altered fire regimes represent threatening processes for this species, although it remains common in the local area and persists in modified areas such as pastures and township margins.

The red goshawk occurs at very low densities across northern Australia and has been recorded in the local area in Litchfield National Park and adjacent properties (Woinarski, 2002a cited in Appendix 4). This bird inhabits coastal and sub-coastal tall open forests and woodlands, tropical savannahs traversed by forested rivers and the margins of rainforest. It is likely to utilise eucalypt forest types, open forests and woodlands in drainage areas and riverine forests in and around the project area. The red goshawk is threatened by land clearing, as well as the disturbance of nest sites. No nest sites for this species occur within the project area.

The partridge pigeon, which prefers mixed eucalypt woodland habitat with a structurally diverse understorey, is restricted in range to the sub-coastal areas of the northern parts of Northern Territory and is known to occur in Litchfield National Park (Woinarski, 2004 cited in Appendix 4). Land clearance and predation by feral cats are key threatening processes.

Mammals

Twenty-eight native mammal species have been identified in the project area, including microchiropteran bats, rodents and macropods. The highest diversity of mammals is in the upland eucalypt forest habitat, while the open drainage and floodplain habitats have low species diversity. Species such as the northern brushtail possum (*Trichosurus vulpecular arnhemensis*) and the agile wallaby (*Macropus agilis*) are common throughout the region. Similar species are present throughout the dry and wet seasons.



Source: Appendix 4 figures 4 and 5

Job No: 836	Compass Resources NL	Records of threatened and near threatened fauna species	Figure No: 7.3
File No: 836_08_F7.03_HB	Browns Oxide Project		

Nocturnal species common in the project area include the brush-tailed phascogale (*Phascogale tapoatafa pirata*), antillopine wallaroo (*Macropus antilopinus*), black flying-fox (*Pteropus alecto*), sugar glider (*Petaurus brevipes*) and feral pig (*Sus scrofa*).

A variety of microchiropteran bat species is present in a range of habitat types across the project area, with the most common species/groups including the *Scotorepens* spp., *Miniopterus schreibersii* and *Nyctophilus* spp.

Significant Species. Six significant species of mammals occur in the project area. All are listed under the TWPC Act and one is also listed under the EPBC Act (Table 7.15) (see Figure 7.3).

Table 7.15 Significant mammal species

Scientific Name	Common Name	Listing	Habitat	Location and Season
Dasyurus hallucatus	Northern quoll	Endangered, EPBC Act Vulnerable, TPWC Act	Upland eucalypt forest, rocky rises	S3, S4, S8 (dry) S2 (wet)
Mesembryiomys gouldi	Black-footed tree rat	Near Threatened, TPWC Act	Eucalypt forest and woodland	S2, S8 (dry) S2 (wet)
Phascogale tapoatafa pirata	Brush-tailed phascogale	Vulnerable, TPWC Act	Upland eucalypt woodland, riparian corridors.	S2, S3 (dry) S2 (wet)
Pseudomys calabyi	Arnhem Land pebblemound mouse	Near Threatened, TPWC Act	Stony woodland	S8 (wet)
Rattus tunneyi	Pale field-rat	Near Threatened, TPWC Act	Melaleuca woodland and open forest	S2, S9 (wet)
Taphozous kapalgensis	Arnhem sheathtail bat	Near Threatened, TPWC Act	Melaleuca woodland	S9 (wet)

The northern quoll is considered common in Litchfield National Park and the local area, although its distribution appears to have decreased from a once-wider extent (Griffiths et al., 1997 cited in Appendix 4). The reduction in range is directly related to disturbance of habitat, i.e., woodland and open woodland on rock outcrops. Predation by feral cats, disease and changed fire regimes are also possible causes for this reduction. It is likely that the northern quoll population in the region will be impacted by the recent arrival of cane toads.

The black-footed tree rat has contracted in distribution across the Northern Territory, with populations appearing to be thinly spread. It is known to occur in Litchfield National Park. Suitable habitat generally includes eucalypt forest and woodland with a dense understorey of small trees and shrubs (Lee, 1995 cited in Appendix 4). Grazing and changes in fire regime appear to reduce the understorey vegetation required by this species.

The brush-tailed phascogale is uncommon and patchily distributed in the region. It has been recently documented in Litchfield National Park, but is not common (Woinarski, 2002b cited in Appendix 4). This animal inhabits drier forest types, although there are some records from riparian/woodland and deciduous vine-thicket. The typical home range for this species is large (up to 150 ha for males), suggesting that a local population is likely to utilise a large area. It is likely that the brush-tailed phascogale population in the region will be impacted by the recent arrival of cane toads.

The Arnhem Land pebblemound mouse is known to exist in Litchfield National Park, although there are no previous records from the Batchelor/Rum Jungle area (Griffiths et al., 1997 cited in Appendix 4). The mouse inhabits stony woodland and eucalypt woodland on stony hills. The threatening processes for this species not known but is expected to include land clearing and fire.

The pale field rat is known to exist in Litchfield National Park and throughout the Coomalie sub-region, and is locally common and widespread. Its habitat is becoming increasingly fragmented and is restricted to melaleuca woodland within the project area.

The Arnhem sheathtail bat has very few records of description and its distribution is restricted to open woodland on floodplain edges, dense melaleuca forest and a mixture of sandstone woodlands and riparian areas (Woinarksi and Milne, 2002 cited in Appendix 4). Habitat modification and land clearing are expected to be the key threatening processes for this species.

Migratory Species

Eight species in or near the project area are covered by the migratory provisions of the EPBC Act (Table 7.16).

Table 7.16 Migratory species listed under the EPBC Act

Scientific Name	Common Name	Habitat	Location and Season
Crocodylus porosus	Estuarine crocodile	Riverine	Aq7 Finniss River main branch (dry)
Apus pacificus	Fork-tailed swift	Aerial feeder	S1, S2, S8 (wet)
Coracina tenuirostris melvvillensis	Cicadabird	Upland Eucalypt woodland, monsoon vine-forest	S1, S2 (wet)
Gallinago megala	Swinhoe's snipe	Drainage areas	Aq5 Finniss River (wet)
Haliaeetus leucogaster	White-bellied sea eagle	Riparian	Av2 (wet)
Hirundapus caudacutus	White-throated needletail	Aerial feeder	S2 (wet)
Merops ornatus	Rainbow bee-eater	Most forest types	S1 - S4, S6, S7 (dry) S1, S2, S8 (wet)
Rhipidura rufifrons	Rufous fantail	Riparian, monsoon vine-forest	S1, Finniss River main branch (dry)

The estuarine crocodile inhabits large rivers and streams, freshwater swamps and floodplain billabongs across the north of the Northern Territory. Several large specimens have been recorded near the project area, although no suitable habitat for this species occurs within the project area itself. Acid rock drainage and aquatic pollution are the main threatening processes.

The fork-tailed swift and white-throated needletail are aerial-feeding species that were not observed using terrestrial habitats within the project area. It is unlikely that vegetation clearing would impact on the population of these species. The rainbow bee-eater is generally a common and widespread species throughout the Northern Territory, with broad habitat requirements. There are no major habitats in the project area for the Swinhoe's snipe, although it is possible that small numbers of migrating waterbirds might temporarily use artificial water sources or flooded areas. The wide range of the white-bellied sea eagle and an absence of nest sites in the project area suggest that this species does not have a significant presence in the project area.

The rufous fantail is common year round in this part of the Northern Territory and does not tend to be migratory. Populations of the cicadabird are seasonally nomadic, retreating to pockets of rainforest in the dry season and locally common during the wet season.

Introduced Species

Four introduced vertebrate fauna species have been identified in the project area and are common in the region: the domestic dog, feral pig, cane toad and feral cat. Of these, the feral pig, cane toad and feral cat are of most concern within the project context.

The feral pig (*Sus scrofa*) is relatively common in the area and is considered the most numerous and destructive introduced mammal species in the region. These animals frequent areas associated with permanent open water and/or drainage channels during the dry season, causing significant ground disturbance. During the wet season, they also cause significant damage to the melaleuca woodland associated with low-lying drainage areas.

The cane toad (*Bufo marinus*) is in the process of colonising the area and large numbers of toads are likely to invade local habitats in the immediate future. It is known that in recently colonised populations such as at the project site, cane toad numbers rapidly increase to levels far in excess of those in older established populations (DEH, 2005b). The biological effect, including lethal toxic ingestion, caused by cane toads is listed as a key threatening process under Schedule 3 of the EPBC Act, with its impact on the northern quoll and reptiles of particular concern (DEH, 2005b).

The feral cat (*Felis catus*) was observed in the project area during the wet season 2005 survey and is relatively common in the region. Predation of native wildlife by feral cats is also listed as a key threatening process under Schedule 3 of the EPBC Act, with particular concern given to their impact on reptile, bird and small mammal populations in the region (DEH, 2005b).

7.2.4 Potential Issues

Habitat Loss and Fragmentation

The proposed project will require the total clearing of areas of land. None of the habitats or ecosystems that are to be cleared or affected by the proposed project are listed as threatened ecological communities under the EPBC Act (DEH, 2005b). There are no World Heritage properties in close proximity, and the nearest conservation reserve is the Litchfield National Park, approximately 30 km west of Batchelor.

Vegetation clearing will potentially increase fragmentation of habitats in the local area, with possible consequences including increased inter- and intra-specific competition for resources due to reduced foraging areas, increased hunting pressure from prey species due to a reduction in habitat providing cover, and the isolation of breeding populations.

Habitat fragmentation can also lead to a change in the environmental conditions along vegetation corridors (such as increased light, wind and temperature). This can often favour the establishment and spread of 'edge' species, which are usually exotic, leading to a shift in vegetation community composition.

Eucalyptus miniata and *E. tetrodonta* (+/- *E. chlorosachys*) open forest to woodland (VC 2 and 3) supports the highest diversity of fauna in the project area, including the northern quoll, the red goshawk and the brush-tailed phascogale. Near-threatened species are also found in this habitat type. The proposed layout consists of a haul road, ROM pad, crushing pad, processing plant and office/administration facilities, all of which are located in this habitat. Project development is likely to include modification, disturbance and some loss of this vegetation community.

The project is not expected to fragment the eucalypt open woodland on rocky rises, riparian, or melaleuca woodland habitat types.

Significant Species

The project will clear vegetation that supports three fauna species of national (and Northern Territory) significance, i.e., the northern quoll, partridge pigeon and the red goshawk. Species that are listed as vulnerable or near threatened under the TPWC Act in the project area include the northern death-adder, yellow-spotted monitor, bush-stone curlew, brush-tailed phascogale, Arnhem sheathtail bat and several rodent species. Habitat used by these species may also be cleared.

The impact on threatened species by clearing of this vegetation may be compounded by the recent arrival of the cane toad to the region.

Fire

Many of the threatened and significant fauna species observed within the project area are negatively impacted by specific fire regimes. Increased project-related activity could result in an increase in unplanned fires with consequent impacts on fauna biodiversity and habitat. The presence and spread of exotic grasses (including gamba grass) can also influence the intensity and distribution of fires.

Introduced Species

A number of the fauna species within the project area, including the northern quoll, brush-tailed phascogale, goannas, snakes and frogs, are likely to be negatively impacted by the recent arrival of cane toads in the Batchelor area.

Feral pigs and feral cats are present in the study area. Feral pigs can cause habitat disturbance and increase the spread of weeds, while feral cats may represent a risk to some of the significant fauna species such as the partridge pigeon.

Acid Rock Drainage

Toxic metal concentrations at low pH, most likely the result of acid rock drainage, are considered the main factor in fish kills and the low fish abundance and diversity in the east branch of the Finniss River below the former Rum Jungle Mine site (Jeffree and Twining, 1998 cited in Appendix 4). However, current practices appear to be aiding the recovery of fish populations.

Mining activities that significantly increase erosion, sedimentation, inflows of toxic metals and changes in pH (e.g., acid rock drainage) are likely to have an impact on local aquatic fauna populations.

Mine Dewatering and Watertable Changes

Mine dewatering, advance dewatering and other hydrological changes have the potential to affect habitats and associated fauna species in the area surrounding the proposed mine pit, although such changes will occur within a context of considerable seasonal fluctuation of groundwater levels. Two potentially vulnerable habitats that occur adjacent to the mine pit are melaleuca woodland and monsoon vine-forest.

Sedimentation of Waterways

Disturbance to soils from construction activities may result in increased soil erosion and transport of soils to local waterways, such as the East Finniss River. This can affect water quality parameters such as total suspended solids, pH and dissolved oxygen, which can alter the quality of habitat for aquatic species.

Traffic

Traffic through the project area and surrounds may lead to collisions with fauna, with the partridge pigeon being particularly vulnerable to traffic impacts.

7.2.5 Avoidance, Mitigation and Management Measures

Avoidance, management and mitigation measures will be developed to minimise the impact of the project on local fauna. The primary impacts to fauna and significant fauna habitats relate to the proposed vegetation clearing and project layout.

The on-going implementation of the site-specific Biological and Land Management Plan (see Section 9.8.3) will ensure that impacts to vegetation communities, habitat and threatened species are sensitively managed.

Habitat Loss and Fragmentation

Measures designed to avoid, mitigate and manage habitat loss will include the preparation of a Mining Management Plan (MMP) to the satisfaction of the Northern Territory Parks and Wildlife Commission prior to vegetation clearing. Other measures are as described in Section 7.1.4.

Fauna Management

In addition to the mitigation and management measures outlined for minimising habitat loss and fragmentation, additional measures to be implemented for the protection of fauna will include:

- No trapping or killing of native wildlife (including fishing) within the mining lease area.
- Controls on firearms, feeding native wildlife and domestic pets.
- Good industry housekeeping practices.

Significant Species

To minimise the effects of the development on significant species, the following measures will be implemented:

- Vegetation disturbance associated with the proposed infrastructure will be minimised where possible to prevent unintended changes in the structure and condition of *Eucalyptus miniata* and *E. tetrodonta* +/- *E. chlorosachys* open forest to woodland and smaller remnants of vine forest.

- During construction, habitat will be protected from disturbance to the greatest extent possible.

- Maintenance of preferred red goshawk habitats, in particular riparian vegetation and Melaleuca communities, will be taken into account when designing fire management practices in the project area.

Impact mitigation will also be achieved by retention of the open woodland and riparian vegetation habitat in the southeast of the project area.

Sedimentation of Waterways

This has been addressed in Section 7.8.3.

Acid Rock Drainage

This has been addressed in Section 7.8.3.

Fire

This has been addressed in sections 9.8.2 and 7.1.4.

Introduced Pests

Management measures to control introduced pests, and hence mitigate potential impacts on significant fauna species, may include:

- Controlling feral pigs and cats in the vicinity of the project area.
- The establishment of small-scale measures, if possible, to reduce the impact of cane toads.

Where relevant and appropriate, site-specific control measures will be consistent with regional and/or Northern Territory management plans.

Mine Dewatering and Water Table Changes

Ongoing monitoring will be undertaken of habitats surrounding the mine pit, especially those dependent on stable water table levels such as the melaleuca woodland, which can provide indication of impacts of mine dewatering and or alteration of groundwater levels.

Traffic Collisions

Appropriate speed limits will be established along roads to enable vehicles to avoid colliding with ground-dwelling fauna emerging from vegetation. Personnel inductions will include road safety and awareness of fauna activity, especially at dawn and dusk.

7.2.6 Residual Impact Assessment

Habitat Loss and Fragmentation

The project's footprint is about 90 ha. Construction will result in habitat loss and fragmentation by the clearing of *Eucalyptus miniata* and *E. tetrodonta* (+/- *E. chlorosachys*) open forest to woodland. This habitat supports high species diversity and significant species in the dry season. However, within the regional context, this represents a minor vegetation and habitat loss in an area where disturbance and other impacts from past mining, clearing, fires, roads and tracks and the introduction of weeds and the feral pig have impacted on the condition and structure of fauna habitat. The nearby Litchfield National Park contains at least comparative, if not greater, composition and diversity of species in an undisturbed area.

Natural regeneration of vegetation, and ultimately rehabilitation, will at least partially compensate for habitat lost during clearing (apart from areas such as the pit).

Significant Species

Significant species will be impacted by the removal of vegetation during clearing of access tracks, ROM pad and other project infrastructure. Specifically, the project will have an impact on the following EPBC and TPWC listed species:

- Disturbance results in sub-optimal conditions for the northern quoll, although previous disturbance of these areas may have already influenced the population of northern quolls at this location.
- Refuge habitat for the brush-tailed phascogale is removed and/or fragmented. The local population of this species is likely to utilise large areas of open forest and woodland habitat in the region as part of a home range. Areas of suitable open forest and woodland habitat surrounding the project area may provide compensatory habitat for this species.
- The project results in altered fire regimes that remove preferred native grass habitat for the partridge pigeon. Carefully managed fire regimes will address this.

Fragmentation of habitat may impact on significant species, making them more vulnerable to predation. Vegetation clearing may also improve conditions for introduced predators such as feral cats, although this is already a significant problem across the Northern Territory.

Vegetation clearing will result in significant species being faced with a reduction in, rather than the complete removal of, suitable habitat. Natural regeneration and rehabilitation of vegetation following project closure will (at least partially) reinstate this habitat for fauna species.

There is the potential large impact of cane toads on significant species in the project area, although this would not be expected to be greater than the impact across the region as densities of the cane toad increases.

Sedimentation of Waterways

This has been addressed in Section 7.8.4.

Acid Rock Drainage

This has been addressed in Section 7.8.4.

Fire

The impact of a large-scale wildfire on fauna would be extensive, notwithstanding the fact that the pit, haul roads and site access road will form a natural fire break against fire coming from the north and northwest. Implementation of appropriate measures is expected to satisfactorily manage the risk of smaller-scale fires with respect to fauna.

Introduced Pests

Management measures are expected to adequately control the impact to fauna of introduced pests such as the feral pig and feral cat within the project area. These species are relatively common in habitats in the wider area. The impact of the cane toad on significant fauna species is likely to be more difficult to manage and cannot be quantified.

Traffic Collisions

Collisions between fauna and traffic are unavoidable, although it is unlikely that these will significantly impact local fauna populations. The noise and vibration from haulage trucks and four-wheel drive vehicles within the study area may act as a deterrent to fauna crossing the road during haulage. Other site roads will be speed-limited.

7.3 Air Quality

An air quality impact assessment for the Browns Oxide Project was undertaken by Holmes Air Sciences and is included as Appendix 1. This section summarises the findings of the assessment.

7.3.1 Existing Conditions

The project area is remote from pollution sources and the only air pollutant that is likely to be present at significant concentrations is particulate matter from wind-blown dust and bushfire smoke during the dry season.

No direct monitoring of existing air quality has been undertaken.

7.3.2 Potential Issues

The main potential air quality issue is liberation of particulate matter (measured as total suspended particulates (TSP), PM_{10} and $PM_{2.5}$)[1] from the handling and transport of ore and waste, and from wind erosion.

Project emissions of combustion products such as carbon monoxide, nitrogen dioxide and sulfur dioxide from the burning of fuels (mostly diesel) and from blasting are in practice too small and too widely dispersed, even on large open cut mines, to impact air quality other than in the immediate vicinity of their discharge.

7.3.3 Avoidance, Mitigation and Management Measures

The following measures will be taken (see Section 9.8.5 for more detail):

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[1] See glossary for definitions.

- Exposed areas susceptible to wind erosion will be kept to the smallest area practicable.
- Trafficked areas will be clearly defined and management practices put in place to ensure that vehicles keep to official roadways and travel at an appropriate speed.
- Dust suppression will be implemented for trafficked areas, exposed surfaces, material transfer points, and similar.
- Containerised transport of products.
- Progressive revegetation.

7.3.4 Residual Impacts

The use of the standard dust control measures for mines in Australia and the specific measures outlined in Section 7.3.3 are expected to ensure that relevant dust assessment criteria (generally based on NSW Department of Environment and Conservation and National Environment Protection Measures for Ambient Air Quality) are met (see Appendix 1). It is estimated that the mine will emit 260 t/a of TSP (or 8 g/s). This is a modest emission rate and mines with a higher TSP and operating with a buffer zone of approximately 2 km are able to comply with ambient air quality criteria.

7.4 Greenhouse Gas Emissions

7.4.1 Emissions Estimates

Greenhouse gas emissions produced during the construction and operation phases of the project have been estimated using AGO [Australian Greenhouse Office] Factors and Methods Workbook (AGO, 2004). Estimates do not include the one-off greenhouse emission from vegetation clearing (see Section 7.1) or minor emissions from the hydrometallurgical process.

During construction, it is estimated that 25 t of diesel (30 kL) will be consumed each week by transport, earthmoving and similar activities, and by one or more on site generators. This will result in an annual point source production of 4,200 t CO_2-e (Table 7.17) and, over the peak nine months of construction, a total of 3,200 t CO_2-e.

Table 7.17 Greenhouse gas emissions

Energy Source	Use	Amount per Year	Energy Content*	Energy per Year (PJ)	Emission Factor*	GHG Emissions per Year (t CO_2-e)
Construction						
Automotive diesel	Transport, earthmoving equipment, construction equipment, generators	1,300 t (1,560 kL)	38.6 GJ/kL	0.06	2.7 t CO_2-e/kL (point source)	4,200

Table 7.17 Greenhouse gas emissions (cont'd)

Energy Source	Use	Amount per Year	Energy Content*	Energy per Year (PJ)	Emission Factor*	GHG Emissions per Year (t CO_2-e)
Operations						
Automotive diesel	Transport, earthmoving equipment, mining equipment	2,600 t (3,120 kL)	38.6 GJ/kL	0.12	2.7 t CO_2-e/kL (point source)	8,400
Electricity	Processing plant, on site power	0.19 PJ (54 GWh)	-	0.19	206 Gg CO_2-e/PJ (full fuel cycle)	39,000
Operations total		-	-	0.31	-	47,400

* AGO (2004).

During operations (excluding exploration), it is estimated that 50 t of diesel (30 kL) will be consumed by the project each week (see Section 4.12.1), with a maximum electrical load of 7.5 MW being sourced from the Power and Water Corporation (PAWC)[1] (see Section 4.12.1). Therefore, annual greenhouse gas emissions are estimated to be 47,400 t CO_2-e during operations (see Table 7.17).

7.4.2 Potential Issues

Compass will need to minimise emissions wherever practicable to ensure compliance with the Northern Territory Government's objective that greenhouse gas emissions from new and expanding operations are as low as practicable.

7.4.3 Avoidance, Mitigation and Management Measures

Methods used throughout construction and operation will reflect best practice for greenhouse gas emission reduction. Specific activities will include:

- Develop and apply policies and procedures for efficient mine operation.
- Minimise haul distances.
- Monitor energy consumption (e.g., diesel and electricity), calculate greenhouse emissions and compare to target emissions.
- Identify and assess economically viable opportunities for improvement.

[1] Energy for the project area will be sourced from the Northern Territory PAWC through gas turbine generators at the Channel Island Power Station.

- Where appropriate, establish measurable greenhouse emission targets that reflect ongoing improvement.
- Prepare bi-annual reports outlining the details of improvement programs designed to reduce total greenhouse gas emissions and improve efficiency.
- Consider use of alternative fuels (e.g., bio-diesel).
- Present a summary of Compass' commitment to minimising the project's contribution to greenhouse gas emissions in the company's annual reports.

The project's environmental management plan will outline a program for greenhouse gas emissions monitoring, review and reporting. The project will not be classified as a large energy user (0.5 petajoules or more per year) that would require public reporting of greenhouse gas emissions.

7.4.4 Residual Impacts

In 1990, total Australian emissions were 395,061 Kt CO_2-equivalent, of which the predicted operations emissions from the Browns Oxide Project will represent an increase of about 0.012%. The project will therefore have a negligible impact on national greenhouse gas emissions.

For comparison, project-related emissions (during operations) are equivalent to the annual greenhouse gas emissions of about 3,160 Australian households (where the average emission is about 15 t of greenhouse gases per year).

7.5 Noise

A noise impact assessment for the Browns Oxide Project was undertaken by Holmes Air Sciences and is included as Appendix 1. This section summarises the findings of the assessment.

7.5.1 Existing Conditions

Anecdotal evidence indicates that existing noise levels in the project area are low, although no quantitative noise survey has been undertaken. The noise assessment assumes that the rating background noise level (RBL) is 30dB(A), which establishes a conservative basis for assessing noise impacts.

7.5.2 Potential Issues

The main potential noise issue is noise increment above background at the closest non-company residence (approximately 2 km to the southwest of the pit). Potential sources of noise and vibration include:

- Mobile mining equipment, including the excavator, drill and bulldozer.
- Reversing alarms.
- Process plant.
- Blasting operations.

7.5.3 Avoidance, Mitigation and Management Measures

The following measures will be taken:

- Mining will occur during day shifts.
- Mobile mining equipment such as bulldozers, trucks and other earthmoving equipment will be fitted with reversing horns. Standard reversing alarms, which typically have a sound power level of 115 dB(A), would almost certainly give rise to noise levels above the night time assessment criterion at least 2 km away. Instead, smart alarms will be used, which reduce noise emissions and use a less tonal sound.
- Crusher will operate during day shift only.
- Noise and blasting impacts will be monitored by complaint. If necessary, additional mitigation measures will be introduced. Strict management of blasting procedures will be undertaken to mitigate the impact from blasting activities. This will address both the design and implementation phases of the blasting process.

7.5.4 Residual Impacts

Noise impacts will be controlled to a level that will meet the assessment criteria that would apply to similar mines in NSW based on the use of acoustic treatment or shielding for the process plant and smart alarms on items of mobile plant.

7.6 Infrastructure and Transport

7.6.1 Existing Conditions

Electricity

Batchelor is connected to the Northern Territory electricity grid and is supplied via a 22-kV branch line from the main 132-kV service line (that runs parallel to the Stuart Highway from Channel Island Power Station on Darwin Harbour to Katherine).

Water and Sewerage

Potable water is supplied to Batchelor via two potable supply bores located within the town boundary. These bores feed a 4.8 ML storage tank from which water is distributed via the local distribution system. There is surplus storage and bore capacity at present with no major upgrades proposed in the next five years (Pudney pers. com. 2005a). Rural areas are serviced by bore water and/or rain tanks.

The Batchelor township is serviced by a gravity-reticulated sewerage system which conveys sewage to waste stabilisation ponds located southwest of the town centre. No system upgrades are proposed in the next five years; however, additional loads may require system augmentation (Pudney pers. com. 2005a).

Telecommunications

Telephone and facsimile services are available in Batchelor via the Telstra network. Telstra's code division multiple access (CDMA) network provides mobile phone coverage.

Transport

Coomalie is presently served by a road network that is based around the Stuart Highway. A sub-arterial road provides access to Batchelor and Litchfield National Park. June to September, inclusive, are the busiest months of the year for traffic with daily vehicle counts from 774 to 959 between the Stuart Highway and Batchelor (Figure 7.4). Similarly, the road from Batchelor to Litchfield National Park is busiest from June to August, inclusive, with vehicle counts ranging between 517 and 700. More than 80% of the vehicles on these roads are sedans/wagons/4WDs/utilities/light vans/bicycles and motorcycles and up to a further 5% are towing trailers/boats/caravans. Up to 3% of vehicles are articulated (Territory Asset Management Services, 2004).

In contrast to the Batchelor and Rum Jungle roads, both of which are sealed, the remainder of roads in the area are connector roads that service the rural and pastoral land uses and, for the most part, are unsealed, which can create difficulties for users with restricted access in times of heavy rain and flooding.

The Darwin to Alice Springs Railway was opened for freight and passengers in January and February 2004, respectively. The railway completes the national railway network and generally runs immediately west of the Stuart Highway alignment. The closest station to the project is Darwin.

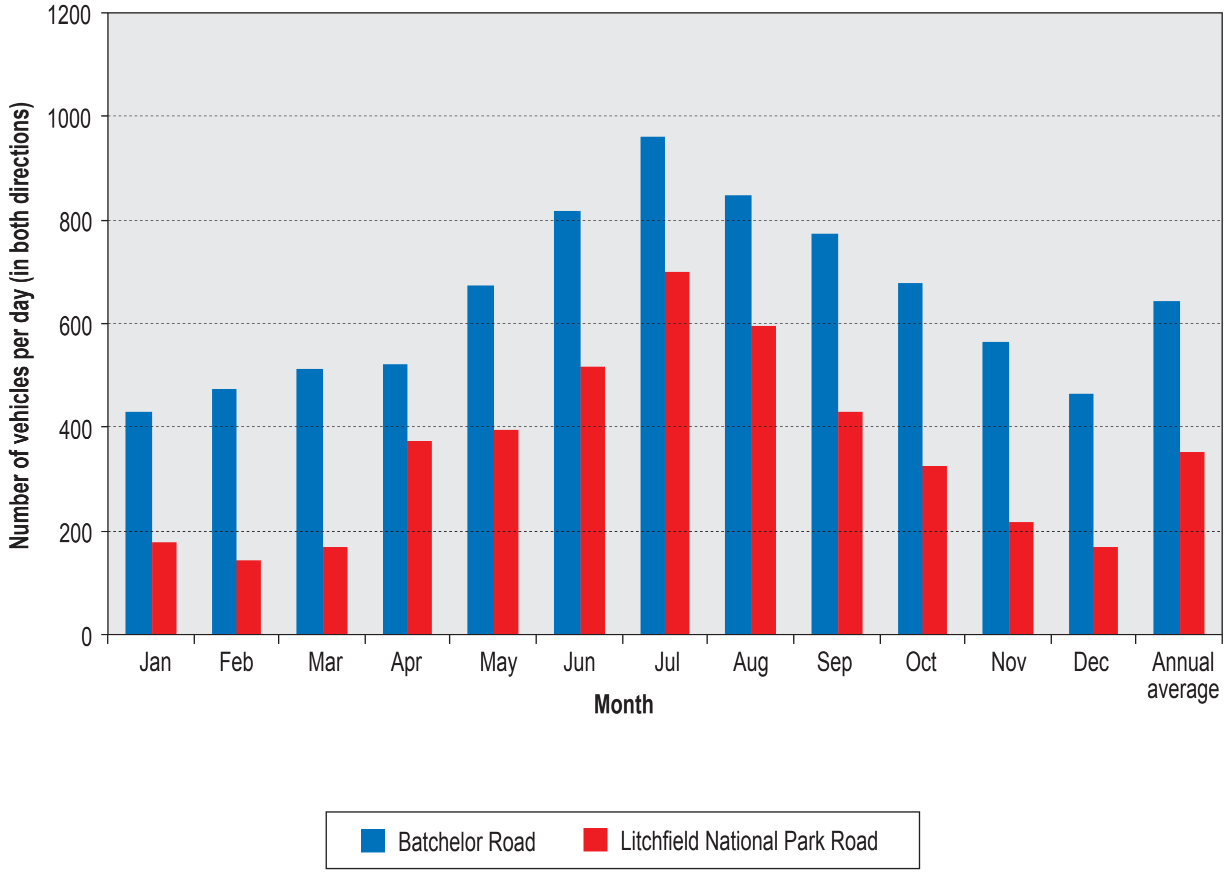
7.6.2 Potential Issues

Potential issues relating to the project include:

- The ability of current services and facilities to support the development (in terms of Batchelor's ability to support an increased population associated with the workforce and the provision of services to the development).
- Changes to local traffic volumes and resulting safety and amenity issues.

7.6.3 Avoidance, Mitigation and Management Measures

Where possible, employees will be sourced from the local area, e.g., Batchelor and Adelaide River, or within commuting distance (this would include employees resident in Darwin, particularly the southern rural areas) so that relocation will be minimised.



Source: Territory Asset Management Services (2004) [R020].

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	File No: 836_08_F7.04_HB	Browns Oxide Project		

Project-associated traffic, e.g., larger construction vehicles and smaller vehicles associated with operations traffic (mainly associated with suppliers and servicing requirements) will be managed to minimise hazards and disruptions. This will include the encouragement of car pooling to reduce traffic quantities and driver fatigue, and instructing employees and contractors to adhere to speed limits on public roads. Compass will monitor amenity issues associated with project-related traffic and transport and, if necessary, will consider other mitigation measures. Contractors employed to transport products and supplies will be expected to comply with appropriate legislation and have their own OHS policies (that include fatigue management) in place.

Lithgow Road is currently a gazetted road that has not been maintained, and it is anticipated that this road will be upgraded and, together with Bevan Road, will provide alternate access for residents who currently rely on the Rum Jungle–White Road route (Plate 7.1). The Rum Jungle Road north of the Litchfield Park turnoff and White Road will be restricted access for the mine site only. Maintenance (especially after the wet season) of these sections of road will be the responsibility of Compass (see Section 4.12).

7.6.4 Residual Impacts

Electricity

The power requirement for the site is approximately 7.5 MW. Electricity requirements for the project will be met by extending the current mains power line from the Northern Territory electricity grid to the site. Compass has discussed this option with the Power and Water Corporation. The existing Batchelor power supply will not be affected by the project.

Water and Sewerage

Water requirements for the project, both potable and processing, will be met by groundwater extraction from an unconfined shallow aquifer (the environmental impacts associated with groundwater extraction are discussed in Section 7.9). It will not be necessary to utilise Batchelor's water scheme.

Taking into account peak tourist demands, population increases associated with short-term construction requirements or the relocation of key operations personnel will be accommodated within Batchelor's existing water scheme, as the biggest influence over demand and supply is outdoor water supply, e.g., sporting ovals and swimming pools (Pudney pers. com., 2005b).

Similarly, based on the average demand per person for sewage treatment, sufficient capacity exists in the sewerage system to accommodate a project-related increase in Batchelor's population (Pudney pers. com., 2005b).

Plate 7.1
Rum Jungle Road and White Road intersection

Plate 7.2
Gauging station GS8150200, immediately downstream of the former Rum Jungle mine site

Plate 7.3
East Finniss River viewed looking upstream from Rum Jungle Road during the late wet season (March 2005)

Transport

Road upgrading and maintenance has been identified as one of the major issues affecting the local community. Because of climatic conditions, costs for road maintenance are high.

During operations, the traffic generated by the project will include employee vehicles, fuel trucks and supply trucks (on a regular basis), and up to four (100 t) trucks per day will transport acid to site and copper cathode product and cobalt and nickel hydroxide or sulfide products from site to the Port of Darwin.

An increase in local traffic will probably be noticeable during construction, which is scheduled to commence in the first quarter of 2006, i.e., the wet season and a quieter time of the year. However, traffic volume will decrease significantly following completion of construction. There will be approximately 365 vehicle movements per week (52 per day) during operations which, for the Litchfield Park Road, is equivalent to approximately 7% of the current maximum daily peak during the tourist season in July, and 30% of the current daily peak during December. Mitigation and management measures outlined in Section 7.6.3 will ensure that traffic hazards and adverse impacts on amenity will be minimal.

Landholders beyond the mine site may experience slightly increased travel distance to and from Batchelor associated with the closure of White Road and a section of the Rum Jungle Road.

7.7 Land and Resource Use

7.7.1 Existing Conditions

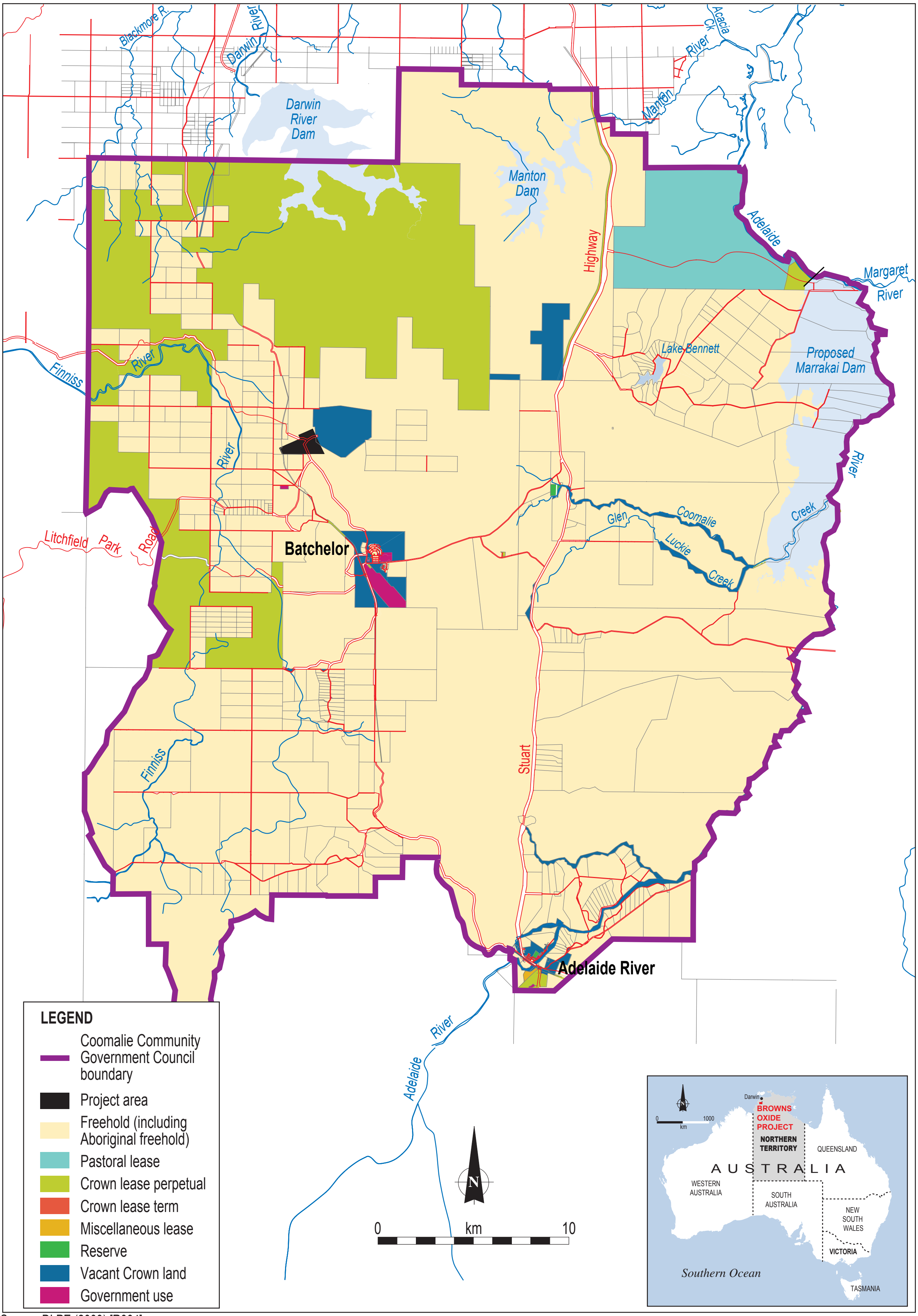
The description of land and resource use is drawn from DLPE (2000).

Land Tenure

The project is located within the Coomalie Community Government Council (Coomalie), which covers a total area of 1,507 km^2 (Figure 7.5). In 2002, approximately 80% of the properties in the area were under freehold title (and this is considerably higher than in any other Northern Territory region, with the exception of urban centres) (Price and Baker, 2003).

Less than 2% of the land was vacant Crown land, including the former Rum Jungle Mine site. Only one property, comprising about 0.01% of the region, is classified as a reserve, and this is located along Coomalie Creek where it intersects the Stuart Highway (Price and Baker, 2003).

The Power and Water Corporation owns or manages 17% of the Coomalie region for protection of the Darwin River Dam catchment. The Northern Territory Land Corporation



Source: DLPE (2000) [R004].

Job No: 836	Compass Resources NL	Coomalie land tenure	Figure No: 7.5
File No: 836_08_F7.05_HB	Browns Oxide Project		

also holds Crown leases over approximately 5% of the area, these being old pastoral stations in the west of the region, and riparian corridors along the Adelaide River. The Finniss River Aboriginal Land Trust owns several freehold blocks covering 180 km^2 (12% of the region) (Price and Baker, 2003).

The project is located in areas of predominantly Aboriginal freehold land (see Figure 7.5) immediately west of, and adjacent to, the historic Rum Jungle Mine. Mining and exploration licences associated with the project are described in Section 4.1.

Land Use Objectives

The Northern Territory *Planning Act* provides for a single integrated Northern Territory Planning Scheme, which comprises land use objectives (policy), development provisions (town, area and community plans) and incorporated documents (assessment criteria and guidelines). For the Browns Oxide Project area, the relevant document under this act is the Coomalie Planning Concepts and Land Use Objectives (DLPE, 2000). Mining activity in this area is consistent with the planning scheme.

The key land use objectives for the Coomalie region are to (DLPE, 2000):

- Protect land and water resources.
- Promote and use the natural attributes of the region.
- Provide an integrated transport network.
- Promote human health.
- Promote tourism development.
- Promote development of mining and extractive industries.
- Protect vegetation and prevent land degradation.
- Protect sites with significant heritage status.

Additional land use objectives in relation to the mining and extractive industry include:

- Providing mine access routes.
- Establishing appropriate land uses on mine sites, as part of the rehabilitation program, prior to mining lease surrender.
- Minimising the impact of mining and extractive industries on human health.

Land Use

Current and proposed land use in Coomalie is defined in DLPE (2000) and summarised in Figure 7.6.

Residential development in Coomalie is either urban, as occurs at Adelaide River and Batchelor, or rural.

Commercial and retail activity is primarily focused in Adelaide River and Batchelor, with some additional services along the Litchfield Park Road. Three zones within the Batchelor Town Plan are allocated for business use.

The main industrial precinct within Coomalie is located at Batchelor where 19 lots cater for industrial, light industrial and service commercial land uses. A second industrial area of 30 lots is located near Batchelor, approximately 2.5 km southwest of the proposed project site.

Horticulture/agriculture is considered to be one of the major and more sustainable contributors to the local economy. There is a strong and growing interest in horticulture with an increasing number of landowners entering the industry, particularly in areas with high ground water potential around Batchelor and along the fertile levees of the Adelaide and Finniss rivers.

Cattle grazing occurs mainly in the southeastern and southwestern parts of Coomalie, although there is property to the south of the project site that is also used for cattle grazing.

The Litchfield National Park is located approximately 30 km west of Batchelor and provides reserved and recreational land use. The 1,800-km^2 park is a large wildlife reserve that protects extensive examples of 'Top End' habitat and is capable of supporting viable populations of most species that live there. The park also includes numerous waterfalls, historical sites and landscape features of geomorphological interest.

Figure 7.6 shows that the Browns Oxide Project is located in an area delineated as 'grazing (natural pastures)' in the Coomalie Land Use Structure Plan.

Resource Use

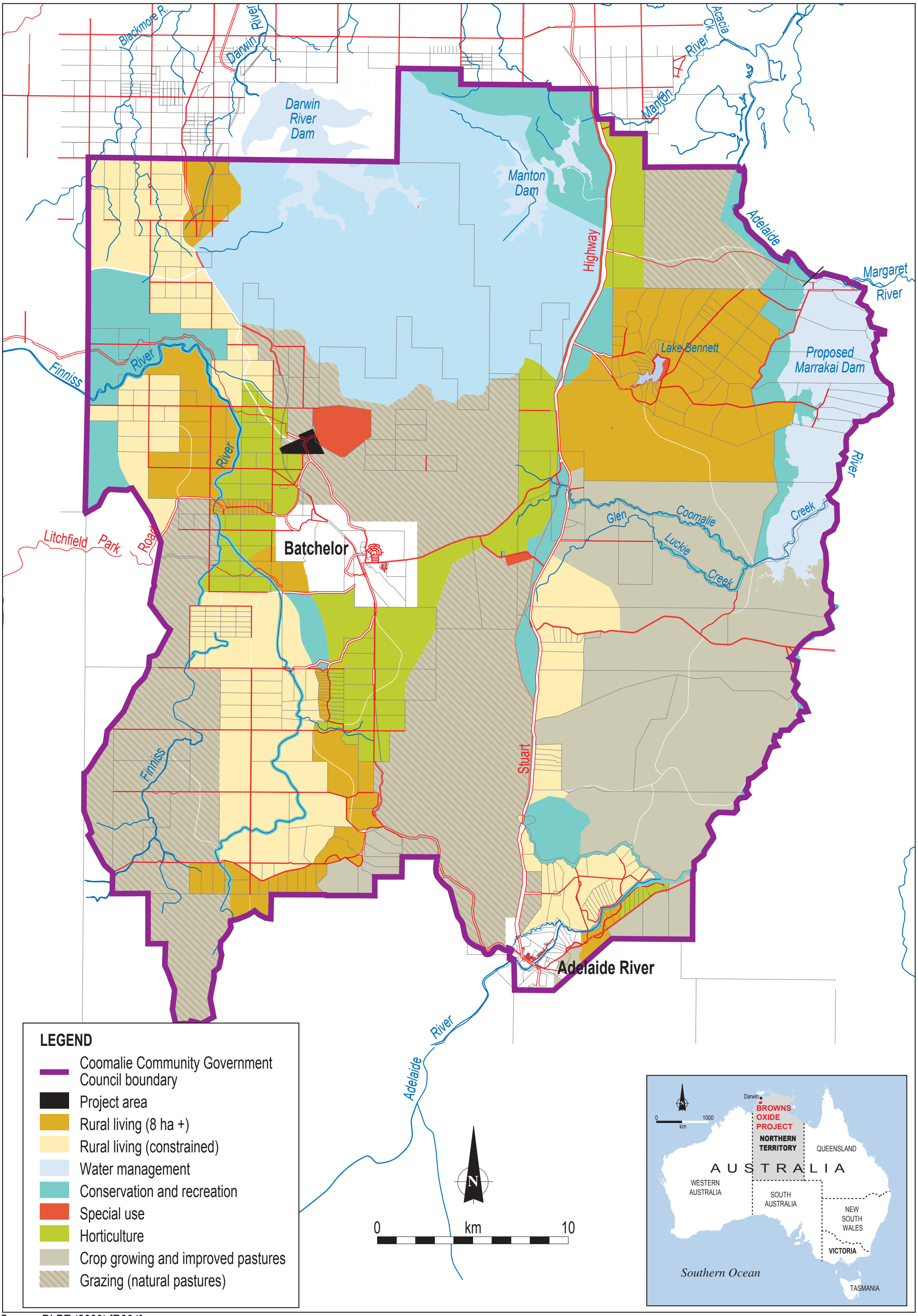
The Coomalie region provides the main source of potable water for greater Darwin, via the Darwin River Dam (and the Manton Dam, now rarely used) (see Figure 7.6). It is proposed that Coomalie will play an important role in Darwin's future water supply with two additional dams being planned.

Good supplies of groundwater are generally available in a range of locations within Coomalie, including the town of Batchelor and areas to the northwest of Batchelor (where the project is located).

Coomalie is recognised as being highly prospective and mineral-rich and the mineral and extractive industry is considered one of Coomalie's strongest sources of employment and economic growth.

7.7.2 Potential Issues

The Browns Oxide Project will utilise approximately 90 ha to extract and process copper, cobalt and nickel. This will alter the current landform and possibly impact land and resource use.



Source: DLPE (2000) [R004].

Job No: 836	Compass Resources NL	Coomalie land use plan	Figure No: 7.6
File No: 836_08_F7.06_HB	Browns Oxide Project		

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7.7.3 Avoidance, Management and Mitigation Measures

The project will be designed, constructed and operated in a manner that is consistent with the Coomalie Planning Concepts and Land Use Objectives (DLPE, 2000), which provides the framework for developing the Coomalie region in a manner that preserves its rural nature while allowing continued development at a sustainable level.

These land use objectives will primarily be achieved by:

- Ongoing consultation and negotiation with the Northern Land Council and traditional owners, to ensure that consideration is given to the traditional use by Aboriginal people of land surrounding the project area when planning project activities.
- Siting and designing infrastructure and ancillary facilities to minimise the footprint to the greatest practical extent.
- Implementing the environmental management plan (Chapter 9).
- The mine closure planning process, including the identification of appropriate post-closure land uses (see Section 9.10).

7.7.4 Residual Impact Assessment

Development of the Browns Oxide Project will be an extension of preliminary mining activities, i.e., exploration and evaluation of resources, that have been undertaken in the region since the late 1940s. Indeed, early records show mining in the area as early as 1907. Given the relatively small footprint of the project within an existing mining area, development of the site will not significantly change the existing land use and will facilitate the expansion of the resource development industry (which is a key land use objective for the Coomalie region).

The project is not located within Darwin's current potable water catchment area; therefore, impacts on the water supply area are not anticipated.

Residual impacts on groundwater resources are discussed in Section 7.9.

Development of the project and associated increased traffic volumes are not expected to deter tourists from visiting the Litchfield National Park. Other opportunities for tourism are discussed in Section 7.10.

7.8 Surface Water

7.8.1 Existing Conditions

Hydrology

East Finniss River. The East Finniss River is an ephemeral stream that drains to the northwest, meeting the Finniss River some 8 km downstream from the project area. A gauging station (GS8150097) is located on the East Finniss River, 5.6 km downstream of the former Rum Jungle Mine site and 2.3 km upstream of the confluence with the Finniss

River (Figure 7.7). This station has been the designated site for estimating annual pollutant loads for the Rum Jungle Rehabilitation Project (see Section 3.2). A continuous gauging station (GS8150200) also operated immediately downstream of the former Rum Jungle Mine site (see Figure 7.7 and Plate 7.2) during the periods 1981–1988 and 1991–1998.

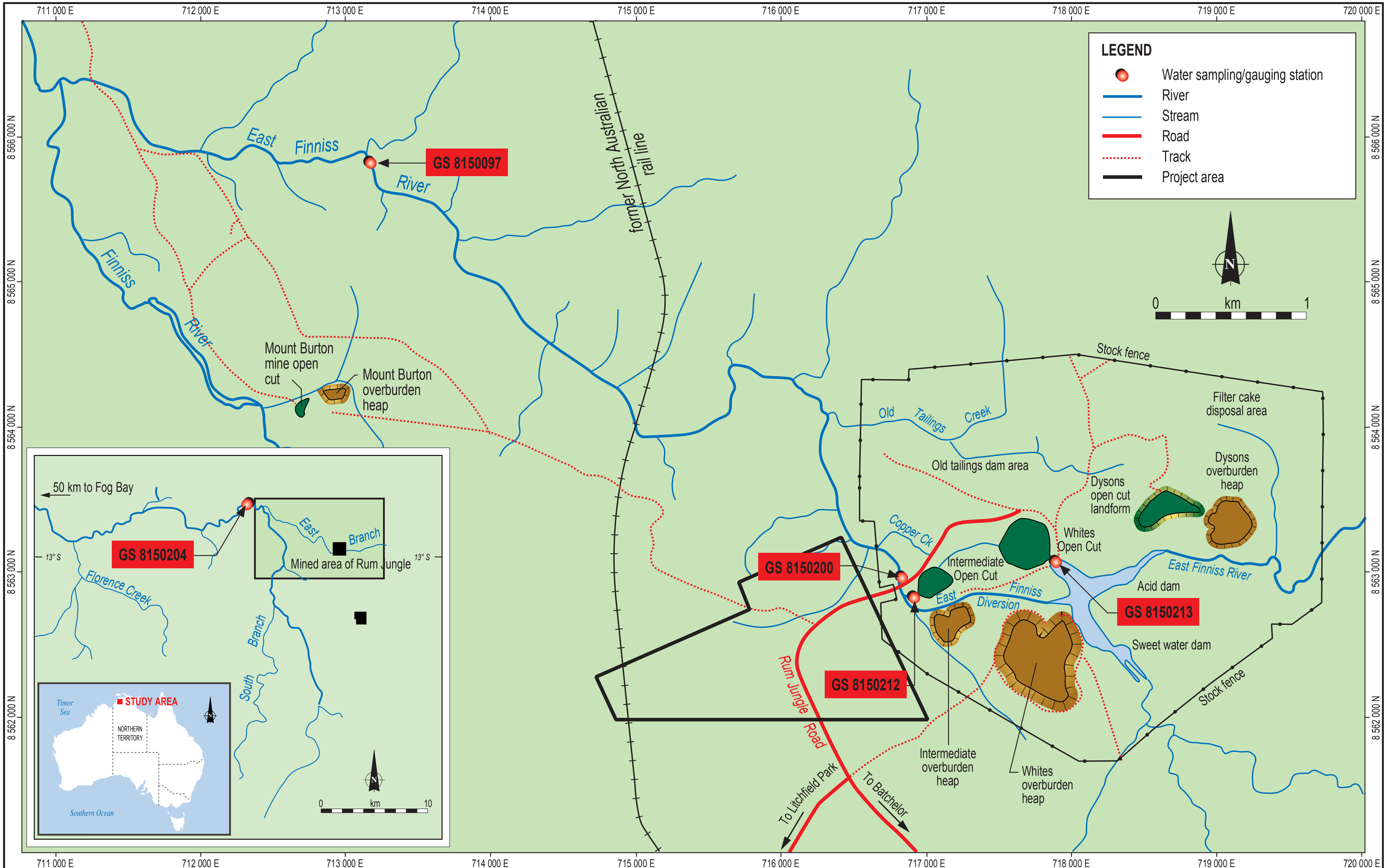
Base flow is generally not established in the East Finniss River (Plate 7.3) until sustained monsoonal rains arrive in January and is generally sustained until April. An annual hydrograph of the East Finniss River at GS8150097 for 1972/73, when rainfall was similar to the annual mean, is shown in Figure 7.8, while a hydrograph for the available record (1965 to 2005) is shown in Figure 7.8. Flow usually commences up to one month later at GS8150097 than at GS8150200, due to early wet season rainfall patterns and the time required to wet-up the river bed (Lawton and Overall, 2002a). Salts evaporated on the river bed following the recessionary flow of the previous year (Plate 7.4) are remobilised during these first rain events. Contaminant inputs to the East Finniss River then occur due to flows from the open cut pits and seepages from the overburden heaps at Rum Jungle.

Finniss River. During the dry season, the Finniss River typically consists of a series of long still pools of about 3 m water depth connected by shallower sections. During the wet season, overbank overflow often occurs and the depth and speed of flow along the river is more uniform than during the dry season (Jeffree and Williams, 1980).

A stream gauging station (GS8150204) operated on the Finniss River several kilometres downstream of the confluence of the East Finniss River (see Figure 7.7) during 1982–88 and 1993–95. Stream gauging stations that are currently operating on the Finniss River are located upstream of the confluence with the East Finniss River (Batchelor; GS8150010) and some distance downstream from the confluence (Gitchams; GS8150180), both at potential dam sites. Hydrographs for the available record for these two locations are shown in Figure 7.9.

Water Quality

Information on water (and sediment) quality of the East Finniss and Finniss rivers is mostly provided by monitoring undertaken by the Department of Natural Resources, Environment and the Arts (DNRETA) and Australian Nuclear Science and Technology Organisation (ANSTO) as part of the Rum Jungle Rehabilitation Project. Additional data is also provided by First National Assessment of River Health (FNARH) macroinvertebrate surveys in 1998–99 and Charles Darwin University (CDU) surveys undertaken during 2003–2005. Data from these programs is described in detail in Appendix 2.



Source: Lawton and Overall, 2002.

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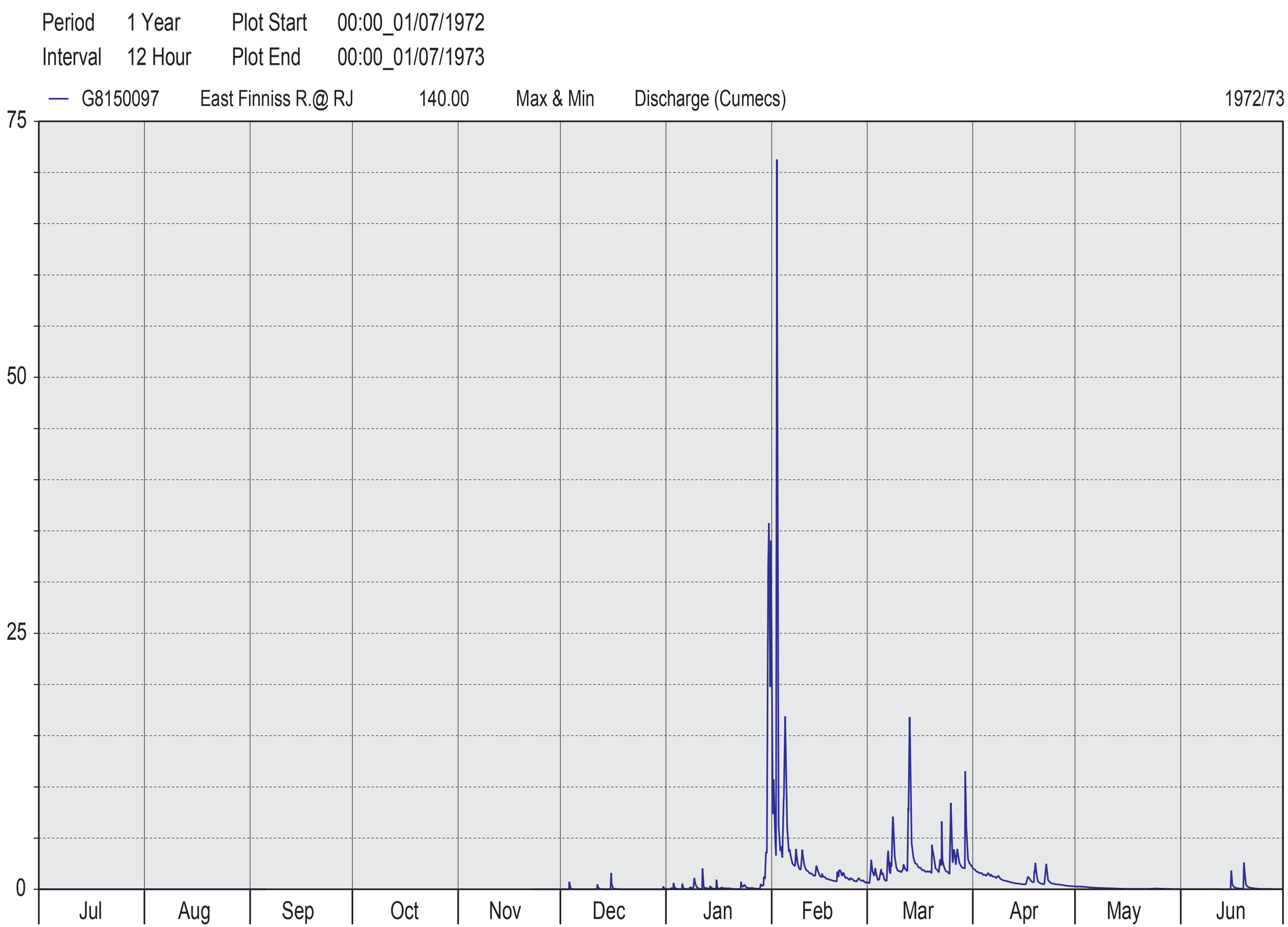
Job No: 836	Compass Resources NL	Water monitoring sites on the Finniss and East Finniss rivers	Figure No: 7.7
File No: 836_08_F7.07_HB	Browns Oxide Project		

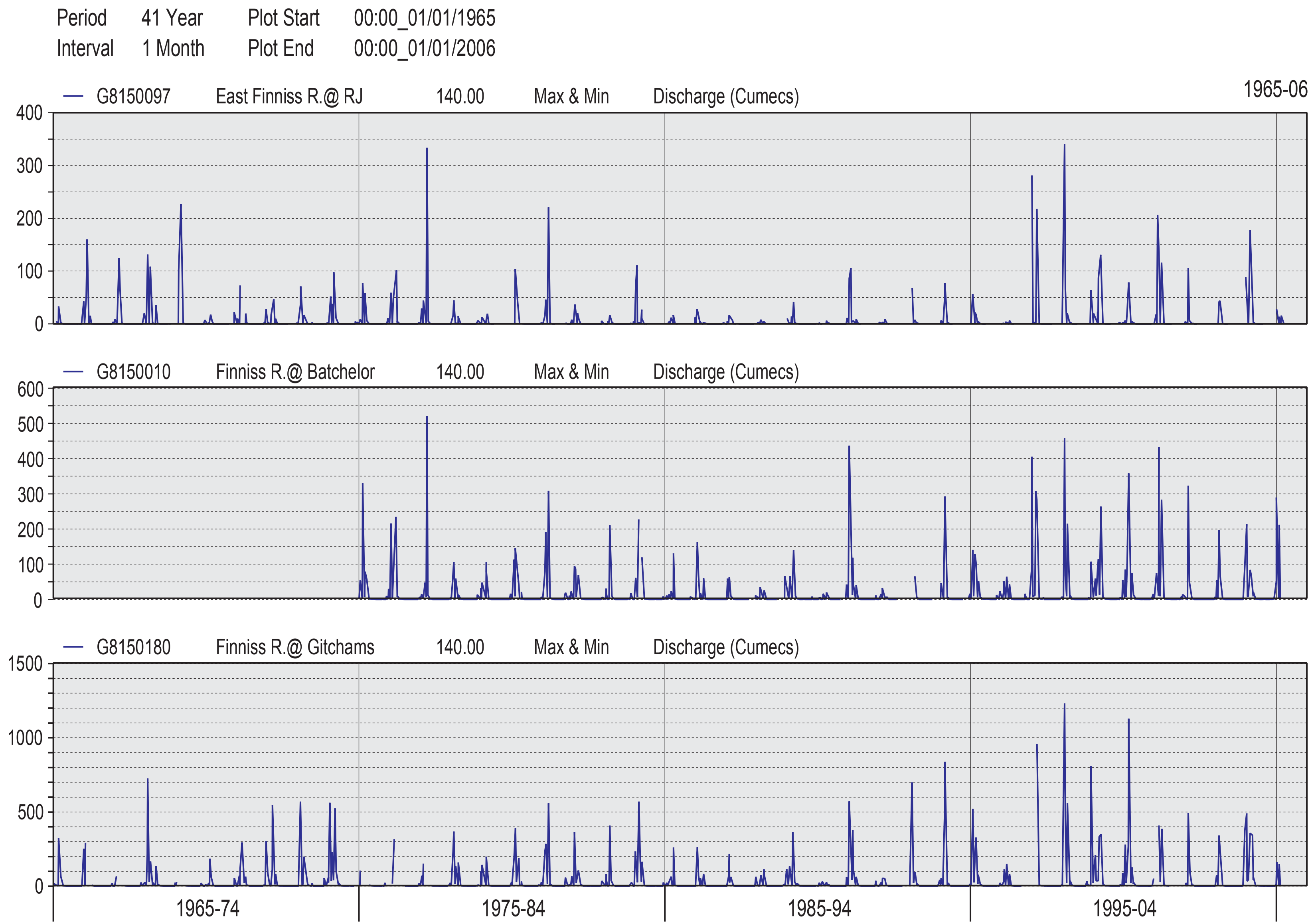


Job No: 836	Compass Resources NL	Annual hydrograph for the East Finniss River at G8150097 during 1972/73	Figure No: 7.8
File No: 836_08_F7.08_HB	Browns Oxide Project		

Plate 7.4
East Finniss River viewed looking upstream from Rum Jungle Road during the dry season (July 2002). Note the salts evaporated on the river bed.

Plate 7.5
Finniss River at Litchfield Park Road (July 2002)

Plate 7.6
Finniss River immediately downstream of Litchfield Park Road (July 2002)



Job No: 836	Compass Resources NL	Hydrographs for the East Finniss River (G8150097) and Finniss River (G8150010 and G8150180) gauging stations	Figure No: 7.9
File No: 836_08_F7.09_HB	Browns Oxide Project		

East Finniss River. Metal loads and concentrations have decreased compared to levels prior to remediation of the Rum Jungle Mine site, however, they remain sufficiently elevated to impact on the freshwater ecosystem of the East Finniss River (Lawton, 1998b). Median total Cu concentrations at GS8150097, 5.6 km downstream of the former Rum Jungle Mine site, have decreased from about 7 mg/L pre-remediation (1968–81) to less than 0.5 mg/L post-remediation (1990–95), i.e., greater than a 90% reduction in concentration (Lawton and Overall, 2002a). Median total Zn concentrations have reduced from about 1.6 mg/L pre-remediation to about 0.4 mg/L post-remediation, i.e., a 75% reduction in concentration. Median total Mn concentrations have reduced from about 3 mg/L pre-remediation to about 1 mg/L post-remediation (1990–95), i.e., a 67% reduction in concentration.

Concentrations of pollutants in the East Finniss River tend to be highest during the first flush of the wet season and during the late wet season recessional flows when dilution effects are minimal.

Approximately 70 t/a of Cu, 80 t/a of Mn and 25 t/a of Zn was estimated to be delivered to the Finniss River from the former Rum Jungle Mine site via the East Finniss River during years of normal rainfall before remediation. Jeffree et al. (2001) determined post-remediation loads (for the period 1990–93) to have been reduced seven times for Cu, five times for Zn, four times for Mn and three times for sulfate. The latest data obtained by CDU in 2003–04 (see Appendix 2) indicates that annual loads of Cu, Mn and Zn remain generally similar to loads reported by Lawton and Overall (2002a) during the late 1990s.

Summary statistics of metal concentrations from 14 sampling occasions undertaken by CDU during the wet seasons of 2003–04 and 2004–05 near GS8150097 are shown in Table 7.18. Also shown in the table are ANZECC/ARMCANZ (2000) Australian water quality guideline (AWQG) trigger values (TVs) for protection of slightly to moderately disturbed ecosystems, which apply to filtered metal concentrations. Values are adjusted for water hardness, based on water being classified as 'very hard'[1]. There is some evidence of a further decrease in metal concentrations since 1990–95. However, concentrations of Cu on all sampling occasions have exceeded TVs for protection of slightly to moderately disturbed ecosystems, which are based on protecting 95% of species with 50% confidence. For ecosystems that can be classified as highly disturbed, it may be considered appropriate to apply a less stringent trigger value, such as TVs that protect 90% of species, or perhaps even 80% (ANZECC/ARMCANZ, 2000). The trigger value for Cu that protects 80% of species and is adjusted for 'very hard' water hardness is 0.013 mg/L, and is still exceeded on all sampling occasions. The median Cu concentration is over four times higher than this less stringent TV.

[1] Data presented in Lawton and Overall (2002a) show water hardness of the East Finniss River to range from 'extremely hard' (400 mg $CaCO_3$/L) about 1 km downstream from the Rum Jungle Mine site to 'very hard' (180–240 mg $CaCO_3$/L) towards the confluence with the Finniss River.

Table 7.18 Metal concentrations in East Finniss River at GS8150097 during wet seasons of 2003–04 and 2004–05

Metal (n=14)		Minimum (mg/L)	Maximum (mg/L)	Median (mg/L)	Mean (mg/L)	% of Metal Present in Filterable Form	AWQG TVs (95% protection level) (mg/L)
Al	Total	0.016	0.483	0.284	0.248	-	-
	Filtered	0.005	0.095	0.032	0.034	14	ID
Cd	Total	0.0002	0.0009	0.0003	0.0004	-	-
	Filtered	0.0002	0.0009	0.0003	0.0003	93	0.0011
Co	Total	0.072	0.215	0.111	0.120	-	-
	Filtered	0.071	0.214	0.110	0.118	99	ID
Cu	Total	0.053	0.182	0.134	0.136	-	-
	Filtered	**0.018**	**0.143**	**0.057**	**0.062**	46	0.0073
Fe	Total	0.127	0.411	0.278	0.269	-	-
	Filtered	0.0007	0.023	0.0006	0.0007	2	ID
Mn	Total	0.221	1.36	0.439	0.534	-	-
	Filtered	0.215	1.29	0.445	0.531	99	1.9
Ni	Total	0.066	0.204	0.099	0.109	-	-
	Filtered	**0.065**	**0.202**	**0.097**	**0.107**	98	0.057
Pb	Total	0.0003	0.0015	0.0010	0.0009	-	-
	Filtered	0.00002	0.0002	0.00002	0.00004	5	0.040
U	Total	0.005	0.014	0.008	0.009	-	-
	Filtered	0.003	0.011	0.005	0.005	58	ID
Zn	Total	0.063	0.277	0.115	0.126	-	-
	Filtered	0.054	**0.289**	**0.107**	**0.118**	94	0.072

ID = insufficient data to establish trigger value.
Values in bold exceed AWQG TV for protection of slightly to moderately disturbed ecosystems (95% protection level).

Concentrations of Ni and Zn also exceed TVs that protect 95% of species.

There is a consistent pollution gradient in the East Finniss River downstream from the former Rum Jungle Mine site. An extensive survey conducted during late wet season flow in 1994 showed that concentrations decrease in a gradient to about half the initial concentration 5.6 km downstream at GS8150097 (Lawton and Overall, 2002a). The recent water quality surveys undertaken by CDU during the 2003–04 and 2004–05 wet seasons also found that metal concentrations near the former Rum Jungle Mine site were up to about two-fold higher than measured further downstream at GS1850097 (see Table 7.18).

The same pollution gradient is evident during the dry season. Dostine (2002) reports that total Cu concentrations in the early 1998–99 dry season were 1.6 mg/L immediately downstream of the former Rum Jungle Mine site, decreasing to 0.02 mg/L near the confluence with the Finniss River. Total Cu concentrations along the East Finniss River were lower during the late dry season, ranging from 0.32 to 0.015 mg/L. The same trend of decreasing concentrations along the East Finniss River and lower concentrations during the late dry season compared to the early dry season were also observed for total Mn and Zn.

The CDU surveys in 2003 and 2004 also included sampling of water pools formed in the East Finniss River during the dry season. At site GS8150097, metals concentrations in these pools were lower compared with concentrations in water flowing down the stream during the wet season, with the exception of Mn. In contrast, concentrations of metals in pools at GS8150200 near the former Rum Jungle Mine site were much higher than concentrations in water flowing down the stream during the wet season.

Extensive dolomite and magnesite formations underlie the former Rum Jungle Mine site. The acid-buffering capacity of these minerals has attenuated many of the impacts from acid rock drainage, although the buffering capacity of carbonate-dominated groundwater pre-remediation was often overwhelmed by the acid generated in the waste rock dumps (Lawton and Overall, 2002a). The median pH of water at GS8150097 was pH 4.2 pre-remediation (1967–81), but has improved since remediation such that the median pH for the period 1990–95 was pH 6.3 (Lawton and Overall, 2002a). CDU surveys in 2003–05 determined the pH at this location to range between 6.2 and 7.5 during the wet season (Appendix 2). The pH of water in two pools formed during the dry season of 2004 was more alkaline, with pH of 7.9 and 8.1. In contrast, upstream near the mine site at GS8150200, water in pools formed during the dry season was acidic with pH ranging between 3.5 and 4.4. The pH increased with the onset of wet seasons flows, ranging between 5.3 and 6.4.

There is limited data for total suspended solids (TSS) in the East Finniss (and Finniss) River, with most of the available data collected during the 1993–94 wet season. This data showed that approximately 111 t of suspended solids passed GS8150200 in the East Finniss River immediately downstream of the former Rum Jungle Mine site, while twice this load (219 t) passed GS8150097, 5.6 km further downstream (Lawton and Overall, 2002a). Concentrations of TSS in 12 flow-weighted composite samples collected at GS8150097 during that wet season ranged between <0.1 and 20.4 mg/L, with 11 of the 12 samples being less than 5 mg/L. The mean concentration of all of these samples was 3.3 mg/L.

More recent sampling between 3 and 28 January 2005 (by CDU) during periods of flow near GS8150097 showed TSS concentrations to range between 3.1 and 6.0 mg/L, with a mean concentration of 4.9 mg/L (Appendix 2). Slightly higher TSS concentrations were measured immediately downstream of the former Rum Jungle Mine site, ranging between 7.4 and 9.5 mg/L. During the same period, TSS concentrations in three samples from the Finniss River (immediately upstream of the confluence with the Finniss River) ranged between 10 and 37 mg/L.

Finniss River. Measurements of water quality of the Finniss River (plates 7.5 and 7.6) were undertaken during post-remediation fish surveys in the dry seasons of 1992 (July–August) and 1995 (July–August). General water quality characteristics of the Finniss River during these dry seasons were generally similar and can be summarised as follows (Jeffree et al. 2001):

- Shallow water depths (2 to 4 m).

- Water temperatures ranging from 19 to 24°C.
- Dissolved oxygen concentrations typically ranging from 70 to 100% saturation near the surface decreasing to approximately 10 to 30% saturation in bottom waters.
- pH ranging between 6 and 8, except at the site downstream from the confluence with Florence Creek (i.e., the furthermost downstream site, 18 km downstream from the confluence with East Finniss River) where pH at the surface was approximately pH 6 decreasing to pH 4.5 at depth.
- Conductivity ranging from 0.01 to 0.38 mS/cm, with the lowest values measured downstream of Florence Creek due to the influence of softer waters from this watercourse which is fed by perennial springs from a sandstone aquifer.
- Low turbidity, ranging from <1 to 7 NTU.

Concentrations of total metals measured in the Finniss River pre- and post-remediation during dry season biological surveys are presented in Jeffree et al. (2001). Average concentrations of Cu, Zn, Co and Ni measured post-remediation in 1992 and 1995 decreased by one to two orders of magnitude downstream of the confluence of the East Finniss River compared with concentrations measured pre-remediation in 1973–74. Manganese concentrations also decreased but to a lesser extent. A decline in metal concentrations was also evident between 1992 and 1995. Concentrations measured along the Finniss River in the 1995 survey are shown in Table 7.19. There is only a small increment in metal concentrations, if any, downstream of the East Finniss River compared with upstream locations.

Table 7.19 Total metal concentrations in Finniss River during the 1995 dry season

Distance from East Finniss River Confluence (km)	Co	Cu	Ni	Mn	Ca	Mg
	mg/L					
-18.0	0.0004	0.001	0.002	0.007	22	31
-0.1	0.0006	0.002	0.002	0.021	18	38
1.0	0.0005	0.004	0.005	0.005	24	39
3.0	0.0011	0.007	0.005	0.003	18	38
15.0	0.0002	0.003	0.003	0.0004	16	26
30.0	0.0008	0.003	0.004	0.021	1	1.4
AWQG TVs	ID	0.0073	0.057	1.9	-	-

ID = insufficient data to establish trigger value.

Also shown in Table 7.19 are AWQG TVs for protection of slightly to moderately disturbed ecosystems. Values are adjusted for water hardness, which is classified as being 'very hard' near the confluence with the East Finniss River. Concentrations of total Cu, Ni, and Mn at all locations in the Finniss River during the 1995 dry season sampling event complied with the TVs (which are applicable to filtered concentrations).

More recent surveys were undertaken in the 1998–99 dry season for the Australia-wide Assessment of River Health (AWARH) (Dostine, 2002). Results presented in Appendix 2 show no evidence of an increase in metal concentrations in the Finniss River downstream of the confluence with the East Finniss River. Total Cu concentrations measured in the 1998–99 are generally similar to concentrations measured in 1995.

Intensive water sampling was undertaken in the Finniss River at two locations, 1.2 km and 2.5 km downstream of the confluence with the East Finniss River, prior to and during the first flush of the East Finniss River in the 1997–98 wet season (Jeffree et al., 2001; Twining et al. 2002). Filtered metal concentrations in the Finniss River at the time when the impact of the first flush from the East Finniss River was greatest are shown in Table 7.20. Concentrations of Cu were over an order of magnitude higher than the AWQG TV, and Ni and Zn concentrations also exceeded respective TVs. However, metal concentrations were substantially reduced from concentrations measured during the first flush in 1973–74 and 1974–75, i.e., prior to remediation of the former Rum Jungle Mine site, particularly Cu which was about two orders of magnitude lower (Jeffree et al., 2001).

More recent wet season surveys have been undertaken by CDU during 2003–04 and 2004–05 in the Finniss River at Litchfield Park Road, located upstream of the confluence with the East Finniss River. Maximum filtered concentrations of all metals were less than AWQG TVs (Appendix 2).

Table 7.20 Filtered metal concentrations in Finniss River during the first flush of the 1997–98 dry season

Distance Downstream from East Finniss River Confluence	Co	Cu	Mn	Ni	Zn
	mg/L				
1.2 km	0.098	**0.155**	0.502	**0.082**	**0.301**
2.5 km	0.084	**0.120**	0.396	**0.075**	**0.134**
AWQG TVs	ID	0.0073	1.9	0.057	0.072

ID = insufficient data to establish trigger value.

Values in bold exceed AWQG TV for protection of slightly-moderately disturbed ecosystems (95% protection level).

Sediment Quality

East Finniss River. A sediment survey was undertaken during April 1993 at 27 sites along the East Finniss River between sites GS8150097 and GS8150200 (Lawton, 1998b). Bed sediments in the East Finniss River were found to be appreciably contaminated with metals. No appreciable decrease in metal concentrations was evident with increasing distance (over 5.6 km) from the former Rum Jungle Mine site. Mean 'total' metal concentrations in the <2000 μm fraction measured in that survey are shown in Table 7.21, along with mean background metals concentrations from control sites and interim Australian sediment quality guidelines (ISQG) recommended by ANZECC/ARMCANZ (2000). The guidelines contain two values, ISQG-low and ISQG-high, which delineate three biological effects ranges:

- Concentrations below the ISQG-low represent a range where adverse biological effects on benthic biota will rarely be observed.

- Concentrations between the ISQG-low and ISQG-high represent a range where adverse biological effects on benthic biota will occasionally be observed.
- Concentrations above the ISQG-high represent a range where adverse biological effects on benthic biota frequently occur.

Table 7.21 Mean 'total' metal concentrations in East Finniss River

Site	Cu	Zn	Mn	Ni
	mg/kg (dry weight)			
1993 survey				
East Finniss River (0–5.6 km downstream of mine; n=27)	**695**	95	240	**80**
Control sites	16	3.5	3.9	3.9
2003/04 survey				
East Finniss River at GS8150097 (n=4)	**632**	35	193	**79**
ISQG-low	65	200	-	21
ISQG-high	270	410	-	52

Values in bold are exceeding the ISQG-low and/or ISQG-high.

Copper and Ni concentrations in sediment of the East Finniss River are well in excess of the upper ISQG, therefore being in the range where adverse biological effects are frequently expected to occur.

A more recent sediment survey was conducted by CDU during 2003–04 (Appendix 2). These data indicate that there has been no improvement in sediment quality in the East Finniss River over the last decade.

Finniss River. Sediment sampling was undertaken in the Finniss River during 1996 at two sites (up to 18 km) upstream of the confluence and three sites (up to 11 km) downstream of the confluence with the East Finniss River (Jeffree et al., 2001). Total metal concentrations in those samples are shown in Table 7.22, along with ISQG recommended by ANZECC/ARMCANZ (2000). There is a marked elevation in metal concentrations at sites downstream of the confluence, decreasing with distance downstream. Metal concentrations in sediment of the Finniss River downstream of the confluence with the East Finniss River are markedly higher than metals concentrations in the sediment of the East Finniss River (see Table 7.21). Copper and Ni concentrations in sediment 4 km downstream of the East Finniss River confluence are about an order of magnitude higher than the ISQG-high, at which levels adverse biological effects frequently occur. At the furthermost downstream site sampled (11 km downstream), Cu and Ni concentrations remain approximately two times higher than ISQG-high values. Zinc and Pb concentrations downstream of the confluence are also at levels where adverse effects could frequently be expected to occur.

Table 7.22 Total metal concentrations in sediment of the Finniss River during 1996

Distance from East Finniss River Confluence	Cd	Co	Cu	Fe	Mn	Ni	Pb	U	Zn
	(mg/kg dry weight)								
-18 km	0.05	5	17	5,454	101	5	16	4	<DL
-0.2 km	0.04	11	30	9,221	230	5	15	2	<DL
4 km	0.30	269	**3643**	12,284	582	**371**	**127**	129	**1,896**
8 km	0.35	193	**1061**	8,426	209	**191**	45	45	**1,748**
11 km	0.22	202	**404**	10,510	551	**98**	37	17	112
ISQG-low	1.5	-	65	-	-	21	50	-	200
ISQG-high	10	-	270	-	-	52	220	-	410

Values in bold exceed the ISQG-high.

Aquatic Ecology

East Finniss River. Pre-remediation fish surveys during low flow showed that very few fish survived in the 10-km section of the East Finniss River downstream of the former Rum Jungle Mine to the Finniss River confluence, where concentrations of Cu and Zn measured in the water were 55 and 44 mg/L, respectively (Jeffree and Twining, 2000). Fish kills were observed to be associated with fish entering the East Finniss River from side streams (Twining, 2002). Post-remediation, in 1996 and 1997, fish kills were still observed to occur in the East Finniss River (Twining, 2002). However, up to seven species of fish have been seen living in the stream, indicating some ecological recovery post-remediation, although this is well short of the potential diversity of up to 18 fish species in similar habitats elsewhere in the Finniss River system (Twining, 2002). Twining (2002) does not list Lorentz's grunter (*Pingella lorentzi*) as one of the seven species observed in the East Finniss River, or 18 species present in the Finniss River system. However, this species is reported to occur in the East Finniss River below the former Rum Jungle Mine site by Allen et al. (2002) and Stirrat (2002) (as cited in Appendix 4). This species is known to occur in Australia only in this location and northern Cape York and is listed as vulnerable under the *Territory Parks and Wildlife Conservation Act*. It is not listed under the EPBC Act.

Pre-remediation surveys of benthic macroinvertebrates in the East Finniss River undertaken in 1973–74 showed similar results to the fish surveys, i.e., numbers of species and individuals were reduced in the 10-km section of the East Finniss River downstream of the former Rum Jungle Mine. A post-remediation survey was undertaken in 1993 (Jackson and Ferris, 1998). The study found that macroinvertebrates remained significantly less diverse and less abundant in the lower reach of the East Finniss River compared with control sites; however, there was evidence of some recovery compared to the severe degradation observed in the pre-remediation survey. A survey of benthic macroinvertebrates was also undertaken on eight occasions over a one year period during 1994–95 to investigate the spatial and temporal effect of effluent from the former Rum Jungle site (Twining et al., 2002; Edwards, 2002). There were significant spatial and temporal changes in macroinvertebrate community composition, which were highly correlated with changes in water quality. The poorest water quality was observed to occur late in the dry season at sites closest to the former Rum Jungle Mine. During the wet season, there was little difference in water quality between impact and reference sites due to the large dilutions and flushing out of any contaminants. Impacts on macroinvertebrates during the wet season are attributed to the physical impacts of high flows rather than toxicity from contaminants (Edwards, pers. com., 2001).

A decapod crustacean survey was undertaken in the East Finniss River on one occasion during 1994, and opportunistically during 1996 (Twining et al., 2002). This taxonomic group was chosen because of its known sensitivity to pH and metals, particularly copper. Numbers of decapod genera were low, which was not unexpected since the East Finniss River is an ephemeral stream. Nonetheless, the survey indicated that contaminants from the former Rum Jungle Mine site were affecting decapods in the East Finniss River, since populations declined to zero upstream of the confluence with the Finniss River and re-appeared only in unaffected sidestreams or upstream of the mine site. However, the distribution of decapods in 1994 had improved from 1974–75 when no decapods were found in the East Finniss River downstream of the former Rum Jungle Mine to its confluence with the Finniss River (Twining et al., 2002).

More recently, extensive macroinvertebrate sampling and AUSRIVAS assessment of the East Finniss River was undertaken between 1995 and 1999 as part of the Australia-wide Assessment of River Health (AWARH), undertaken as part of the National River Health Program. These investigations, which involved 38 early dry season and 34 late dry season site visits, found most locations in the East Finniss River to be severely or extremely impaired.

Finniss River. Pre-remediation, fish kills occurred in the Finniss River for at least 15 km downstream of the confluence with the East Finniss River during the first flush of the wet season when moderate inflow from the East Finniss River coincided with low flows in the Finniss River (Jeffree and Williams, 1975). Post-remediation fish surveys were repeated in the Finniss River during the dry seasons of 1992 and 1995 (Jeffree et al., 2001). Comparison of these results with those of the pre-remediation surveys showed appreciable changes to fish communities downstream of the confluence with the East Finniss River (Jeffree et al., 2001). Prior to remediation, the impacted region of the Finniss River had reduced diversity and abundance of fish compared to sites unexposed to elevated concentrations of contaminants. Post-remediation, no statistically significant differences were observed in fish diversity or abundance between impact sites, i.e., sites downstream of the confluence with the East Finniss River, and unimpacted sites (sites upstream of the East Finniss River confluence and downstream of the Florence Creek confluence). An average of seven species were taken from the unimpacted zone compared with nine to ten species collected at sites in the impact zone.

The recovery in the abundance and diversity of fish species in the impacted zone of the Finniss River is attributed to the reduction in metal loads and concentrations following remediation (Jeffree et al. 2001). Prior to remediation, fish kills during the first flush were thought to be responsible for the residual impact on fish populations observed in the dry season surveys (Jeffree et al., 2001). The recovery in fish abundance and diversity may also possible be due to evolutionary tolerance to elevated concentrations of contaminants over four decades of exposure (Jeffree et al., 2001).

Pre-remediation surveys of decapod crustaceans in the Finniss River undertaken in 1973–74 showed similar results to the fish surveys, i.e., numbers of species and individuals were reduced downstream of the confluence with the East Finniss River. Below the confluence with Florence Creek, 30 km downstream of the confluence with the East Finniss River, no effect was observed. Post-remediation surveys of decapod crustaceans in the Finniss River were undertaken during the dry seasons of 1994, 1995 and 1996 (Twining et al., 2002). In the 1994 survey, there was a marked reduction in the population of shrimps and prawns for at least 14 km downstream of the confluence, similar to trends obtained in fish surveys prior to remediation (Jeffree and Williams, 1975). However, in 1996, decapod populations were higher immediately downstream of the confluence with the East Finniss River than at control sites. These data suggest that there was an improvement in the Finniss River system over the three years of the surveys (1994–96) which was attributed to a decrease in the impact of mine wastes, although such an interpretation is complicated by some inconsistencies in the surveys (Twining et al., 2002).

Macroinvertebrate sampling and AUSRIVAS assessment was also undertaken in the Finniss River under the National River Health Program between 1995 and 1999 (Dostine, 2002). Assessment using a model considered the least sensitive to seasonal bias showed the Finniss River immediately downstream of the confluence with the East Finniss River to be significantly impaired, whereas upstream of the confluence was similar to reference conditions (Dostine, 2002). However, assessments using alternative models showed that conditions at sites downstream of the East Finniss River confluence were similar to reference conditions.

7.8.2 Potential Issues

Key Issues

A range of activities associated with the project will generate stressors that could report to the local drainage, as shown in Table 7.23.

Given the nature of the project, i.e., a mine involving an open pit and a processing plant to generate metal products, the primary contaminants at issue are sediments and trace metals. Other miscellaneous chemicals that are typically used during mining and ore processing (e.g., oils, grease and process reagents) and contaminants associated with treated sewage effluent, are considered to be minor contaminants, since wastes and wastewaters will be collected and managed to appropriate standards, as described in sections 4.11 and 4.14.5. Hazardous materials will be managed as described in Section 4.15.

Table 7.23 Summary of project activities and potential water quality stressors

Activity	Consequence	Primary Stressors
Land clearing/earth works	Erosion	TSS Metals
Mining	Pit dewatering/waste rock dump drainage	TSS Metals Sulfate pH
Ore processing	TSF discharges (if required)/runoff/spills/ seepage	TSS Metals Sulfate Process reagents
Road traffic	Runoff	TSS Metals Tyre/brake lining particles Fuel/lubricant/coolant/hydraulic fluid
Vehicle maintenance	Runoff/spills	Oil and grease/solvents Metals Detergents
Offices and amenities	Runoff/sewage discharges	TSS Metals Nutrients Organic matter Pathogens

Key potential issues are those associated with impacts on downstream water quality that may occur due to the following:

- General stormwater runoff.
- Runoff from TSF embankment (containing encapsulated PAF material)[1].
- Discharge of excess water from the main sedimentation trap.
- Seepage from the TSF.
- Pit water/intercepted groundwater (during operations and post-closure).

These issues are addressed in the following sections.

Water Management Framework

Water quality management in Australia is based on the following approach (ANZECC/ARMCANZ, 2000):

[1] Acid rock drainage is, and has been, an issue at a number of operations in the Northern Territory and hence also requires consideration in this project.

- Identify the environmental values that are to be protected in a particular waterbody and the spatial designation of the environmental values (i.e., decide what values will apply where).

- Identify management goals and then select the relevant water quality guidelines, tailored to local environmental conditions, for measuring performance. Based on these guidelines, set water quality objectives to maintain the environmental values (taking account of social, cultural, political and economic concerns).

- Develop statistical performance criteria to evaluate the results of the monitoring program.

- Develop tactical monitoring programs focusing on the water quality objectives.

- Initiate appropriate management responses to attain (or maintain if already achieved) the water quality objectives.

The management and protection of the Northern Territory's water resources is controlled under the *Water Act* and managed according to the National Water Quality Management Strategy (as described above). Beneficial uses (environmental values) recognised under the act are:

- Agricultural—to provide irrigation water for primary production including related research.

- Cultural—to provide water to meet aesthetic, recreational and cultural needs.

- Aquaculture—to provide water for commercial production of aquatic animals including related research.

- Public water supply—to provide source water for drinking purposes delivered through community water supply systems.

- Environment—to provide water to maintain the health of aquatic ecosystems.

- Riparian—public rights and ownership rights to take water for domestic and/or stock purposes.

- Manufacturing industry—to provide water for secondary industry including related research.

Waste discharge to natural waters is prohibited unless licensed under the act. Waste discharge licences are only available where beneficial uses of the receiving waters have been declared after consultation with relevant stakeholders. Beneficial uses are currently not declared for the Finniss River system.

Once the environmental values for the Finniss River system have been declared, the level of water quality necessary to maintain each value must then be determined. This may be broadly defined through the establishment of management goals that describe in more detail what is to be protected. These goals should again consider stakeholder needs and desires and reflect specific problems and threats to environmental values. Establishment of environmental concerns and management goals allows identification of appropriate water quality indicators, which may be biological, physical and/or chemical parameters (e.g., toxicant concentrations). It is then possible to select guidelines for establishing specific water quality objectives, which are the specific water quality targets that also consider social, cultural, economic or political constraints agreed between stakeholders or set by local jurisdictions.

ANZECC/ARMCANZ (2000) recognises that water quality needed to support desired environmental values may not be attainable immediately and that there may be considerable costs associated with achieving the desired water quality. A lower quality may therefore be accepted based on a full cost-benefit analysis, i.e., agreed environmental values and management goals should consider practicality as well as desirability.

In principle, the framework described above can be applied to the Finniss River system downstream of the project. However, a number of factors that are specific to this river system (and are described in more detail in sections 7.8.1 and 3.2) need to be taken into account in terms of setting achievable and realistic objectives:

- The current degraded nature of the river downstream of the former Rum Jungle Mine site (and the project area).
- The occurrence of metal concentrations in the East Finniss River that exceed ANZECC/ARMCANZ (2000) freshwater aquatic ecosystem trigger values for the protection of 80% of species, with the median copper concentration measured in the wet seasons of 2003–2004 and 2004–2005 being more than four times higher than the trigger value.
- The contamination gradient along the East Finniss River, and the Finniss River downstream of their confluence.
- A degree of recovery in the Finniss and East Finniss rivers since remediation of the former Rum Jungle site, as indicated by biological and water chemistry data collected to date. Establishment of baseline conditions for the Browns Oxide Project will therefore be difficult since the existing environment is in a state of flux and the future extent of possible recovery (if any–see the following point) is unknown.
- The potential deterioration in water quality with no further activity. A rehabilitation design specification for the former Rum Jungle waste rock dump cover system was to reduce water infiltration rates to less than 5% of incident rainfall, and to reduce the oxidation rate of pyrite and the rate at which pollutants were transported to the environment. This target was met for the first 10 years following cover placement, representing a 10-fold reduction over rates measured prior to rehabilitation. However, there is now evidence that the covers are failing since infiltration rates have increased to 5–10% of incident rainfall (Bennett, 2002). As a result, pollutant loads from the waste rock dumps may increase over the next 20 to 30 years to a level about 30 to 50% of loads prior to rehabilitation. It is therefore possible that, with no further activity on the site, the ecological health of the Finniss River system may again deteriorate.

It should therefore be recognised that, while it may be possible to set measurable objectives, it may be impossible or impractical to set requirements based on water quality (or similar) measurements or testing. Compass therefore proposes that requirements be established in terms of works to be implemented and practices to be adopted based on Best Practice Environmental Management.

Given the above and the fact that making reasonable quantitative predictions of achievable objectives is not possible at this stage, Compass proposes the following water management strategy for the project:

- Implementation of a 'best practice' approach to water management, including:
  - Installation of sediment control structures.
  - Separation of clean and dirty water.
  - Maximum reuse of dirty water.
  - Testing and treatment of excess water to ensure it is of suitable quality prior to release.
  - Release of excess water during periods of high river flow to ensure maximum dilutions (when discharge water quality is worse than receiving water quality).
  - Establishment of a comprehensive monitoring program of the surface waters that may be affected by the project.
- A management target of maintaining, and allowing improvement of, the existing ecosystem, consistent with the approach recommended by ANZECC/ARMCANZ (2000) for Condition 3 (highly disturbed) ecosystems. The water quality of any point source discharges and the East Finniss River upstream and downstream of the project area will be monitored, and regular AUSRIVAS surveys (or similar) conducted, to determine whether this target is achieved.

7.8.3 Avoidance, Mitigation and Management Measures

General Stormwater Runoff

Construction methods to be implemented to minimise site disturbance are described in Section 4.5.2. Management of stormwater runoff is described in Section 4.14.2.

Surface water from disturbed areas will be collected and directed to sedimentation traps to allow settling of suspended sediments. There will be two smaller sedimentation traps and a main sedimentation trap, with the latter draining most of the site. Water from this trap will be recycled to the process water dam for reuse in the plant. Excess water in the two smaller sedimentation traps will be pumped to the main sedimentation trap. If the capacity of the main sedimentation trap is exceeded, water will be discharged to the East Finniss River. This water will be monitored to determine if it is of suitable quality for release and treated as required. Compass will further develop this water treatment system in the detailed engineering design (see Section 4.14) [C].

Acid Rock Drainage

Waste rock. Key features of the proposed waste rock management strategy (Section 4.9.2) include:

- Using most of the waste rock mined as bulk fill in the TSF embankment construction.
- Encapsulating all PAF rock generated by the project within the TSF embankment.
- Providing direct supervision by suitably experienced personnel during construction to ensure that the required high degree of geotechnical and structural control is obtained.

Tailing. Key features of the proposed tailing management strategy (Section 4.10.3) include:

- Construction of a TSF that will comprise an embankment around all sides, where this embankment will consist of various ‘zones’ of different material.
- Subaerial deposition of the tailing.
- Collection of excess water in a decant pond for re-use in the process plant.
- Monitoring for variables such as dusting (from the tailing beaches) and seepage (through the TSF embankment).
- Installation of a suitable cover on the TSF on closure, such as a ‘store and release’-type cover (see Section 9.10.5).

Pit. During operations, pit water reports to the main sedimentation trap. The potential for development of ARD from pit walls will be monitored during development of the mine. If necessary, various management strategies would be investigated to control ARD, such as application of layers of Virotech Terra B® and shotcrete to PAF material in pit walls to inhibit oxidation. Pit water quality will be monitored during operations (and post-closure) to determine if ARD is occurring.

An option for final void closure, should ARD be considered a significant issue, is to divert the East Finniss River through the pit to rapidly fill the void. As described in NTMC (2004), rapidly flooding an open pit where the potential exists for ARD is considered the best means of creating a water body of reasonable quality, since this limits the opportunity for sulfide oxidation to occur in the pit walls and floor. Maintaining good quality pit water is important since it represents a valuable resource, and also facilitates pit dewatering at a later date to access further ore reserves (without the need for expensive water treatment).

Discharge of Excess Water from the TSF

Tailing decant will be recovered and returned to the process circuit via the process water dam (see Section 4.14.4). The TSF is designed to retain sufficient volume for retention of runoff from major rainfall events, including the wettest year on record (1996/97) for the period 1958 to 2004. Under extreme conditions, water would be released via the emergency spillway and drain to the main sedimentation trap. As described above, if the capacity of the main sedimentation trap is exceeded, water would be discharged to the East Finniss River, after monitoring and treatment as required (see Section 4.14).

Seepage from the TSF

Management of seepage from the TSF is described in Section 4.10.3.

Water Produced from Mine Dewatering

Mine water produced during operations, comprising groundwater inflows and incident rainfall over the pit area, will be pumped to the main sedimentation trap. Any water discharged from this trap will be monitored and treated as required, as discussed in Section 4.14.

As described in Section 4.14.3, interception bores will also be used to assist in the pit dewatering. It is proposed that excess water produced from these bores will be discharged directly to the East Finniss River, depending upon the quality of the groundwater. Possible strategies for managing this water, should it be contaminated due to historical legacies associated with the Rum Jungle Mine site, are further discussed in Section 7.8.4.

7.8.4 Residual Impact Assessment

General Stormwater Runoff

Increased loads of TSS may be expected to report to the East Finniss River, despite the incorporation of design and management measures specifically aimed at minimising and mitigating off-site releases. Sediment delivery will be highest in the early construction phases of the project and will decrease as sediment controls come online, progressive rehabilitation is undertaken and sediment erodibility decreases. Issues associated with delivery of sediment to receiving waters primarily relate to elevation of suspended sediment loads and in-stream sediment deposition downstream of the mine site. The majority of suspended sediment will be transported downstream during high-flow events. Therefore, during mining construction and operations significantly increased TSS concentrations are likely to be associated with storm events.

The main impacts are therefore expected to be:

- Changes in water quality (increased TSS and, to a lesser extent, metal concentrations).
- Physical alteration of stream habitats (in-stream deposition).
- Changes in stream trophic structure including fish and macroinvertebrate food supplies.

These impacts may cause a temporary decrease in the abundance and biomass of fish and macroinvertebrates in the already-stressed East Finniss River, and the displacement of sediment-intolerant species into clear water tributaries. Predictions concerning impacts on the aquatic environment are generally difficult to accurately quantify.

Correspondingly greater emphasis will therefore be placed on monitoring, with Compass establishing a comprehensive monitoring program of the East Finniss and Finniss rivers.

Impacts on water quality due to excess water discharges from the main sedimentation trap are considered further below.

Acid Rock Drainage

The management and mitigation measures that are to be incorporated into the construction, operation and closure of the TSF are expected to ameliorate the volume and/or quality of ARD. Nevertheless, given the difficulties in quantitatively predicting the effectiveness of these measures, Compass will obtain improved estimates of ARD during project development and will closely monitor TSF runoff and drainage [C].

In addition to examining indicators of ARD (e.g., pH, conductivity and sulfate concentrations), the monitoring program will include trace metals that may occur in elevated concentrations in the waste rock, as indicated by recent geochemical testwork (Appendix 9) and described in Section 4.9.1. The observed enrichments of greatest environmental significance were arsenic, copper, cobalt and lead. It is also possible that other non-enriched metals, such as manganese, nickel and zinc, could occur at elevated concentrations in the event that sulfide oxidation occurs and acid generation occurs. The findings of that testwork will be reviewed in light of additional information to be obtained from further geochemical testwork that has been commissioned by Compass, and the monitoring program revised as required [C]. Monitoring for these elements will reflect the possibility that runoff and drainage can contain elevated concentrations of certain metals (and salt), even in the absence of acid conditions (NTMC, 2004).

Additional management and mitigation measures will be investigated as required (incorporating information obtained as the mine is developed), including options for ongoing collection and treatment of ARD prior to discharge should this prove to be warranted [C].

Discharge of Excess Water from the Main Sedimentation Trap

It is not currently possible to predict the likely quality (or exact quantity) of excess water in the main sedimentation trap requiring discharge to the East Finniss River and hence subsequent impacts on receiving water quality (which is already severely degraded).

A preliminary (monthly) water balance for the main sedimentation trap has been prepared using records from the wettest year, driest year and a year close to the mean annual rainfall for the period 1958 to 2004 (Section 4.14). As described in Section 4.14.3, interception bores will be installed to intercept groundwater before it seeps into the pit. The water balance for the main sedimentation trap therefore assumes that minimal volumes of groundwater report to the trap.

The water balance shows that excess water would require discharge from the main sedimentation trap between January and March of the mean year (1972/73) and driest year (1985/86), and between December and March of the wettest year (1996/97). Note that this excess water would not include any overflow from the TSF, which has sufficient capacity to hold water for the wettest year on record for the period 1958 to 2004.

Corresponding flows in the East Finniss River for these months, obtained from the hydrological record at GS8150097 (see Figure 7.7), are shown in Table 7.24 along with the excess water discharge rates for the various rainfall scenarios. During the mean rainfall year (1972/73), between 57 and 81 dilutions of the main sedimentation trap discharge would be expected to be achieved in the East Finniss River at GS8150097. The main sedimentation trap discharge therefore represents between 0.5 and 2.0% of the total water volume at this location under the climatic scenarios considered in this analysis.

During detailed design and operations, Compass will both undertake to obtain improved estimates and closely monitor water quality in the trap. Analysis results for the water and receiving water would be provided to DPIFM on a regular basis, e.g., fortnightly, during periods when discharge is likely to occur. This information, together with discharge data, will allow assessment of impacts on receiving water quality. Provision will also be made for the water to be treated, if necessary, prior to release (see Section 4.14).

As described in Section 7.8.2, it is proposed that the management target be to maintain, and allow improvement of, the existing ecosystem, consistent with the approach recommended by ANZECC/ARMCANZ (2000) for Condition 3 (highly disturbed) ecosystems. The water quality of point source discharges and the East Finniss River upstream and downstream of the project area will be monitored, and regular biological surveys conducted, to determine whether this target is achieved.

Table 7.24 Flow rates and dilutions of excess sedimentation trap water discharged to the East Finniss River

		Dec	Jan	Feb	Mar
Mean year (1972/73)	Excess trap water (m^3/s)	-	0.022	0.055	0.033
	East Finniss flow (m^3/s)	-	1.261	3.279	2.674
	Dilutions	-	*57*	*60*	*81*
Wettest year (1996/97)	Excess trap water (m^3/s)	0.041	0.152	0.091	0.053
	East Finniss flow (m^3/s)	2.887	15.41	8.173	9.236
	Dilutions	*70*	*101*	*90*	*174*
Driest year (1985/86)	Excess trap water (m^3/s)	-	0.013	0.024	0.003
	East Finniss flow (m^3/s)	-	2.268	1.159	0.394
	Dilutions	-	*174*	*48*	*131*

Seepage from the TSF

'Shallow' seepage through the embankment will be collected in a toe drain and recycled, while 'deep' seepage, which preliminary calculations indicate to be in the order of 0.30 L/s (Appendix 8), will be captured during operations by either interception bore(s) or the groundwater drawdown cone resulting from the pit. On closure, indicative seepage rates are expected to range from 0.25 L/s in the wet season to zero in the dry season (see Section 4.10.3). Flow in the East Finniss River at GS 8150200 during the wet season is in the order of 1000 L/s (Lawton and Overall, 2002a). Seepage from the TSF reporting to the East Finniss River would therefore comprise less than 0.03% of the total volume of water in the river and is therefore expected to have insignificant impact on existing water quality.

Excess Water Produced from Interception Bores

Some uncertainty currently exists concerning the quality of water that will be produced from interception bores. The studies described in Appendix 3 indicate that a single aquifer is operating in the project area. Consequently, as groundwater is drawn down during dewatering, contaminated groundwater from the Rum Jungle site may join deeper, cleaner groundwater that is moving toward the mine. As described in Section 7.9.1, monitoring of groundwater quality to the east of the project area has occurred as part of the Rum Jungle Rehabilitation Project. The contaminated shallow groundwater, containing high levels of metals, high salinity and low pH due to leachate from the waste dump, generally flows radially away from the dumps before deviating with the regional groundwater flow towards the East Finniss River. Lawton and Overall (2002a) found that in-flow of groundwater to the East Finniss River approximately 500–700 m downstream of GS8150200 was not a source of contaminants from the former Rum Jungle Mine site. Rather, the acid buffering capacity of the carbonate-dominated groundwater discharge at this location may be attenuating impacts on the East Finniss River from acid drainage by increasing pH and thereby precipitating metals.

Some of the water contained within Intermediate Open Cut at Rum Jungle may also be drawn into the groundwater system and report to interception bores. This will depend upon whether the East Finniss River presents a barrier to groundwater movement due to a relic water mound beneath the river or, conversely, whether there is increased transmissivity due to the presence of fracture zones. The drawdown predicted in the vicinity of Intermediate Open Cut due to mine dewatering for the Browns Oxide Project is between one and eight metres, assuming that the East Finniss River does not present a constraint to such drawdown (Appendix 3). Drawdown within the open cut is unlikely to be much greater even if there is connectivity between Intermediate Open Cut and the Browns Oxide Pit, since the depth of most of the latter pit will generally be only 20 to 25 m, limiting the hydraulic gradient along any fracture lines.

Physico-chemical profiles of the water column in Intermediate Open Cut were undertaken in April 1998 (Lawton and Overall, 2002b). Results from measurements taken at 5 m intervals to 30 m depth are presented in Table 7.25. Also shown in the table are measurements of water quality in the East Finniss River immediately downstream of the Rum Jungle Mine site, undertaken by CDU (Appendix 2).

Table 7.25 Water quality of Intermediate Open Cut compared with East Finniss River

Parameter	Intermediate Open Cut	East Finniss River at GS8150200	
	(range between 0 to 30 m depth; n=7)	(range during wet seasons 2003/04 and 2004/05; n=11)	(concentrations measured in pools formed in dry season, Aug 2003 and Nov 2004; n=2)
Filtered metals (mg/L)			
Cu	0.10–0.30	0.07–0.34	137–171
Mn	0.38–0.91	0.27–1.52	327–411
Zn	0.02–0.06	0.08–0.51	322–419
Ni	0.08–0.15	0.08–0.31	156–197
Fe	0.02–0.38	0.003–0.07	0.38–2.2
Al	0.15–0.22	0.02–0.19	481–693
pH	5.3–6.9	5.3–6.4	3.5–3.9
DO (% sat.)	64–92	75–112	93–103
Conductivity (μS/cm)	125–161	149–466	4,500–5,230
Ca (mg/L)	4–6	-	-
Mg (mg/L)	9–12	-	-
SO_4 (mg/L	48–71	-	-

These data show that water in Intermediate Open Cut is generally of similar, or better, quality to that flowing in the East Finniss River. During the dry season, water in the open cut is of much better quality than water contained in pools formed along the river bed. Water drawn into groundwater from Intermediate Open Cut, and consequently discharged to the East Finniss River during dewatering of the Browns Oxide Pit, is therefore unlikely to have adverse impact on the river system. Minimal drawdown (less than 1 m) is predicted to occur in Whites Open Cut (see Appendix 3), hence water from this pit is not expected to significantly impact the quality of water produced from interception bores.

Rather, the potential exists for groundwater discharges to improve the condition of the river system. This could occur by discharging groundwater to the East Finniss River during the dry season, thereby preventing the accumulation of contaminants in seepage from Rum Jungle waste rock dumps accumulating in the river bed due to evaporative concentration and precipitation (see Section 7.8.1). This would reduce contaminant concentrations in the river system during the first flush (which has previously been associated with fish kills) and recessional flows, when concentrations are highest due to the minimal dilution of contaminants migrating from the Rum Jungle site (see Appendix 2). The benefit of such a strategy would depend on the hydrological regime of the East Finniss and Finniss rivers, and the quality of the groundwater. If implemented, monitoring would be undertaken to determine that the Finniss River system is not adversely impacted during the dry season by inflows from the East Finniss River.

As described in Appendix 3, there is some uncertainty concerning groundwater transmissivity and therefore the amount of groundwater likely to be produced by interception bores. Groundwater inflows are predicted to vary between 30 and 60 L/s depending on the stage of excavation, although higher inflows may occur depending on the influence of geological faults. These estimates, which were predicted using analytical methods, are conservative when placed in the context of groundwater yields measured during excavation of Whites Open Cut, when 750 million gallons was pumped from the pit during its four year life (AIMM, 1965). That pumping rate equates to about 25 L/s for the 110 m deep pit, which is located along the same geological fault line as the proposed Browns Oxide Project pit. Note that during excavation of Whites Open Cut, the groundwater entered the mine at a depth of 50 to 60 m (Lawton, 2005; pers comm.), i.e., at much greater depth than the Browns Oxide Pit (which is mostly 20 to 25 m).

Since some uncertainty exists regarding the quality and quantity of groundwater that will be produced by the interception bores, it is proposed that a similar water management approach be adopted as for excess water discharges from the main sedimentation trap, i.e., Compass will obtain improved estimates of quality and quantity of possible discharges and will fully inform DPIFM of such information. Additional water management strategies would be implemented should groundwater discharges be considered to adversely impact the existing water quality of the East Finniss River. These could include:

- Preferential use of contaminated groundwater as makeup water in the process plant.
- Treatment, by lime addition to increase pH and precipitate metals, to achieve a suitable quality prior to discharge.
- Pumping groundwater to Whites and Intermediate open cuts and, to increase storage capacity, possibly stopping the wet season diversions of the East Finniss River through these pits.

It should be noted that, in relation to the second and third options, liability issues associated with this possibly contaminated groundwater would need to be addressed.

7.9 Groundwater

This section is based primarily on the groundwater assessment described in Appendix 3.

7.9.1 Existing Conditions

Groundwater System

Groundwater occurs at depths ranging from 2 to 12 m below surface in the project area, with an average depth of about 4 m. The groundwater levels fluctuate seasonally, with an average range of about 5 m. Groundwater hydrographs coincide with the monsoonal climate, with rainfall recharging aquifers during the wet season. Groundwater levels commence to rise about December in the early wet season and peak in February. The peak is followed by recession that continues until the annual rise starts again in the following wet season.

The rapid cyclic groundwater response to rainfall indicates that the aquifers in the project area are unconfined. The regular recessions also indicate that the groundwater system is dynamic, with groundwater discharging to creeks or taken up by transpiration. There is some evidence that groundwater levels have increased over recent years, which is thought attributable to the above average rainfall that has occurred during the 1990s.

Previous studies have proposed that there is both a shallow and deep aquifer system in the east of, and extending towards, the project area (Appendix 3). The shallow aquifer was considered to be only a few meters deep in the shallow lateritic soil and responsible for most of the contaminant migration from the old Rum Jungle dumps. The deeper aquifer was regarded as being a fractured system that is poorly connected and has little groundwater movement.

More recent studies undertaken for the Browns Oxide Project suggest a different conceptual model for the groundwater system (Appendix 3). Analysis of hydrographs shows that there is dynamic groundwater recharge and discharge in both deep and shallow bores. The uniformity of the responses suggests that similar groundwater processes such as recharge and discharge are occurring over a wide area and through a deep, relatively continuous saturated zone. Fracture zones may enhance this connectivity between shallow and deep aquifers. The aquifer boundaries and extent of connectivity are therefore considered to be uncertain, although it is thought that the aquifer may be regarded as a single unit rather than as separate and shallow deep aquifers. A trial pit (Plate 7.7) was excavated to 31 m depth in 1999 to obtain bulk ore samples for the project. Observations during the excavation were that groundwater inflows were observed to occur from the footwall carbonates, faulted ground and hanging wall amphibolites. It is therefore thought likely that some separation in groundwater levels occurs between individual water-bearing features.

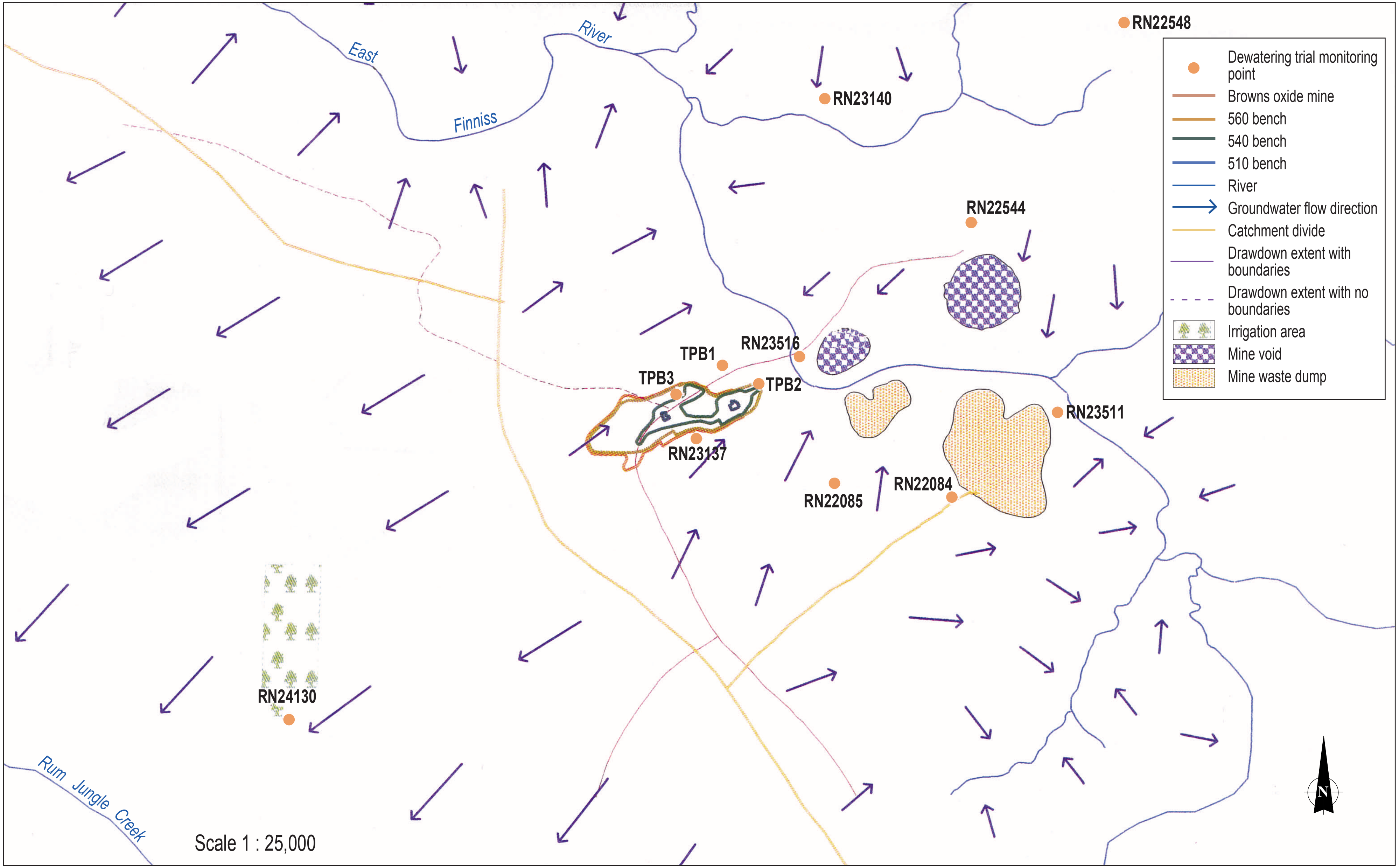
Testing of the Coomalie Dolostone aquifer for water supply purposes at Batchelor in the early 1980s indicated a transmissivity somewhat higher than values obtained for the aquifer at the project site. It is also worth noting the presence of transmissive karstic features within the fresh to slightly weathered aquifer.

Groundwater Flow

Insufficient information is currently available to prepare a groundwater map showing watertable contours. However, general trends in groundwater flow can be predicted based on the conceptual model of the groundwater system. If the aquifer is unconfined, groundwater movement would be expected to reflect the surface topography. Groundwater would therefore move towards the major creeks where it may sustain baseflow following the wet season or may sustain water in pools in otherwise dry creek beds. Potential groundwater flow paths in the project area based on the topography are shown in Figure 7.10.

Plate 7.7
Partially backfilled trial pit (March 2005)

Plate 7.8
Groundwater borehole monitoring near the trial pit



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Compass Resources NL

Browns Oxide Project

Potential groundwater flow paths

Figure No: 7.10

During excavation of the trial pit, groundwater was intercepted approximately 8 m below surface. Evaluation of groundwater monitoring (Plate 7.8) undertaken during dewatering of the pit indicates that drawdown is also influenced by lithology or geological structure (Appendix 3). Groundwater might therefore be intercepted by mine excavations at between 4 and 8 m below surface, depending on the time of the year.

Groundwater drawdown in most of the bores monitored during the trial pit dewatering is considered to be attributable to the natural recession with season and not due to dewatering (Appendix 3). However, three bores (TPB1, 2, and 3) located between 140 and 240 m from the centre of the trial pit showed clear responses to pumping, with drawdown ranging from 0.8 to 3.3 m. A fourth bore (RN 23516) located 360 m from the trial pit also exhibited a drawdown of 0.14 m attributable to dewatering. Geological mapping indicates that this bore is linked to the pit by a fault. The drawdown registered at this bore may therefore not be representative of other locations in the aquifer equidistant from the trial pit.

Groundwater Users

Groundwater users near the project area are described in Section 3.2.4.

Groundwater Quality

Monitoring of groundwater quality to the east of the project area has occurred as part of the Rum Jungle Rehabilitation Project. The 'shallow aquifer' was found to be contaminated with high levels of metals, high salinity and low pH due to leachate from the waste dumps, with typical concentrations being 10 to 100 mg/L copper, manganese, nickel and cobalt, pH of 3 to 4 and conductivity of 2,000 to 13,000 μS/cm (Appendix 3). This contaminated shallow groundwater generally flows radially away from the dumps before deviating with the regional groundwater flow towards the East Finniss River (Appendix 3). Monitoring conducted up to 1986 indicated that the contamination of the 'deep aquifer' was confined to the immediate vicinity of the former Rum Jungle overburden heaps and open cuts. Water quality near Whites overburden heap had a conductivity in excess of 30,000 μS/cm and pH of about 4. Pollutant transport is thought to be minor in the 'deep aquifer' compared with the 'shallow aquifer' (Appendix 3). There is considered to be insufficient data to make reasonable estimates of pollutant loads in groundwater originating from the former Rum Jungle Mine site (Gibson, 1998).

Investigations undertaken for the Rum Jungle Rehabilitation Project indicate that, although there is in-flow of groundwater to the East Finniss River approximately 500–700 m downstream of GS8150200, this is not a source of contaminants from the former Rum Jungle Mine site. Rather, the acid buffering capacity of the carbonate-dominated groundwater discharge at this location may be attenuating impacts on the East Finniss River from acid drainage by increasing pH and thereby precipitating metals (Lawton and Overall, 2002a).

With respect to the actual project area, groundwater quality was measured in observation bores impacted by drawdown during dewatering of the trial pit. The results are summarised in Table 7.26. Shallow groundwater in the weathered zone of the Whites Formation is poorer quality and slightly acidic compared with the deeper water reported in Table 7.26 (Appendix 3).

Table 7.26 Groundwater quality in trial pit monitoring bores

Bore	Aquifer	pH	Conductivity (μS/cm)
TPB1	Weathered carbonate aquifer	7.1	235
TPB2	Weathered Whites Formation/carbonate contact	5.9	3,550
TPB3	Fault zone	6.9	260

7.9.2 Potential Issues

Development of the Browns Oxide Project will require advance dewatering and/or in-pit pumping to prevent groundwater from accumulating in the pit. Removal of groundwater will create a cone of groundwater depression (most probably an elliptical-shaped cone) around the pit that may:

- Reduce water groundwater availability for other users.
- Reduce baseflows to surface waters.
- Drawdown water contained within Rum Jungle Mine pits, exposing sulfide material in pit walls to oxidation and consequently generating ARD.
- Remove water from the root zone of surrounding vegetation.

Note that the impact on surface water quality due to discharge of groundwater produced from interception bores and/or pit dewatering, and issues associated with drawing contaminated groundwater from the Rum Jungle Mine site, are addressed in Section 7.8.

7.9.3 Avoidance, Mitigation and Management Measures

The groundwater drawdowns predicted in Appendix 3 are calculated based on an infinite mine life. Since the mine life is four years only, predicted impacts are likely to be less than indicated. The high rainfall and rapid recharge during the wet season also suggests that there will be recovery in groundwater levels following impacts generated during the dry season. Targeted drawdown may provide some reduction in impact on groundwater levels.

As described in Section 4.14.3, water produced from dewatering bores will be discharged directly to the East Finniss River, thereby mitigating impacts on the baseflow of this stream.

Given the uncertainty regarding the extent and duration of impacts, emphasis will be placed on refining the predictions concerning groundwater behaviour. Should adverse impacts occur to groundwater users, mitigation measures may involve supplying suitable alternative water [C].

7.9.4 Residual Impact Assessment

Reduced Groundwater Availability

Mine dewatering will impact the aquifers by lowering groundwater and changing groundwater flow directions. Impacts have been predicted using analytical methods and extrapolating observations from the trial pit dewatering (Appendix 3)[1].

In the absence of boundary conditions, drawdown impacts are calculated to extend to between 1,000 and 1,500 m from the mine pit. The extent of the drawdown is shown in Figure 7.11, considering both constrainment by catchment boundaries and no such constrainment. It should be noted that this assessment does not consider the influence of faults. The association of high aquifer yield with faults suggests that drawdown preferentially extends in the direction of these structures. Although it is considered unlikely that drawdown impacts will extend to the irrigation area some 1.5 km southwest of the mine, minor impacts cannot be discounted due to the existence of geologic faults that extend from the mine to this area. As discussed in Section 7.9.3, if impacts were to occur to groundwater users, alternate water may be supplied from suitable dewatering bores.

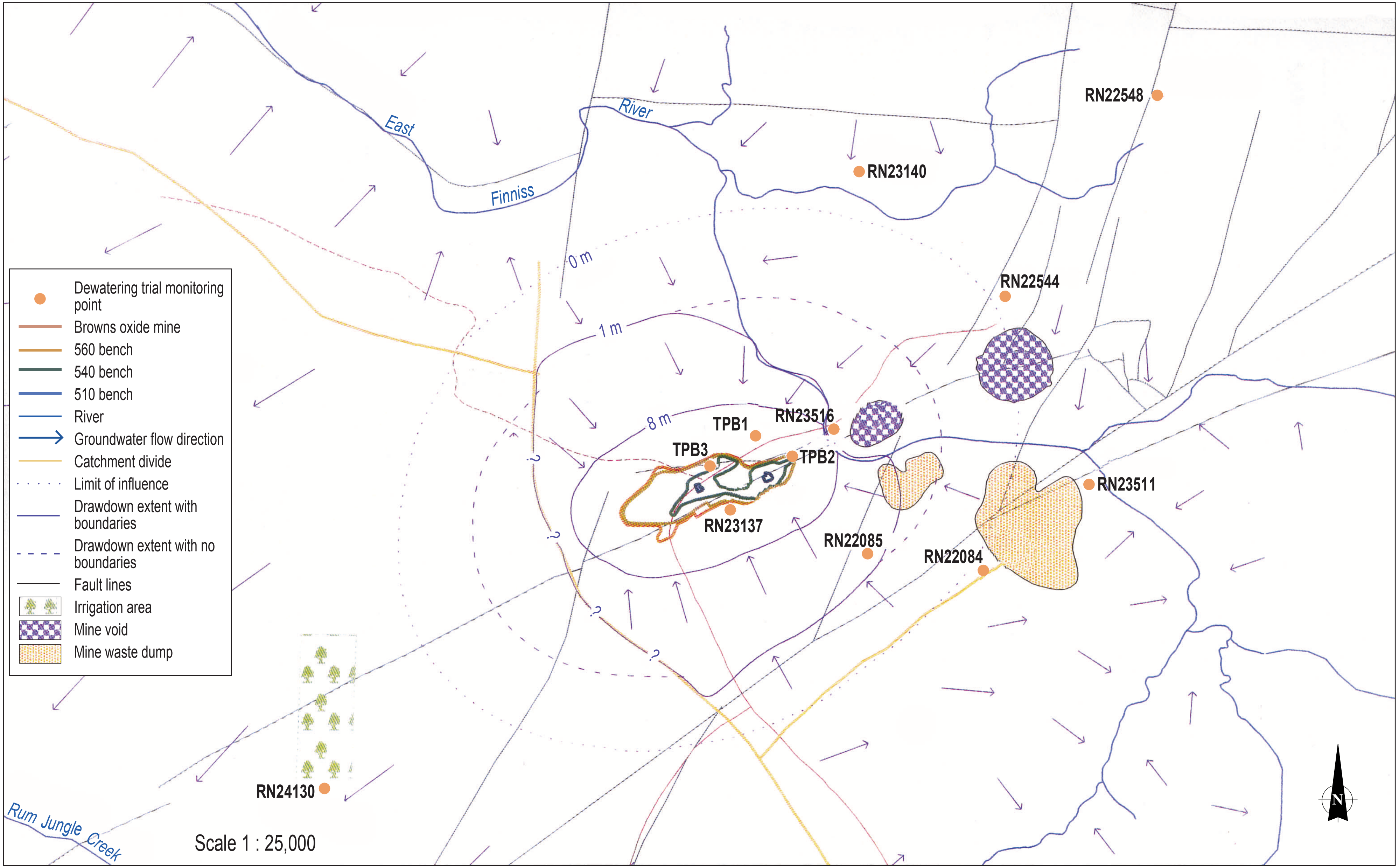
Reduced Baseflows to East Finniss River

Mine dewatering is not expected to significantly impact the baseflow of the East Finniss River since water produced from dewatering bores, if of suitable quality, will be discharged to the East Finniss River.

Reduced Water Levels in Rum Jungle Mine Pits

As discussed in Section 7.8.4, the drawdown predicted in the vicinity of Intermediate Open Cut due to mine dewatering for the Browns Oxide Project is between one and eight metres, assuming that the East Finniss River does not constrain groundwater movement. Drawdown within the Intermediate Open Cut is unlikely to be much greater even if there is connectivity between this pit and the Browns Oxide Pit, since the depth of most of the latter pit will only be 20 to 25 m, limiting the hydraulic gradient along fracture

[1] Note that drawdowns will be influenced by geological boundaries and recharge sources (such as surface streams) and the influence of these boundaries has yet to be determined.



enesar people and place	Job No: 836 / File No: 836_08_F7.11_HB	Compass Resources NL / Browns Oxide Project	Possible groundwater drawdown with distance from the mine

Figure No: 7.11

lines. The drawdown predicted in Whites Open Cut is less than one metre (see Figure 7.11). As described above, groundwater drawdowns are likely to be less than predicted since calculations are based on an infinite mine life whereas the mine life is only four years and there will be water table recharge during wet seasons.

Given the limited drawdown predicted within the Rum Jungle open cuts, it is considered unlikely that fresh sulfide material within pit walls will be exposed to the atmosphere. Water levels within the open cuts and the presence of sulfide materials on exposed pit walls will be monitored. In the event that there is potentially an issue with ARD generation due to drawdown, appropriate management measures would be implemented. These might include returning extracted groundwater back into the pits to raise water levels.

Reduced Water in Root Zones

Mine dewatering and other hydrogeological changes may impact habitats and associated fauna species surrounding the proposed mine pit, with two potentially vulnerable habitats containing melaleuca woodland and monsoon vine-forest occurring in the vicinity (Appendix 4). However, the impacts of groundwater drawdown will be diminished by replenishment of the water table during the wet season. Monitoring will be undertaken of vegetation surrounding the mine pit, particularly melaleuca woodland and monsoon vine-forest, to determine potential impacts due to mine dewatering and/or alteration of groundwater levels.

7.10 Socio-economic

7.10.1 Existing Conditions

Population Characteristics

The population of Batchelor has been increasing since 1991 (Table 7.27), which is consistent with trends in Darwin and the Northern Territory in general (ABS, 2002a).

Table 7.27 Population characteristics 1991 to 2001

Year	Population	Change in Number	% Change over time
Batchelor			
1991	635		
1996	645	10	1.5
2001	727	82	12.7
Darwin			
1991	88,147		
1996	99,601	11,454	13.0
2001	109,419	9,818	9.9

Source: ABS (2002a), ABS (2002b).

The population of rural areas (which excludes Batchelor and Adelaide River) within Coomalie nearly doubled between 1991 and 1996, which reflects a trend toward rural living. However, the population is unlikely to grow significantly further in the short-term due to physical constraints imposed by available land and water resources (DLPE, 2000).

Figure 7.12 shows that a high proportion of the population is aged between 10 and 14 years and 35 and 39 years, with these two groups accounting for 13.1% and 10.8% of the total population, respectively. This illustrates a predominantly family-orientated population with a high number of dependents. The smaller number of elderly people may indicate that people do not tend to retire to the area, although Day (pers. com. 2005) indicated that Batchelor is a popular retirement place for those who do not want to leave the Northern Territory, as it is well serviced and close to Darwin.

The gender ratio of the population, i.e., 51% females versus 49% males, slightly favours females.

Ethnicity

The 2001 census shows that 77% of the population were Australian-born and that 39% of the population are of Aboriginal and/or Torres Strait descent (ABS, 2002b).

Religion

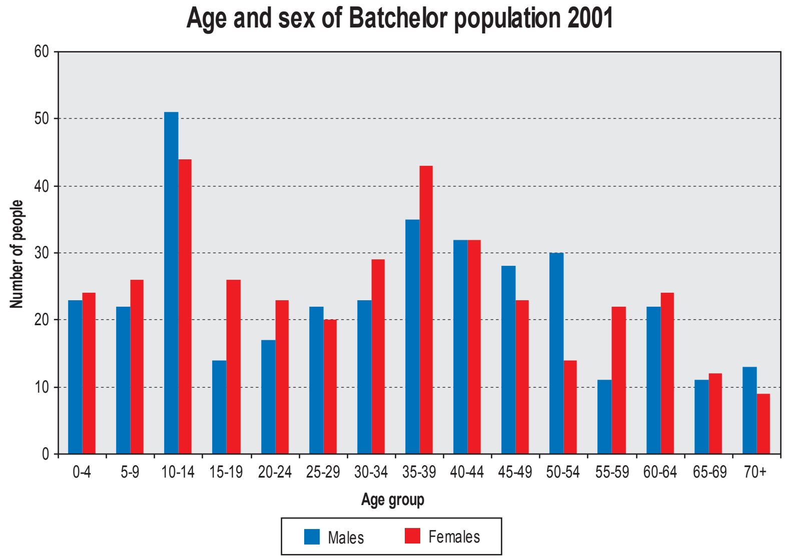
The majority of people are affiliated with a Christian religion (55%), with most following either the Anglican or Catholic church (ABS, 2002b).

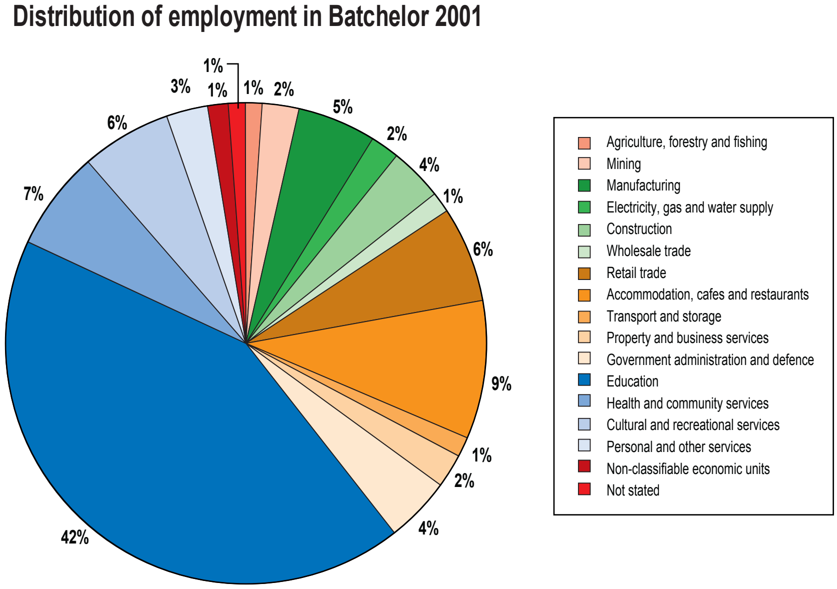
Employment

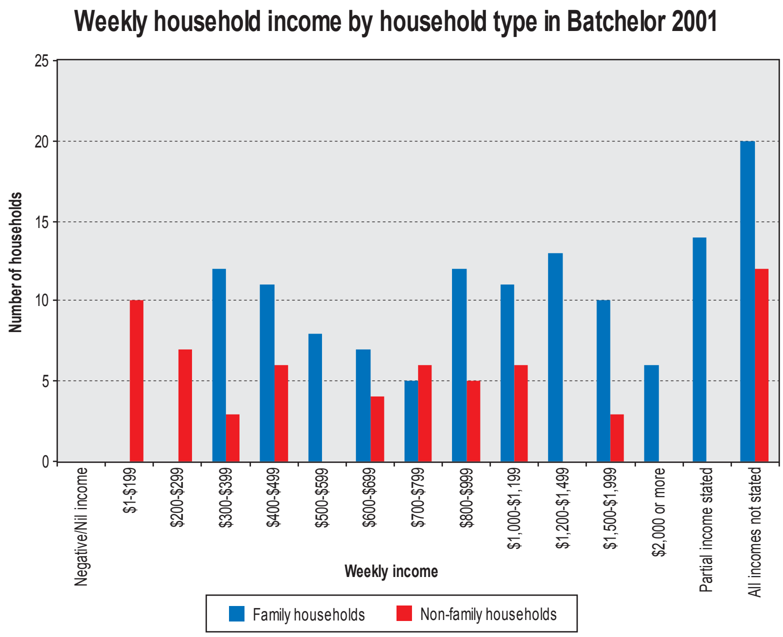
According to 2001 census data, 250 people were employed in Batchelor, representing 93.1% of the labour force[1]. This is similar to the Northern Territory in general, where 94.1% of the labour force was employed (compared with 92.6% in 1996 and 88.6% in 1991 (ABS, 2002a). Consequently, Batchelor has a slightly higher unemployment rate than that for the entire Northern Territory, i.e., 6.9% compared with 5.9%, respectively (ABS, 2002a) and (ABS, 2002b).

Employment distribution indicates that the education sector is the largest employer with 42% (105 people) of the workforce being employed in this sector (see Figure 7.12). The hospitality industry is the second largest employer, comprising 9% (23 people) of Batchelor's workforce. This is followed by health and community services (7%) (17 people), retail trade and cultural recreational services (each 6% [16 people]). The mining industry employs 2% (6 people) of Batchelor's workforce.

[1] Labour force is defined, for the population aged >15 years, as those currently employed (full-time and part-time) plus those unemployed and looking for work.







Source: ABS (2002b) Census data.

Job No: 836	Compass Resources NL	Batchelor demographics	Figure No: 7.12
File No: 836_08_F7.12_HB	Browns Oxide Project		

Education and Child Care

2001 census data for Batchelor indicated that 18% of people (over 15 years of age) had obtained a qualification beyond secondary schooling, while 46% had no qualification (ABS, 2002b).

The Batchelor Area School caters for students from preschool to Year 10 and provides study facilities for Year 11 students (with facilities for Year 12 by correspondence). The school currently accommodates 160 students but has the capacity to accommodate 350 students (Otway pers. com. 2005).

Sailing, archery, mountain biking, bush walking, canoeing and climbing are some of the services offered to students from all over the Northern Territory at the Batchelor Outdoor Education Centre (Otway pers. com., 2005).

The Batchelor Institute of Indigenous Tertiary Education (BIITE) is controlled and operated by indigenous Australians and specialises in working with Aboriginal and Torres Strait Islander students from across Australia. The institute offers courses in education, humanities, business, community studies, health and science for over 3,000 students, and contains a well-equipped trade education centre which is currently not being utilised.

Child care and after-school care facilities are provided at the Yera Child Care Centre in Batchelor for children aged up to 12 years. Although licensed and staffed for up to 50 children, the average attendance is 22 children per day (Burnett pers. com., 2005).

Income

The average weekly income per household in Batchelor depends on whether it is a family[1] or non-family household. The 2001 census data revealed that family households, on average, had a higher weekly income than non-family households. The most common income for family households was $1,200 to $1,499 per week (i.e., $62,400 to $77,948 per annum) compared with $1 to $199 per week (i.e., $52 to $10,348 per annum) for a non-family household (see Figure 7.12).

Accommodation

2001 census data recorded 272 private dwellings in the township of Batchelor, 53% of which were separate houses. A total of 239 (88%) dwellings were occupied and 33 (12%) unoccupied. Of those private dwellings that were occupied, 21% were fully owned, 10% were being purchased and 46% were rented. The remaining dwellings were either under another tenure scheme (such as rent-free or life tenure schemes (10%) or tenure was not stated (13%) (ABS, 2002b).

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[1] Family is defined by the ABS as two or more persons, one of whom is at least 15 years of age, who are related by blood, marriage (registered or defacto), adoption, step or foster, and who are usually resident in the same household.

Most of the rental properties are rented by BIITE staff. Approximately five to eight properties are currently available for rent and about the same number is available for sale (Wain pers. com., 2005a).

A range of temporary accommodation options is available in Batchelor, such as motels (including budget rooms), resort accommodation, self-contained cottages, stockman's quarters, and camping and caravan parks. Sufficient accommodation venues exist to cater for the demand during the tourist season, although accommodation is booked to capacity most of the time (Wain pers. com., 2005b).

Tourism

A regional tourist information centre is located at Batchelor. The town has approximately 250,000 visitors each year as they travel to Litchfield National Park. The tourist season coincides with the dry season and extends from April to September, when the weather is pleasant and flooding does not prohibit access or swimming.

Most of the tourists are on self-drive tours and use Batchelor as a base to explore the surrounding area, often spending the night in town. Organised bus tours bring day visitors from Darwin.

Tourism forms a significant part of Batchelor's economic base.

Community Services and Facilities

Batchelor contains a range of day-to-day services and facilities. However, residents travel to Coolalinga (approximately 50 km north of Batchelor) for regular shopping trips and to Darwin (approximately 65 km north of Batchelor) for non-essential purchases and to access health, education and financial services.

The following community services and facilities are provided in Batchelor (Table 7.28 and Figure 7.13).

Table 7.28 Summary of community facilities and services in Batchelor

Service/Facility	Facility/Service Available in Batchelor
Health	• Batchelor Community Health Centre (general practitioner available Monday, Tuesday, Thursday and Friday morning, 24-hr emergency medical care) • Specialist doctors visit regularly • Chemist agencies (health centre and general store)
Childcare and Education	• Batchelor Area School (Prep to Year 10; Year 11 and Year 12 by correspondence) • Batchelor Institute of Indigenous Tertiary Education • Batchelor Outdoor Education Centre • Batchelor playgroup • Yera Child Care Centre • Batchelor Community Library

Table 7.28 Summary of community facilities and services in Batchelor (cont'd

Service/Facility	Facility/Service Available in Batchelor
Shops and Commercial Services	• Batchelor General Store (Plate 7.9) • Post office • Motels • Caravan parks • Laundromat • Hair salon • Car wash • Conference facilities • Restaurants
Local Police and Emergency Services	• Police station • Fire brigade • Bushfires Council NT
Local Industrial Services	• Airfield • Bore rehabilitation and installation services • Building contractors • Earth-moving contractors • Electrical contractors • Petrol suppliers
Recreational Facilities	• Tennis courts • Basketball/netball courts • Swimming pool • Bowling club and bowling green • Cricket oval and cricket nets • Touch football • Batchelor oval • Bicentennial Park • ANZAC Park • Jack White Park • Rum Jungle South Recreation Lake • Gliding club • Parachute club
Cultural/Entertainment Facilities	• Coomalie Cultural Centre • Batchelor butterfly farm • Havlik Park (mini replica of old gothic European castle) • WWII aerodrome and museum • Scenic flights • St Francis Anglican Church • Outback Gospel Ministries Assembly of God
Waste Disposal Facilities	• Batchelor dump (rubbish tip for dry waste and transfer station for domestic waste)

Source: CCGC (2004).

Batchelor Index

Accommodation/dining
1 Batchelor Resort
2 Lake Bennett Wilderness
3 Jungle Drum Bungalows
4 Batchelor Historic Retreat
5 Batchelor Resort
6 Lake Bennett Wilderness Resort
7 Jungle Drum Bungalows
8 Batchelor Bird and Butterfly Resort

Caravan Park / Campground
1 Batchelor Resort Caravillage
2 Banyan Tree Caravan Park
3 Coomalie Caravan Park
4 Wangi Falls Kiosk and Van Park
5 Litchfield Tourist Park
6 Wangi Tourist Park
7 Litchfield Campground and Monsoon Café

Historic Sites
1 Battle of Australia WWII Commemorative Cairn

Sport and Recreation
1 Darwin Parachute Club
2 Northern Air Charter
3 Bicentennial Park
4 Batchelor Swimming Pool
5 Rum Jungle Recreation Park
6 Bowling Green
7 Tennis Courts
8 Batchelor Oval

Motor Vehicle Services
1 Batchelor Service Station

Health Services
1 Batchelor Health Clinic St. Johns Ambulance

Emergency Services
1 Batchelor Police Station
2 Fire Station
3 Bushfire Control

Services
1 Batchelor General Store
2 Batchelor Post Office
3 Batchelor Information Centre
4 Coomalie Cultural Centre
5 Parks and Wildlife
6 Batchelor School Office
7 Batchelor Institute

Sites
1 Karlstein Castle
2 Batchelor Bird and Butterfly Farm

Source: Northern Territory Discovery Trails (undated).

Job No: 836	Compass Resources NL	Town layout of Batchelor	Figure No: 7.13
File No: 836_08_F7.13_HB	Browns Oxide Project		

Plate 7.9
Batchelor General Store

Plate 7.10
Site RM1 facing southeast

Plate 7.11
Site RM1 viewing mine lease marker

Services provided in Darwin include:

- Darwin General Hospital.
- Darwin Private Hospital.
- Specialist medical services.
- Shops and services not available in Batchelor.
- Secondary schools.
- Technical and further education centres.
- University.
- Registered training organisations.

Northern Territory Economics

The ABS estimates that the Northern Territory real gross state product (GSP) increased by 0.4% in 2003/2004 to $9.2 billion. This was below the national increase of 3.8% and represented the lowest GSP growth of all state and territory jurisdictions (Northern Territory Treasury, 2005).

Mining is the most significant industry in the Northern Territory, accounting for 21.9% of the GSP in 2002/2003 and averaging 21.3% per annum over the past five years. The territory's expenditure on mineral exploration in 2002/2003 was $49 million, representing an increase of 1.2% from the previous year (only the second year of growth since 1995/1996) and 6.7% of Australian exploration expenditure. In response to declining mineral exploration, the Northern Territory Government has implemented a four-year initiative that provides $15.2 million to provide geoscientific data to promote prospectivity (Northern Territory Budget, undated).

In 2002/2003, the mining sector contributed $175 million in wages and spent a further $778 million on operational expenses within the Northern Territory[1] (Kirby pers. com., 2005). It is estimated that in 2003/2004, $37 million was contributed to the government in the form of royalty revenue (Northern Territory Budget, undated).

7.10.2 Potential Issues

Socio-economic issues associated with the project include:

- Employment opportunities for the local community.
- Increased economic activity within the community and the Northern Territory.
- Potential attraction for the tourism industry (e.g., establishing tours of the project).
- Potential impacts on local traffic, roads and infrastructure.
- Altered local lifestyle and public amenity.

The main issue is the need to maximise the socio-economic benefits associated with the project while minimising adverse impacts.

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1 Comparable figures are not yet available for 2003/2004.

7.10.3 Avoidance, Mitigation and Management Measures

During operations, the project will create approximately 79 full-time jobs. During construction, up to 100 jobs will be created. Where possible, recruitment of these jobs will focus on the local community in accordance with Compass's employment policy [C]. Based on recent experiences at similar operations, it is anticipated that approximately 20% (13) of employees will be Aboriginal. In particular, Compass will provide employment and training opportunities for the traditional owners and will develop specific procedures for the administration and implementation of these opportunities [C]. Compass will use goods and services provided by local companies where possible.

Key personnel are most likely to commute from Darwin. Approximately 20 employees are expected to already live locally in either Batchelor or Adelaide River, with the balance of the workforce commuting from Darwin on a daily basis. It is anticipated that senior management, consultants and short-term contractors will utilise the available hotel/motel accommodation in Batchelor.

Compass will expand community consultation to include community meetings, maintenance of noticeboards and information sessions as required to keep the community informed as development proceeds (see Chapter 6). A complaint mechanism will also be established and disseminated.

Key socio-economic indicators will be assessed via the monitoring program for the project (Section 9.9.5).

7.10.4 Residual Impacts

Employment

Additional employment opportunities will be a major benefit to the local and broader communities. The project will inject approximately $4.5 million during the six to nine-month construction period, and $8.4 million annually during operations, in wages (including contractors) into the community (approximately 25% locally). This represents approximately 5% of the mining sector's contribution to wages in the Northern Territory and will have consequent flow-on effects.

Economic

The majority of the capital cost for development of the project will be spent in the Northern Territory, particularly the regional area (including Darwin). This cash injection will have a flow-on effect to other businesses and industries, which in turn will strengthen their economic viability. During operations, annual expenditure on regional goods and services is expected to be approximately $18 million, which will provide an economic boost to existing services and industries. Of this, approximately $200,000 to $300,000 annually will be spent locally in Batchelor, i.e., 2% of the mining sector's operational expenditure in the Northern Territory.

Monetary benefits will flow to the Northern Territory and federal governments in the form of taxes such as company, income and pay-roll tax. Royalties will also be paid to the Northern Territory Government.

Community Services and Facilities

The project will have minimal impact on existing services and facilities in Batchelor given that the workforce will be sourced locally or from Darwin and there will be minimal, if any, new demand.

Education

One hundred and sixty students currently attend the Batchelor Area School, but there is sufficient capacity to cater for double the number of students at all levels from preschool to Year 10 if, and as, required.

Accommodation

The construction workforce is expected to be sourced from Darwin; however, some may choose to stay locally if accommodation is available. Given that the construction peak is scheduled to occur in July/August 2006, coinciding with the tourist season, availability will be constrained by tourist demand. Daily commuting of the construction (and some of the operations) workforce, to and from Darwin raises road safety issues such as driver fatigue. Compass will consider establishing a bus service to transport employees to and from Darwin if there is sufficient demand.

Tourism

Other business opportunities could be associated with development of the project, such as the potential for mine site visits as a tourist activity building on the interest that is already associated with the historical Rum Jungle Mine.

7.11 Biting Insects

7.11.1 Existing Environment

The project is located in an area with distinct dry and wet seasons (see Section 3.1). Surface drainage is ephemeral and distinct ponds and billabongs form during the dry season, in contrast to extensive flooding during the wet season, that often results in large areas of shallow-ponded water. These conditions are conducive to mosquito breeding.

The Medical Entomology Branch (MEB) of the Centre for Disease Control in the Department of Health and Community Services in Darwin has determined that breeding populations of mosquitoes and biting midges are present in the vicinity of the Browns Oxide Project, e.g., Batchelor and surrounding areas such as Mt Grace Magnesium Mine and Woodcutters Mine (Whelan, P. et. al., 2000 and MEB, 2001).

7.11.2 Potential Issues

Twenty different pest mosquitoes occur in the Northern Territory, some of which are capable of spreading harmful diseases such as Murray Valley encephalitis, Ross River and Barmah Forest virus disease (CDC, undated).

The potential for large and uncontrollable mosquito and biting midge breeding presents a potential nuisance and health risk (DLPE, 2000). This potential risk applies to Batchelor and surrounding areas given the ephemeral nature of, and riparian vegetation associated with, creeks draining the project area.

Inappropriate management with respect to impounded and pit water, surface drainage and sewage associated with the project could exacerbate existing, or create new, mosquito-breeding habitats.

7.11.3 Avoidance, Mitigation and Management Measures

Biting insect control will be incorporated into project design and management measures will be implemented to eliminate breeding areas and provide personal protection in accordance with:

- Guidelines for preventing mosquito breeding sites associated with mining sites (MEB, 1997).
- The prevention of mosquito breeding in sewage treatment facilities (Whelan, 1997).
- Recommendations for design details of sewage pond effluent reuse or disposal facilities to prevent mosquito breeding (Whelan, 1998).
- Personal protection from mosquitoes and biting midges in Northern Territory (Whelan, 2004).

Specific management measures are detailed in the Biological and Land Management Plan (Section 9.8.3).

Advice will be sought from the MEB if mosquito breeding is detected within the project area or biting insects become pests.

7.11.4 Residual Impacts

Soil erosion and sediment deposition, ponding of rain water in excavations, e.g., borrow pits, and disturbance to drainage lines during the construction phase will have the potential to create temporary mosquito breeding sites. Maintenance and rehabilitation of these areas in accordance with the guidelines and recommendations listed in Section 7.11.3 will minimise opportunities for mosquito-breeding habitats to establish.

Appropriate design of water storages (including the TSF which will contain standing water) with respect to depth and slope and management of marginal semi-aquatic reeds and grass will further reduce the potential for mosquito breeding.

Artificial containers can collect rainwater and become potential mosquito breeding sites; however, appropriate management of these containers will minimise this potential. The introduction of exotic mosquito species will be prevented by taking adequate precautions with respect to the import and disposal of artificial containers (receptacles).

Biting insect problems, when they occur, are likely to be greatest one hour either side of sunset and sunrise.

7.12 Archaeology and Heritage

7.12.1 Legislative Context

Commonwealth Legislation

The Commonwealth EPBC Act and *Environment and Heritage Legislation Amendment Act (No 1) 2003* protect significant heritage sites. The Register of the National Estate or the National Heritage List may provide listings relevant to this assessment.

Places included on the National Heritage List are deemed to be of exceptional natural and/or cultural significance. Places included on the Register of the National Estate represent places with significant Aboriginal, historic or environmental values. The register contains places that have varying status, as described in Table 7.29.

Table 7.29 Site status on the Register of the National Estate

Status	Description
R	Registered. The place is listed on the Register of the National Estate.
ID	Identified. The Commission has formally considered the values of this place and decided that it should be publicly proposed for entry in the register. The place is awaiting publication in the gazette and the press to give full effect to this decision.
RE	Removed from the register or Interim List. The place has been removed from the Register or list via a public process that provides for the submission of objections.
IL	Interim List. The place has been publicly proposed for entry in the register and the Australian Heritage Council (AHC) may be awaiting objections, considering objections, or seeking other data before making a decision on whether the place should be entered on the register proper.
IP	Indicative Place. Data provided to or obtained by the Commission has been entered into the database and the place is at some stage in the assessment process. The AHC has not made a decision on whether the place should be entered into the Register.
D	Destroyed. The place has been destroyed before being assessed or listed.
REJ	Rejected. The AHC has assessed the place and found that it does not warrant entry in the register in its own right.

Source: AHC (2005a).

Places listed on either the Register of the National Estate or the National Heritage List are included on the Australian Heritage Database.

Northern Territory Legislation

It is an offence under the Northern Territory *Heritage Conservation Act* to damage, destroy, alter or carry out work of any sort on declared or prescribed archaeological or heritage sites without the consent of the Minister or Minister's delegate. This act places constraints on owners of private property, local government and the Crown in relation to two types of heritage sites, i.e.:

- Places or objects listed on the Northern Territory Heritage Register are declared heritage places and objects. These are protected under Section 33 of the act.
- Prescribed archaeological places and objects that are protected under sections 29 and 31 of the act.

Declared heritage places and objects are categorised on the Northern Territory Heritage Register database (NTHR, 2005) according to their site status, as described in Table 7.30.

Prescribed archaeological places and objects are listed on the Archaeological Sites Register. The listing of a place or object on this register does not necessarily mean that the place or object is protected or holds any legal significance under the Northern Territory *Heritage Conservation Act*.

Table 7.30 Site status on the Northern Territory Heritage Register

Status	Description
D	Declared heritage place.
NR	Not recommended. Heritage Advisory Council (HAC) determined that the place did not meet heritage assessment criteria and did not hold sufficient value to warrant declaration under the Act.
RF	Refused by the Minister. HAC recommended for declaration and Minister refused to do so.
P	Proposed. HAC has determined that the place warrants declaration under the act but has not yet made its recommendation to the Minister.
RV	Revoked. Declaration as a heritage place has been revoked.
N	Nominated. HAC has yet to complete its assessment of the heritage value of the place.

Source: NTHR (2005).

7.12.2 Existing Conditions

The following is a summary of the AAPA authority certificates, a desktop study of the Australian Heritage Database and findings of the archaeological survey performed by Bengaze Pty Ltd (Appendix 6).

AAPA Authority Certificates

Compass has previously obtained Authority Certificate No. 95/013 and No. 98/104 in relation to works within or adjacent to the project area, and intends to obtain a further Authority Certificate from the AAPA in relation to the project.

Desktop Study

The Australian Heritage Database lists five locations of heritage significance in the general area surrounding the project site (AHC, 2005b). These are listed in Table 7.31.

There are no previously recorded archaeological places or objects and no National Trust-listed properties within a 5 km radius of the project site (NTNT, 2005)

The historic Rum Jungle Mine Manager's House is listed on the Northern Territory Heritage Register database. The house, which is situated on 2,960 m^2 of land, is located in Batchelor itself and provides a reminder of the town's past link to the former Rum Jungle Mine during the 1950s and 1960s.

As previously indicated, the project site is immediately west of the former Rum Jungle Mine site. Parts of this mine have recently been nominated to the NTHR, under the summary of 'Uranium Mining in the Northern Territory', where it is proposed that the Rum Jungle Uranium Project has acquired historic significance as one of the Commonwealth Governments' largest industrial undertakings in the Northern Territory during the 1950s. The recent nomination is awaiting assessment and a recommendation to the Minister after a period of public comment.

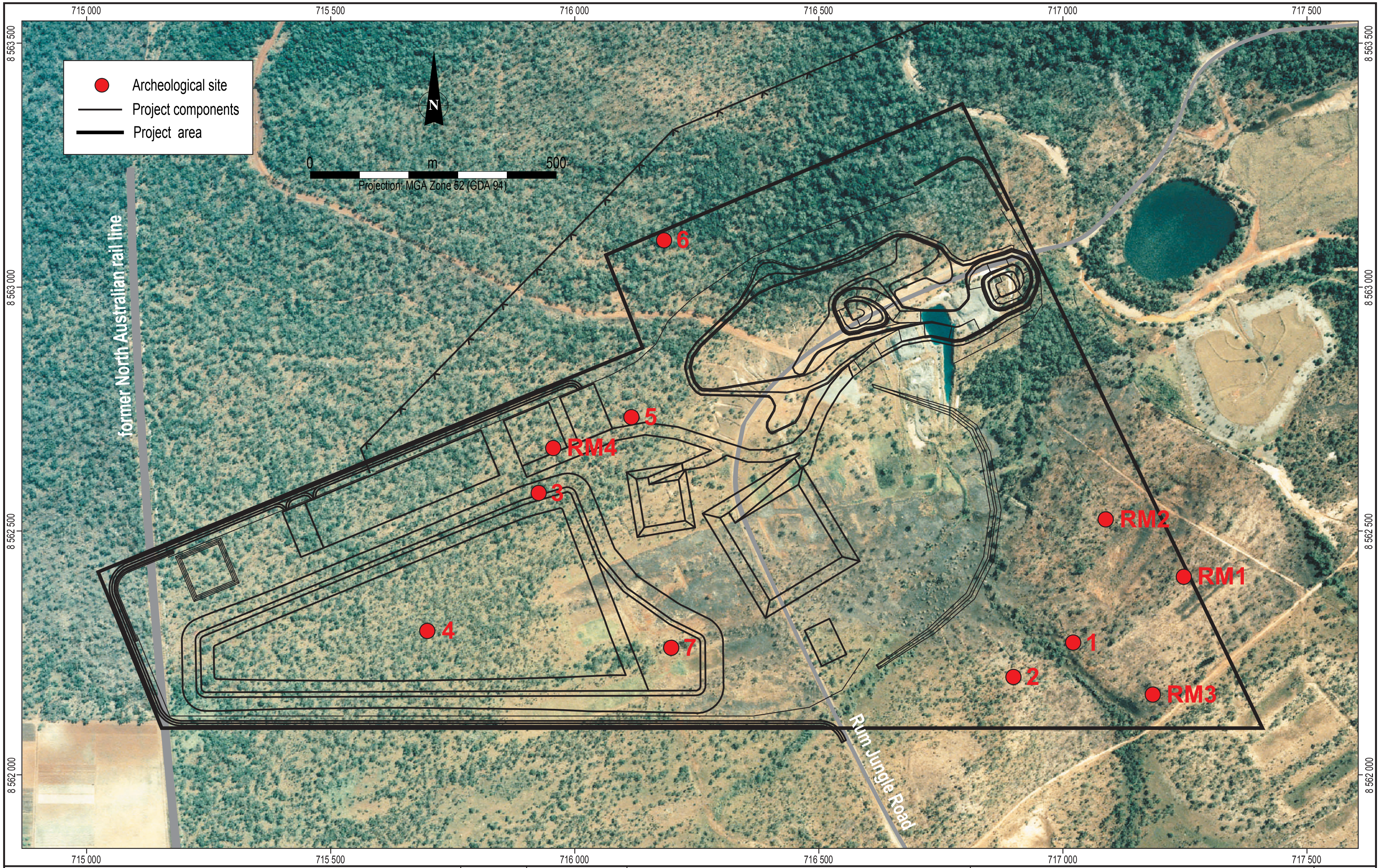
Table 7.31 Australian Heritage Database listings for the Batchelor region

Place	Location	List, Class & Legal Status	Description
Coomalie Dolomite site, Batchelor	Batchelor Road, 2.5 km east of Batchelor	All sites are listed on the Register of the National Estate as 'indicative places'.	Prominent outcrop of Coomalie Dolomite containing stromatolite fossils of regional significance.
Coomalie Creek cut	Stuart Highway, 11 km northeast of Batchelor		Perennial freshwater stream between two steep rocky hills.
Finniss and Reynolds rivers floating grass mats	Finniss and Reynolds rivers floodplains, Batchelor		Series of billabongs with well-developed floating grass mats, an important habitat for the estuarine crocodile.
Kubiling Springs jungle	10 km west-northwest of Labelle Downs Outstation		Floristically diverse Group 4 monsoon rain forest.
Reynolds River Tabletop Range	Channel Point Rd, 12 km west of Batchelor to coast		Very large area that includes a wide variety flora and fauna species and communities (including many rare and endangered species).

Source: AHC (2005b).

Archaeological Survey

Begnaze Pty Ltd (Appendix 6) undertook an archaeological survey in August 2005 to describe the nature and significance of any archaeological material located within the boundaries of the proposed mine site. Four archaeological sites, seven areas of isolated artefacts (background scatters) (Figure 7.14) and three historic sites were located during the survey. The sites are:



Job No: 836	Compass Resources NL	Archaelogical sites	Figure No:
File No: 836_08_F7.14_HB	Browns Oxide Project		7.14

- **RM1**. An artefact scatter and mine lease marker. This is a small low-density stone artefact scatter (Plate 7.10 and Plate 7.11). Sixteen artefacts, consisting of unretouched flakes that were all manufactured from quartz, were identified. The average density was one artefact per square meter, with the highest density of five per square metre. The site is located in the area that is not proposed to be disturbed and was assessed as being of low archaeological significance.
- **RM2**. A stone artefact scatter (Plate 7.12). This site is in an area that has been previously disturbed by mining activities and contains a maximum density of five stone artefacts per metre square, with an average density of two artefacts per metre square. The site contains unretouched flakes, two bifacial quartz points and two quartz cores, all made from quartz. Also present was one quartzite core, four tuff flakes and a flake made from volcanic material. The site was assessed as being of low to moderate archaeological significance.
- **RM3**. A small low-density stone artefact scatter. This site is located on a low quartz outcrop, although there was evidence that quarrying occurred at the site. The site was four by three metres with an average density of less than 0.2 artefacts per square metre and a maximum density of three artefacts per square meter. The artefacts were quartz flakes and two broken tuff flakes. The site was assessed as having low archaeological significance.
- **RM4**. A stone artefact scatter. This is a small artefact scatter site of three by one meters, with an average density of five artefacts per square meter. The site consisted of unretouched flakes made of quartz with one quartzite flake and was assessed as having low archaeological significance.
- **Background scatters**. Seven areas with a background scatter of isolated stone artefacts were identified. The majority of the artefacts were unretouched flakes manufactured from quartz.
- **Historic Site – Mine lease marker**. Located in the same position as RM1 (see Plate 7.11), the marker is associated with past mining activities. It is considered to be of low to moderate historic significance.
- **Historic Site – North Australian Railway**. A gravel bed on which the tracks were laid and in some sections the top layer of gravel has been removed (Plate 7.13). Metal bolds and other metal fragments were found along the line, which is considered to be of low historic significance.
- **Historic Site – CRA Mine headframe**. Located in the southern side of Rum Jungle Road near the corner with Whites Road. The mine headframe is relatively intact and in good condition (Plate 7.14).

7.12.3 Issues

Issues relating to the conservation of Aboriginal and non-Aboriginal heritage in the proposed project area focus on the need to:

Plate 7.12
Site RM2 facing west

Plate 7.13
North Australian rail line remnant

Plate 7.14
Old headframe

- Avoid, where possible, current known locations of significance.
- Minimise the potential disturbance to locations of archaeological significance discovered during project activities.
- Manage adverse impacts where they are unavoidable.

7.12.4 Avoidance, Mitigation and Management Measures

The sites identified during the archaeological survey will be protected through the establishment of exclusion zones in consultation with the Northern Territory Heritage Office.

However, if sites RM1, RM3, RM4, the background scatters of isolated artefacts, the mine lease marker or the North Australian Railway line are to be destroyed or disturbed by the development, permission to destroy the sites will be sought from the Minister for Natural Resources, the Environment and Heritage. No further mitigating procedures will be necessary for compliance with the provisions of the Northern Territory *Heritage Conservation Act*.

If site RM2 is to be disturbed by the development, then permission to destroy the site will be sought from the Minister for Natural Resources, the Environment and Heritage, and a detailed surface survey will be carried out before it is to be disturbed.

The CRA Mine headframe will be either donated to an interested party in Batchelor to be displayed in the town or moved to an alternative site where it will be protected.

It is possible that artefacts may be discovered during the development of the project. Therefore, a process will be implemented to identify and protect such future finds. Aboriginal and historical archaeologists will be on call during project construction in the event that archaeological material is detected.

The site-specific Cultural Heritage Management Plan detailed in Section 9.8.8 will ensure that impacts are managed in a culturally sensitive manner.

7.12.5 Residual Impact Assessment

There will be limited residual impacts. If the sites of archaeological significance are not to be disturbed during the development then they will be considered restricted areas and will not be entered.

7.13 Radiology

A radiological assessment for the Browns Oxide Project was undertaken by the Australian Nuclear Science and Technology Organisation (ANSTO) and is included as Appendix 7. This section summarises the findings of the assessment.

7.13.1 Existing Conditions

While the Browns Oxide Project is adjacent to the historic Rum Jungle copper and uranium mine, the concentration of naturally occurring radioactive material (NORM) in Browns oxide ore is very low and is below the regulatory exemption level (1 Bq/g of any naturally occurring radionuclide other than ^{40}K).

Uranium concentrations have been measured in a series of ten composite ore core samples collected from 4 to 10 m depth. The mean uranium concentration was 13.9 mg/kg (8.1 to 28.6 mg/kg), while the total combined activity of the ore was 5.32 ± 0.59 Bq/g. The ^{238}U in the ore contributed 0.29 Bq/g to this total and each of its progeny contributed less than 0.43 Bq/g. The activity of ^{232}Th and its progeny are all less than 0.022 Bq/g. The concentration of uranium and thorium in waste rock has not been measured, as the concentrations of these elements are expected to be higher in the mineralised ore than in the waste rock.

The concentrations of uranium and thorium in groundwater were both found to be <1 μg/L with the corresponding radionuclide activities being less than the detection limits (<0.02 to <3.6 Bq/L).

7.13.2 Potential Issues

The potential radiological issues are:

- Radiological doses to the workforce and the public.
- Uranium concentrations in ore and throughout the processing circuit.
- Radioactivity of end-products.
- Radiological impacts on the environment.
- Radiological issues at mine closure such as NORM in the TSF and disposal of contaminated process plant equipment.

7.13.3 Avoidance, Mitigation and Management Measures

The entry of NORM into the environment will be minimised through the physical control of waste rock (see Section 4.9.2), tailing (see Section 4.10.3), erosion (see Section 4.5.2) surface water (see sections 4.14.2 and 7.8), discharge of excess water from the TSF (see Section 9.8.4), seepage from the TSF (see Section 9.8.4) and dust (see Section 7.3.3).

Should radioactive scales, equipment, materials and/or neutralisation waste become evident during operations, specialist advice about maintenance and disposal will be sought.

Given that the radiological dose received by mine workers will be less than the allowed exposure limit for a member of the public (1 mSv/year), there will be minimal occupational health and safety requirements specific to radioactivity. However, procedures to minimise the inhalation of dust will also reduce the radiation dose received through this pathway. Minimisation of radiological dose to workers and the public will be further addressed in the Occupational Health and Safety Plan.

7.13.4 Residual Impact Assessment

Appendix 7 concludes that 'the use of available modelling tools for dose calculation indicates that the impact of the Browns project on the environment will be minimal' under normal operating conditions.

Radiological Dose

Radiological doses to the workforce and the public have been calculated by ANSTO (Appendix 7) based on a conservative range of exposure scenarios to various workgroups and the public. Potential radiation exposure pathways considered were:

- External gamma radiation.
- Inhalation of long-lived radionuclides via dust.
- Inhalation of radon.
- Ingestion of long-lived radionuclides.
- Injection of radionuclides through wounds or accidents.

The dose calculations only consider the first three pathways, with the last two pathways, ingestion and injection, being insignificant if normal occupational hygiene practices are followed. The estimated dose to indicative workgroups and the public from each of these pathways and the estimated total dose is summarised in Table 7.32.

Table 7.32 Estimated radiological doses

Workgroup	Estimated Dose (mSv/year)			
	External Gamma Radiation	Inhalation of Long-lived Radionuclides via Dust	Inhalation of Radon	Total
Ore stockpile	0.25	0.04	<0.01	<0.30
Ore transport	0.06	0.04	<0.01	<0.11
Ore loading and unloading	0.06	0.20	<0.01	<0.27
Public exposure	0.03	<0.01	negligible	<0.04

The total dose rate to members of the general public from mining and ore processing activities (<0.04 mSv/year) is well below the allowed exposure limit for a member of the public of 1 mSv/year.

The total dose to workers from all pathways in mining and ore handling and crushing is <0.3 mSv/y, well below the allowed exposure limit for a member of the public. Handling of waste rock, which will have lower uranium and thorium concentrations than the ore, will not pose a significant radiological risk.

Ore Processing

It is expected that uranium will dissolve in the process leach stage. The uranium will accumulate in recycled process water to be removed as part of the neutralisation waste. In addition, ^{226}Ra may also be present at low concentrations in the leach solutions and appear at high concentrations in scales on equipment surfaces and/or absorbed into synthetic materials such as filter cloths and rubber linings.

Presence of Radioactivity in End-Products

The regulation of naturally occurring radioactivity in the mining industry is currently changing internationally and within Australia. The presence of radioactivity in end-products being transported and marketed overseas is also becoming of increasing importance, because of more stringent exemption concentrations specified by the regulatory authorities. These exemption concentrations are the basis for products exported from Australia possibly being classified as radioactive.

The presence of radionuclides, including ^{210}Po, in acid process liquors, intermediate (Pb, Co/Ni) and metal products cannot be predicted but will be monitored during plant operation.

Radiological Impacts on the Environment

Current regulatory controls on radiological impact are based on the assumption that the protection of humans will result in the protection of the environment. On this basis, given that the radiation dose to the public is well below the allowed exposure limit, the environment is considered to be adequately protected.

A radiological risk assessment (RRA) has been undertaken by ANSTO (Appendix 7) examining two worst-case scenarios: 1) a tailing spill resulting in tailing solids covering the bottom of a pool in the East Finniss River and 2) tailing dust containing the highest recorded ^{238}U concentrations is not suppressed and blankets an area of naturally vegetated ground.

For Scenario 1, the initial (tier-1) RRA dose estimates indicate that the maximum dose to the most susceptible wildlife group (frogs), 4,800 μGy/h, may exceed the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) guideline (4,800 μGy/h).

For Scenario 2, the initial (tier-1) RRA dose estimates indicate that the maximum dose to fungi is 26 μGy/h, which is lower than the UNSCEAR guideline of 40 μGy/h.

Given that these scenarios will be avoided by the implementation of an environmental management program, ANSTO concludes, '[t]he use of available modelling tools for dose calculation indicates that the impact of the Browns project on the environment will be minimal' (Appendix 7).

Mine Closure

The tailing will contain some NORM, and the TSF will be constructed and operated to prevent mobilisation of tailing solids as dust and to prevent environmentally significant radionuclide concentrations entering groundwater or surface water after mine closure.

Following closure, any radioactively contaminated process plant equipment will require appropriate decontamination and disposal.