



Cowal Gold Project

ENVIRONMENTAL

Impact Statement



Appendices A – C

2

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ENVIRONMENTAL Impact Statement

Volume 2 Appendices A – C

- A Cowal Gold Project Species Impact Statement
- B Soils, Agricultural Suitability/Land Capability and Soil Resources
- C Waste Geochemistry

Appendix A

Cowal Gold Project Species Impact Statement

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13 March 1998

Director-General
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Dear Director-General

The enclosed Species Impact Statement (SIS) for the Cowal Gold Project has been prepared by Resource Strategies Pty Ltd, Commonwealth Scientific Industrial Research Organisation (CSIRO) Wildlife and Ecology, Associate Professor David Goldney (Charles Sturt University) and Greg Richards and Associates Pty Ltd.

North Limited believe the SIS to represent an accurate statement of the Company's project development intentions and proposals for environmental management.

Yours sincerely

North Limited

Richard Knight

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EXECUTIVE SUMMARY

Section 1 – Introduction

Section 1 presents background information on the preparation of the SIS and introduces the Project location and setting. The history of the Project is briefly discussed and the principles of ecologically sustainable development are reviewed with regard to the primary environmental aims of the proposed development.

Key components or findings include:

- In accordance with NPWS Information Circular No. 3 (1996b), the principal purpose of the SIS is to facilitate identification of potential threatened species issues considered likely to arise as a result of the proposed development, therefore allowing for the provision of appropriate amelioratory measures.
- Refusal of the original (1995) Development Application (DA) lead to North re-assessing the environmental management and compatibility of the Project with Lake Cowal from "first principles".
- The 1997 SIS, EIS and DA represents North's re-assessment and re-design initiatives and proposes a new Project that is philosophically and physically different in several key areas.

Section 2 – Project Description

This section provides a summary of the proposed development based on information contained in Section 2 of the EIS. The general mining operations arrangement and layout is presented, as well as the proposed mining, ore processing and mine waste management methods. Cyanide usage and flow path throughout the mining and processing operations is also described. Summarising information contained in Appendix G of the EIS, the cyanide destruction process is outlined as is the proposed tailings storage and management strategies.

Key components or findings include:

- The general arrangement of the proposed Project is designed to minimise environmental impact using a number of criteria such as segregation of up-catchment runoff and site water runoff, location of tailings storages as far away as practicable from the Lake and progressive rehabilitation compatible with the ecology and critical conservation values of the Lake environment.
- Mining components and associated infrastructure would cover an area of approximately 940 ha.
- Raw water requirements for the Project would primarily be met through open pit dewatering, recycling within the processing plant and the tailings decant and return system. Make-up water would be pumped from an external groundwater borefield located approximately 20 km to the east-northeast of the proposed open pit.
- Power to the Project would be supplied by a 132 kV electricity transmission line from the south (Temora),

aligned to avoid areas known or considered likely to be utilised by substantial numbers of birds.

- Project construction would be expected to take around 24 months with mining proposed to occur for 8 years. Processing of mined ore reserves would be expected to occur for an additional 4 years.
- Following destruction, CN_{WAD} concentration of tailings entering the storage would be less than 30 mg/L 100% of the time and less than 20 mg/L for 90% of the time.
- Thereafter, residual cyanide (and species thereof) would be subject to decay mechanisms considered likely to be enacted at the Project including volatilisation; association/disassociation of metal complexes; anaerobic biodegradation; and degradation of iron cyanide complexes by UV radiation.
- Use of saline groundwater (as opposed to fresh water) for raw processing water is likely to increase the decay of cyanide within the entrained tailings liquor once deposited in the storage.

Section 3 – Existing Environment

The physiographic setting of the Project area and surrounds is presented in this section, including land resources such as meteorology, soils and landuse. Water resources viz. surface and ground waters are also overviewed. As a component of the description of the existing environment, the Lake Cowal wetland system is discussed in a local and regional context.

Key components or findings include:

- Three major soil types have been identified in the proposed MLA area: hard pedal red duplex soils; grey, brown and red cracking clays; and hill soils.
- Since European settlement native vegetation of the central western slopes region has undergone far-reaching changes, as evidenced in the NSW Wheat-belt area where up to 95% of original native vegetation has been removed for cropping and grazing (Sivertsen & Metcalfe, 1995).
- Approximately 17 conservation reserves occur within a 200 km radius of the Project area.
- When full (approximately 7 years out of 10) Lake Cowal overflows into Nerang Cowal which in turn overflows to Manna Creek, Bogandillon Creek and ultimately into the Lachlan. Without inflows, high evaporative losses can lower the Lake from full to minimal storage levels within 12 months.
- Lake Cowal forms part of a large ephemeral inland wetland system described as one of the most significant waterbird concentration areas in NSW. In recognition of the significance of the Lake as a waterbird habitat, in 1992 the Lake was listed on the Register of the National Estate.

Section 4 – Ecological Overview of Lake Cowal

Following on from the preliminary discussion of the Lake Cowal system presented in Section 3 of the SIS, this section

provides further details on the Lake Cowal environment. Features discussed include regional patterns of vegetation, flora of the Project area and conservation status of the vegetation communities identified. Fauna habitats of the Project area and surrounds are also described. Surveys of fauna in the subject area are detailed including methodologies and results. Seasonality influences on survey results are also discussed.

Key components or findings include:

- Habitat assessment was based on previous habitat assessment (Vestjens, 1977), dominant vegetation types, density of hollow-bearing trees, occurrence of substratum (such as fallen tree limbs, logs, decorticated bark, leaf litter and suitably dense ground cover), levels of disturbance (historic, current and on-going), fire regime and abundance of water. Four primary habitat types were delineated at the Project area and surrounds: lakebed; riparian zone; cleared lands with scattered woodland; and vegetated slopes.
- Specific surveys of the Project area and surrounds have been conducted by Greg Richards and Associates (1997a), Mount King Ecological Surveys (1997), Gunninah Consultants (1995), Hawking (1991, 1995), Environmental and Educational Services (EES) (1992a,b,c, 1993a,b,c, 1994a,b,c, 1995a,b,c, 1996a,b,c, 1997a,b,c), and Lane (1989, 1990, 1991a,b,c).
- Numerous investigations of avifauna at Lake Cowal and its surrounds have been undertaken over the last 20 years including: Vestjens (1977), Braithwaite *et al.* (1985a,b; 1986a,b;), Kingsford *et al.* (1989, 1990), Lawler (1989), Lane (1989, 1990, 1991a,b,c), EES (1992a,b,c, 1993a,b,c, 1994a,b,c, 1995a,b,c, 1996a,b,c, 1997a,b,c), Gunninah Consultants (1995) and Crome (1995).
- A total of 277 bird species have been recorded from or are considered as possible occurrence in the Lake Cowal region (Gunninah Consultants, 1995; Lane, 1989; 1990, 1991a,b,c; EES, 1992a,b,c, 1993a,b,c, 1994a,b,c, 1995a,b,c, 1996a,b,c, 1997a,b,c; Vestjens, 1977; Lawler, 1989; Hatton, 1991 in Gunninah Consultants, 1995; Illawarra Bird Observers Club in Gunninah Consultants, 1995). A number of these records are likely to be exceptional vagrants and others may have been misidentified.
- A number of threatened bird species (eg. Australasian Bittern [*Botaurus poiciloptilus*], Freckled Duck [*Stictonetta naevosa*], Blue-billed Duck [*Oxyura australis*], Black-necked Stork [*Ephippiorhynchus asiaticus*], Osprey [*Pandion haliaetus*], Brolga [*Grus rubicundus*] and Painted Snipe [*Rostratula benghalensis*]) have been recorded from the Lake. Within the proposed MLA area the Freckled Duck (*Stictonetta naevosa*) has been recorded.
- Survey of terrestrial fauna (reptiles, amphibians, mammals) of the Project area and surrounds was undertaken by Gunninah Consultants in April 1994. All habitats of the Project area were surveyed including open woodland, grassland, lakeside vegetation and open forest. Various methodologies were utilised in the 1994 survey including Elliott box trapping, pitfall trapping, amphibian call recording, spotlighting and active diurnal searches for animals, or evidence of animal occurrence (scats, bones, tracks, diggings etc.).
- Further to the 1994 bat survey Greg Richards & Associates (1997a) conducted a bat fauna survey of the Project area between 20-25 October, 1997. A total of 16 sites were sampled including three at the proposed pit/plant site, five at the proposed waste emplacements, three at an inventory site and five at the proposed tailings storage areas. An inventory site is one that is not an impact zone.
- Habitats surveyed included Eucalypt woodland, River Red Gum, *Callitris* woodland, stock dams and the edge of Lake Cowal. Methodology utilised in the 1997 bat survey included sonar detectors, harp traps, triplining and habitat searches.
- A total of 58 terrestrial fauna species (excluding birds) have been recorded from the Project area and surrounds, including 16 mammals (excluding bats), 31 reptiles and 11 amphibians (Vestjens, 1977; Gunninah Consultants, 1995).
- Vestjens (1977) recorded five bat species; the 1994 microchiropteran bat survey yielded six additional species (Gunninah Consultants, 1995); and the 1997 survey yielded three additional species.
- The Yellow-bellied Sheathtail-bat is listed in the TSC Act and was recorded electronically near the lake shore, to the east of the Project area. The Little Pied Bat and Troughton's Bat are also listed as vulnerable in the TSC Act and were recorded from Wamboyne Mountain area approximately 5 km north of the Project area in the 1994 survey.
- A baseline monitoring programme of aquatic macroinvertebrates of Lake Cowal was conducted in March/April 1991 and supplemented by a further study in January 1995 (Hawking, 1991, 1995). The supplementary invertebrate sampling by Hawking (1995) provided a baseline of invertebrates (diversities and densities) in the area to be disturbed by the proposed pit and sampled sites previously sampled by Hawking (1991). Aquatic sampling included the collection of benthic fauna, pelagic macroinvertebrates and plankton using a variety of recognised techniques.
- A total of 49 species of macroinvertebrates were collected from Lake Cowal during the 1991 monitoring survey (Hawking, 1991). In the 1995 monitoring survey 25 species of macroinvertebrates were collected from the core (20 species) and sweep net samples (12 species), with seven species common to both methods. Hawking (1991, 1995) found that the Lake margins (shallow water) were the areas richest in species diversity and abundance.
- Kirra Environmental Group (1991) investigated invertebrate fauna of Lake Cowal and found lake sediments were low in invertebrate diversity; open waters were low in invertebrate diversity and abundance; shallows with Canegrass were high in invertebrate

diversity but low in abundance; and invertebrates associated with vegetation were high in diversity and abundance.

- The baseline studies found that mean total copper, cadmium, lead, zinc, arsenic and mercury values for all species sampled were below the National Food Authority (NFA) standards.
- Fourteen species of fish have been recorded from Lake Cowal by Vestjens (1977) and Fisheries Research Institute (1997), including five introduced species.

Section 5 – Threatened Species

Using the information gathered during the flora and fauna surveys of the Project and Lake areas, as well as information and data contained in various databases, a list of threatened species known or considered likely to occur in the area was compiled. From this data set a threatened species list for the Project area was prepared and a discussion of the principal ecological components and population status of each species was undertaken.

Key components or findings include:

- In consultation with the NSW NPWS Threatened Species Unit (Western Division), a preliminary threatened plant species list for the Lake Cowal region was prepared (Charles Sturt University, 1997; Bower, 1997). This list was compiled using reference sources such as Briggs and Leigh (1995 Revised Edition), Sivertsen & Metcalfe (1995), NPWS database (Wilddata) records for the area, as well as various anecdotal records.
- A list of all fauna species known, or considered likely to occur in the region was compiled by accessing a number of records and databases (Gunninah Consultants, 1995; Lane, 1989, 1990, 1991a,b,c; Environmental and Educational Services, 1992a,b,c, 1993a,b,c, 1994a,b,c, 1995a,b,c, 1996a,b,c, 1997a,b,c; Vestjens, 1977; Greg Richards and Associates, 1997a; Lawler, 1989; Hatton, 1991 in Gunninah Consultants, 1995; NSW Bird Atlases, in Gunninah Consultants, 1995; Illawarra Bird Observers Club, in Gunninah Consultants, 1995; NPWS, 1997; CSIRO, 1997).
- Based on the information contained in the database, a threatened species list was prepared for the Project area in consultation with the following organisations: NSW National Parks and Wildlife Service; Commonwealth Scientific Industrial Research Organisation (CSIRO) – Division of Wildlife and Ecology; and Greg Richards and Associates.
- Based on the information contained in Section 5A, the 8 Part Test Flora Report (Charles Sturt University, 1997; Bower, 1997) and pursuant to the requirements of the Director-General of the NPWS, the following threatened plant species were considered in the SIS for the proposed development: Austral Pillwort (*Pilularia novae-hollandiae*); and Winged Peppergrass (*Lepidium monoplocoides*).

- The 8 Part Test of Significance report for the Cowal Gold Project (Resource Strategies *et al.*, 1997) examined 25 bird, 14 mammal, one amphibian and two reptile species previously identified in consultation with the Western Zone team of the NPWS. The report, prepared in association with a specialist panel of authors from CSIRO, Charles Sturt University and specialist environmental consultants, concluded that for a selected number of species, the information available at the time was inconclusive with respect to some potential or identified impacts.
- Accordingly the Director-General of the NPWS requires that the following species be addressed in the SIS: Blue-billed Duck (*Oxyura australis*), Freckled Duck (*Stictonetta naevosa*), Australasian Bittern (*Botaurus poiciloptilus*), Black-necked Stork (*Ephippiorhynchus asiaticus*), Brolga (*Grus rubicunda*), Painted Snipe (*Rostratula benghalensis*), Yellow-bellied Shearwater (*Saccolaimus flaviventris*), Greater Long-eared Bat (*Nyctophilus timoriensis*) and Little Pied Bat (*Chalinolobus picatus*).

SECTION 6 – Potential Impacts of the Proposed Development on Flora and Fauna and Associated Mitigation Measures

The potential impacts of the proposed development are described including those relating to land resources, bushfire, water resources, final void, salinity, cyanide toxicity, removal of vegetation and habitat resources, dust and air quality emissions, noise and blasting, mining infrastructure and human presence/interference. For each potential impact, amelioratory measures are presented.

Key components or findings include:

- Potential impacts of the Cowal Gold Project with regard to soils and erosion include: loss of in-situ soil resources from beneath mine landforms; breakdown of soil structure; alteration of the physical and chemical properties of soils; erosion of soil eg. from the outer batters of the waste emplacements and tailings storages; and increased erosion rates due to the exposure of dispersive soils.
- An Integrated Erosion, Sediment and Salinity Control Plan would be developed for the construction and operational phases of the mine, to control erosion and sedimentation in the area disturbed by mining activities.
- A detailed Project Soil Stripping and Management Plan (including designs for soil and water management) would be prepared in association with the Department of Land and Water Conservation (DLWC), prior to the commencement of mine construction activities.
- A preliminary risk assessment of the Project has been undertaken by Ansto Safety and Reliability (1997). The assessment identified potential risks to the public, public property and the environment (both on and off-site), which include: spillage of process reagents and chemicals; spillage of fuels; spillage of oily wastes; disposal of other waste materials; sewage; leaching of salts from mine

generated wastes (waste rock and tailings); and release of process water or tailings containing cyanide.

- A detailed Hazardous Waste and Chemical Management Plan is to be prepared for the Project. The Plan would contain appropriate emergency response procedures in the event of spillage resulting in land contamination.
- A Waste Management Plan would be prepared for the Project and would provide detail on the appropriate handling, disposal and recycling procedures for wastes generated at the Project site.
- Potential causes of bushfire in the area include the spread of fire from the surrounding areas, the proposed MLA (either by naturally started fires or uncontrolled burning-off) or the spread of fire from the Project site following an on-site accident.
- A Bushfire Management Plan would be established in consultation with the bushfire control officer at the Bland Shire Council and other relevant government authorities.
- The potential impacts associated with the proximity of the mine to Lake Cowal include: alteration of the hydrology of the Lake as a result of containing and using waters that would otherwise flow into the Lake; increased turbidity during construction; increased salinity due to exposure of saline soil and waste rock; and structural stability of the final mine landforms adjacent to the Lake.
- The Project would not directly use water from the Lake for water supply or any other purposes.
- A silt curtain is to be maintained around the working face of the temporary isolation bund as it is constructed in order to trap fine sediment and prevent suspended material migrating into the main body of the Lake.
- The water management strategy incorporates design elements to contain surface runoff or seepage likely to contain increased salt concentrations. The water management strategy for the emplacements involves maximising rainfall absorption, minimising runoff and directing any seepage towards the open pit thereby minimising the potential for increased salinity.
- Hydrogeological studies have found that structural and hydrological connectivity between the proposed open pit and Lake does not exist to any significant degree. The maximum final void water level (post-closure) would be in excess of 20 m below the lakebed.
- The structural design and final profiles of the waste emplacements, tailings storages and lake isolation system effectively preclude the risk of instability.
- It is proposed to bury the water supply pipeline from the Bland Creek palaeochannel borefield. Burial of the portion of the pipeline that crosses the Lake would only be possible during periods of low water levels. If the Lake level is too high to allow burial at the time of construction the pipeline would be placed on the floor of the Lake and buried at a later date when water levels allow. During burial of the pipe a temporary silt curtain

would be erected around the disturbed area to trap fine sediment and prevent suspended material migrating into the main body of the Lake.

- The potential impacts on both surface and groundwaters within the area of the tailings storages relate to: incident rainfall runoff from the external embankments; seepage; overtopping and spillage of surface water; rupture and spillage from either the tailings delivery or return water pipelines; and cyanide levels in the storages.
- The proposed seepage control methods for the tailings storages include: pre-stripping of soils beneath the embankment foot print; construction of a moisture conditioned and compacted, low permeability storage floor; and installation of an under-drainage and decant network.
- The geochemical properties of the foundation layer are expected to provide further control of potential impacts on water quality. The potential mechanisms by which this may occur are: consolidation of tailings materials above the clay blanket to reduce permeability; and adsorption of tailings chemicals onto clay colloids within the foundation layer and pre-existing subsoils beneath the storage.
- The tailings storages have been designed not to be overtopped and to minimise the risk of incidental spillage.
- A bunded pipeline corridor would serve to contain any potential for losses or spills in the event of pipe rupture. An automatic shutdown mechanism is to be provided on tailings/process water pumps to enable the early detection of major leaks or failures. In the event that spillage does occur within the bunded area, the affected area would be ameliorated in accordance with the procedures contained in the Hazardous Waste and Chemical Management Plan.
- The salinity of the final void surface water after filling (approximately 100 years) is expected to range seasonally from around 20,000 – 40,000 $\mu\text{S}/\text{cm}$ over summer and up to 60,000 $\mu\text{S}/\text{cm}$ in winter.
- Several studies have investigated the salt water tolerance of waterbirds (Moorman *et al.*, 1991; Basham and Mewaldt, 1988) and found that some species are tolerant of hypersaline environments. Mahoney and Jehl (1986a) found that two species of birds, Wilson's Phalarope (*Phalaropus tricolor*) and American Avocet (*Recurvirostra americana*) which occupy hypersaline lagoons in the Great Basin of western North America, were able through a combination of behavioural and anatomical adaptations to rid their prey of most adherent lake water and thereby largely avoid the problems of salt-loading and the ingestion of harmful ions. The Eared Grebe (*Podiceps nigricollis*) and Californian Gull (*Larus californicus*) also have adaptations enabling existence in hypersaline environments (Mahoney and Jehl, 1986b; 1986c).
- A number of Australian bird species are tolerant of high salinity waters, with fauna displaying many adaptations

to cope with salinity-associated stress (Prof W.D. Williams, pers comm, 1997). These are particularly prevalent in the Lake Eyre basin and other Australian inland lakes (*ibid.*).

- Hypersaline lakes on Rottnest Island (Western Australia) have been found to support numerous wader and shorebird species (Saunders and De-Rebeira, 1986). Additionally Australia's naturally occurring salt lakes provide breeding areas for several bird groups including stilts and avocets and refuge areas for ducks, swans, gulls and terns (Prof. W.D. Williams, pers comm, 1997).
- Potential impacts of dust on fauna (*viz.* birds and livestock) at the Project area and surrounds was investigated by Hunt (1997). Assessment of the elemental composition of soil and subsoil from the proposed tailings and tailings storage areas revealed that potential dust from this area during construction and operation would fall within the normal range of acceptability for surface soils for birds and livestock (Hunt, 1997). Pascoe *et al.* (1996 in Hunt, 1997) provides an extensive review of metal toxicity in waterfowl. The report found that upstream sediments at a reservoir in Montana, USA, contained high levels of copper, arsenic, cadmium and zinc, however the daily intake of metals by waterfowl were below or within acceptable toxicity ranges.
- It is considered that dust fallout from the Cowal Project mine would have no adverse effect on waterbirds or livestock using the area (Hunt, 1997).
- Dust can affect vegetation by inhibiting physiological processes such as photosynthesis, respiration and transpiration and allow penetration of phytotoxic gaseous pollutants (Farmer, 1993; Eller, 1977). A study on the effect of dust on photosynthesis and its significance for plants (Thompson *et al.*, 1984) found that photosynthesis and leaf diffusion resistance was reduced at 5 to 10 g dust per m² leaf surface. Given that predicted dust deposition contours indicate that levels of less than 0.5 g/m²/month would be experienced (Pavel Zib and Associates, 1997) at the main bird breeding areas some 4.5 km from the proposed MLA area, vegetation species diversity and abundance is unlikely to be deleteriously affected.
- A range of air quality safeguards are to be employed to reduce emissions of atmospheric dust from the Project. These safeguards are based on current control techniques as recommended for open pit mining in NSW by the EPA.
- During the construction phase standard dust control measures would be implemented including intensive watering, road surfacing and restricting the speed of vehicles travelling on unsealed surfaces.
- No firm policy or guidelines exist on the noise levels considered acceptable, or conversely, the level or character of noise that may disturb or otherwise affect the primary ecological components of bird species (Richard Heggie Associates, 1997). Airblast associated with blasting has the potential to affect birds (Richard Heggie Associates, 1997).
- Numerous studies have been undertaken on the effects of noise on wildlife (Shaw, 1978; Busnel, 1978; Ames, 1978; Lynch & Speake, 1978; Allaire, 1978; Streeter *et al.*, 1979, Algers *et al.*, 1978 in Richard Heggie Associates, 1997; Poole, 1982 in Richard Heggie Associates, 1997). In essence the studies indicate that many species are well adapted to human activities and noises.
- Birds tend to habituate to constant, steady noise levels, even of a relatively high level in the order of 70 dBA (Richard Heggie Associates, 1997).
- A review of a number of relevant studies (Heinemann, 1970; Stadlerman, 1958 in Richard Heggie Associates, 1997) found that the effects of airblast have been observed in birds at levels of approximately 131 dB – 140 dB Linear and above (Richard Heggie Associates, 1997). The predicted level of airblast at 1.5 km from the Project is 107 dB Linear. This level of airblast is 45 times and 16 times, respectively, lower than the documented levels of 140 dB and 131 dB Linear (*ibid.*). At 4.5 km distance (*ie.* at the main waterbird breeding area) the level is 95 dB Linear (Appendix H).
- The noise impact assessment for the Project (Richard Heggie Associates, 1997) found that the maximum adverse conditions contributed noise level at 1.5 km (the closest conceivable bird breeding areas of significance on Lake Cowal) was 53 dBA during construction (L_{A1}) (*ie.* the level exceeded for 1% of the time). This level is clearly well below (more than 7 times lower) than the level of 70 dBA, above which, some degree of environmental changes in birds have been observed (*ibid.*). During operations the maximum predicted contributed noise levels under adverse conditions were even lower; 45 dBA (at 1.5 km) and <30 dBA (at 4.5 km) respectively.
- To reduce the impact of noise on the surrounding environment, blasting and noise emissions are to be within EPA standards.
- Little information is available on the potential impacts of lighting on wildlife and specifically, birds. Potential impacts of lighting at the proposed development however are likely to focus on the alteration (in some instances an increase) of forage zones, primarily for insectivorous bird and bat species.
- The presence of lights and concentrations of bats may increase the incidence of predation on them by owls (Greg Richards and Associates, 1997b). Although there appears to be little study on the topic, there have been numerous observations of bats appearing to forage above the lights for the majority of the time (*ibid.*). Apparently bats seldom cross the light cone except when chasing insects (Belwood and Fullard, 1984, Schnitzler *et al.*, 1987, Kronwitter, 1988, Hickey and Fenton, 1990, Rydell, 1991; all in Greg Richards and Associates, 1997b), which is assumed to be a predator avoidance strategy (Hickey and Fenton, 1990 in Greg Richards and Associates, 1997b).

- Bird mortality on cyanide-bearing tailings storage facilities is recognised locally and internationally as an environmental problem (Hansard, 1995; Kay, 1990; Donato, 1997). The results of study and research conducted by Donato (1997) indicate that at levels of CN exposure below 50mg/L CN_{WAD}, mortalities approach zero. The findings of the Donato (1997) study support other published information that reducing CN_{WAD} concentrations to below 50mg/L reduces mortalities in open impoundments. For example, Henny *et al.* (1994) recorded no mortalities below 59 mg/L CN_{WAD} concentration in a study in North America. Above this concentration, mortalities increase significantly.
- Following consultation with a number of regulatory bodies and recognised experts, potential bird mortality as a consequence of CN toxicity, is to be mitigated to the greatest possible extent by destruction of CN. The destruction process is designed to result in CN levels in the tailings storages of less than 20 mg/L for 90% of the time and 30 mg/L for the remainder of the time. This level is in accordance with EPA criteria for the Project.
- A site specific monitoring programme is to be implemented, whereby tailings storages are to be patrolled twice a day every day for evidence of fauna being affected by tailings water.
- With regard to the potential for adverse impacts to occur when bats consume water from cyanide tailings storages, bat mortality at tailings dams at gold mines in the United States have been recorded (Clark, 1991), at unknown cyanide levels.
- Research on the toxicity of cyanide to bats (Clark *et al.*, 1991) found that Little Brown Bats (*Myotis lucifungus*) have an LD₅₀ sensitivity of 8.4 mg of sodium cyanide per kilogram of body weight (mg/kg). As a comparison, the LD₅₀ for the Mallard Duck is 1.48 mg/kg.
- There is evidence that cyanides are neither mutagenic, teratogenic, nor carcinogenic (Ballantyne, 1987), nor is there any biomagnification in living organisms, apparently due to its rapid detoxification. Detoxification occurs when absorbed cyanide metabolises through transulfuration in the presence of enzymes to produce thiocyanate which is excreted. This is a rapid process and animals can apparently ingest high sub-lethal doses of cyanide over an extended period without harm (Eisler, 1991).
- The detoxification process in a bat could be expected to be similar to the processes in other animals. No accumulation of cyanide is therefore expected.
- In conjunction with a monitoring programme to determine the usage of tailings storage areas by bats, contingent bat exclusion mechanisms would be developed if required. This could entail strategic emplacement of sensor-activated units to emit bursts of ultrasound to "jam" echolocation signals of microchiropteran bats. Radio-tracking of individuals could be incorporated into the mitigation measures to test the necessity and efficiency of any mechanisms employed.
- As a further contingency, cyanide levels could be reviewed and if necessary altered at the destruction point.
- Impacts associated with potential bird strike and mining infrastructure relate primarily to electricity transmission line collision. Research on avian mortality caused by electricity transmission lines (eg. Faanes, 1987; Anderson *et al.*, 1977; Beaulaurier, 1981; Kingsford, 1990; Longworth & McKenzie, 1987; Rusz *et al.*, 1986; Murray & Winning, 1992; CSIRO, 1996) indicates that in the absence of pre-planning and assessment, inappropriate alignment of lines can result in significant bird mortality.
- In a study of transmission line bird strike management at Lake Cowal (CSIRO, 1996) it was found that although there are variations in the response of birds from location to location and species to species, there are a number of common engineering design and siting considerations which are critical to lowering the frequency of bird strikes.
- In order to minimise bird strike the transmission line siting and design features should include (where practicable): identify significant bird habitat and minimise proximity of powerlines by a preferred 400 m; avoid as many over-water crossings as possible; place lines adjacent to and near the base of hills, rows of trees or cliffs to provide a natural screen that birds would automatically fly over; share the same easement as existing similar lines as long as the vertical dimension of the strike zone is not increased in foggy areas; place lines parallel to prevailing winds; decrease the vertical dimension of the stacked powerlines by placing wires in a horizontal array; visual aids such as orange PVC balls and coloured vibration dampers can be used in open areas of higher bird-strike potential although their success may be based more on human perception than verifiable evidence (Rusz, 1990 in CSIRO, 1996); and in flight path areas use fast-growing trees along the transmission line easement to create a visual screen and barrier to bird flight.
- In regard to vegetation clearance the following approximate areas would be disturbed as a result of the proposed development: 35 ha of Eucalyptus Woodland; 700 ha of predominantly cleared agricultural land with scattered Bimble Box Woodland; 20 ha of Fringing River Red Gum; 100 ha of Lake bed; 50 ha Mixed Woodland; and 35 ha of Wilga Woodland.
- The Project area would be rehabilitated by revegetating the new landforms with selected communities of endemic vegetation that are both suitable to the physiographic and hydrological features of each landform, whilst expanding on the areas of remnant endemic vegetation that currently exist in the immediate region.

- Potential impacts generally associated with the removal and/or modification of areas of habitat relate to loss of resources that contribute to the lifecycle components of an array of fauna (ie. breeding, foraging, dispersal etc.). The proposed development would entail the loss of portions of the following potential habitat areas: lakebed; riparian zone; cleared land with scattered woodland; and vegetated slopes.
- Rehabilitation of the Project area would result in expansion of habitat opportunities for wetland and terrestrial fauna species, primarily due to the establishment of a greater extent of endemic vegetation. A greater diversity of habitat types would become available (possibly increasing species diversity) and the extent of habitats would increase.

Section 7 – Rehabilitation

Summarising Section 5 of the EIS this section of the SIS outlines rehabilitation strategies proposed for the Project. Philosophies, objectives and protocols relating to land clearance, soil and waste handling, erosion and sediment control are presented. Final landform and revegetation development concepts are detailed for the new lake foreshore; mine waste emplacements, final void, tailings storages and infrastructure areas. Rehabilitation maintenance and monitoring is also detailed.

Key components or findings include:

- The rehabilitation philosophy for the Project is to operate as a non-intrusive land user and to create stable rehabilitated landforms that increase the areas of endemic vegetation in the Project area and the status of terrestrial-aquatic habitats.
- Revegetation of the final landforms would be with local native vegetation communities, selected specifically for their suitability to the created elevation, substrate conditions and the overriding objective of re-establishing local native vegetation on the Project area.
- The new Lake foreshore comprises a temporary isolation bund, lake protection bund and lower batter of the perimeter waste emplacement and the intervening section of lakebed between the temporary isolation bund and the lake protection bund.
- With respect to the new Lake foreshore the creation of a freshwater ecological community is an aim of the rehabilitation programme. Freshwater communities such as waterfowl habitat are composed of four types of zones (Braithwaite, 1975): flood zone; littoral zone; rush zone; and permanent water zone.
- The revegetation proposals for waste emplacements aim to re-establish the endemic, remnant woodland, shrub and grassland communities that characterise the wider region (after Sivertsen and Metcalfe, 1995). The communities include Watercourse – Riverine Floodplain, Flat to Gently Undulating Slopes, Low Ridges and Hills and Hill Tops and Elevated Land.

Section 8 – Long Term Compatibility

This section provides a summary of the relevant components of the long term compatibility study undertaken for the Project, as presented in Appendix N of the EIS. Specifically, a summary is provided of the findings of long term ecological compatibility assessment of the Project with the critical conservation values of the Lake, compiled by Goldney *et al.* (1997).

Key components or findings include:

- The long term health and biodiversity of the Lake system is most likely already being negatively influenced by cumulative regional land uses. These include grazing, cropping, irrigation and other agricultural practices, flow regulation and water use patterns in the Lachlan catchment.
- The phenomenon of “ecological lag” (ie. the time lapse between action and ecological impact created by the natural resilience of an ecological system) is likely to be evidenced in any long term wide ranging study of the Lake. Such effects would likely be demonstrated by increases in regional soil and water salinity, the presence of chemicals and changes in species diversity in the Lake system.
- Lake usage and intrinsic value as a wetland habitat is already variable from year to year as a result of the combination of natural (seasonal/climatic) events and induced (eg. river regulation) cycles. The ramifications of these influences may take considerable periods of time to become evident.
- Despite these influences the Lake remains a valued and diverse natural asset which would benefit strongly from the development and implementation of a long term management and protection strategy.
- Like many other lakes in Australia, Lake Cowal's value to bird life relates to its shallow depth and to the cycles of flooding and drying that have occurred over a large period of time. As a consequence of evaporation of innumerable floodwaters, a rich store of nutrients has accumulated.
- Integral to the Lake's ecology is its periodic drying which results in the release of nutrients in mineral form from the built-up organic matter. When the lake fills after a period of drying, it is these nutrients that generate the temporary bloom of aquatic life on which many birds thrive. When Lake Cowal is dry, contains little water or otherwise has become less productive of aquatic life under relatively stable water level conditions, wetland habitats of other inland river floodplains provide this critical resource.
- As a wetland system Lake Cowal provides, albeit episodically and for relatively short periods of time, habitat for wetland bird life that is of national significance.

- Mine landforms that are located proximal to or within the Lake's foreshore would not impinge on nor reduce to any significant degree the Lake's breeding habitat, size or habitat diversity.
- The Lake protection bund can be reformed as a new expanded foreshore and ecotone (ie. the terrestrial/wetland interface), increasing existing habitat and species diversity potential.
- The presence of the final void is likely in the long term to create a saline "sink" which would develop its own simple but persistent ecosystem adjacent to the Lake. Some impact on individual birds and other fauna could occur as a result of direct long term use of void waters by occasional individuals, although it is not likely to be of sufficient extent or frequency to impact population survival.
- Lake Cowal meets the criteria for Ramsar listing and proximity to a mining development does not disqualify its future nomination. The mine could be developed and rehabilitated in such a way that the ecological character (and value) of the wetland is not affected.
- The location of an electricity transmission line between the Nerang-Cowel and Lake Cowal bird habitats is likely to result in significant mortality. The relocation of the line to source Project power requirements from Temora to the south has effectively eliminated this risk.
- Any short-term increase in competitor or feral animal and weed species as a result of new landforms (eg. bunds, waste emplacements, final void, and tailings storages) is an inevitable part of ecosystem development and is not considered a significant long term conservation issue. Rehabilitation/revegetation plans based on ecological principles can be designed to enhance long term native species habitat, compared to the modified habitats occurring around the Lake today which favour introduced and feral species.
- A mine located in the Lake Cowal catchment has the potential to act as a catalyst for the development and implementation of catchment management and Lake protection measures considered desirable for the long term health of the Lake.
- Vegetative and faunal habitats that are modified from the natural conditions exist today in the Lake and surrounding ecosystems. The existing landscapes have been modified by a combination of human settlement, clearing, fire and pasture improvement practices.
- Woodland habitat area has been significantly reduced from that which existed prior to the introduction of broad acre farming and grazing. Remnant ridge top vegetation and woodlands proximal to the mine area exist on road reserves, Cowal West Hill and Wamboyne Mountain (ridge top vegetation) and in scattered isolated remnants.
- Weed species are commonly found in association with native and introduced grass cover and in woodland or ridge top tree-dominated areas (eg. Wamboyne Mountain) that have been disturbed by grazing.
- Uncleared patches of woodland with grassy understorey are not well-represented and are of high conservation value.
- Rehabilitation designs for the bund and mine landforms near to the Lake have considerable potential to enhance the dryland/lake ecotone interface via ecologically-driven revegetation strategies. This would have the effect of extending the existing shoreline length and replacing riparian and wetland vegetation removed by past clearing practices.
- Likewise, rehabilitation strategies for the remaining terrestrial components of the waste emplacement and the entire tailings storage and services areas can include the re-establishment of a greater area of woodland and grassland than currently exists, negating any impact on long term woodland conservation values.
- The impact of feral animals and weeds on terrestrial habitats as a result of these rehabilitation actions is considered negligible.
- Overall, the risk of mine development affecting terrestrial habitat conservation values is considered to be negligible given the successful implementation of appropriate rehabilitation strategies and designs. In fact, enhancement could be foreseen with the implementation of ecologically sound rehabilitation strategies.

Section 9 – Social and Economic Aspects

In accordance with the requirements of the Director-General, this section provides a summary of a report on the social and economic significance of the proposed development at the local, state and national levels (CIE, 1997), presented as Appendix K of the EIS.

Key components or findings include:

- The Cowal Gold Project would produce in Bland Shire:
 - a reduction in the rate of decline in population;
 - gains in population in the critical 20-40 years age group;
 - significantly improved job opportunities leading to a reduction in a migration corrected measure of unemployment;
 - more than 100 per cent increase in the value of resource production in the shire;
 - improvements in health service funding and staffing; and
 - large gains to local government revenues.
- The number of jobs created by the mine and potentially open to local residents would equate to the size of the present pool of (measured) unemployed in the shire.
- There would be a clear gain in population in the 20-34 years age group compared with a no mine scenario. This would yield significant gains to the community of Bland Shire in terms of improved prospects for health, education and general retail activity.

- There would be an increase of around 12 per cent in the shire of pre and primary-aged children, compared with a no mine scenario. An increase in high school aged children would occur beyond the ten year horizon.
- An injection of population in the critical young adult age group would help to break the vicious circle affecting the provision of medical and hospital services.
- By the year 2007, the population of Bland Shire is expected to be 484 persons higher than if there were no mine.
- At a broader economy level, modelling indicates that the mine would produce an increase in New South Wales Gross State Product of \$190 million and create in the order of 740 jobs statewide.
- Specifically, the Cowal Gold Project would provide approximately 180 jobs and \$9 million in wages and salary in the region, with the construction phase of the project providing up to 300 jobs and around \$220 million in capital expenditure.
- The flow-on effects of the Cowal Gold Project could give rise to an additional 52 jobs and \$4 million in income throughout the shire.
- Expenditure in the shire induced by new wage and salary payments could be as high as \$5.1 million a year. This represents 25 per cent of the estimated current retail turnover in Bland Shire.
- Around \$22 million of the construction expenditure would occur within the shire. Temporary accommodation of workers could increase accommodation takings in the shire by up to \$3 million.
- The mine is expecting to incur \$79 million a year in non-labour operating expenses. If the experience of the Northparkes Mine (Parkes Shire) is an indication, then Bland Shire could conservatively gain from an estimated \$7.1 million of direct expenditure by the mine in the shire.
- Over the life of the Project the mine is estimated to produce total output to the value of \$1.3 billion. It is expected to outlay a total of \$905 million in operating expenditure comprising \$305 million in mining related expenditure, \$509 million in processing related expenditure, \$32 million in royalties and \$59 million of other expenditure.
- Additional benefits to the community from the mine include improvements to the viability of the current air service and increased activity in the residential property market where turnover has been low.
- A direct demand of 30 houses by North would provide a large, positive boost to the flat residential property market in West Wyalong. Property turnover would stimulate the real estate services sector.
- By providing sustained increases in demand, the establishment of a mine in Bland Shire would tend to increase the confidence of business in their employment and investment decisions.

Section 10 – Legislative Requirements

This section summarises the relevant legislative requirements for the ecological aspects Cowal Gold Project, as detailed in Section 1 of the EIS.

Key components or findings include:

- Relevant project permitting and approvals include:
 - *Environmental Planning and Assessment Act 1979*
 - *Threatened Species Conservation Act 1995*
 - *Fisheries Management Act 1994*.
- This Species Impact Statement (SIS) has been prepared under the auspices of the *Threatened Species Conservation Act 1995* (TSC Act) and the requirements of the Director-General of the New South Wales (NSW) National Parks and Wildlife Service (NPWS), dated 7 November 1997 (Attachment A1).
- Table ES-1 presents a summary of the Director-General's requirements and the appropriate sections of the SIS where they are addressed.

Section 11 – Alternatives Considered

Summarising Section 1 of the EIS, this section briefly discusses the alternatives considered in development of the proposed Project.

Key components or findings include:

- North have analysed the Project at a range of scales and the application of a number of defining criteria into the analyses has resulted in the emergence of an optimum-sized Project.
- From an environmental perspective, there are no advantages to operating a significantly smaller or larger Project than that proposed as only the life of the Project changes and not the overall potential impacts of the Project.
- The distribution of the gold mineralisation at the Cowal Gold Project does not lend itself to underground mining as gold ore initially occurs near surface and is not contained in discrete veins of significant width.
- No economic quantities of gold occur west of the Lake's full storage level (ie. the open pit cannot be moved to avoid intrusion into the Lake).
- With respect to Project water supply, alternative pipeline routes have been assessed and include a route around the Lake (as opposed to across it). On balance, it is concluded that a pipeline buried or laid across the Lake placed under the terms of an appropriate Environmental Management Plan can be justified and would result in less disturbance to creeks and landholders than the longer routes.
- As a consequence of an options study, on-site power generation utilising gas or diesel could not be justified on economic grounds and the selected power supply option is an electricity transmission line from Temora. Appendix D presents the EIS for the electricity transmission line proposed by Great Southern Energy (GSE) and provides further information on power generation and electricity transmission line route options.

Table ES-1 New South Wales National Parks and Wildlife Service Director-General's Cowal Gold Project SIS Requirements and SIS Reference Summary Table

Issue to be Addressed and Information to be Included	Main Text Reference	Attachment Reference
<i>The Proposal and Surrounding Areas</i>		
A topographic map of the locality detailing the location of the proposal, any locally significant areas for threatened species such as parks and reserves, and areas of high activity such as townships, regional centres and major roads.	Figures A-1, A-2, A-3, A-9	
The type of action proposed shall be detailed, including the timetable for carrying out of the proposed development and the number of hectares affected.	Section 2	
A plan of the subject area to be provided showing the location and type of vegetation communities present within the subject area and the scale of the plan.	Figure A-11	
A colour aerial photograph of the locality shall be provided showing the subject site and the scale of the photography.	Figures A-3, A-4, A-5	
<i>Initial Site Assessment</i>		
A list of subject species shall be provided. Consideration shall be given to the habitat types present within the study area, recent records of threatened species in the locality and the known distribution of threatened species.	Section 5	
In defining the study area consideration shall be given to possible indirect effects of the action on the area surrounding the subject site (eg. altered grazing patterns of native and introduced herbivores, altered hydrology regimes or soil erosion).	Sections 4, 6	
In describing the study area consideration shall be given to the previous land uses and the effect of these land uses on the study area.	Section 4	
A description of fauna habitat components such as the frequency of tree hollows, presence of logs and groundcovers, density and structure of understorey vegetation, soil types and presence of water points etc. shall be given. Fauna habitat for subject species shall be described with particular reference to those components of the habitat that are used and for what purpose (feeding, roosting, nesting etc.).	Sections 4.2.1, 6.14	
<i>Threatened Species Survey Methods</i>		
A fauna and flora survey is to be completed in the study area. Targeted surveys shall be conducted for all subject species. A recognised authority such as the Australian Museum for animals and the Royal Botanic Gardens for plants shall confirm species of taxonomic uncertainty.	Sections 4.1.1, 4.2.2	
A full description of the methodology used in the fauna and flora surveys and habitat assessment shall be provided, including survey techniques and effort employed, number and location of traps, size of survey sites, dates of surveys, the time spent on surveys and weather conditions. Where possible, surveys should be undertaken during seasons and climatic conditions during which the subject species are most likely to be detected.	Sections 4.1.2, 4.2.2	
Any areas which may act as corridors or habitat links between the study area and adjacent areas of likely habitat for subject species shall be identified and described.	Section 4	
A full list of the flora and fauna found during the course of surveys shall be included. Such information is indicative of the habitat quality of the site.	Section 4	A3, A4, A5, A6, A7
The effect of the season and weather shall be considered with respect to the results of the survey.	Section 4.2.3	
<i>The Habitat of Threatened Species</i>		
The location of any threatened species recorded during the SIS survey shall be represented on a map of the study area.	Figure A-16, Section 5.2	
A description of the habitats occupied within the region by each of the subject species should be provided. This description should include not only floristic and structural information but also information on the condition of the habitats.	Sections 3.4, 4.1.1, 5.1, 5.3	
In the same way, a description of the habitats occupied within the study area by each of the subject species should be provided. A comparison of the available habitats within the study area in relation to the region should then be undertaken.	Sections 4.1.2, 4.2.1	
The habitat of each of the subject species within the study area shall be represented on a map.	Figure A-12	
As far as possible, the distribution of the local population of each threatened species recorded from the study area should be determined.	Section 5.2	
The condition of the habitats should be determined, described and recorded, eg. structural complexity of the vegetation, evidence of grazing/browsing damage, presence of flora species susceptible to grazing, fire history. The condition and regional distribution of similar habitats outside the study area should also be recorded.	Sections 4.2.1, 6.15	
<i>Matters of Social and Economic Impact</i>		
The economic costs likely to be incurred and the benefits likely to accrue to the proponent as a result of this development shall be addressed in the SIS. This shall include a discussion of the sensitivity of the analysis to any assumptions made in the calculation of the benefits/costs.	Section 9	

**Table ES-1 New South Wales National Parks and Wildlife Service Director-General's Cowal Gold Project
SIS Requirements and SIS Reference Summary Table Continued**

Issue to be Addressed and Information to be Included	Main Text Reference	Attachment Reference
<i>Matters of Social and Economic Impact</i>		
An evaluation of the social consequences of the development shall be carried out. This would consider who gains and who loses from the action and where those people are located, ie. distributional considerations. Social impacts may include those that affect the net welfare of society and those that impact on the individual or group. With respect to the proponent this analysis may require consideration of the management of other lands under his control.	Section 9	
<i>Matters of Ecologically Sustainable Development</i>		
The principles of ecologically sustainable development, are described in section 6(2) of the <i>Protection of the Environment Administration Act 1991</i> must be addressed. The SIS must seek to demonstrate how this development satisfies these principles or how the development could be modified to address these principles.	Section 1.4	
The regional context of the effects of this development on ESD principles must also be considered.	Section 1.4	
<i>Assessment of Likely Impacts</i>		
The assessment matters listed below shall be addressed:		
For all subject species, the SIS shall state the following:		
the location, nature and extent of habitat removal or modification which may result from the proposed action; and	Sections 6.13, 6.14	
the potential impact of the removal of habitat on the species, population or ecological community; and	Sections 6.13, 6.14	
other potential impacts, both direct and indirect, upon threatened species that may occur as a result of the proposal; and	Section 6	
the likely contribution of the proposed action to the threatening processes acting on populations of those species in the locality.	Section 6	
measures proposed to ameliorate the impacts of the proposal.	Section 6	
A discussion of other populations of subject species in the region shall be provided. The long term security of the other habitats shall be examined as part of this discussion. The relative significance of the subject site for subject species in the local context shall be provided.	Sections 5.2, 5.3, 6.15	
If movement corridors for subject species are present within the subject site, the impact of the proposal on these areas shall be discussed.	Section 6	
<i>Amelioration</i>		
The following issues shall be addressed:		
In discussing alternatives to the proposal, and the measures proposed to mitigate the effect of the proposal, consideration shall be given to developing long term management strategies to protect areas within the study area which are of particular importance for the subject species. This may include proposals to restore or improve habitat.	Sections 6, 7, 8, 11	
Any proposed on-going monitoring of the effectiveness of the mitigation measures shall be provided.	Section 7.4	
In providing a list of other approvals the following shall be included:		
- any consent required under Part 4 of the <i>Environmental Planning and Assessment Act 1979</i> including the name of the consent authority and when it is proposed to make the development application; or - any approvals required under Part 5 of the <i>Environmental Planning and Assessment Act 1979</i> including the name of the determining authority(ies), the basis for the approval and when these approvals are proposed to be obtained.	Section 10	
<i>Form of Species Impact Statements</i>		
A species impact statement must be signed by the principal author of the statement and by:	See inside front cover	
- the applicant for the licence; or - if the species impact statement is prepared for the purposes of the <i>Environmental Planning and Assessment Act 1979</i>, the applicant for development consent or the proponent of the activity proposed to be carried out (as the case requires).		
<i>Content of Species Impact Statements</i>		
A species impact statement must include a full description of the action proposed, including its nature, extent, location, timing and layout and, to the fullest extent reasonably practicable, the information referred to in this section.	Section 2	
A species impact statement must include the following information as to threatened species and populations:		
a general description of the threatened species or populations known or likely to be present in the area that is the subject of the action and in any area that is likely to be affected by the action;	Section 5	

**Table ES-1 New South Wales National Parks and Wildlife Service Director-General's Cowal Gold Project
SIS Requirements and SIS Reference Summary Table Continued**

Issue to be Addressed and Information to be Included	Main Text Reference	Attachment Reference
an assessment of which threatened species or populations known or likely to be present in the area are likely to be affected by the action;	Sections 5, 6	
for each species or population likely to be affected, details of its local, regional and State-wide conservation status, the key threatening processes generally affecting its habitat requirements and any recovery plan or threat abatement plan applying to it;	Sections 5.2, 5.3	A7
an estimate of the local and regional abundance of those species or populations;	Section 5.3	A7
a general description of the threatened species or populations known or likely to be present in the area that is the subject of the action and in any area that is likely to be affected by the action;	Section 5	A7
a full description of the type, location, size and condition of the habitat (including critical habitat) of those species and populations and details of the distribution and condition of similar habitats in the region;	Sections 4.1.2, 4.1.3, 4.2.1	A7
a full assessment of the likely effect of the action on those species and populations, including, if possible, the quantitative effect of local populations in the cumulative effect in the region;	Section 6	
a description of any feasible alternatives to the action that are likely to be of lesser effect and the reasons justifying the carrying out of the action in the manner proposed, having regard to the bio-physical, economic and social considerations and the principles of ecologically sustainable development;	Section 11	
a full description and justification of the measures proposed to mitigate any adverse effect of the action on the species and populations, including a compilation (in a single section of the statement) of those measures;	Section 6, Table A-19	
a list of any approvals that must be obtained under any other Act or law before the action may be lawfully carried out, including details of the conditions of any existing approvals that are relevant to the species or population.	Section 10	
A species impact statement must include the following information as to ecological communities: - a general description of the ecological community present in the area that is subject of the action and in any area that is likely to be affected by the action; - for each ecological community present, details of its local, regional and State-wide conservation status, the key threatening processes generally affecting it, its habitat requirements and any recovery plan or any threat abatement plan applying to it; - a full description of the type, location, size and condition of the habitat of the ecological community, and details of the distribution and condition of similar habitat in the region; - a full assessment of the likely effect of the action on the ecological community, including, if possible, the quantitative effect of local populations in the cumulative effect in the region; - a description of any feasible alternatives to the action that are likely to be of lesser effect and the reasons justifying the carrying out of the action in the manner proposed, having regard to the biophysical, economic and social considerations and the principles of ecologically sustainable development; - a full description and justification of the measures proposed to mitigate any adverse effect of the action on the ecological community, including a compilation (in a single section of the statement) of those measures; - a list of any approvals that must be obtained under any other Act or law before the action may be lawfully carried out, including details of the conditions of any existing approvals that are relevant to the ecological community.	Sections 3, 4, 5, 6	
A species impact statement must include details of the qualifications and experience in threatened species conservation of the person preparing the statement and of any other person who has conducted research or investigations relied on in preparing the statement.	Section 12	

1.0 INTRODUCTION

1.1 Background

This Species Impact Statement (SIS) has been prepared under the auspices of the *Threatened Species Conservation Act 1995* (TSC Act) and the requirements of the Director-General of the New South Wales (NSW) National Parks and Wildlife Service (NPWS), dated 7 November 1997 (Attachment A1).

This SIS is to accompany the Environmental Impact Statement (EIS) and Development Application (DA) to be lodged by North Gold (WA) Limited (North) for the proposed Cowal Gold Project.

In accordance with a NSW NPWS Information Circular (No. 3, 1996b), the principal purpose of this SIS is to facilitate identification of potential threatened species issues considered likely to arise as a result of the proposed development, therefore allowing for the provision of appropriate ameliorative measures.

1.2 Project Location

The Cowal Gold Project area (herein known as the Project area) is located on the western side of Lake Cowal in Central New South Wales, approximately 38 kilometres (km) north-east of West Wyalong and 55 km south-west of Forbes (Figure A-1). In total, the proposed Mining Lease Application (MLA) area covers approximately 2,650 hectares (ha) (Figure A-2). The Project area lies within the local government area of Bland Shire.

Figures A-3, A-4 and A-5 present aerial and oblique views of the Project area and surrounds.

1.3 Project History

North Limited commenced exploration along the western side of Lake Cowal in 1981. From 1988 to 1994, exploration effort was concentrated on the Endeavour 42 (E42) orebody to increase the size and confidence of the resource by infill and deep drilling. Over 550 drill holes have been placed in the deposit to enable definition of the mineralisation and the resource. It is the development of E42 which is the subject of the SIS and EIS.

In August 1995, North submitted a Development Application (DA) and an EIS for a proposal to mine E42. The Application was refused consent on environmental grounds, causing North to re-assess the environmental management and compatibility of the Project with Lake Cowal from "first principles".

In developing the Project from first principles a range of development scenarios were examined (summarised in Section 11 of this document) and a study into the Project's compatibility with critical conservation values of Lake Cowal over the long term was completed (reported in Appendix N of the EIS). North also re-examined consultation objectives for the Project which are detailed in Section 1.2 of the EIS.

Major outcomes from this process were:

- an additional process being added to the mill, resulting in a significant reduction in the use of cyanide;
- introduction of new cyanide destruction technology and increased recycling of cyanide within the mill;

- movement of the tailings storages further away from the edge of Lake Cowal;
- reduction in the number of tailing storage cells from four to two;
- a new electricity transmission line corridor from Temora to the south of Project (to avoid Lake Cowal-Nerang Cowal habitats);
- more detail on the rehabilitation concepts;
- a *Statement of Intent* which documents the above and other commitments and details how North would conduct its activities during the assessment of the new Project DA.

The 1997 EIS, SIS and new DA for the Cowal Gold Project represents North's reassessment and re-design initiatives and proposes a new Project which is philosophically and physically different in several key areas.

1.4 Ecologically Sustainable Development

Ecologically sustainable development (ESD) is defined by the Commonwealth of Australia's National Strategy for ESD (1992) as using, conserving and enhancing the community's resources so that ecological processes, on which life depends, are maintained and the total quality of life now and in the future, can be increased.

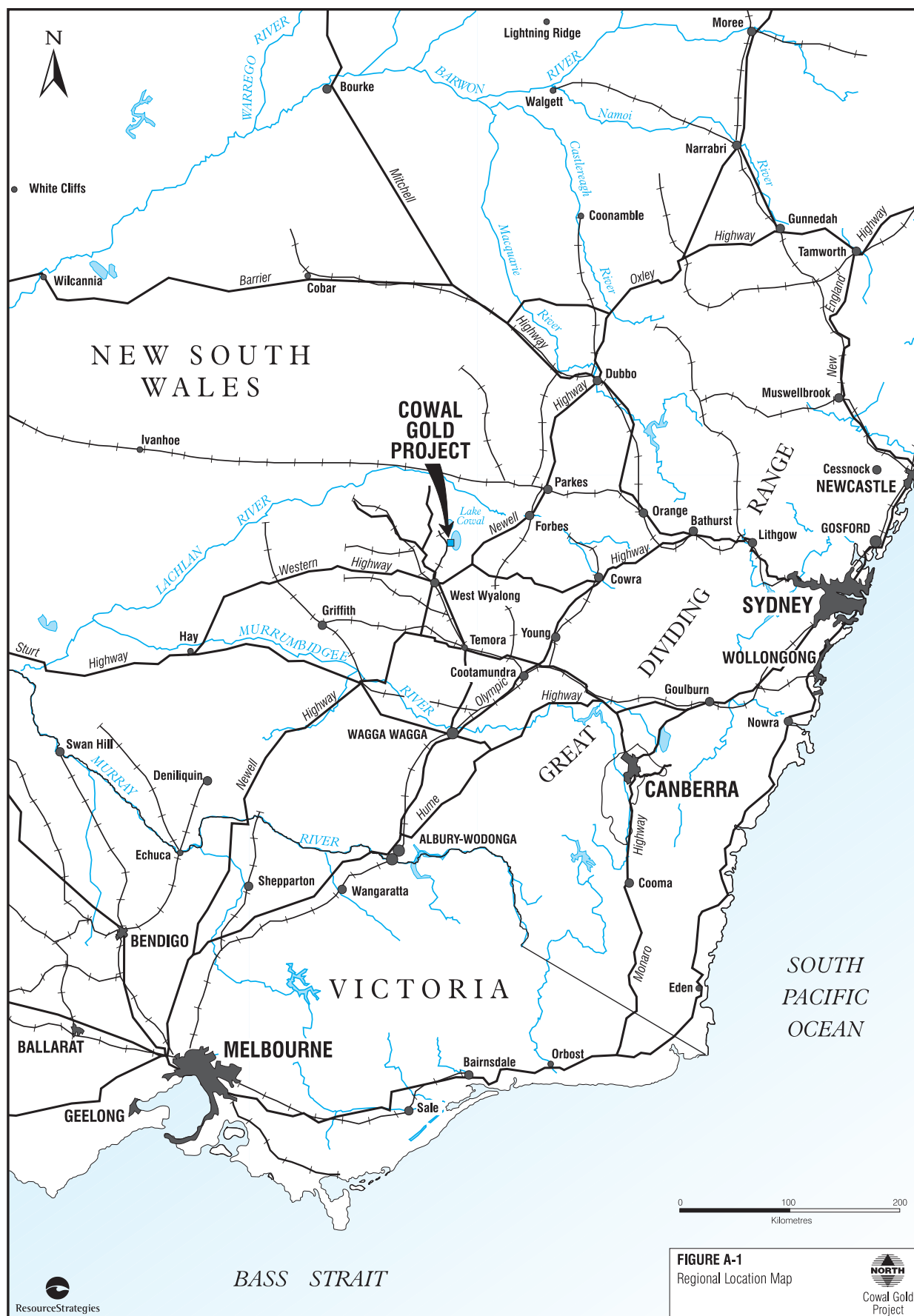
The principles of Ecologically Sustainable Development are described in the *Protection of the Environment Administration Act 1991* (Section 6(2)) and are as follows:

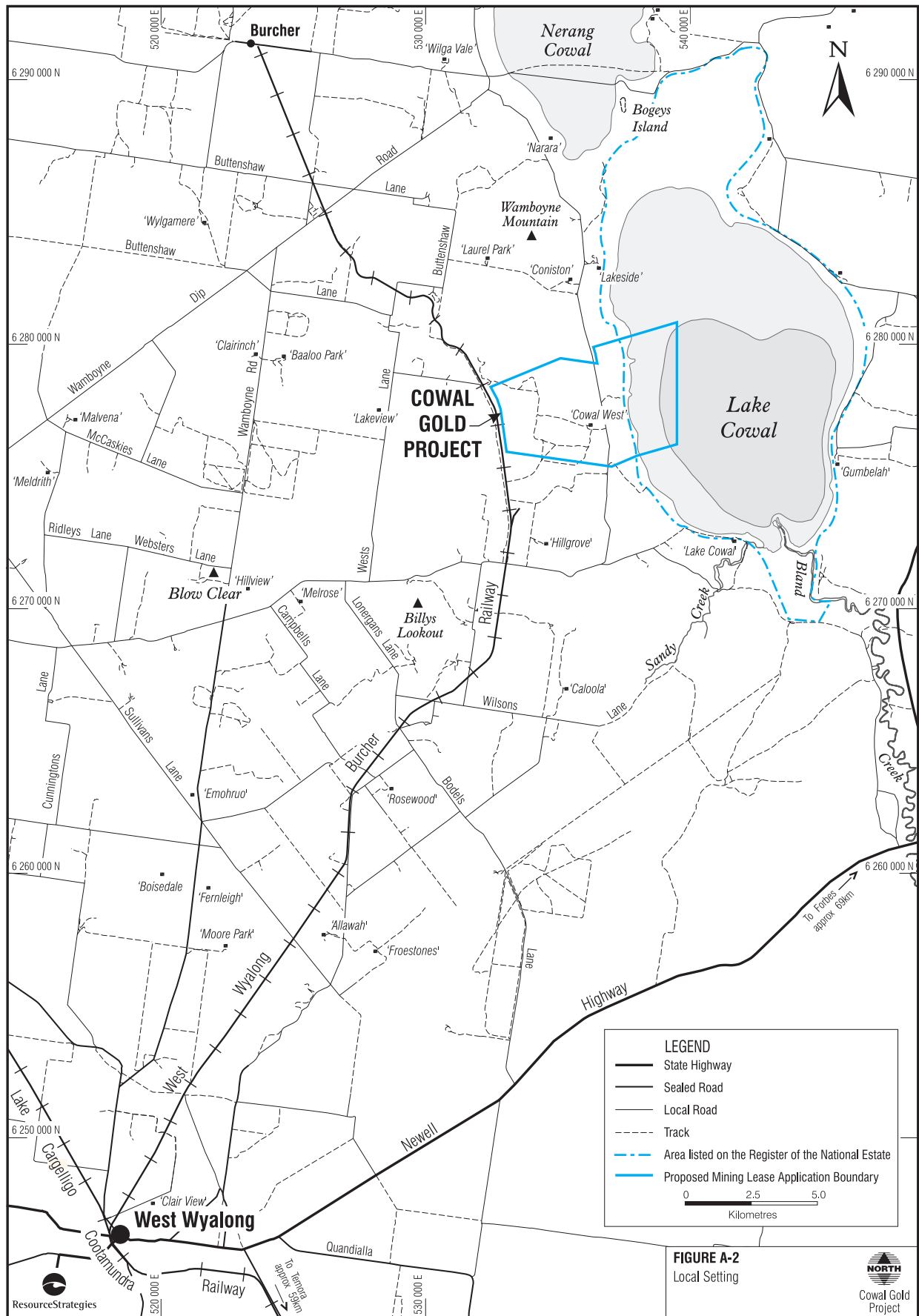
- The precautionary principle – namely, that if there are threats of serious or irreversible environmental damage, then a lack of full scientific certainty should not be used as a reason for postponing measures to prevent environmental degradation.
- Inter-generational equity – namely, that the present generation should ensure that the health, diversity and productivity of the environment is maintained or enhanced for the benefit of future generations.
- Conservation of biological diversity and ecological integrity.
- Improved valuation and pricing of environmental resources.

The Wetlands Policy of the Commonwealth Government of Australia (WPCG) (Department of Environment, 1997) notes that ESD represents one of the greatest challenges facing Australian government, industry, business and community sectors in the forthcoming years.

While it is widely recognised that there is no readily identifiable point where achievement of ESD can be recognised, the WPCG (Department of Environment, 1997) finds that two main features distinguish an ecologically sustainable approach to development:

- giving consideration, in an integrated way, to the wider economic, social and environmental implications of decisions and actions taken, for the local, national and international community; and
- taking a long term view when taking those decisions and actions.

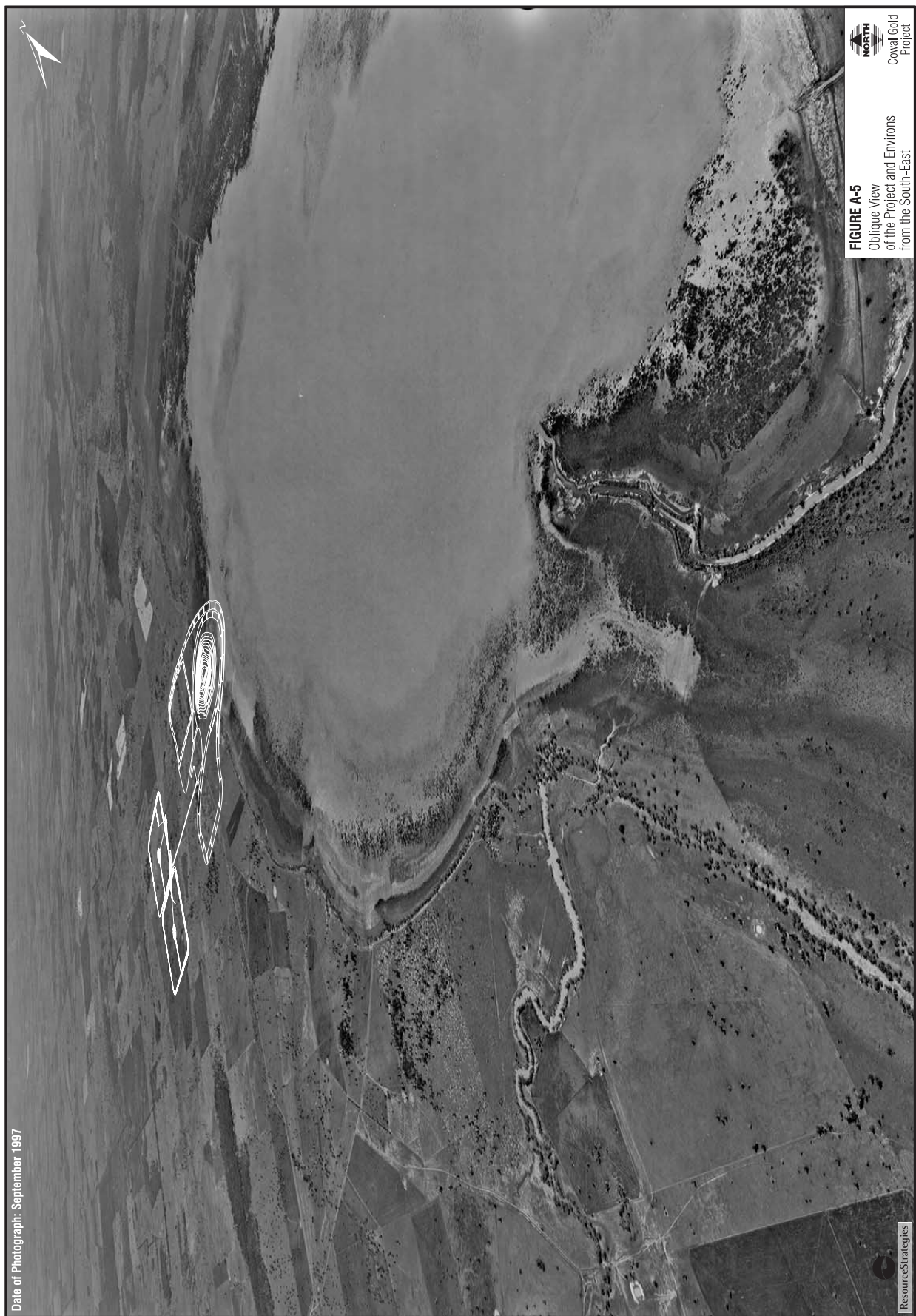




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The principles of ESD have been applied to all aspects of the Project and incorporated in Project planning and are contained in Section 1 of the Cowal Gold Project EIS and are presented below.

1.4.1 Precautionary Principle

1. The application of the precautionary principle to the mining proposal is described as:
 - adoption by the company of external and internal codes of practice, guidelines, standards and principles for exploration, environmental management, rehabilitation and community relations activities;
 - comprehensive study, planning, evaluation, and development of Project proposals;
 - extensive consultation with government, landholders and community groups;
 - objective and comprehensive environmental impact and risk assessment of Projects;
 - comprehensive environmental management systems;
 - research and development programmes; and
 - industry environmental review, education and knowledge-sharing networks.

All of the above aspects have been incorporated into the Project through the EIS process. The EIS and SIS has focussed on identifying all risks to the Lake Cowal environment even over the very long term.

2. Substantial effort has been made to identify all potential effects (both short and long term) thus minimising the risk of externalities arising as a result of the Project. Fauna issues have been thoroughly addressed within the EIS and SIS and management of mine wastes would ensure that environmental risks are minimal or negligible. Hydrological and long term compatibility issues have been similarly addressed.
3. There is significant potential for ESD in terms of North's commitment to implement innovative technologies which would further enhance waste rehabilitation, and improve the environmental efficiency of the mining operation. In recognition of precautionary principles, only proven Best Management Practice techniques have been incorporated into Project design and rehabilitation practices.
4. It is also anticipated that the development of DUAP conditions of consent for the Project would provide further assurance that ESD principles are consistently met.
5. The rehabilitation strategy designed for the Project utilises proven and innovative technology and is based on comprehensive hydrological, botanical and fauna studies.
6. Both proven and innovative technology has also been employed in the water management system planned for implementation at the commencement of the Project and for retention at the close of operation.
7. A monitoring programme would accompany the rehabilitation strategy to ensure no unforeseen deleterious affects occur on land and water systems.

1.4.2 Social Equity (Inter- and Intra-Generational) Issues

The proposed Cowal Gold Project meets the principles of inter and intra generational equity by:

1. Implementing water and waste management strategies which would mitigate the risks of environmental degradation to negligible levels, thus not foreclosing on options for future generations with regard to the use of natural resources.
2. Implementing measures which would ensure that natural resource values including biodiversity and ecological integrity are not undermined.
3. Undertaking that the development area would not be relinquished prior to the successful implementation of the rehabilitation plans; the details of which would be outlined in a Final Rehabilitation Report submitted for Department of Mineral Resources' approval. The nature of the disturbances are such that complete rehabilitation is possible, ie. there is no reliance on future technological innovation to complete rehabilitation of North lands.
4. Responding to concerns expressed by the community during public consultation.
5. Undertaking investigation and assessment of heritage values represented within the DA area, during which consultation with the West Wyalong Local Aboriginal Land Council was carried out.
6. Stimulating local and regional economies.
7. Providing valuable export earnings.
8. Rehabilitating approximately 930 ha of land during the mine life. In recognition of the four guiding principles of ESD, only proven technology in rehabilitation techniques have been adopted to enhance wildlife diversity (via endemic community revegetation plans, and foreshore reformation) and ecological integrity. Rehabilitated surfaces have the potential to be a valuable natural resource. The final void water resource may have the potential to provide an additional natural resource and habitat for some avifauna.
9. Reafforestation areas would represent significant environmental gains in terms of wildlife habitat values, securing land and soil structures, and an increase in net carbon sequestration capacity. The construction of suitable terrestrial and perhaps aquatic habitats in addition to those already available would provide further diversification.
10. The site would potentially offer valuable research examples of mine rehabilitation and habitat restoration/enhancement.

1.4.3 Biodiversity and Ecological Integrity Issues and Greenhouse Emissions

North Limited is a voluntary signatory to the Australian Government's Greenhouse Challenge programme aimed at reducing greenhouse gas emissions per unit of production.

By the end of 2001, Projects planned by North Ltd would save about 94,000 tonnes of CO₂ with tree-planting programmes expected to sequester an additional 32,600 million tonnes of CO₂. During the next four years North's total emissions would increase as a result of increased production, although emissions would be 17% below "no action" levels. Energy efficiency would significantly improve.

The proposed Lake Cowal development meets biodiversity, ecological integrity and greenhouse emissions by:

1. Rehabilitation efforts at the Cowal Project site (the gain of about 600 ha of woodland) would result in a net increase in CO₂ absorption capacity (in the order of 237,000 tonnes)¹. The amount of CO₂ produced by the operation would represent approximately 0.018% of the 1996 national greenhouse gas emission rate (currently estimated at 600 million tonnes).

The net gain of vegetated lands at the site would act as a carbon sink and provide a valuable natural resource for future generations, thus contributing to intergenerational equity and ecological integrity. An example of the benefits of woodland revegetation on site is the gain in carbon sequestration capacity within the waste emplacements. Presently a grassland community, the rehabilitation plan would see the establishment of tree cover on the site. Seed stock from local landscapes would be utilised for habitat enhancement for wildlife and to achieve a self-sustaining ecosystem which meets the long term goals of conservation of biodiversity and ecological integrity.

2. The mine site operational management plan has been designed such that the long term species diversity and abundance in the area is not compromised. Measures include:
 - an extensive rehabilitation and revegetation programme;
 - adoption of mine site and transmission line layout design to minimise clearance of areas of native regenerating vegetation;
 - implementation of water management systems designed to ensure the ecological integrity of the Cowal wetland system is not compromised; and
 - commitment to on-going monitoring to enable assessment of the impacts of the mine operation on endemic flora and fauna populations.

1.4.4 Improved Valuation and Pricing of Environmental Resources

1. North is aware of the Commonwealth and State Government Sustainable Development policy and/or legislation which seeks to apply values to natural resources as a means of integrating environmental costs into the impact assessment process.
2. Recognition of these concerns has been expressed by past Inquiries, however recognition also, of the difficulty in ascribing monetary values to many of the environmental issues considered.

¹ Calculation based on the Australian Methodology for the Estimation of Greenhouse Gas Emissions and Sinks, National Greenhouse Inventory Committee, Department of the Environment, Sport and Territories, 1994.

3. It is considered that the large extent of scientific investigations that have taken place at Cowal and the amount of future scientific research committed to in the EIS has and would continue to enhance and increase the value of the site's natural resources. This includes an expanded and publicly available scientific database.
4. To assist decision-making in this area, North has completed a Multi-Criteria Analysis of different development scenarios and their impact on different environmental values (Appendix K of the EIS, Attachment 1).

2.0 PROJECT DESCRIPTION

2.1 Mineral Resource

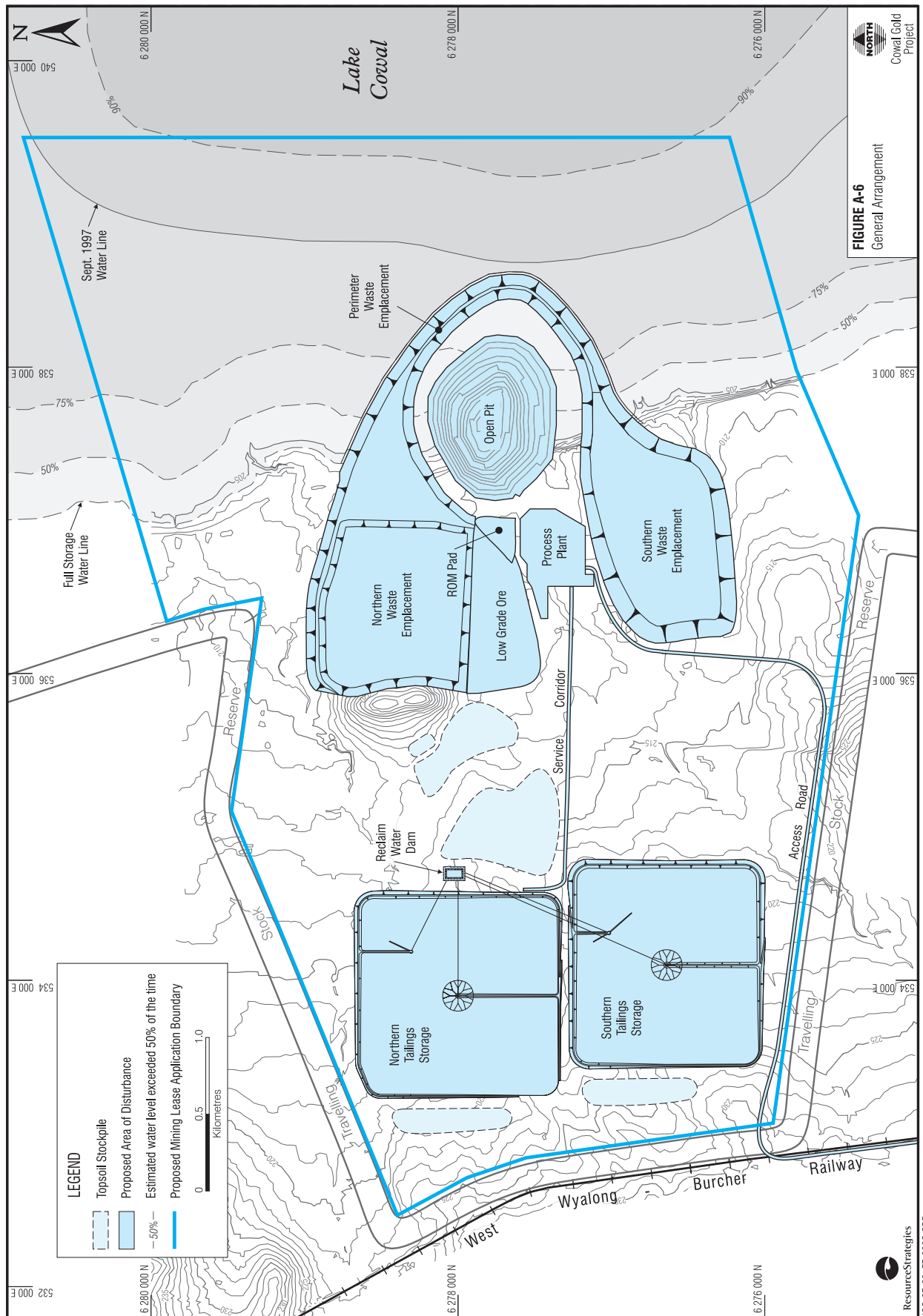
Some 76 Mt of ore (comprising approximately 3.2 million ounces of contained gold or 2.7 million ounces of recoverable gold) is to be mined and processed. The gold ore is differentiated into oxide (20%) and primary ore (80%). The two ore types would be selectively handled and separated during mining and processing due to the different mineral processing requirements for gold extraction.

2.2 General Arrangement

The general arrangement of the Cowal Project has been designed to minimise environmental impact using the following criteria:

- Incorporation of environmental considerations and enhancements into all Project components.
- Construction of appropriate structures to enable the secure, permanent diversion of up-catchment runoff, control of site water runoff and secure on-site containment of potentially contaminated water.
- Creation of a safe operating environment for employees, contractors and visitors (eg. through the separation of mine equipment and general traffic).
- Creation of a compact site layout in order to minimise the overall disturbance area and ore and waste haulage distances;
- Provision of all-weather access to major infrastructure components.
- Progressive rehabilitation of the mine site during operation and complete rehabilitation following cessation of mining.
- Rehabilitated landforms to be compatible with the ecological status and critical conservation values of the Lake and its immediate surrounds.

The general arrangement of the mine site during operation is shown on Figure A-6. Section 2 of the EIS presents the general arrangement of the mine site during construction (Year -1) and operational years (Years 1 – 13). Section 7 of this document presents further general arrangements showing how progressive rehabilitation is achieved as well as representation of final site rehabilitation.



The major components included in the general arrangement design are:

- Open pit;
- Processing plant and associated infrastructure;
- Run of mine (ROM) ore stockpile pad;
- Low grade ore stockpile pad;
- Tailings storages;
- Waste rock emplacements;
- Lake protection bund;
- Temporary isolation bund;
- Sedimentation and erosion control structures;
- Water supply borefield and connecting pipeline;
- Open pit de-watering borefield and associated pipelines;
- Power supply line;
- Main access road;
- Internal roads and haul roads;
- Administration/site office area;
- Sewage treatment plant; and
- Contractors areas.

In total, mining components and associated infrastructure would cover an area of approximately 940 ha.

The location and design of the mine site layout incorporates the following key attributes:

- Location of major infrastructure components (processing plant, ore stockpiles, waste emplacements) within a relatively small area adjacent to the open pit.
- Siting of the ore stockpile areas in close proximity to the processing plant.
- Location and design of the waste emplacements to form a low profile, stable final landform whilst at the same time, minimising haul distances from the pit.
- Design of a lake protection bund and temporary isolation bund between the Lake and the open pit that is revegetated immediately after construction is completed. The revegetated landform (new Lake foreshore) has been designed to enhance its long term stability and compatibility with Lake foreshore features (Section 5 of the EIS).
- Siting of two tailings storages approximately 3.5 km to the west of the pit.

An overview of the proposed mine development is presented below.

2.2.1 Mining Method Overview

The disseminated distribution of gold bearing veins, relatively low grades and geometry of the Cowal orebody means that the mining of the deposit lends itself to open pit methods rather than underground extraction. Open pit mining typically offers increased economies of scale by extracting larger tonnages of low grade ore and using relatively low cost bulk mining methods.

The open pit mining method proposed for the Cowal Project is typical of open pit mining operations throughout

Australia and the world. The waste rock (rock containing no commercial gold) and ore (rock containing commercially viable quantities of gold) is broken through a routine sequence of in-pit drilling and blasting. Broken rock is loaded into large rear dump trucks using hydraulic excavators and hauled from the pit to be placed within dedicated waste emplacements or, in the case of the ore, direct to the primary crusher or a run-of-mine (ROM) stockpile. A provisional mining and ore processing schedule for the Cowal Project is presented in Section 2 (Table 2-1) of the EIS. The open pit mining method allows for the progressive deepening and widening of the pit as overburden is removed and the orebody exposed. The Cowal open pit would be progressively developed (deepened and widened) during the eight years of mining. A detailed mining schedule is presented in Section 2 (Table 2-4) and a detailed processing schedule is presented in Section 2 (Table 2-6) of the Environmental Impact Statement.

2.2.2 Ore Processing Overview

Broken ore would be hauled directly (or if necessary transferred from the ROM pad) to a primary crusher located adjacent to the processing plant where it would be crushed to a nominal 175 mm. The crushed ore would be conveyed to a crushed ore stockpile before being transferred by conveyors to the grinding circuit (semi-autogenous grinding (SAG) mill and ball mill).

The finely ground ore follows separate processing streams depending on whether oxide or primary ore is being milled. Primary ore would pass through a flotation circuit where the gold containing sulphide minerals would be preferentially floated off as a concentrated "froth". This froth would be re-ground and transferred to a conventional Carbon in Leach (CIL) cyanide leaching circuit. The oxide ore would go directly to a separate and larger cyanide leaching circuit.

The gold extracted in the cyanide leaching circuit would be concentrated in the gold recovery circuit. The final product would consist of doré bars, which would be poured and temporarily stored in a dedicated gold room. The finely pulverised residual rock left over after flotation and leaching processes (tailings) would be treated to destroy cyanide to the prescribed limits then pumped to one of two tailing storages. Further detail on ore processing is presented in Section 2.6 of the EIS.

2.2.3 Associated Infrastructure Overview

Other infrastructure associated with mining and ore processing at the Cowal Gold Project includes the water supply system, power supply network, external access route and internal roads. Raw water requirements for the project would primarily be met through open pit dewatering, recycling within the processing plant and the tailings water decant and return system. Where the demand exceeds the available supply from these sources, make-up water would be pumped from an external groundwater borefield located approximately 20 km to the east-northeast. The borefield is located within the Bland Palaeochannel and would be linked to the project via a buried pipeline.

Electrical power supply to meet the demands of the project would be supplied by a new 132kV line to be constructed from Temora. Details of the electricity transmission line are given in Appendix D of the EIS. Road access to the site would be via an upgraded route from West Wyalong. Within the proposed MLA, haul roads and internal roads would be constructed as necessary to provide transport links between the processing plant, tailings storages, waste emplacements and open pit.

2.2.4 Mine Waste Management

Details of the waste management practices to be employed at the Project are contained in Section 2 of the EIS and are summarised below.

Approximately 128 Mt of waste rock would be removed from the pit during the eight years of mining. Following Year 3, waste rock quantities would progressively decrease as the ore to waste ratio increases.

Geochemical characterisation has been conducted for open pit waste rock material and mine tailings in order to identify waste types, assist the development of waste handling strategies and minimise potential adverse environmental impacts (EGi, 1997). The geochemical characterisation included evaluation of acid forming characteristics and assessment of element enrichment and solubility. A detailed account of the geochemical characterisation of mine waste is presented in Appendix C of the EIS.

2.3 Project Construction and Mining Schedules

Table A-1 presents a schedule for the proposed construction activities including the installation of the pit dewatering bores, temporary isolation bund, reconstructed foreshore, tailing storages, processing plant, access road, administration building, and miscellaneous infrastructure.

The proposed mining method is a conventional open pit, occurring in stages as the pit is widened and progressively deepened. The mining schedule is presented in Table A-2.

2.4 Use of Cyanide at Cowal Gold Project

2.4.1 Cyanide Use During Ore Processing

A detailed study has been undertaken summarising the current knowledge on the use, toxicity and management of cyanide at the Cowal Gold Project (Appendix G of the EIS). Cyanide has been shown to be the only proven method for economically extracting gold at the Cowal Project. Figure A-7 shows the flows of cyanide for the processing of oxide and primary ores. A description of the process is summarised below.

Sodium cyanide would be trucked to the site, most likely in solid briquette form packaged in either dedicated isotainers or a heavy plastic bag (capable of taking the weight of all of the 1 tonne of contents) enclosed in plywood. The cyanide would be unloaded directly into a storage area located near the processing plant. The cyanide would be taken from the store as required and mixed in a dedicated mixing tank from where it would be conveyed to the oxide and primary

leaching circuits. Cyanide consumption for the oxide and primary circuits has been estimated at 0.8 and 0.3 kg of cyanide per tonne of ore, respectively.

Barren slurry (once the gold has been removed) exiting the oxide ore leaching circuit would pass directly to a thickener. The thickener is designed to remove water from the slurry and therefore thicken the tailings. In the case of the oxide ore, this process is estimated to recycle approximately 25% of the cyanide for reuse. Treating the tailings through a cyanide destruction point prior to discharge to the tailings storages would further reduce the cyanide concentration in the tailings. The CN_{WAD} concentration of tailings entering the tailings storages at the point of discharge would be less than 30 mg/L for 100% of the time and less than 20 mg/L for 90% of the time.

Approximately 92% of primary ore from the flotation circuit becomes tailings. These tailings do not contain cyanide. The remaining 8% of primary ore will be passed on to the primary ore leaching circuit for further processing.

The resulting barren slurry from the primary ore leaching circuit (containing cyanide) would pass through the first of two cyanide destruction points before being combined with the tailings from the primary ore flotation circuit. The dilution effect of combining the two tailing streams would further reduce cyanide levels by about a 20:1 dilution. The combined tailings would be thickened before passing through a second cyanide destruction point. The tailings would then be discharged to the tailings storages.

The heated cyanide used in the elution of gold from carbon passes into the electrowinning circuit where it would be recycled.

Oxide tailings would pass through a single destruction point after leaving the thickener. A second back-up destruction would also be available prior to the thickener.

2.4.2 Cyanide Destruction

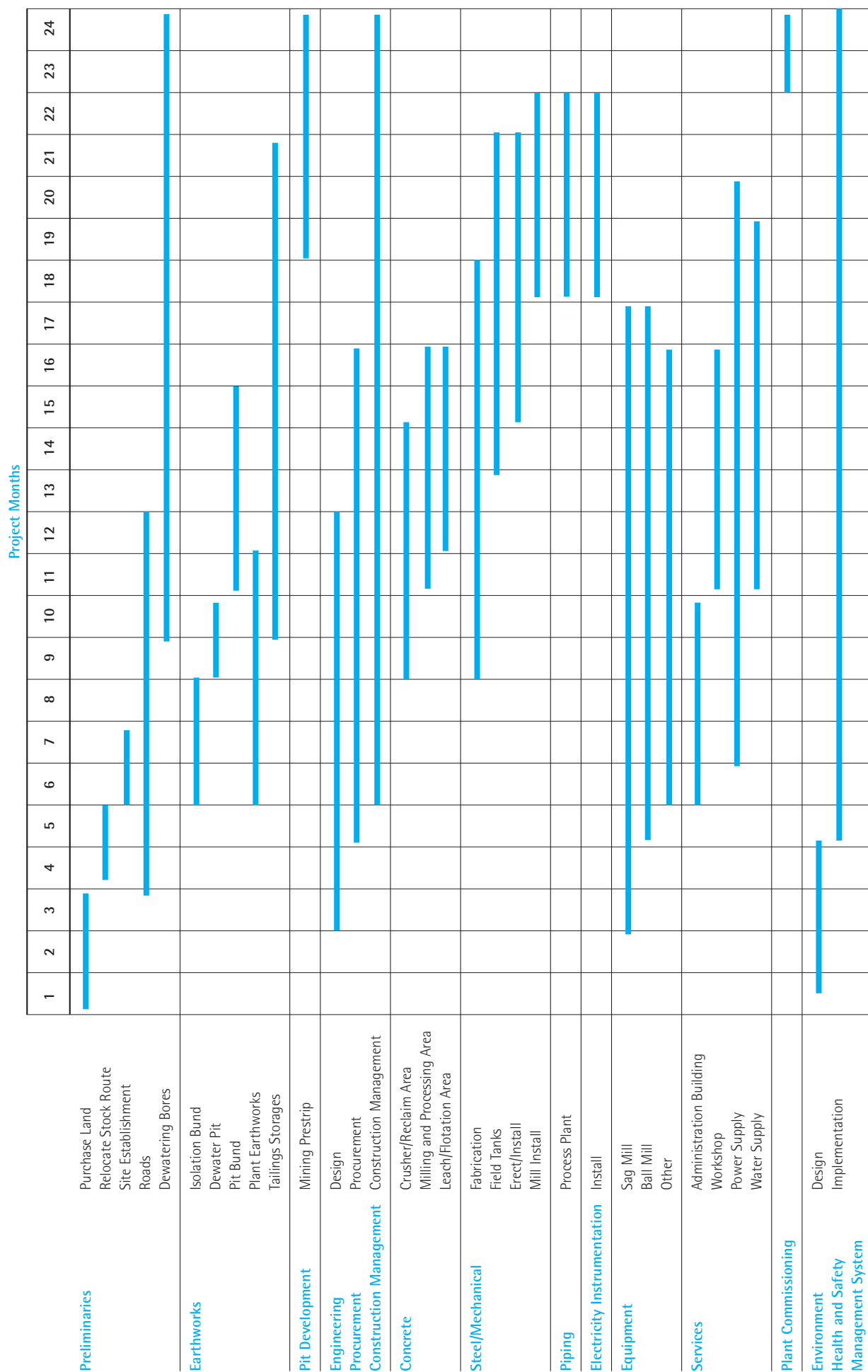
Cyanide destruction would be achieved by the Interlox Caro's acid process. This destruction method has been tested on oxide and primary ore from the Cowal Project and was found to deliver fast and effective destruction down to low levels if necessary.

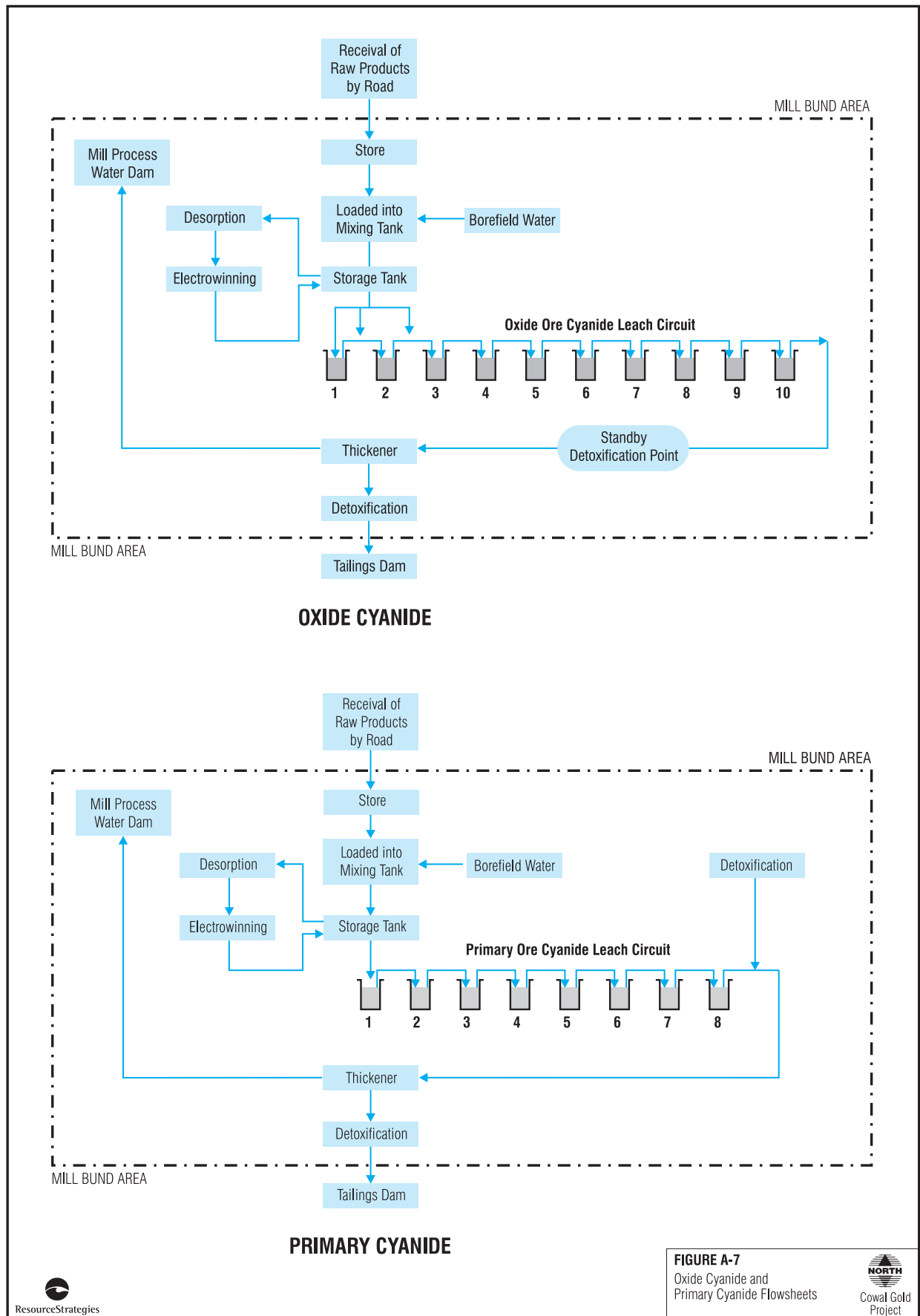
Caro's acid is a mixture of sulphuric acid and hydrogen peroxide both of which would be separately transported and stored on site. The two cyanide destruction points would be served by two Caro's acid mixing chambers. The quantity of Caro's acid added to the tailings would be regulated by an on-line free cyanide measurement to ensure cyanide in the tailings is destroyed down to licensed levels. Appendix G of the EIS provides further detail of the Caro's acid destruction process at the Cowal Project.

2.4.3 Tailings Disposal

Approximately 76 Mt of tailings would be produced over the life of the mine. The quantity of gold removed during processing is relatively small and almost all material passing through the processing plant would go to the tailings storages.

Table 2-2 Construction Phase Schedule





The tailings would be pumped at approximately 55% solids to the tailings storages. The pipeline would run at ground level, through culvert road crossings and with a bunded corridor. Tailings would be discharged into the tailings storages via spigots located around the perimeter.

With an average field dry density in the range between 1.50 t/m³ to 1.55 t/m³ total tailings requiring storage would be approximately 50 Mm³. Tailings would be deposited in two storages located approximately 3.5 km west of the Lake shoreline.

Geochemical characterisation has been conducted on oxide and primary flotation/concentrate recombined tailings (EGi, 1997). In summary, oxide and primary tailings were both classified as non-acid forming. Leach columns used to assess the long term leaching behaviour and seepage chemistry of the tailings indicate sulphate salts may be generated following deposition. The tailings pore water and ponded surface water (containing any generated salts, metals and cyanide forms) would be captured by the tailings underdrainage network and decant tower for recycling in the processing plant.

Cyanide from the Cowal Project processing plant can arrive at the tailings storages in three forms, as free cyanide, as a range of cyano-metal complexes or as thiocyanate. These forms are interchangeable depending on the chemical make-up of the liquor in the tailings storages. The bulk of decay in the tailing storage would happen through the process of volatilisation. Other significant decay paths include: association/disassociation of metal complexes; anaerobic biodegradation to relatively innocuous non-cyanide species; and degradation of iron cyanide complexes by UV radiation to WAD and FREE cyanide species. A detailed description of the decay mechanisms of these forms is provided in Appendix G of the EIS.

The use of saline groundwater (as opposed to fresh water) for raw water in gold processing would increase the decay of cyanide within the entrained tailings liquor once

deposited in the storage (EGi, 1997). Rapid decay of CN from the ponded tailings liquor would result in CN_{WAD} concentrations for oxide tailings from 5 to 10 mg/L and 10 to 15 mg/L for the primary tailings. Once discharge ceases it is expected that CN_{WAD} complexes would decay to very low concentrations within two to three months.

Further detail regarding cyanide management can be found in Appendix G of the EIS. The toxicity of cyanide and its potential impact on wildlife is addressed in Section 6 of this document.

3.0 EXISTING ENVIRONMENT

3.1 Physiographic Setting

The Project area is characterised by flat to gently undulating land with scattered remnant vegetation. Much of the landscape in the Lake Cowal district has been cleared for grazing and cropping activities. The remaining vegetation is predominantly woodland with a grassy (primarily non-endemic) understorey typically associated with rocky elevated areas, impeded drainage areas and road verges (Anne Clements and Associates, 1995). Few uncleared patches of vegetation remain. Vegetation of the Project area and surrounds is presented in greater detail in Section 4.1 of this document.

Major physical features within the surrounding environment include Lake Cowal, Wamboyne Mountain (RL 412 m, 5 km north of the Project area) and Billys Lookout (RL 368 m, 7 km south-west of the Project area).

The Cowal region is characterised by a semi-arid/temperate climate and the major soil types identified within the proposed MLA include hard pedal red duplex soils; grey, brown and red cracking clays; and hill soils (DLWC, 1994). Soils of the Lake Cowal area display duplex characteristics with thin A₁ organic surface horizons, typically underlain by dispersive subsoils.

Table A-2 Provisional Mining and Processing Schedule

Phase	Year	Mined Ore (Mt)	Mined Waste (Mt)	Mined Total (Mt)	Total Ore Processed (Mt)
Construction/Pre-production	-2	0	0	0	0
	-1	1.7	13.8	15.5	0
Mining and Processing Operation	1	11.3	18.5	29.8	6.9
	2	10.6	20.9	31.5	6.1
	3	10.7	27.5	38.2	6.0
	4	9.7	24.4	34.1	6.0
	5	10.0	15.5	25.5	6.0
	6	7.7	2.5	10.2	6.0
	7	7.9	2.4	10.3	6.0
	8	6.6	2.6	9.2	6.1
Processing Only Operation	9	-	-	-	6.9
	10	-	-	-	6.0
	11	-	-	-	6.0
	12	-	-	-	6.0
	13	-	-	-	2.2
Total		76.2	128.1	204.3	76.2

3.2 Land Resources

3.2.1 Meteorology

Climate

The Cowal region is located on the boundaries of the south-eastern semi-arid and the south-eastern temperate regions of Australia (Austin & Nix, 1978).

A summary of meteorological data collected from various regional stations is presented in Table A-3.

Temperature

Historical data show the warmest months within the region are November through to March, with cooler temperatures occurring from May through to August/September.

Mean monthly temperatures for the Project area are presented in Table A-4.

Relative Humidity

Relative humidity has been recorded at the Forbes and West Wyalong Stations. Relative humidity at West Wyalong for 9 am ranges from 21% in October and November to 39% in June and July. Afternoon (3 pm) levels range from 31% in December to 59% in June.

Wind Speed and Direction

Wind roses compiled from data collected from the on-site meteorological station indicate that the Project area is influenced by winds from the south-west. Wind speeds during the year are generally moderate and usually range between 6 and 10 km/hr, increasing up to 20 km/hr in summer during the afternoons.

Rainfall

Table A-4 indicates that the sum of the mean annual rainfall for Forbes, Condobolin and Wyalong is 527 mm, 448 mm and 483 mm respectively.

The ratio of summer (November to April) to winter (May to October) rainfall is approximately less than 1:3 and lies in the range 250 to 500 mm per year.

Evaporation

The sum of the mean annual evaporation based on the Condobolin Agricultural Research Station records is 2,045 mm per year (Class "A" pan). The regional average monthly rainfall and evaporation data presented in Table A-4 shows that rain falls uniformly throughout the year while evaporation fluctuates between summer and winter and on average exceeds rainfall by more than four-fold.

Table A-4 Project Area Average Daily Air Temperature

Month	Average Daily Air Temperature (Project Area)	
	Maximum °C	Minimum °C
June 1995	13.2	6.5
July 1995	11.3	5.1
August 1995	17.8	6.1
September 1995	18.6	7.4
October 1995	23.3	11.1
November 1995	25.8	14.5
December 1995	27.9	15.6
January 1996	31.3	18.5
February 1996	N/A	N/A
March 1996	27.3	15.7
April 1996	21	10.1
May 1996	18.4	8.7
June 1996	N/A	N/A

N/A = data not available

Table A-3 Regional Meteorology Stations Data Summary

Month	Relative Humidity				Air Temperature		Average Rainfall			Evaporation
	Daily Average (West Wyalong)		Daily Average (Forbes)		Daily Average (Forbes)		Forbes (mm)	Condobolin Post Office (mm)	Wyalong Post Office (mm)	Condobolin Agricultural Station (mm)
	9.00 am (%)	3.00 pm (%)	9.00 am (%)	3.00 pm (%)	Max. (°C)	Min. (°C)				
January	28	34	51	33	32.7	17.4	50.2	45.8	44.8	310.1
February	26	34	57	36	32.1	17.1	44.1	38.8	36.6	262.2
March	24	35	60	38	29.1	14.3	43.1	38.3	36.5	226.5
April	28	41	68	44	23.9	9.8	40.4	32.6	37.6	134.5
May	37	53	79	54	19.0	6.1	44.2	36.6	42.6	74.3
June	39	59	85	63	15.1	4.1	43.3	36.1	42.9	49.3
July	39	57	85	62	14.2	2.8	42.7	34.4	42.5	52.5
August	34	51	80	55	16.3	3.9	42.8	36.4	40.1	79.8
September	31	47	69	46	19.8	6.3	41.8	30.9	35.1	115.7
October	21	42	59	41	24.1	9.5	48.9	42.7	45.9	181.6
November	21	34	52	35	28.2	12.8	40.6	35.4	35.3	239.7
December	25	31	50	32	31.2	15.6	45.5	40.7	43.4	318.9
Annual Total							527.6	448.7	483.3	2045.1

Monthly trends in evaporation show January and December as having the highest rates of evaporation (310 mm and 318 mm respectively), while June and July record the lowest rates (49 mm and 53 mm respectively).

When considering average annual rainfall, a strong moisture deficit (net difference between evaporation and rainfall) is evident for an average year. This moisture deficit is most pronounced during summer months, coinciding with periods of higher evaporation.

3.2.2 Soils

In 1994 North commissioned the Department of Conservation and Land Management (now the Department of Land and Water Conservation [DLWC]) to conduct comprehensive soil surveys. The soil survey report provides information and data for the characterisation of overburden as well as baseline data necessary for the identification of soils resources for the planning and implementation of rehabilitation programmes associated with the Project.

The DLWC survey (1994) identified three mapping units, which consist of the following major soil types:

- Hard pedal red duplex soils;
- Grey, brown and red cracking clays; and
- Hill soils.

3.2.3 Landuse

Landuse surrounding the Project area is dominated by sheep and to a lesser extent, cattle grazing (on both native and improved pastures) and grain cropping (mainly wheat and barley). A small number of intensive livestock operations (eg. small scale piggery) are also located within the vicinity of the Project area. Grazing and occasional cropping within the high-water mark of the Lake occurs when moisture and market conditions are suitable. Irrigation farming is practised to the north-east of the Lake in the Jemalong-Wyldes Plains Irrigation District.

Since European settlement native vegetation in the Central Western Slopes region has undergone far-reaching changes (Goldney and Bowie, 1990), due primarily to its importance for agricultural production. This change is evident also in the wider New South Wales Wheat-belt area where up to 95% of the original native vegetation has been removed for cropping and grazing purposes (Murray-Darling Basin Ministerial Council, 1987).

A number of State Forests are located between approximately 8 and 25 km of the Project area, including Euglo and Nerang Cowal State Forests to the north, Lake View and Corringale State Forests to the west, The Clear Ridge, Wirra, Boxall and Back Creek State Forests to the south and Little Blow Clear, Blow Clear and Hiawatha State Forests to the south-west.

Conservation reserves with a 200 km radius of the Project area are listed below:

- Black Swamp (c. 200 km south-west of the Project area);

- Buddigower Nature Reserve (c. 45 km south-west of the Project area);
- Charcoal Tank Nature Reserve (c. 46 km south-west of the Project area);
- Cocoparra National Park (c. 120 km south-west of the Project area);
- Cocoparra Nature Reserve (c. 110 km south-west of the Project area);
- Conimbla National Park (c. 85 km south-southeast of the Project area);
- Goobang National Park (c. 105 km north-east of the Project area);
- Ingalba Nature Reserve (c. 90 km south of the Project area);
- Loughnan Nature Reserve (c. 140 km west of the Project area);
- Nangar National Park (c. 100 km east-northeast of the Project area);
- Narrandera Nature Reserve (c.150 km south-southwest of the Project area);
- Nombinnie Nature Reserve (c. 145 km west-northwest of the Project area);
- Pulletop Nature Reserve (c. 130 km south-west of the Project area);
- Round Hill Nature Reserve (c.125 km north-west of the Project area);
- Weddin Mountains National Park (c. 60 km south-east of the Project area);
- Woggoon Nature Reserve (c. 100 km north-northwest of the Project area); and
- Yathong Nature Reserve (c. 185 km north-west of the Project area).

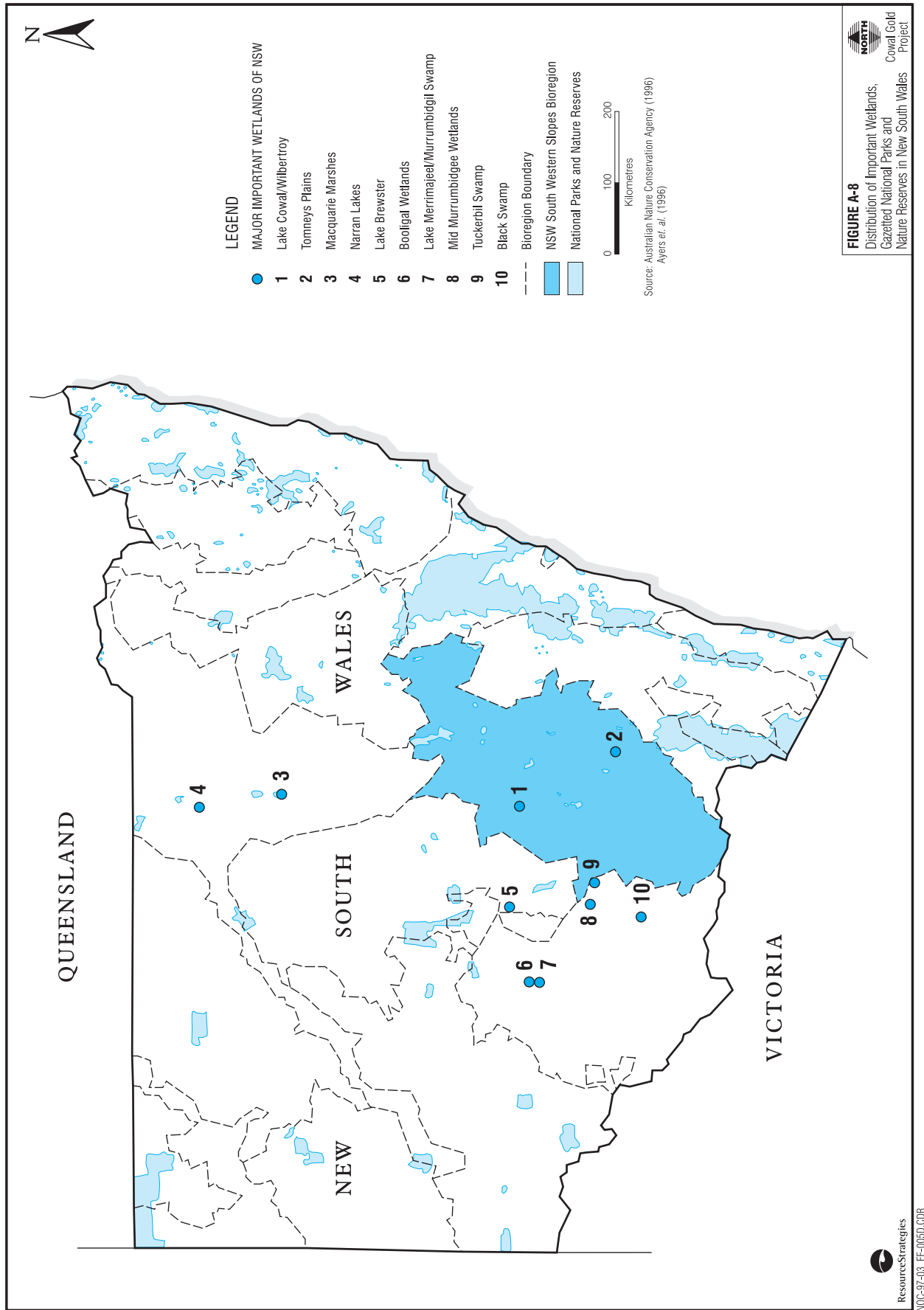
Figure A-8 presents a schematic of the gazetted National Parks and Nature Reserves in NSW.

A small number of farmhouses occur in the vicinity of the proposed MLA and are accessed via an unsealed public road that runs north-south through the proposed mine site.

A Game Reserve presently situated in the northern portion of the proposed MLA (to be relocated) provides public access to Lake Cowal and was used primarily for camping during the previous duck hunting seasons.

The West Wyalong-Burcher railway runs parallel to the western proposed MLA boundary and is used exclusively for grain transport during the harvest period.

In past years Lake Cowal has been an important recreational and commercial fishing resource (Fisheries Research Institute, 1997) however the proliferation of the European carp (*Cyprinus carpio*) is likely to have impacted on catch composition in recent years.



3.3 Water Resources

3.3.1 Surface Water

The Lachlan River Valley has a catchment area of some 84,700 km² and incorporates around 400,000 ha of recognised wetlands (Department of Water Resources [DWR], 1989) of which Lake Cowal is a part. The Lachlan River has an estimated mean annual flow of 1,270,000 million litres (ML) at Forbes.

Lake Cowal forms part of the Wilbertroy-Cowal wetlands located on the Jemalong plain, which is a fluvial landform, formed in the lower reaches of Bland Creek. The plain extends to the Lachlan River in the north and is bounded by ridgelines to the east and west. Lake Cowal receives inflow from Bland Creek, which drains into the Lake at its southern end. Bland Creek commands a catchment area of some 9,500 km² upstream of the Lake.

Inflows to the Lake also occur from the Lachlan River via breakout flows during major flood events in the Lachlan, causing back flooding to Lake Cowal. The breakout flows enter the Lake via modified floodways at the north-eastern side of the Lake. The Lake also receives inflow from incident rainfall.

When full Lake Cowal overflows into Nerang Cowal to the north which in turns overflows to Manna Creek, Bogandillon Creek and ultimately into the Lachlan River. The Lake is substantially inundated approximately seven years out of ten, with relatively small increases in Lake water depth leading to significant increases in the area of inundation due to the flat, shallow nature of the Lake. Without inflows, drying of the Lake is driven predominantly by high evaporative losses which can reduce the Lake from a full storage to minimal storage levels within 12 months.

A baseline surface water quality and sediment monitoring programme was undertaken by North from 1991 to 1992. Conductivity was sampled from 1991 to 1996. A summary of the water chemistry analysis is presented in Section 3.3 of the EIS.

3.3.2 Groundwater

Groundwater resources within the region occur in two distinct forms associated with differing geological formations. These are shown schematically in Figure 3-6 (Section 3) of the EIS and consist of:

1. Lachlan Formation (Bland Creek Palaeochannel): comprising an aquifer of quartz gravel fractured bedrock; and
2. Cowra Formation: comprising aquifers of isolated sand and gravel lenses in the silt and clay alluvial deposits associated with the formation. Groundwater associated with these perched aquifers generally exhibits higher salinity and lower yields than the fractured bedrock aquifer of the Lachlan Formation.

Groundwater movement within the region is thought to have been significantly modified since the initiation of surface water irrigation in the Jemalong and Wyldes Plain

irrigation district. Prior to irrigation, groundwater flow would have followed a northerly direction along the Bland Creek Palaeochannel towards the confluence with the Lachlan River. A significant groundwater mound in the shallow alluvial sequences has developed around the Warroo Prior Stream along which has been constructed a major irrigation supply channel. As a result, groundwater flow from Bland Creek no longer discharges to the Lachlan System.

Studies (Coffey Partners International, 1995) have indicated that groundwater within the project area is associated with fractured volcanic bedrock and transported cover. These aquifers are generally low yielding and saline.

Water quality parameters have been measured within the proposed open pit area and within the Lake Cowal and Nerang Cowal area and the results are included in Appendix F of the EIS.

3.4 Lake Cowal and Other Wetlands of New South Wales

The Lake Cowal wetland system (Lake Cowal and Nerang Cowal) forms part of a large ephemeral inland wetland system that has been described as one of the most significant water bird concentration areas in NSW by the Australian Heritage Commission (AHC) (1992) (Figure A-2 and A-3). In 1992 the Lake was listed by the AHC on the Register of the National Estate.

In accordance with mapping and assessment undertaken by Australian Nature Conservation Agency (ANCA) as part of the compilation of the *Directory of Important Wetlands in Australia* (2nd edition, 1996), Lake Cowal lies within the Lake Cowal/Wilbertroy wetlands system, in the NSW South-western Slopes biogeographic region (Figure A-8).

The Lake Cowal/Wilbertroy wetland is an extensive lake system occurring in a shallow basin on the Lachlan River floodplain. It contains a chain of wetlands including Lake Cowal, Nerang Cowal and Bogandillon Swamp. The Lake Cowal/Wilbertroy wetland system is estimated to have a total area of approximately 29,000 ha, although the extent of area inundated varies significantly with inflows and evaporation.

In addition to the Lake Cowal/Wilbertroy wetland system, 94 wetlands in New South Wales have been classified in the Directory as significant (Figure A-8). These wetlands include Tomneys Plain (c. 150 km south-east of the Project area), Macquarie Marshes (c. 320 km north of the Project area), Narran Lakes (c. 410 km north of the Project area), Lake Brewster (c. 125 km north-west of the Project area), Booligal wetlands (c. 225 km south-west of the Project area), Lake Merrimajee/Murrumbidgee swamp (c. 225 km south-west of the Project area), Mid Murrumbidgee wetlands (c. 150 km south-west of the Project area), Tuckerbil swamp (c. 125 km south-west of the Project area) and Black swamp (c. 200 km south-west of the Project area). In total, wetland areas in NSW cover some 2,128,000 ha (ANCA, 1996).

In addition to these wetland systems, the NSW Department of Water Resources have described the wetlands of the

Lachlan Valley in the *Water Management Strategy for Wetlands of the Lachlan Valley Floodplain* (DWR, 1992). The wetlands of the Lachlan Valley are presented in Figure A-9. As part of the Management Strategy, the DWR divided the Lachlan Valley into major wetland divisions based on geomorphologic, hydrologic and vegetative characteristics (Table A-5).

Table A-6 presents the dominant vegetation (and areas) of the Lachlan Valley wetland divisions. Areas of shared dominant vegetation of the wetland divisions are presented

in Table A-7.

Tables A-6 and A-7 indicate that a number of wetland divisions in the Lachlan Valley have vegetation associations similar to those of the Lake Cowal/Wilbertroy wetlands. In several divisions however the vegetation associations cover a greater area than in the Lake Cowal/Wilbertroy wetlands. For example, the Middle Lachlan has around 42,580 ha of River Red Gum habitat (representing 48% of the division area) compared to approximately 1,970 ha in the Lake Cowal/Wilbertroy wetlands (which equates to around 8%

Table A-5 Wetlands of the Lachlan River Floodplain

Division No.	Wetland	Approximate Distance and Direction from Lake Cowal	Approximate Total Wetland Area (ha)
1	Upper Lachlan	15 km east	7,450
2	Middle Lachlan	5-200 km north-west	88,890
3	Bundaburrah	5 km east	3,900
4	Wilbertroy – Cowal	–	25,600
5	Goolbang Creek	15 km north-northeast	5,180
6	Wallamundry – Wallaroi anabranch system	3 km north	12,440
7	Booberoi Creek	35 km north-west	8,700
8	Willandra Creek	140 km north-northwest	107,160
9	Middle Creek	170 km west	23,610
10	Merrowie Creek	175 km west	34,480
11	Cabbage Garden	168 km west	21,260
12	Yandumblin	225 km west-southwest	5,090
13	Merrimajeel Creek System	250 km south-west	19,650
14	Lower Lachlan	265 km south-west	42,010
15	Pimpara Creek	295 km south-west	1,760
16	Great Cumbung Swamp	325 km south-west	31,940
			413,520

Source: Adapted from DWR (1992)

Table A-6 Wetland Vegetation of the Lachlan Valley Floodplain

Wetland Areas by Dominant Vegetation (ha)										
Division No.	Open Water (A)	Cumbungi (B)	Common Reed (C)	Lignum (D)	Nitre (E)	Canegrass (F)	River Red Gum (G)	Black Box (H)	Grey Box (I)	Yellow Box (J)
1	350	0	0	0	0	0	4,930	0	10	0
2	8,960	0	0	7,230	0	0	42,580	28,020	520	0
3	90	0	0	0	0	0	1,970	0	0	0
4	11,830	0	0	0	0	0	1,990	630	1,790	0
5	100	0	0	0	0	0	3,770	0	0	0
6	820	0	0	210	0	0	7,530	3,150	160	320
7	110	0	0	0	0	0	6,550	2,040	0	0
8	0	0	0	6,970	00	1,250	0	5,010	0	0
9	0	0	0	0	12,560	30	0	8,460	0	0
10	450	0	0	11,040	4,170	90	770	16,230	0	0
11	240	0	0	60	1,540	0	0	19,000	0	0
12	30	0	0	1,850	0	0	2,480	90	0	0
13	70	0	0	9,430	2,240	0	1,120	3,910	0	0
14	1,380	0	0	550	950	210	12,280	15,370	0	0
15	0	0	0	0	0	0	550	880	0	0
16	810	0	3,900	880	0	300	13,080	12,750	0	0

Source: Adapted from DWR (1992)

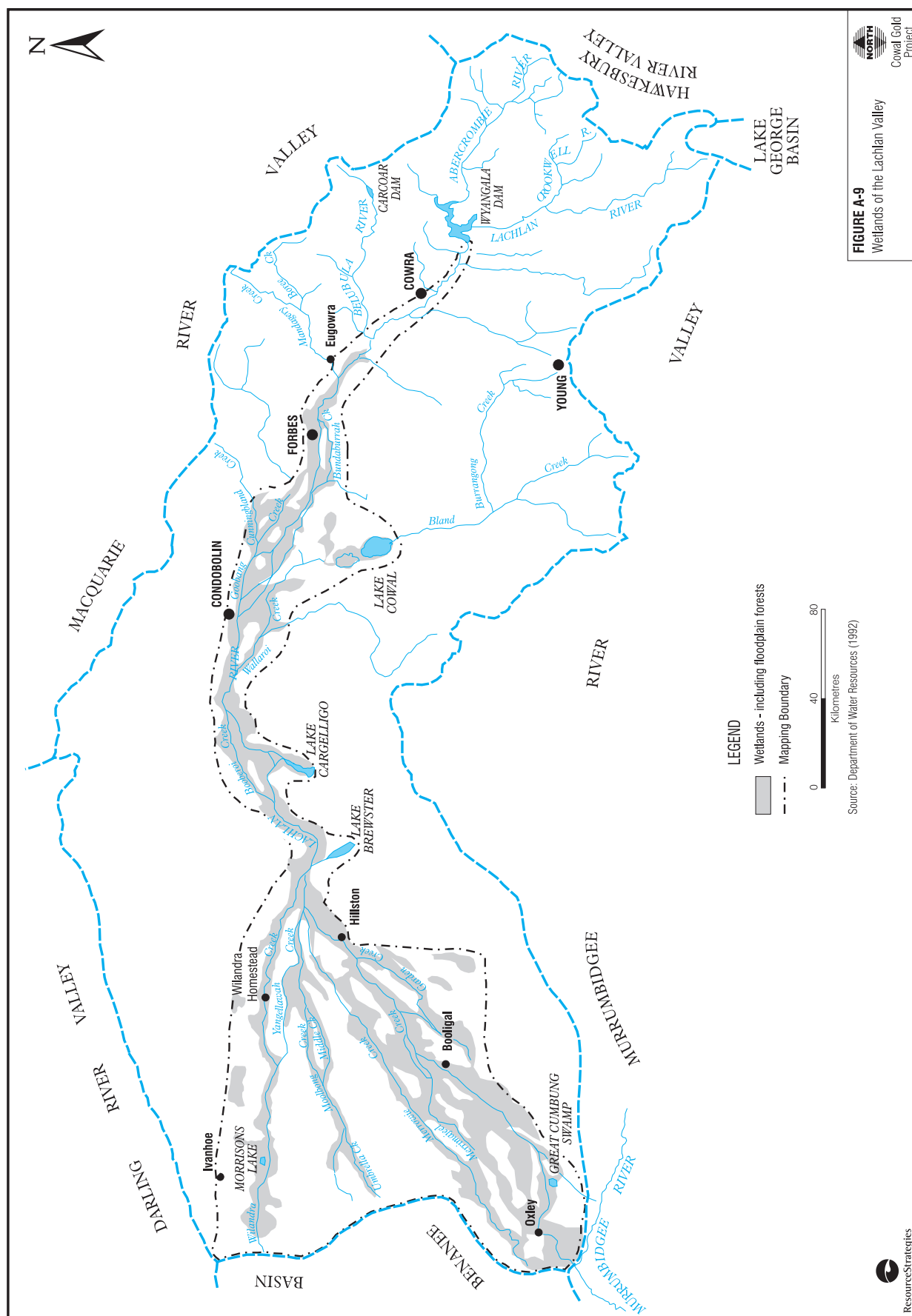


Table A-7 Vegetation Combinations of the Wetlands of the Lachlan Valley Floodplain

Division No.	Wetland Areas by Dominant Vegetation (ha)														
	A, B	A, D	A, D, E	A, D, G	A, D, H	A, G	A, G, H	A, G, H, I	A, H	A, I	A, I, J	D, E	D, G	D, H	E, H
I, J															
1	0	0	0	0	0	120	0	0	0	0	0	0	0	0	0
2	140	0	0	0	0	430	0	0	440	0	0	0	530	0	0
3	0	0	0	0	0	1,260	0	0	0	0	0	0	0	0	0
4	0	620	0	130	0	5,880	0	1,290	80	0	0	0	0	0	0
5	0	0	0	0	0	0	0	0	0	0	70	0	0	0	0
6	0	0	0	0	0	0	20	0	0	10	0	0	0	0	0
7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8	0	1,350	0	0	260	0	0	0	0	0	0	0	0	820	0
9	0	0	0	0	0	0	0	0	0	0	0	1,170	0	0	1,390
10	0	0	330	0	0	0	0	0	380	0	0	1,020	0	0	0
11	0	0	0	0	0	400	0	0	20	0	0	0	0	0	0
12	0	0	0	0	0	510	0	0	0	0	0	0	130	0	0
13	0	60	0	0	0	110	0	0	0	0	0	1,730	900	0	80
14	0	0	0	0	0	2,570	0	0	0	0	0	0	8,670	30	30
15	0	0	0	0	0	200	0	0	130	0	0	0	0	0	0
16	60	160	0	0	0	0	0	0	0	0	0	0	0	0	0

Source: adapted from DWR (1992)

Legend:

- | | | |
|------------------|-------------------------|-----------------------------|
| A. Open Water | 1. Upper Lachlan | 9. Middle Creek |
| B. Cumbungi | 2. Middle Lachlan | 10. Merrowie Creek |
| C. Common Reed | 3. Bundaburrah | 11. Cabbage Garden |
| D. Lignum | 4. Wilbertroy-Cowal | 12. Yandumbilin |
| E. Nitre | 5. Goolbang Creek | 13. Merrimajee Creek System |
| F. Canegrass | 6. Wallamundry-Wallaroi | 14. Lower Lachlan |
| G. River Red Gum | Anabranck System | 15. Pimpara Creek |
| H. Black Box | 7. Booberoi Creek | 16. Great Cumbung Swamp |
| I. Grey Box | 8. Willandra Creek | |
| J. Yellow Box | | |

of the wetland division area).

In addition to the Lachlan Valley wetland areas, vegetation associations characteristic of Lake Cowl occur throughout the state. For example, the vegetation of the Macquarie Marshes wetland system which cover an area of approximately 200,000 ha (ANCA, 1996), is composed of a number of species that occur at the Lake Cowl/Wilbertroy wetlands including River Red Gum (*Eucalyptus camaldulensis*), Lignum (*Muehlenbeckia florulenta*), Black Box (*E. largiflorens*) and Poplar Box (*E. populnea*) (DLWC, 1996b; ANCA, 1996). Like many of the NSW wetlands, the Macquarie Marshes are of local, regional and national importance as well as being an important breeding site for several nesting waterbirds (eg. Marchant and Higgins, 1990; DLWC, 1996b).

Numerous surveys have shown that wetlands in New South Wales support large numbers of waterbirds (Braithwaite *et al.*, 1985a, 1985b; Braithwaite *et al.*, 1986a, 1986b; Kingsford *et al.*, 1989, 1990, 1991; Brooker, 1993; Frith, 1967; Green, 1992, NSW NPWS, 1994) and provide important breeding habitat for waterbirds (Carrick, 1962; Marchant & Higgins, 1990). These wetlands are particularly important in providing drought refuge when wetlands in other regions are dry (ANCA, 1996), evidenced by the recording of 78,100 breeding pairs of ibis and a high diversity of other bird species in the Lachlan and Murrumbidgee wetlands in the 1990 – 91 (Magrath, 1992).

Extensive ground and aerial surveys of waterbirds on 30 wetlands in north-western New South Wales were conducted by the NSW NPWS from 1987 to 1990 (NPWS, 1994). Several lakes were also surveyed in 1993 and 1994. Results of these surveys show that bird species diversity was high with over 60 species recorded, 25 of which were recorded breeding. It was also found that three wetlands supported more than 50,000 waterbirds each (Bulloo overflow – 106,600; Mullaoolka Basin – 50,300; Salt Lake – 70,400) (NPWS, 1994). A further nine supported more than 10,000 waterbirds (Lake Altibouka – 19,600; Lower Bells Lake – 13,000; Bancannia Lake – 41,800; Lake Bullea – 15,330; Lake Nichebulka – 10,500; Peery Lake – 35,900; Poloko Lake – 28,700; Yantabangee Lake – 20,800; Yantabulla Swamp – 40,700).

The NPWS survey noted that waterbird numbers were likely to be underestimated by the aerial surveys and that numbers of waterbirds on the lakes were at least double those obtained.

With regard to the occurrence of wetland habitat in NSW, it is noted that were data available for say average number of "bird days" of utilisation of different wetlands in NSW over a sufficient period (for example 30 years to account for environmental variability), assessment would highlight the importance of Lake Cowl.

Wetlands in Australia also provide critical habitat for migratory waders (Maher, 1990). Hundreds of thousands of birds migrate between Australia and the Northern Hemisphere each year, covering a distance of some 9,000 km (Brady and Riding, 1996). Most birds breed on tundras and

swamps in countries such as Alaska, Japan, China and Russia and migrate to Australia to avoid winter (Van Gessel, 1982).

Coastal wetlands and more permanent swamps are of particular importance for their provision of habitat for migratory wading birds (Brady and Riding, 1996). However, large numbers of migratory wading birds have also been observed on inland wetlands following flooding. For example, over 100 migratory wader bird species were found on 15 wetlands in north western New South Wales (NPWS, 1994).

Australia is signatory to the Bonn Convention (involving the conservation of migratory species) and has international agreements which relate to the conservation, preservation and protection of important habitat areas and migratory bird species.

These agreements include:

- Agreement between the Government of Australia and the Government of Japan for the Protection of Migratory Birds and Birds in Danger of Extinction and their Environment (JAMBA); and
- Agreement between the Government of Australia and the Government of the People's Republic of China for the Protection of Migratory Birds and their Environment (CAMBA).

Species protected by the JAMBA and CAMBA agreements that are known to occur at Lake Cowl include the Cattle Egret (*Ardeola ibis*), Great Egret (*Egretta alba*), Glossy Ibis (*Plegadis falcinellus*), Painted Snipe (*Rostratula benghalensis*), Caspian Tern (*Sterna caspia*) and Red-necked Stint (*Calidris ruficollis*).

4.0 ECOLOGICAL OVERVIEW OF LAKE COWAL

4.1 Flora

4.1.1 Regional Patterns of Vegetation

The Project area lies within the botanical subdivision of Central Western Slopes of New South Wales as defined by Harden (1990-1993). Numerous vegetation surveys and maps have been produced for this region including those by Beeston *et al* (1980), Jacobs and Pickard (1981), Cardale (1987), Goldney and Bowie (1990), Harden (1990-1993), Norris and Thomas (1991), Sivertsen (1993) and Sivertsen & Metcalfe (1995).

Sivertsen and Metcalfe (1995) mapped the remnant native vegetation of the Forbes and Cargelligo Southern Wheat-belt, an area encompassing some 2,400,650 ha. The study area extended from the Lachlan River and latitude 33° to the north, longitude 145°30'E to the west, latitude 34°S to the south to a line separating the western slopes and the western plains in the east.

A total of 582 species of flora (465 native and 117 exotic species) were recorded by Sivertsen and Metcalfe (1995) composed primarily of grasses, composites, peas and saltbushes. In total twenty remnant vegetation associations were classified from a number of community types such as

riparian and floodplain remnants, undulating peneplain remnants, footslope remnants and hill and ridge remnants.

Native woody vegetation was found to be dominated by eucalypt woodland composed of a composite of eucalyptus species, determined by the dominant landform and soil type.

On the floodplains River Red Gum (*E. camaldulensis*) and Black Box (*E. largiflorens*) dominated, while the hill and footslope remnants were characterised by Dwyers Red Gum (*E. dwyeri*) and Mugga Ironbark (*E. sideroxylon*).

Poplar Box (*Eucalyptus populnea* subsp. *bimbi*), Grey Box (*E. microcarpa*), Fuzzy Box (*E. conica*) and Gum Coolibah (*E. intertexta*) were dominant on heavier peneplain soils while Congoo Mallee (*E. dumosa*) and Glossy-leaved Red Mallee (*E. oleosa*) were typically more abundant on the lighter peneplain soils. White Cypress Pine (*Callitris glaucophylla*) occurred throughout the area.

Three rare or threatened Australian plants (ROTAP) (Briggs and Leigh, 1988) were identified from the Wheat-belt region viz. *Lomandra patens*, *Phebalium obcordatum* and *Stipa eremophila*. However, one of these is an error as *Stipa eremophila* does not appear in the ROTAP list (Lembit, 1997).

4.1.2 Vegetation of the Project Area and Surrounds

As noted above, vegetation mapping has been of very broad scale or of limited extent and hence few detailed vegetation surveys for the Lake Cowal region have been produced.

Beadle (1948) was one of the first to produce a more detailed map of the vegetation of the region, which included the western and northern shores of Lake Cowal. Beadle (1948) identified four vegetation associations namely Poplar Box (*E. populnea*), Poplar Box/White Cypress Pine (*E. populnea/Callitris glaucophylla*), Grey Box (*E. microcarpa*) and Tumbledown Red Gum/Mugga Ironbark (*E. dealbata/E. sideroxylon*).

Flora survey and reporting of the mining operations area (including the proposed water supply borefield and pipeline) has been undertaken by Anne Clements and Associates (1995, 1996), Charles Sturt University (1997) and Bower (1997).

In 1993 some 740km² of the Lake Cowal district (20km east-west and 37km north-south) was surveyed, covering an area extending from Kerribrew Ridge in the north-western corner to Bland Creek near Marsden in the south-eastern corner (Anne Clements & Associates, 1995). During this survey 411 species comprising approximately 21% weeds were recorded. Five of the weed species recorded are listed as noxious within the Bland Shire, although only one of these (*Lycium ferocissimum*) was recorded from the proposed MLA.

Spearwood (*Acacia doratoxylon*) – Dwyers Red Gum (*E. dwyeri*) – White Cypress Pine (*C. glaucophylla*) was found to be the most widespread alliance occurring mainly on the ridgetops. Transitional lower slope vegetation was dominated by *C. glaucophylla*, while on the undulating landforms, open woodland (*E. populnea*) was predominant.

The undulating landforms with gilgai were dominated by *E. populnea* and Belah (*Casuarina cristata*) in the wetter, undrained patches. Narrow bands of River Red Gum (*E. camaldulensis*) occurred on lake, river and creek lines.

No ROTAP species were recorded during the 1993 survey however a single species listed as endangered in the TSC Act, Austral Pillwort (*Pilularia novae-hollandiae*), was identified from gilgai south of the proposed processing plant and from the Bland Creek floodplain approximately 12 km south-east of the mining operations area.

The proposed borefield water supply pipeline route was surveyed in 1996 (Anne Clements & Associates, 1996). The pipeline would follow road reserves from the existing borefield before running south of the main bird breeding areas in the Lake and across the Lake west-southwest towards the proposed mine site.

It was concluded that the installation of the pipeline is not likely to adversely impact any of the existing flora including the: fringing forest of the Lake shore; Lake vegetation; lucerne paddocks; cleared grazing paddocks; cleared crop land or road reserve areas (Anne Clements & Associates, 1996).

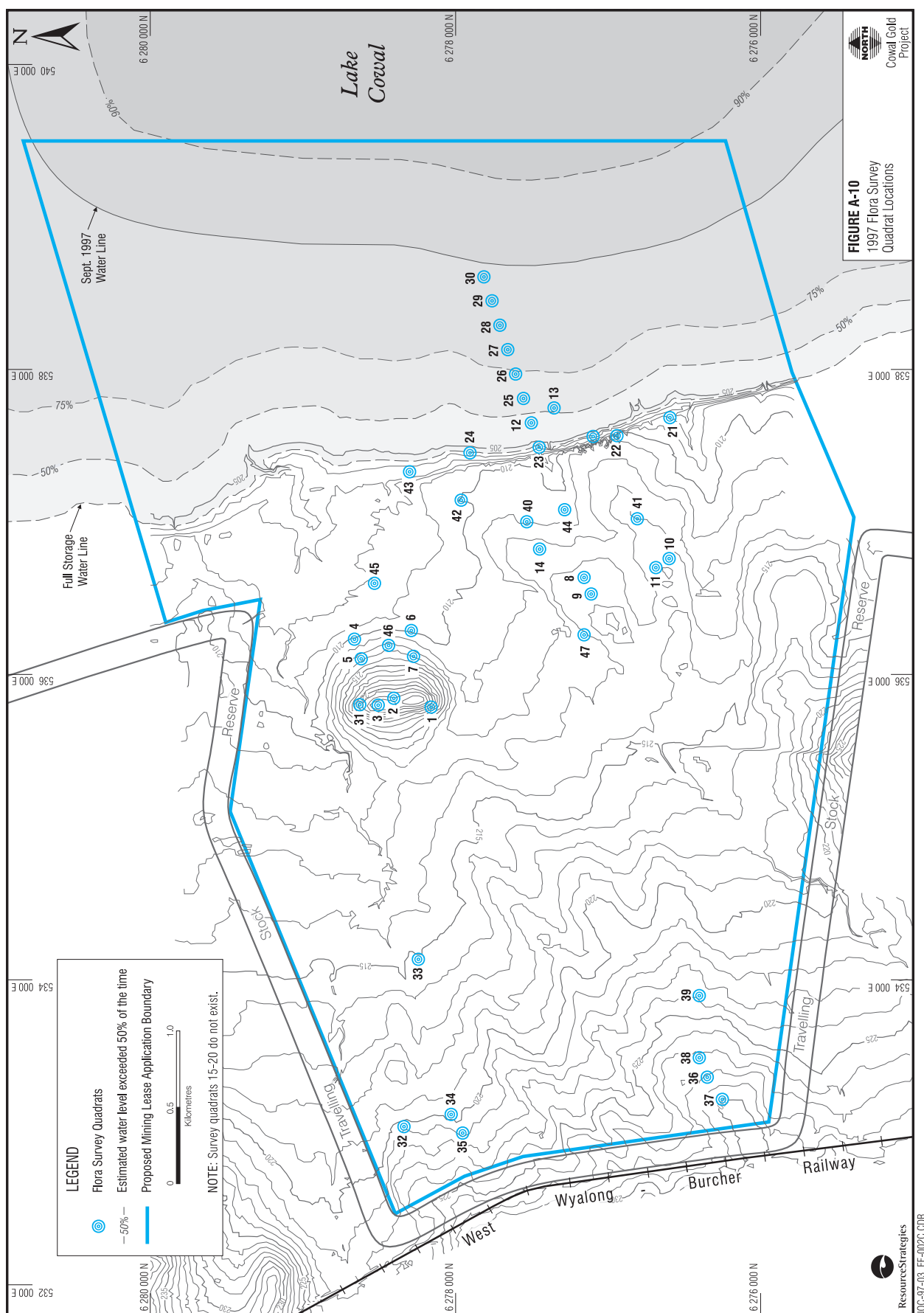
To increase the botanical database, an additional flora survey and assessment of the mining operations area was undertaken by Charles Sturt University in September and October 1997 (Attachment A3). The 1997 study employed quadrat-based cover/abundance assessments of specific areas of the Project area including the tailings storages, waste emplacement zones and the mine infrastructure and pit area. Figure A-10 shows the survey quadrat locations. A plan of vegetation communities of the Project area and surrounds is presented in Figure A-11.

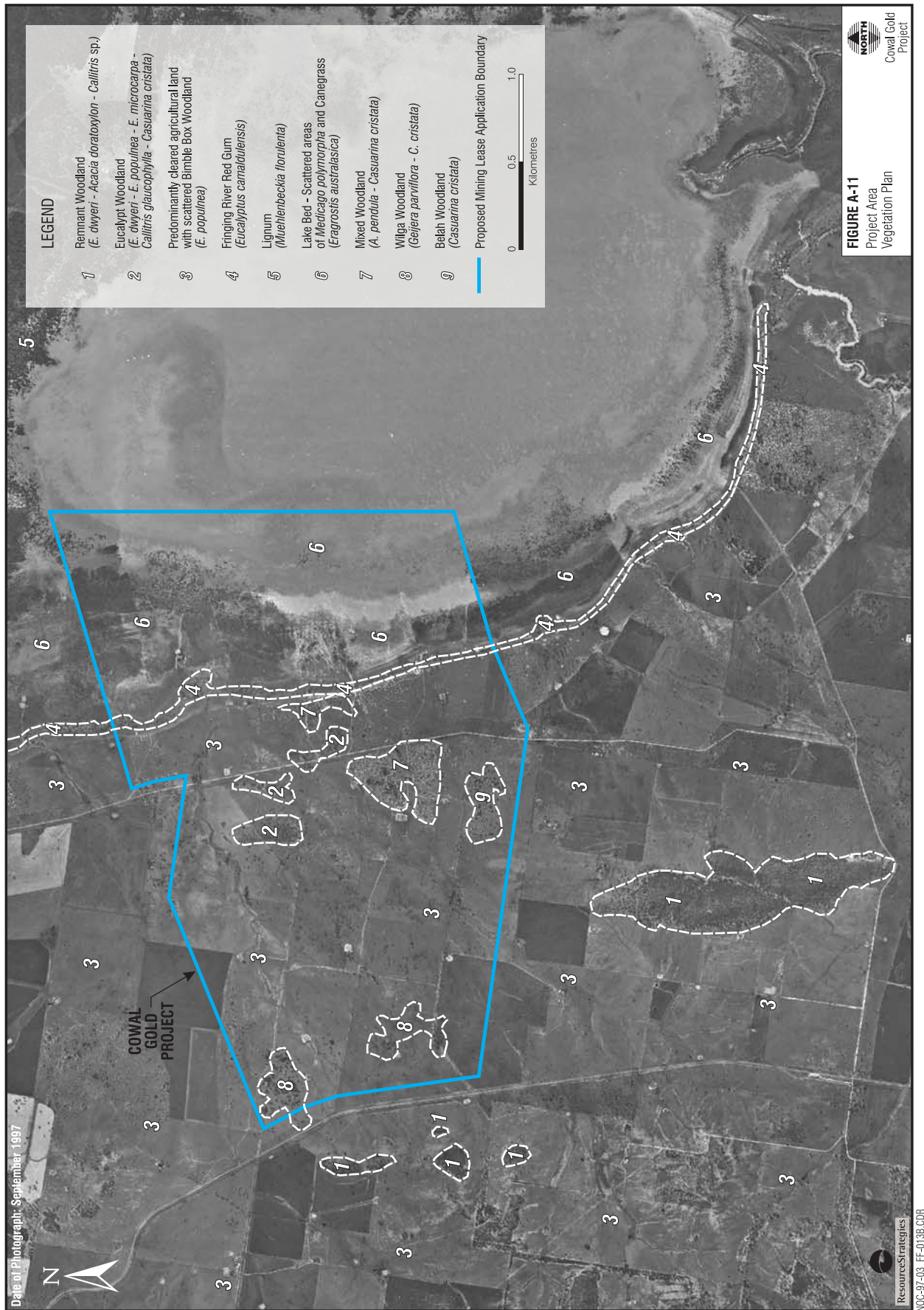
A total of 141 species were recorded during the 1997 survey of which 42 (30%) were weed species. Target searches were undertaken for a list of ROTAP and threatened plant species compiled by the NSW National Parks and Wildlife Service (NPWS) and Bower (1997). None of these species were identified during the 1997 survey period.

Based on the flora survey and mapping of the mining operations area and surrounds, nine main plant communities have been described (after Bower, 1997; Charles Sturt University, 1997). These communities have been defined by the largest and most numerically dominant plant species and are as follows:

Community 1 – Remnant Woodland (*Eucalyptus dwyeri* – *Acacia doratoxylon* – *Callitris endlicheri*)

This community occurs only on the high exposed ridges with shallow soils. Given the isolated occurrence of rocky outcrops and ridges in the generally flat landscape of the Lake Cowal region, this community occurs as scattered unconnected islands amongst other communities. The shallow soils on which this community occurs are unsuitable for farming or grazing and most of it has been relatively free from clearance or disturbance although some areas





have been affected by quarrying for gravel or harvesting of timber for fencing. This community type does not occur in the proposed MLA area and no examples of it are likely to be affected by the proposal (Bower, 1997).

Community 2 – Eucalypt Woodland (*E. dwyeri* – *E. populnea* – *E. microcarpa* – *Callitris glaucophylla* – *Casuarina cristata*)

This community occurs mainly on well-drained sloping country and low ridges. Within the proposed MLA area it is prominent on the Cowal West Hill, where it has been considerably thinned from natural densities. The most common associate is Poplar Box (*Eucalyptus populnea*) which would have occurred naturally as disconnected islands around the base of isolated ranges and on low hills and ridges in the area, but to a lesser extent than the former community.

White Cypress Pine (*C. glaucophylla*) is a component of many communities in which it is not necessarily dominant. Areas of this community have been largely cleared for farming and grazing and *C. glaucophylla* itself is a valued timber tree and in former times was used extensively for fencing and building.

Community 3 – Predominantly Cleared Agricultural Land with Scattered Bimble Box Woodland (*Eucalyptus populnea*)

This is the major plant community of the region. It dominates the upper strata of the flatter landscapes that have largely been cleared for farming and grazing. Poplar Box frequently associates with White Cypress Pine and other boxes, particularly Grey Box (*E. microcarpa*). On wetter sites Belah (*Casuarina cristata*) is a common associate. A variety of large shrubs or small trees also occur in this community including Myall (*Acacia pendula*), River Cooba (*A. stenophylla*), Wilga (*Geijera parviflora*) and Rosewood (*Alectryon oleifolius*). Pre-white settlement, the Bimble Box community would have been continuously connected through the area.

Community 4 – Fringing River Red Gum (*Eucalyptus camaldulensis*)

River Red Gum (*E. camaldulensis*) occurs along the edges of Lake Cowal and lines the creeks that enter and leave it. Its upper limit is the high water mark of the Lake and it extends for a short distance into the areas that flood. *Acacia stenophylla* is an occasional associate. Only a few River Red Gum trees occur within the proposed MLA area as most of the lakeshore has been severely thinned and, in this section, only scattered remnant trees remain.

Community 5 – Lignum (*Muehlenbeckia florulenta*)

Dense thickets of Lignum occur in the northern sections of Lake Cowal and form the basis of the breeding habitat for many of the waterbirds. Open areas without Lignum tend to be covered in Nardoo (*Marsilea drummondii*) and Water Milfoil (*Myriophyllum verrucosum*) when the Lake is inundated. Scattered River Red Gums may occur amongst the Lignum. No significant amounts of Lignum occur within the proposed MLA area.

Community 6 – Lakebed (*Eragrostis australasica* – *Medicago polymorpha*)

Sections of the shallow waters of the Lake support a Swamp Canegrass (*Eragrostis australasica*) – Burr Medic (*Medicago polymorpha*) community, particularly in the southern sections. A band of Swamp Canegrass occurs within the proposed MLA area. The area of swamp Canegrass communities alters with the flooding cycling of the Lake.

Community 7 – Mixed Woodland (*Acacia pendula* – *Casuarina cristata*)

This community occurs mainly on the alluvial flats and isolated remnants of this community occur within the proposed MLA area and would be affected by the proposed development. On drainage impeded gilgai areas, Belah (*Casuarina cristata*) is commonly the dominant associate.

Community 8 – Wilga Woodland (*Geijera parviflora* – *Casuarina cristata*)

Wilga (*G. parviflora*) is widespread in the area, reaching its optimum density on alluvial gilgai soils and other heavy soils on flats or lower slopes. It is commonly associated with trees such as *Alectryon oleifolius*, *C. cristata* and *E. microcarpa*. Portions of this community would be affected by the proposed development viz. the tailings storages and drainage works.

Community 9 – Belah Woodland (*Casuarina cristata*)

This commonly occurs on drainage impeded gilgai areas on grey soils. It is a common associate in many other communities (eg. Community 2 and Community 3). *C. cristata* woodland occurs in the south of the proposed MLA area and would be traversed by the proposed access road.

In summary the 1997 flora survey and reporting found that the areas within the mining operations area that would be disturbed/modified as a result of the proposed development are either:

- (i) dominated by weeds (viz. the lakebed, shoreline and understorey of the woodland areas); or
- (ii) extensively cropped (eg. the southern tailings storages); or
- (iii) contain areas of relatively high species diversity even after many decades of grazing and cultivation (eg. northern waste emplacement) however these species are common and not restricted to the Lake Cowal region.

4.1.3 Vegetation Community Conservation Status

National Conservation Status

The 1995 Atlas of Plant Communities in Australia (Specht *et al.*, 1995) describes the conservation status of the above listed communities in Table A-8:

Conservation Status in New South Wales

The NPWS document *Establishing Priorities for the Conservation of Rare or Threatened Plants and Plant Associations in New South Wales* (Benson, 1989) describes

the conservation status and nominates a risk assessment code for plant communities in NSW. The conservation status and risk codes of those associations identified from the Project area are described in Table A-9.

Conservation Status in Central Western New South Wales

Based on conservation ratings given by Hayden (1971), Jacobs and Pickard (1981), Cardale (1987), Bell (1978) and Specht *et al.* (1974), Goldney and Bowie (1990) have assigned a conservation status to various vegetation alliances in the central western slopes region. Those that relate to the Project area and surrounding vegetation, are presented in Table A-10.

4.2 Fauna

4.2.1 Habitats of the Project Area and Surrounds

Based on previous habitat assessment (Vestjens, 1977), dominant vegetation types, density of hollow-bearing trees, occurrence of substratum (such as fallen tree limbs, logs, decorticated bark, leaf litter and suitably dense ground cover), levels of disturbance (historic, current and on-going), fire regime and abundance of water, the following primary habitat types were delineated at the Project area and surrounds.

Table A-8 Conservation Status of Project Area and Surrounds Plant Communities

Community ⁺	Conservation Status [*]
1 <i>Eucalyptus dwyeri</i> Open scrub/woodland	Adequate: the plant community is well conserved in several large reserves which represent the range of biogeographic regions in which it occurs, each reserve exhibiting ecological diversity.
2 <i>Callitris glaucophylla</i> Low woodland/open forest	Reasonable-Adequate: the plant community is conserved in a large reserve or a number of small reserves which represent a large part of the range of biogeographic regions in which the community occurs; ecological diversity is usually present in the reserves.
3 <i>Eucalyptus populnea</i> (± <i>E. melanophloia</i> ± <i>E. orgadophila</i>) Open forest/woodland	Reasonable-Adequate: the plant community is conserved in a large reserve or a number of small reserves which represent a large part of the range of biogeographic regions in which the community occurs; ecological diversity is usually present in the reserves.
4 <i>Eucalyptus camaldulensis</i> Woodland	Reasonable: the plant community is conserved in a large reserve or a number of small reserves which represent a large part of the range of biogeographic regions in which the community occurs; ecological diversity is usually present in the reserves.
5 <i>Muehlenbeckia florulenta</i> Low/mid-height shrubland	Adequate: the plant community is well conserved in several large reserves which represent the range of biogeographic regions in which it occurs, each reserve exhibiting ecological diversity.
6 <i>Eragrostis australasica</i> Reedland	Reasonable: the plant community is conserved in a large reserve or a number of small reserves which represent a large part of the range of biogeographic regions in which the community occurs; ecological diversity is usually present in the reserves.

⁺ While the species composition described by Specht *et al.* (1995) to identify individual vegetation communities may not exactly mirror that of the communities present at the Project area, the dominant structural characteristics are considered analogous to the extent to enable meaningful comparison.

^{*} The conservation of each plant community was assessed using the following criteria: conservation in a reserve, size and number of the reserves, diversity of plant communities in the reserve and representation in all biogeographic regions in which it occurs (Specht *et al.*, 1995).

Table A-9 Conservation Status in NSW of Vegetation Associations of the Project Area

Association [*]	Conservation Status	Risk Code	Comments
<i>Eucalyptus</i> sp. aff. <i>dwyeri</i>	2	N	Occurs in hilly country.
<i>E. populnea</i> - <i>E. microcarpa</i>	1	E	Mostly cleared for crops; Narromine area.
<i>E. camaldulensis</i>	2	V	Largest stands, which occur in South Western Plains and South Far Western Plains, are not conserved and are threatened by changes in water regime (regeneration) and logging.
<i>Eragrostis australasica</i>	2	V	Clay pans, semi-arid areas threatened by dryland cropping.

^{*} Not all of the associations recorded at the Project area have been classified by Benson (1989). Source: Benson (1989)

Conservation Status 1 = Not conserved or if so only minuscule areas are located in reserves.

2 = Inadequately conserved, either because only relatively small areas are located in reserves or major parts of its geographical range remains unprotected.

Risk Code E = Endangered – likely to become extinct within a few decades if action is not taken to rectify the decline of the association and protect and manage areas.

V = Vulnerable – likely to become endangered within a few decades if action is not taken to rectify the decline of the association and protect and manage areas.

N = Not threatened in the foreseeable future however this could change if landuse changes.

Table A-10 Conservation Status of Major Vegetation Alliances in the Central Western Region

Alliance	Structure	Location	Status
<i>E. populnea</i> – <i>Callitris</i> sp.	Low woodland/tall shrubland	Plains	2
<i>E. camaldulensis</i>	Woodland/forest, fringing forest	Slopes, plains, along rivers	2

Source: Adapted from Goldney and Bowie (1990)

Status 2 = Poorly conserved in region but conserved elsewhere

Lakebed

Lake Cowal is a shallow, ephemeral lake that is significantly dry for about three years out of ten. Filling of the Lake is episodic and variable. Without inflows, drying of the Lake consists predominantly of evaporative losses, with a period of approximately three years taken to reduce the Lake from full storage to minimal storage levels. Subsequently the amount of lakebed covered in water is highly variable.

The vegetation on the lakebed of Lake Cowal is adapted to the irregular wetting and drying cycle. When inundated, propagules of ephemeral aquatic plants germinate and grow rapidly providing a food source for similarly ephemeral invertebrates and nomadic waterbirds. When dry, the bare lakebed is colonised by the seeds of many grasses and herbs creating a temporary grassland. The shallower parts of the lakebed also feature permanent swamp vegetation (viz. Lignum and Canegrass) which can tolerate the extremes of wetness and dryness.

Within the Project area the vegetation of the lakebed is composed almost uniformly of the naturalised plant *Medicago polymorpha* and to a lesser extent, *Eragrostis australasica*.

Like many other lakes in Australia, Lake Cowal's value to bird life relates to its shallow depth and to the cycles of flooding and drying that have occurred over a large period of time. As a consequence of evaporation of innumerable floodwaters, a rich store of nutrients has accumulated.

Integral to the Lake's ecology is its periodic drying which results in the release of nutrients in mineral form from the built-up organic matter. When the lake fills after a period of drying, it is these nutrients that generate the temporary bloom of aquatic life on which many birds thrive. When Lake Cowal is dry, contains little water or otherwise has become less productive of aquatic life under relatively stable water level conditions, wetland habitats of other inland river floodplains provide this critical resource. Waterbirds are generally adept at moving sometimes hundreds of kilometres to suitable habitat.

Thus in this wetland system Lake Cowal provides, albeit episodically and for relatively short periods of time, habitat for wetland bird life that is of national significance.

Riparian Zone

The riparian zone of Lake Cowal and tributaries comprises mainly a fringing woodland of River Red Gums which has been substantially thinned as a result of past land uses. The transition between the riparian zone and the surrounding vegetation is sharp and corresponds to the high water level of the Lake.

Shrub layer development and ground substrate is almost non-existent in this highly disturbed strip and hence it is unlikely to provide habitat opportunities for terrestrial fauna. Microchiropteran bat species known to utilise tree hollows as roost sites could potentially occur in this habitat.

Cleared Lands with Scattered Woodland

Predominantly cleared, open land that has undergone cropping and grazing, scattered isolated woodlands dominated by Poplar Box (*E. populnea*) and associated species occur sporadically. The landform is generally flat to gently undulating and dissected by occasional shallow gullies. Scattered patches of gilgai soils occur throughout the area. These feature irregular mounds and depressions, which provide microhabitats for some plant species. The tree cover on gilgai is dominated by *E. populnea* and Belah (*Casuarina cristata*).

Amphibian species (viz. frogs) may inhabit the gilgai depressions during periods of suitable rainfall however the open nature of the area (increased risk of predation) and relatively high levels of disturbance that have contributed to a reduction in the micro and macro habitat values of the area, are likely to preclude significant usage or reliance.

The prevalence of feral predator and competitor species (eg. fox and rabbit) is likely to have substantially reduced the value of this habitat as a breeding and/or foraging resource.

Vegetated Slopes

To the west of Lake Cowal a series of north-south oriented ridges rises above the surrounding flatter terrain. The most prominent is Wamboyne Mountain in the north, which rises to 412 m, or 207 m above the high watermark of the Lake, while Billys Lookout in the south, is a lower hill at 368 m. Within the proposed MLA area a small rise (223 m) known as Cowal West Hill occurs about 1.7 km from the Lake edge. The lower slopes of Wamboyne Mountain and Billys Lookout and the greater majority of Cowal West Hill, are dominated by White Cypress Pine (*Callitris glaucophylla*). This grades into the ridgetop vegetation which is dominated by Spearwood (*Acacia doratoxylon*), Dwyer's Red Gum (*Eucalyptus dwyeri*) and *C. glaucophylla*.

Figure A-12 presents a plan of the habitats of the Project area and surrounds.

4.2.2 Fauna Surveys of the Project Area and Surrounds

Numerous fauna surveys of the Lake Cowal area and surrounds have been undertaken since the late 1970s and have included survey of terrestrial fauna and aquatic fauna with the focus primarily on waterbirds.

Specific survey of the Project area and surrounds has been conducted by Greg Richards and Associates (1997a), Mount King Ecological Surveys (1997), Gunninah Consultants (1995), Hawking (1995), Environmental and Educational Services (EES) (1992a,b,c, 1993a,b,c, 1994a,b,c, 1995a,b,c, 1996a,b,c, 1997a,b,c), Hawking (1991) and Lane (1989, 1990, 1991a,b,c).

Avifauna

Numerous investigations of avifauna at Lake Cowal and its surrounds have been undertaken over the last 20 years and includes Vestjens (1977), Braithwaite *et al.* (1985a, b; 1986a, b), Kingsford *et al.* (1989, 1990), Lawler (1989), Lane (1989, 1990, 1991a,b,c), EES (1992a,b,c, 1993a,b,c, 1994a,b,c, 1995a,b,c, 1996a,b,c, 1997a,b,c), Gunninah Consultants (1995) and Crome (1995).



Methodology

Bird survey of the Project area was undertaken in April 1994 (Gunninah Consultants, 1995). Habitats surveyed include open woodland, grassland, lakeside vegetation and open forest. Bird observation routes for the study are presented in Figure A-13. This survey targeted terrestrial species (eg. passerines and parrots), aquatic species (eg. cormorants, ducks and grebes), species utilising both wetland and terrestrial habitats (eg. egrets, herons and ibis) and shorebirds (eg. plovers, dotterels and rails).

Specific waterbird surveys at Lake Cowal and surrounds (Lane, 1989;1990, 1991a,b,c; EES, 1992a,b,c, 1993a,b,c, 1994a,b,c, 1995a,b,c, 1996a,b,c, 1997a,b,c) have been carried out since August 1989 using a series (four) of set transects. The four transects include T1 – Project area shoreline; T2 – south-southwestern shoreline; T3 – north-eastern shoreline and T4 – south-eastern shoreline and are illustrated on Figure A-14.

The four transects, ranging from 2.0 to 3.5 km in length and 300 m wide (Lane, 1989, 1990, 1991a,b,c; EES, 1992a,b,c, 1993a,b,c, 1994a,b,c, 1995a,b,c, 1996a,b,c, 1997a,b,c), were surveyed for waterbirds in August, October and January of each year throughout the survey period. No counts were made in the season of August 1990 to January 1991 as the design of the monitoring programme was being assessed at that time. Up until the October 1997 survey 23 individual surveys had been completed, representing eight August – October – January survey seasons. The transects covered some 11 linear kilometres of the open shores of the Lake. Waterbirds were counted along each transect over a one or two day period on each visit. Aerial reconnaissance was also undertaken in October 1989, January 1990, January 1993 and January 1995. These waterbird surveys are continuing.

Surveys of waterbird breeding activity have also been conducted from August 1989 to October 1997 (Lane, 1989, 1990, 1991a,b,c; EES, 1992a,b,c, 1993a,b,c, 1994a,b,c, 1995a,b,c, 1996a,b,c, 1997a,b,c). Surveys were conducted in August, October and January to span the breeding season of species likely to be using the Lake. Areas of Lignum, River Red Gum and Canegrass were surveyed from canoe or boat for breeding waterbirds. Occasional aerial reconnaissance (October 1989, January 1990, January 1993 and January 1995) was also undertaken when low breeding activity was suspected. Incidental observations of breeding activity or young birds, particularly along the four shore-based transects (T1, T2, T3 and T4) used for monitoring waterbird abundance, were also recorded.

Vestjens (1977) surveyed the northern half of Lake Cowal for avifauna from 1969 to 1976. The area included Bogeys Island in the north, large Lignum areas in the south and the northern and north-western shores (*ibid.*). The study area was visited for a week every month (except in 1974 and 1975 when the area was visited three and five times respectively). A standard route of approximately 55 km was surveyed by canoe for avifauna. Shore areas were surveyed by vehicular and pedestrian means.

Results

A total of 277 bird species have been recorded or are considered possible occurrences in the Lake Cowal region (Gunninah Consultants, 1995; Lane, 1989, 1990, 1991a,b,c; EES, 1992a,b,c, 1993a,b,c, 1994a,b,c, 1995a,b,c, 1996a,b,c, 1997a,b,c; Vestjens, 1977; Lawler, 1989; Hatton, 1991 in Gunninah Consultants) Illawarra Bird Observers Club in Gunninah Consultants, 1995; CSIRO,1997;NPWS,1997) (Attachment A4), although a number of these are exceptional vagrants and others may have been misidentified.

Based on total bird counts obtained from the transects during the August 1989 to October 1997 survey period (Lane, 1989,1990,1991a,b,c; EES, 1992a,b,c; 1993a,b,c; 1994a,b,c; 1995a,b,c; 1996a,b,c; 1997a,b,c), the Grey Teal (*Anas gracilis*) was the most abundant waterbird species recorded with 22,133 individuals, followed by the Eurasian Coot (*Fulica atra*) with 12,667 individuals and Australian Pelican (*Pelecanus conspicillatus*) with 6,760 individuals.

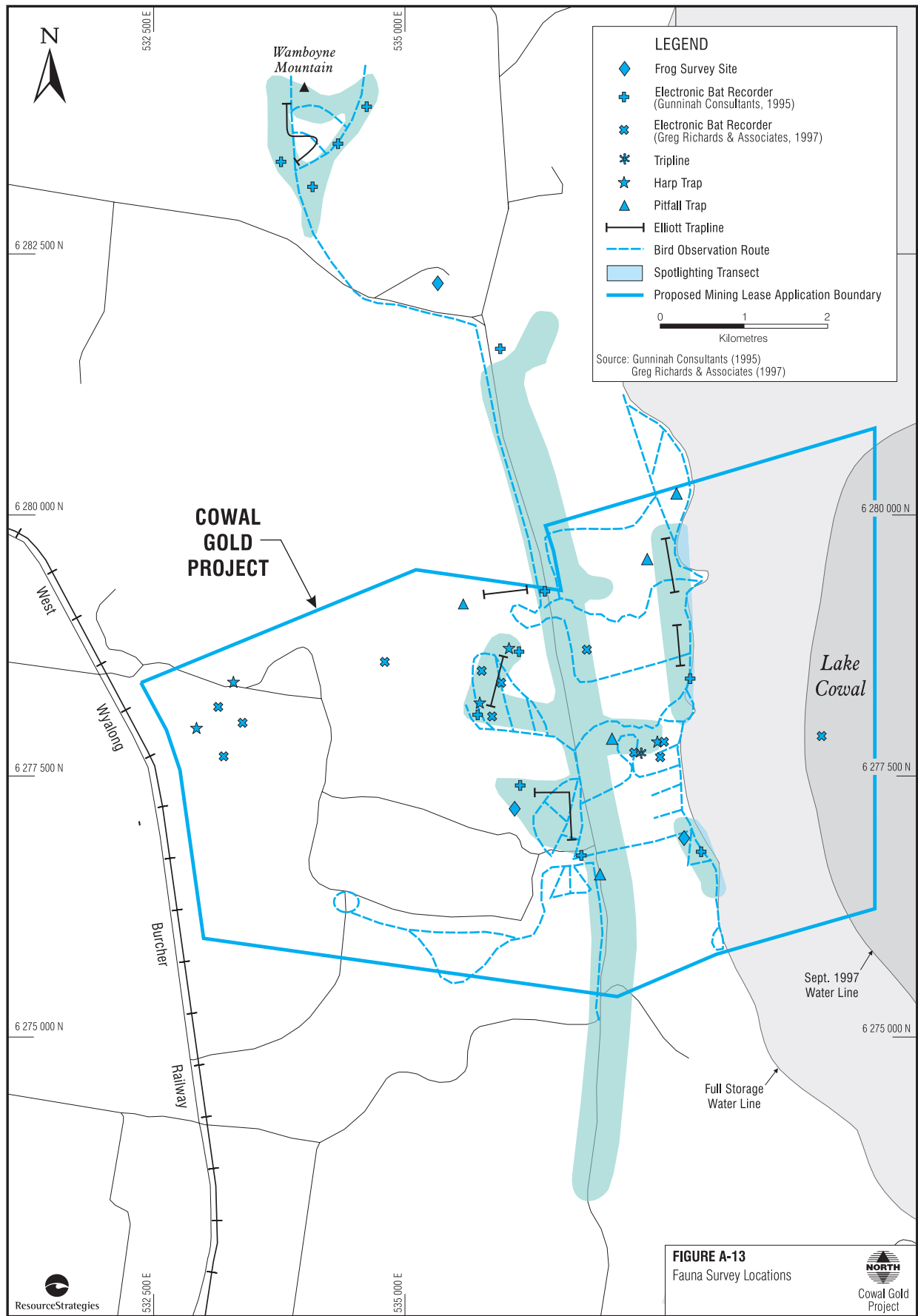
The Black-winged Stilt (*Himantopus himantopus*) (2,798), Pacific Black Duck (*Anas superciliosa*) (2,448), Purple Swampphen (*Porphyrio porphyrio*) (3,003) and Black Swan (*Cygnus atratus*) (2,798), were the next most abundant species.

The highest overall abundance of waterbirds and the highest number of species were recorded in the month of January (*ibid.*), in the season of summer drought across Australia. Other taxa to be recorded most frequently during January include Great Egret (*Egretta alba*), Royal Spoonbill (*Platalea regia*), Pacific Black Duck (*Anas superciliosa*), Australasian Shoveler (*Anas rhynchos*), Masked Lapwing (*Vanellus miles*), Latham's Snipe (*Gallinago hardwickii*) and Silver Gull (*Larus novaehollandiae*) (*ibid.*).

A number of threatened waterbird species have been recorded at Lake Cowal viz. Australasian Bittern (*Botaurus poiciloptilus*), Freckled Duck (*Stictonetta naevosa*), Blue-billed Duck (*Oxyura australis*), Black-necked Stork (*Ephippiorhynchus asiaticus*), Osprey (*Pandion haliaetus*), and Brolga (*Grus rubicundus*). Table A-11 indicates the abundance of each species recorded during the 1989-1997 transect surveys.

The Freckled Duck is the only threatened species likely to ever occur on the Lake in moderate numbers (Crome, 1995). The Blue-billed Duck, Brolga and the Australasian Bittern appear to occur there only sporadically and in low numbers (*ibid.*).

Blue-billed Ducks are present in small numbers at any time in deeper water (Crome, 1995). Large flocks of Brolgas are known to occur in the Gulf country of northern Queensland and are common inhabitants of coastal floodplains (*ibid.*) and as such, are considered a rare visitor to the region. Naturally rare and secretive, the Australasian Bittern prefers dense reed and Cumbungi beds to the open areas (*ibid.*) that characterise much of Lake Cowal.



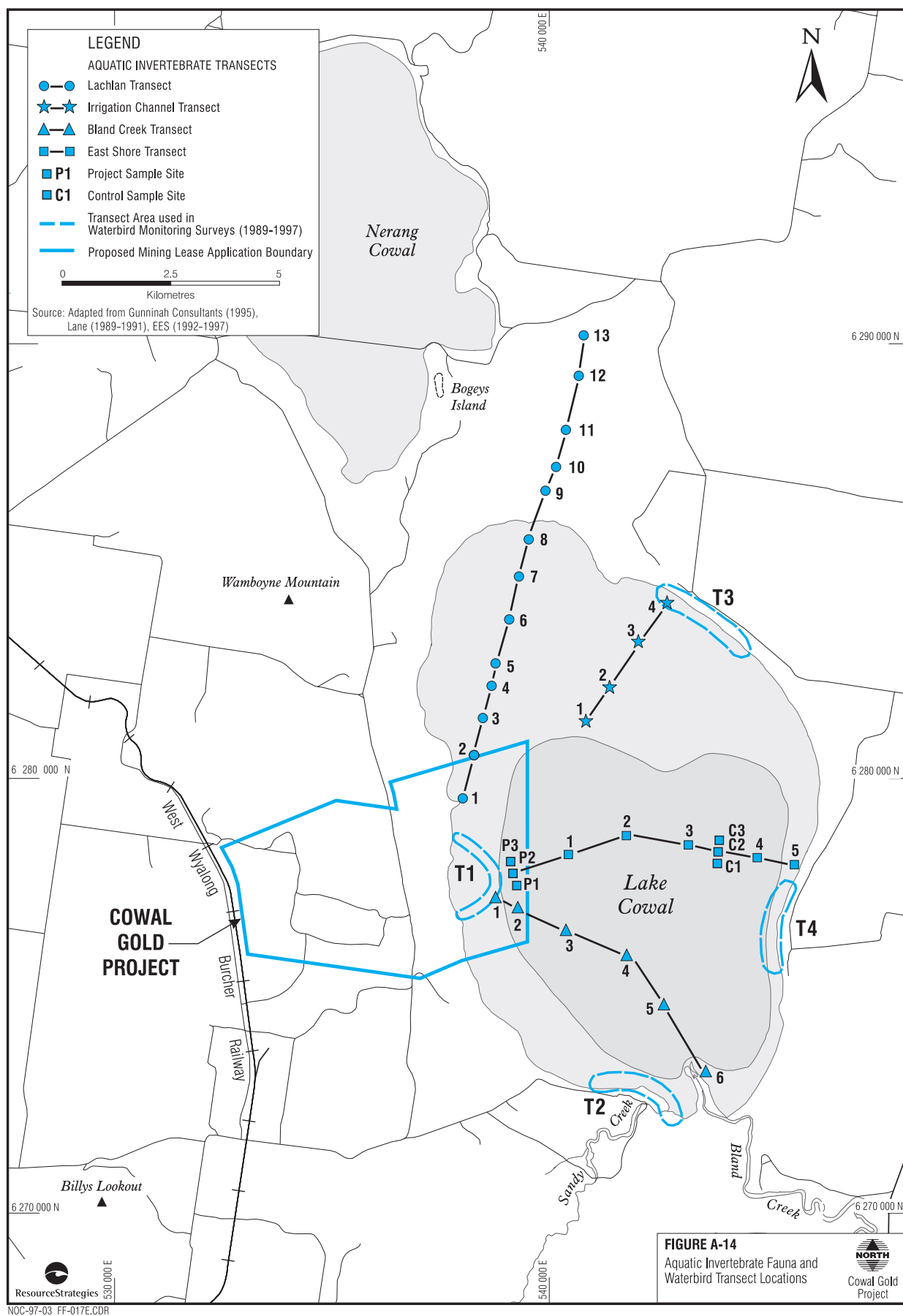


Table A-11 Abundance of Threatened Species Recorded on the Lake Cowal Transects (1989–1997)

Species	Scientific Name	Abundance of Threatened Species Recorded on Transects (1989–1997)						Total
		Oct 89	Jan 90	Jan 93	Jan 94	Jan 95	Aug 96	
Australasian Bittern	<i>Botaurus poiciloptilus</i>	–	–	1	1	–	–	2
Blue-billed Duck	<i>Oxyura australis</i>	–	13	–	–	–	–	13
Freckled Duck	<i>Stictonetta naevosa</i>	4	23	–	–	14	28	69
Brolga	<i>Grus rubicundus</i>	–	3	–	–	2	–	5

Source: Lane (1989; 1990, 1991a,b,c); EES (1992a,b,c; 1993a,b,c; 1994a,b,c; 1995a,b,c; 1996a,b,c; 1997a,b,c).

Figure A-15 illustrates the large year to year variation in total waterbird counts recorded on the transects at Lake Cowal. This variation in abundance is also illustrated in patterns of individual species (Attachment A5).

For example, three survey periods (August 1991, October 1991, January 1992) revealed abundances of the Grey Teal on transects varied from 111 to 68 to 1,649, respectively. Likewise abundances of the Australian Pelican on transects varied from 155 to 242 to 1,063 in August 1994, October 1994 and January 1995, respectively.

Waterbird presence and absence is not only influenced by the conditions within a wetland but also by regional and national weather (particularly rainfall) and wetland availability (Crome, 1995). A species may be abundant for several weeks on a particular wetland and then disappear overnight (*ibid.*).

It should be noted that transect counts of waterbirds at Lake Cowal are not necessarily indicative of the flux and dynamics of waterbird populations at Lake Cowal. For example, only 59 Australian Shelducks (*Tadorna tadornoides*) and a single Pink-eared Duck (*Malacorhynchus membranaceus*) were counted on the survey transects in January 1992, yet there was a flock of more than 800 Australian Shelducks and 120 Pink-eared Ducks in the northern parts of the Lake during the 1992 survey season (Crome, 1995; EES, 1992a). Similarly, in October 1989, no Nankeen Night Herons (*Nycticorax caledonicus*) were recorded on the transects; however over 400 were recorded off the transects but still within the region at this time (Crome, 1995; Lane, 1990).

Thirty-six waterbird species have been recorded breeding at Lake Cowal from August 1989 to October 1997 (Attachment A6). Survey records (Crome, 1995; Lane, 1989, 1990, 1991a,b,c; EES, 1992a,b,c, 1993a,b,c, 1994a,b,c, 1995a,b,c, 1996a,b,c, 1997a,b,c) indicate that the major breeding areas occur in the wooded and vegetated parts to the north of the Lake viz. in the Lignum/River Red Gum expanses some 4.5 km to the north of the Project area.

Seasonally breeding activity is greatest in October and January, with 32 species recorded breeding in January, 11 species recorded in August and 26 species recorded in October (Lane, 1989, 1990, 1991a,b,c; EES, 1992a,b,c, 1993a,b,c, 1994a,b,c, 1995a,b,c, 1996a,b,c, 1997a,b,c). Very little breeding appears to occur in August. Species recorded breeding at the Lake in August are the White-faced Heron,

Australian Shelduck, Grey Teal, Hardhead, Eurasian Coot, Black Swan, Pacific Black Duck, Pink-eared Duck, Australian Wood Duck, Silver Gull and White-bellied Sea Eagle.

Species known to breed colonially at the Lake include Darter, Great Cormorant, Pied Cormorant, Little Black Cormorant, Little Pied Cormorant, Great Egret, Intermediate Egret, Nankeen Night Heron, Glossy Ibis, Australian White Ibis, Straw-necked Ibis, Royal Spoonbill, Yellow-billed Spoonbill and Silver Gull.

None of the colonially nesting species have been recorded breeding in August, with the exception of a small number of Silver Gulls. The Silver Gulls were recorded breeding at two places in the northern end of the Lake in August 1991. The rest of the colonial nesting activity appears to have commenced mostly in September, as breeding was well established by the October surveys.

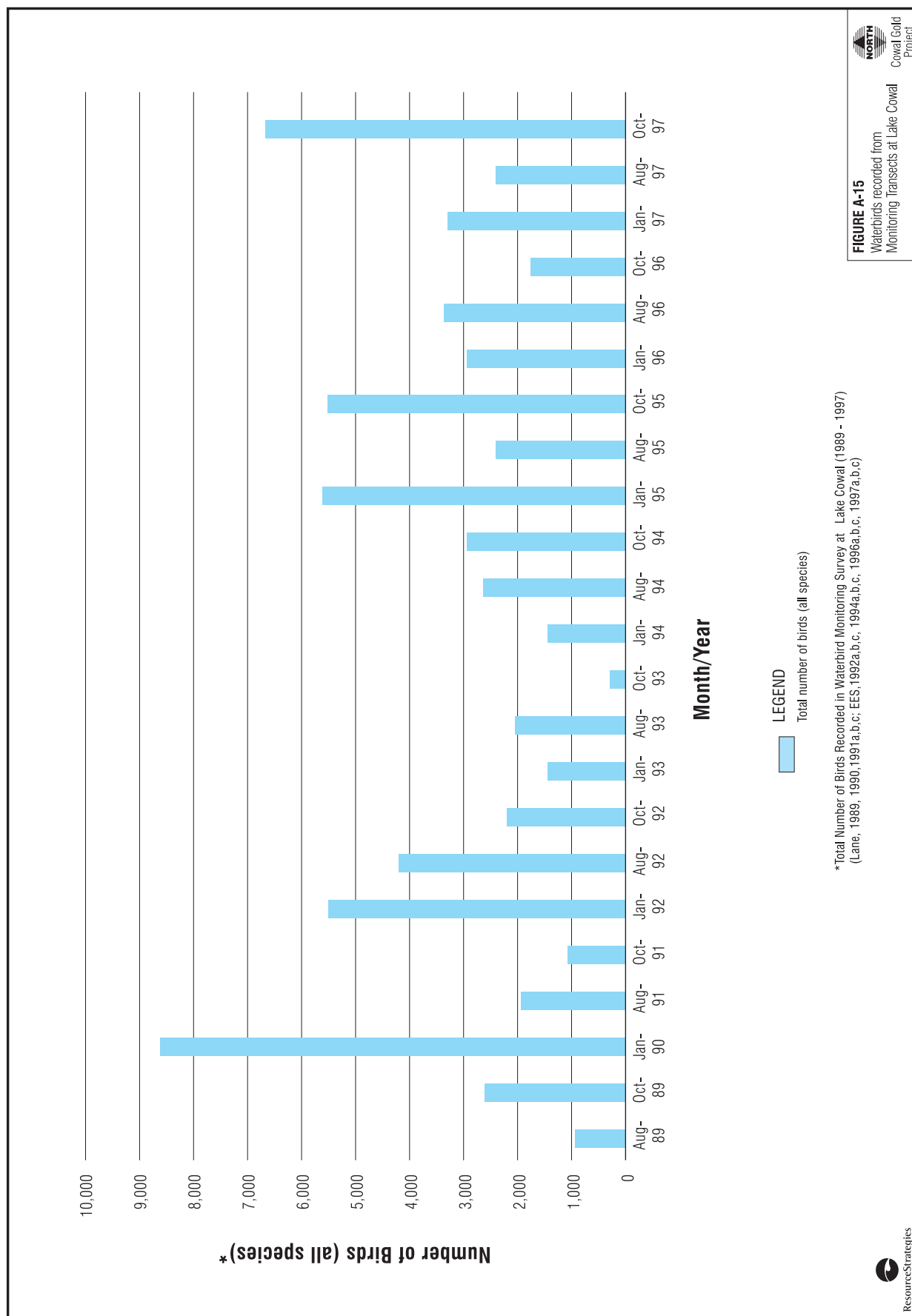
The colonially breeding species appeared to adopt set locations for breeding. Breeding activity of ibis and Royal Spoonbill mainly takes place in the large stands of Lignum.

Darter and Yellow-billed Spoonbill were recorded in stands of River Red Gum (and isolated trees) in open water. The Little Black Cormorants generally breed in the denser stands of River Red Gum, while Pied Cormorants tended to breed in individual trees (Lane, 1989, 1990, 1991a,b,c; EES, 1992a,b,c, 1993a,b,c, 1994a,b,c, 1995a,b,c, 1996a,b,c, 1997a,b,c).

Over eight breeding seasons (August 1989 –October 1997) very little colonial breeding activity was recorded within 2.5 km of the proposed development (Lane, 1989, 1990, 1991a,b,c; EES, 1992a,b,c, 1993a,b,c, 1994a,b,c, 1995a,b,c, 1996a,b,c, 1997a,b,c; EES, 1992–1997). Grey Teal was the only species to be recorded breeding in the Project area transect (incidental observations). In August 1995 two Pacific Black Duck young were observed on a dam in the Project area (EES, 1995b). Other bird breeding activity recorded in the proposed MLA vicinity includes the Whiskered Tern (1989/90), Gull-billed Terns (1989–90), Silver Gull (1991/92/93/94), Black Swan (1993/94), White-necked Heron (1993/94), White-faced Heron (1993/94) and Darter (1995).

Terrestrial Fauna

Vestjens (1977) recorded terrestrial fauna (reptiles, amphibians, mammals) occurring in the northern half of Lake Cowal from 1969 to 1976. The area included Bogeyes Island in the north, large Lignum areas in the south and northern and north-western shores (*ibid.*). The study area



was visited for a week every month (except in 1974 and 1975 when the area was visited three and five times respectively).

Survey of terrestrial fauna (reptiles, amphibians, mammals) of the Project area and surrounds was undertaken by Gunninah Consultants in April 1994. All habitats of the Project area were surveyed including open woodland, grassland, lakeside vegetation and open forest. Various methodologies were utilised in the 1994 survey including Elliott box trapping, pitfall trapping, amphibian call recording, spotlighting and active diurnal searches for animals, or evidence of animal occurrence (scats, bones, tracks, diggings etc.). A summary of methodologies and results of the 1994 terrestrial fauna survey is presented below. Fauna survey sites are presented in Figure A-13.

Methodology

- Elliott Traps

A total of 103 Elliott traps were placed at the Project site in April 1994. The Elliott traps were baited with a mixture of rolled oats, peanut butter and honey and set for five consecutive nights, achieving a total of 515 trap nights.

- Pitfall Traps

A total of 17 pitfall traps were set for five consecutive nights throughout the Project area in April 1994, achieving a total of 85 trap nights.

- Amphibian Call Recording

Recordings were made of amphibian calls for approximately 5 hours in total in the Lake foreshore area and surrounds.

- Nocturnal Survey

Pedestrian spotlighting was undertaken over the Project area for a total of approximately 22 hours during April 1994.

- Active Searching and General Observation

All habitats in the study area were searched for animals or evidence of animal occurrence over a total of approximately 5 days during April 1994. The occurrence of tracks, diggings, bones and scats were identified where possible.

Results

A total of 58 terrestrial fauna species (excluding birds) have been recorded from the Project area and surrounds, including 16 mammals (excluding bats), 31 reptiles and 11 amphibians (Vestjens, 1977; Gunninah Consultants, 1995) (Attachment A4).

- Mammals

Native terrestrial mammal species recorded from the Project area and surrounds included the Short-beaked Echidna (*Tachyglossus aculeatus*), Yellow-footed Antechinus (*Antechinus flavipes*), Eastern Grey Kangaroo (*Macropus giganteus*), Sugar Glider (*Petaurus breviceps*) and the Common Brushtail Possum (*Trichosurus vulpecula*) (Gunninah Consultants, 1995). The Red Kangaroo (*Macropus rufus*) was also recorded from the region (Vestjens, 1977).

It should be noted that the Yellow-footed Antechinus was recorded from the Wamboyne Mountain area only and the identification of the Sugar Glider was hampered by the infrequency of calls and strong winds (Gunninah

Consultants, 1995). One semi-aquatic mammal, the Water-rat (*Hydromys chrysogaster*) was also recorded during the 1994 survey. All of these species are common and widespread within their range (Strahan, 1995).

Numerous introduced species were recorded during the 1994 survey including the Cow (*Bos taurus*), Sheep (*Ovis aries*), Pig (*Sus scrofa*), Cat (*Felis catus*), Fox (*Vulpes vulpes*), Brown Hare (*Lepus capensis*), Rabbit (*Oryctolagus cuniculus*) and House Mouse (*Mus musculus*). The Black Rat (*Rattus rattus*) has also been recorded from the region (Vestjens, 1977).

A list of mammal species known or considered likely to occur in the Lake Cowal region is presented in Attachment A4.

- Reptiles

Habitat searches and pitfall trapping recorded the Lace Monitor (*Varanus varius*), Thick-tailed Gecko (*Underwoodisaurus milii*), Spiny-palmed Shinning-skink (*Cryptoblepharus carnabyi*), Eastern Brown Snake (*Pseudonaja textilis*), Southeastern Morethia Skink (*Morethia boulengeri*), Wood Mulch-slider (*Lerista muelleri*) and Bearded Dragon (*Pogona barbata*) (Gunninah Consultants, 1995). A further 24 reptile species have been recorded from the region (Vestjens, 1977). Reptile species considered possible occurrences in the Lake Cowal region are presented in Attachment A4 (CSIRO, 1997; NPWS, 1997).

No threatened reptile species have been recorded in the Project area.

- Amphibians

The following amphibian species were recorded during the 1994 survey: Sloane's Froglet (*Crinia sloanei*), Crucifix Toad (*Notaden bennettii*), Wrinkled Toadlet (*Uperoleia rugosa*), Peron's Tree-frog (*Litoria peronii*), Marsh Frog (*Limnodynastes fletcheri*) and the Spotted Grass Frog (*L. tasmaniensis*). All of these species are common to abundant and widespread throughout their ranges (Cogger, 1994).

Vestjens (1977) recorded an additional five species from Lake Cowal and surrounds viz. the Eastern Sign-bearing Froglet (*Crinia parinsignifera*), Sudell's Frog (*Neobatrachus sudelli*), Green Tree-frog (*Litoria caerulea*), Giant Banjo Frog (*Limnodynastes interioris*) and the Salmon-striped Frog (*L. salmini*).

An amphibian species database for the region (CSIRO, 1997; NSW NPWS, 1997) is included in Attachment A4.

Microchiropteran Bats

Methodology

- Electronic Detectors

Vestjens (1977) recorded bat species occurring in the northern half of the Lake from 1969 to 1976. Full details of methodology are unknown however bat calls heard at night were identified and bats were also seen flying during the day.

As a component of the 1994 survey an Anabat™ sonar detection device was used to record the high frequency calls of microchiropteran bats. Recordings were made at

10 sample sites for approximately 30 minutes tapping per site (Figure A-13). Call records were analysed and identified (where possible).

Further to the 1994 bat survey Greg Richards & Associates (1997a) conducted a bat fauna survey of the Project area between 20-25 October, 1997 (Attachment A7). A total of 16 sites were sampled including three at the pit/plant site, five at the waste emplacements, three at the inventory site and five at the tailings storages areas (Table A-13). An inventory site is one that is not an impact zone. Habitats surveyed included Eucalypt woodland, River Red Gum, *Callitris* woodland, stock dams and the edge of Lake Cowal (Table A-12).

Methodology utilised in the 1997 bat survey included sonar detectors, harp traps, triplining and habitat searches. A summary of methodology employed for the habitat areas is presented below and survey sample sites are presented in Figure A-13.

Bat fauna were recorded throughout the night using Anabat™ echolocation call detectors with a voice activated switching device. A total of 12 nights of electronic detecting of echolocation calls was undertaken (detecting was carried out from dusk until dawn). Species-specific echolocation calls were analysed using digitised computer displays and identifications made. Identifications were made after each night, in the event that a threatened species had been recorded and may have required specialised, intensive and/or extended survey.

- Harp Traps

A total of 5 harp traps were set for two nights (from dusk until dawn each night) in each wooded habitat. The harp traps were used to target/capture species with low intensity echolocation calls, which may not have been recorded

electronically. Plastic net wings approximately 15 m long were attached to the sides of the trap frame to increase the catch area.

- Triplining

Triplining (ie. monofilament fishing line that is stretched tightly just above a water surface) targets bats that fly low to drink from a waterbody. Bats are captured as they swim to the bank after falling into the water upon contact with the tripline. Triplining was conducted from dusk for approximately 3 hours one evening at Site 2 (a stock dam near the exploration base) to survey species that could be expected in the area where the plant and pit are proposed to be constructed.

- Habitat Searches

Although there are no limestone caves in the area (Matthews, 1985 in Greg Richards & Associates, 1997a), searches for other potential subterranean roost sites in the wider locality were conducted. Other potential roosts likely to be used by bats (eg. ceilings of disused buildings and mud nests of Fairy Martins) were also visually inspected.

The 1997 bat survey was carried out in conditions regarded as ideal. Night temperatures were relatively mild for most of each night, there was no rainfall and moonlight was absent.

Results

Five bat species were recorded by Vestjens (1977):

White-striped Freetail-bat (*Nyctinomus australis*)

Little Free-tail Bat (*Mormopterus planiceps*)

Lesser Long-eared Bat (*Nyctophilus geoffroyi*)

Gould's Wattled Bat (*Chalinolobus gouldii*)

Unknown Forest Bat (*Vespadelus* sp.)*

* At the time of Vestjens (1977) survey, the taxon *Vespadelus* (then known as *Eptesicus*) contained just one species *E. pumilus*. After several taxonomic revisions the genus was changed to *Vespadelus* and now contains 9 species. The Vestjens (1977) record could be one of several *Vespadelus* species that are known from the area (Greg Richards, pers. comm., 1997).

Table A-12 Bat Survey Methodology Summary

Site	Habitat	Methodology	Project Area Location
1	River Red Gum patch	Harp trap, detector	Pit/plant site
2	Stock dam near exploration base	Detector, triplining	Pit/plant site
3	Eucalypt woodland	Detector	Waste emplacement site
4	Stock dam in open pasture	Detector	Inventory site
5	Edge of Lake Cowal	Detector	Inventory site
6	Eucalypt woodland	Detector	Waste emplacement site
7	Eucalypt woodland	Harp trap	Waste emplacement site
8	River Red Gum patch	Detector	Pit/plant site
9	<i>Callitris</i> woodland	Detector	Tailings storages site
10	<i>Callitris</i> woodland	Harp trap	Tailings storages site
11	<i>Callitris</i> woodland	Detector	Tailings storages site
12	<i>Callitris</i> woodland	Harp trap	Tailings storages site
13	<i>Callitris</i> woodland	Detector	Tailings storages site
14	Stock dam in open pasture	Detector	Inventory site
15	Eucalypt woodland	Harp trap	Waste emplacement site
16	Eucalypt woodland	Detector	Waste emplacement site

Source: Greg Richards and Associates (1997a)

The 1994 microchiropteran bat survey yielded six additional species:

Troughton's Bat (*Vespadelus troughtoni*)
 Southern Forest Bat (*Vespadelus regulus*)
 Little Forest Bat (*Vespadelus vulturnus*)
 Inland Broad-nosed Bat (*Scotorepens balstoni*)
 Little Broad-nosed Bat (*Scotorepens greyii*)
 Little Pied Bat (*Chalinolobus picatus*)

The 1997 survey yielded two additional species:

Yellow-bellied Sheathtail-bat (*Saccolaimus flaviventris*)
 Chocolate Wattled Bat (*Chalinolobus morio*)

The Lesser Long-eared Bat, Troughton's Bat, Inland Broad-nosed Bat, Little Broad-nosed Bat and the Little Pied Bat were recorded from the Wamboyne Mountain area only, during the 1994 survey. The Lesser Long-eared Bat and Little Broad-nosed Bat were recorded from the Project area in the 1997 survey.

The Yellow-bellied Sheathtail-bat is listed in the TSC Act and was recorded electronically near the lake shore, to the east of the Project area. The Little Pied Bat and Troughton's Bat are also listed as vulnerable in the TSC Act and were recorded from Wamboyne Mountain area approximately 5 km north of the Project area in the 1994 survey.

No megachiropteran bats were recorded during the survey and no flying-fox camps were known to occur in the area.

The search for subterranean roost sites found that vertical shafts of old mines in the region were doubtfully suitable as bat roosts as many of these mineshafts had been filled in.

For further details of the 1997 bat survey and assessment refer to Attachment A7.

Aquatic Fauna

A baseline monitoring programme of aquatic macroinvertebrates of Lake Cowal was conducted in March/April 1991 and supplemented by a further study in January 1995 (Hawking, 1991; Hawking, 1995). The supplementary invertebrate sampling by Hawking (1995) provided a baseline of invertebrates (diversities and densities) in the area to be disturbed by the proposed pit and sampled sites previously sampled by Hawking (1991). Aquatic sampling included the collection of benthic fauna, pelagic macroinvertebrates and plankton using a variety of recognised techniques as summarised below.

In 1991, 34 sites on four transects were selected for sampling: the Bland transect (6 sites), East transect (11 sites), Irrigation transect (4 sites) and Lachlan transect (13 sites) (Humphries *et al.*, 1991). A summary of methodologies and results of the fish, crustacean and macroinvertebrate monitoring programmes is presented below. Survey sites are presented in Figure A-14.

Methodology

• Metal Concentrations

As part of the aquatic baseline studies in 1991/1992, metal concentrations (cadmium, copper, lead, zinc, arsenic and mercury) were measured in Yabbies (*Cherax destructor*), Prawns (*Macrobrachium australiense*), Golden Perch (*Macquaria ambigua*) and European Carp (*Cyprinus carpio*) by NSR Environmental Consultants (1995).

Yabbies (*Cherax destructor*) and prawns (*Macrobrachium australiense*) were sampled using yabby traps and hoop traps baited with meat scraps, liver or carp. Yabbies were obtained from all four transects located within the Lake and prawns were sampled at the Lachlan and Irrigation transects (Figure A-14).

Yabbies were sexed, measured (carapace length) and had their tails removed and frozen on the day of capture. Prawns were frozen whole on the day of capture. Their carapace lengths were measured, sorted into similar size groupings and further sample preparation was undertaken at the laboratory.

Fresh whole fish were supplied by commercial fishermen. The fish were measured and dissected within 18 hours of obtaining the samples. Dissected tissues (liver and muscle samples) were immediately frozen. The sex and maturity of each fish was recorded where possible.

The following sampling methodology was undertaken in the 1991 macroinvertebrate monitoring survey:

• Artificial Substrate Samplers

To sample invertebrates colonising substrates, artificial substrate samplers were placed at several sites (Canegrass habitats, Lignum habitats, mud bottom habitats) in Lake Cowal. The artificial substrate samples were collected five weeks later.

• Dredging

Mussels were sampled using a box dredge which was towed behind the boat over a distance of approximately 200 m around the sample site. Core samples taken for benthic fauna were also checked for mussels.

In 1995, seven of the previous sites (Bland 1, Bland 5, Project 2, East 2, Control 2, Lachlan 1 and Lachlan 7) were sampled in this supplementary study. Four additional sites were sampled: two within the pit area and two between the pit area and the proposed new lake foreshore.

Macroinvertebrates collected by sampling were identified and checked by recognised experts. The following sampling methodology was undertaken in both the 1991 and 1995 monitoring programmes:

• Plankton Net

Plankton was sampled from each site using a 49 µm plankton net. The plankton net was hauled over a 3 m horizontal distance, just under the surface.

• Sediment Cores

Benthic fauna was collected using a hand operated sediment corer. Five sediment cores were taken at each site and contents were sieved through mesh sizes of 10 mm, 2 mm and 500 µm.

- Sweep Nets

Pelagic macroinvertebrates were collected from the side of a boat using a sweep net (300 µm mesh netting). Ten sweeps were taken at each site, each sweep sampling an area of approximately 3 m in length.

In the 1995 survey physical parameters (water temperature and water depth) were also recorded at each site.

Results

- Fish and Crustaceans

The baseline studies found that mean total copper, cadmium, lead, zinc, arsenic and mercury values for all species sampled were below the National Food Authority (NFA) standards.

More than 50% of the reported cadmium and lead values in Golden Perch and European Carp and more than 50% of the reported lead values in yabbies and mercury values in prawns, were less than the detection limit (NSR Environmental Consultants, 1995).

The following fourteen species of fish have been recorded from Lake Cowal by Vestjens (1977) and Fisheries Research Institute (1997).

Australian Smelt (*Reptropinna semoni*)
 Goldfish (*Carassius auratus*)*
 Freshwater Catfish (*Tandanus tandanus*)
 European Carp (*Cyprinus carpio*)*
 Silver Perch (*Bidyanus bidyanus*)
 Mosquito Fish (*Gambusia holbrooki*)*
 Big-headed Gudgeon (*Philypnodon grandiceps*)
 Rainbow Trout (*Onchorhynchus mykiss*)*
 Western Carp Gudgeon (*Hypseleotris klungzingeri*)
 Redfin Perch (*Perca fluviatilis*)*
 Golden Perch (*Macquaria ambigua*)
 Bony Bream (*Nematalosa erebi*)
 Murray Cod (*Maccullochella peelii*)
 Macquarie Perch (*Macquaria australasica*)

* Introduced Species

Young (1979a in Gunninah Consultants, 1995) also conducted surveys of fish fauna at Lake Cowal of three aquatic habitats. Young (1979a in Gunninah Consultants, 1995) found that Golden Perch preferred shallow areas with Lignum and Canegrass or deeper water along the reaches of Bland Creek. The Redfin Perch was most abundant in open water with Canegrass, however also utilised shallow water with Lignum, Canegrass and Eucalypts (Young, 1979a in Gunninah Consultants, 1995).

- Macroinvertebrates

A total of 49 species of macroinvertebrates were collected from Lake Cowal during the 1991 monitoring survey (Hawking, 1991). In the 1995 monitoring survey 25 species of macroinvertebrates were collected from the core (20 species) and sweep net samples (12 species), with seven species common to both methods. In the 1991 survey the sweep net collections were dominated by the backswimmer *Anisops gratus* and the crustacean *Macrobrachium*

australiense. *Anisops gratus* also dominated the 1995 sweep net samples, as well as the crustacean *Paratya australiensis*. The core samples predominantly contained a diverse assortment of oligochaete and chironomid species in both the 1991 and 1995 surveys. The artificial substrates sampling colonising invertebrates in the 1991 survey also collected predominantly chironomids. No live mussels were collected from dredging or cores (Hawking, 1991). Hawking (1991, 1995) found that the Lake margins (shallow water) were the areas richest in species diversity and abundance.

Kirra Environmental Group (1991) investigated invertebrate fauna of Lake Cowal and found:

- lake sediments were low in invertebrate diversity;
- open waters were low in invertebrate diversity and abundance;
- shallows with Canegrass were high in invertebrate diversity but low in abundance; and
- invertebrates associated with vegetation were high in diversity and abundance.

4.2.3 Seasonality

Flora

Flora of the Project area and surrounds has been surveyed in September, October, December and January (Charles Sturt University, 1997; Anne Clements & Associates, 1995, 1996).

It is considered that over 90% of flora species likely to be occurring within the proposed MLA would have been identified during these surveys (Bower, pers. comm., 1997; Burrows, pers. comm., 1997).

In the October survey, most herbaceous plants were flowering providing an ideal vegetation sampling period (Anne Clements & Associates, 1995). In December grasses were also in full flower (*ibid.*).

Austral Pillwort (*Pilularia novae-hollandiae*) is a threatened species that was recorded from the western edge of Lake Cowal and along the riparian zone of Bland Creek near the confluence with the Lake in the 1993 vegetation survey (Anne Clements & Associates, 1995). This species was not recorded during the 1997 survey despite target searches of gilgai areas and other potentially suitable habitat areas.

The Winged Peppergrass (*Lepidium monoplacoides*) has not been recorded from the survey areas. It is a cryptic annual (Doherty, pers. comm., 1997) or possibly perennial species (Cunningham *et al.*, 1981), that reaches a height of 15-20 cm (Leigh *et al.*, 1984). This species mainly flowers in the August-October period although flowering can continue until December (*ibid.*). Given that *Lepidium* is a genus known to be highly palatable to stock (Bower, pers. comm., 1997), it is considered that the high grazing activity would have excluded this species from the area.

Fauna

Terrestrial Fauna

Survey of terrestrial fauna of the Project area and surrounds was conducted monthly from 1969 to 1976 (except in 1974 and 1975 when the area was visited three and five times

respectively) (Vestjens, 1977), in April 1994 (Gunninah Consultants, 1995) and October 1997 (Greg Richards and Associates, 1997a).

- Amphibians

The call of male amphibians is widely used in the identification of frogs (Cogger, 1994). For example, the call of the male Southern Bell Frog (*Litoria raniformis*) a summer breeder and a threatened species considered a possible occurrence in the region, can be heard from August to April (Robinson, 1993; Cogger, 1994). Given the timing and prevailing weather conditions it is considered likely that was this species to occur in the area, it would have been recorded in the surveys of the area.

Furthermore, in winter *L. raniformis* is known to hibernate in the mud at the bottom of ponds or under logs or stone in cold regions (Ayers *et al.*, 1996). Given the historic landuse of the Project area and surrounds (ie. cropping, grazing) it is considered that the cumulative effects of tillage and trampling would have excluded this species from the area. This is also likely to apply to burrowing frog species such as Sudell's Frog (*Neobatrachus sudelli*), Eastern Banjo Frog (*Limnodynastes dumerilii*) and Water-holding Frog (*Cyclorana platycephala*) which have been identified (or considered as possible occurrences) in the region (CSIRO, 1997; NSW NPWS, 1997).

- Reptiles

Vestjens (1977) recorded 30 reptile species monthly from 1969 to 1976. A further 31 reptiles are considered possible occurrences in the region (CSIRO, 1997; NSW NPWS, 1997).

Reptiles are ectothermic (ie. cold-blooded) and are able to maintain a desired body temperature by regulating their position within the surrounding environments (Hoser, 1989). Hence, many reptiles would bask in the sun or on warm ground in order to raise their body temperature and hide under cover if it gets too hot (*ibid.*). Activity may decline at cooler temperatures (Mount King Ecological Surveys, 1997). Given that monthly surveys of reptiles were conducted, it is considered that most reptile species occurring in the area would have been identified.

- Mammals

Many arboreal mammals (eg. Brush-tailed Phascogale and Squirrel Glider), Wallabies (eg. Brush-tailed Rock-wallaby), Kangaroos (eg. Red Kangaroo) and other terrestrial mammals (eg. Spotted-tailed Quoll) are active all year round, although some behaviour may be influenced by seasonal variances (eg. on long winter nights the Brush-tailed Phascogale may not emerge from their nests until after midnight). In light of this, it is considered that the majority of mammal species occurring in the area would have been identified during the April 1994 survey.

Further to the bat fauna surveys undertaken in Autumn, 1994 (Gunninah Consultants, 1995) Greg Richards and Associates carried out bat surveys in October 1997.

Climatic conditions have been found to influence bat activity (Richards, 1989). Lumsden & Bennett (1995) found that there was a marked seasonality in activity patterns of

bat fauna in the semi-arid Mallee region of Victoria. Activity (as revealed by trap captures) peaked over the spring to early autumn months when daytime temperatures were high and nights mild (*ibid.*).

The October bat survey was carried out in conditions regarded as ideal, ie. night temperatures were relatively mild for most of each night, there was no rainfall and moonlight was absent (Greg Richards and Associates, 1997a). The number of echolocation calls recorded in the 1997 survey exceeded 100 bat passes indicating that the bat fauna community was reasonably active. Given that mild and clear weather conditions were experienced in the April 1994 survey, the greater majority of bat fauna of the area at the time are likely to have been recorded. Furthermore, the bat fauna of the region is considered likely to be coming out of winter torpor and would be active to maintain fat reserves during the time of the 1997 survey (Richards, pers. comm., 1997).

- Aquatic Fauna

The wide range of sampling of aquatic fauna (macroinvertebrates, fish) undertaken at Lake Cowal by Kirra Environmental Group (1991), Hawking (1991), Hawking (1995), Young (1979b in NSR Environmental Consultants), Vestjens (1977), Gunninah Consultants (1995), Fisheries Research Institute (1997) provide a good database of aquatic fauna at the Lake. These surveys account for seasonal factors that affect the physiological nature of the Lake and hence, the population fluctuations of aquatic biota at Lake Cowal which are extremely variable due to the natural drying and filling cycles of the Lake (Humphries *et al.*, 1991).

- Birds

An extensive list of avifauna species occurring at Lake Cowal has been developed (Attachment A4) from the numerous avifauna surveys that have been conducted at Lake Cowal and surrounds over the past 20 years. For example, Vestjens (1977) recorded avifauna monthly at Lake Cowal from 1969 to 1976. In addition, a waterbird monitoring programme carried out from 1989 to 1997 by Lane (1989, 1990, 1991a,b,c) and EES (1992a,b,c; 1993a,b,c; 1994a,b,c; 1995a,b,c; 1996a,b,c; 1997a,b,c) recorded waterbird abundance and breeding activity every August, October and January.

5.0 THREATENED SPECIES

5.1 Threatened Species of the Lake Cowal Region

5.1.1 Flora

In consultation with the NSW NPWS Threatened Species Unit (Western Division), a preliminary threatened plant species list for the Lake Cowal region was prepared (Charles Sturt University, 1997; Bower, 1997). This list (Table A-13) was compiled using reference sources such as Briggs and Leigh (1995 Revised Edition), Sivertsen & Metcalfe (1995), NPWS database (Wildata) records for the area, as well as various anecdotal records.

Table A-13 Threatened Flora Species of the Lake Cowal Region

Scientific Name	Occurrence of Potential Habitat in the Project Area	Potential for Project to Impact on Species' Population Status
<i>Bothriochloa biloba</i>	3-4	C-D
<i>Callitriche cyclocarpa</i>	3-4	C-D
<i>Goodenia macbarronii</i>	3-4	C-D
<i>Kippistia suaedifolia</i>	4	D
<i>Lepidium aschersonii</i>	4	D
<i>Pilularia novae-hollandiae</i>	2	B
<i>Stemmacantha australis</i>	4	D
<i>Stipa wakoolica</i>	4	D
<i>Swainsona murrayana</i>	4	D
<i>Swainsona recta</i>	4	D
<i>Tylophora linearis</i>	3-4	C-D

Legend:**Occurrence of Potential Habitat in the Project Area**

1 Significant habitat resources present 2 Moderate habitat resources present
 3 Marginal habitat resources present 4 Minimal or no habitat resources present

Potential for Project to Impact on Species' Population Status

A Significant impact potential B Moderate impact potential
 C Marginal impact potential D Minimal or no impact potential

In accordance with the requirements of Section 5A of the *Environmental Planning and Assessment Act* (as amended), an 8 Part Test of Significance report was prepared for the plant species listed above (Bower, 1997). The report was submitted to the NSW Department of Urban Affairs and Planning (DUAP) and the NPWS on the 13 October 1997.

The 8 Part Test concluded that based on the information at hand at the time, the proposed development is unlikely to have a significant effect on any threatened flora, species, populations or ecological communities or their habitats. A summary of the 8 Part Test findings are presented in Table A-13.

5.1.2 Fauna

In compiling a threatened fauna species list for the Project area, a list of all fauna species known or considered likely to occur in the area was prepared (Attachment A4). The list has been compiled by accessing a number of records and databases (Gunninah Consultants, 1995; Lane, 1989, 1990, 1991a,b,c; Environmental and Educational Services, 1992a,b,c; 1993a,b,c; 1994a,b,c; 1995a,b,c; 1996a,b,c; 1997a,b,c; Vestjens, 1977; Greg Richards and Associates, 1997a; Lawler, 1989; Hatton, 1991 in Gunninah Consultants, 1995; NSW Bird Atlasers, 1995; in Gunninah Consultants, 1995; Illawarra Bird Observers Club in Gunninah Consultants, 1995; NSW NPWS, 1997; CSIRO, 1997).

From this list a preliminary threatened fauna species list was compiled (Table A-15) in consultation with the following organisations:

- *NSW National Parks and Wildlife Service*

Utilising the information and records contained within the Service document *Threatened Species of Western New*

South Wales (Ayers *et al.*, 1996), the Threatened Species Unit of the Western Zone of NPWS provided a preliminary threatened species list for the Project area.

- *Commonwealth Scientific Industrial Research*

Organisation (CSIRO) – Division of Wildlife and Ecology

A specialist team (Braithwaite, Catling, Kearns, Mason, Burt, Schodde, Stanger and Wombey) prepared a comprehensive list of fauna normally expected to occur in the area, including vagrants other than exceptional seabirds. This list was prepared using CSIRO records of species that have occurred or may occur in the area (including unrealistic vagrants amongst the birds); the NPWS Atlas of NSW Wildlife database; records and information contained in Gunninah Consultants (1995), Vestjens (1977) and Cooper & McAllan (1995). This table includes fauna that are listed under the legislative frameworks of the Commonwealth *Endangered Species Protection Act, 1992* (ESP Act) and the TSC Act.

- *Greg Richards and Associates*

This firm provided expert advice and input on the microchiropteran bat species assemblages of the Lake Cowal region (Attachment A7).

This list contained 45 species comprising one amphibian, two reptiles, 14 mammals and 28 birds.

Based on a host of factors such as habitat requirements, essential behavioural patterns and distribution records, it was concluded that the threatened fauna species list for the Lake Cowal region include all of the species contained on the list with the exception of the following three birds:

- Plains Wanderer *Pedionomus torquatus*
- Grey Ternlet *Procelsterna cerulea*
- Masked Owl *Tyto novaehollandiae*

The Plains Wanderer is typically associated with open native grasslands (Schodde and Tidemann, 1995; Morcombe, 1992; Simpson and Day, 1996) and is a species that is considered to be threatened by cultivation, grazing, fire, predation and to an unknown extent pesticides and hunting (Garnett, 1992; Baker-Gabb, 1990). Given the nature of land use in the Lake Cowal region and hence the highly degraded status of any potential habitat for this species, coupled with the prevalence of predatory species and the effects of grazing, it was considered that this species was unlikely to occur in the region.

As previously noted Attachment A4 contains species that are considered to be unrealistic vagrants and possibly some misidentified species. This is likely to be the case for the Grey Ternlet which is an oceanic species (Simpson and Day, 1996) and may possibly have been confused with a number of Terns recorded from the area (eg. Gull-billed Tern, Caspian Tern, Whiskered Tern, White-winged Black Tern).

In regard to the Masked Owl, critical habitat components for this species includes roomy cavities in large mature trees for nesting (and sometimes roosting) and open forest and woodland (as well as adjacent farmland and open country) for foraging (Debus, 1993; Debus & Rose, 1994).

Table A-14 Threatened Fauna Species of the Lake Cowal Region

Common Names	Scientific Names	Occurrence of Potential Habitat (Breeding, Foraging, Roosting) in the Project Area	Potential for Project to Impact on Species' Population Status
Amphibians and reptiles			
Southern Bell Frog	<i>Litoria raniformis</i> (Keferstein)	3-4	D
Pink-tailed Worm-lizard	<i>Aprasia parapulchella</i> (Kluge)	3-4	D
South-eastern Lined Earless Dragon	<i>Tympanocryptis lineata pingicollis</i> (Mitchell)	3-4	D
Birds			
Malleefowl	<i>Leipoa ocellata</i> (Gould)	4	D
Magpie Goose	<i>Anseranas semipalmata</i> (Latham)	3	C
Blue-billed Duck	<i>Oxyura australis</i> (Gould)	2-3	B-C
Freckled Duck	<i>Stictonetta naevosa</i> (Gould)	2	B
Australasian Bittern	<i>Botaurus poiciloptilus</i> (Wagler)	3-4	C-D
Black-necked Stork	<i>Ephippiorhynchus asiaticus</i> (Latham)	3	D
Osprey	<i>Pandion haliaetus</i> (Linnaeus)	4	D
Square-tailed Kite	<i>Lophoictinia isura</i> (Gould)	4	D
Black-breasted Buzzard	<i>Hamirostra melanosternon</i> (Gould)	4	D
Grey Falcon	<i>Falco hypoleucos</i> (Gould)	4	D
Brolga	<i>Grus rubicunda</i> (Perry)	2-3	C
Australian Bustard	<i>Ardeotis australis</i> (J.E. Gray)	4	D
Plains-wanderer	<i>Pedinomus torquatus</i> (Gould)	4	D
Black-tailed Godwit ^{+,++}	<i>Limosa limosa</i> (Linnaeus)	3	C
Painted Snipe ⁺	<i>Rostratula benghalensis</i> (Linnaeus)	2	B-C
Bush Stone-curlew	<i>Burhinus grallarius</i> (Latham)	4	D
Grey Ternlet	<i>Procelstema cerulea</i> (Bennett)	4	D
Glossy Black-Cockatoo	<i>Calyptorhynchus lathami</i> (Temminck)	4	D
Major Mitchell's Cockatoo	<i>Cacatua leadbeateri</i> (Vigors)	4	D
Superb Parrot	<i>Polytelis swainsonii</i> (Desmarest)	3-4	C-D
Swift Parrot	<i>Lathamus discolor</i> (Shaw)	3-4	C-D
Turquoise Parrot	<i>Neophema pulchella</i> (Shaw)	3-4	C-D
Masked Owl	<i>Tyto novaehollandiae</i> (Stephens)	4	D
Regent Honeyeater	<i>Xanthomyza phrygia</i> (Shaw)	3-4	C-D
Painted Honeyeater	<i>Grantiella picta</i> (Gould)	3-4	C-D
Southern Scrub-robin	<i>Drymodes brunneopygia</i> (Gould)	4	D
Chestnut Quail-thrush	<i>Cinclosoma castanotus</i> (Gould)	4	D
Gilbert's Whistler	<i>Pachycephala inornata</i> (Gould)	3-4	D
Mammals			
Spotted-tailed Quoll	<i>Dasyurus maculatus</i> (Kerr)	4	D
Brush-tailed Phascogale	<i>Phascogale tapoatafa</i> (F. A. Meyer)	4	D
Koala	<i>Phascolarctos cinereus</i> (Goldfuss)	4	D
Squirrel Glider	<i>Petaurus norfolcensis</i> (Kerr)	4	D
Brush-tailed Rock-wallaby	<i>Petrogale penicillata</i> (J.E. Gray)	4	D
Yellow-bellied Sheath-tail-bat	<i>Saccolaimus flaviventris</i> (Peters)	2	B
Large Bentwing-bat	<i>Miniopterus schreibersii</i> (Kuhl)	4	D
Greater Long-eared Bat	<i>Nyctophilus timoriensis</i> (Geoffroy [Saint-Hilaire])	3	C
Large-eared Pied Bat	<i>Chalinolobus dwyeri</i> (Ryan)	4	D
Little Pied Bat	<i>Chalinolobus picatus</i> (Gould)	3	C
Eastern False Pipistrelle	<i>Falsistrellus tasmaniensis</i> (Gould)	4	D
Southern Myotis	<i>Myotis macropus</i> (Gould)	4	D
Inland Forest Bat	<i>Vespadelus baverstocki</i> (Kitchener, Jones & Caputi)	4	D
Eastern Cave Bat	<i>Vespadelus troughtoni</i> (Kitchener, Jones & Caputi)	3	C

+ Species listed on China-Australia Migratory Birds Agreement (CAMBA) ++ Species listed on Japan-Australia Migratory Birds Agreement (JAMBA)

Occurrence of Potential Habitat in the Project Area

1 Significant habitat resources present 2 Moderate habitat resources present 3 Marginal habitat resources present 4 Minimal or no habitat resources present

Potential for Project to Impact on Species' Population Status

A Significant impact potential B Moderate impact potential C Marginal impact potential D Minimal or no impact potential

Recent studies on habitat resources (Scotts, 1994), indicate that for species such as the Masked Owl, old, large, living and dead trees are key forest or woodland attributes for activities such as nesting, shelter, roosting, perching and foraging. These activities are limited by resources such as tree hollows (of various sizes, depths, position and aspect), open cavities and large branches.

Based on these key attributes and the limiting resources, habitat for Masked Owls is essentially limited to areas of woodland, forest or scattered trees which contain old, large, living and dead trees ie. old-growth elements. Old-growth forest is ecologically mature and has been subjected to negligible unnatural disturbance (Australian Museum Business Services, 1995) and have survived a long-term absence of severe canopy disturbance so that the dominant upper strata trees are large, old, well-spaced with abundant hollows and where groundcover includes numerous large, decaying and hollow logs (*ibid.*).

The mobility and ranging behaviour of *T. novaehollandiae* enable it to utilise large areas as a forage resource including cleared, open land characteristic of the Lake Cowal region.

However, as noted above its essential habitat components effectively discount any reliance upon such areas. It was therefore concluded that based on this information and the distribution records for this species, it was unlikely to occur in the assessment area.

In addition, two threatened microchiropteran bats (Large Bentwing-bat and Inland Forest Bat) were added following a review of a bat record database for the area (Greg Richards and Associates, 1997b).

The factors contained in Section 5A (ie. 8 Part Test of Significance) were addressed, with respect to the potential impacts of the proposed development on the 42 threatened fauna species, populations or ecological communities or their habitat (Resource Strategies *et al.*, 1997). The 8 Part Test report was submitted to DUAP and NPWS on the 13 October 1997.

Based on the information at hand at the time, the key findings of the 8 Part Test assessment were as follows:

- No local viable populations of threatened fauna species would be likely to be placed at risk of extinction. The proposal is predicted to result in the loss of minor areas of potential forage/habitat primarily associated with small remnant woodland areas, open disturbed grassed land including the area subject to inundation, as well as the ecotone transitional zones. This loss would not be considered to be significant in terms of the availability of eminently more suitable habitat in the immediate locality and wider region.

- In relation to the regional distribution of the habitat of a threatened species, it was considered unlikely that a significant area of known habitat would be modified/removed as a result of the proposal. Certain species known to occur in the locality may potentially occur at the site. It was considered that the proposed works would not constitute a significant adverse impact on local populations of any of these species subject to the findings of other specialist assessments, currently in hand, including operational phase components such as air quality, acoustics and tailings storages management. Relevant post-operational assessment focuses on final void status. This is based on the prevalence of areas of more suitable habitat to the north and north-east and (to a lesser extent) south of the proposed MLA area, the relative mobility of many species and the high level of disturbance across much of the Project site which has effectively reduced the potential value of the site as a habitat resource.
- Given the existing ecological condition of the Project area, the proposed development would be unlikely to alienate movement corridors or limit dispersal options for any local viable threatened species population and it would be unlikely that an area of known habitat for any threatened species would be likely to become isolated from currently interconnecting or proximate areas of habitat. Extensive rehabilitation of the Project site would aim to provide a means for the creation, enhancement and embellishment of linking corridors to potentially allow for linear genetic exchange between fauna populations occurring in the area.
- For a selected number of species (two flora, six bird and three bat species) the currently available information was inconclusive with respect to potential or identified impacts and Director-General's Requirements for an SIS were requested (Attachment A1).

5.2 Threatened Species of the Project Area and Surrounds

5.2.1 Plants

Based on the information contained in Section 5A, 8 Part Test report (Charles Sturt University, 1997; Bower, 1997) and pursuant to the requirements of the Director-General of the NPWS (Attachment A1), the threatened plant species in Table A-15 are to be considered in the SIS for the proposed development.

A discussion of the primary ecological components of these species is presented below.

Austral Pillwort (*Pilularia novae-hollandiae*)

Description

Austral Pillwort is a semi-aquatic fern with long creeping rhizomes (Lembit, 1997). Widespread but uncommon

Table A-15 Threatened Flora Species of the Project Area and Surrounds

Common Name	Scientific Name	Status as per Briggs and Leigh (1995)	Status as per <i>Threatened Species Conservation Act 1995</i>
Austral Pillwort	<i>Pilularia novae-hollandiae</i>	–	Endangered
Winged Peppergrass	<i>Lepidium monoplocoides</i>	Endangered	Endangered

(Harden, 1990), it is known to occur in seasonally dry depressions, margins of marshes (*ibid.*) and gilgai country (Bower, 1997).

There are no National Parks or Nature Reserves close to the project site which are likely to contain populations of *P. novae-hollandiae*.

Distribution/Habitat

P. novae-hollandiae has been collected from the central coast, southern tablelands and south west slopes of NSW (Harden, 1990). This species also occurs in northern and western Victoria, South Australia and Tasmania. It is not listed as endangered or vulnerable nationally (Briggs and Leigh, 1995).

The survey of the Lake Cowal region by Anne Clements & Associates (1995) recorded *P. novae-hollandiae* from the western edge of Lake Cowal and along the riparian zone of Bland Creek near the confluence with the Lake (Figure A-16). These findings represented an extension of the known range of *P. novae-hollandiae* in the Central Western Slopes of New South Wales (Bower, 1997). Target survey of the proposed disturbance areas associated with the Project (Charles Sturt University, 1997) did not record this species.

Potential habitats within the Project area include gilgai areas and areas fringing the Lake shore. These habitats are also available outside the Project area in the surrounding environment. In the absence of information on the population distribution of this species, these habitat area types are considered to reflect the potential distribution of a local population of *P. novae-hollandiae*. Distribution records demonstrate that habitat resources for this species are available in the wider region.

Current collections may not reflect the true abundance of *P. novae-hollandiae* given its relatively short lifecycle (in response to the ephemeral nature of its habitats) and inconspicuous presence, which suggests that unless targeted, survey may not detect it (Bower, 1997).

Winged Peppergrass (*Lepidium monoplacoides*)

Description

Lepidium monoplacoides is a cryptic annual (Doherty, pers. comm., 1997) or possibly perennial (Cunningham *et al.*, 1981) forb*, that reaches a height of 15-20 cm (Leigh *et al.*, 1984). This species flowers in the August-October period although flowering can continue until December (*ibid.*).

Distribution/Habitat

Originally widespread in the semi-arid regions of NSW (ie. north-west plains, south-west plains, north far west plains, south far west plains), Victoria and possibly South Australia (Ayers *et al.*, 1996), this species has been recorded from the Cober, Bourke, Lake Cargelligo, Deniliquin and Enabalong districts (Ayers *et al.*, 1996). More recently the Winged Peppergrass was recorded from the Riverine Plain (Benson *et al.*, 1997).

Little detailed information exists on the habitat requirements of this species but records exist from semi-arid areas (in NSW and Victoria) which support mallee scrub (Leigh

et al., 1984). In the western NSW region collections of this species have been from widely scattered localities in the east (Cunningham *et al.*, 1981) primarily in Bimble Box communities, however it undoubtedly also occurs in other vegetation types (*ibid.*).

L. monoplacoides has not been recorded from the Project area or surrounds (Anne Clements and Associates, 1995, 1996; Charles Sturt University, 1997). Given the historical landuse practices of the area, it is considered that potential habitats in the Project area are very limited and hence the occurrence of a local population is considered unlikely.

5.2.2 Birds

The 8 Part Test of Significance report for the Cowal Gold Project (Resource Strategies *et al.*, 1997) examined 25 bird species previously identified in consultation with the Western Zone team of the NPWS.

The report, prepared in association with a specialist panel of authors from CSIRO, Charles Sturt University and specialist environmental consultants, concluded that for a selected number of species, the information available at the time was inconclusive with respect to some potential or identified impacts.

Accordingly the Director-General of the NPWS requires that the following bird species (Table A-16) be addressed in the SIS.

A discussion of the primary ecological components of the six threatened bird species is presented below. All have been recorded as occurring in the Lake Cowal region (Figure A-16).

Australasian Bittern (*Botaurus poiciloptilus*)

Breeding/Nesting

Little specific information exists on the breeding characteristics of this species (Marchant & Higgins, 1990) although the Australasian Bittern is thought to prefer shallow, vegetated freshwater or brackish swamps (Garnett, 1992).

The breeding season is thought to be from October to February (Marchant & Higgins, 1990) with breeding taking place generally in stands of Phragmites, *Typha* and rushes (*ibid.*; Garnett, 1992). Records do exist however in areas of

Table A-16 Threatened Bird Species of the Project Area and Surrounds

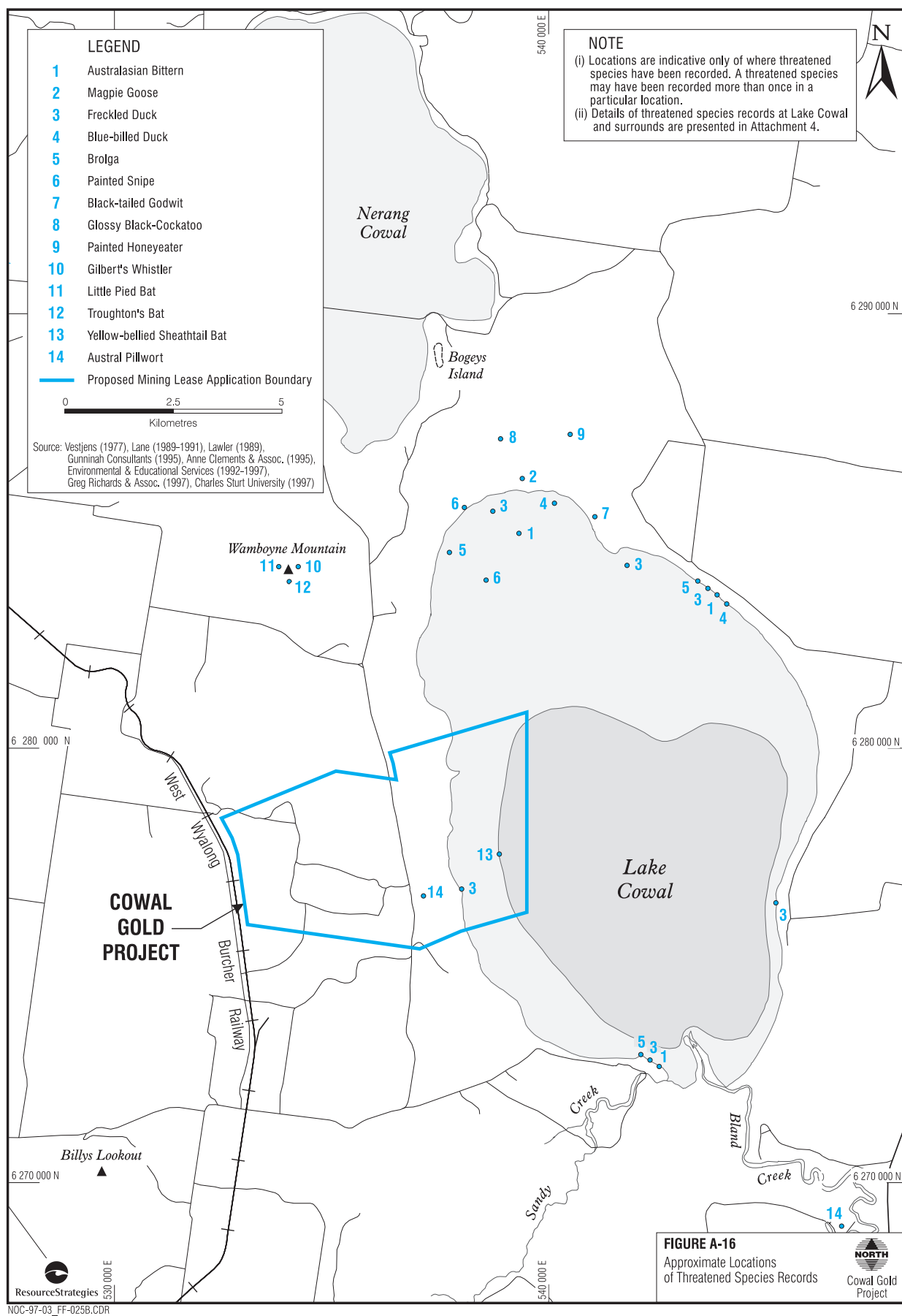
Common Names	Scientific Names	Status in NSW ⁺
Blue-billed Duck	<i>Oxyura australis</i> (Gould)	V
Freckled Duck	<i>Stictonetta naevosa</i> (Gould)	V
Australasian Bittern	<i>Botaurus poiciloptilus</i> (Wagler)	V
Black-necked Stork	<i>Ephippiorhynchus asiaticus</i> (Latham)	V
Brolga	<i>Grus rubicunda</i> (Perry)	V
Painted Snipe ¹	<i>Rostratula benghalensis</i> (Linnaeus)	V

⁺ As per *Threatened Species Conservation Act, 1995*

V = Vulnerable – a species not presently endangered but at risk of disappearing from the wild over a long period through continued depletion.

¹ Protected under International Agreement: China-Australia Migratory Birds Agreement (CAMBA).

* Herbaceous or slightly woody annual or sometimes perennial plant (McDonald *et al.*, 1990)



stunted bushes and trees with a grassy understorey (30 cm) (Hobbs, 1961 in Marchant & Higgins, 1990).

Nests are well-constructed platforms of pieces of reeds or rushes, usually located above the waterline in dense cover on the edge of freshwater swamps and pools (Ayers *et al.*, 1996; Kingsford, 1991; Pizzey, 1980).

Suitable breeding habitat is likely to occur in the northern portion of the Lake where local populations (were any to occur) are likely to concentrate, while the Project area is considered unlikely to contain potentially suitable breeding habitat resources.

Foraging

Feeding is primarily a crepuscular (around dawn/dusk) and nocturnal activity, with most foraging occurring in shallow water less than 30 cm deep (*ibid.*). The Australasian Bittern has however been recorded feeding during the day (Binns, 1958 in Marchant & Higgins, 1990).

The diet comprises frogs, small reptiles, yabbies and small fish (Lindsey, 1992), eels (Marchant & Higgins, 1990) as well as leaves and fruit (Pizzey, 1980).

Records of single birds in March and October 1977 (Vestjens, 1977), January 1993 and January 1992 (EES, 1992a,b,c; 1993a,b,c; 1994a,b,c; 1995a,b,c; 1996a,b,c; 1997a,b,c) suggest that this species may have utilised the northern portion of the Lake as a forage resource. It is unlikely that the Project area would contain adequate forage resources.

Roosting

Little is known of the social organisation of this species (Marchant & Higgins, 1990) however Serventy (1985 in Ayers *et al.*, 1996) notes that the Australasian Bittern constructs roosting platforms from trampled reeds in dense cover over deep water.

Potential nesting habitat at the Lake is restricted to the vegetated northern portions, some 4.5 km from the Project area.

Movement/Distribution

The Australasian Bittern is an uncommon but at times locally abundant species which is probably sedentary in areas of permanent habitat (Pizzey, 1980). Elsewhere *B. poiciloptilus* may be nomadic or migratory (Serventy, 1985 in Ayers *et al.*, 1996) and it is evidently capable of extensive dispersal/movement to seek refuge from drought and to take advantage of good rains (Garnett, 1992).

This species is widespread in Tasmania, Western Australian (declining), Victoria and NSW with the majority of records in this state occurring in the Murray-Darling Basin (Morris *et al.*, 1981; Smith & Chafer, 1987 in Marchant & Higgins, 1990; Hobbs, 1961 in Marchant & Higgins, 1990). Elsewhere in NSW, *B. poiciloptilus* are scarce, restricted generally to near coastal areas (*ibid.*).

The Action Plan for Australian Birds (Garnett, 1992), lists the following conservation reserves in which *B. poiciloptilus* occurs in NSW:

- Dharug National Park (c.320 km east-northeast of the Project area);

- Botany Bay National Park (c.350 km east-southeast of the Project area);
- Myall Lakes National Park (c.475 km east-northeast of the Project area);
- Kinchega National Park (c.455 km west-northwest of the Project area);
- Kosciusko National Park (c.215 km south-east of the Project area);
- Macquarie Marshes Nature Reserve (c. 320 km north of the Project area);
- Towra Point Nature Reserve (c.350 km east-southeast of the Project area);
- Hexham Swamp Nature Reserve (c.400 km east-north-northeast of the Project area);
- Kooragang Island Nature Reserve (c.410 km east-northeast of the Project area);
- Morrisons Lake Nature Reserve (c.280 km west-northwest of the Project area); and
- Nocoleche Nature Reserve (c.490 km north-northwest of the Project area).

Other public lands in NSW in which this species is known to occur include vegetated swamps on uncommitted Crown land, game reserves and water storage basins, particularly in coastal areas (Garnett, 1992). Other land in NSW in which this species is known to occur includes vegetated swamps on private property (Garnett, 1992).

Records of distribution of this species in NSW (Ayers *et al.*, 1996; Garnett, 1992; Marchant & Higgins, 1990) indicate that the Project area does not represent a distribution limit of this species.

Black-necked Stork (*Ephippiorhynchus asiaticus*)

Breeding/Nesting

In the absence of serious study, this species is considered to be a solitary breeder occurring in or near freshwater swamps (Lindsey, 1992; Ayers *et al.*, 1996; Marchant & Higgins, 1990).

Occupied nests have been recorded in all months in Queensland and from January to September in the Northern Territory (Marchant & Higgins, 1990). Nest sites are generally in or near freshwater swamps, on top or as high as possible in the fork of a tall, live or dead tree (Schultz, 1989 in Marchant & Higgins, 1990). Nests are huge structures up to 2 m across (Marchant & Higgins, 1990).

This species has also been recorded nesting in trees and on a rocky outcrop (*ibid.*) and nests may be used year after year by the same pairs (Schodde & Tidemann, 1995).

Although Lake Cowal is approaching the south-western extent of its distribution, vagrant pairs may potentially use the suitably vegetated portions in the north of the Lake.

Foraging

While foraging, *E. asiaticus* stride through shallow water up to 0.5 m deep, sweeping their bill for fish, frogs, reptiles, small crustaceans especially crabs and prawns (Pizzey, 1980);

Lindsey, 1992; Schodde & Tidemann, 1995). Small rodents, insects and occasionally carrion are also eaten (Marchant & Higgins, 1990; Kingsford, 1991).

Lake Cowal represents a potential forage resource for this species.

Roosting

The Black-necked Stork roosts singly or in pairs at night typically at the edge of a wetland previously patronised at dusk (Marchant & Higgins, 1990). During the day *E. asiaticus* have been observed resting at or near the edge of a wetland (Schulz, 1989 in Marchant & Higgins, 1990).

Given this species' penchant for nest location and nesting material, it is considered likely that the vegetated, northern portions of the Lake offer potential nesting resources. The cleared, open nature of the Project area is likely to preclude this species from nesting there.

Movement/Distribution

Although apparently largely sedentary, some Black-necked Storks may be potentially nomadic, travelling long distances (Marchant & Higgins, 1990). Records from Victoria in March through to July suggest dispersal of juveniles occurs often in the breeding season (Serventy, 1985 in Ayers *et al.*, 1996).

Primarily a coastal species, *E. asiaticus* is widespread along the eastern and northern coast lines. In the Western Zone of NSW (including Lake Cowal) the Black-necked Stork is an infrequent visitor, present primarily during widespread flooding (Ayers *et al.*, 1996) during exceptional seasons (Marchant & Higgins, 1990). This species is unlikely to have ever had a permanent presence within western NSW (Ayers *et al.*, 1996).

The nearest conservation reserve in which *E. asiaticus* is known to occur is Budderoo National Park (c.315 km south-east of the Project area) (Ayers *et al.*, 1996).

The Project area represents the south-western limit of this species' distribution in NSW (after Ayers *et al.*, 1996).

Brolga (*Grus rubicunda*)

Breeding/Nesting

In northern Australia, Brolgas breed at the start of the wet season (November, December) and after winter rains in southern Australia (Bransbury, 1991).

Pairs form bonds for life, vigorously defending a substantial breeding territory of up to 2.5 km², which may include several marshes (Arnol *et al.*, 1984). A pair may maintain the same territory for years (Briggs, 1990).

Nest sites are typically in shallow wetlands or shallows of deep wetlands, among tussock-grass, sedge, Canegrass, within a grassy tidal flat, rice crops and occasionally on a floodplain (Arnol *et al.*, 1984; Bransbury, 1991).

A local population of species (were one to occur) may potentially use Lake Cowal (ie. the northern, vegetated portions) as a breeding resource.

Foraging

Preferring to forage in moist mud for plant tubers (Arnol *et al.*, 1984; Archibald & Swengel, 1984 in Marchant &

Higgins, 1993), Brolgas shift forage habitats in response to drought and subsequent reduction in food supply.

Foraging by day, the Brolga has a varied diet that includes seeds, grain, insects and other invertebrates, as well as small vertebrates (Lindsey, 1992; Gowland, 1989 in Marchant & Higgins, 1993). Feeding mostly occurs near water although Brolgas are known to also feed in grasslands, dry wetlands or cultivated areas (Kingsford, 1991).

The Project area may provide marginal forage opportunities for this species.

Roosting

Brolgas tend to roost at night in shallow water (Archibald & Swengel, 1984 in Marchant & Higgins, 1993; Gowland, 1989 in Marchant & Higgins, 1993) and to a lesser extent, on sandbanks, small islands and beneath *Melaleuca* riparian vegetation.

Roost size ranges from small family groups to over 1,000 birds (Gowland, 1989 in Marchant & Higgins, 1993).

The northern portion of Lake Cowal is likely to offer potentially suitable nesting habitat for this species.

Movement/Distribution

The Brolga is partly migratory, dispersing in flocks (sometimes large) between dry-season refuges and wet-season breeding areas (*ibid.*; Lindsey, 1992). Hydrological changes have the potential to reduce the availability of habitat refuge for this species, although Serventy (1985 in Ayers *et al.*, 1996) notes that artificial dams provide refuges for vagrant Brolgas.

The Brolga is widespread and generally abundant in northern and eastern Australia (Marchant & Higgins, 1993). In NSW it occurs along major river systems on the north-western slopes of the Great Dividing Range and Riverina (Hobbs, 1961 in Marchant & Higgins, 1990).

Records of this species in conservation reserves in the region include Yathong Nature Reserve (c.185 km north-west of the Project area) and Round Hill Nature Reserve (c.125 km north-west of the Project area), although vagrants at the latter.

The Brolga has also been recorded from northern areas of central and western NSW (Western Zone), with the tributary creeks of the Warrego River being particularly important (Ayers *et al.*, 1996). It has also been observed in the Macquarie Marshes, Narran Lake and Nocolche Nature Reserves, in the Riverina, frequently on plains in the Urana District, on the Lachlan River, from Condobolin to Lake Cargelligo and in the south at "Kelleen" Station on irrigated land in the early 1980s (Siepen, 1987).

Brolgas are considered rare south of about 30° latitude (*ibid.*). This species has been recorded from the Lake Cowal region (Lane, 1989, 1990, 1991a,b,c; EES, 1992a,b,c, 1993a,b,c, 1994a,b,c, 1995a,b,c, 1996a,b,c, 1997a,b,c; Vestjens, 1977).

The Project area does not represent a known distribution limit for this species (after Lindsey, 1992; Ayers *et al.*, 1996).

Blue-billed Duck (*Oxyura australis*)

Breeding/Nesting

Breeding occurs as a regular seasonal event in some areas (where it is only slightly affected by water level) and as a continuous/opportunistic event in other parts of their range (Marchant & Higgins, 1990).

Breeding birds are thought to be sedentary although juveniles and inexperienced adults may drift into potential breeding areas over a period of weeks (Wheeler, 1960 in Marchant & Higgins, 1990).

When breeding, *O. australis* disperse to well-vegetated freshwater swamps and lakes and become very secretive (Slater *et al.*, 1986).

Primarily a solitary nester, *O. australis* construct a deep, cup-shaped domed structure usually of dead *Typha* leaves (Marchant & Higgins, 1990).

Extensive breeding records exist for the Murray-Darling system with records from along Willandra Creek and other tributary creeks of the Lachlan River, Narran Lake and Lignum swamps along the Paroo (Pizzey, 1980).

Blue-billed Ducks have been recorded breeding in the northern, Lignum-dominated areas of Lake Cowal (Lane, 1989, 1990), and it is possible that this area may constitute a component of the breeding habitat resources for a local population of this species.

Foraging

Blue-billed Ducks are completely aquatic and feed on seeds and leaves of a wide variety of aquatic plants and insect larvae (Lindsey, 1992; Schodde & Tidemann, 1995; Marchant & Higgins, 1990). Food is obtained mostly by diving in deep water, usually in the permanent freshwater zone of waterbodies where the water is clear and there is an absence of turbulence and the substrate is firmer (Braithwaite, 1976a). Food is also taken from the water surface and overhanging vegetation (Frith, 1982).

Blue-billed Ducks are secretive birds, feeding in open water within or beside tall dense vegetation preferring to remain far from shore if dense cover is available in the centre parts of the wetland (Frith, 1982).

This species is also known to gather to forage on saline wetlands and salt lakes (mainly in winter) when salinity levels are reduced by fresh water runoff (Frith, 1982; Jaensch *et al.*, 1988 in Marchant & Higgins, 1990).

Given that Blue-billed Ducks are secretive birds, it is considered that the open and cleared nature of the Project area lakeshore would limit the area as a forage habitat.

Roosting

Blue-billed Ducks generally are solitary although communal roosting may occur (Marchant & Higgins, 1990). Roosting is both diurnal and nocturnal, usually on open water or in a small concealed bay and not out of the water or in thick vegetation (*ibid.*).

Potential nesting habitat exists in the Lignum and/or Canegrass areas that occur primarily in the northern portion of the Lake.

Movement/Distribution

Blue-billed Ducks generally undertake short-distance movements between breeding swamps and overwintering lakes (Marchant & Higgins, 1990) such as the permanent swamps of the Murray River system where large winter-flocks regularly gather (Frith, 1982; Lowe, 1958 in Marchant & Higgins 1990; Johnsgard, 1965 in Marchant & Higgins, 1990).

The range of this species is considered to expand and contract according to rainfall and availability of habitat (Ford, 1958; Wheeler, 1960; Hobbs, 1961; Missen & Timms, 1974; all in Marchant & Higgins, 1990).

The Blue-billed Duck is widespread in Victoria, Western Australia and New South Wales where it occurs mostly in the Murray-Darling Basin (Morris *et al.*, 1981). It is also common on the lower Murray and larger South Australian lakes around the Mount Lofty Range, Adelaide Plains and Kangaroo Island. Scattered records exist for Queensland and South Australia while vagrant birds have been recorded in Tasmania and Northern Territory (Marchant & Higgins, 1990).

Conservation reserves in the region in which *O. australis* is known to occur include Willandra National Park (c.220 km west-northwest of the Project area) and Macquarie Marshes Nature Reserve (c.320 km north of the Project area).

The Project area does not represent a distribution limit for this species (after Ayers *et al.*, 1996).

Painted Snipe (*Rostratula benghalensis*)

Breeding/Nesting

Breeding is strongly influenced by local conditions, but occurs mainly from August to February in southern Australia and earlier in northern Australia (Morris *et al.*, 1981). Records indicate that for this species Lake Cowal is an important breeding refuge (Schodde, pers. comm., 1997). Land usage within the Project area has resulted in this area being unsuitable for breeding and foraging, with breeding more likely to occur in the swamps and channels of the northern shore of the Lake (*ibid.*) where a local population would be likely to congregate.

Painted Snipe nest among tall rank tussocks of grass, reeds, rushes or samphire* (Jaensch, 1986, 1989 in Marchant & Higgins, 1993). Nests are frequently on small, muddy islands or mounds surrounded by shallow freshwater (*ibid.*).

Foraging

The Painted Snipe feeds in the mud along the swamp edges, foraging for vegetation, seeds, insects, worms and molluscs, crustaceans and other invertebrates (Pizzey, 1980; Vestjens, 1977).

Feeding is primarily a crepuscular activity although nocturnal foraging may occur (Marchant & Higgins, 1993). Food is gleaned from the edge of water and mudflats with the bill used to probe soft ground and scythe through shallow water (*ibid.*).

* Cliff plant with aromatic, saline fleshy leaves.

Roosting

Roosting behaviour of this species is not well known (Marchant & Higgins, 1993).

Painted Snipes spend most of the day hidden in dense swamp vegetation (Pringle, 1987). Birds have been observed resting under Lignum bushes and *Melaleuca* (Leach *et al.*, 1987).

The Project area is unlikely to contain potential nesting habitat given the level of disturbance and vegetation clearance.

Movement/Distribution

Possibly dispersive or migratory in Australia, its movements are unknown and its occurrence is erratic and unpredictable (Lindsey, 1992; Marchant & Higgins, 1993). Occasional records from remote places indicate species can move long distances (*ibid.*).

Dispersive movements of *R. benghalensis* are attributed to local conditions, i.e. move to flooded areas; disperse from drying to permanent wetlands and from areas affected by drought (Lane, 1987).

Records show that *R. benghalensis* occurs in the north-west along the Paroo, in wetlands along the eastern fringe and around the Lachlan/Murrumbidgee confluence (*ibid.*).

Lake Cowal is considered to be an important core refuge for the Painted Snipe according to the Australian Wildlife Collection records (Schodde pers. comm., 1997).

The nearest conservation reserve in which *R. benghalensis* is known to occur is Kosciusko National Park (c.215 km south-east of the Project area) and Wollemi National Park (c.265 km east-northeast of the Project area) (Ayers *et al.*, 1996).

The Action Plan for Australian Birds (Garnett, 1992) lists *R. benghalensis* as being recorded irregularly in numerous wetland reserves; irregularly on a wide variety of public wetlands and on private land with wetlands.

The Project area does not represent a known distribution limit of this species (after Ayers *et al.*, 1996; Morcombe, 1992; Simpson & Day, 1996).

Freckled Duck (*Stictonetta naevosa*)

Breeding/Nesting

Little information exists on the breeding dynamics of this species (Marchant & Higgins, 1990) although it is thought to occupy a breeding season that extends from June to December (Frith, 1965; Lowe & Lowe, 1974; Braithwaite, 1976b).

A solitary breeder, nests are typically well-spaced even in relatively high densities (Ayers *et al.*, 1996; Braithwaite & Frith, 1969) and are usually constructed in Lignum (*Muehlenbeckia florulenta*) (Braithwaite, 1976b).

It is also known to nest in *Melaleuca* and seasonally flooded, coastal *Melaleuca-Casuarina* swamps (Jaensch, 1989 in Marchant & Higgins, 1990; Frith, 1977) and even abandoned nests of the Eurasian Coot (*Fulica atra*) (Ayers *et al.*, 1996), Straw-necked Ibis (*Threskiornis spinicollis*) (Marchant &

Higgins, 1990) and Black Swan (*Cygnus atratus*) (Jaensch, 1989 in Marchant & Higgins, 1990).

Important breeding areas are in the immense temporary swamps created by floodwaters within the Lake Eyre and Bulloo Drainage Divisions (Braithwaite, 1976b; Garnett, 1993). It also breeds in several swamps within the Murray-Darling Division, notably those such as the Currawinya Lakes along the Paroo where over 10,000 Freckled Ducks have been recorded (Jenkins, 1997) and Lachlan Rivers and others within the Riverina district (Braithwaite, 1976b; Garnett, 1993). In the Western Zone breeding is stimulated by flooding (Briggs, 1990) and this species has been recorded breeding in the northern portion of Lake Cowal (Lawler, 1989). As for the Blue-billed Duck, the northern portion of the Lake possibly represents a component of the habitat (breeding) utilised by local populations of this species.

Foraging

The Freckled Duck is a specialist filter feeder (Crome, 1985 in Marchant & Higgins, 1990; Braithwaite, pers. comm., 1997). Its diet consists primarily of algae, seeds of various aquatic plants (grasses and sedges), invertebrates, small fish and vegetative matter (Schodde & Tidemann, 1995; Martindale, 1986).

Freckled Ducks feed at the edge of wetlands or in shallow productive waters using a number of foraging mechanisms, eg. bottom-filtering, surface filtering and up-ending (Frith, 1977), although most food is taken by "suzzling" water or soft muds (Marchant & Higgins, 1990).

The Project area and surrounds provides potential forage habitat opportunities for the Freckled Duck.

Roosting

Outside of the breeding season (June – December) communal congregations (up to 100) of Freckled Ducks (Ayers, *et al.*, 1996) are known to roost diurnally (Marchant & Higgins, 1990) typically on exposed mud banks, sand banks, dense cover, emergent snags (posts) and to a lesser extent, on the water (*ibid.*).

The Lignum/Canegrass areas that occur in the northern portion of the Lake are likely to support nesting *S. naevosa* during periods where adequate water perseveres.

Movement/Distribution

This species is largely sedentary during wetter years and irregularly dispersive in the drier seasons (Pizzey, 1980; Marchant & Higgins, 1990). The majority of the population in south-east Australia moves towards the coast (Marchant & Higgins, 1990).

Population numbers and distribution patterns are apparently correlated with inland rainfall (Martindale, 1988 in Marchant & Higgins, 1990; Hewish, 1988 in Marchant & Higgins, 1990).

Endemic to south-east and south-west Australia (Marchant & Higgins, 1990), the Freckled Duck is widespread in NSW, notably the north-west and Murray-Darling Basin areas (Braithwaite *et al.*, 1985a; Frith, 1982; Morris *et al.*, 1981). In Queensland, it occurs mainly in the central and southern

portions (Martindale, 1986) while it is widespread throughout Victoria and Western Australia (Martindale, 1986).

Aerial surveys of waterbirds of Lake Wyara and Lake Numalla in the south-western arid region of Queensland (Kingsford & Porter, 1994) revealed that these lakes are probably the most important dry refuge habitat on the continent for Freckled Duck (*ibid.*).

Scattered records exist for South Australia (Close & Jaensch, 1984 in Marchant & Higgins, 1990) and in Tasmania vagrant Freckled Ducks have been recorded (Green, 1977 in Marchant & Higgins, 1990).

In the region, this species is particularly well-known from the Lachlan-Murrumbidgee junction, Barrenbox Swamp, Lake Cowal, Black Swamp (when wet) and Tullakool evaporation ponds (Braithwaite, pers. comm., 1997; Frith, 1977; Serventy, 1985, in Ayers *et al.*, 1996). The Freckled Duck is also recorded frequently from other locations along the Murrumbidgee, Murray and Lachlan Rivers and in the Macquarie Marshes (Frith, 1977; Serventy, 1985 in Ayers *et al.*, 1996).

Other conservation reserves in the region in which *S. naevosa* occurs include Round Hill Nature Reserve (c.125 km north-west of the Project area) and Yathong Nature Reserve (c.185 km north-west of the Project area).

This species is not at a known distribution limit (Garnett, 1993; Lindsey, 1992; Pizzey, 1980; Ayers *et al.*, 1996) in the Project area.

5.2.3 Mammals

Fourteen mammal species identified in consultation with the western zone team of the NPWS were assessed by the 8 Part Test of Significance Report for the Cowal Gold Project (Resource Strategies *et al.*, 1997).

Following the 8 Part Test of Significance, the Director-General of the NPWS requires that the following mammal species (Table A-17) be addressed in the SIS.

The following discussion of the primary ecological components of the threatened microchiropteran bats to be considered in the SIS is a summary of information contained in Greg Richards and Associates (1997b).

Table A-17 Threatened Mammal Species of the Project Area and Surrounds

Common Name	Scientific Name	Status in NSW ⁺
Yellow-bellied Sheathtail-bat	<i>Saccolaimus flaviventris</i>	V
Greater Long-eared Bat	<i>Nyctophilus timoriensis</i>	V
Little Pied Bat	<i>Chalinolobus picatus</i>	V

⁺ As per *Threatened Species Conservation Act, 1995*

V = Vulnerable – a species not presently endangered but at risk of disappearing from the wild over a long period through continued depletion.

Yellow-bellied Sheathtail-bat (*Saccolaimus flaviventris*)

Very little is known about the biology of this species, though breeding has been analysed from museum specimens by Chimimba and Kitchener (1987). The general ecology has been reviewed by Richards (1983c, 1995c).

This species has never been recorded in caves although large colonies (around 40 individuals) have been found in some roosts (Hall, pers. comm. in Greg Richards & Associates, 1997b).

It has been hypothesised, based on flight characteristics, that this species may be restricted to roosts in emergent trees because it needs a clear space below the roost to gain flight speed (Richards and Hall, 1997).

S. flaviventris appears to be quite rare, especially in southern latitudes. Field surveys by the consultant in the Murwillumbah-Lismore area indicated that a large foraging range may be required, because detector passes were low and it appeared from these data that just a few individuals were making large circuits (Richards, unpublished in Greg Richards and Associates, 1997b). During an intensive survey in the Shoalwater Bay Military Training Area in central Queensland, that comprised 9 weeks of field work using 55 sites across two seasons, *S. flaviventris* was patchily distributed and restricted to denser habitats (Richards 1992a, 1993).

This species is listed as Vulnerable in the NSW TSC Act, but is not listed in the national Bat Action Plan (Richards and Hall, 1996) because of its widespread distribution. Dickman (1994) considers that the status of this species is "stable" in western NSW, as does Stephens (1992) for the Murray Mallee area.

Potential habitat at the Project area and surrounds includes the woodland remnants and the open water of Lake Cowal.

Breeding

Females of this species have the typical pattern of breeding in summer, with a single young being weaned by the following early autumn (Chimimba and Kitchener, 1987).

Foraging

This species can be assumed to forage primarily upon insects that are hunted by aerial intercept, which is typical of species with long tapered wings (high aspect ratio) and a high wing loading. This indicates (supported by field observations) that flight is fast, with little manoeuvrability, and given the loud, long-range echolocation call, insects would be captured by interception rather than being pursued.

Roosting

S. flaviventris roosts only in relatively large tree hollows located high in a tree and situated such that there is enough clear space at the exit to allow an unencumbered drop until the bat attains normal flight speed.

Movement/Distribution

There is no information available in relation to movement or migration patterns that this species may exhibit. Richards

(1983b, 1995b) concluded that because some *S. flaviventris* has been caught during the 1980's in situations where they appeared to be exhausted and in open view of the public, that they may have been undertaking pre-winter migrations.

Because several individuals of this species have been recorded over the last year to be afflicted with Lyssavirus (similar to rabies) the individuals observed may not have been exhausted but instead may have been diseased and unable to fly. The "migration" hypothesis therefore needs to be revised.

In inland NSW, this species is known from Sturt, Kinchega and Nocolleche National Parks and is probably also present in the Willandra Lakes World Heritage Region, Mungo and Mallee Cliffs National Parks and Yathong Nature Reserve. One would suspect, given the broad distribution of this species in western NSW, that it would also occur in the remainder of the reserve network in this region, as well as those in coastal areas of the state.

Lake Cowal is within the widespread distribution of this species.

Greater Long-eared Bat (*Nyctophilus timoriensis*)

The little that is known of the biology of this species has been reviewed by Richards (1983b) and Parnaby (1995). The latter author has taxonomic evidence to show that, although in earlier publications it was shown to be distributed over southern Australia, this taxon is in fact a complex of three or four species. One of these is basically restricted to the Murray-Darling Basin.

The Greater Long-eared Bat has been recorded from Lake Cowal, represented by a specimen collected in the 1960s and lodged in the Australian National Wildlife Collection at CSIRO, Canberra. The species is known to be quite rare, though this in part may be related to the difficulty of capture in the relatively open vegetation that it inhabits. However, during the intensive studies of Lumsden *et al.* (1995), only one individual was recorded in a total of 1556 captures of bats in rural northern Victoria. Lumsden (1994) stated that only four records of this species are known from Victoria.

In a general discussion of conservation status, Dickman (1994) considers this species to be stable in western New South Wales. However, Stephens (1992) reported that *N. timoriensis* was "a species of serious concern" in the Murray Mallee area. Conversely, Lumsden *et al.*, (1995) proposed that "... the ability of bats to fly, their spatial scale of movement and their social organisation (eg. their overlapping foraging areas, colonial roosting habits, interspecific tolerance) are key factors that enable these species to live successfully within the farmland environment and that have prevented regional extinctions ...".

The Murray-Darling Basin form of *N. timoriensis* has been listed as Vulnerable in the forthcoming national Bat Action Plan (Richards and Hall, 1996).

Breeding

Richards (1983b) stated that this species probably bears twin young in summer. The breeding period is undoubtedly correct, but the number of young was postulated from data on better known sibling species.

Foraging

This species can be assumed as primarily foraging upon insects that are gleaned from substrates. This is shown by morphological characters that reflect this type of hunting:

- the wings have a low aspect ratio, providing slow but highly manoeuvrable flight; and
- the long ears would be used for locating the sounds of insect calls, as shown in the sibling species *Nyctophilus geoffroyi* (Hosken *et al.*, 1994).

Feeding from substrates by long-eared bats is also evidenced by the high proportion (about 75%) of caterpillars in the diet of the Tasmanian sibling currently known as *Nyctophilus timoriensis sherrini* (O'Neill and Taylor, 1989).

Woodland remnants existing in the Project area is a potential habitat for this species.

Roosting

Long-eared bats appear to be quite flexible in their roost selection, but have a predilection for tree hollows, exfoliating bark, or dense foliage (eg. Lunney *et al.*, 1988; 1995). At Lake Cowal, this species would be expected to roost in the first two situations.

Movement/Distribution

There is no knowledge of any movement or migration patterns that this species may exhibit. However, given its flight morphology characteristics, it is unlikely to undertake the long distance migrations noted for high wing aspect ratio species.

The general pattern of vegetation in the project area is one of depauperate grazing land, with scattered trees and remnant patches of woodland. There is some evidence that in New South Wales, in particular the Murray-Darling Basin, this species may have a preference for large tracts of Red Gum forest (Richards, unpubl.), though in Victoria it has also been captured in mallee and Buloke (Lumsden 1994).

In New South Wales there are records of this species from Mungo and Cocoparra National Parks, Buddigower, Yathong, and Pilliga Nature Reserves, and the Willandra Lakes World Heritage Region.

The Lake Cowal area is roughly in the middle of this species' distribution, which includes NSW, Victoria, eastern south Australia. There is also a single record from Fanning River Station, near Townsville, Queensland, but this may require verification.

Little Pied Bat (*Chalinolobus picatus*)

The little that is known of the biology of *C. picatus* has been contributed by Richards (1979), and the species has been reviewed by Richards (1983a, 1995a). It appeared to only require caves or their substitutes for roosting, but had also

been found in buildings (Hall and Richards, 1979). Richards (1979) reported on a large (numbering approximately 40) breeding colony behind an open sliding door in an old building at Yathong Nature Reserve. A colony is suspected to roost in disused mineshafts at Buddigower Nature Reserve, just to the south of West Wyalong.

Apart from being very patchily distributed, it is also considered to be quite rare. As well as being listed as Vulnerable in the NSW TSC Act, it is also listed in the International Union for the Conservation of Nature (IUCN) category Lower Risk – near threatened in the national Bat Action Plan (Richards and Hall, 1996). Dickman (1994) considers that the status of this species is “stable” in western NSW, as does Stephens (1992) for the Murray Mallee area.

Breeding

Females of this species are likely to give birth during late November and early December, as do sibling species. Females “normally bear two young in the summer” (Richards 1983a, 1995a). Very little else is known about the breeding biology of this species.

Foraging

This species can be assumed to forage primarily upon insects that are hunted by aerial pursuit, which is indicated by morphological characters that reflect this type of hunting, such as its wing aspect ratio and wing loading.

The Project area contains potential forage habitat where remnant patches of woodland remain.

Roosting

C. picatus appears to be an obligate cave-dweller, although the record of a breeding colony in a disused building (Richards, 1979) must be noted in this context. With the apparent absence of caves in the region (Matthews, 1985 in Greg Richards and Associates, 1997b), it is likely to utilise suitable disused mines in the area. Quite a few mines in the nearby old gold and tin areas have been reported, but the majority of these appear (from relevant data sheets) to be shafts, though some also have drives (Bowman, 1977 in Greg Richards and Associates, 1997b).

A mine suitable for bats is known from Buddigower Nature Reserve, to the south of West Wyalong, however inspection and survey did not detect the presence of any microchiropteran bat species.

Movement/Distribution

There is no information available in relation to movement or migration patterns that this species may exhibit.

Dwyer (1966), concluded that females of a sibling species, *C. dwyeri*, separated from most of the males in a regional population during the summer breeding season and by the following autumn the breeding colony had dispersed. The breeding biology of *C. picatus* may be similar.

In New South Wales there are records of this species from the Willandra Lakes World Heritage Region, Mungo National Park, Mallee Cliffs National Park, Nocolche National Reserve, and Yathong National Reserve. The type locality

is Depot Glen, near Milparinka, which may now be within a reserve. One would suspect, given the broad distribution of this species in western NSW, that it would also occur in the remainder of the reserve network in this region.

Lake Cowal is at the eastern edge of the distribution of this species.

5.3 Threatened Species Population Status

The following is a summary of the population status of the threatened species known or considered likely to occur in the Project area and surrounds.

5.3.1 Austral Pillwort (*Pilularia novae-hollandiae*)

Population Status

This species is listed as endangered in accordance with the TSC Act 1995. As previously noted, species listed as endangered are:

- those that are likely to become extinct unless the circumstances and factors threatening their abundance, survival or evolutionary development cease to operate; or
- species whose numbers have been reduced to such a critical level, or their habitats have been so drastically reduced, that they are in immediate danger of extinction.

Austral Pillwort is not listed on the Rare or Threatened Australian Plant (ROTAP) list (Briggs and Leigh, 1996).

Major Threats

Based on the information that is available on the ecology of this species, threats to Austral Pillwort are likely to be in the form of loss of potential habitat through drainage works, grazing and cropping.

5.3.2 Winged Peppergrass (*Lepidium monoplacoides*)

Population Status

This species is listed as endangered in accordance with the TSC Act 1995 (see above for definitions).

Under the coding system devised for ROTAP species (Briggs and Leigh, 1996), plants are assigned a code from three categories that give an overall view of the population size and distribution. The ROTAP code for Winged Peppergrass is 3ECi, where:

- 3 Distribution – species with a range over 100km in Australia but occurring only in small populations which are mainly restricted to highly specific and localised habitats;
- E Conservation Status – species of serious risk of disappearing from the wild state within one or two decades if present land use and other casual factors continue to operate; and
- Ci Reservation and Adequacy of Reservation – this symbol is used to indicate when a species is known to be represented within a National Park or other proclaimed Reserve. When accompanied by i it indicates that the

species is considered to be inadequately reserved, with a total population of less than 1,000 plants known to occur within conservation reserves.

Major Threats

The population decline of this species is most likely attributable to past and on-going effects of grazing by domestic stock, Rabbits, increased numbers of Kangaroos and land clearing for agriculture (largely cereal cropping) (Leigh *et al.*, 1984; Ayers *et al.*, 1996).

It is noted that this genus is highly palatable to stock (Bower, pers. comm., 1997).

5.3.3 Australasian Bittern (*Botaurus poiciloptilus*)

Population Status

The Australasian Bittern is listed as vulnerable (TSC Act 1995). A species that is vulnerable is not presently endangered but at risk of disappearing from the wild over a long period through continued depletion of suitable habitat.

The species survival status of this bird species is insufficiently known (in Western Australia there are probably fewer than 100 pairs but in the east there has been no attempt to survey the population) (Garnett, 1992). The dearth of records of this species may be attributable to the rarity of this bird and/or its cryptic nature (*ibid.*).

Major Threats

The main threat to this species has been drainage of swamps for agriculture (Marchant and Higgins, 1990; Garnett, 1993; Kingsford, 1991).

In addition, salinisation of wetlands as a consequence of excessive clearance in catchments has adversely affected vegetation cover essential for this species (*ibid.*). Grazing and cropping of swamp vegetation prevents the re-establishment of nesting and roosting habitat.

5.3.4 Black-necked Stork (*Ephippiorhynchus asiaticus*)

Population Status

This bird is considered scarce at the south-eastern extremity of its range in north-eastern New South Wales. However it remains common and secure (albeit at low density), from north-western Australia to northern Queensland (Morcombe, 1992).

In NSW the Black-necked Stork is listed as vulnerable (TSC Act 1995).

Major Threats

There are no major threats to the Black-necked Stork, although encroachment of development may exclude it from particular wetland areas due to its apparent intolerance of disturbance (Marchant and Higgins, 1993; Ayers *et al.*, 1996; Kingsford, 1991).

5.3.5 Brolga (*Grus rubicunda*)

Population Status

The Brolga is generally abundant in northern Australia and uncommon in southern and inland Australia (Marchant and Higgins, 1993). It is listed as vulnerable on the TSC Act 1995.

Major Threats

Egg mortality and chick predation can cause a considerable loss to Brolga populations (Serventy, 1985 in Ayers *et al.*, 1996; Pizzey, 1980, Arnol *et al.*, 1984; Ayers *et al.*, 1996). Activities and events such as illegal egg collecting, flooding of nest sites, trampling by cattle grazing, predation by Crows, Raptors, Pigs, Cats and Foxes are the main factors contributing to egg and chick mortality (*ibid.*).

As well as the effects of trampling, grazing indirectly affects density of food items. Hydrological changes that result in drainage of wetland area affect breeding opportunities for Brolgas and numerous birds are still shot or poisoned illegally especially in the wheat belt areas of NSW and VIC (Ayers *et al.*, 1996).

5.3.6 Blue-billed Duck (*Oxyura australis*)

Population Status

The Blue-billed Duck is considered as vulnerable in NSW (TSC Act 1995).

The status of this species is difficult to determine (Johnsgard and Carbonell, 1996). Estimates of the population of this species via aerial survey (eg. Braithwaite *et al.*, 1985a,b, 1986a,b) are considered to be only a small proportion of the actual number given the shy and retiring nature of this bird and its preference for dense vegetation. Flocks numbering in the several thousands have been observed in some favoured wintering sites (eg. Lake Kangaroo, VIC) (*ibid.*).

Major Threats

Destruction or modification of breeding habitat is the greatest threat to the continued survival of this species (Marchant and Higgins, 1990; Ayers *et al.*, 1996). Drainage works, clearing (of potential nest sites), grazing, increased salinity and groundwater extraction are of particular concern. Hunting also poses an on-going threat to this species (*ibid.*).

5.3.7 Painted Snipe (*Rostratula benghalensis*)

Population Status

The survival status of this species is presently insufficiently known (Garnett, 1992). A decline in the abundance of this bird has been reported in south-west Australia and it is rarely observed throughout its range. However this species is cryptic and crepuscular and may be more common than suspected (*ibid.*).

The Painted Snipe is vulnerable in NSW (TSC Act 1995).

Major Threats

The reasons for the decline of this species are not conclusively documented however threats include drainage of habitat, grazing by stock or other activities that result in degradation of habitat (Garnett, 1992).

5.3.8 Freckled Duck (*Stictonetta naevosa*)

Population Status

This species is listed as vulnerable according to the TSC Act 1995.

The population size of the Freckled Duck fluctuates greatly (Garnett, 1993). A census of the population following a severe drought in January – February 1983 placed the population at around 19,000 (*ibid.*). More recently 10,000 Freckled Ducks were recorded from the Currawinya Lakes (Jenkins, 1997) and it is likely that numbers exceed the previous estimation (Kingsford and Porter, 1993).

Major Threats

Historic and continued drainage of suitable wetland habitat threatens the population status of this species (Jaensch and Vervest, 1988). Similarly clearing of Lignum and *Melaleuca* swamp vegetation removes potential breeding habitat for Freckled Ducks (Ayers *et al.*, 1996; Garnett, 1993). Cultivation and grazing of these cleared areas prevents the regeneration of nesting habitat. Illegal hunting of the Freckled Duck is considered to pose a significant risk to this species (Garnett, 1993).

5.3.9 Yellow-bellied Sheath-tail-bat (*Saccolaimus flaviventris*)

Population Status

As noted in Section 5.2.3 of this document *S. flaviventris* appears to be quite rare, especially in southern latitudes (Greg Richards and Associates, 1997b). This species is listed as Vulnerable in the NSW TSC Act, but is not listed in the national Bat Action Plan (Richards and Hall, 1996) because of its widespread distribution. Dickman (1994) considers that the status of this species is "stable" in western NSW, as does Stephens (1992) for the Murray Mallee area.

Major Threats

While little is known of the biology of this species, clearing of hollow-bearing trees (removes potential roost sites), grazing (can cause a reduction in regeneration of potential roost trees) and predation by feral Cats, are thought to be the main threats to this species (Greg Richards and Associates, 1997b; Ayers *et al.*, 1996).

5.3.10 Greater Long-eared Bat (*Nyctophilus timoriensis*)

Population Status

The species is known to be quite rare, though this in part may be related to the difficulty of capture in the relatively open vegetation that it inhabits (Greg Richards and Associates, 1997b).

In a general discussion of conservation status, Dickman (1994) considers this species to be stable in western New South Wales. However, Stephens (1992) reported that *N. timoriensis* was "a species of serious concern" in the Murray Mallee area. Conversely, Lumsden *et al.*, (1995) proposed that "... the ability of bats to fly, their spatial scale of movement and their social organisation (eg. overlapping foraging areas, colonial roosting habits, interspecific tolerance) are key factors that enable these species to live successfully within the farmland environment and that have prevented regional extinctions ...".

The Murray-Darling Basin form of *N. timoriensis* has been listed as Vulnerable in the forthcoming national Bat Action Plan (Richards and Hall, 1996) and this species is considered vulnerable in NSW (TSC Act 1995).

Major Threats

There are no confirmed reasons for the decline of this species however habitat loss due to clearing for agriculture, habitat modification due to harvesting of River Red Gum forests are suspected threats (Richards and Hall, 1996).

5.3.11 Little Pied Bat (*Chalinolobus picatus*)

Population Status

Apart from being very patchily distributed the Little Pied Bat is considered to be quite rare (Greg Richards and Associates, 1997b). As well as being listed as Vulnerable in the NSW TSC Act, it is also listed in the IUCN category Lower Risk - near threatened in the National Bat Action Plan (Richards and Hall, 1996). Dickman (1994) considers that the status of this species is "stable" in western NSW, as does Stephens (1992) for the Murray Mallee area.

Major Threats

Loss of mature roost trees in inland areas has been confirmed as a major threat to this species (Richards and Hall, 1989). The loss of a known maternity roost (on Yathong Nature Reserve) in the early 1980s is likely to have impacted on the population of this species (Richards and Hall, 1996).

6.0 POTENTIAL IMPACTS OF THE PROPOSED DEVELOPMENT ON SUBJECT FLORA AND FAUNA SPECIES AND MITIGATION MEASURES

This section of the SIS deals with the potential impacts of the proposed development on the subject flora and fauna. This section presents potential Project-related impacts (and mitigation measures) as well as outlining those potential impacts and mitigation measures applicable to a suite of flora and fauna assemblages known or considered likely to occur in the area.

6.1 Background Perspective

The effects of human occupation on the natural environments of the central western region of NSW can be seen most directly in the alteration of habitats of indigenous species and the consequent changes to species represented in both the flora and fauna of the region (Goldney & Bowie, 1990).

Extensive clearing in the slopes and plains of Central Western NSW have occurred (*ibid.*) and many vegetation alliances characteristic of the original vegetative structure of the area have been considerably modified by grazing (Sivertsen & Metcalfe, 1995).

The impacts from the Project discussed in this section are limited to those likely to affect the nine species covered by this SIS. A summary of potential impacts of the Project on subject flora and fauna and associated mitigation measures

are presented in Table A-20. For a more comprehensive assessment of impacts refer to Section 4 of the EIS.

6.2 Land Resources

6.2.1 Potential Impacts

The development of the Cowal Gold Project would require the modification of the existing topography of the Project area. The open pit, waste rock emplacements, tailings storages and several water management structures are permanent features which, once rehabilitated, would form part of a new final landform.

The water management strategy for the Project would require the development of a permanent Up-catchment Diversion System and Internal Catchment Containment System. The development of these features would necessitate the modification of the size of the catchments and surface water flow paths within three catchment areas that are partly covered by the proposed MLA. A brief summary of the hydrological impacts of these activities is provided in Section 6.5.1.

Other potential impacts of the Cowal Gold Project with regard to soils and erosion and which could affect the subject flora and fauna species include:

- of in-situ soil resources from beneath mine landforms;
- breakdown of soil structure beneath hard stand areas and traffic areas;
- alteration of the physical and chemical properties of soils that are stripped and stockpiled;
- reduced quality (structure, fertility and microbial activity) of long-term stockpiled soil;
- contamination of soil with saline water/subsoil, process reagents and chemicals;
- erosion of soil from the outer batters of the waste emplacements and tailings storages, the verges of access and haul roads and areas in which vegetation has been cleared or water is concentrated;
- increased erosion rates due to the exposure of dispersive soils.

At the cessation of mining operations (Year 8), the open pit would be approximately 1,000 m long, 850 m wide and have a depth of about 325 m. The volume of the final void would be approximately 80,000 ML. Potential impacts associated with the final void on subject flora and fauna species include:

- water management issues such as isolation of the pit from Lake Cowal, long term hydrology, water quality; and
- impacts on native fauna from use of the void.

Principle six of the NSW Wetlands Management Policy (DLWC, 1996a) requires rehabilitation of wetland disturbed by the development or the construction, on-going maintenance and monitoring of a compensatory wetland.

In the Policy wetlands are defined as *"areas that are wet for a long enough period such that the plants and animals*

living in them are adapted to, and often dependent on, living in wet conditions for at least part of their life cycle". That is, wetlands are areas:

- inundated with water on a temporary or permanent basis;
- inundated with water that is usually slow moving or stationary;
- inundated with water that is shallow; and
- inundated with water that may be fresh, brackish or saline (DLWC, 1996a).

Based on the definitions given in the Wetlands Management Policy the proposed development would entail modification of approximately 120 ha (ie. 20 ha Fringing River Red Gum and 100 ha Lakebed) of "wetland" habitat.

6.2.2 Mitigation Measures

An integrated Erosion, Sediment and Salinity Control Plan would be developed for the construction and operational phases of the mine, to control erosion and sedimentation in the area disturbed by mining activities.

A detailed water management system for the Project has been developed and is contained in Appendix F and summarised in Sections 2.9 and 4.2 of the EIS.

Control of erosion through the stabilisation and revegetation of disturbed areas is proposed as part of the progressive rehabilitation strategy (Section 5 of the EIS). Additional measures proposed to be adopted to mitigate potential impacts on soils include:

- minimising the area disturbed by the Project and restricting access to non disturbed areas;
- ripping and rehabilitation of hard stand areas and roads no longer required for access;
- avoidance of soil stripping operations during particularly wet or dry periods, minimising of compaction during scrapping and dozing of soil and the use of ameliorants where required (eg gypsum application to dispersive soils);
- use of silt fences and temporary sediment traps to minimise sediment movement;
- use of diversion banks, channels and rip-rap structures to divert surface water around disturbed areas and to control runoff velocity;
- maintaining soil stockpile slopes at a maximum acceptable angle to resist erosion;
- the use of spoon drains, table drains and concrete culverts to control surface runoff from access roads; and
- leaving unstable and salty soil horizons in-situ beneath mine landforms, where possible.

The preparation of a detailed Project Soil Stripping and Management Plan (including designs for soil and water management) is proposed in association with the Department of Land and Water Conservation (DLWC), prior to the commencement of mine construction activities.

The open pit would remain post-closure as a void enclosed

on three sides by waste rock emplacements. The isolation function of the lake protection bund is designed to provide a permanent barrier between Lake Cowal and the void.

The rehabilitation of the permanent embankments surrounding the open pit to create a new foreshore with features to enhance wildlife habitat and ecotone characteristics (eg. small-scale topographic variations, shallow water areas, vegetation associations) is proposed. Section 5 of the EIS describes the rehabilitation strategy of the proposed new foreshore.

Rehabilitation objectives would involve both providing habitat to the subject fauna species and the propagation of subject flora species.

The rehabilitation strategies and long-term compatibility goals for the final void are discussed in Section 5 and Appendix N of the EIS respectively. The salinity of the final void is also addressed in Section 6.6 of this document.

It is proposed to leave the open pit as a void once mining operations cease. Backfilling of the void with waste rock is not a viable option due to the prohibitive costs and the necessity to keep the entire open pit active throughout the mining operations due to the shape of the orebody.

Operational and post-closure safety and stability considerations are to be considered as part of the Mining Rehabilitation and Environmental Management Process (MREMP) (operational issues) and the final Rehabilitation Report (post-closure issues). As a minimum, the following measures would typically be taken:

- fencing and/or bunding to control access;
- determination of optimal batter and berm characteristics; and
- visually blend the void into the landscape with bunding and revegetation.

Water balance and long-term water quality modelling for the final void has been undertaken and is presented in Appendix F of the EIS.

In accordance with Principle six of the *NSW Wetlands Management Policy* (DLWC, 1996), the proposed rehabilitation plan focuses on the enhancement of existing wetland resources through the creation of the new lake foreshore habitat area. This area would equate to approximately 15 ha of wetland.

In addition to the new lake foreshore wetland, an area of approximately 1,350 ha of North-owned land (to the north of the proposed MLA) is potentially available for wetland enhancement via land management practices and specific rehabilitation initiatives.

6.3 Potential Land Contamination

The Cowal Gold Project would involve the processing of gold-bearing ore from the open pit using a combination of flotation and cyanide leaching techniques. Table 2-7 in Section 2 of the EIS lists the major chemicals, reagents and other materials to be used and stored at the site.

A preliminary risk assessment of the Project has been undertaken by Ansto Safety and Reliability (1997) and is presented in Appendix L of the EIS. The assessment identified risks to the public, public property and the environment (both on and off-site).

6.3.1 Potential Impacts

The main potential sources of land contamination at the Project site are:

- spillage of process reagents and chemicals;
- spillage of fuels;
- spillage of oily wastes;
- disposal of other waste materials;
- sewage;
- leaching of salts from mine generated wastes (waste rock and tailings); and
- release of process water or tailings.

Subject flora and fauna species may be impacted by spillages through:

- movement of contaminants into waterbodies;
- permanent damage to environs at the spill site.

6.3.2 Mitigation Measures

An assessment of potential risks associated with the development of the Cowal Gold Project is detailed in Appendix L of the EIS. The assessment identified the greatest environmental risk to be potential road transport accidents leading to spillage of hazardous materials (ie. process reagents, process chemicals and fuels). Proposed in-place prevention measures and protective responses have been detailed for each identified environmental risk scenario (Table L8 of Appendix L of the EIS). In summary these measures include the following:

- appropriate driver training to minimise the risk of spillage occurring during transportation;
- appropriate packaging of potentially hazardous materials during transportation;
- compliance with appropriate regulations for the transport of hazardous materials;
- provision of adequately sized and appropriately bunded on-site storage areas (designed to the appropriate regulations);
- appropriate operator training for the storage, use and disposal of hazardous materials;
- development of appropriate storage/spill/fire identification and management systems; and
- a rehabilitation strategy that caters for the covering and stabilisation of saline wastes.

A detailed Hazardous Waste and Chemical Management Plan is to be prepared for the Project as outlined in Section 6 of the EIS. The Plan would contain appropriate emergency

response procedures in the event of spillage resulting in land contamination.

A Waste Management Plan would be required for the Project and would provide detail on the appropriate handling, disposal and recycling procedures for wastes generated at the Project site.

Further detail regarding potential sources of land contamination at the Project site and mitigation measures proposed can be found in Section 4 and Appendix L of the EIS.

6.4 Bushfire Hazard

6.4.1 Potential Impacts

Bushfire hazard within the Project area is generally considered to be low due to the extensive areas of cleared grazing land, and low fuel loads that occur within the proposed MLA. Potential causes of bushfire in the area include the spread of fire from the surrounding areas, the proposed MLA (either by naturally started fires or uncontrolled burning-off) or the spread of fire from the Project site following an on-site accident.

6.4.2 Mitigation Measures

North have advised that the Cowal Gold Project would be operated in a manner designed to minimise the threat of bushfire. All employees would undergo training on bushfire hazard. A bushfire management plan would be established in consultation with the bushfire control officer at the Bland Shire Council and other relevant government authorities.

6.5 Water Resources

6.5.1 Lake Cowal

Potential Impacts

The assessment of potential impacts on the conservation status and critical conservation values of Lake Cowal has been undertaken as a component of a long term compatibility study of the Project (refer to Appendix N of the EIS). Several of the identified critical conservation values for Lake Cowal have a significant bearing on the management of water resources at the proposed Cowal Gold Project. These values relate to the existing hydrological cycle and water quality of the Lake. Other critical conservation values identified include wetland habitat, terrestrial habitat and aesthetic character of the Lake.

The location of the Cowal orebody is such that mining of the deposit would require part of the open pit to extend beyond the full storage level of Lake Cowal. A series of isolation embankments would be constructed between the Lake and the pit to hydrologically isolate the Lake from the mine. A description of the lake isolation system is provided in Section 2 of the EIS. The water management strategy for this component of the mine is presented in Appendix F of the EIS.

The potential impacts associated with the proximity of the mine to Lake Cowal and therefore potentially on the habitat of subject fauna species are as follows:

- alteration of the hydrology of the Lake as a result of containing and using waters that would otherwise flow into the Lake;
- increased turbidity during the construction of the temporary isolation bund, lake protection bund and water supply pipeline from the Bland Creek palaeochannel;
- increased salinity due to exposure of saline soil and waste rock material during open pit pre-stripping and emplacement of waste materials;
- seepage of lake water into the open pit (or vice versa); and
- structural stability of the final mine landforms adjacent to the Lake, ie. risk of increased sedimentation.

Mitigation Measures

The Cowal Gold Project would be considered unlikely to have any measurable affect on the water balance of Lake Cowal (Appendix N of the EIS). The Project would not directly use water from the Lake for water supply or any other purposes.

A silt curtain is to be maintained around the working face of the temporary isolation bund as it is constructed in order to trap fine sediment and prevent suspended material migrating into the main body of the Lake. The water management strategy during the construction of the lake isolation system is described in Appendix F of the EIS.

Following stabilisation and revegetation of the outer batters of the lake isolation system, any runoff from the outer batter surfaces is anticipated to be of suitable quality (comparable to runoff from undisturbed areas) to enable release to the Lake. In addition, sediment fluxes entering the Lake from the Project site are expected to reduce from the pre-mine levels, as the final void would intercept the majority of site runoff (Appendix N of the EIS).

Soil and waste rock characterisation programmes have identified materials to be disturbed during the construction phase that have the potential to generate salinity (Appendices B and C respectively of the EIS). Accordingly, the water management strategy (Appendix F of the EIS) incorporates design elements to contain surface runoff or seepage likely to contain increased salt concentrations. The water management strategy for the emplacements involves maximising rainfall absorption, minimising runoff and directing any seepage towards the open pit thereby minimising the potential for increased salinity.

The potential for seepage occurring from the Lake to the open pit (or vice versa) has been assessed by hydrogeological studies (Appendix N). Structural and hydrological connectivity between the two features does not exist to any significant degree. In addition the maximum void water level is predicted to be some 20 m below the Lakebed.

The structural design and final profiles of the waste emplacements, tailings storages and lake isolation system effectively preclude the risk of instability which could cause impact on the Lake (refer to Appendix N of the EIS for further discussion of water resources).

It is proposed to bury the water supply pipeline from the Bland Creek palaeochannel borefield to the project site. Burial of the portion of the pipeline that crosses the Lake would only be possible during periods of low water levels. If the Lake level is too high to allow burial at the time of construction the pipeline would be placed on the floor of the Lake and buried at a later date when water levels allow. During burial of the pipe (all water levels) a temporary silt curtain would be erected around the disturbed area to trap fine sediment and prevent suspended material migrating into the main body of the Lake.

6.5.2 Surface Water Quality

Potential Impacts

Surface water runoff from mine landforms and disturbed areas could potentially contain sediment, salinity, dissolved salts, oil and grease and process reagents. The potential sources of surface water contamination include:

- waste rock emplacements;
- ROM and low-grade ore stockpiles;
- tailings storages and reclaim dam including pit dewatering cells;
- pit dewatering;
- process water;
- processing plant;
- sewage treatment facilities; and
- other infrastructure (roads, stockpiles).

Potential impacts on subject flora and fauna from these events include:

- movement of contaminants into waterbodies;
- exposure of species to harmful levels of contaminants; and
- degradation of critical habitat areas.

Mitigation Measures

Detailed water studies have been undertaken in order to design a comprehensive water management system to reduce any potential surface water and groundwater impacts. As described in Appendix F and summarised in Section 2.0 of the EIS, the overall objective of the Cowal Gold Project water management system is to contain all potentially contaminated water (contained water) generated within the Project area while diverting all other water around the perimeter of the site. Water management strategies have been developed in conjunction with the mine waste and soil management strategies to mitigate the potential impacts described above. The management strategies involve the following principles:

- minimising disturbance areas;
- containment of potentially contaminated water;
- recycling of contained water;
- progressive stabilisation and revegetation of disturbed areas.

Mitigation Measures

Once dewatering commences and the pit is excavated, significant volumes of saline water would become available. Coffey Partners International (1995) have modelled this situation in order to determine the dewatering requirements.

Monitoring of local and regional groundwater levels is to be undertaken during development of the open pit to confirm expected impacts.

6.5.3 Tailings Storages

Potential Impacts

The tailings storages are located some 3.5 km west of the Lake shoreline. Section 2 of the EIS details the design, construction and function of the storage. The potential impacts on both surface waters within the area of the tailings storages relate to:

- incident rainfall runoff from the external embankments;
- seepage;
- overtopping and spillage of surface water;
- rupture and spillage from either the tailings delivery or return water pipelines; and
- toxic cyanide levels in the storages (Section 6.13 of this document).

Specific potential impacts on subject flora and fauna include:

- contaminants of critical habitat areas and waterbodies;
- long-term seepage impacts on wetland habitat of Lake Cowal.

Although the waste characterisation assessment conducted for the Project (Appendix C of the EIS) has predicted waste rock would be non-acid forming, the potential for saline seepage occurring from tailings and certain potential construction materials was identified. Saline seepage and sediment mobilisation from the tailings storages could, if uncontrolled, impact upon downstream water resources.

Mitigation Measures

The mitigation measures to reduce potential erosion and sediment transport from disturbed areas are described in Sections 2 and 4 and Appendix F of the EIS. Watering of exposed surfaces during construction activities may also be used to reduce dust and sediment mobilisation.

The proposed seepage control methods for the tailings storages are:

- pre-stripping of soils beneath the embankment footprint;
- construction of a moisture conditioned and low permeability compacted storage floor; and
- installation of an under-drainage and decant network.

The implementation of these control methods is designed to provide a physical control barrier to control seepage from the tailings storages area. The geochemical properties of the foundation layer may provide further control of potential

impacts on water quality. The potential mechanisms by which this may occur are:

- consolidation of tailings materials above the clay blanket to reduce permeability; and
- adsorption of tailings chemicals onto clay colloids within the foundation layer and pre-existing subsoils beneath the storage.

The proposed rehabilitation and water monitoring strategies for the tailings storages and waste emplacements (described in Sections 5 and 6 of the EIS) have been designed to facilitate long term restoration of mine landforms, including the management of any seepage.

The tailings storages have been designed not to be overtopped and to minimise the risk of incidental spillage.

A bunded pipeline corridor would serve to contain any potential for losses or spills in the event of pipe rupture. An automatic shut-down mechanism is to be provided on tailings/process water pumps to enable the early detection of failures. In the event that spillage does occur within the bunded area, the affected area would be ameliorated in accordance with the procedures contained in the Hazardous Waste and Chemical Management Plan (Section 6 of the EIS).

Detailed analyses and modelling of seepage migration from the tailings storages (Appendix N) indicate that, as with all tailings storages, a limited amount of seepage would occur through the embankment and the storage floor. Due to the drawdown effect of the pit dewatering, the seepage flow (during mining operations and post-closure) would be permanently diverted to flow towards the open pit/final void where it would be contained (post-closure).

As discussed in Appendix N, any residual contaminants which enter the groundwater system below the tailings storages are expected to either be immobilised or substantially reduced in concentration near the base of the storage. It is expected that arsenic and zinc would essentially be immobilised in the soil profile. The groundwater modelling indicates residual cyanide concentrations would be reduced by a factor of one thousand (to negligible levels) near the base of the tailings storages.

6.6 Final Void Water Quality

6.6.1 Potential Impacts

A description of void water quality and stratigraphy is provided in Appendix C (Geochemical Studies) and Appendix N (Long Term Compatibility) of the EIS and is summarised in Section 7 of this document. Void water is predicted to be non-acid (EGi, 1997).

During the filling stage the Cowal void would exhibit a steady progression toward seasonal stratification. After filling, the long-term scenario would include a trend in deep water toward hyper-salinity. In the surface mixed layer there would be a mid-year (approximately June – August) seasonal increase in salinity from that approximating sea-water to a level approaching twice that of sea-water.

During the summer months the concentration of salinity in this layer would return to about sea-water levels.

Several studies have investigated the salt water tolerance of waterbirds (Moorman *et al.*, 1991; Basham and Mewaldt, 1988) and some studies have reported harmful effects of salt water on birds (Windingstad *et al.*, 1987).

Numerous studies have however found that species are tolerant of hypersaline environments. Mahoney and Jehl (1986a) found that two species of birds, Wilson's Phalarope (*Phalaropus tricolor*) and American Avocet (*Recurvirostra americana*) which occupy hypersaline lagoons in the Great Basin of western North America, were able through a combination of behavioural and anatomical adaptations to rid their prey of most adherent lake water and thereby largely avoid the problems of salt-loading and the ingestion of harmful ions. The Eared Grebe (*Podiceps nigricollis*) and Californian Gull (*Larus californicus*) also have adaptations enabling existence in hypersaline environments (Mahoney and Jehl, 1986b; 1986c).

A number of Australian bird species are tolerant of high salinity waters, with fauna displaying many adaptations to cope with salinity-associated stress (Prof W.D. Williams, pers comm, 1997 in Goldney, *et al.*, 1997). These species are particularly prevalent in the Lake Eyre basin and other Australian inland lakes (*ibid.*).

Review of a number of relevant studies and reference sources indicates that plankton and possibly fish can occur in saline (and hypersaline) water bodies (Swanson *et al.*, 1988; Kingsford and Porter, 1992; 1993; Moorman *et al.*, 1991) such as the final void.

6.6.2 Mitigation Measures

The shallow surrounds of the void waterline are to be rehabilitated in such a manner to maximise seasonal habitat opportunities for the subject waterbird species (and waterbirds in general). Rehabilitation procedures are described in Section 7 of this document and Section 5 of the EIS.

The salinity of the void surface water after filling is expected to range seasonally from around 20,000–40,000 $\mu\text{S}/\text{cm}$ over summer and up to 60,000 $\mu\text{S}/\text{cm}$ in winter. This is comparable with the ranges found in natural inland salt lakes.

6.7 Air Quality

6.7.1 Potential Impacts of Dust on Wildlife and Vegetation

A detailed assessment of the existing air quality and the potential impacts of the Project was carried out by Pavel Zib and Associates (1997) and is contained in Appendix I of the EIS. Section 3.6 of the EIS summarises the existing air quality of the Project area.

Atmospheric dust emissions are expected to be the main atmospheric emissions associated with the Project. Other possible sources of air emissions would be exhaust fumes from mobile equipment, blasting fumes and evaporative

emissions from the processing area. All these emissions are expected to be minor.

Potential impacts of dust on the subject fauna (*viz.* birds and livestock) at the Project area and surrounds were investigated by Hunt (1997) in Appendix I of the EIS.

Assessment of the elemental composition of soil and subsoil from the proposed tailings and tailings storages areas revealed that potential dust from this area during construction and operation would fall within the normal range of acceptability for surface soils for birds (and livestock) (Hunt, 1997).

Low concentrations of heavy metals were found in dust samples taken from the Project area. Potential dust deposition in areas accessible to birds (or grazing livestock) was considered negligible (*ibid.*).

Pascoe *et al.* (1996 in Hunt, 1997) provide an extensive review of metal toxicity in waterfowl. The report found that upstream sediments at a reservoir in Montana, USA, contained high levels of copper, arsenic, cadmium and zinc, however the daily intake of metals by waterfowl were below or within acceptable toxicity ranges.

It is considered therefore that dust fallout from the Cowal Gold Project would have no adverse effect on waterbirds, and therefore no adverse effect on the subject species, or livestock using the area (Hunt, 1997).

Dust can affect vegetation by inhibiting physiological processes such as photosynthesis, respiration, transpiration and allow penetration of phytotoxic gaseous pollutants (Farmer, 1993; Eller, 1977). Visible injury symptoms may occur and generally there is decreased productivity (Farmer, 1993).

A study on the effect of dust on photosynthesis and its significance for plants (Thompson *et al.*, 1984) found that photosynthesis and leaf diffusion resistance was reduced at 5 to 10 g dust per m² leaf surface.

Given that predicted dust deposition contours indicate that levels of approximately 0.5 g/m²/month would be experienced (Pavel Zib and Associates, 1997) at the main bird breeding areas adjacent to the proposed MLA area, vegetation species diversity and abundance is unlikely to be deleteriously affected.

6.7.2 Mitigation Measures

A range of air quality safeguards are to be employed to reduce emissions of atmospheric dust from the Project. These safeguards are based on current control techniques as recommended for open pit mining in NSW by the EPA. The main components of the controls can be summarised as follows:

During the construction phase standard dust control measures would be implemented including intensive watering, road surfacing and restricting the speed of vehicles travelling on unsealed surfaces.

Dust control practices to be implemented during the operational phase of the Project may include the following:

- regular watering of haul roads and other internal roads;
- minimising the area of soil stripping ahead of operations to minimise areas of exposed ground;
- prevention of truck overloading and the resulting spillage during loading and hauling;
- fitting of drills with dust suppression equipment;
- regular maintenance of all haul roads;
- progressive rehabilitation of mine landforms;
- limiting the freefall height during ore/waste stockpiling and dumping operations; and
- water sprays to be fitted to primary crusher, conveyor and stockpile feed points.

6.8 Acoustics

6.8.1 Potential Impacts of Noise and Blasting on Wildlife

Ambient noise surveys were conducted in July, August and December 1994 and January 1995 in order to characterise and quantify the existing acoustical environment in the area surrounding the proposed mine site and the predicted project related noise emission levels. These surveys are described in Section 3.7 and Appendix H of the EIS.

Whilst some specific studies are reported in the scientific literature, no firm policy or guidelines exist on the noise levels considered acceptable, or conversely, the level or character of noise that may disturb or otherwise affect the primary ecological components of bird species (Richard Heggie Associates, 1997).

Richard Heggie Associates (1997) identified the major sources of noise and vibration emissions associated with the Cowal Gold Project as:

- noise emissions from mobile plant and equipment during the construction phase;
- noise emissions from mining operations including fixed processing plant and mobile equipment;
- ground vibration and airblast emissions resulting from blasting operations; and
- noise emissions from traffic on public roads.

Noise

With respect to the subject bird species, numerous studies have been undertaken on the effects of noise on wildlife (Shaw, 1978; Busnel, 1978; Ames, 1978; Lynch & Speake, 1978; Allaire, 1978; Streeter *et al.*, 1979; Algers *et al.*, 1978 in Richard Heggie Associates, 1997; Poole, 1982 in Richard Heggie Associates, 1997). In essence the studies indicate that many species are well adapted to human activities and noises.

Birds tend to habituate to constant steady noise levels, even of a relatively high level in the order of 70 decibels (dBA) (Richard Heggie Associates, 1997).

It was also found that continuous exposure to higher levels (70 dBA – 85 dBA and above) may cause some degree of

behavioural changes in birds (non-specific to species) (*ibid.*).

Project noise levels under adverse weather conditions (1.5 m/s wind) were predicted at various distances from the near edge of Lake Cowal for the various phases of the construction and mining operations.

The analysis found that the maximum adverse conditions contributed noise level at 1.5 km (the closest conceivable bird breeding area of significance on Lake Cowal) was 53 dBA during construction (L_{A1}) (ie. the level exceeded for 1% of the time) (*ibid.*). This level is clearly well below (more than 7 times lower) than the level of 70 dBA, above which, some degree of environmental changes in birds have been observed (*ibid.*). During operations the maximum predicted contributed noise levels under adverse conditions were even lower; 45 (at 1.5 km) and <30 dBA (at 4.5 km), respectively.

Blasting

Richard Heggie Associates (1997) note that sudden loud or impulsive impact noises may be capable of causing birds to become startled which if repeated in the longer term, may affect feeding and possibly breeding habits in some bird species.

A review of a number of relevant studies (Heinemann, 1970; Stadlerman, 1958 in Richard Heggie Associates, 1997) found that the effects of airblast have been observed in birds at levels of approximately 131 dB – 140 dB Linear and above (Richard Heggie Associates, 1997). The predicted level of airblast at 1.5 km from the Project is 107 dB Linear. This level of airblast is 45 times and 16 times, respectively, lower than the documented levels of 140 dB and 131 dB Linear (*ibid.*). At 4.5 km distance (ie. at the main waterbird breeding area) the level is 95 dB Linear (Appendix H).

Furthermore, literature review has shown that with respect to impulsive acoustic stimuli (eg. sonic boom, explosion), the majority of published reports of well controlled experiments concluded that the behaviour (including breeding) of domestic animals and some characteristically shy, wild species (*viz.* Wild Turkey) was unaffected by repeated sonic booms (Welch & Welch, 1970; Lynch & Speake, 1978).

6.8.2 Mitigation Measures

North propose to implement noise control and monitoring programmes during construction and operation. These measures are outlined in Section 4 of the EIS and include maintaining blasting and noise emissions within EPA standards, and hence, well within the researched levels for bird life disturbance.

6.9 Artificial Lighting

6.9.1 Potential Impacts

Little information is available on the potential impacts of lighting on wildlife and specifically, birds.

Potential impacts of lighting at the proposed development however are likely to focus on the alteration of forage zones, primarily those for the subject bat species for insectivorous bird species in general. Birds such as Australian

Owlet-nightjar (*Aegotheles cristatus*) and Kookaburra (*Dacelo novaeguineae*) have been observed foraging on insects around lights at sporting fields (pers. obs.) and studies (Rydell, 1992; Blake *et al.*, 1994; Hickey & Fenton, 1990, all in Greg Richards and Associates, 1997b) show that insects can be up to 40 times more prevalent around lights (street lights, low and high pressure sodium lamps).

Greg Richards and Associates (1997b) notes that at the Cowal Gold Project bats are likely to congregate around lighting and that the bat species likely to be foraging in the area would be those in the aerial pursuit foraging species. This activity could be considered a potential issue given that some bat species may be drawn away from their natural foraging habitat (*ibid.*). Conversely bats foraging around artificial lighting may be considered a positive impact, drawing insects away from habitat that may not necessarily be suitable for the aerial pursuit foraging species as a forage resource and concentrating prey in more accessible areas (*ibid.*). In areas such as the Lake Cowal region where forage opportunities for bats are likely to have been severely reduced since European settlement, provision of regular concentrations of food supplies for bats may be considered a positive impact (*ibid.*).

The presence of lights and concentrations of bats may increase the incidence of predation on them by owls (*ibid.*). Although there appears to be little study on the topic, there have been numerous observations of bats appearing to forage above the lights for the majority of the time (*ibid.*). Apparently bats seldom cross the light cone except when chasing insects (Belwood and Fullard, 1984, Schnitzler *et al.*, 1987, Kronwitter, 1988, Hickey and Fenton, 1990, Rydell, 1991; all in Greg Richards and Associates, 1997b.), which is assumed to be a predator avoidance strategy (Hickey and Fenton, 1990 in Greg Richards and Associates, 1997b).

6.9.2 Mitigation Measures

Based on the information presented above, it is considered that only positive impacts would result from artificial lighting and therefore no mitigation measures in regard to flora/fauna would be required.

6.10 Human Interference

6.10.1 Potential Impacts

Potential impacts from human interference and presence associated with a mining operation can include harassment of fauna, vehicle related mortalities and illegal hunting (US Department of the Interior, 1994) and mortalities in tailings storages.

6.10.2 Mitigation Measures

To ensure potential impacts associated with human interference on the subject flora and fauna and fauna species in general are minimised, access to the Project area is to be restricted to Project staff, contractors and authorised visitors. Vehicular speed limits are to be set and enforced across the Project area thus greatly reducing the potential for fauna mortality as a result of vehicle strike.

Outside the Project area deaths from traffic movements would essentially be unavoidable but can be minimised through adhering to speed limits and general awareness of fauna using particular road areas, eg. through signage.

Domestic pets and firearms would be prohibited from the Project area and employees and contractors would not be permitted to take native fauna or encourage fauna through feeding.

A clean, rubbish-free environment would be maintained throughout the Project area particularly around the administration and contractor areas. This would discourage scavenging and reduce the potential for colonisation of those areas by non-endemic fauna (eg. introduced rodents).

6.11 Tailings Water and Cyanide Toxicity

A detailed description of cyanide (CN) and CN usage at the Project is provided in Appendix G of the EIS and summarised in Section 2 of this document. The following is a synopsis of the potential impacts of the cyanide flow-path on subject fauna and waterbirds generally at the Project.

6.11.1 Potential Impacts

Ostensibly birds and bats and any animals not excluded by the fence around the tailings storages could potentially be affected by exposure to CN in water at the Project tailings storages. Birds however are the only group of wildlife which are likely to arrive in significant numbers regularly at the Project site.

Birds

Bird mortality on cyanide-bearing tailings storages facilities is recognised locally and internationally as an environmental problem (Hansard, 1995; Kay, 1990; Donato, 1997).

CN in the tailings storages at the Project site could be either ingested by birds through drinking of water, inhaled as hydrogen cyanide gas (HCN) or absorbed through skin contact with water or tailings slurry (eg. wading or swimming in contaminated water).

Once absorbed into the bloodstream, cyanide bonds strongly with iron, copper and sulfur which are constituents of many enzymes and proteins, in particular, the enzyme cytochrome oxidase which is essential to the utilisation of oxygen (Smith and Mudder, 1991). The inactivation of the enzyme leads to cellular asphyxiation and tissue death. Rapid damage to the central nervous system and the heart can also result from breathing high levels of cyanide over a short time, which can result in respiratory arrest and death (*ibid.*).

Donato (1997) investigated the impacts on wildlife caused by toxic tailings at seven gold mining operations in the Northern Territory. In this study, a total of 218 bird species were recorded on the case study mining leases and 71 species were recorded using tailings storage facilities. A total of 1,255 bird mortalities were recorded from four case study mining leases within a two year period.

The results of the study and research conducted by Donato (1997) indicate that at levels of CN exposure below 50mg/L WAD cyanide limit, mortalities approach zero.

Published information and field work illustrates the differences in lethal limits between species (eg. Ballantyne, 1974 in Donato, 1997; Wiemeyer *et al.*, 1986 in Donato, 1997). In terms of sub-lethal effects, work by Pristos and Ma (1997) and Ma and Pristos (1997) identifies cellular effects of CN on key organs of the Mallard Duck (however cellular activity did revert to control levels after a period of time).

Species behaviour can also increase a birds exposure to CN toxicity (Donato, 1997). A species that uses supernatant as a roost would be less exposed to CN toxicity than a species that filter feeds through supernatant and slurry (Donato, 1997). Some species have been found to be diving in supernatant *viz.* Grebes (*Tachybaptus* sp.) and Hardhead (*Aythya australis*) which would increase their exposure to CN (Donato, 1997).

The presence of macroinvertebrates in tailings storages pond water may act as an attractant to the subject waterbirds. However, aquatic organisms have been found to be adversely affected by concentrations of cyanide (free) as low as 1 mg/L (Sedlak *et al.*, 1997). Therefore it is considered that aquatic biota would be unlikely to occur in the tailings storages pond water.

Wiemeyer *et al.*, (1986) in Donato (1997) found that some birds are able to recover from extreme exposure to CN. Birds affected by CN have been found to be easily resuscitated with oxygen and are often able to be released within 24 hours (Donato, 1997).

The findings of the Donato (1997) study support other published information relevantly reducing WAD cyanide concentrations to below 50mg/L reduces mortalities in open impoundments. For example, Henny *et al.* (1994) recorded no mortalities below 59 mg/L WAD cyanide concentration in a study in North America. Above this concentration, mortalities increase significantly. The nature of the operating environment (such as the Cowal Gold Project next to a wetland) can justify a more prudent approach to CN levels in tailings storages.

Bats

The bat survey of the Project area (Greg Richards and Associates, 1997a) notes that the only threatened species recorded (ie. the Yellow-bellied Sheath-tail-bat – *S. flaviventris*), was not found foraging over small water points such as stock dams and appeared to prefer the larger waterbody of Lake Cowal itself. Whether it requires free water in its diet, as opposed to obtaining it from insect prey, is unknown.

From the data from the few hours of bat survey (trip-lining) at one stock dam, and the data from inventory sites at this and other stock dams, there is an indication that a portion of the community that consumes free water.

Further to this, the bat survey and assessment (Greg Richards & Associates, 1997a) found that only three species were actually caught at the water surface by trip-lines, whereas five species were detected foraging over stock dams. Furthermore, two species (*C. morio* and *V. regulus*)

were trip-lined but not detected over dams and both were only recorded in one habitat each (*ibid.*).

With regard to the potential for adverse impacts to occur if or when bats consume water from cyanide tailings storages, bat mortality at tailings dams at gold mines in the United States have been recorded (Clark, 1991), at unknown cyanide levels.

The only identifiable research on the toxicity of cyanide to bats was prepared by Clark *et al.* (1991) who found that Little Brown Bats (*Myotis lucifugus*) have an LD₅₀ sensitivity of 8.4 mg sodium cyanide/kg of body weight. (As a comparison the LD₅₀ for the Mallard Duck is 1.43 mg/kg of body weight).

The presence of macroinvertebrates in tailings storages pond water may act as an attractant to bats. However, aquatic organisms have been found to be adversely affected by concentrations of cyanide (free) as low as 1 mg/L (Sedlak *et al.*, 1997). Therefore it is considered that aquatic biota attractive to bats would be unlikely to occur in the tailings storages pond water. The lack of a food source, habitat and bright lighting in the tailings storage area, plus low CN levels in the tailings storage suggest that bat mortality should not be an issue of significance. Notwithstanding, specific monitoring and, if required, mitigation is proposed (refer mitigation measures).

6.11.2 Mitigation Measures

Birds

Following consultation with a number of regulatory bodies and recognised experts, potential bird mortality as a consequence of CN toxicity, is to be mitigated to the greatest possible extent by destruction of CN compounds (Appendix G of the EIS and Section 2 of this document). The destruction process is designed to result in CN levels in the tailings storages of less than 20 mg/L for at least 90% of the time and 30 mg/L at all times. This level is in conservative accordance with EPA discussions on the Project which were previously determined following consideration of the following key points:

- the need for conservatism due to difficulty of setting a universal cyanide threshold for protecting birds due to highly individualistic behaviour of birds and differences between mines;
- a recognition of industry experience which indicates bird mortalities are only "virtually" eliminated at 50 mg/L CN_{WAD};
- consideration of the potential for chronic and sub-lethal effects and synergistic effects from other chemicals in tailings;
- consideration of likely natural degradation in conjunction with the attractiveness of the delta or beach habitat created near the discharge point;
- practical management and economic considerations; and
- large numbers of birds which use Lake Cowal and the likelihood of the significant use of the tailings storages.

In addition to chemical reduction of CN levels, a number of mechanisms to deter birds from tailings ponds have been employed at mining operations throughout the world.

A review of relevant literature (eg. Nevada Mining Association *et al.*, 1990; Bomford & O'Brien, 1990; Donato, 1997; Hagelstien, 1997 in Donato, 1997; Dodds-Smith and Filas, 1996; Wildlife Control Technology Inc., 1996) suggests that the use of physical deterrents alone as a control measure, has limited long term value. Measures such as broadcast of audio and visual stimuli to scare/repel birds are widely accepted as having limited success in the short term and minimal in the longer term.

Netting of tailings storages is a more proven control measure on small areas however over larger expanses such as the storage areas at the Cowal Gold Project, inherent factors such as difficulty of structural maintenance, aesthetic impact and impediments to bird retrieval, preclude the use of this expensive technique.

A site specific monitoring programme is to be implemented, whereby tailings storages are to be patrolled twice a day for evidence of birds being affected by tailings water.

Bats

Previous studies at a gold mine in north Queensland, Greg Richards and Associates (1997c) showed that there were significant differences in bat species richness and abundance when tailings dams were compared with natural water sources, with both variables being higher at the latter. This was attributed to the lack of vegetation surrounding tailings cells. Richards (1994 and unpublished PhD studies) concluded that in temperate forests bat species richness was positively correlated with the diversity and density of understorey plants, which apparently dictates the level of insect prey. It is highly likely then, that at the Cowal Gold Project area, where the amount of aquatic vegetation and aquatic insects would be insignificant or at least substantially lower than at natural waterbodies, that the two tailings storages may not be attractive to bats (Greg Richards and Associates, 1997a).

Based on the information presented on the potential impacts of cyanide to bat populations mitigation measures have been developed that effectively account for the following predicted scenarios:

Scenario 1 Local (and subject) bat species diversity is reduced as a result of drinking tailings pond water. US-experience (eg. Clark, 1991) notes that bats have been deleteriously affected by CN in tailings storages albeit at unknown cyanide levels.

Scenario 2 Bats (including subject species) are not affected by low CN levels, evidenced by the toxicity tests in the US and fact that no records exist for bat mortality related to usage of tailings storages in Australia and mortality information from the US is limited despite extensive reporting requirements in that country for operational mines.

In light of the above, the following mitigation measures would be proposed:

- Following the assessment of the results of a monitoring programme to determine the usage of tailings storage areas by bats, bat exclusion mechanisms would be developed if required. This would entail strategic emplacement of sensor-activated units to emit bursts of ultrasound to "jam" echolocation signals of micro-chiropteran bats. Radio-tracking of individuals would be incorporated into the mitigation measures to test the necessity and efficiency of any mechanisms employed.

As a further contingency, cyanide levels would be reviewed and if necessary altered at the destruction process.

It should be noted that for the mining operation detailed in the Clark (1991) paper, fundamental differences exist between it and the proposed Cowal operation. Relevantly no cyanide destruction process is operated at the Ridgeway mine (pers. comm. P. Jarvis, Manager – Environment, Ridgeway Mine, South Carolina) and hence the ability to control cyanide levels exiting the processing plant is nil.

The Ridgeway case study records bat mortalities at cyanide levels around 20 mg/L free cyanide. Test results using Caro's acid destruction on Cowal ore indicates substantially reduced free cyanide levels, in the order of 5 to 6 mg/L (to achieve levels of 20 to 30 mg/L CN_{WAD}).

Further to the above, it is understood that at the Ridgeway mine lighting of the tailings impoundment to assist with identification and recovery of wildlife, acted as an attractant for bats (pers. comm. P. Jarvis, Manager – Environment, Ridgeway Mine, South Carolina). No such lighting is proposed for the Cowal Project tailings storages and as a contingent mitigation measure, diversionary lighting could be used to further discourage use of the area by bats.

Other Fauna

It is proposed to fence the tailings storages to exclude medium to large terrestrial fauna from the area. CN in the tailings storages areas would be kept at a level of less than 20 mg/L for at least 90% of the time and less than 30 mg/L at all times to limit potential impacts on fauna that are not excluded by the fence. Daily patrols of tailings storages for fauna and appropriate response measures would be undertaken.

Rehabilitation initiatives of the tailings storages areas during operations would be such that minimal habitat opportunities would be created for terrestrial fauna, thus the potential for their occurrence would be considered low.

As a general mitigation aim, tailings ponds would be maintained as small as possible through continual recycling through the processing plant.

6.12 Bird Strike and Mining Infrastructure

6.12.1 Potential Impacts

Impacts associated with potential bird strike and mining infrastructure relate primarily to electricity transmission line

collision. Appendix D of the EIS provides a detailed discussion of the potential impacts of electricity transmission line bird strike. A summary of this information is presented below.

Research on avian mortality caused by electricity transmission lines (eg. Faanes, 1987; Anderson *et al.*, 1977; Beaulaurier, 1981; Kingsford, 1990; Longworth & McKenzie (1987); Ruzs *et al.*, 1986; Murray & Winning, 1992; CSIRO, 1996) indicates that in the absence of pre-planning and assessment, inappropriate alignment of electricity transmission lines can result in significant bird mortality. Ruzs (1990 in CSIRO, 1996) specifically notes a discernible set of characteristics for birds frequently recorded colliding with electricity transmission lines, including:

- species with awkward flight characteristics;
- relatively large body size;
- birds that lack manoeuvrability in the air; and
- species that fly at night.

Accordingly, birds such as Swans, Pelicans, Cranes, Herons, Waterfowl and Gulls are typically most frequently involved in collisions (Faanes, 1987). Of the subject species, the Brolga and Black-necked Stork may be affected by electricity transmission line.

6.12.2 Mitigation Measures

Appendix D of the EIS contains details on the ameliorative measures that can be incorporated into the design, construction and operation of an electricity transmission line. These measures are summarised below:

In a study of electricity transmission line bird strike management at Lake Cowal (CSIRO, 1996) it was found that although there are variations in the response of birds from location to location and species to species, there are a number of common engineering design and siting considerations which are critical to lowering the frequency of bird strikes. These include:

- length of the powerlines between poles because most strikes occur in mid-span air space;
- the vertical plane or profile of conductors is more important than the horizontal profile;
- the horizontal profile of conductors parallel to the ground for descending birds;
- the height of the conductors above the ground in relation to the flight lanes and local bird behaviour;
- the height of the earth or ground wire above the conductors;
- the relationship of the lines to natural flight screens such as hills and trees;
- the orientation of the conductor across flight lanes and their visibility in relation to the sun;
- the diameter of the conductor or its enhanced visibility by means of visual aids; and

- the proximity to water, wetlands and important habitat.

In order to minimise bird strike transmission line siting and design features should include (where practicable):

- identify significant bird habitat and minimise proximity of powerlines by a preferred 400 m;
- avoid as many over-water crossings as possible;
- place lines adjacent to and near the base of hills, rows of trees or cliffs to provide a natural screen that birds would automatically fly over;
- share the same easement as existing similar lines as long as the vertical dimension of the strike zone is not increased in foggy areas;
- place lines parallel to prevailing winds;
- decrease the vertical dimension of the stacked powerlines by placing wires in a horizontal array;
- use visual aids such as orange PVC balls and coloured vibration dampers in open areas of higher bird-strike potential although their success may be based more on human perception than verifiable evidence (Rusz, 1990 in CSIRO, 1996); and
- in flight path areas use fast-growing trees along the transmission line easement to create a visual screen and barrier to bird flight.

The proposal to bring the 132 kV line from Temora, as opposed to Forbes and near (or between Lake Cowal and Nerang Cowal) was based on a need to reduce the potential impact of bird strike.

6.13 Removal/Modification of Existing Vegetation

Clearing has been the most obvious change to native vegetation in the region however several other processes have had effects on the vegetation assemblages. These processes include grazing of native shrub and grass species by domestic stock and feral grazers; weed incursion and introduction of exotic species; alterations to pre-settlement fire regimes; modification and pollution of waterways; increased use of pesticides and fertilisers; and isolation of portions of remnant vegetation (Adamson and Fox, 1982; Goldney and Bowie, 1990; Sivertsen and Metcalfe, 1995). Mining, rural settlement and forestry have also contributed to vegetation change in the region (Adamson and Fox, 1982).

Similarly, a number of State Forests and private woodlots in the region were actively managed to encourage growth of some species (eg. *Callitris glaucophylla*) thus necessitating the need for clearance of other native species (eg. *Eucalyptus populnea* subsp. *bimbi*) (Sivertsen and Metcalfe, 1995).

The proposed development of the Cowal Gold Project would entail disturbance of approximately 940 ha comprising those mine components listed in Section 2.2 of this SIS (Figure A-6).

Discussion of the potential impacts of the Project on native vegetation which may provide habitat to the subject species is provided below.

6.13.1 Native Vegetation

Potential Impacts

As noted in Section 4.1.2 of this document, botanical survey and assessment of the Project area and surrounds (Anne Clements & Associates, 1995, 1996; Charles Sturt University, 1997; Bower, 1997) identified the presence of nine main vegetation communities.

Community 1 Remnant Woodland (*Eucalyptus dwyeri* – *Acacia doratoxylon* – *Callitris endlicheri*)

This community occurs on high exposed ridges with shallow soils, generally as scattered, unconnected islands (Bower, 1997). This community type does not occur within the proposed MLA area and no examples of it are likely to be affected by the proposed development (*ibid.*).

Community 2 Eucalypt Woodland (*E. dwyeri* – *E. populnea* – *E. microcarpa* – *Callitris glaucophylla* – *Casuarina cristata*)

Occurring mainly on well-drained sloping country and low ridges, this community is prominent on Cowal West Hill within the proposed MLA area. The proposal would entail removal of approximately 35 ha (ie. 70%) of this community type, within the proposed MLA area.

Community 3 Predominantly Cleared Agricultural Land with Scattered Bimble Box Woodland (*Eucalyptus populnea*)

A major plant community of the south-western slopes region, it dominates the upper strata of the flatter landscapes that have largely been cleared for agriculture. Within the proposed MLA, approximately 700 ha (approximately 47%) of this community type would be removed/modified as a result of the proposed development.

Community 4 Fringing River Red Gum (*Eucalyptus camaldulensis*)

Remaining tracts of this community are generally restricted to narrow riparian strips associated with the margins of watercourses and the Lake. In the proposed MLA boundary this community occurs as a relatively degraded thin strip along the Lake high water mark. The Project would necessitate removal of approximately 20 ha (approximately 40%) of this strip.

Community 5 Lignum (*Muehlenbeckia florulenta*)

Dense thickets of Lignum occur primarily in the northern portion of Lake Cowal. No significant clumps of Lignum would be removed/modified as a result of the proposed works.

Community 6 Lakebed (*Medicago polymorpha* – *Eragrostis australasica*)

The proposed development, viz. the open pit and waste emplacement areas, would entail the removal of approximately 100 ha (approximately 11%) of this community type from the proposed MLA area).

Community 7 Mixed Woodland**(*Acacia pendula* – *Casuarina cristata*)**

This community is typically represented by isolated clumps of trees or remnant patches in otherwise cleared land. It occurs mainly on the alluvial flats and Belah (*Casuarina cristata*) is commonly the dominant associate. The proposal would entail removal of approximately 50 ha (approximately 70%) of this community type from the proposed MLA area.

Community 8 Wilga Woodland**(*Geijera parviflora* – *Casuarina cristata*)**

Reaching its optimum density on alluvial gilgai soils and other heavy soils on flats and lower slopes, Wilga (*G. parviflora*) is widespread in the area. The proposed development viz. the tailings storages and drainage works would entail the removal of approximately 35 ha (approximately 60%) of this community type from the proposed MLA area. This community typically occurs in disjunct patches.

Community 9 Belah Woodland (*Casuarina cristata*)

C. cristata is a common associate of many vegetation communities in the region, occurring primarily on drainage impeded gilgai areas on grey soils. Occurring in the south of the proposed MLA area, the proposed development would entail the removal of approximately 1 ha (approximately 3%) of this community type from the proposed MLA area.

Mitigation Measures

The Project area would be rehabilitated by revegetating the new landforms with selected communities of endemic vegetation that are both suitable to the physiographic and hydrological features of each landform, whilst expanding on the areas of remnant endemic vegetation that currently exist in the immediate region.

It is proposed that regional seed collecting programs would commence in the construction phase, to allow sufficient time to commence rehabilitation of the new Lake foreshore at the completion of foreshore reconstruction activities. It is North's intention to improve the status of endemic remnant vegetation in the region.

Details of the proposed rehabilitation are presented in Section 5 of the EIS and Section 7 of this document. There would be a focus on using subject flora species in the species mix of the rehabilitated landforms. Mitigation measures pertinent to the individual vegetation communities identified from the Project area and surrounds are presented below.

Detailed description of the understorey species commonly associated with the following vegetation types, to be used in the rehabilitation programme are presented in Section 7.

Community 1 Remnant Woodland (*Eucalyptus dwyeri* – *Acacia doratoxylon* – *Callitris endlicheri*)

Although this community type does not occur within the proposed MLA area, *Acacia doratoxylon* and *Callitris endlicheri* are associated with hilltops, elevated lands, low ridges and hills in the region and therefore may be used in revegetation of the tailings, waste emplacements, Cowal West Hill and upper slopes of new landforms (Figure A-17).

Hence the expanse of this community would be increased in the region.

Community 2 Eucalypt Woodland (*E. dwyeri* – *E. populnea* – *E. microcarpa* – *Callitris glaucophylla* – *Casuarina cristata*)

This community type would be used to revegetate the footslopes of Cowal West Hill and the waste emplacement batters and surrounds (Figure A-17). *Casuarina cristata* and *E. microcarpa* would also be used to revegetate areas fringing the Lake and drainage lines. Following revegetation of the Project area, this community would be of greater extent than prior to the development.

Community 3 Predominantly Cleared Agricultural Land with Scattered Bimble Box Woodland (*Eucalyptus populnea*)

E. populnea would be planted on the Cowal West Hill footslopes and the waste emplacement batters and surrounds (Figure A-17).

Community 4 Fringing River Red Gum (*Eucalyptus camaldulensis*)

Revegetation of the fringing areas of the Lake and drainage lines with River Red Gums would ensure that the trees removed at the beginning of the development are replaced in greater numbers.

Community 5 Lignum (*Muehlenbeckia florulenta*)

Lignum would predominantly be planted along the Lake foreshore. Lignum may also be utilised in revegetation of fringing areas of the Lake and along drainage lines. A considerable quantity of Lignum (compared to the amount that presently exists) would be established in the proposed MLA area.

Community 6 Lakebed (*Medicago polymorpha* – *Eragrostis australasica*)

Revegetation of the Lakebed is detailed in Section 7 and presented in Figure A-18. The freshwater communities of Lake Cowal can be divided into 4 types of zones, viz. flood zone, littoral zone, rush zone and permanent water zone. The Lakebed would be revegetated with species such as Lignum and Burr Medic (flood zone), Canegrass and White Water Lily (littoral zone), Cumbungi and Rush (rush zone), Foxtail and Pond Weed (permanent water zone). It is expected that a wide variety of aquatic floral communities would establish in the absence of significant competition for Lake landuses (eg. grazing, cropping).

Community 7 Mixed Woodland (*Acacia pendula* – *Casuarina cristata*)

This vegetation type would be used to revegetate the waste emplacement batters, Cowal West Hill footslopes and surrounds (Figure A-17). *C. cristata* would also be planted on areas fringing the Lake and on drainage lines.

Community 8 Wilga Woodland (*Geijera parviflora* – *Casuarina cristata*)

Wilga and Belah would be incorporated into revegetation of the Cowal West footslopes, waste emplacements and surrounds. Belah would also be used to revegetate areas fringing the Lake and on drainage lines.

SHALLOW LAKE	WATERCOURSES - RIVER FLOODPLAIN	FLAT - GENTLY UNDULATING SLOPES	LOW RIDGES - HILLS	HILLTOPS - ELEVATED LAND
EXAMPLE OF LANDFORM: Lake Cowal and new lake foreshore	EXAMPLE OF LANDFORM: Fringing lake vegetation and drainage line vegetation	EXAMPLE OF LANDFORM: Footslopes below Cowal West; waste emplacement batters and surrounds	EXAMPLE OF LANDFORM: Cowal West tops and upper slopes of new landforms	EXAMPLE OF LANDFORM: Tailings and waste emplacements top surfaces
VEGETATION ASSOCIATION: Freshwater Plants	VEGETATION ASSOCIATION: River Red Gum Woodland	VEGETATION ASSOCIATION: Eucalypt Woodland Alliance No.1	VEGETATION ASSOCIATION: Eucalypt Woodland Alliance No. 2	VEGETATION ASSOCIATION: Eucalypt Woodland Alliance No.3
TYPICAL SPECIES: Refer Figure A-18	TYPICAL SPECIES: Windmill Grass Lignum River Red Gum Yellow Box Grey Box Belah Rosewood Blackbox	TYPICAL SPECIES: Poplar Box Yellow Box Fuzzy Box Grey Box Blakely's Red Gum White Cypress Pine Belah Myall River Cooba Wilga Rosewood	TYPICAL SPECIES: Windmill Grass Redleg Grass Daphne Heath Red Stringybark Mugga Ironbark Tumble-down Red Gum Black Cypress Pine Lancewood	TYPICAL SPECIES: Windmill Grass Redleg Grass Daphne Heath Mugga Ironbark Yellow/Red Box Long-leaved Box Black Cypress Pine Lancewood
RL ~205m	RL ~206-220m	RL ~210-225m	RL ~220-230m	RL ~230-245m
Not to Scale	Source: Adapted from Bralwell (1975), Briggs & Threlk (1995), Bralwell (1997), Cowal & Smith (1998), DUNCAN (1998), GARDNER & BOWIE (1999), SWENSON & METCALFE (1995).			
ResourceStrategies	FIGURE A-17 Conceptual Revegetation Strategy Proposed Vegetative Successional Communities			

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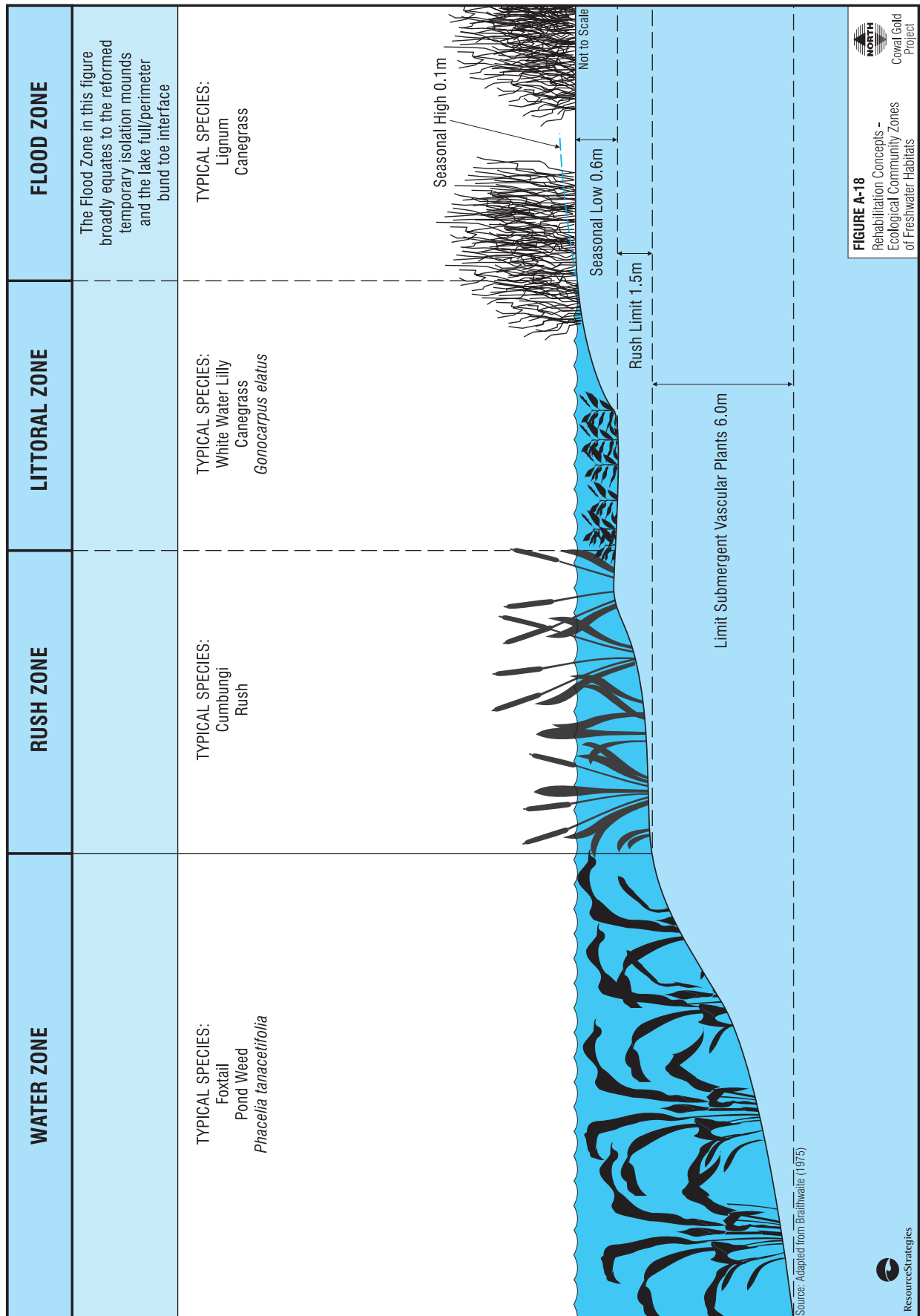


FIGURE A-18
Rehabilitation Concepts -
Ecological Community Zones
of Freshwater Habitats

Community 9 Belah Woodland (*Casuarina cristata*)

Revegetation of the fringing areas of the Lake and drainage lines with *C. cristata* would ensure that this community would be of greater extent than prior to the development.

6.13.2 Weeds

Potential Impacts

During the 1993 botanical survey of the Project area and surrounds (Anne Clements and Associates, 1995), a total of 411 species were recorded composed of approximately 21% weed species (Charles Sturt University, 1997).

The 1997 survey of the Project area (*viz.* the proposed major disturbance areas) recorded 141 plants of which, around 30% were weeds (*ibid.*).

Five species recorded during the 1993 survey were listed as noxious on the Bland Shire Noxious Weeds list. However only one of these species, African Blackthorn (*Lycium ferocissimum*), was recorded from within the proposed MLA (*ibid.*). This species was not recorded during the 1997 survey.

The presence and possible introduction of noxious weed species poses a potential threat to native plant species, by reducing floristic structure and diversity.

Disturbance, such as those associated with mining activities, can act as a catalyst for weed incursion and if management initiatives are not enacted, proliferation of weeds can occur.

Mitigation Measures

Weed infestations can be very difficult to control and therefore emphasis should be placed on prevention rather than cure. A control program would be implemented in consultation with appropriate advisory bodies such as the Department of Agriculture, Bland Shire Council and Rural Lands Protection Board to control or remove existing weed species and to limit the potential for their reintroduction. The spread of weeds would be monitored annually as detailed in Section 7.

6.14 Removal/Modification of Existing Habitat

Potential impacts generally associated with the removal and/or modification of areas of habitat, relate to loss of resources that contribute to the lifecycle components of the subject fauna species. Potential impacts associated with disturbance of the Project area habitats, are detailed below.

Specifically within the proposed MLA subject species could be expected to show preference for the lakebed, riparian zone and vegetated slopes habitats.

Potential Impacts

Lakebed

As noted in Section 4.2.1 of this document, the Lakebed habitat area could potentially afford habitat (breeding and foraging) opportunities for amphibians, birds and small and large mammals such as macropods and microchiropteran bats. Notwithstanding the diminished potential habitat value of this area, any habitat resources presently available for fauna within the lakebed disturbance area, would be lost as a result of the proposed development and the removal of approximately 100 ha of this habitat type.

Riparian Zone

This habitat area comprises a narrow riparian strip of River Red Gum (*E. camaldulensis*), that has been substantially thinned as a result of past land uses.

In a study of River Red Gums and waterbird nesting (Briggs and Thornton, 1995), it was found that the River Red Gum wetlands such as those of the middle and lower Murrumbidgee River support large numbers of breeding waterbirds (Maher, 1990; McGrath, 1992), *viz.* Pelecaniformes and Ciconiiformes (Briggs and Thornton, 1995).

While the River Red Gum riparian habitat at the Project area has undergone degradation in recent years, any inherent habitat values associated with those trees in the proposed disturbance area (*ie.* nesting resources for birds such as Cormorants, Herons, Darters, Egrets and Spoonbills), would be lost as a consequence of clearance of approximately 20 ha of this habitat type.

Greg Richards and Associates (1997a) notes that loss of hollow-bearing trees could infer a loss of potential roost habitat for bats such as Yellow-bellied Sheath-tail-bat (*Saccolaimus flaviventris*), Eastern False Pipistrelle (*Falsistrellus tasmaniensis*), Greater Long-eared Bat (*Nyctophilus timoriensis*) and Inland Forest Bat (*Vespadelus baverstocki*).

Cleared Land with Scattered Woodland

This habitat type characterises the greater majority of the Lake Cowal region. A relict of past and present land use, this habitat is composed of numerous (and typically small) fragmented areas of woodland amidst large expanses of predominantly cleared, grazing land.

As noted in Section 4.2.1, habitat values of this area relate principally to potential breeding, nesting, roosting, foraging and dispersal resources for mobile fauna (*eg.* bats, birds) as well as isolated potential habitat areas for amphibians and reptiles (*ie.* moister gilgai areas). Removal of approximately 700 ha (47%) of this habitat type from within the proposed MLA, would entail loss of this potential habitat resource.

Vegetated Slopes

Approximately 35 ha of this habitat type would be removed as a consequence of the proposed development.

Fragmentation of native vegetation into numerous disjunct patches (*ie.* with varying degrees of connectivity), has probably been responsible for a decline in the range and/or abundance of a number of species that are known to inhabit woodland vegetation (Saunders, 1993).

Based on studies undertaken on the *Effect of Habitat Fragmentation on Regional Bird Populations: Lessons from the Western Australian Wheatbelt* (Saunders, 1993), it has been determined that selective clearance of woodland areas can result in an overall reduction of bird species diversity. Birds such as Tree-creepers, Honeyeaters and Lorikeets that are dependent on woodland can be adversely affected by loss of nest sites and food resources.

Mitigation Measures

Rehabilitation of the Project area would result in expansion of habitat opportunities for wetland and terrestrial fauna species, primarily due to the establishment of a greater extent of endemic vegetation. This would happen on a progressive basis. A greater diversity of habitat types would become available (possibly increasing species diversity) and the extent of habitats would increase. Rehabilitation measures are outlined in Section 5 of the EIS and Section 7 of this document. Section 8 provides an assessment of the long term compatibility of the development in regard to terrestrial and wetland habitats.

Across all the habitat types, any hollow-bearing trees would be inspected by suitably qualified personnel prior to clearance.

6.15 Fauna Issues

Further to Sections 6.1-6.12, potential impacts on flora and fauna of the Lake Cowal region are discussed below. Associated mitigation measures are also presented.

The pressures on faunal populations in general of the Central Western region of NSW continue to be:

- clearing of habitat for agricultural purposes;
- drainage of wetlands and damming of waterways;
- competition from feral introductions;
- past rabbit plagues;
- the isolation of remnant vegetation;
- the widespread road system;
- land use management practices (including use of toxic chemicals, control burning, mining, forestry, works etc);
- illegal hunting, trapping and fishing;
- changing fire regimes; drought; stocking rates;
- disease; and
- predation by feral animals.

(Goldney and Bowie, 1990)

6.15.1 Aquatic Biota

Potential Impacts

Potential impacts to aquatic biota of the Lake Cowal as a result of the Project relate primarily to those presented in Section 6.2.2 – Water Resources, of this document. Aquatic biota of the Project area and surrounds may have undergone impacts from other factors such as:

- clearing and fuel reduction burning (primarily of Lignum or River Red Gum) practices;
- invasion by introduced fish species;
- cultivation of the Lakebed for crop production; and
- use of fertilisers, soil conditioning agents and biocides in agricultural runoff and irrigation water (Humphries *et al.*, 1991).

Mitigation Measures

Mitigation measures to reduce or exclude potential impacts on aquatic biota relate primarily to those presented in Section 6.2.2 – Water Resources, of this document.

6.15.2 Amphibians and Reptiles

Potential Impacts

Amphibians typically are restricted to water bodies such as rivers, creeks, or lagoons however they do undertake forays across elevated terrain in damp conditions. Reptiles can generally disperse over many land types however preference is likely to be for areas where cover/protection from predators is available.

In a general sense, an enormous array of human activities impinge upon the viability of amphibian populations including:

- insecticide use in agricultural and horticultural areas, particularly aerial spraying;
- land reclamation by drainage in wetland areas, resulting in loss of breeding sites;
- the conversion of temporary ponds to dams for stock use resulting in the destruction of peripheral sheltering sites; and
- introduction of the Mosquito Fish (*Gambusia holbrooki*) which preys on frog eggs and tadpoles.

(Tyler, 1994 in Tyler, 1997).

Cogger *et al.* (1993) identified reptile communities in a number of habitats and regions in Australia as being under threat. Relevantly, one of those habitats is the fragments of original mallee (tall shrubland) and woodland habitats in the wheatbelt of western NSW (*ibid.*).

Threats affecting the greatest number of species are habitat clearance, overgrazing by domestic stock, cropping, urban development and predation by introduced mammals (Foxes, Cats and Rats) (Cogger *et al.*, 1993).

Reference to Attachment A4 indicates that 18 amphibian and 65 reptiles have been recorded from the Lake Cowal region. Threatened species recorded include the Southern Bell Frog (*Litoria raniformis*) and three reptiles (Pink-tailed Legless Lizard – *Aprasia parapulchella*, Burton's Snake-lizard – *Lialis burtonis*, Lined Earless Dragon – *Tympanocryptis lineata* subsp. *pinguicollis*).

Vestjens (1977) noted that amphibians were significantly more prevalent in the low-lying areas of the Lake shore and flood plain, than any of the other habitat areas surveyed. The preference for this area was postulated to be a function of the increased forage value of the areas especially during periods of inundation when numerous arthropods living in the soil and amongst vegetation, are flushed.

Based on the information presented above, potential impacts of the Project to amphibians and reptiles include drainage of suitable wetland areas, loss of essential/preferred microhabitat features and subsequent decline in food resources, sedimentation/siltation of water

bodies, increased risk of mortality from vehicles, disruption to dispersal/movement behaviour and increased risk of exposure and predation.

Mitigation Measures

Based on the information concerning threats to amphibians and reptiles (Tyler, 1997; Cogger *et al.*, 1993) and the results of herpetological survey of the Project area and surrounds, the proposed development is considered unlikely to impact on significant numbers of amphibians and/or reptiles. However the proposed rehabilitation programme for the Project includes features which provide for the creation of amphibian and reptile habitat. For example the development of the woodland systems across much of the Project area would potentially increase habitat opportunities for reptiles and expand dispersal options for local populations.

Potential amphibian microhabitat is likely to be created as the freshwater ecological community successional structure develops.

A Feral Pest Management Plan for the Cowal Gold Project is to be prepared in accordance with the best practice guidelines and recommendations of the Australian Nature Conservation Agency – Vertebrate pests Committee Working Group (1995) and the NPWS. This management plan would ensure the potential fauna habitat opportunities to be created by the rehabilitation works, are not compromised.

6.15.3 Birds

Potential Impacts

In a general sense, a number of birds are threatened or are suspected as becoming threatened by a wide variety

of processes (Garnett, 1993). Notwithstanding natural processes such as cyclones or displacement by other endemic taxa, these threats are principally a function of human action/presence (*ibid.*).

A summary of the former and current threats to Australian bird taxa as detailed in Garnett (1993) is presented in Table A-18.

In the Central Western Slopes Region (Goldney & Bowie, 1990), pressures on avifauna populations are likely to be those outlined in Section 6 – Fauna Issues.

On a more localised scale, potential impacts on bird species diversity and abundance as a consequence of the construction and operation of the proposed mining development generally include:

- loss of habitat as a result of clearance which can result in removal/reduction of forage resources, nesting areas and materials, breeding opportunities, roost sites, refuge and harbour areas and dispersal capabilities;
- creation of disturbed "edge" areas can encourage introduction of non-endemic species that are able to out-compete niche rivals and displace resident birds thus, leading to a reduction in the overall avifauna diversity and abundance; and
- changes to habitat resources and hence resident avifauna assemblages can modify/disrupt inherent food-chain mechanisms (eg. increase in cleared open areas could potentially encourage increased aerial predation from raptors).

Table A-18 Threats to Australian Birds*

	Current Threats		Former Threats		Total
	Confirmed	Speculative	Confirmed	Speculative	
Clearance and fragmentation of habitat:					
Agriculture	32	4	22	9	67
Mineral extraction	2	4	4		10
Softwood plantations	2	1	2		5
Urban development	4	3	1		8
Other environmental modification:					
Altered fire regimes	16	35		4	55
Grazing and/or trampling	10	35		7	52
Fishing		3			3
Disease		3		3	6
Pollution		7			7
Erosion	1	1			2
Environmental weeds	2	9		1	12
Forestry operations	3	14			17
Changed hydrological regimes	1	3	2	1	7
Climatic variation	2	7		2	11
Shortage of nesting hollows (variety of causes)	3	20		1	24
Predation	3	20		1	24
Competition	8	29	9	9	55
Direct exploitation	3	20		1	24
Other	1	4			5

Source: Garnett (1993)

* Numbers of taxa affected; totals do not necessarily equal the sums of current and former threats because taxa can be subject to more than one threat.

Further to the potential impacts listed above, specific components of the proposed development may also affect bird populations. These are listed below and discussed in more detail in Sections 6.2 to 6.13:

- disruption to essential behavioural patterns as a result of noise generation and blasting activity, dust and air quality emissions, introduction of artificial lighting, road traffic and human interference; and
- increase in the mortality rate via exposure to/drinking of toxic residues (viz. cyanide) and collision with artificial structures (eg. powerlines, mining infrastructure).

Mitigation Measures

Measures designed to ameliorate potential impacts on avifauna are detailed in Sections 6.2 to 6.13.

6.15.4 Mammals

Potential Impacts

Goldney & Bowie (1990) note that in the Central Western Region of NSW ground dwelling mammals have been most affected by past and on-going landuses.

In a working paper on the possible factors inducing faunal changes in western NSW and north-western Victoria in the 19th century, Allan (1983 in Goldney and Bowie, 1990) notes that the extinction of medium-sized ground dwelling mammals predated the major land clearance programmes of Europeans, the periods of gross overstocking of sheep and cattle, the arrival of feral animals (particularly rabbits and foxes) and the major droughts of the late 19th century (*ibid.*). It was postulated that the extinction of this group of mammals in north-western Victoria and western NSW is related to the rapid demise of the Aboriginal population particularly along waterways (*ibid.*). It is argued that it was the rapid removal of the Aboriginal land management practice of firing that initiated the sudden and dramatic extinction of the medium-sized mammals (*ibid.*).

Further to those pressures on fauna of the Central Western Region of NSW listed in Section 6, potential impacts of the proposed development specifically relate to bats and include:

- removal of potential roost trees for hollow-obligate bats such as the Greater Long-eared Bat (*Nyctophilus timoriensis*) and Eastern False Pipistrelle (*Falsistrellus tasmaniensis*), primarily associated with loss of mature River Red Gum (*E. camaldulensis*) along the Lake foreshore;
- reduction in forage opportunities by removal of woodland vegetation and vegetative structure, known to attract potential prey species;
- impacts of ingestion of potentially toxic cyanide laden pond water in the tailings storages and decant areas.

Mitigation Measures

As previously noted, mammalian species diversity and abundance of the Lake Cowal region is low as a consequence of a host of factors such as habitat clearance, hunting, altered fire regimes, proliferation of feral species,

grazing and cropping practices. A number of bat species have however been recorded from the area and the mitigation measures presented herein would focus on microchiropteran bat fauna and the potential impacts listed.

The rehabilitation programme is to include revegetation of extensive areas with Eucalypt woodland. Development of a woodland system has the potential to provide future roost and/or forage opportunities for bats, over and above those that presently exist.

Section 6.13.2 presents measures for mitigating potential adverse impacts on bat fauna as a result of exposure to CN in the tailings storages areas.

6.15.5 Threatened Flora and Fauna Species

Section 6.2 – 6.13 details those primary potential impacts that could occur as a result of the proposed development of the Cowal Gold Project. Specific, subject species-related potential impacts of the Project and associated mitigation measures are highlighted below.

Austral Pillwort (*Pilularia novae-hollandiae*)

Potential Impacts

Major threats to this species are listed in Section 5.3.1. In relation to the proposed development, potential impacts to the Austral Pillwort are likely to be from loss of potential habitat areas (ie. portions of the Lake foreshore and gilgai land).

Mitigation Measures

Potential mitigation measures are likely to be limited by the habitat requirements of this species (that is the ephemeral nature of *P. novae-hollandiae*). However the embayments and foreshore areas subject to flooding and drying that are proposed to be created as a component of the rehabilitation works, may offer habitat opportunities for this species. Advice would be sought from appropriate sources regarding establishment of this species in these zones when they are created. Rehabilitation of these areas would be progressive.

Winged Peppercress (*Lepidium monoplacoides*)

Potential Impacts

The Project could potentially threaten this plant by clearing of potential habitat areas and if grazing is to be a component on final landuse objectives, grazing may reduce prospects of this plant colonising within the proposed MLA area.

Mitigation Measures

Little detailed information exists on the habitat requirements of this species, however collections of this species from the western NSW region have been found primarily in Bimble Box communities. Subject to availability and to advice from recognised authorities, *L. monoplacoides* would be incorporated into the species mix to be developed for the Bimble Box communities revegetation.

Australasian Bittern (*Botaurus poiciloptilus*)

Potential Impacts

As per the major threats to this species (as outlined in Section 5.3.3), potential impacts to the Australasian Bittern

include alteration of hydrological regimes to the extent that any essential habitat components in the Lake Cowal system are adversely affected. Continuation/expansion of grazing and cropping practices in potential habitat areas thus preventing establishment of nesting and roosting habitat, is also a potential impact to this species.

The Project area is considered unlikely to contain potentially suitable breeding or foraging habitat for this species as the Australasian Bittern prefers shallow areas vegetated with reeds or rushes.

Mitigation Measures

The new Lake foreshore rehabilitation and revegetation works include vegetation and habitat components that are considered suitable for this species as nesting/roosting/foraging resources.

Exclusion of grazing and cropping from much of the foreshore area would allow natural recruitment and regeneration of potentially suitable Bittern habitat.

Black-necked Stork (*Ephippiorhynchus asiaticus*)

Potential Impacts

While there are no major threats to this species (Marchant & Higgins, 1993), human encroachment associated with the proposed development may potentially exclude this bird from the Project area and immediate surrounds.

The lakebed of the Project area potentially represents a forage resource for this species. However, it is considered that the vegetated areas to the north of the Lake would offer more suitable habitat resources for this vagrant species.

This species is also considered to be particularly susceptible to collision with the electricity transmission line based on the characteristics noted previously (Section 6.14).

Mitigation Measures

Potential forage habitat resources for this species are likely to develop as a component of the foreshore restoration and revegetation programme.

Mitigation measures relating to minimising the potential for bird strike of the electricity transmission line are summarised in Section 6.14.

Brolga (*Grus rubicunda*)

Potential Impacts

Altered environmental flows and flooding patterns can potentially adversely impact on Brolga egg and chick mortality. Introduction and/or absence of control of feral, predator species such as the Fox (*Vulpes vulpes*), Cat (*Felis catus*) and Pig (*Sus scrofa*), at the Project area can also lead to increased egg and chick mortality.

Feeding mostly occurs near water, however Brolgas are known to also feed in grasslands, dry wetlands or cultivated areas. Therefore disturbance to the lakebed, riparian zone and cleared land with scattered woodland may impact upon potential habitat resources of this species.

Mitigation Measures

The removal of grazing from the wetland areas within the proposed MLA would aid in the re-establishment of potential Brolga habitat (ie. forage) areas.

The pest control plan for the Project area would aim to eradicate feral species such as the Fox and Cat, which are considered major threats to Brolga chick and egg survival.

Blue-billed Duck (*Oxyura australis*)

Potential Impacts

Changes to the hydrology of the Lake such as intrusion of saline groundwater and water extraction, could potentially result in losses of wetland vegetation thus, reducing breeding, foraging and roosting opportunities for this species.

The lakebed habitat area could potentially afford foraging opportunities for the Blue-billed Duck. However, given that Blue-billed Ducks are secretive birds and prefer dense vegetation, it is considered that the open and cleared nature of the Project area lakeshore would limit the area as a forage habitat.

Based on the breeding/foraging requirements of this species, the Project area is not considered to offer suitable habitat resources.

Mitigation Measures

Given this species' apparent sensitivity to hydrological change, potential hydrological impacts of the proposed development and associated mitigation measures are summarised in Section 6.5. Final void status and amelioration is described in Section 6.6. Creation of areas potentially suitable as foraging and nesting habitat for the Blue-billed Duck would further mitigate any potential impacts on local populations of this species as a result of the proposed development.

A variety of monitoring programmes (noise, air quality, waterbird abundance and diversity) would be undertaken at the Project area and surrounds.

Painted Snipe (*Rostratula benghalensis*)

Potential Impacts

Although the main threats to this species are not conclusively documented, the proposed development could potentially affect a local population of this species by draining potential habitat areas and/or allowing uncontrolled grazing and cropping to occur in such areas.

Land usage within the Project area has resulted in this area being largely unsuitable for breeding and foraging, which are more likely to occur in the swamps and channels of the northern shore of the Lake.

Mitigation Measures

Lake Cowal has been identified as an important refuge for the Painted Snipe (Schodde, pers. comm., 1997). Detailed modelling, monitoring and reporting indicates that the Project would not deleteriously affect the existing

environmental flows and status such that the known habitat areas of the Lake, are compromised.

The habitat creation components of the rehabilitation programme would have the potential to increase and enhance habitat opportunities for this species.

Freckled Duck (*Stictonetta naevosa*)

Potential Impacts

Any component of the Project that has the potential to adversely impact on the potential habitat areas of this species, ie. Lignum dominated areas primarily to the north of the proposed MLA, could result in a reduction of Freckled Duck numbers and breeding activity at the Lake.

Specifically potential impacts could result from the construction of the pit new Lake foreshore. The lakebed provides potential forage habitat opportunities for the Freckled Duck.

Mitigation Measures

The proposed development would not entail removal of any significant areas of potentially suitable Freckled Duck breeding habitat, ie. Lignum dominated regions to the north of the proposed MLA.

Additionally potential habitat for the Freckled Duck is likely to be created as a component of the rehabilitation programme.

Yellow-bellied Sheath-tail-bat (*Saccolaimus flaviventris*)

Potential Impacts

Although little is known of the biology of this species (Greg Richards and Associates, 1997b) removal of hollow bearing trees (with potential roost sites) as a component of the proposed development could impact on the status of any local population. Occurrence of feral cats as an indirect effect (eg. in response to potential rodent population fluxes) of mining operations could also potentially adversely impact on this species.

Mitigation Measures

Hollow bearing trees in the proposed disturbance areas would be searched for bats by suitably qualified personnel, prior to removal. Should bats be detected a relocation programme would be undertaken.

As part of the rehabilitation programme extensive areas would be revegetated with Eucalypt woodland which would provide future potential roost sites and forage opportunities for this species. A pest control programme would help ensure that feral cats are controlled in the Project area.

To further mitigate the potential loss of habitat resources, artificial roost boxes would be placed within suitable habitat in the wider area. Artificial roosts have been widely used in America as a conservation measure (Richards, pers comm, 1997).

Greater Long-eared Bat (*Nyctophilus timoriensis*)

Potential Impacts

Known to roost in tree hollows, the proposed development has the potential to impact on this species by removing any potential roost sites contained within the River Red Gum (*E. camaldulensis*) trees to be cleared as a consequence of constructing the open pit and waste emplacements.

Mitigation Measures

Revegetation of the Project area with hollow-bearing species of Eucalypts (particularly River Red Gums) would in the longer term provide potential habitat for this bat species. Surveys conducted at the Project area did not identify any *N. timoriensis* roosting in the River Red Gum fringing the Lake. However, further monitoring and inspection of this habitat would be conducted prior to the removal of any mature River Red Gums. If detected bats would be relocated.

Artificial bat roost boxes have been widely used as a conservation measure in America (Richards, pers. comm, 1997) and could be utilised as a mitigation measure for this Project.

Little Pied Bat (*Chalinolobus picatus*)

Potential Impacts

The loss of mature roost trees in inland areas has been confirmed as a major threat to this species (Richards & Hall, 1996).

The loss of mature, hollow bearing River Red Gums (*E. camaldulensis*) from the Lake margin could potentially limit roosting opportunities for any local *C. picatus* population.

Mitigation Measures

The target survey did not indicate that the River Red Gums fringing the Lake are being used as a roosting habitat. However, the habitat would be searched for bats prior to removal and if required, bats would be relocated.

Areas fringing the Lake would be revegetated with Eucalypt species including River Red Gums. In time, these trees may provide suitable resources for roosting and foraging requirements.

Placement of artificial roost boxes would provide roosting resources for bats.

6.15.6 Impact and Mitigation Summary

Table A-19 presents a summary of the potential impacts of the Project on subject flora and fauna species and/or their habitats. Associated mitigation measures are also presented in Table A-19.

Table A-19 Summary of Potential Impacts of the Project on Subject Flora and Fauna Species and/or their Habitats and Associated Mitigation Measures

Potential Impacts of the Project	Mitigation Measures
Land Resources Modification of the existing topography (open pit, waste rock emplacements, tailings storages).	- Provide permanent barrier between Lake Cowal and open pit, viz. lake protection bund; - Rehabilitation of permanent embankments would result in a new foreshore with features to enhance wildlife habitat and ecotonal characteristics.
Bushfire hazard	Bushfire Management Plan - Key relevant components include: - compliance with <i>Bush Fires Act, 1949</i> and requirements of Bland Shire Council; - aspects relating to fuel management and fire incident control; - provision of adequate fire breaks, appropriate and well-maintained fire equipment, appropriate staff training and spark arresters on mobile equipment.
- Soils and erosion: - loss of in-situ soil resources; - breakdown of soil structure; - alteration of physical/chemical properties; - reduced quality; - contamination; - erosion and sedimentation.	Soil Management Strategy - Key relevant components include: - establishment of soil suitability for rehabilitation purposes; - determination of suitable soil stripping, handling and storage procedures; - formulation of a Soil Management Plan. Integrated Erosion, Sediment and Salinity Control Plan - Key relevant components include: - sequencing of construction works to minimise the area of disturbance at any one time; - specific sediment control works to be installed prior to any surface disturbance; - detailed Water Management Plan (see below); - control of erosion through the stabilisation and revegetation of disturbed areas; - maintain downstream (Lake) water quality. Hazardous Waste and Chemical Management Plan - Key relevant components include: - detail on the appropriate transport, handling, disposal and recycling procedures for wastes generated at the Project area; - emergency response procedures; - compliance with relevant statutory considerations and Australian Standards; - regular maintenance of a hazardous substances and fuel and oil register; - personnel training procedures. Mining Rehabilitation and Environmental Management Process - Key relevant components include: - Mining Operations Plan (MOP) and Annual Environmental Management Report (AEMR); - all mining and rehabilitation operations; - relevant environmental controls and procedures necessary for compliance with lease conditions; - annual review of environmental site performance; - review of documentation by government agencies.
Final Void - Operational and post-closure safety; - Water management issues (isolation of the pit from Lake Cowal, long term hydrology, water quality); - Impacts on native fauna from use of the void.	- Fencing and bunding to control access and ensure safety will be undertaken; - Water management strategies; - The shallow surrounds of the void waterline would be rehabilitated in such a manner to enhance seasonal habitat opportunities for waterbirds.
Water Resources - Alteration of hydrology; - Increased turbidity; - Increased salinity; - Structural stability of the final mine landforms (ie. increased sedimentation); - Potential impacts associated with pit dewatering activities including: - drawdown effects associated with dewatering over the life of mine; - changes to the hydrogeological regime; - disposal of highly saline extracted groundwater.	Water Management Strategy - Key relevant components include: - maximising infiltration, minimising runoff and directing any seepage towards the open pit; - lake isolation system (lake protection bund); - silt curtain around temporary isolation bund; - final void to intercept runoff; - design elements incorporated to contain surface runoff and control seepage; - water supply pipeline to be buried when the Lake is dry. If Lake level is too high to allow burial, a temporary silt curtain will be erected during pipeline construction; - minimising disturbance areas; - containment of potentially contaminated water; - recycling of contained water; - progressive stabilisation and revegetation of disturbed areas; - monitoring of local and regional groundwater levels; - water extracted during pit dewatering would be pumped to temporary on-site storages, then used in the processing plant.

Table A-19 Summary of Potential Impacts of the Project on Subject Flora and Fauna Species and/or their Habitats and Associated Mitigation Measures

Potential Impacts of the Project	Mitigation Measures
Tailings Storages • overtopping and spillage of surface water; • rupture and spillage from either the tailings delivery or return water pipelines; • toxic cyanide levels in the storages; • potentially resulting in a reduction of species diversity and abundance through loss of habitat resources.	Integrated Erosion and Sediment Control Plan and Progressive Rehabilitation • proposed seepage control measures would include: – pre-stripping of soils beneath the embankment footprint; – construction of a moisture conditioned and compacted low permeability storage floor; – installation of an under-drainage and decant network; - and would provide a physical control barrier to prevent seepage from the tailings storage area. – geochemical properties would provide further control of potential impacts on water quality; • tailings storages to be designed not to be overtopped and to minimise the risk of incidental spillage; • bundled pipeline corridor; • automatic shut-down mechanism. • destruction of cyanide (CN) compounds to produce CN levels in the tailings storage areas of less than 20 mg/L for 90% of the time and less than 30 mg/L for the rest of the time; • monitoring plan focusing on potential microchiropteran bat activity over tailings storage areas will enable appropriate ameliorative measures (eg. jamming of echolocation signals using bursts of ultrasound) to be designed and implemented; • daily inspection (and if necessary appropriate response) of tailings storages for evidence of fauna being affected by tailings water; • fencing of tailings storages to exclude terrestrial fauna; • tailings storages batter rehabilitation to minimise potential habitat opportunities.
Air Quality • atmospheric dust emissions; • other air emissions including exhaust fumes, blasting fumes and evaporation emissions from the processing area. • potentially resulting in disruptions to essential behavioural patterns.	• construction and operational dust emissions would be in the range of acceptability for surface soils for birds and livestock (Hunt, 1997); • a range of air quality safeguards will be employed based on current control techniques as recommended for open pit mining in NSW by the EPA (eg. watering, vegetative screening).
Noise and Blasting • construction and operational noise emissions (including blasting); • sudden loud or impulsive noises are capable of causing birds to become startled and may affect feeding and possibly breeding habits in some bird spp; • continuous exposure to higher noise levels may cause some degree of behavioural changes in birds.	• research indicates that the behaviour of domestic and wild species was not significantly affected by impulsive acoustic stimuli such as an explosion or sonic boom; • the Project would meet the noise level design goals and blast emission criteria; • on-going bird surveys.
Mining Infrastructure • Artificial lighting – alteration of forage zones (primarily for insectivorous bird and bat species). • Electricity transmission line – bird strike associated with electricity transmission lines.	• based on a review of relevant literature reference sources, it is considered that no adverse impacts on fauna would result from lighting from the Project and hence, no specific mitigation measures would be required; • design of transmission line to include consideration of a number of ameliorative measures (eg. line alignment, pole height, conductor plane arrangement, route selection); • where appropriate and required, visual aids (eg. PVC balls, coloured vibration dampeners) would be used.
Human Interference • harassment of fauna; • fauna mortality associated with vehicle strike; • introduction of non-endemic species.	• access to the Project area to be restricted to authorised (inducted) personnel; • prohibition of domestic pets and firearms within the proposed MLA area.
Removal of Existing Vegetation • within the proposed MLA area, loss of approximately: – 35 ha of Eucalypt woodland; – 700 ha of predominantly cleared agricultural land with scattered Bimble Box woodland; – 20 ha of fringing River Red Gum woodland; – 100 ha of Lake bed; – 50 ha of mixed woodland; – 35 ha of Wilga woodland. • introduction of weed and noxious plant species; • potentially resulting in loss of biodiversity.	• revegetation of approximately 930 ha of land using local and endemic native tree, shrub and grass species; • rehabilitation programme aims to re-create greater areas of woodland than currently exists. • development of weed control programme and management plan, in consultation with appropriate advisory bodies (eg. Department of Agriculture, Bland Shire Council, Rural Lands Protection Board).
Removal of Existing Habitat • loss of habitat resources (ie. breeding, roosting, foraging, movement, harbour, etc.) associated with the following habitat types identified in the proposed MLA: – lakebed; – riparian zone; – cleared land with scattered woodland; – vegetated slopes.	• ultimate expansion of existing habitat opportunities as a result of revegetation programmes undertaken as a component of the rehabilitation works; • prior to disturbance, all potentially suitable habitat trees to be inspected for fauna (eg. roosting bats) with a relocation programme to be undertaken should fauna be detected; • provision of artificial roost and den sites for arboreal fauna and bats.

Table A-19 Summary of Potential Impacts of the Project on Subject Flora and Fauna Species and/or their Habitats and Associated Mitigation Measures Continued

Potential Impacts of the Project	Mitigation Measures
Removal of Existing Habitat Continued	
- potentially resulting in reduction of species diversity and abundance. - Alteration of aquatic biota species diversity and abundance as a consequence of: - changed hydrological conditions; - increased turbidity; - increased salinity.	- Project not to use any Lake water; - silt curtains to be used during construction periods; - burial of borefield water supply pipeline to be carried out when Lake is dry; - stabilisation and revegetation of the outer batters of lake isolation bund to be undertaken as soon as possible; - containment of surface runoff; - waste emplacement to incorporate need for maximising rainfall adsorption, minimising runoff and direction of seepage to the open pit.
A component common to the potential impacts above are the rehabilitation concepts for the Project	
- Key relevant concepts include: - adoption of land clearance protocols; - soil/waste stripping to be progressive and in accordance with pre-determined guidelines for topsoil and subsoil handling, storage and management; - operational erosion and sediment control (and hence the protection of Lake water quality); - establishment of permanent up-catchment and internal water management systems; - final landforms to be progressively constructed and layered; - revegetating landforms with selected communities of endemic vegetation; - expansion of habitat opportunities for wetland and terrestrial fauna species; - design of landforms and selection of revegetation species in accordance with accepted principles of long-term sustainability; - exclusion of grazing while vegetation is established; - establishment and maintenance of seed and plant stock; - maintenance and monitoring of success of rehabilitation programme; - rehabilitation concepts have been determined for the following Project landforms.	
New Lake Foreshore	
- Rehabilitation objectives include: - creation of a freshwater ecological community (flood zone, littoral zone, rush zone and permanent water zone).	
Mine Waste Emplacements	
- Rehabilitation objectives include: - re-establish endemic remnant woodland, shrub and grassland communities that characterise the wider region; - revegetation plan to recognise associations that naturally occur across the continuum of slope and elevation.	
Final Void	
leave the void surrounds safe and revegetated.	
Tailings Storages	
- Rehabilitation objectives include: - establishment of permanently stable landforms; - stabilisation of batters during operations so that minimal habitat resources are provided; - post operations, establishment of vegetative communities which are local and endemic and enhance remnant habitat extension opportunities; - exclude widespread grazing and primary production.	
Infrastructure Areas	
- Rehabilitation objectives include: - dismantling of infrastructure and removal from site; - infrastructure areas tested for contamination from fuels and lubricants and any contaminated soils removed for proper disposal; - revegetated with local endemic seed and tubestock.	

Further to the mitigation measures noted above, monitoring of waterbirds and breeding activity would be continued. Additional monitoring associated with rehabilitation is detailed in Section 7 of this report.

7.0 REHABILITATION

This section summarises proposals for the progressive rehabilitation concepts for the cessation of mining and on-site processing as detailed in Section 5 of the EIS.

The rehabilitation proposals presented herein are preferred concepts only. Refinement of the programme would be undertaken in consultation with key government agencies and other stakeholders. Accordingly, the rehabilitation plan must maintain a degree of flexibility to take into account future consultations, research and design.

7.1 Rehabilitation Philosophy and Objectives

The rehabilitation philosophy for the Project has been formulated in consideration of the following factors:

- the location of the Project within an area acknowledged for its conservation status as an inland wetland ecosystem; and
- the need to operate and rehabilitate the proposed mine in such a way that the conservation status of the Lake and its critical conservation values are preserved.

The rehabilitation philosophy for the Project then, is as follows:

"To operate as a non-intrusive land user and to create stable rehabilitated landforms that increase the areas of endemic vegetation in the Project area and the status of terrestrial-aquatic habitats."

This philosophy has lead to the following rehabilitation objectives:

- (i) The design and implementation of rehabilitation works at the new Lake foreshore in a manner consistent with the NSW State Wetlands Management Policy (DLWC, 1996a);
- (ii) Ensuring that the water quality of Lake Cowal is not detrimentally affected by the new landforms;
- (iii) Revegetating the new landforms with selected communities of endemic vegetation that are both suitable to the physiographic and hydrological features of each landform and which expand on the areas of remnant endemic vegetation that currently exist in the immediate region;
- (iv) Run-of-mine placement of subsoils and topsoils on final landforms to enable the progressive establishment of the selected vegetation. This requires that the covers be of sufficient depth and properties to absorb and store all but the most extreme rainfall;
- (v) The expansion of habitat opportunities for wetland and terrestrial fauna species;
- (vi) The design of landforms and selection of revegetation species in accordance with accepted principles of long term sustainability (eg. genotypic variation, vegetation dynamics and water/drought/frost tolerances); and
- (vii) Exclusion of grazing while resilient and persistent vegetation (in self-sustaining ecosystems) are established with decisions on managed grazing to be made after this time.

A number of key, specialist studies have contributed to the rehabilitation objectives, including:

- soil and waste geochemical investigations (Appendices B and C of the EIS);
- vegetation surveys and vegetation association mapping (Appendix A of the EIS);
- regional remnant vegetation studies such as those conducted by Sivertsen and Metcalfe (1995); and
- the findings of the long-term compatibility studies, notably the ecological compatibility and final void studies (Appendix N of the EIS).

7.1.1 Land Clearance

Section 6.15 details the proposed clearance at the Project site, which is approximately 940 ha.

Although progressive, the majority of surface disturbance would occur in the construction phase and first three years of mining operations.

Land clearance protocols to be adopted for the Project would be as follows:

- (i) Completion of all pre-mining commitments (eg. salvage of Aboriginal artefacts in pit area or approval of soil conservation and erosion control plans).

- (ii) Potentially suitable habitat trees within the proposed disturbance area to be checked by suitably qualified personnel for presence of fauna (eg. roosting bats) with a relocation programme to be undertaken in the event that they occur.
- (iii) Land clearance and soil/waste stripping (for rehabilitation and construction purposes) to be progressive and in accordance with appropriate pre-determined guidelines for topsoil and subsoil handling, storage and management.

7.1.2 Soil and Waste Handling

The soils and waste materials (weathered rock, oxide and primary rock) to be excavated by Project activities have been assessed for their geochemical properties and suitability for rehabilitation purposes (Appendices B – Soils and C – Waste Geochemistry of the EIS).

Topsoil would be stripped, stored and/or progressively replaced as the final surface material on new landforms. Low-salinity subsoil would be stockpiled for replacement on final landforms as "subsoil" or a plant-rooting and moisture retention medium.

Gypsum-treated subsoil would be selectively used as (covered) construction fill or be stockpiled and subsequently reused on final landforms as deep cover on the tailings storages and waste rock emplacements. The amelioration of dispersive (sodic) properties during stockpiling (and in the comparatively short duration of exposure on final landforms prior to being covered with low salinity subsoil and topsoil) would be effected by the addition of gypsum, in accordance with existing agronomic practices.

The majority of the oxide waste rock material mined from the pit would be placed in the waste rock emplacements or used as select (covered) fill for construction works.

The primary waste rock from the pit would be placed in the waste rock emplacements, to be deep covered by oxide waste followed by subsoil covers and topsoil, prior to revegetation.

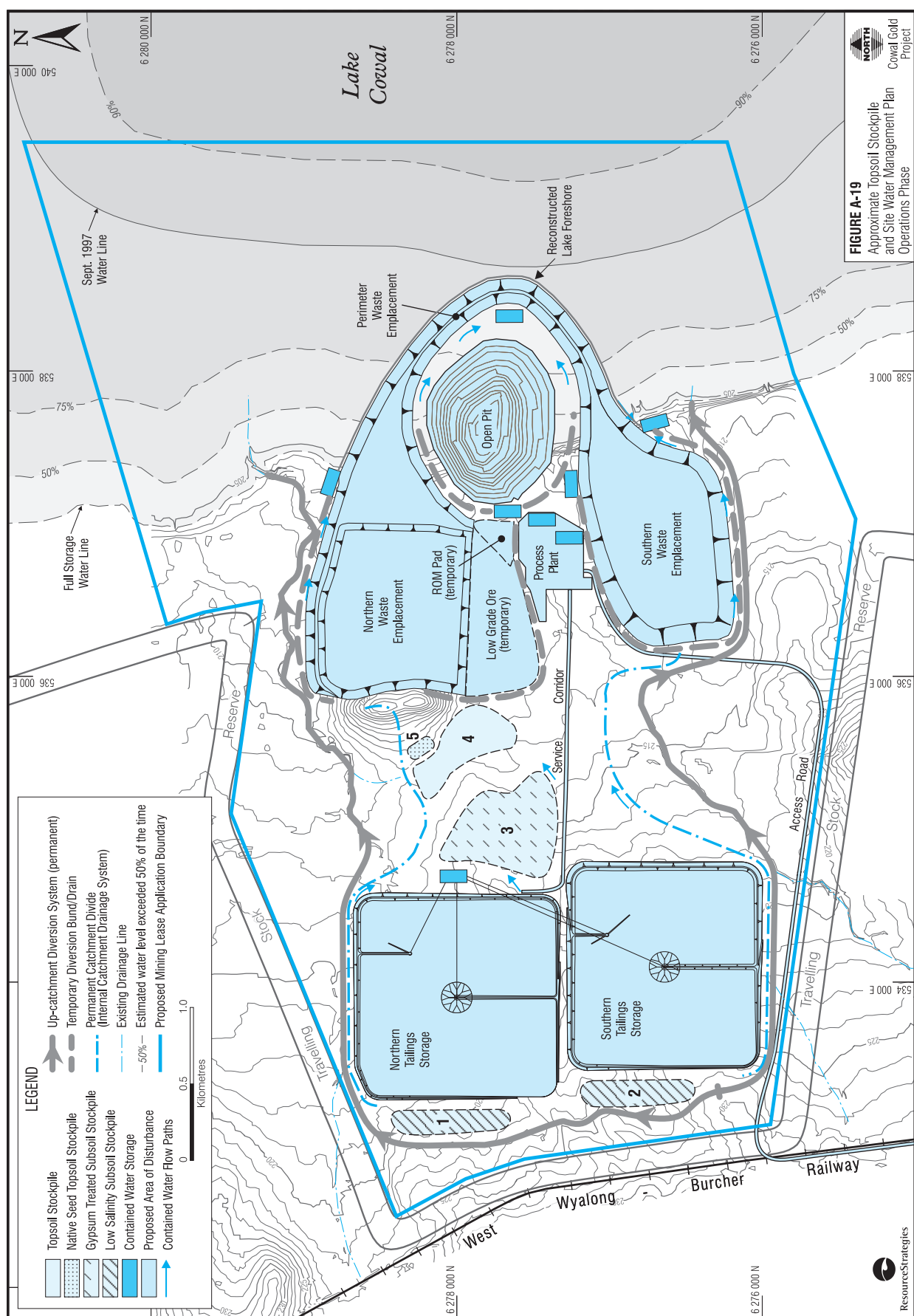
Figure A-19 presents the approximate location of the topsoil and subsoil stockpiles.

7.1.3 Erosion and Sediment Control Rehabilitation Works

Operational erosion and sediment control (ie. while the mine landforms are being constructed and rehabilitated) is detailed in Appendix F and Section 2.9 of the EIS. Summarised details as they relate to landform rehabilitation are presented below.

The guiding principle of erosion and sediment control is the protection of Lake water quality. This is to be achieved by the establishment of permanent Up-catchment and Internal water management systems (Figure A-19).

The Internal Containment System (ICS) effectively and permanently isolates the Lake from mine site runoff, with the exception of the eastern perimeter of the waste



emplacement (comprising the temporary isolation bund, the lake protection bund and a portion of the perimeter waste emplacement).

The ICS enables runoff from the great majority of Project landforms to be contained on-site for use by the Project. The system is to be created by the construction of a stabilised drain around the tailings storages (in the west) draining eastwards to link with existing natural drainage lines to the Lake. Water entering these drains is Up-catchment water and can be classified as of "undisturbed" origin. Runoff from areas inside the drains is "internal" and forms the Internal Containment System.

Early stabilisation of the permanent catchment divide is a priority and would be conducted in the first three months of construction. Stabilisation methods are detailed in Section 5 of the EIS.

Runoff control and rehabilitation works on the eastern perimeter of the waste emplacement would require detailed protocols and management systems to allow only runoff of water of a quality equivalent to surrounding non-mine areas to the Lake. This would be achieved by the following construction activities:

- construction of a temporary isolation bund and new Lake foreshore; and
- top surface and batter erosion and sediment control.

The above features are detailed in Section 5 of the EIS.

7.1.4 Final Landform Concept Development

- Final mining landforms are to be designed (where possible) to be compatible with regional landscape features. The landforms are to be progressively constructed and layered as a run-of-mine operation wherever possible and left with untrimmed surface roughness to lower runoff coefficients and promote water absorption and storage.
- Revegetation of the final landforms would be with local native vegetation communities, selected specifically for their suitability to the created elevation, substrate conditions and the overriding objective of re-establishing local native vegetation on the Project area.

7.2 Final Landform and Revegetation Concepts

This section presents the rehabilitation concepts for the various Project landforms, coupled with the revegetation enhancement opportunities that arise from interactive planning of the landforms.

7.2.1 New Lake Foreshore

The new Lake foreshore comprises the following landforms:

- temporary isolation bund;
- lake protection bund and lower batter of the perimeter waste emplacement; and
- the intervening section of lakebed between the temporary isolation bund and the lake protection bund.

Concept

Planning a rehabilitation strategy for a particular environment, habitat and/or ecological community such as a lake foreshore, requires identification and consideration of those key factors that contribute to the inherent value of that system and the assemblage of species it is likely to attract.

The Species and their Habitat

In Australia there are 19 species of waterfowl, each with specific habitat requirements based on their biological characteristics (after Braithwaite, 1978, 1975). Each species may also use different habitats, often in an annual cycle, according to requirements for movements, foraging, breeding and moulting. For example, grazing waterfowl (eg. Magpie Goose, Wood Duck) may use wetlands mainly as a focal point of refuge for daily dispersal and grazing in surrounding grasslands (*ibid.*)

The Nature of Waterfowl Habitat

In essence, rainfall patterns and flooding are the basis for the provision of nearly all waterfowl habitats (Braithwaite, 1975).

Within each of the different habitats is a dynamic system with specific and usually temporary qualities that are the basis of the requirements of waterfowl (*ibid.*). In order to capture these qualities, water level fluctuations, vegetation growth and ecosystem change is the key to successful habitat creation.

Several regional surveys of waterfowl habitat have been undertaken in Australia (Riggert, 1966; Lavery, 1966; Goodrick, 1970; Vestjens, 1977; Lawler, 1989, Maher & Braithwaite, 1992). These surveys have indicated that certain types of habitat have been recognised as particularly important for waterfowl. For most species, breeding occurs in seasonal or temporary to semi-permanent freshwater habitats while permanent and saline habitats provide important refuge, feeding and moulting areas (Braithwaite, 1975).

The importance of certain habitat types appears to typically lie in their ability to provide an abundance of waterfowl food resources. As waterfowl species tend to specialise in a range of food types, species utilisation of habitat types varies accordingly (Frith *et al.*, 1969; Braithwaite & Norman, 1974, 1975). In general there are three main ecological communities used by waterfowl: grassland, freshwater systems and saline systems (Braithwaite, 1975).

Freshwater Ecological Community

With respect to the new Lake foreshore the creation of a freshwater ecological community is an aim of the rehabilitation programme.

Freshwater communities as waterfowl habitat, are composed of four types of zones (Braithwaite, 1975):

- flood zone;
- littoral zone;
- rush zone; and
- permanent water zone.

These zones would be adopted as the basis for the revegetation strategy for the new Lake foreshore with particular emphasis on the flood, littoral and rush zones (use of water zone concepts would be limited due to the fluctuating nature of the lake levels). When selecting revegetation species, the Lake's hydrological regime (wetting and drying cycles) as well as species performance during revegetation trials would be considered.

Water depth, permanence and regularity of inundation determine which of the freshwater communities would occur in a given situation (Figure A-18). Reference to Figure A-20 (and for detail, Appendix F of the EIS) shows that the Lake level fluctuates over a considerable lateral extent (due to its flat bed). Consequently it would be expected that a wide variety of aquatic floral communities would establish in the absence of significant competition for Lake landuses (eg. grazing, cropping).

Flood Zone

This community is the most temporary of the freshwater habitats for waterfowl. A flood provides an immediate food source for a number of species (eg. Grey Teal) in the form of waterborne seed and insects (Frith, 1959). With the stabilisation and subsequent recession of floodwaters, the nutrient supplies in the shallow water support vigorous breeding of aquatic invertebrates and plankton. Ducklings of the Grey Teal are known to forage heavily on these aquatic insects as is the adult Pink-eared Duck, which also utilises the plankton (*ibid.*).

Littoral Zone

Littoral communities are characteristic of temporary or seasonal swamps, where there is an absence of water turbulence.

Ecological succession is the key to formation of littoral communities and their utilisation by waterfowl (Braithwaite, 1975). The drying out of the floor of the littoral zone is essential. The bottom is consolidated for optimum germination of aquatic plants and nutrients are released from oxidation of organic matter on exposure to air. Inundation causes an effect not dissimilar to a flood, the differences being water level fluctuations are usually less rapid, the inundation occurs over a longer period, there is less turbulence from water currents and the water has time to clear as suspended solids settle. With an adequate nutrient supply these factors are conducive to the growth of a characteristically vigorous plant community (families Characeae, Nymphaeaceae, Alismataceae, Gramineae, Haloragaceae) and an accompanying invertebrate fauna. Water snails (*Physastra*) and caddis fly (*Trichoptera*) larvae for example, can proliferate in this community type (Braithwaite & Frith, 1969).

Rush Zone

In Australia two genera of rushes predominate: Cumbungi (*Typha*) and Rush (*Eleocharis*). Both are important food plants, particularly in times of drought. The seeds of both genera are important to many waterfowl and in the south, the new shoots and leaf bases of *Typha* are a major food of Black Swans (Frith, Braithwaite and McKean, 1969).

Water Zone

A wide variety of aquatic plants (mainly of the families Potamogetonaceae, Hydrocharitaceae, Ceratophyllaceae and Haloragaceae) occur in water that is too deep for the establishment of rushes. The main requirements for their establishment appear to be water clarity, absence of turbulence and a reasonably firm substrate (Frey, 1966). Minor areas of this zone may occur about the new foreshore, particularly after consecutive wetter seasons.

Grazing waterfowl utilise the foliage of many of these plant genera. Other waterfowl utilise the seed or abundant invertebrates found in the foliage. In the absence of ancillary communities such as those that occur in the littoral zone, it is the species composition, health and vigour of the plants in permanent water that is the key determinant of the productivity of a permanent wetland (Braithwaite, 1975).

With respect to the short section of lakebed between the (rehabilitated) isolation bund and the perimeter bund, similar principles would apply whereby specific planting of zonal plant communities is proposed (Figure A-18). The design and layout of the new Lake foreshore is to reflect the aim of ecological enhancement. Consequently, the new Lake foreshore would be constructed and profiled with points and embayments at the Lake/land ecotone (approximately RL 205.65 m).

Revegetation proposals for this component of the new Lake foreshore have considered the micro-variations in slope, elevation and hydrology of the area (Figure A-21). The overriding objective is to attempt to re-establish similar plant communities to those which would have occurred in these habitats prior to significant clearing and intensive landuse. A range of vegetative concepts are proposed, from Eucalypt woodland on the foreshore batters (banks), to Lignum/Canegrass and a variety of aquatic plant assemblages in the littoral zone. The opportunity to trial the establishment of regionally endangered species (such as Austral Pillwort) in this zone is proposed. The suppliers of revegetation species are expected to be local contractors or specialist nurseries and, if opportunities arise, from landuse activities elsewhere around the Lake translocating species or their seed banks to the Project area.

7.2.2 Mine Waste Emplacements

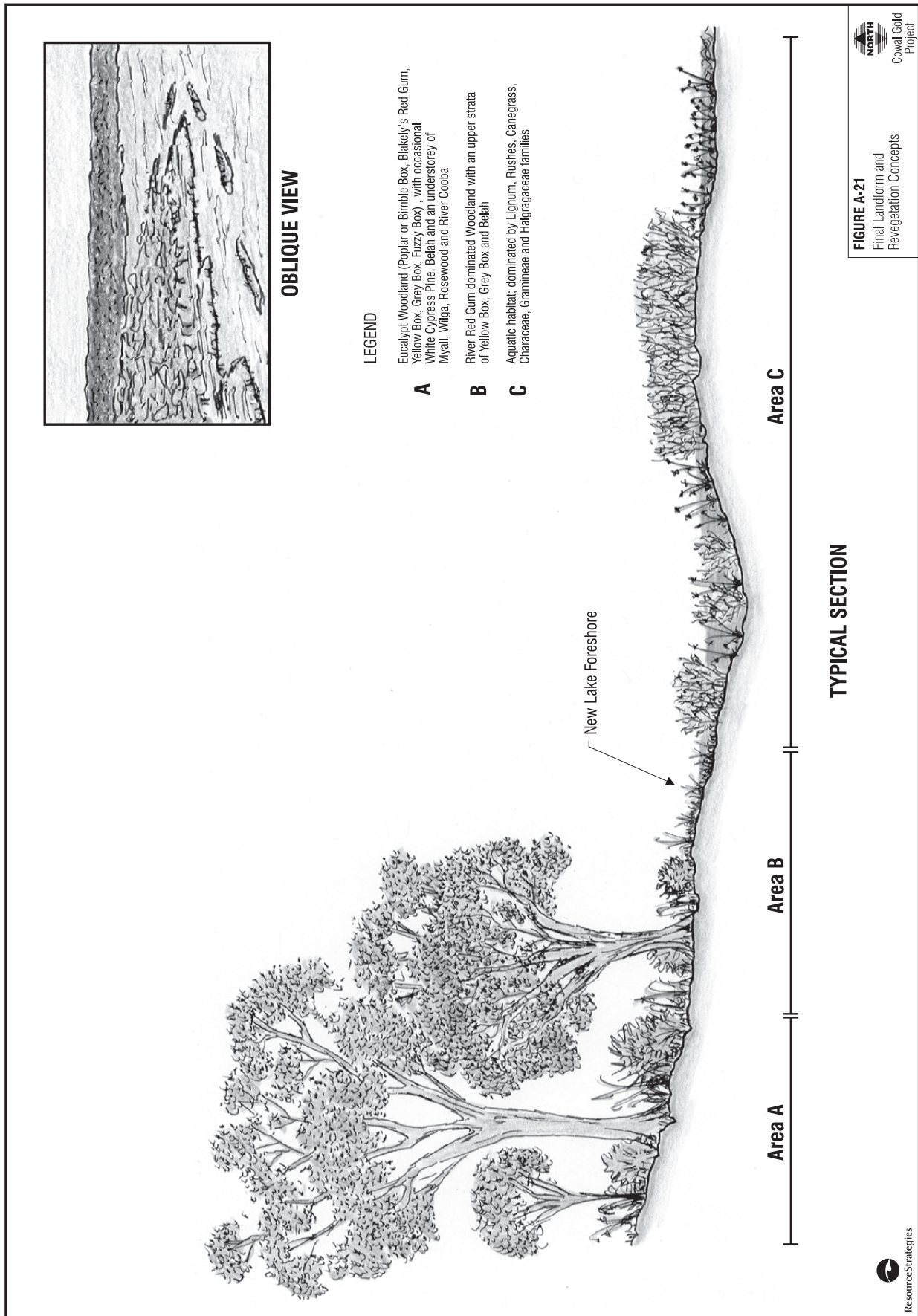
Revegetation of Waste Emplacements

The revegetation proposals for waste emplacements aims to re-establish the endemic, remnant woodland, shrub and grassland communities that characterise the wider region (after Sivertsen and Metcalfe, 1995).

Figure A-17 presents a conceptual view of the relationships between topography, elevation and vegetative association on the new Project landforms.

The revegetation plan would endeavour to re-establish native endemic woodland and understorey and recognises the alliances that may naturally occur across the continuum of slope and elevation. These alliances are described as follows.





Watercourse – Riverine Floodplain

River Red Gum (*Eucalyptus camaldulensis*) Woodland

This community type typically occurs on riverine floodplains in deep, heavy, grey alluvial soils where it often forms a monoculture woodland community (Bower & Semple, 1993).

Transitional or ecotone associations with this community include:

- *E. melliodora* (Yellow Box);
- *E. microcarpa* (Grey Box);
- *Casuarina cristata* (Belah).

E. camaldulensis dominates the upper strata of this community type and understorey species include *Chloris truncata* (Windmill Grass), *Alectryon oleifolius* (Rosewood), *Muehlenbeckia florulenta* (Lignum), *Baumea juncea* and *Sida intricata*.

Flat to Gently Undulating Slopes

Eucalypt (*Eucalyptus populnea*, *E. blakelyi*, *E. melliodora*, *E. microcarpa*, *E. conica*) Woodland (Alliance No. 1)

This alliance (and variations thereof) is predominant on the agricultural lands of the western slopes, plateau country and granite basin. It is typically found on undulating, well-drained land (Bower & Semple, 1993).

Transitional or ecotone associations with this alliance include:

- *E. melliodora* (Yellow Box);
- *Callitris glaucophylla* (White Cypress Pine);
- *Casuarina cristata* (Belah).

The upper stratum of this community is dominated by *Eucalyptus* spp with occasional *Callitris glaucophylla* (White Cypress Pine) and *Casuarina cristata* (Belah). A variety of large shrubs or small trees occur in the mid-storey including *Acacia pendula* (Myall), *A. stenophylla* (River Cooba), *Geijera parviflora* (Wilga) and *Alectryon oleifolius* (Rosewood).

Low Ridges and Hills

Eucalypt (*E. dealbata*, *E. sideroxylon*) Woodland (Alliance No. 2)

This alliance occurs mainly on the slopes of dry hills on skeletal well-drained soils, extending to the tops of rocky ridges where it associates with *Callitris endlicheri* (Black Cypress Pine) and *Acacia doratoxylon* (Lancewood) (Bower, 1997; Bower & Semple, 1993).

Typically occurring as tall woodland, community structure is characterised by a sclerophyll mid-understorey and a savannah understorey. Other major overstorey species include *E. macrorhyncha* (Red Stringy Bark), *E. melliodora* (Yellow Box) and *E. blakelyi* (Blakely's Red Gum). Understorey species include *Brachyloma daphnoides* (Daphne Heath), *Bursaria spinosa* (Sweet Bursaria), *Chloris truncata* (Windmill Grass) and *Bothriochloa macra* (Redleg Grass).

Hill Tops and Elevated Land

Eucalypt (*E. dealbata*, *E. sideroxylon*, *E. macrorhyncha*, *E. goniocalyx*, *E. polyanthemus*) Woodland (Alliance No. 3)

This alliance dominates dry hilltops on poorer, skeletal soils typical of the rocky (primarily uncleared), elevated areas in the region.

Other overstorey species in this woodland alliance include *E. blakelyi* (Blakely's Red Gum) and *E. melliodora* (Yellow Box). Understorey species composition is similar to that found on the low ridges and hills.

7.2.3 Final Void

Characteristics

At the completion of mining, the final void would comprise a landform that is some 1,000 m long, 850 m wide and 325 m deep. Set back from the void on three sides would be the revegetated slopes of the waste emplacements, gradually rising some 15 m above the surrounds of the void (to RL 223 m). The volume of the void would be about 80,000 ML.

A detailed report on void hydrology and filling is presented in Appendix F (Water Management) of the EIS. Appendix N (Compatibility) of the EIS also presents the results of the long term compatibility study, including void limnology and water quality.

Groundwater inflows, rainfall, and site runoff are expected to gradually increase the level of water in the void over a period of about 100 years. After this period, the void water level would reach equilibrium at a level approximately (± 1 to 2 m) 25 m below the pit rim (or 22-24 m below the Lake full storage water level. The void water would not spill and is hydrogeologically isolated from and lower than the Lake water (Appendix N of the EIS).

Void Water Quality and Stratigraphy

Geochemical studies (Appendix C of the EIS) have concluded that the void water quality would not be acidic due to the characteristics of the wall rocks, and would be dominated by the overriding influence of saline groundwater to the void. Under the expected near neutral prevailing pH conditions in the void, the solubility of any metals would remain low. Furthermore, oxidation of any wall rock sulphide minerals effectively ceases as the rocks are progressively covered by water. The void stratigraphy and water quality study (Appendix N of the EIS) indicates the following:

- During the filling stage the void would exhibit a steady progression toward seasonal stratification. After filling, the long-term scenario would include a trend in deep water toward hyper-salinity. In the surface mixed layer there would be a mid-year (approximately June – August) seasonal increase in salinity from that approximating sea-water to level approaching twice that of sea-water. During the summer months the concentration of salinity in this layer would return to about sea-water levels (Tropical Water Solutions, 1997).
- Due to the length of this filling time (>100 years) some of the biological and chemical features of the void would be well advanced prior to complete filling. Nonetheless the void would continue to evolve after it has filled, with changes in its biological and chemical characteristics. These would in turn have a significant influence on its seasonal physical behaviour.

- With respect to biological status and salinity, Australia contains a number of species tolerant of high salinity waters, with fauna displaying many adaptations to cope with salinity-associated stress. These are particularly prevalent in the Lake Eyre basin and other Australian inland lakes. In highly saline lakes (approximately twice that of sea-water) macrophytes are absent and phytoplankton is dominated by species of *Dunaliella*. In less saline waters other algal species may be present and some cyanobacterial species. Additionally Australia's naturally occurring salt lakes provide breeding areas for several bird groups including stilts and avocets and refuge areas for ducks, swans, gulls and terns. (Refer to Section 6.6 for further information on the potential impacts and mitigative measures relating to final void salinity).

A preliminary assessment indicates that eutrophication and blue-green algal blooms in the void are not predicted given the lack of nitrogen and phosphorus sources, lack of catchment input nutrient sources, and lack of organic matter.

With respect to metals, their solubility is expected to remain low and at levels that do not pose any threat to water quality (EGi, 1997).

Void Rehabilitation Concepts

Objectives

The objectives of void rehabilitation are:

- (i) to leave the void surrounds safe (for humans and stray stock) and revegetated in a manner consistent with the overall Project rehabilitation philosophy and objectives; and
- (ii) where feasible, create habitat opportunities for waterbirds at the approximate level at which void water would reach equilibrium.

Concepts

The top batter of the void, which would extend almost to the expected final equilibrium water level, would be left at the constructed angle (approximately 1:2). The first berm (at approximately RL 185 m) would be planted with understorey of the River Red Gum woodland alliance (Windmill grass, Rosewood) and the batter and berm surfaces left in a roughened state to encourage succession and to provide micro-habitat. In the longer term, there may be opportunities to develop habitat for waterfowl and other species on the seasonally inundated berm.

These concepts, which serve to maximise the limited opportunities for batter habitat re-establishment that would occur over a long period of time are shown in Figure A-22.

7.2.4 Tailings Storages

Rehabilitation Objectives

Tailings storages rehabilitation objectives are:

- (i) to establish permanently stable landforms;
- (ii) during operations, to stabilise batters so that they provide minimal habitat value for bird life (ie. pasture cover);
- (iii) post-operations, to establish vegetative communities which are endemic to the region and which enhance remnant habitat extension opportunities;

- (iv) to exclude widespread grazing and primary production.

Rehabilitation of the storage batters can be progressive as the storages are lifted by upstream methods. Rehabilitation of the storage surfaces can only be undertaken at the completion of milling (Year 12 onwards).

Surface Rehabilitation Zone

The cover system selected for the tailings storages is similar in intent and design to the waste emplacement in that it is designed to:

- (i) absorb the rainfall that falls on the surface; and
- (ii) support a woodland ecosystem.

Rehabilitation Concepts

During operational years, the batters would be revegetated using native grasses. Post-mining revegetation using the communities detailed in Figure A-17 and Section 7.2.2, planted as tubestock and seed would be undertaken.

Revegetation communities on tailings storages top surfaces would include the following:

- In the central, occasionally wet area, species selected from the Riverine Woodland alliance, comprising River Red Gum (*E. camaldulensis*) and understorey species from the freshwater communities such as *Typha domingensis* (Cumbungi) and Rush (*Eleocharis* sp.).
- On the remainder of the covered storage surface, species representative of the low ridges alliance depicted in Figure A-17 (representing those species that occur on low ridges to elevations of around RL 225 m).

Figures A-23, A-24 and A-25 depict the progressive rehabilitation concepts for the Project area, including the tailings storages, waste emplacements and void for Year 1, Year 8 and end of life, respectively.

Figure A-20 presents a conceptual aerial view of the Project area following the exclusion of primary production (grazing and cropping) and following the establishment of vegetation communities.

7.2.5 Infrastructure Areas

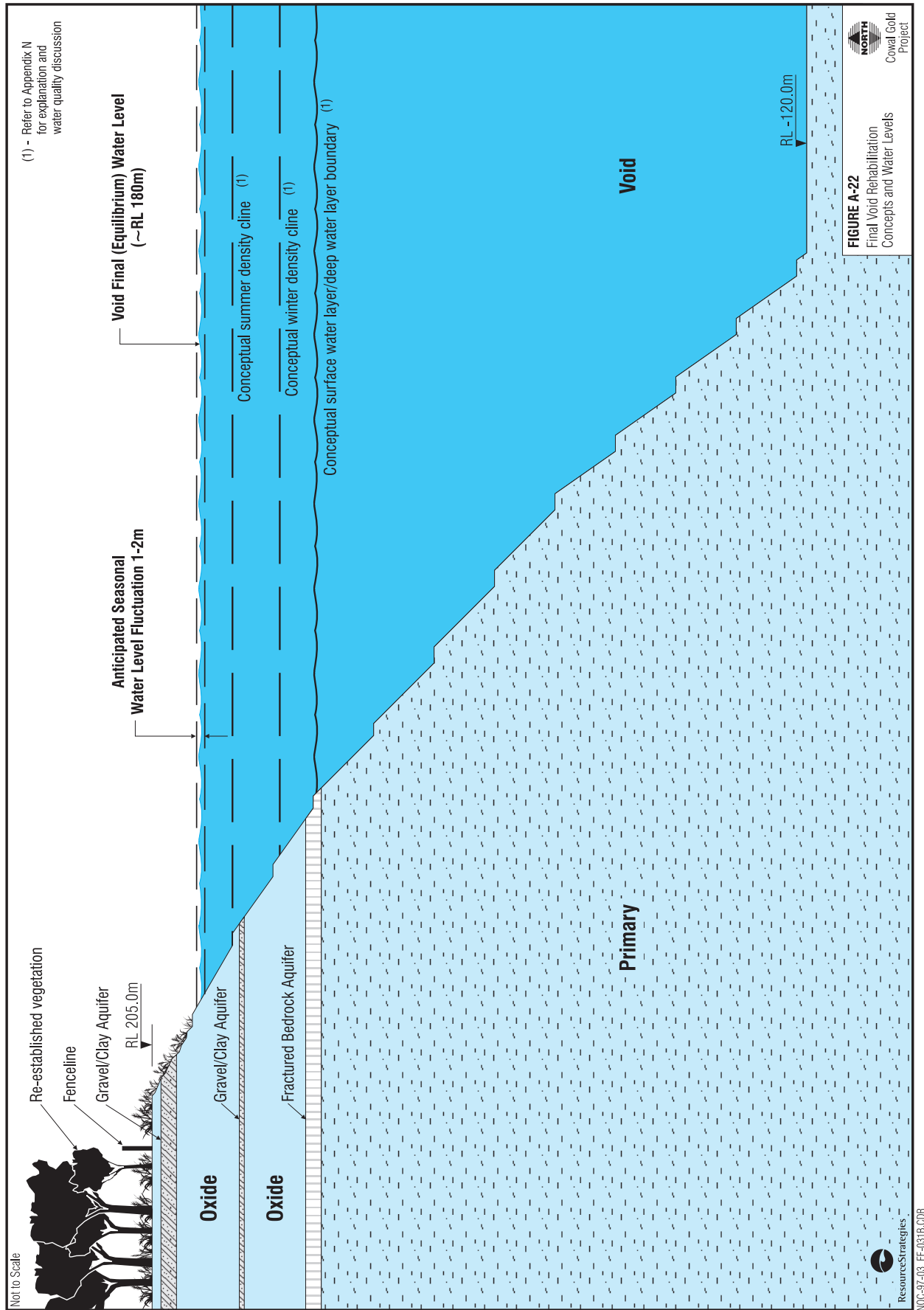
Infrastructure areas include the processing mill, administration areas, workshops, ancillary roads and explosives storage areas.

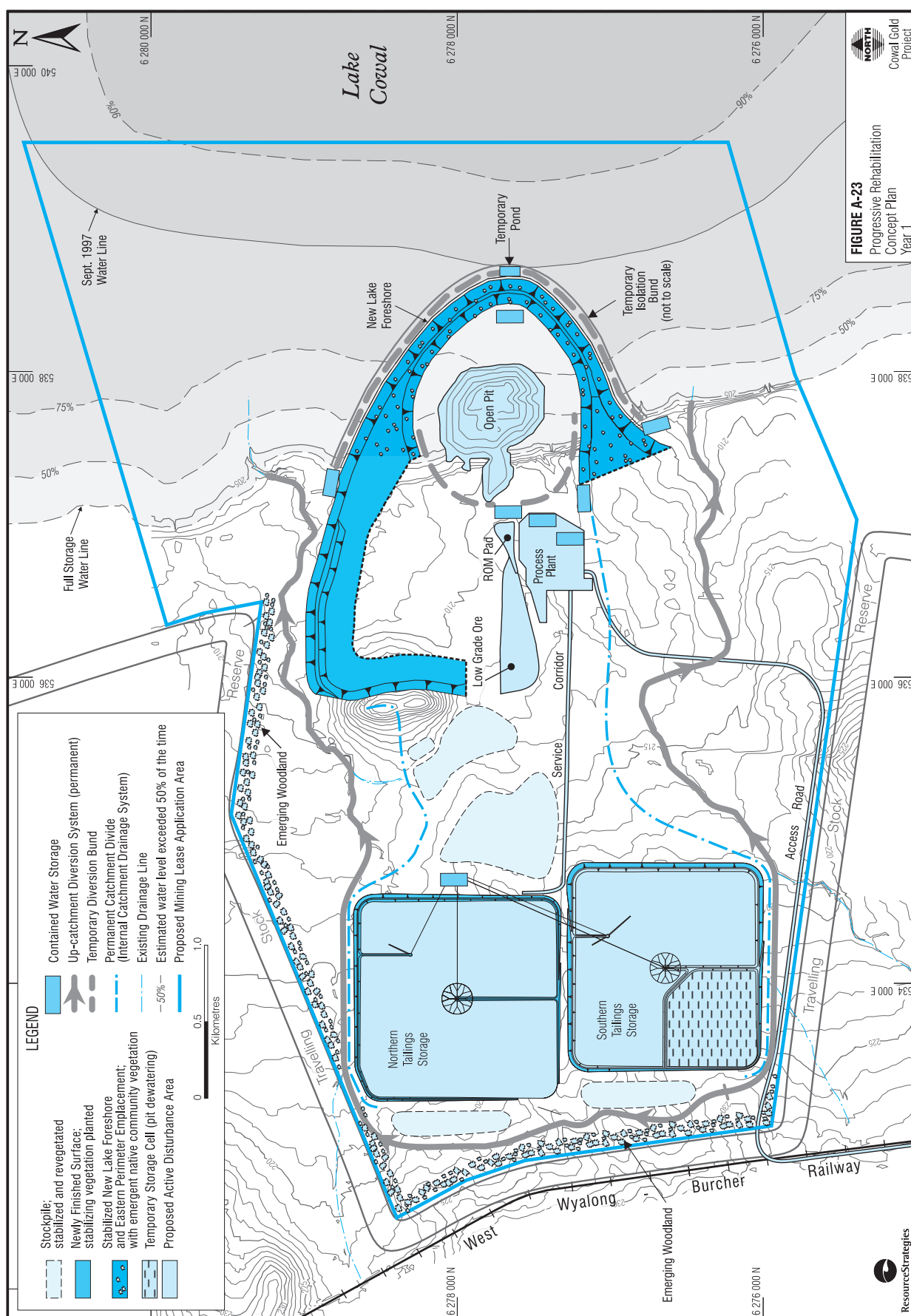
At the completion of mining (end Year 8) the mine fleet would be demobilised from site and the mill, administration buildings and contractors workshop would be dismantled and removed from the Project site.

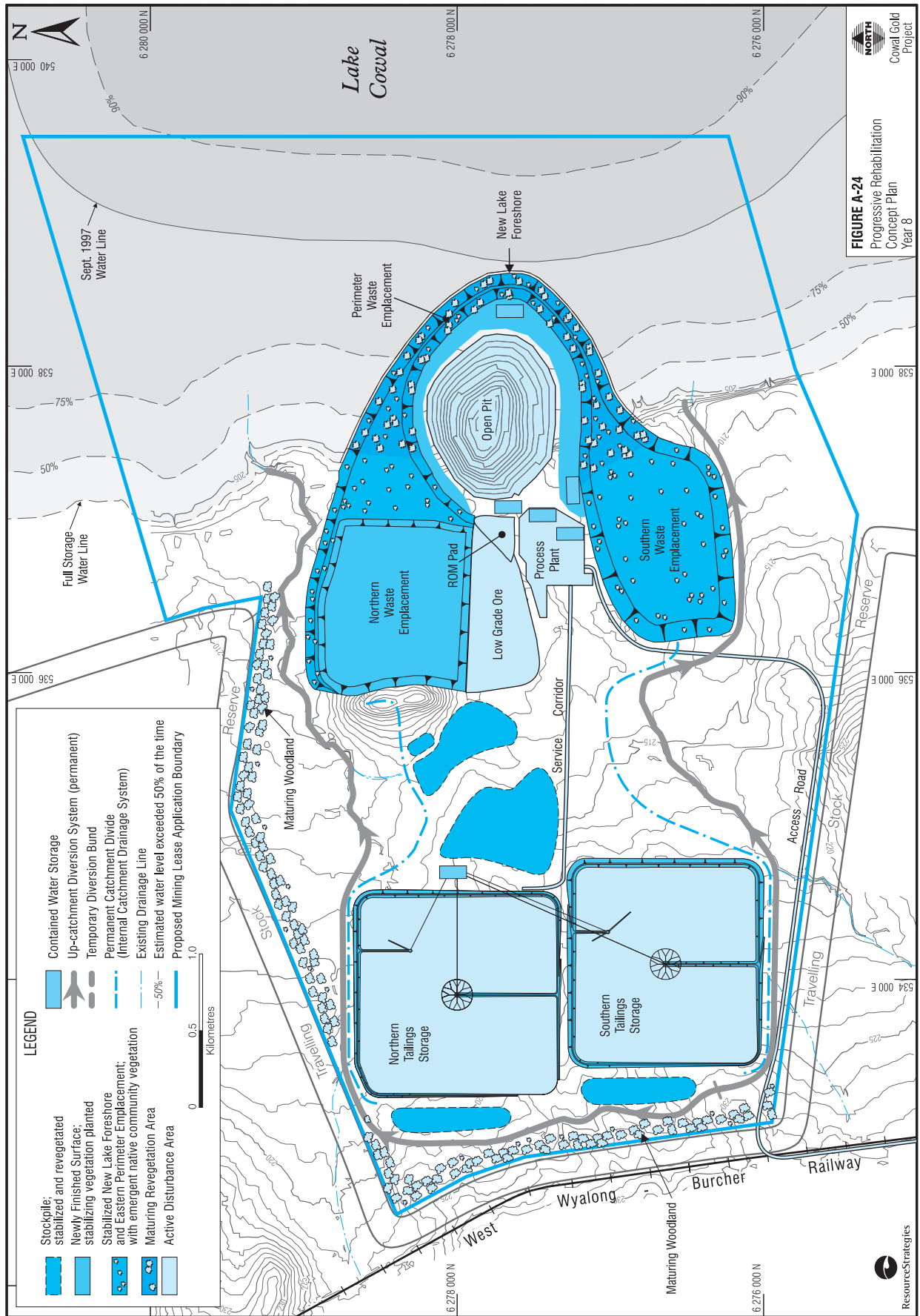
The infrastructure footprint area would be tested for contamination from fuels and lubricants and any contaminated soils removed for proper disposal in accordance with EPA requirements. The area would then be contour ripped, topsoiled and revegetated with endemic seed and tubestock.

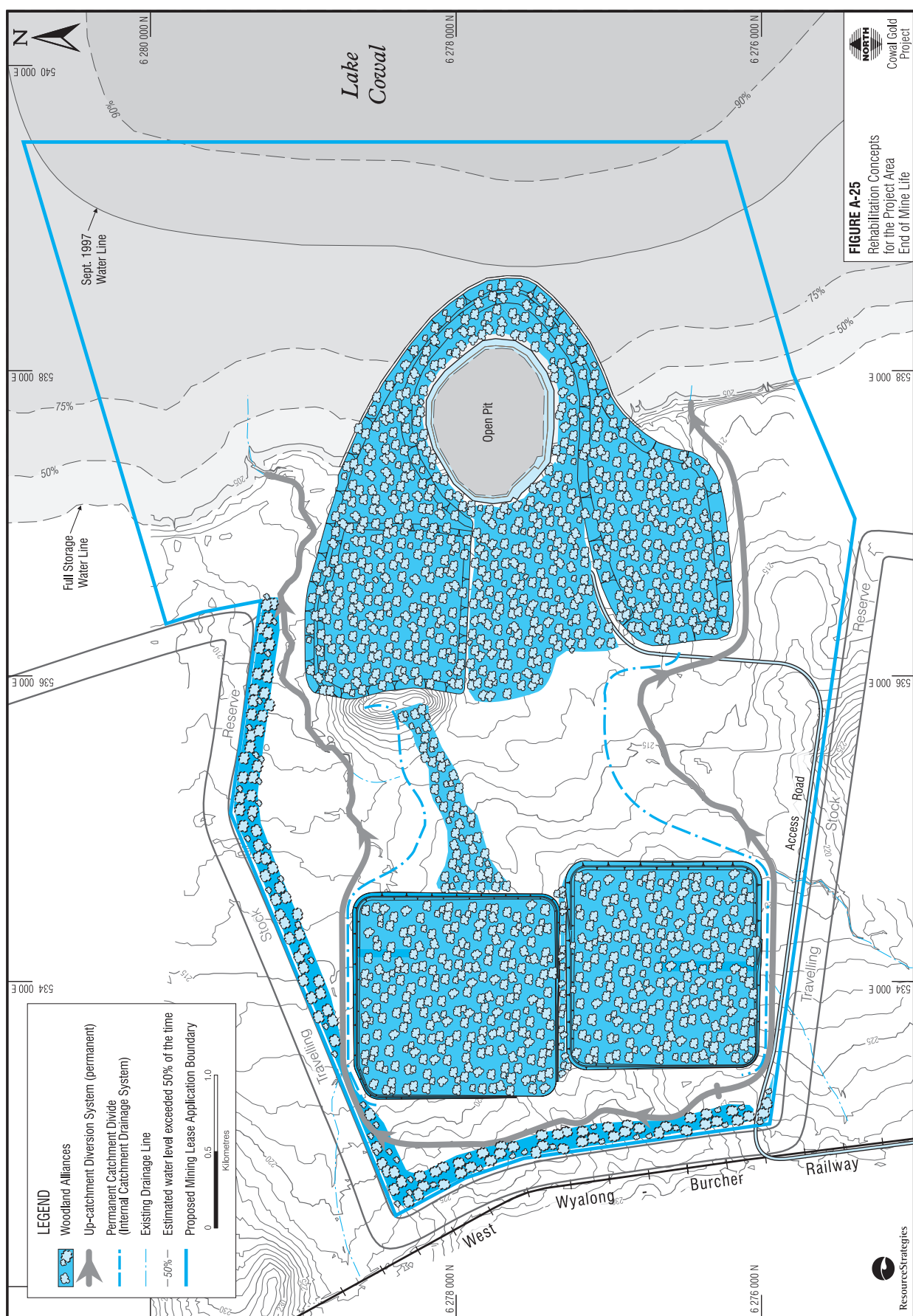
The bores and associated pump stations may be transferred to regional landholders or alternatively, dismantled and the bores plugged and capped.

The water supply pipeline would either be raised and dismantled for recycling or kept in place for local use if









required. If dismantled, the section of pipeline in the bed of Lake Cowal would be raised when the Lake is dry. If this is not possible due to successive high rainfall seasons, any decision to remove the pipeline under strict environmental management procedures would be discussed with the authorities. Given the maintenance period for Cowal Project rehabilitation it is likely, however, that the Lake would be sufficiently dry at some stage in this period.

All open drillholes would be backfilled and tracks revegetated in accordance with the procedures adopted for waste emplacements and site roads.

7.3 Seed and Plant Stock

The access to a large reserve and wide variety of local and endemic seed stock is fundamental to the success of the rehabilitation programme.

It is proposed that regional seed collecting programmes (perhaps involving local community groups, Landcare Groups, as well as contracted professional teams) would commence in the construction phase, to allow sufficient time to initiate rehabilitation of the new Lake foreshore at the completion of foreshore reconstruction activities.

North have previously engaged professional local landowners to germinate and maintain tree and shrub stock and may elect to continue this practice. Alternatively, a professional nursery or a site-based nursery (or regionally based Landcare facility) may be established, particularly focussing on the freshwater community plants and woodland understorey species required for revegetation works.

Recently developed seed treatment technology, particularly with woodland eucalypt species would also be undertaken (eg. smoking, scouring) to enhance germination rates and establishment success.

7.4 Maintenance and Monitoring

It is proposed that by the second annual MREMP meeting, a detailed Rehabilitation Procedures and Maintenance Plan (RPMP) would be prepared and authorised by stakeholders. This document is pivotal to the success of the rehabilitation proposals at the Project site and in particular, North's intention to enhance the overall depauperate status of endemic remnant vegetation in the region.

It would be expected that the Plan would cover:

- seed collection protocols;
- seed germination and maintenance procedures;
- tubestock maintenance;
- soil moisture and compaction requirements prior to planting;
- topsoil storage and maintenance;
- seeding rates and scouring methods;
- tubestock planting procedures;
- freshwater plant handling and planting procedures;
- erosion control procedures;

- access and fencing of germinating areas;
- criteria for measuring revegetation success;
- erosion control on newly planted surfaces;
- weed control and herbicide protocols in the Project catchment; and
- criteria for assessing rehabilitation standards and completion status.

8.0 LONG TERM COMPATIBILITY

Studies have been undertaken (Kalf and Associates, 1997; Gilbert and Sutherland, 1997; Coffey Partners International, 1997; Knight Piesold, 1997; EGi, 1997; Goldney *et al.*, 1997; EDAW, 1997; Tropical Water Solutions, 1997) to address the issue of long term compatibility of the proposed development. Long term is considered to mean that period of time stretching on from the point at which rehabilitation of the Project is complete, revegetation is well established and mining tenure is relinquished.

The primary objective of the long-term compatibility study was to identify the ways in which a mine may impact on the critical conservation values of Lake Cowal beyond the operating phase when the potential for management intervention to correct environmental problems is limited.

Outlined below is an overview of key study findings grouped in terms of the identified critical conservation values of the Lake (as previously noted in Section 1.4). Findings have been further split into conclusions reached with respect to baseline conditions/trends and assessed potential long-term impacts following mine closure and rehabilitation.

Each key study finding is referenced to a source document provided in the attachments to Appendix N of the EIS.

8.1 Lake Hydrological Cycle and Water Quality

The information presented below relating to baseline and assessment conclusions of the hydrological studies of the Lake and its relationship with the proposed development, is a summary of information contained in Gilbert and Sutherland (1997), Kalf and Associates (1997), Knight Piesold (1997) and Tropical Water Solutions (1997).

8.1.1 Baseline Conclusions

- The hydrology of the Lake is characterised by strong event-driven cyclic changes (eg. with respect to lake level, volume and salinity).
- The environmental condition of the Lake is most likely subject to increasing influence from:
 - existing agricultural land use practices;
 - flow regulation practices and water use patterns in the Lachlan River.
- Lake water quality may also be affected, in the long term, by saline groundwater migration and rising groundwater levels associated with irrigation of agricultural land to the east and north-east.

Assessment Conclusions

- The Cowal Gold Project is unlikely to have any measurable effect on the water balance of the Lake.
- Sediment fluxes entering the Lake from the Project site are expected to reduce from those currently occurring, as the final void would intercept the majority of site runoff.
- Salt loads estimated to enter the Lake from the Project site are expected to decrease below pre-mining levels.
- At some time following the cessation of mining, the water level in the final void would reach steady state equilibrium some 22-24 m below the Lake's full storage water level. All groundwater flow in the Project area would be permanently directed towards the final void.
- It is not hydraulically feasible for saline waters in the final void to flow upgradient and leak into the bottom of the Lake.
- Water loss, if any, from Lake Cowal to the underlying aquifer and hence to the final void would be negligible and impossible to measure.
- Any residual contaminants which enter the groundwater system below the tailings storages are either immobilised or substantially reduced in concentration near the base of the storage. Arsenic and zinc are essentially immobilised in the soil profile. Residual cyanide concentrations reduce by a factor of one thousand (to negligible levels) near the base of the tailings storages.
- Given the natural groundwater salinity, constrained groundwater flow to the final void and evaporation effects in the final void, the level of contribution of tailings and waste emplacement salinity to groundwater salinity is not an issue of environmental significance.
- Final void water quality in the long term, would trend towards deep water hypersalinity. In the surface mixed layer there would be a seasonal variability in salinity from about sea-water levels in the summer months to levels approaching twice these levels during winter. It is likely that the final void would support salt tolerant species of plankton similar to those found in Australia's natural salt lakes. Similarly, specialised macrophytes may establish around the void edges.
- The structural design and final profiles of the tailings storage facility, waste emplacements and perimeter bund effectively preclude the risk of instability which could cause impact on the Lake. The stability of these structures is preserved even under severe earthquake conditions.

8.2 Ecosystem – Wetland Habitat

The following information is a summary of the main findings of the ecological long term compatibility study of the Project and Lake Cowal (Goldney *et al.*, 1997).

8.2.1 Baseline Conclusions

- The long term health and biodiversity of the Lake system is most likely already being negatively influenced by cumulative regional land uses. These include grazing,

cropping, irrigation and other agricultural practices, flow regulation and water use patterns in the Lachlan catchment.

- The phenomenon of "ecological lag" (ie. the time lapse between action and ecological impact created by the natural resilience of an ecological system) is likely to be evidenced in any long term wide ranging study of the Lake. Such effects would likely be demonstrated by increases in regional soil and water salinity, the presence of chemicals and changes in species diversity in the Lake system.
- Lake usage and intrinsic value as a wetland habitat is already variable from year to year as a result of the combination of natural (seasonal/climatic) events and induced (eg. river regulation) cycles. The ramifications of these influences may take considerable time to become evident.
- Despite these influences the Lake remains a valued and diverse natural asset which would benefit strongly from the development and implementation of a long term management and protection strategy.
- Like many other lakes in Australia, Lake Cowal's value to bird life relates to its shallow depth and to the cycles of flooding and drying that have occurred over a large period of time. As a consequence of evaporation of innumerable floodwaters, a rich store of nutrients has accumulated.
- Integral to the Lake's ecology is its periodic drying which results in the release of nutrients in mineral form from the built-up organic matter. When the lake fills after a period of drying, it is these nutrients that generate the temporary bloom of aquatic life on which many birds thrive. When Lake Cowal is dry, contains little water or otherwise has become less productive of aquatic life under relatively stable water level conditions, wetland habitats of other inland river floodplains provide this critical resource.
- As a wetland system Lake Cowal provides, albeit episodically and for relatively short periods of time, habitat for wetland bird life that is of national significance (Maher and Braithwaite, 1992).

8.2.2 Assessment Conclusions

- Mine landforms that are located proximal to or within the Lake's foreshore would not impinge on nor reduce to any significant degree the Lake's breeding habitat, size or habitat diversity.
- The perimeter waste emplacement can be reformed as a new expanded foreshore and ecotone (ie. the terrestrial/wetland interface), increasing existing habitat and species diversity potential.
- The presence of the final void is likely in the long term to create a saline "sink" which would develop its own simple but persistent ecosystem adjacent to the Lake. Some impact on individual birds and other fauna could occur as a result of direct long term use of void waters by

occasional individuals, although it is not likely to be of sufficient extent or frequency to impact population survival.

- Lake Cowal meets the criteria for Ramsar listing (ie. a wetland of international importance) and proximity to a mining development does not disqualify its future nomination. The mine could be developed and rehabilitated in such a way that the ecological character (and value) of the wetland is not affected.
- The location of an electricity transmission line between the Nerang-Cowal and Lake Cowal bird habitats is likely to result in significant mortality. The relocation of the line to source Project power requirements from Temora to the south (Appendix D of the EIS) has effectively eliminated this risk.
- Any short-term increase in competitor or feral animal and weed species as a result of new landforms (eg. waste rock emplacements, void, tailings storages areas) is an inevitable part of ecosystem development and with management is not considered a significant long term conservation issue.
- The rehabilitation/revegetation plans based on ecological principles have been designed to enhance long term native species habitat opportunities, compared to the modified habitats occurring around the Lake at present which favour introduced and feral species.
- A mine located in the Lake Cowal catchment has the potential to act as a catalyst for the development and implementation of catchment management and Lake protection measures considered desirable for the long term health of the Lake.

8.3 Ecosystem – Terrestrial Habitat

8.3.1 Baseline Conclusions

- Vegetative and faunal habitats that presently exist in the Lake and surrounding ecosystems are modified from the natural conditions. The existing landscapes have been modified by a combination of human settlement, clearing, altered fire regime and pasture improvement practices.
- Woodland habitat area has been significantly reduced from that which existed prior to the introduction of broad acre farming and grazing. Remnant ridge top vegetation and woodlands proximal to the mine area exist on road reserves, Cowal West Hill, Wamboyne Mountain and Billys Lookout (ridge top vegetation) and in scattered isolated remnants.
- Weed species are commonly found in association with native and introduced grass cover and in woodland or ridge top tree-dominated areas (eg. Wamboyne Mountain) that have been disturbed by grazing.
- Uncleared patches of woodland with grassy understorey are not well-represented in the region and are of high conservation value.

8.3.2 Assessment Conclusions

- Rehabilitation designs for the perimeter emplacement and mine landforms would enhance the dryland/lake ecotone (interface). This has the effect of extending the existing shoreline length, and replacing riparian and wetland vegetation removed by past clearing practices.
- Likewise, rehabilitation strategies for the remaining terrestrial components of the waste emplacements and the entire tailings storages and services areas include the re-establishment of a greater area of woodland and grassland than currently exists, negating any impact on long term woodland conservation values.
- With appropriate management the impact of feral animals and weeds on terrestrial habitats as a result of these rehabilitation actions is considered negligible.
- Overall, the risk of mine development affecting terrestrial habitat conservation values is considered to be negligible given the successful implementation of appropriate rehabilitation strategies and designs. In fact, enhancement could be foreseen with the implementation of ecologically sound rehabilitation strategies.

9.0 SOCIAL AND ECONOMIC ASPECTS

The social and economic significance of the proposed Cowal Gold Project at the local, state and national levels is reported by CIE (1997) and is contained in Appendix K. A summary of this report's findings is contained in Section 4 of the EIS and is presented below.

For the purpose of the following discussion, the local community is considered to be those people living in the Bland Shire which includes West Wyalong, Wyalong, and many small townships and farmhouses in the vicinity of these centres. Social context is determined by reviewing influences on the population of the Bland Shire and the availability of community services and infrastructure. The implications of the project have been predicted by assessing the economic and other impacts on the local community, including adequacy of existing infrastructure to accommodate an increase in demand from the project workforce.

9.1 Employment Effects

9.1.1 Construction Phase

The construction phase is expected to last for 2 years, with an average workforce of approximately 180 persons with a peak of approximately 300.

A portion of the construction work force would be involved in both the construction phase and ongoing operational phase.

Although contractors would be encouraged to preferentially hire local labour, it is likely that the majority of the staffing requirements would be for specialist labour sourced from outside the region. This construction workforce would provide significant multiplier effects to the local economy through increases in retail, wholesale and trade services.

The demand for trades and labourers during the Project's construction phase could assist in temporarily ameliorating unemployment in the district and provide growth opportunities for local business.

9.1.2 Operational Phase

The Project would require 200 employees during the first eight years of the operational phase. At the completion of mining (year 8) employee numbers would decline to about 90. It is expected that 90 of the 200 employees would be employed by North directly, with the remaining 110 employed by contractors. Approximately 60% of the 200 positions are expected to be filled by local residents with the remainder being sourced from either existing North staff or from outside the region.

Accordingly, significant impact on local employment is anticipated providing opportunities for the unemployed and the part-time or underemployed. Increased employment opportunities would assist in reducing the out-migration currently experienced among certain age groups.

9.2 Housing

During the construction phase, it is expected that there would be a high demand for temporary accommodation including motels, rental properties and caravan parks.

West Wyalong is well suited to cater for a transient population due to its location on the cross-roads of the Newell Highway and the Mid Western Highway. The town has 14 motels and 2 caravan parks which have adequate capacity to accommodate approximately 160 employees in motels alone during the construction phase (given the current low occupancy rates).

Demand for permanent housing would be high prior to the commencement of the operation phase through to when full production is reached. The demand for housing is stimulated by the employees who would reside in the local area.

North has estimated that approximately 30 houses would be required for staff. Four houses have been acquired to date and the remainder would be either purchased direct or newly constructed.

North's demand for property would provide a boost to the residential property market which has experienced a lull over recent years. The current lull in the property market may be attributed to the high reserve prices set by property owners in the area (CIE, 1997). Existing residential properties are only likely to be purchased if they are cheaper than building new houses tailored for employees and their families.

9.3 Social Infrastructure

9.3.1 Potential Impacts

The anticipated permanent population increases in local centres during the construction and operation phases are expected to comprise a mixture of age groups, both single

and married. Accordingly, a range of community services and facilities would be required, including recreational, sporting, child health and social welfare facilities and services.

9.3.2 Mitigation Measures

Existing facilities and services within the Bland Shire include:

- health facilities (including two full-time and one part-time doctors, 3 days a week dental service, hospital and regular specialist and community health services);
- educational facilities including family day care, playgroups, primary schools, one high school and a TAFE campus;
- recreational facilities including tennis courts, golf course, gymnasium and sports ovals;
- social and community services including social security advisors, Red Cross, Aboriginal Land Council, Homecare and Meals-on-Wheels; and
- cultural/entertainment facilities including hotels, restaurants and churches.

Considering the existing diverse range of services and facilities locally available and a degree of spare capacity due to the declining population of West Wyalong, the demand generated by the incoming Project population are not expected to unduly exceed the existing levels of services and facilities.

9.4 Social Adjustment

9.4.1 Potential Impacts

The West Wyalong communities would experience some inevitable social adjustments in response to the proposed development.

The influx of people to the existing social networks may impact on the existing local social structure.

With an increase in the local population base, increases in employment opportunities, business turnover, optimum use of sporting facilities and other infrastructure is anticipated.

Adverse social effects may include:

- increased traffic offences;
- brawling;
- petty crimes;
- increased town activity that may result in a loss of character.

Over the life of the mine, population increases are expected to ease but not eliminate a net population outflow from West Wyalong.

9.4.2 Mitigation Measures

The expected increase in employment opportunities generated directly and indirectly by the Project would assist in arresting the out-migration among certain age groups such as school leavers.

Negative outcomes of social adjustment shall be minimised through a number of community initiatives aimed at integrating the newcomer population with the local population. Such initiatives shall include specially organised sporting and social activities, and regular consultation between Project management and local authorities.

9.5 Property Demand and Values

9.5.1 Potential Impacts

It is estimated that North would purchase or construct 30 houses for new staff. Houses to be constructed would be built on new plots or existing plots. Increased demand for residential property is expected to provide stimulus to the existing property market and may, depending on supply conditions, allow residents to achieve reservation prices that have been placed on their properties. Improvement in West Wyalong's services, facilities and road infrastructure is expected to have a positive impact on local property values.

A previous study assessed properties surrounding the Northparkes gold and copper project, some 75 km north east of the proposed mine site. The assessment reviewed property transactions and included discussions with local property agents and landholders. The findings of the study indicated that the mine has had no detrimental effect on property values in the immediate areas surrounding the mine buffer zone. Property values had shown an increase from the period prior to the approval to the time of reporting (1995). The mine was not considered by buyers (around the time of reporting) to be a significant factor in their decision to buy or not to buy.

9.5.2 Mitigation Measures

The purchase of all land in the vicinity of the Project area would limit the availability of arable grazing land in the short-term. Given the limited land area occupied by the mine, no change in the value of agricultural production is expected.

9.6 Economic Effects

An increase in demand for accommodation and general goods and services including food, beverages and entertainment would be experienced during the construction phase. The 12 year operational phase would provide a diverse range of economic benefits to the local, regional and national economies. The benefits to the local community are expected to be substantial through an increase in demand for goods and services and the housing industry due to an increase in demand for accommodation.

It is anticipated that the total capital expenditure for the mine would be approximately \$220 million with approximately 10% of capital expenditure expected to occur within the local region.

Increased expenditure by wage and salary earners is also expected with the production of approximately \$9 million in wages and salaries and an anticipated associated increase in expenditure of up to \$5.1 million.

Employment flow-on effects are also likely to increase the number of job opportunities which result from the mine (52 jobs estimated over and above direct employment of 200) and therefore an increase in \$4 million in income.

Statewide benefits are expected to include an increase in the gross state product for NSW to an estimated annual total of \$190 million. Additional economic benefits include general permitting fees, royalties and taxes to the Federal and State Governments.

9.7 Urban Infrastructure

9.7.1 Impacts on Tourism

Tourism in the area is a substantial contributor to the local economy. Tourist activity in West Wyalong is heavily based on its strategic location at the cross roads of the Mid Western Highway (linking Sydney to Adelaide) and the Newell Highway (linking Melbourne to Brisbane).

The mine is not expected to have a detrimental effect on tourism in the area as it is not visible from either of the two major highways running through the town. The prohibition of duck shooting in NSW has significantly reduced the number of people visiting the Lake for recreational activity and sport.

There would be a reduction in the availability of short-term accommodation during the Projects construction phase. This is not expected to present a problem as the town is well situated for short-term accommodation with a total of 14 motels and 2 caravan parks.

10.0 LEGISLATIVE REQUIREMENTS

Summarised below are the relevant key legislative requirements for the Cowal Gold Project as detailed in Section 1 of the EIS.

10.1 Statutory Requirements, Local and Regional Environmental Plans and State Environmental Planning Policies

Legislation permitting and licensing requirements relevant to the ecological aspects of the Project and existing environment is presented in Table A-20.

10.1.1 Environmental Assessment Approval Process

The Project area (including part of the water pipeline) is located within the local government area of Bland Shire Council. The borefield and the remainder of the water pipeline are located in Forbes Shire. The DA for the Project has been lodged with the Minister for Urban Affairs and Planning in accordance with Part 4 of the EP&A Act and SEPP 34.

10.1.2 Local Environmental Plans

Bland Shire Council

The EP&A Act provides for planning instruments based on the zoning of land according to its suitability for given uses.

The most common planning instrument is the local environmental plan (LEP) prepared by Councils for part or all of a local government area. The portion of the Project to be undertaken in Bland Shire includes the mine, site facilities, the mine access road and sections of the water pipeline.

The environmental planning instrument applicable to the Project area within Bland Shire is the Bland LEP (1993).

The Bland LEP (1993) zones the land required for the Project as "1(a) – General Rural Zone". Under this LEP, development for mining purposes is permissible in this zone with development consent.

Lake Cowal is shown on Bland LEP map no. 2 as a "wetland" and "conservation area". The map also designates:

- an area adjacent to the Lake as "nature reserve" (corresponds to a Game Reserve No. 509); and
- some small portions of land to the north of the proposed mine site as "environmentally sensitive land". This designation attracts the operation of clause 24, which relevantly states:

"24(1) In this clause, "clearing" means the destruction or removal of trees and other vegetation, but does not include the clearing of re-growth from land previously cleared for agricultural use, or the cutting

down of individual trees for farm purposes, such as fencing or firewood, which may be carried out without the consent of the Council.

- (2) A person shall not clear land within a conservation area or clear environmentally sensitive land without the consent of the Council.
- (3) A person shall not, except with the consent of the Council:
 - (a) erect a building within a conservation area; or
 - (b) clear, drain or fill a wetland or construct a levee on a wetland within a conservation area.
- (4) In determining an application for consent required by subclause (2) or (3), the Council shall make an assessment of:
 - (a) the risk of soil erosion or other land degradation;
 - (b) the loss of important vegetation systems and natural wildlife habitats; and
 - (c) the extent to which the carrying out of the proposed development in accordance with the consent would affect the historic, scientific, cultural, social, archaeological, natural or aesthetic significance of the conservation area,

Table A-20 Relevant Project Permits – Cowal Gold Project

Issue	Statute	Government Agency	Approval/Commentary
Mine Development	<i>Environmental Planning and Assessment Act 1979</i>	Minister for Urban Affairs and Planning	Development consent under the <i>Environmental Planning and Assessment Act</i> will be required for both the mine itself and associated infrastructure (electricity transmission line, water pipeline, access road). Under SEPP 34, the Minister for Urban Affairs and Planning is the consent authority. In addition: • SEPP 33 – a person who proposes to make a Development Application to carry out development for the purposes of a potentially hazardous industry must prepare a preliminary hazardous analysis (in accordance with DUAP circulars); and • Section 77(3) of the <i>Environmental Planning and Assessment Act</i> – if a Development Application is in respect of a critical habitat or is likely to significantly affect threatened species, populations or ecological communities, or their habitats, the application must be accompanied by a species impact statement prepared in accordance with Division 2 of Part 6 of the <i>Threatened Species Conservation Act 1995</i>.
Flora and Fauna	<i>Threatened Species Conservation Act 1995</i>	National Parks and Wildlife Service	The <i>Threatened Species Conservation Act 1995</i> governs the content of the species impact statement which must accompany a Development Application made in respect of development which is likely to significantly affect threatened species, populations or ecological communities.
	<i>Fisheries Management Act 1994</i>	Minister for Fisheries	Under the <i>Fisheries Management Act</i> , a person is prohibited from carrying out dredging or reclamation work in any waters except under the authority of a permit issued by the Minister (Division 3 of Part 7).
	<i>National Trust of Australia (New South Wales) Act 1990</i>	National Trust of Australia	In 1987, Lake Cowal was classified as a "Landscape Conservation Area", by the National Trust. However the National Trust may exercise its powers under the <i>National Trust of Australia (New South Wales) Act 1990</i> only if the land is vested in the Trust.
	<i>Australian Heritage Commission Act 1975 (Cth)</i>	Australian Heritage Commission	Lake Cowal was listed on the Register of the National Estate in 1992, pursuant to the <i>Australian Heritage Commission Act 1975</i> . The reason for the listing was stated to be that the Lake is "one of the most significant waterbird concentration areas in New South Wales". The listing constrains the Commonwealth Government from actions that might adversely affect the listed area, but does not place any legal constraints on the actions of owners of private property or on State or Local Governments.

and may attach conditions to minimise any adverse effects."

Further to the above clause 10(1)(d) of the Bland LEP is also relevant. This clause provides:

- "10(1) The Council shall not consent to an application to carry out development on land within Zone No. 1(a) ... unless it has taken into consideration, if relevant, the effect of the carrying out of that development on ...*
- (d) the protection of areas of significance for nature conservation or of high scenic or recreational value, and places and buildings of archaeological or heritage significance including Aboriginal relics and places;"*

The table to clause 9 of the LEP lists objectives of the 1(a) General Rural Zone to include the protecting, enhancing and conserving of "water resources for use in the public interest", "areas of significance for nature conservation" and "places of heritage significance, including Aboriginal relics and places". The combined operation of the objectives clause for the 1(a) Zone and clause 9(3) of the LEP is negated by SEPP 45 ("Permissibility of Mining"). Clause 5(2) of SEPP 45 states:

- "(2) ... if mining is permissible on land with development consent in accordance with an environmental planning instrument if the consent authority is satisfied as to certain matters specified in the instrument, mining is permissible on that land with development consent without the consent authority having to be satisfied as to those specified matters."*

Forbes Shire Council

The environmental planning instrument applicable to the Project area within Forbes Shire is the Forbes LEP (1986).

The Forbes LEP (1986) zones the land required for the electricity transmission line and the water pipeline as "1(a) – General Rural". The LEP permits the construction and use of this infrastructure with development consent.

The Forbes LEP includes a clause 9 which is identical to clause 9 of the Bland LEP (1993) which is discussed above.

10.1.3 Regional Environmental Plans

Regional environmental plans potentially relevant to the Project area include the Jemalong Land and Water Management Plan, Lake Cowal Management Plan and the Mid Lachlan Pilot Project for Regional Vegetation Management Plans. All plans are currently incomplete with finalisation expected by June 1998.

The management recommendations resulting from the completed plans will be incorporated within mine operating requirements. Brief descriptions of the plans are presented below.

Jemalong Land and Water Management Plan

This plan has been formulated to facilitate management strategies to address the major concern of salinisation done

to rising groundwater. The formulation of the plan has been underway since 1991.

Lake Cowal Management Plan

A component of the Jemalong Plains Land and Water Management Plan, this plan's primary objectives are soil structure and vegetation cover conservation. Management considerations, therefore, include feral pest control (eg. carp), agricultural practices and revegetation strategies.

Mid Lachlan Pilot Project for Regional Vegetation Management Plans

This plan is a pilot plan for Regional Vegetation Management Plans which will be prepared in support of the proposed Native Vegetation Conservation Act. The aims of the plan include the identification of priorities for the restoration of native vegetation habitat as well as identifying native vegetation areas which will/will not require consent to clear.

10.1.4 State Environmental Planning Policies (SEPP)

SEPP 11 – Traffic Generating Developments

SEPP 11 requires the consent authority to refer a copy of the Development Application for the Project to the Roads and Traffic Authority (RTA).

SEPP 33 – Hazardous and Offensive Development

SEPP 33 requires the consent authority, in considering a Development Application for a potentially hazardous or a potentially offensive industry, to take into account current guidelines or circulars published by the Department of Urban Affairs and Planning, consultations with public authorities, any preliminary hazard analysis, any feasible alternatives to the carrying out of the development and the reasons for choosing the development the subject of the application and any likely future use of the land surrounding the development. For potentially hazardous development, SEPP 33 requires a preliminary hazard analysis to be prepared and submitted with the Development Application.

SEPP 34 – Major Employment Generating Industrial Development

The effect of the SEPP 34 is to make the Minister for Urban Affairs and Planning the consent authority for the Project.

SEPP 44 – Koala Habitat Protection

In response to a statewide decline of Koala populations, the Department of Urban Affairs and Planning has enacted State Environmental Planning Policy – Koala Habitat Protection (SEPP 44). The policy aims to "encourage the proper conservation and management of areas of natural vegetation that provide habitat for Koalas, to ensure permanent free-living populations over their present range and to reverse the current trend of population decline."

SEPP 44 was gazetted on the 6 January 1995 and commenced operation on the 13 February 1995.

In order to determine whether SEPP 44 applies to the Project area, it is necessary to consider the following:

- *Does the subject land occur in a Local Government Area identified in Schedule 1?*

The proposed Cowal Gold Project mining area is located within the Bland Shire Local Government Area (LGA) which is not listed in Schedule 1 of SEPP 44. The proposed water supply borefield and pipeline (greater majority thereof) is located north-east of the Project area (Figure A-3) in the Forbes Shire LGA, which is listed in Schedule 1 of SEPP 44. Accordingly, this determination would focus on the proposed borefield development in the Forbes LGA.

- *Is the landholding to which the DA applies greater than 1 hectare in area?*

The proposed borefield and water supply pipeline easement covers an area of approximately 10 ha.

- *Is the land potential Koala habitat, ie. does the site "contain areas of native vegetation where the trees of types listed in Schedule 2 constitute at least 15% of the total number of trees in the upper or lower strata of the tree component?"*

Based on a flora report of the proposed borefield and pipeline route (Anne Clements & Associates, 1996) and examination of aerial photography (1:50,000, 1997), the upper or lower strata of the tree component, although sparse, is characterised by River Red Gum (*Eucalyptus camaldulensis*) and Poplar or Bimble Box (*E. populnea*). Both these species are listed in Schedule 2 of SEPP 44 and based on that, the area is potential Koala habitat.

- *Is there core Koala habitat on the subject land and is there a requirement for the preparation of a Plan of Management for identified core Koala habitat?*

In accordance with SEPP 44 core Koala habitat is defined as "an area of land with a resident population of koalas, evidenced by attributes such as breeding females (that is, females with young) and recent sightings of and historical records of a population".

Examination of NPWS records (Ayers *et al.*, 1996), CSIRO database records and the results of various fauna surveys conducted in the Lake Cowal region (eg. Gunninah Consultants, 1996; Vestjens, 1977) indicates a relative paucity of recent Koala records in the region. This combined with the absence of substantive quantities of preferred Koala feed trees, the occurrence of large tracts of cleared land and the presence of dogs, suggests that the area does not contain core Koala habitat.

SEPP 45 – Permissibility of Mining

The effect of the application of SEPP 45 to the Project is discussed under Section 10.1.2 (Local Environmental Plans) of this document.

11.0 ALTERNATIVES CONSIDERED

11.1 Project Scale

By industry standards, the Cowal Gold Project is a medium-sized mine and a low-medium grade orebody. In general terms, the scale of a mining Project (ie. the amount of rock

mined and milled each year and the life of the Project) is dictated by the grade of the ore, the costs of treatment, the size of the orebody and the calculated pay-back period for return on investment.

North have analysed the Project at a range of scales from small (eg. 1 million tonnes of ore milled per annum) to large scale (eg. 10 million tonnes per annum). Application of a number of defining criteria into the analyses results in the emergence of an optimum-sized Project.

Due to differing mine production schedules from year to year and an orebody of approximately 76 million tonnes of ore, requires a mill capable of treating up to 7 million tonnes of ore per annum. From an environmental perspective, there are no advantages to operating a significantly smaller or larger Project than that proposed as only the life of the Project changes and not the overall impacts of the Project.

11.2 Mining Methods

Gold-bearing orebodies (as opposed to alluvial deposits) can be mined in three ways: by open pit methods (whereby mining excavates a pit from the surface downwards) or by underground methods (whereby the orebody is accessed via a small surface opening leading to subsurface excavations which follow the orebody), or by a combination of open pit leading to an underground facility.

By virtue of their form and occurrence, underground mining methods are best suited to deeper, narrower, more confined orebodies (eg. where gold is contained in veins or "ore shoots"). Open pit mining methods are suited to orebodies which are located closer to the earth's surface and wherein minerals are more disseminated throughout the rock mass (requiring a bulk mining approach to recover the distributed minerals).

The distribution of the gold mineralisation at the Cowal Gold Project does not lend itself to underground mining as gold ore initially occurs near surface and is not contained in discrete veins of significant width.

11.2.1 Heap Leach Alternative

As discussed in Section 8.4, the only viable technology for the Project involves the use of cyanide in a strictly controlled "closed" process. Two options are generally used depending on the characteristics and mineralogy of the rock, viz: leaching the heaped ore on a prepared pad with cyanide solution (heap leaching), or fine grinding the ore and leaching it with cyanide solution in large steel tanks (carbon in leach or carbon in pulp technology). Because the Cowal ore is not physically and metallurgically amenable to economic heap leaching, the latter method has been adopted.

Open-pit mining is typically conducted by either front-end loaders/excavators and trucks, or by draglines and trucks. The latter method has been developed for very large scale mines where large quantities of comparatively softer materials (eg. coal) are excavated. Open-pit mining using

front-end loaders/excavators and trucks is therefore the most applicable mining method for the Cowal deposit.

No economic quantities of gold occur west of the Lake's full storage level (ie. the open pit cannot be moved to avoid intrusion into the Lake).

11.3 Water Supply

The milling of gold ores such as Cowal requires water to convey the finely crushed rock throughout the extraction process, to act as a medium for the chemicals used to liberate the gold from its host mineralisation and to convey the residue from milling (ie. tailings) to the tailings storages.

Water is also required for activities such as dust suppression on roads and crushing facilities, equipment washdown areas and workforce showers and washrooms.

Sometimes, the safe and stable mining of an orebody requires advance dewatering of the rock (sufficient in some cases to provide a significant proportion of Project water demand). Advance dewatering of saline water associated with the Cowal orebody would be required, but it would not generate sufficient water for all processing needs for the life of the Project. The immediate area's groundwater resource is inadequate to make up the shortfall, and the surrounding landform, drainage and water use characteristics and laws do not permit the extraction of surface waters for the Project. Consequently, the Project has identified a groundwater source some 20 km to the east-northeast of the orebody, in the Bland Creek palaeochannel.

The Project's water supply would comprise:

- secure storage and use of pit dewatering waters (ie. there would be no discharge of saline waters pumped ahead of mining);
- maximum recycling of water used in ore processing and tailings disposal;
- total reuse of stormwater held in runoff dams located in the Project's disturbance area (the internal catchment containment system);
- a groundwater supply scheme for raw water make-up consisting of four unobtrusive bores located on road reserves to the east of the Project area, a holding tank, and a buried pipeline laid across the bed of Lake Cowal to the mill site.

Alternative pipeline routes have been assessed and include a route around the Lake (as opposed to across it). On balance, it is concluded that a pipeline buried or laid across the Lake placed under the terms of an appropriate Environmental Management Plan can be justified and would result in less disturbance to creeks and landholders than the longer routes.

11.4 Processing and Tailings Storages

The processing and extraction of gold from the ore results in a finely ground unmineralised residue known as tailings, which is normally disposed of in specifically engineered and constructed storages (tailings storages facilities). Deposited

tailings settles from the slurry and dries to a solid mass. When completed, the dams are then covered and revegetated.

Alternatively, a proportion of tailings are sometimes dewatered and returned to the mining area (eg. as backfill in some underground mines or, more rarely, completed open pits).

The absence of underground potential and the mining of the Cowal orebody as a single pit necessitates the construction of surface tailings storages facilities.

Alternatives for the location of the storages have been assessed, including:

- their location more distant from the mill (eg. 10-20 km west);
- locating both the mill and the storages 10-20 km west of the pit;
- trucking or railing the ore or concentrate to an existing facility (eg. Northparkes some 120 km away);
- using alternative gold leaching technology other than cyanide;
- introducing a flotation circuit to the mill to reduce (concentrate) the amount of primary ore requiring cyanide treatment by 95%.

These options are discussed in further detail in Section 1 of the EIS and have been addressed in a multi-criteria analysis report prepared for the Project (refer to Appendix K of the EIS).

11.5 Waste Rock Disposal

Mined material that does not contain economic mineralisation is termed waste rock. This is normally disposed of in constructed emplacements which are revegetated throughout the mine's life.

In-pit disposal of waste rock is only feasible when more than one open pit is operated concurrently. Backfilling the pit with waste rock at the completion of mining would render the Project totally uneconomic and due to the bulking (swell) factor created by blasting and mining rock, only about 75% of the total waste rock volume would fit back in the pit.

Potential exists to re-establish a greater and more diverse amount of habitat as a result of the proposed waste emplacement rehabilitation design.

Successful waste rock rehabilitation in the central NSW mining province is demonstrated at the Temora, Northparkes, London-Victoria and Browns Creek mines.

11.6 Power Supply

A feasibility study for Project power supply options based on economic, environmental and technical factors has been undertaken by North.

As a consequence of the options study, on-site power generation utilising gas or diesel could not be justified

on economic grounds and the selected power supply option is an electricity transmission line from Temora. Appendix D presents the EIS for the electricity transmission line proposed by Great Southern Energy (GSE) and provides further information on power generation and electricity transmission line route options.

12.0 PARTICIPANTS

Allen Kearns – B.Sc. Agr. (Hons), University of Sydney (1971)

Allen has more than 20 years experience in environmental impact assessment, natural resource management, environmental chemistry, ecosystem rehabilitation and project management.

He has previously worked for 13 years in the international engineering and environmental consulting firm of Dames & Moore managing offices and multidisciplinary scientific and engineering consulting groups in Darwin, NT; Sacramento, California, USA and Paris, France. Prior to this he worked at Lawrence Berkeley Laboratory, University of California, Berkeley, USA on groundwater contamination chemistry and the Australian Institute of Marine Science, Townsville, QLD on marine pollution impacts from heavy metals and organochlorine pesticides.

He is currently Assistant Chief in charge of Communication and Business Development at CSIRO Division of Wildlife and Ecology and Program Leader for Applied Resource Ecology, responsible for developing integrated ecological applications from the Division's research and technology development for use in decision-making for natural resource management. The major emphasis of these integrated ecological applications is in ecosystem management and the self-sustaining rehabilitation of degraded landscapes.

Wayne Braithwaite – B.Sc. University of Sydney (1962); M.Sc. University of Sydney (1965); Ph.D. Australian National University (1971)

Wayne joined the CSIRO Division of Wildlife, later the Division of Wildlife and Ecology, as a research officer in 1962. His research, until 1977, focused on the ecology and management of waterfowl. Following a forests industry request of CSIRO for advice concerning the impacts of forest management on native fauna, his research focus was transferred, in 1977, to the forests of eastern Australia, notably in the state of New South Wales.

He is currently focusing his energies towards advisory and consultancy activities to State and Federal governments, industry and conservation groups and to the legal profession.

Publications include some 100 research and technical papers, advisory and consultancy reports related to the conservation management of Australian fauna. Recent consultancy activities include direction of reviews of Fauna Impact Statements for State Forests of New South Wales for the Eden, Wingham, Coffs Harbour-Urunga, Morisset, Dorrigo, Queanbeyan-Badja, and Murwillumbah Management Areas, the direction of the "Murwillumbah

Management Area Fauna Survey", also for State Forests of New South Wales and a report, "*Botanical Survey and Assessment. Proposed Residential Development on Land Owned by Ardel Ltd, at Allambie Heights, Sydney*", prepared for the law firm Allen, Allen and Hemsley.

Peter Catling – B.Sc.(Hons), Australian National University, Canberra (1972); Diploma in Agriculture, Wagga Agricultural College (1965)

Peter has considerable experience in the study of wildlife ecology, particularly ground dwelling fauna. Since becoming a Principal Research Scientist at CSIRO Wildlife & Ecology, he has been involved in a range of research projects, including the effects of cane toads on fauna; distribution and abundance of ground-dwelling forest fauna; effects of wildfires on fauna; dingo, fox and feral cat predation on native fauna; dingo ecology and reproduction; house mouse ecology; diet of rabbits in relation to seasonal conditions; water and energy requirements of free-living mammals; kangaroo and wallaby reproduction; and reproductive hormones in the Tammar Wallaby.

He is currently continuing research into the distribution and abundance of ground dwelling vertebrate fauna and vertebrate pest control. He is the CSIRO representative on the Scientific Committee of the *Threatened Species Conservation ACT 1995* for New South Wales, the Research Working Group on Forest Wildlife and Habitat Management, Australian Forestry Council and the Bushfire Council of the Australian Capital Territory.

John Wombey – Associate Diploma of Applied Science, Canberra College of Advanced Education (1978)

As Collection Manager, he is an essential component of the Australian National Wildlife Collection held at CSIRO Wildlife & Ecology. His areas of expertise include herpetology, field survey, taxonomy and biogeographic assessment of species as well as curatorial techniques for vertebrate museum specimens. More recently he has been involved with creating computer database systems for storage and retrieval of specimen information and is the current Secretary/Treasurer of the Australian Society of Herpetologists, Incorporated.

Richard Schodde – Ph.D. University of Adelaide (1970); B.Sc. (Hons) University of Adelaide (1960)

Richard is both the Curator-Director of the Australian National Wildlife Collection (Land Vertebrates) and Project Leader for the Genetic Diversity and Biogeography of Australian Wildlife project. He is also compiler of the Zoological Catalogue of Australia (Aves) for the Australian Biological Resources Study. He has previously worked as an Experimental Scientist at CSIRO Division of Land Research as a systematic botanist, botanical surveyor and fauna collector for New Guinean resources surveys.

His current research interests include methodology and techniques in biological survey and vegetation habitat mapping; production of flora and fauna surveys; development and curation of biological collections; vertebrate taxonomy, including classical morphological,

morphometric and cladistic taxonomic methodologies; and analysis of species-subspecies systematics and geographic variation in the South-west Pacific flora and bird fauna.

The National Collection now holds the most comprehensive series, biogeographically, of Australo-Papuan birds in the southern hemisphere and has encouraged extensive collaboration with other national collections and international natural history museums dealing with bird fauna and flora of South-west Pacific.

Ian Mason – New South Wales HSC (St Gregory's Agricultural College) (1968)

Ian has contributed almost 30 years technical assistance at CSIRO Wildlife & Ecology and at the Australian National Wildlife Collection. His expertise includes general field survey, identification and taxonomic assessment of species specialising in ornithology; museum preparation and curation; computer data storage and statistical software applications packages; and photo-interpretation and vegetation-habitat mapping for biological survey.

He has participated in a number of field programmes and is presently participating in the collection, taxonomic and biogeographic assessment of the avifauna of Australia and offshore islands.

David Goldney – BSc Dip Ed (University of Adelaide) (1963) PhD (University of Queensland) MEIA

David is an Associate Professor in Wildlife Ecology and Management at Charles Sturt University, Head of the Environmental Studies Unit, Bathurst Campus and Associate Director of the Johnstone Centre of Parks, Recreation and Heritage, one of the University's six research centres.

David has lived and worked in the Central Western Region of NSW since 1972. He has carried out research and published in the following discipline areas; plant physiology, plant and vertebrate ecology, environmental flows, platypus ecology, environmental extension, conservation biology, landscape ecology, environmental management, environmental impact assessment, integration of nature conservation and sustainable agriculture, environmental sociology, remnant woodland sustainability and the distribution and abundance of vertebrate species in the CWR.

He currently supervises 2 Honours students, three masters students and six PhD students.

In the past decade David has been the recipient of research grants in excess of \$1.5 M from competitive State and Commonwealth sources as well as private industries.

Greg Richards – currently completing a PhD, University of NSW

Greg has been involved in bat research for nearly three decades and is internationally recognised as an expert in the taxonomy and ecology of Australia's bat fauna. Greg has extensive experience in bat survey work, bat fauna assessment, management and conservation planning.

Greg is currently principal of the Wildlife Research and Ecological Assessment Consultancy firm – Greg Richards and Associates Pty Limited. Prior to this, Greg worked for CSIRO Division of Wildlife and Ecology for 27 years, starting as a technician and finishing as an Experimental Scientist in the Resource Ecology Assessment Program.

He has worked internationally in Cambodia, United Kingdom, Germany, Netherlands, India, Thailand, Sarawak (Borneo), United States of America and Costa Rica on taxonomic research, survey methodology for fauna management, bat conservation programs and has played an advisory role to United Nations Sustainable Development Program (India) and World Wide Fund for Nature (Thailand). Greg is also a scientific adviser to Bat Conservation International and is a member of the Species Survival Commission of the International Union for the Conservation of Nature and Natural Resources.

Projects currently being undertaken by Greg Richards and Associates include compilation of the National Action Plan for Bat Conservation (ANCA), bat fauna assessment at the Jabiluka Uranium Lease (Northern Territory), bat population monitoring for a new wind farm in New South Wales and adviser to the National Parks and Wildlife Service for comprehensive regional assessments of forests. Greg has a publication list that exceeds 100 entries and, has edited and contributed to chapters on bats in publications such as *The Mammals of Australia*, *Encyclopaedia of Australian Wildlife*, *The Australian Museum Complete Book of Australian Mammals* and is a referee for research papers and scientific articles in numerous scientific journals. Greg is also founder and President of the Australasian Bat Society.

Damien Lynes – B. App. Sc. (Coastal Management).

Damien is a Senior Environmental Manager with over five years experience in environmental impact assessment and approval processes. He has compiled numerous Environmental Impact Statements, Environmental Management Plans, Public Environmental Reviews and Statement of Environmental Effects reports for a number of local government and private industry developments, including projects for large-scale mining operations in New South Wales, Queensland, Northern Territory, Fiji, Namibia and Greece as well as projects for local and state Government authorities (eg. Tweed Shire Council, Lismore City Council, NSW Department of Land and Water Conservation and NSW Department of Agriculture).

He has specialist expertise in ecological (fauna and flora) impact assessment and as a Project Manager he has been responsible for the preparation of several major Species Impact Statement and Ecological Assessment reports including the provision of field survey and sampling expertise for a range of developments.

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Legislation

- New South Wales Threatened Species Conservation Act 1995
- New South Wales Environmental Planning and Assessment Act 1979
- New South Wales Fisheries Management Act 1994
- National Trust of Australia (New South Wales) Act 1990
- Commonwealth Australian Heritage Commission Act 1975
- State Environmental Planning Policy 11 – Traffic Generating Developments
- State Environmental Planning Policy 33 – Hazardous and Offensive Development
- State Environmental Planning Policy 34 – Major Employment Generating Industrial Development
- State Environmental Planning Policy 44 – Koala Habitat Protection
- State Environmental Planning Policy 45 – Permissibility of Mining
- Bland Shire Council Local Environmental Plan 1993
- Forbes Shire Council Local Environmental Plan 1986
- Commonwealth Endangered Species Protection Act 1992

Attachment A1

Attachment A1

Director-General's Requirements



NSW
NATIONAL
PARKS AND
WILDLIFE
SERVICE

Richard Peters
Manager Project Approvals
North Limited
GPO Box 1903R
Melbourne VIC 3001

Our reference:
Your reference: WZ1997/204

WZ 1997/204
PC:pc

Dear Mr Peters,

**RE: DIRECTOR-GENERAL'S REQUIREMENTS FOR A SPECIES
IMPACT STATEMENT FOR THE PROPOSED COWAL GOLD
PROJECT**

Thank you for your letter dated 13 October 1997 requesting the Director-General's requirements for a Species Impact Statement (SIS) for the Cowal Gold Project.

Sections 109 and 110 of the *Threatened Species Conservation Act 1995* (TSC Act) describe the form and content of an SIS. For your information I have provided a copy of these sections in Appendix 1. Pursuant to Section 111 of this Act, I have limited and modified these matters and provided additional matters to be addressed, as described below:

Definitions

The definitions given below are relevant to these requirements:

development has the same meaning as in the *Environmental Planning and Assessment Act 1979*.

activity has the same meaning as in the *Environmental Planning and Assessment Act 1979*.

subject site means the area which is proposed for development/activity.

study area is the subject site and any additional areas which are likely to be affected by the proposal, either directly or indirectly.

locality means the area within a 50 km radius of the study area.

region means a biogeographical region that has been recognised and documented such as the Interim Biogeographical Regions of Australia

subject species means those threatened species which are considered known or likely to occur in the study area.

All other definitions are the same as those contained in the TSC Act.
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Matters which have been limited or modified

I consider that the following Section 110 matters need not be addressed by your SIS.

- All reference to endangered populations and endangered ecological communities. The TSC Act does not currently list any endangered populations or ecological communities in the area likely to be affected by the application;
- Reference to recovery plans and threat abatement plans in Section 110(2)(c). No recovery plans or threat abatement plans have been approved in accordance with the TSC Act.
- Section 110(2)(e). This section is a replication of 110(2)(a);
- All reference to critical habitat. There is currently no declared critical habitat in the area likely to be affected by the application; and
- Section 110(2)(g). The matters raised in this section of the act have been clarified by the requirements below.

Matters to be Addressed

The SIS must meet all the matters specified in Sections 109 and 110 of the TSC Act with the exception of those matters limited above. In addition to these sections (Appendix 1) I require the matters described below to be addressed. Previous surveys and assessments may be used to assist in addressing these requirements. All references used throughout the SIS must be cited and listed in a bibliography.

1. Description

The SIS must include the information requested below:

The proposal and surrounding areas

- 1.1 A topographic map of the locality at the most detailed scale available should be provided. This map should detail the location of the proposal, any locally significant areas for threatened species such as parks and reserves, and areas of high activity such as townships, regional centres and major roads.
- 1.2 The type of action proposed shall be detailed, including the timetable for the carrying out of the proposed development and the number of hectares affected.
- 1.3 A plan of the subject area will be provided. This plan will show the location and type of vegetation communities present within the subject area and the scale of the plan.
- 1.4 A colour aerial photograph of the locality (or reproduction of such a photograph) shall be provided. This aerial photograph should clearly show the subject site and the scale of the photograph.

Initial site assessment

- 1.5 A list of subject species shall be provided. In determining these species, consideration shall be given to the habitat types present within study area, recent records of threatened species in the locality and the known distribution of threatened species. Databases such as the NPWS Atlas of NSW Wildlife and information from the Royal Botanic Gardens and Australian Museum may be used to assist in compiling the list. The following species shall be included in the list of subject species:

Fauna

<i>Oxyura australis</i>	Blue-billed Duck
<i>Stictonetta naevosa</i>	Freckled Duck
<i>Botaurus poiciloptilus</i>	Australasian Bittern
<i>Ephippiorhynchus asiaticus</i>	Black-necked Stork
<i>Grus rubicunda</i>	Brolga
<i>Rostratula benghalensis</i>	Painted Snipe
<i>Saccolaimus flaviventris</i>	Yellow-bellied Sheath-tail-bat
<i>Nyctophilus timoriensis</i>	Greater Long-eared Bat
<i>Chalinolobus picatus</i>	Little Pied Bat

Flora

<i>Pilularia novae-hollandiae</i>	
<i>Lepidium monoplocoides</i>	Winged Peppergrass

- 1.6 In defining the study area consideration shall be given to possible indirect effects of the action on the area surrounding the subject site: for example altered grazing patterns of native and introduced herbivores, altered hydrology regimes or soil erosion.
- 1.7 In describing the study area, consideration shall be given to the previous land uses and the effect of these land uses on the study area. Relevant historical events may include fire history, clearing, logging for posts or charcoal, and agricultural activities.
- 1.8 A description of fauna habitat components such as the frequency of tree hollows, presence of logs and groundcovers, density and structure of understorey vegetation, soil types and presence of water points etc. shall be given. The condition of the habitat within the study area shall be discussed, including the prevalence of introduced species. Fauna habitat for subject species shall be described with particular reference to those components of the habitat that are used and for what purpose (feeding, roosting, nesting etc.).

Threatened species survey methods

- 1.9 A fauna and flora survey is to be conducted in the study area. Targeted surveys shall be conducted for all subject species. Species of taxonomic uncertainty

shall be confirmed by a recognised authority such as the Australian Museum for animals and the Royal Botanic Gardens for plants.

- 1.10 A full description of the methodology used in the fauna and flora surveys and habitat assessment shall be provided, including survey techniques and effort employed, number and location of traps, size of survey sites, dates of surveys, the time spent on surveys and weather conditions. Where possible, surveys should be undertaken during seasons and climatic conditions during which the subject species are most likely to be detected.
- 1.11 Any areas which may act as corridors or habitat links between the study area and adjacent areas of likely habitat for subject species shall be identified and described.
- 1.12 A full list of the flora and fauna found during the course of surveys shall be included. Such information is indicative of the habitat quality of the site.
- 1.13 The effect of the season and weather shall be considered with respect to the results of the survey.
- 1.14 The methodology of surveys is the responsibility of the consultant and as stated in 1.12 above must be fully documented in the SIS. Suggested methodologies for certain aspects of the field survey are:
 - the study area should be stratified to reflect natural variation across the area and the intensity of direct and indirect effects as a result of the proposed development.
 - a map of the attributes (e.g. vegetation) used to stratify the study area should be included.
 - each unit of land delineated by the stratification should be sampled for flora and fauna.
 - survey effort should be concentrated on, but not restricted to, those areas likely to be most impacted on by direct and indirect effects of the development.

The habitat of threatened species

- 1.15 The location of any threatened species recorded during the SIS survey shall be represented on a map of the study area.
- 1.16 A description of the habitats occupied within the region by each of the subject species should be provided. This description should include not only floristic and structural information but also information on the condition of the habitats.
- 1.17 In the same way, a description of the habitats occupied within the study area by each of the subject species should be provided. A comparison of the available habitats within the study area in relation to the region should then be undertaken.
- 1.18 The habitat of each of the subject species within the study area shall be represented on a map.

- 1.19 As far as possible, the distribution of the local population of each threatened species recorded from the study area should be determined.
- 1.20 The condition of the habitats should be determined, described and recorded e.g. structural complexity of the vegetation, evidence of grazing/ browsing damage, presence of flora species susceptible to grazing, fire history. The condition and regional distribution of similar habitats outside the study area should also be recorded.

Matters of social and economic impact

- 1.21 The economic costs likely to be incurred and the benefits likely to accrue to the proponent as a result of this development shall be addressed in the SIS. This shall include a discussion of the sensitivity of the analysis to any assumptions made in the calculation of the benefits/costs.
- 1.22 An evaluation of the social consequences of the development shall be carried out. This will consider who gains and who loses from the action and where those people are located, i.e. distributional considerations. Social impacts may include those that affect the net welfare of society and those that impact on the individual or group. With respect to the proponent this analysis may require consideration of the management of other lands under his control.

Matters of ecologically sustainable development

- 1.23 The principles of ecologically sustainable development, are described in section 6(2) of the *Protection of the Environment Administration Act 1991* must be addressed. The SIS must seek to demonstrate how this development satisfies these principles or how the development could be modified to address these principles.
- 1.24 The regional context of the effects of this development on ESD principles must also be considered.

2. Assessment of likely impacts

The assessment matters listed below shall be addressed:

- 2.1 For all subject species, the SIS shall state the following:
- the location, nature and extent of habitat removal or modification which may result from the proposed action; and
 - the potential impact of the removal of habitat on the species, population or ecological community; and
 - other potential impacts, both direct and indirect, upon threatened species that may occur as a result of the proposal; and
 - the likely contribution of the proposed action to the threatening processes acting on populations of those species in the locality.
 - measures proposed to ameliorate the impacts of the proposal.

- 2.2 A discussion of other populations of subject species in the region shall be provided. The long term security of the other habitats shall be examined as part of this discussion. The relative significance of the subject site for subject species in the local context shall be provided.
- 2.3 If movement corridors for subject species are present within the subject site, the impact of the proposal on these areas shall be discussed.

3. Amelioration

The following issues shall be addressed:

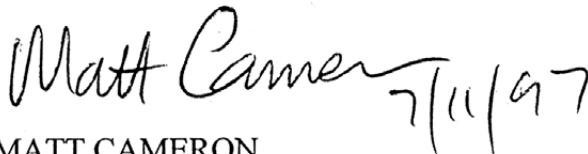
- 3.1 In discussing alternatives to the proposal, and the measures proposed to mitigate the effect of the proposal, consideration shall be given to developing long term management strategies to protect areas within the study area which are of particular importance for the subject species. This may include proposals to restore or improve habitat.
- 3.2 Any proposed on-going monitoring of the effectiveness of the mitigation measures shall be provided.

4. Additional Information

- 4.1 In providing a list of other approvals the following shall be included;
- any consent required under Part 4 of the *Environmental Planning and Assessment Act 1979* including the name of the consent authority and when it is proposed to make the development application; or
 - any approvals required under Part 5 of the *Environmental Planning and Assessment Act 1979* including the name of the determining authority(ies), the basis for the approval and when these approvals are proposed to be obtained.

Should you require any further information on these requirements please contact Peter Christie, Threatened Species Officer, Western Zone on 02-6883 5347.

Yours sincerely,



MATT CAMERON
Manager, Threatened Species,
WESTERN ZONE

Appendix 1 : Section 109 & 110 of the Threatened Species Conservation Act, 1995

Division 2 Species impact statements

109 Form of species impact statements

- (1) A species impact statement must be in writing.
- (2) A species impact statement must be signed by the principal author of the statement and by:
 - (a) the applicant for the licence, or
 - (b) if the species impact statement is prepared for the purposes of the *Environmental Planning and Assessment Act 1979*, the applicant for development consent or the proponent of the activity proposed to be carried out (as the case requires).

110 Content of species impact statements

- (1) A species impact statement must include a full description of the action proposed, including its nature, extent, location, timing and layout and, to the fullest extent reasonably practicable, the information referred to in this section.
- (2) A species impact statement must include the following information as to threatened species and populations:
 - (a) a general description of the threatened species or populations known or likely to be present in the area that is the subject of the action and in any area that is likely to be affected by the action,
 - (b) an assessment of which threatened species or populations known or likely to be present in the area are likely to be affected by the action,
 - (c) for each species or population likely to be affected, details of its local, regional and State-wide conservation status, the key threatening processes generally affecting its habitat requirements and any recovery plan or threat abatement plan applying to it,
 - (d) an estimate of the local and regional abundance of those species or populations,

- (e) a general description of the threatened species or populations known or likely to be present in the area that is the subject of the action and in any area that is likely to be affected by the action,
 - (f) a full description of the type, location, size and condition of the habitat (including critical habitat) of those species and populations and details of the distribution and condition of similar habitats in the region,
 - (g) a full assessment of the likely effect of the action on those species and populations, including, if possible, the quantitative effect of local populations in the cumulative effect in the region,
 - (h) a description of any feasible alternatives to the action that are likely to be of lesser effect and the reasons justifying the carrying out of the action in the manner proposed, having regard to the biophysical, economic and social considerations and the principles of ecologically sustainable development,
 - (i) a full description and justification of the measures proposed to mitigate any adverse effect of the action on the species and populations, including a compilation (in a single section of the statement) of those measures,
 - (j) a list of any approvals that must be obtained under any other Act or law before the action may be lawfully carried out, including details of the conditions of any existing approvals that are relevant to the species or population.
- (3) A species impact statement must include the following information as to ecological communities:
- (a) a general description of the ecological community present in the area that is subject of the action and in any area that is likely to be affected by the action,
 - (b) for each ecological community present, details of its local, regional and State-wide conservation status, the key threatening processes generally affecting it, its habitat requirements and any recovery plan or any threat abatement plan applying to it,
 - (c) a full description of the type, location, size and condition of the habitat of the ecological community, and details of the distribution and condition of similar habitat in the region,

- (d) a full assessment of the likely effect of the action on the ecological community, including, if possible, the quantitative effect of local populations in the cumulative effect in the region,
 - (e) a description of any feasible alternatives to the action that are likely to be of lesser effect and the reasons justifying the carrying out of the action in the manner proposed, having regard to the biophysical, economic and social considerations and the principles of ecologically sustainable development,
 - (f) a full description and justification of the measures proposed to mitigate any adverse effect of the action on the ecological community, including a compilation (in a single section of the statement) of those measures,
 - (g) a list of any approvals that must be obtained under any other Act or law before the action may be lawfully carried out, including details of the conditions of any existing approvals that are relevant to the ecological community.
- (4) A species impact statement must include details of the qualifications and experience in threatened species conservation of the person preparing the statement and of any other person who has conducted research or investigations relied on in preparing the statement.
- (5) The requirements of subsections (2) and (3) in relation to information concerning the State-wide conservation status of any species or population, or any ecological community, are taken to be satisfied by the information in that regard supplied to the principal author of the species impact statement by the National Parks and Wildlife Service, which information that Service is by this subsection authorised and required to provide.
-

Attachment A2

North's Statement of Intent

NORTH LIMITED

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**STATEMENT OF INTENT BY NORTH LIMITED****Concerning the Proposed Cowal Gold Project****Overall Environmental Intent**

North recognises that the proposed Cowal Gold Project lies directly within an area acknowledged for its high conservation status as an inland wetland ecosystem. This Environmental Impact Statement endeavours to address in a comprehensive way the interaction of the proposed mine with that ecosystem, both in terms of the ecosystem's components and as a whole. The design and operation of the proposed mine, as well as final closure objectives, have been developed around ecologically driven principles. This fundamental philosophy has guided the proposed placement of key facilities, their shape, stability, final use and, in particular, the way in which the area is to be rehabilitated. North has recognised that in planning for a development in this area, the long term preservation of critical conservation values must be taken into account. Should development consent be obtained, North are committed to developing, operating, decommissioning and rehabilitating the Cowal Gold Project in such a manner as to ensure that the conservation status of the lake is unaffected and that critical conservation values are preserved for future generations.

Overall Approach to Issues

North's objective is to build consensus on the development of the Cowal Gold Project. In doing so North will engage in a comprehensive Environmental Impact Assessment process, consult openly with all stakeholders, listen genuinely to issues raised and address those issues in a constructive way. Information on the Project will be made as widely available as possible. North will encourage public and government agency review of its proposals as well as conducting a rigorous internal review programme.

Development Concept

In preparing this new Development Application and Environmental Impact Statement for the Cowal Gold Project, North has sought to address concerns raised in the consideration of the original proposal submitted for development consent in 1995. This new proposal for the Cowal Gold Project includes:

- Relocation and ecologically sensitive reformation of a section of the lake foreshore to keep the development separate from Lake Cowal. This will be done to maximise synergy with the existing shoreline features and ecology, ensure long term stability and achieve appropriate noise, dust, water quality and light control outcomes.
- The development of an open cut mine which extends beyond the high water mark of the Lake has required North to examine in detail the long term options for the final void and the protection of ecological values.
- A significantly different processing proposal for mined gold bearing ore which includes the:
 - use of a flotation (or concentrator) circuit to significantly reduce cyanide use;
 - use of cyanide destruction and recycling technologies;
 - movement of the tailings storages 3.5 km from the lake;
 - reduction in the number of tailings storage cells from four to two.
- The emplacements which will permanently store rock which contains no commercial gold (waste rock) will be developed and rehabilitated in such a way as to both ensure protection of the surrounding environment and provide for enhanced flora and fauna habitat.
- The powerline to the Project has been relocated from the previously proposed route between Lake Cowal and Nerang Cowal and is aligned to avoid migratory waterbird flight paths.

These proposals and how they were derived in preference to other options are addressed in detail in this new Environmental Impact Statement. This new Environmental Impact Statement also provides detail on studies recently undertaken to address the issue of the Cowal Gold Project's long term compatibility with Lake Cowal. In terms of the economic benefits the Cowal Gold Project can bring to rural NSW, North will seek to maximise local employment and use of services.

STATEMENT OF INTENT BY NORTH LIMITED Continued

Specific Environmental Undertakings

Since the last Development Application North has made a number of environmental undertakings. These are reiterated in this Statement of Intent. As part of the new Development Application, North will:

- ensure bird breeding areas at the north of Lake Cowal remain undisturbed by the mine;
- ensure that the quality of water in Lake Cowal is not detrimentally affected by the mine;
- set a new standard in cyanide control which can protect bird life and uses state of the art technology;
- provide appropriate security to the government to ensure the area is fully rehabilitated;
- support activities which promote special interest tourism and long term sustainable development in the Lake Cowal region;
- carry out its activities in a manner which is consistent with the *NSW State Wetlands Management Policy (1996)*.

Signed



Richard Knight

Executive Director – Development

Attachment A3

Cowal Gold Project Area Botanical Survey, 1997

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1.0 INTRODUCTION

As part of the original EIS for the Cowal Gold Project a report on the terrestrial flora of the Lake Cowal District was prepared by Anne Clements and Associates (Appendix F, August 1995). The surveys were carried out during 19–25 October and 1–7 December 1993 after good rainfall in late winter and spring. The lake was full at the time of sampling.

This 1993 survey recorded 411 species of which 21% were exotic species (weeds). None of these species were in the Briggs and Leigh (1988) or the then current CSIRO ROTAP listing. Five species (*Hypericum perforatum*, *Lycium ferocissimum*, *Sorghum halepense*, *Xanthium occidentale* and *X. spinosum*) were on the Bland Shire's noxious weeds list. Only *L. ferocissimum* was recorded in the project area in one quadrat of transect 12.

The 1997 project area is approximately 6 km east-west and 5 km north-south (Figure 1). The 1993 survey covered an area of 20 km east-west and 37 km north-south. In the 1993 survey 126 spot locations were surveyed for tree and shrub presence/absence although the dimensions of the "spots" were not specified. In addition 115, 10 m wide transects were surveyed. The transects appeared to consist of 3 contiguous 10 x 10 m quadrats in which species presence/absence was recorded to permit an assessment of relative frequency. Analysis of data from Anne Clements & Associates (1995) is presented in Appendix 1. Of the spot locations, 7 of 126 (6%) were inside or within 1 km of the 1997 project area, while 14 of the 115 transects (12%) were inside or within 1 km of the project area.

In the present study quadrat based cover/abundance assessments of specific areas of the project area such as the tailings storage, waste emplacements and mine pit area were carried out to increase the botanical data available.

Recently a list of ROTAP and threatened species that might occur at the site has been developed by Dr C. Bower and the NSW NP&WS (Tables 1 and 2) and targeted searches for these species also occurred.

2.0 MATERIALS AND METHODS

Forty-one semi-permanent quadrats were established in the following areas, with the number of quadrats per area in brackets:

- i) the northern tailings storage area (4),
- ii) the southern tailings storage area (4),
- iii) Cowal West Hill (4),
- iv) the northern waste emplacement (5),
- v) the southern waste emplacement (5), and
- vi) the mine pit and processing plant area including:
 - a) the dryland area (6),
 - b) the 1 – 2 km of lake edge or shoreline that would be affected by the pit or bund (5), and
 - c) the lake bed (8).

Figure 2 presents the general arrangements of the Project and Figure 3 presents survey quadrat locations.

The quadrats were 10 x 10 m. Most, if not all, of the project area is agricultural land. Previous studies in similar pasture types has shown 4 x 4 m to be an effective minimal quadrat size and thus 10 x 10 m allows a large safety margin. A cover/abundance measure was assigned to each species based on a modified Braun-Blanquet scale (Table 3). The quadrats were established and assessed during 22 – 24 September 1997 and assessed again during 18 – 19 October 1997.

Table 1 List of endangered, vulnerable and threatened plant species that may occur at the project site. The "Flora" column provides the volume and page number for these species in the Flora of NSW (Harden 1990 – 1993). The "sub" column indicates how many botanical subdivisions in NSW (Flora of NSW) the species is recorded for. Habitat descriptions are from the Flora of NSW.

Species	Family	Flora	Sub	Habitat
<i>Pilularia novae-hollandiae</i>	Marsileaceae	1:71	3	seasonally dry depressions and margins of marshes
<i>Lepidium aschersonii</i>	Brassicaceae	1:470	2	no habitat description
<i>Swainsona recta</i>	Fabaceae, Faboideae	2:435	4	grows in grassland and open woodland, often on stony hillsides
<i>Swainsona murrayana</i>	Fabaceae, Faboideae	2:439	5	often grows with <i>Maireana</i> species on heavy soils, especially in depressions
<i>Kippistia suaedifolia</i> (syn. <i>Minuria suaedifolia</i>)	Asteraceae	3:169	1	saline lakes and depressions, often in association with gypsum
<i>Stemmacantha australis</i>	Asteraceae	3:327	2	usually grows on heavy soils
<i>Goodenia macbarroni</i>	Goodeniaceae	3:459	7	grows in damp sandy soils
<i>Tylophora linearis</i>	Asclepiadaceae	3:533	2	grows in dry scrub in the West Wyalong districts
<i>Callitriche cyclocarpa</i>	Callitrichaceae	3:622	??	this species is not listed in the Flora of NSW
<i>Bothriochloa biloba</i>	Poaceae	4:440	6	grows in woodland on poorer soils
<i>Stipa wakoolica</i>	Poaceae	4:647	2	grows on floodplains of the Murray R. tributaries

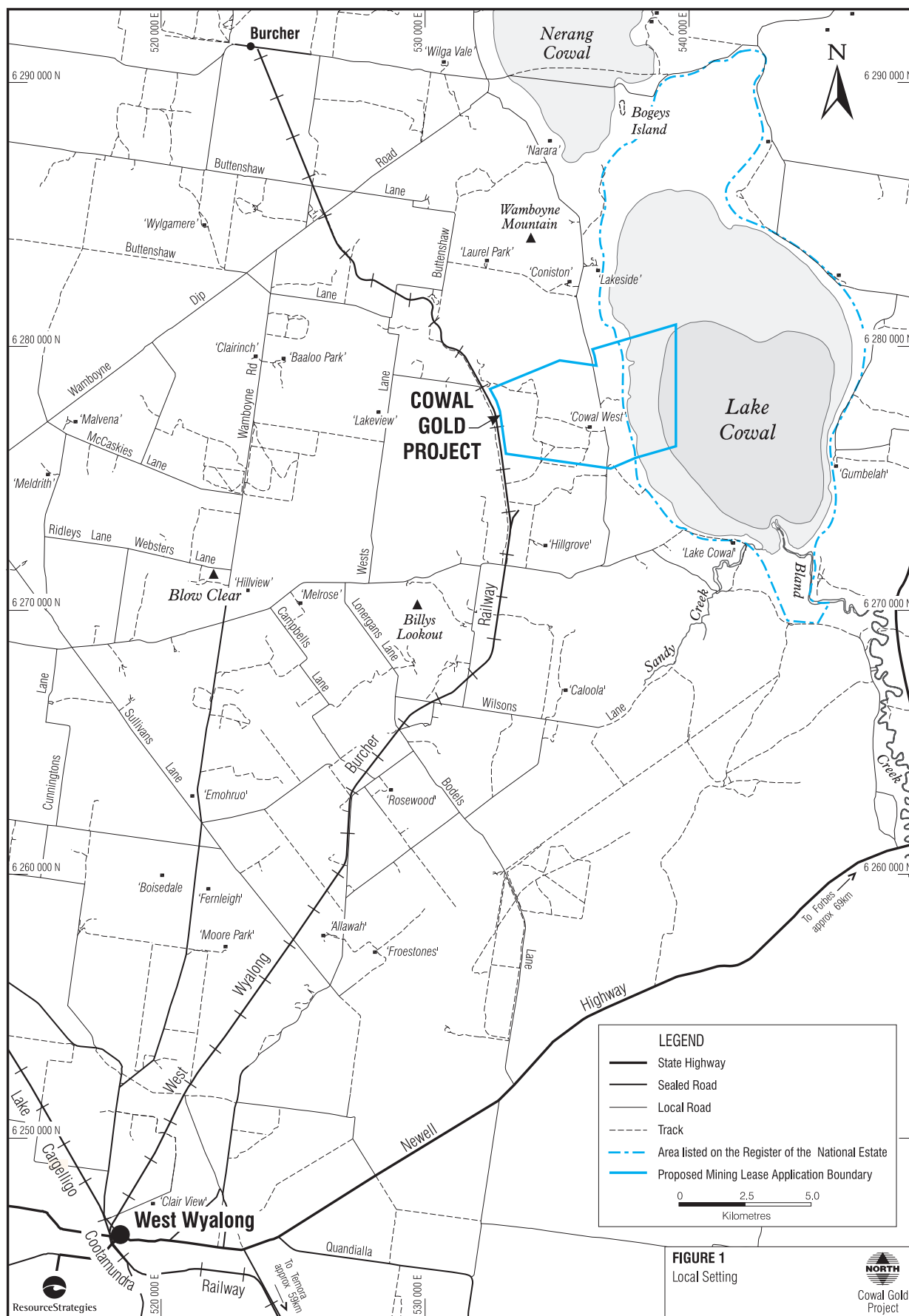


Table 2 Conservation status of the species listed in Table 1. ESPA = Endangered Species Protection Act 1992, TSCA = Threatened Species Conservation Act 1996.

Species	ESPA – older version	ESPA – August 1997	TSCA 1996
<i>Pilularia novae-hollandiae</i>	–	–	endangered
<i>Lepidium aschersonii</i>	endangered	–	vulnerable
<i>Swainsona recta</i>	endangered	endangered	endangered
<i>Swainsona murrayana</i>	vulnerable	vulnerable	vulnerable
<i>Kippistia suaedifolia</i> (syn. <i>Minuria suaedifolia</i>)	–	–	endangered
<i>Stemmacantha australis</i>	endangered	endangered	presumed extinct
<i>Goodenia macbarroni</i>	–	vulnerable	vulnerable
<i>Tylophora linearis</i>	–	endangered	endangered
<i>Callitriche cyclocarpa</i>	vulnerable	vulnerable	vulnerable
<i>Bothriochloa biloba</i>	vulnerable	vulnerable	vulnerable
<i>Stipa wakoolica</i>	–	–	endangered

The quadrats on the lake bed were 90 m apart and were part of a transect that was perpendicular to the lake shore starting near the North Limited sheds. The furthest quadrat (Q30) was adjacent to the rain gauge station and at the time of the September sampling the lake's water level was approximately 100 m further out from this point. In the dryland areas quadrats were generally widely dispersed in the specified areas but quadrats were selectively located where there appeared to be a diversity of species, ie. within most areas there was a distinct patchiness in the vegetation and thus if there was a weed dominated area next to an area with what appeared to be a high diversity of native species the latter was chosen. Thus the quadrat results present a more favourable assessment (from a botanical rather than an agricultural viewpoint) of the vegetation than would totally random location of the quadrats.

At the September assessment few native grasses or

chenopods were recorded as they had not or were just beginning to flower. The gilgai depressions were full of water at the time of the September assessment. At the October assessment only the largest gilgai depressions were at most partially filled, the top soil was dry in all areas including the lake bed and several previously abundant annual species had withered away. Between the two assessment periods the northern 40% of the northern tailings cell had been sprayed with glyphosate (Roundup CT) (C. Carnegie pers. comm.) and thus Q33 was not reassessed.

In addition to the quadrat based sampling searches for the listed ROTAP and threatened species (Tables 1 and 2) were also carried out.

3.0 RESULTS

The principal results are presented in the following tables and Figure 4. Figure 4 presents a plan of vegetation communities for the Project area and surrounds. For a full listing of species recorded for each quadrat and their cover/abundance values see Appendix 2. A total of 141 species were recorded of which 42 (29.8%) were weed species.

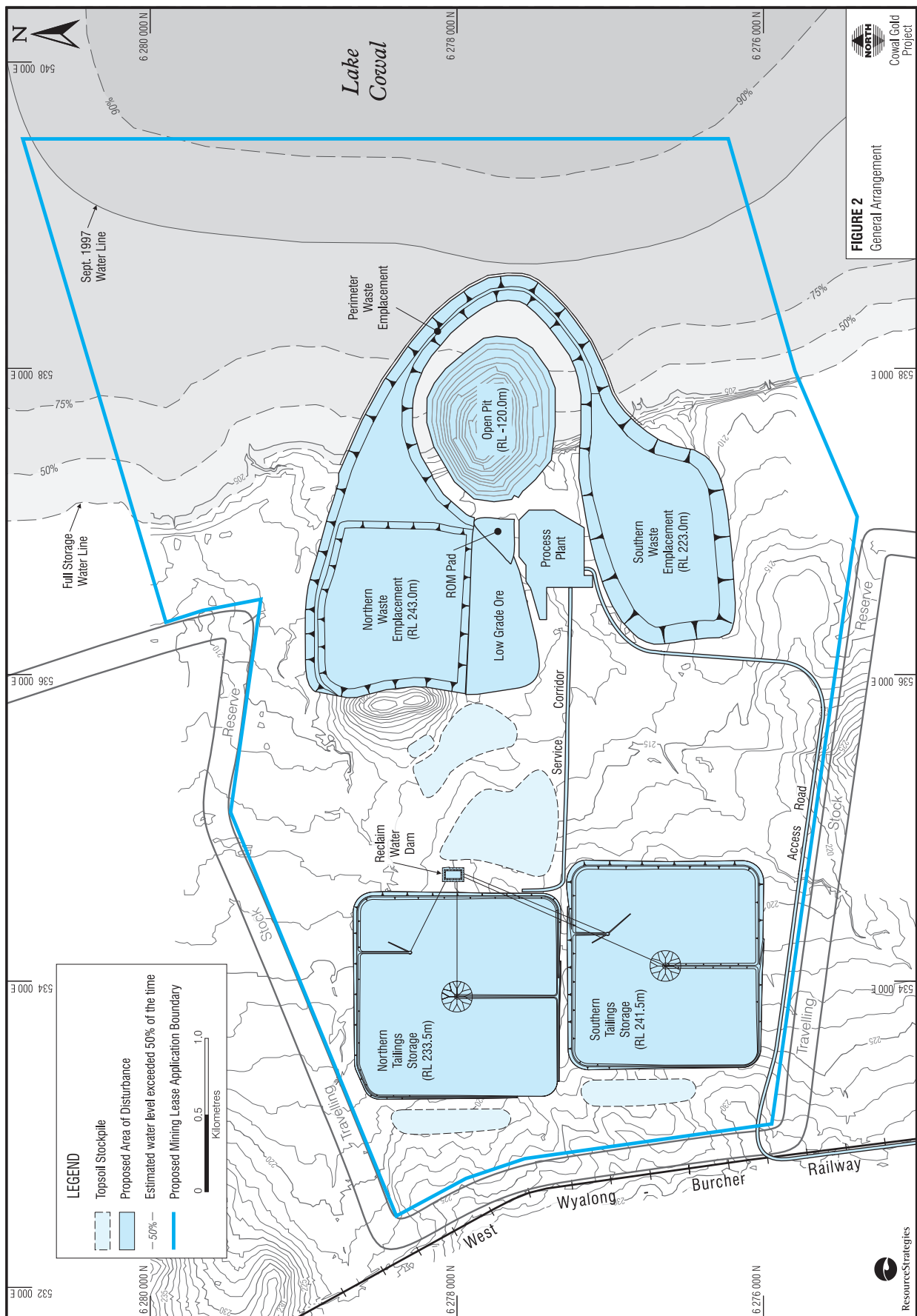
Table 10 indicates that when few species are recorded in a quadrat it is probable that most of these species will be weeds and conversely that when a large number of species are recorded most of these will be natives. Table 10 also indicates that the lake bed and shoreline were the most disturbed areas surveyed and the waste emplacements had the greatest diversity of native species. However the lowest percentage of weeds recorded in any quadrat was 31% (Q3) and only 8 of the 41 quadrats had less than 40% weed

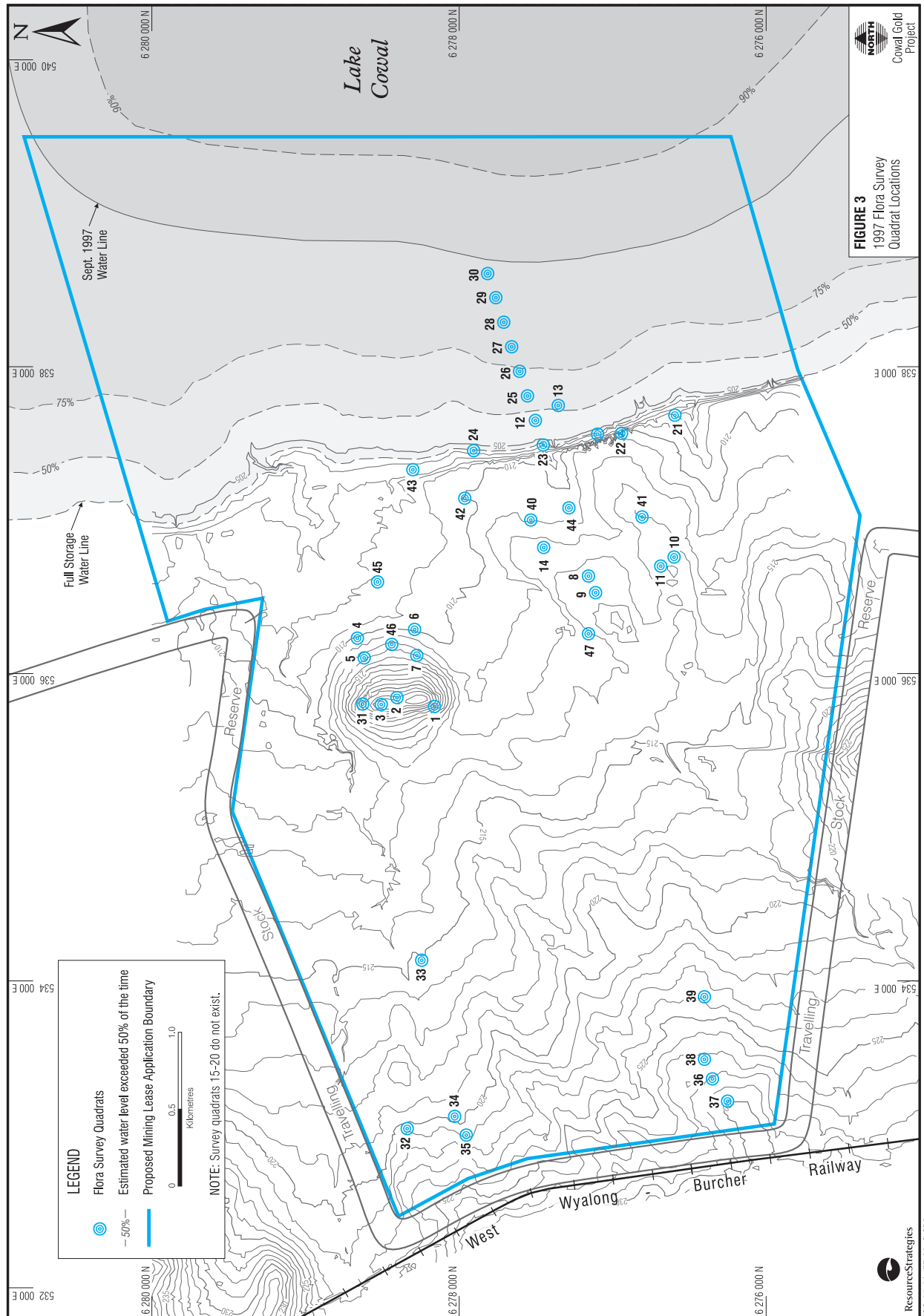
Table 3 Modified Braun-Blanquet Cover Abundance Values

Cover abundance value	Description
1	uncommon and < 5% cover
2	common and < 5% cover
3	abundant and < 5% cover
4	5 – 25% cover
5	25 – 50% cover
6	50 – 75% cover
7	75 – 100% cover

Table 4 Lake Bed

	Q12	Q13	Q25	Q26	Q27	Q28	Q29	Q30	Average
Total No. Species	16	14	9	9	14	14	9	14	12
No. weed species	11	10	8	5	9	8	5	7	7.9
% weed species	68.8	71.4	88.9	55.6	64.3	57.1	55.6	50	64
No. native species	5	4	1	4	5	6	4	7	4.5





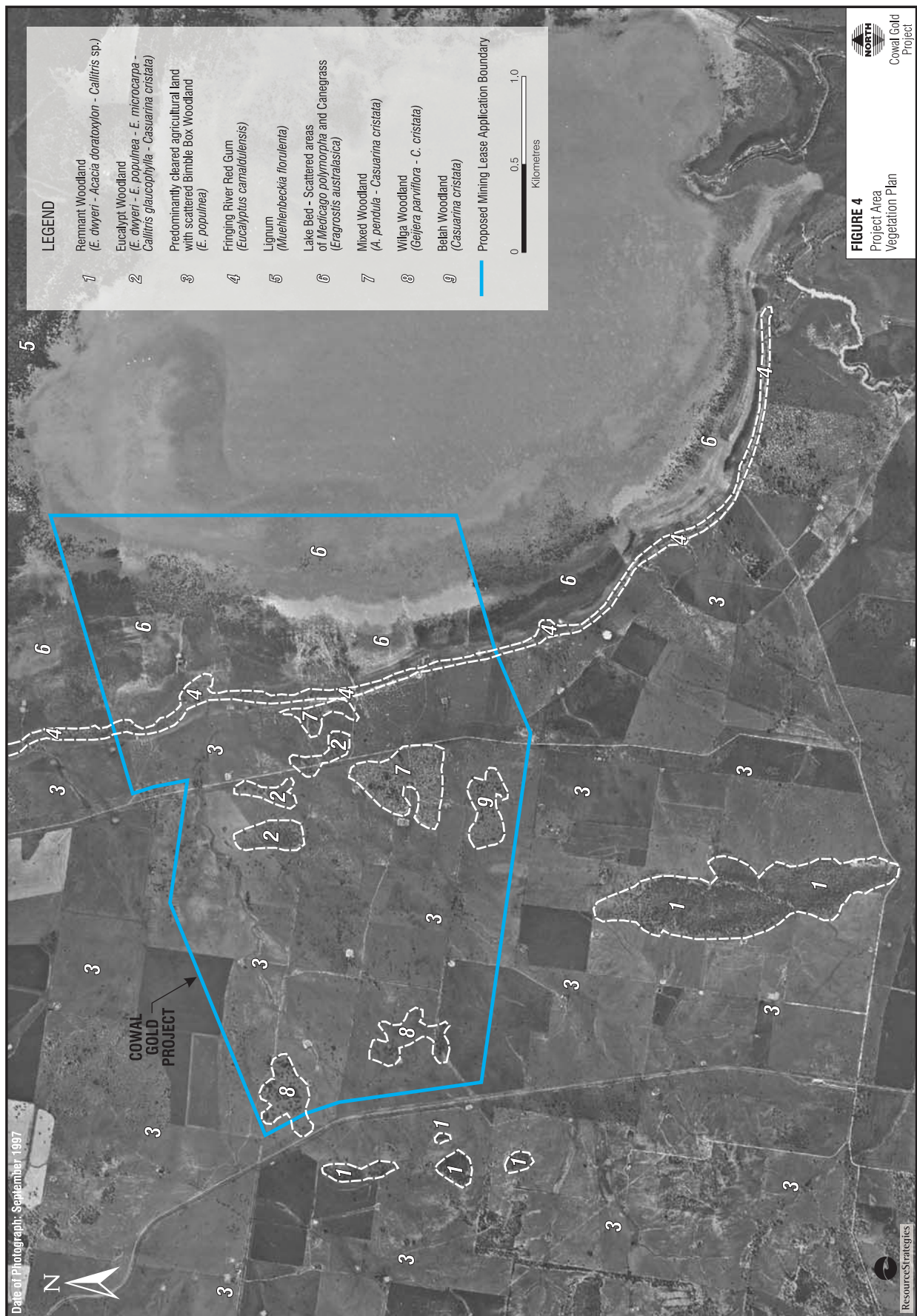


Table 5 Shoreline

	Q21	Q22	Q23	Q24	Q43	Average
Total No. Species	27	37	20	19	33	27
No. weed species	17	24	12	12	20	17
% weed species	63	64.9	60	63.2	60.6	62
No. native species	10	13	8	7	13	10

Table 6 Northern and Southern Tailings Cells

	Q32	Q33	Q34	Q35	Q36	Q37	Q38	Q39	Average
Total No. Species	28	'18'	20	32	31	30	23	27	26
No. weed species	15	'9'	10	18	13	12	12	17	13
% weed species	53.6	'50'	50	56.3	41.9	40	52.2	63	51
No. native species	13	'9'	10	14	18	18	11	10	13

Table 7 Cowal West Hill

	Q1	Q2	Q3	Q31	Average
Total No. Species	36	40	36	25	34
No. weed species	15	15	11	10	13
% weed species	41.7	37.5	30.6	40	38
No. native species	21	25	25	15	21

Table 8 Quadrats between the Shoreline and the Main Road

	Q14	Q40	Q41	Q42	Q44	Q45	Average
Total No. Species	25	28	37	42	41	38	35
No. weed species	12	14	19	19	17	14	16
% weed species	48	50	51.4	45.2	41.5	36.8	45
No. native species	13	14	18	23	24	24	19

Table 9 Northern and Southern Waste Emplacements

	Q4	Q5	Q6	Q7	Q46	Q8	Q9	Q10	Q11	Q47	Average
Total No. Species	49	50	43	42	56	46	47	49	44	48	47
No. weed species	19	22	19	21	22	20	17	18	19	19	20
% weed species	38.8	44	44.2	50	39.3	43.5	36.2	36.7	43.2	39.6	42
No. native species	30	28	24	21	34	26	30	31	25	29	28

Table 10 Various Plant Species Diversity Averages for the Six Site Classifications

Site type	Average number of species per quadrat	Average number of weed species per quadrat	Average % of weed species per quadrat	Average number of a native species per quadrat
Lake bed	12	7.9	64	4.5
Shoreline	27	17	62	10
Tailings storage	26	13	51	13
Cowal West Hill	34	13	38	21
Shoreline to main road	35	16	45	19
Waste emplacements	47	20	42	28

species indicating that all the sampled areas of the project site are quite disturbed. That 30% of the species recorded for the project area were weeds while in each quadrat weed species constituted more than 31% of the species recorded

indicates that the weed species are generally widespread and/or abundant.

The vast majority of the cover/abundance values were three or less, ie. less than 5% cover (Appendix 2). Table 11 lists

those species for which a cover/abundance value of four or greater was recorded at least once.

Table 11 Species recorded with a cover/abundance value of 4 or greater. A recording of, for example, '6@4' indicates the species was recorded at 6 quadrats with a cover/abundance value of 4.

Species	Total no. of quadrats with cover/abundance >3	Number of quadrats @ cover/abundance >3
* <i>Arctotheca calendula</i>	8	6@4, 2@5
<i>Calocephalus sonderi</i>	4	2@4, 1@5, 1@6
<i>Hyalosperma semisterile</i>	2	2@4
* <i>Hypochaeris glabra</i>	1	1@4
<i>Rhodanthe corymbiflora</i>	2	2@4
<i>Rhodanthe floribunda</i>	1	1@4
<i>Rhodanthe pygmaea</i>	4	4@4
* <i>Echium plantagineum</i>	1	1@5
* <i>Sisymbrium irio</i>	2	1@4, 1@5
* <i>Medicago polymorpha</i>	12	3@4, 1@5, 2@6, 6@7
* <i>Trifolium arvense</i>	1	1@4
* <i>Trifolium glomeratum</i>	1	1@4
* <i>Trifolium subterraneum</i>	1	1@4
* <i>Trifolium tomentosum</i>	3	2@4, 1@5
* <i>Erodium moschatum</i>	1	1@4
* <i>Bromus hordeaceus</i>	1	1@4
<i>Eragrostis australasica</i>	4	3@4, 1@5
* <i>Hordeum leporinum</i>	6	3@4, 2@5, 1@6
* <i>Hordeum marinum</i>	1	1@4
* <i>Lolium perenne</i>	9	3@4, 3@5, 3@6
* <i>Vulpia</i> sp.	4	4@4

* Weed Species

Table 11 is dominated by weed species and shows that simply stating the average percentage of weed species per quadrat (Table 10) underestimates the 'weediness' of the quadrats, especially for the lake bed, shoreline and tailing cells.

In terms of presence/absence rather than cover/abundance the 9 most common species recorded were all weeds (*Trifolium glomeratum*, *Hypochaeris glabra*, *Arctotheca calendula*, *Sonchus oleraceus*, *Vulpia* sp., *T. tomentosum*, *Hordeum leporinum*, *Lolium perenne* and *Medicago polymorpha*) and they were found at 27 to 38 of the 41 quadrats (Appendix 2). Note that all of these species, except *Sonchus oleraceus*, are present in Table 11. Fifteen of the 21 most common species were weeds.

In terms of presence/absence the most common native species were, in descending order, *Stipa scabra*, *Crassula sieberana*, *Danthonia* sp., *Plantago turritifera*, *Maireana humillima*, *Enteropogon acicularis*, *Vittadinia* sp., *Calocephalus sonderi*, *Sida corrugata*, *Erodium crinitum*,

Sclerolaena birchii, *Rhodanthe corymbiflora*, *Isoetopsis graminifolia*, *Rhodanthe pygmaea*, *Calotis hispidula*, *Oxalis perennans* and *Einadia nutans* (Appendix 2). Note that in contrast to the weed species only three of these native species are present in Table 11.

Of the 141 species 73 were found in 1-5 quadrats, 30 in 6-10 quadrats, 7 in 11-15 quadrats, 11 in 16-20 quadrats, 9 in 21-25 quadrats and 11 in 26-38 quadrats.

A brief botanical description of the areas is as follows:

i) Northern Tailings Storage Area

The main feature of this area was two relatively dense stands of *Casuarina cristata*. The understorey beneath these was dominated by two weed species *Sisymbrium irio* and *Urtica urens* as these areas would be used as stock camps.

ii) Southern Tailings Storage Area

At the time of sampling over 90% of this area was under a wheat crop. The area sampled was a 20 - 40 m wide access path between two wheat fields. Quadrat 38 was located near a dense clump of *Casuarina cristata* and had the same domination as Qs 32 and 34 by *Sisymbrium irio*. South west of these trees were some wildflower displays dominated by species of *Hyalosperma*, *Rhodanthe* and *Goodenia*. As noted a large part of the northern tailings storage area was sprayed with herbicide in what was probably preparation for sowing a crop in autumn 1998. Presumably this also occurred to the southern tailings storage area and represents a major periodic vegetation disturbance for most of the western half of the project area.

iii) Cowal West Hill

While most of the understorey of the hill was dominated by weed grasses (species of *Bromus*, *Hordeum*, *Lolium* and *Lamarckia*) and *Arctotheca calendula* there were some areas (Qs 2 and 3) with a relatively high diversity of native species (25 species respectively). A fence runs approximately north-east to south-west across Cowal West Hill. The northern paddock has a much greater cover of *A. calendula* than the southern paddock.

iv) Northern and Southern Waste Emplacements, Dryland Pit and Processing Area

As in most parts of the project site this area was quite variable with weed dominated areas interspersed with areas with a relatively high native species diversity and abundance. Quadrats 4, 5, 8, 9, 10, 11, 46 and 47 in the waste emplacement were the 8 most diverse quadrats assessed and averaged over 29 native species per 10 x 10 m.

v) Lake Shoreline

The banks of the shoreline were dominated by weeds (Table 10) and even the less disturbed areas had a small number of native species in low abundance.

vi) Lake Bed

Unlike the areas described above the lake bed was very uniform in species composition. This area was dominated by *Medicago polymorpha* and to a lesser extent *Eragrostis australasica*. Besides the cane grass if other native species previously grew here as the lake receded they are essentially

no longer present. It is possible but unlikely that other species might grow on the lake bed after good autumn rains or a summer/autumn recession of the lake.

No species from the list targetted species (Tables 1 and 2) were recorded in the quadrat surveys or in general traverses of the site.

4.0 DISCUSSION

The lake bed in the project area had a simple plant community dominated by a single weed species and a single widespread native grass species. The shoreline has a greater species diversity but is dominated by weed species. The areas proposed for the tailings storage, waste emplacement and processing area are variable in composition with weed dominated areas adjacent to areas with a relatively high diversity of native species. All the native species recorded are widespread and relatively common in NSW.

The areas that would be extensively disturbed in the proposed project are either:

- i) dominated by weeds (the lake bed, the shoreline and the understorey of the woodland/forest areas),
- ii) extensively cropped (most of the tailings storage areas), or
- iii) have some areas of relatively high native plant species abundance and diversity even after many decades of domestic stock grazing and some cultivation but these native species are not restricted to the project area or the Lake Cowal region.

A similar survey was conducted during the spring of 1996 in the White Cypress Pine dominated State Forests between Wagga Wagga and Narrandera (National Estates Project 96 422 "Assessment of the Conservation Value of White Cypress Pine State Forests"). See Table 12 for a summary of the main results of this study.

In study NEP 96 422 each of the 105 quadrats was assessed 4 times at monthly intervals during spring and early summer and thus higher species numbers per quadrat could be expected than in the present study. On the basis of the September and October assessments at the project area it appears that the waste emplacements are very similar, in terms of average total species diversity, native species diversity and weed percentages, to a White Cypress Pine State Forest in the South West Slopes under moderate to high grazing pressure. Thus, in comparison to areas with limited grazing, it appears that the waste emplacements are not of high conservation value especially given their percentage of weed species and that the sample quadrats were preferentially placed in areas of apparent native plant species diversity.

Anne Clements and Associates (1995) recorded a list of indicator species of different grazing regimes. The species they associate with no/limited grazing were not found in any quadrats of the present study while the four species associated with very severe grazing (*Hordeum leporinum*, *Medicago polymorpha*, *Carthamus lanatus* and *Arctotheca calendula*) were frequently recorded in the present study and at least one of these four species was found in every quadrat assessed.

In summary, the areas that would be extensively disturbed have had a long history of agricultural modification and the plant species that are now present are either weeds or native species that are common in similar habitats in the Central West Plains and the South West Plains and often in other regions of NSW and states of Australia.

5.0 REFERENCES

- Briggs, J.D. and Leigh, J.H. (1988). *Rare or Threatened Australian Plants*. Special Publication No. 14. Australian National Parks and Wildlife Service, Canberra.
- Clements, Anne and Associates (1995). *Lake Cowal Gold Project*. Appendix F: Terrestrial Flora Report: Lake Cowal District.
- Harden, G.J. (1990-1993). *Flora of New South Wales*. Vols 1 – 4. NSW University Press.

Table 12 Main results of study NEP 96 422

Site type	Average number spp. per quadrat	Average % weed species per quadrat	Average number native spp. per quadrat
Severe grazing	29.4	59	11.1
Moderate to high grazing pressure	50.7	39.5	29.9
Limited grazing	49.6	29.5	37.2

Appendix 1

Analysis of Data from Anne Clements and Associates (1995) for Transects 11-13 and 84-93 and 7 Spot Locations

Analysis of data from Anne Clements and Associates (1995) for transects 11-13 & 83-93 and 7 spot locations.

Anne Clements and Associates (1995, Appendix F) did not provide a listing of how many species were recorded in each of their transects nor a total of how many times a species was recorded in the 115 transects (345 quadrats). These figures are provided for the transects within or near the project area in Table 1 and Appendix 2. Of the 411 species found in the regional study 122 (30%) were recorded in the project area. The main finding is that the transects in the woodland or lower slope areas (transects 84-87) had a relatively high native species diversity (av. 22 native species/transect, ie. 22 native species in 10 x 30 m) while the other transects had an average of only 11 native species/transect. Five transects were recorded as having no weed species while 7 had over 25% weed species and in 2 transects almost half the species recorded were weeds.

Of the project area's 122 species 84 (69%) were found in 4 or less of the 42 quadrats which make up the 14 transects,

ie. most species recorded were of limited distribution in the project area although widely different habitats were assessed and therefore few species would be recorded in a large number of quadrats.

The spot locations (Table 2) recorded relatively few species compared to the transects.

In terms of the area classifications used in the 1997 study Clements' transects and spot locations can be classified as follows:

Lake bed: - - - -

Shoreline: 3N, T88, T91, T93

Tailings cells: - - - -

Cowal West Hill: T86

Shoreline to main road: 4G, 2P, 3D, T11-13, T89, T90, T92

Waste emplacements: 2H, 4H, 4F, T83-85, T87

A comparison of the transect figures of Anne Clements and Associates with those of the present study for the waste emplacements are provided below (Table 3).

Table 1 Various Species Records for the Transects of Anne Clements and Associates that were within the Project area

	11	12	13	83	84	85	86	87	88	89	90	91	92	93
Total no. spp.	15	27	29	11	27	26	32	37	11	4	14	5	25	4
No. weed spp.	0	12	11	0	7	7	10	10	2	0	2	0	13	0
% weed spp.	0	44	38	0	26	27	31	27	18	0	14	0	52	0
No. native spp.	15	15	18	11	20	19	22	27	9	4	12	5	12	4

Table 2 Species recorded in the Spot Locations Assessed in the Project area

	2H	2P	3?D	3N	4F	4G	4H
<i>Callitris glaucophylla</i>			•				
<i>Calotis hispidula</i>		•					
<i>Allocasuarina luehmannii</i>			•			•	
<i>Casuarina cristata</i>		•			•		•
<i>Acacia pendula</i>	•	•					
<i>Eremophila mitchellii</i>		•					
<i>Eucalyptus camaldulensis</i>				•			
<i>Eucalyptus microcarpa</i>			•		•		
<i>Eucalyptus populnea</i>		•					
<i>Amyema miquelii</i>	•						
<i>Geijera parviflora</i>		•			•		
<i>Alectryon oleifolius</i>		•			•		
<i>Stackhousia monogyna</i>			•				
<i>Stipa scabra</i>			•				

Table 3 Various Average Figures regarding Plant Species Diversity of the 1993 and 1997 studies for the Waste Emplacement Areas

	1993	1997
Average no. spp.	25	47
Average no. weed spp.	6	20
Average % weed spp.	27	42
Average no. native spp.	19	28

Appendix 2

Species Records for the Project Site

The recordings include those of Anne Clements and Associates (T11-13, 83-93) from 1993 and those of Burrows (Q1-14, 21-47). The 1993 values indicate the presence/absence of a species in 3 contiguous quadrats, thus a value of 2 indicates the species was present in 2 of the 3 quadrats which composed a transect. The 1997 values are Braun-Blanquet cover/abundance values for the September and October assessments, thus a recording of '4,1' indicates that species had 5 - 25% cover at the September assessment but was uncommon and <5% cover at the October assessment.

Family	Intro	Genus	Species	Subspecies Form/Var	Common Name	T11	T12	T13	T83	T84	T85	T86	T87	T88	T89	T90	T91	T92	T93	#
MARSILEACEAE		Marsilea	angustifolia		Narrow-leaf Nardoo						1									1
MARSILEACEAE		Marsilea	drummondii		Common Nardoo	3			1							2				3
MARSILEACEAE		Marsilea	hirsuta		Nardoo				3											1
MARSILEACEAE		Pilularia	novae-hollandiae		Austral Pillwort	1														1
SINOPTERIDACEAE		Cheilanthes	sieberi	sieberi	Mulga Fern							1								1
CUPRESSEACEAE		Callitris	glaucoophylla		White Cypress Pine							3								1
AMARANTHACEAE		Alternanthera	species A		Joyweed	1			2					2		3	3	1		6
AMARANTHACEAE		Ptilotus	semilanatus		Lamb's Tails					1										1
APIACEAE		Daucus	glochidiatus	form D	Australian Carrot						1									1
ASTERACEAE	•	Arctotheca	calendula		Capeweed		2	2				2	1							4
ASTERACEAE		Bracteantha	bracteata		Sticky Everlasting							3								1
ASTERACEAE		Calocephalus	sonderi		Pale Beauty-heads					3	2	1	3					3		5
ASTERACEAE		Calotis	hispidula		Bogan Flea		1			3			3							3
ASTERACEAE	•	Centaurea	melitensis		Maltese Cockspur									1						1
ASTERACEAE	•	Cirsium	vulgare		Spear Thistle								2							1
ASTERACEAE	•	Conyza	bonariensis		Flaxleaf Fleabane								3							1
ASTERACEAE		Eclipta	platyglossa		Yellow Twin Heads	1			1		2									3
ASTERACEAE		Gnaphalium	sphaericum		Japanese Cudweed								1							1
ASTERACEAE	•	Hypochoeris	glabra		Smooth Cat's Ears							2					2			2
ASTERACEAE		Pseudo-gnaphalium	luteoalbum		Jersey Cudweed													3		1
ASTERACEAE		Rhodanthe	corymbiflora		Grey Sunray			1		1	1		3							4
ASTERACEAE		Rhodanthe	floribunda		Com. White Sunray					2										1
ASTERACEAE	•	Sonchus	asper		Prickly Sow-thistle					1										1
ASTERACEAE	•	Sonchus	oleraceus		Common Sowthistle						2	2	3					2		5
ASTERACEAE		Stuartina	muelleri		Spoon Cudweed							2								1
ASTERACEAE		Triptilodiscus	pygmaeus		Common Sunray								1							1
ASTERACEAE		Vittadinia	cuneata	hirsuta	Fuzzweed				1											1
BORAGINACEAE	•	Echium	plantagineum		Paterson's Curse			3	3		3						2			4
BRASSIACEAE		Lepidium	papillosum		Warty Peppergrass											1				1
BRASSIACEAE		Lepidium	pseudohyssopifolium		Peppergrass						3	1	1							4
BRASSIACEAE	•	Sisymbrium	irio		London Rocket					2			1							3

CARYOPHYLLACEAE • Petrorhagia			velutina	Velvet Pink			1	1
CASUARINACEAE	Casuarina	cristata		Black Oak/Belah			2	1
CHENOPODIACEAE	Atriplex	?spinibractea		Spiny-fruit Saltbush			1	1
CHENOPODIACEAE	Chenopodium	desertorum	microphyllum.	Desert Goosefoot				1
CHENOPODIACEAE	Chenopodium	melanocarpum		Black Crumbweed				2
CHENOPODIACEAE	Einada	nutans	linifolia	Climbing saltbush			2	1
CHENOPODIACEAE	Maireana	enchylaenoides		Wingless Bluebush			1	1
CHENOPODIACEAE	Rhagodia	spinescens		Spiny Saltbush			1	
CHENOPODIACEAE	Salsola	kali	var. kali	Prickly Saltwort				1
CHENOPODIACEAE	Sclerolaena	birchii		Galvanised Burr			2	3
CONVOLVULACEAE	Dichondria	repens		Kidneyweed			1	1
CRASSULACEAE	Crassula	decumbens	decumbrens	Stonecrop			2	
CRASSULACEAE	Crassula	peduncularis		Purple Stonecrop			1	
CRASSULACEAE	Crassula	sieberana		Australian Stonecrop			1	3
ELATINACEAE	Elatine	gratioloides		Waterwort			1	
FABACEAE •	Medicago	polymorpha		Burr Medic			2	
FABACEAE •	Medicago	truncatula		Barrel Medic				2
FABACEAE •	Trifolium	angustifolium		Narrow-leaf Clover			1	1
FABACEAE •	Trifolium	arvense		Haresfoot Clover			1	1
FABACEAE •	Trifolium	glomeratum		Clustered Clover			1	1
FABACEAE •	Trifolium	tomentosum		Woolly Clover				1
FABACEAE	Acacia	pendula		Boree			1	2
GERANIACEAE •	Erodium	cicutarium		Common Crowsfoot			1	
GERANIACEAE	Erodium	crinitum		Blue Crowsfoot				2
GOODENIACEAE	Goodenia	hederacea		Forest Goodenia			1	
HALORAGACEAE	Myriophyllum	crispatum		Water-milfoil			2	
HALORAGACEAE	Myriophyllum	variifolium		Water-milfoil			2	
LAMIACEAE •	Salvia	verbenaca		Wild Sage			1	
LOBELIACEAE	Pratia	concolor		Poison Pratia			2	1
MALVACEAE •	Malva	parviflora		Small-flowered Mallow			3	1
MALVACEAE	Sida	ammophila		Sand Sida			2	
MALVACEAE	Sida	corrugata		Corrugated Sida			3	2

Family	Intro	Genus	Species	Subspecies Form/Var	Common Name	T11	T12	T13	T83	T84	T85	T86	T87	T88	T89	T90	T91	T92	T93	#
MALVACEAE		Sida	trichopoda		Narrow-leaf Sida			2												1
MYRTACEAE		Eucalyptus	camaldulensis		River Red Gum									1		1	1	2	1	5
MYRTACEAE		Eucalyptus	dwyeri		Dwyer's Red Gum							2								1
MYRTACEAE		Eucalyptus	populnea	bimibil	Bimble Box		2				3		1							3
NYCTAGINACEAE		Boerhavia	diffusa/dominii		Tar Vine						3		2							2
ONAGRACEAE		Ludwigia	peplodes	montevideensis	Water Primrose											1				1
OXALIDACEAE		Oxalis	perennans		Wood-Sorrel		1	2				2	2							4
PLANTAGINACEAE		Plantago	cunninghamii		Sago-weed				2											1
PLANTAGINACEAE		Plantago	turrifera		Small Sago-weed								1							1
POLYGONACEAE		Muehlenbeckia	florulenta		Lignum	3								1		2		1		4
POLYGONACEAE	•	Polygonum	aviculare		Wireweed											1				1
POLYGONACEAE		Rumex	brownii		Slender Dock						2		3							2
POLYGONACEAE	•	Rumex	crispus		Curled Dock									1		3		2		3
POLYGONACEAE		Rumex	tenax		Shiny Dock	1	1													2
SAPINDACEAE		Alectryon	oleifolius	elongatus	Western Rosewood				1				1							2
SCROPHULARIACEAE		Limosella	curdieana		Large Mudwort	1														1
SOLANACEAE	•	Lycium	ferocissimum		African Blackthorn		1													1
SOLANACEAE		Solanum	esuriale		Quena									1						1
SOLANACEAE	•	Solanum	nigrum		Black-berry Nightshade							1								1
VERBENACEAE	•	Phyla	nodiflora		Carpet weed													1		1
ALISMATACEAE		Danthonium	minus		Starfruit	3			3											2
ANTHERICACEAE		Arthropodium	minus		Small Vanilla Lily				1											1
CYPERACEAE		Carex	inversa		Knob Sedge		1				1									2
CYPERACEAE		Cyperus	gymnocaulos		Spiny Sedge									2						1
CYPERACEAE		Eleocharis	plana		Spike Rush				3						1					2
CYPERACEAE		Eleocharis	sp			3														1
JUNCACEAE		Juncus	aridicola		Tussock Rush				1											1
JUNCACEAE		Juncus	flavidus		Tussock Rush	2			3						1					3
JUNCACEAE		Juncus	usitatus		Common Rush				1											1
POACEAE		Agrostis	avenacea	var. avenacea	Blown Grass											2				1
POACEAE		Amphibromus	macrorhinus		Swamp Wallaby Gr.	1			3											2

Family	Intro	Genus	Species	Subspecies Form/Var	Common Name	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Q11	Q12	Q13	Q14	Q21
MARSILEACEAE		Marsilea	sp					"3,1"	"1,0"	"1,2"				"0,1"						
SINOPTERIDACEAE		Cheilanthes	sieberi	sieberi	Mulga Fern															
AMARANTHACEAE		Alternanthera	nana		Hairy Joyweed				"0,1"					"0,1"	"0,1"	"0,1"	"0,1"			
AMARANTHACEAE		Ptilotus	semilanatus		Lamb's Tails			"1,0"												
AMARANTHACEAE		Ptilotus	spathulatus		Pussy-tails						"2,1"	"0,1"	"0,1"	"2,1"	"0,1"	"0,1"				
APIACEAE		Daucus	glochidiatus	form D	Australian Carrot	"1,0"	"0,1"	"1,1"	"0,2"	"0,2"	"3,0"	"3,3"	"3,0"	"3,0"	"2,0"					
ASTERACEAE	•	Arctotheca	calendula		Capeweed	"3,2"	"4,1"	"4,3"	"4,4"	"3,2"	"3,2"	"4,3"	"2,0"		"2,1"		"1,0"		"1,1"	"4,2"
ASTERACEAE		Bracteantha	bracteata		Sticky Everlasting		"1,1"	"0,2"		"0,1"										
ASTERACEAE		Brachycome	lineariloba		Hard-headed Daisy									"2,0"						
ASTERACEAE		Calocephalus	sonderi		Pale Beauty-heads	"0,6"	"0,3"	"0,1"	"0,4"	"0,4"	"0,3"	"0,3"	"0,2"	"0,4"	"0,3"	"0,1"	"0,1"			
ASTERACEAE		Calotis	cuneifolia		Purple Burr Daisy															"0,1"
ASTERACEAE		Calotis	hispidula		Bogan Flea	"2,0"	"3,1"	"3,1"	"3,1"	"2,1"	"3,0"	"3,1"			"2,0"					
ASTERACEAE		Calotis	lappulacea		Yellow Burr Daisy										"0,1"					
ASTERACEAE	•	Carthamus	lanatus		Saffron Thistle		"0,1"	"1,1"	"1,2"	"1,2"	"1,3"	"0,1"	"1,3"							
ASTERACEAE	•	Centaurea	meltensis		Maltese Cockspur							"0,2"								
ASTERACEAE		Chrysocephalum	apiculatum		Yellow Buttons		"1,0"							"3,0"						
ASTERACEAE	•	Cirsium	vulgare		Spear Thistle											"1,0"	"1,1"	"3,2"		
ASTERACEAE		Gnaphalium	sphaericum		Japanese Cudweed															"1,1"
ASTERACEAE	•	Hedynois	rhagodioides		Cretan Weed			"1,1"	"0,2"	"2,2"	"0,3"	"0,2"								
ASTERACEAE		Hyalosperma	semisterile		Golden/Orange Sunray									"4,3"						
ASTERACEAE	•	Hypochoeris	glabra		Smooth Cat's Ears	"2,1"	"1,1"	"4,3"	"3,3"	"3,2"	"3,2"	"3,3"	"2,1"	"2,2"	"2,2"	"3,1"	"0,1"			"0,2"
ASTERACEAE		Isotopsis	graminifolia		Woolly Heads	"1,0"		"3,1"	"3,1"	"3,1"	"3,1"	"3,0"		"1,0"	"3,0"	"3,0"				
ASTERACEAE		Rhodanthe	corymbiflora		Grey Sunray	"2,2"	"3,1"			"0,2"	"0,2"	"0,1"	"0,3"	"3,3"	"3,1"	"4,3"	"0,1"			
ASTERACEAE		Rhodanthe	floribunda		Com. White Sunray				"1,0"	"4,0"	"2,0"	"3,0"	"3,3"	"3,3"						
ASTERACEAE		Rhodanthe	pygmaea		Pigmy Sunray	"2,2"		"0,1"	"3,3"	"3,4"	"3,4"	"3,3"	"3,3"		"3,0"	"2,0"				
ASTERACEAE	•	Soliva	sp			"1,0"	"1,1"	"3,1"	"2,1"	"2,1"	"2,0"	"2,0"		"3,0"	"1,0"	"1,0"				
ASTERACEAE	•	Sonchus	asper		Prickly Sow-thistle			"0,1"									"1,0"	"2,1"		
ASTERACEAE	•	Sonchus	oleraceus		Common Sowthistle		"1,0"	"1,0"	"1,0"	"1,0"	"1,1"	"1,1"	"2,1"	"0,1"	"2,1"	"0,1"	"0,1"	"0,1"		"0,1"
ASTERACEAE		Stuartina	muelleri		Spoon Cudweed	"1,0"	"3,0"	"2,0"	"3,0"		"1,0"	"2,0"								
ASTERACEAE		Triptilodiscus	pygmaeus		Common Sunray	"3,1"	"3,3"	"3,3"	"3,3"	"0,3"	"2,3"	"3,1"			"3,0"					
ASTERACEAE		Vittadinia	PINK/PUR FL				"1,1"	"0,1"	"2,2"	"1,2"	"1,2"	"1,1"	"1,1"	"1,1"	"1,1"					"1,1"

BORAGINACEAE	• Echium	plantagineum	Paterson's Curse	"1,1"	"1,1"	"2,3"	"1,1"	"1,0"	"1,1"	"0,1"	"1,1"	"1,1"	"3,3"
BRASSIACEAE	Lepidium	africanum	Peppergrass							"0,1"		"1,1"	
BRASSIACEAE	Lepidium	pseudohyssopifolium									"0,1"		
BRASSIACEAE	Cuphonotus	humistratus	Mother-of-misery				"1,0"	"1,1"		"2,0"	"1,0"	"3,0"	
CARYOPHYLLACEAE	• Petrorhagia	velutina	Velvet Pink			"0,1"							
CARYOPHYLLACEAE	• Spergularia	rubra	Sandspurrey	"0,1"	"1,1"					"1,1"	"0,1"	"1,1"	"1,2"
CASUARINACEAE	Casuarina	cristata	Black Oak/Belah							"0,1"			
CHENOPODIACEAE	Atriplex	?spinibractea	Spiny-fruit Saltbush							"1,1"	"1,1"	"1,2"	"1,1"
CHENOPODIACEAE	Atriplex	sp				"1,0"							
CHENOPODIACEAE	Atriplex	BUSH										"1,1"	
CHENOPODIACEAE	Chenopodium	desertorum	Desert Goosefoot	"0,1"	"0,1"				"2,1"		"0,1"		
CHENOPODIACEAE	Einada	nutans	Climbing saltbush	"1,1"	"1,1"		"1,1"		"0,1"	"2,1"	"1,0"	"1,1"	"1,1"
CHENOPODIACEAE	Enchylaena	?tomentosa	Ruby Saltbush						"0,1"				
CHENOPODIACEAE	Maireana	?humillima	Bluebush	"0,1"	"1,0"	"1,0"	"1,2"	"1,1"	"1,1"	"1,1"	"0,1"	"0,1"	
CHENOPODIACEAE	Maireana	microphylla	Eastern Cottonbush						"1,1"				
CHENOPODIACEAE	Sclerolaena	birchii	Galvanised Burr	"1,1"	"1,1"	"3,2"	"1,1"	"0,1"	"2,1"	"2,1"	"2,1"	"2,2"	
CHENOPODIACEAE		B. GREEN							"0,1"	"0,1"	"0,1"		
CONVOLVULACEAE	Convolvulus	erubescens	Bindweed				"0,1"		"0,2"	"0,1"			
CONVOLVULACEAE	Dichondria	repens	Kidneyweed			"1,1"							
CRASSULACEAE	Crassula	decumbens	decumbrens									"3,2"	
CRASSULACEAE	Crassula	sieberana	Australian Stonecrop	"3,1"	"3,1"	"3,0"	"3,1"	"2,0"	"3,1"	"2,0"	"1,0"	"2,0"	"1,0"
EUPHORBIACEAE	Chamaesyce	drummondii	Caustic Weed							"1,1"			
FABACEAE	Glycine	sp	Glycine			"0,1"							
FABACEAE	• Medicago	minima	Small Woolly Burr Medic		"2,1"	"3,0"	"2,2"	"2,1"	"3,1"	"3,3"	"1,0"	"3,0"	"1,0"
FABACEAE	• Medicago	polymorpha	Burr Medic	"3,2"	"1,1"	"1,2"	"3,2"	"0,1"	"2,1"	"0,3"	"2,3"	"0,3"	"7,6"
FABACEAE	• Medicago	truncatula	Barrel Medic		"0,2"	"0,1"	"0,1"	"0,1"	"0,2"	"0,1"	"0,2"		"1,3"
FABACEAE	• Trifolium	angustifolium	Narrow-leaf Clover		"0,1"	"0,1"	"0,1"	"0,1"	"0,2"	"0,1"	"0,1"	"0,1"	"0,1"
FABACEAE	• Trifolium	arvense	Haresfoot Clover	"0,2"	"2,3"	"2,3"	"0,2"	"3,3"	"2,1"	"2,3"	"0,1"	"3,3"	"0,1"
FABACEAE	• Trifolium	campestre	Hop Clover						"0,1"				"2,0"
FABACEAE	• Trifolium	glomeratum	Clustered Clover	"0,2"	"0,1"	"0,1"	"0,2"	"0,3"	"0,1"	"0,3"	"0,3"	"0,3"	"0,3"
FABACEAE	• Trifolium	subterraneum	Subterranean Clover	"1,0"			"1,1"		"0,1"	"1,0"	"2,0"		
FABACEAE	• Trifolium	tomentosum	Woolly Clover			"0,1"	"0,2"	"0,1"	"2,1"	"1,1"	"2,1"	"1,2"	"3,4"

Family	Intro	Genus	Species	Subspecies Form/Var	Common Name	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Q11	Q12	Q13	Q14	Q21
FABACEAE		Acacia	pendula		Boree								"0,1"	"0,1"	"1,1"	"0,1"				
GERANIACEAE	•	Erodium	cicutarium		Common Crowsfoot	"1,0"				"1,0"	"1,0"		"3,0"		"2,0"					"1,0"
GERANIACEAE		Erodium	crinitum		Blue Crowsfoot	"1,1"	"1,0"	"1,1"	"1,1"	"1,1"	"2,1"	"2,1"			"0,1"					
GERANIACEAE	•	Erodium	moschatum		Musky Crowsfoot						"2,1"									"1,1"
GOODENIACEAE		Goodenia	hederacea	hederacea	Forest Goodenia			"0,1"												
GOODENIACEAE		Goodenia	pinnatifida		Cut-leaf Goodenia	"0,1"		"1,1"	"1,1"	"1,1"	"0,1"				"0,2"					
GOODENIACEAE		Goodenia	pustilliflora		Small-flower Goodenia			"1,0"	"3,0"	"3,0"	"3,1"	"3,0"	"3,2"	"1,0"	"2,0"	"2,0"				
MALVACEAE		Sida	?corrugata			"1,0"	"0,1"	"0,1"	"1,1"	"1,1"	"1,1"	"0,1"	"0,1"	"1,1"	"0,1"	"1,0"				
MALVACEAE		Sida	?trichopoda				"0,1"			"0,1"			"1,1"		"0,1"					"0,1"
NYCTAGINACEAE		Boerhavia	diffusa/dominii		Tar Vine			"0,1"												
OXALIDACEAE		Oxalis	perennans		Wood-Sorrel			"1,1"					"1,1"		"1,1"					"2,2"
PLANTAGINACEAE		Plantago	turrifera		Small Sago-weed	"1,1"	"1,1"	"1,0"	"1,1"	"0,1"	"2,0"	"3,1"	"3,1"	"3,3"	"3,0"	"3,2"				
POLYGONACEAE		Rumex	brownii		Slender Dock		"1,1"	"1,1"											1	
POLYGONACEAE		Rumex	SP NARR LEAF														"0,1"	"1,1"		"1,0"
ROSACEAE		Aphanes	australiana		Australian Piert										"1,0"					
RUTACEAE		Geijera	parviflora		Wilga															"0,1"
SOLANACEAE		Solanum	esuriale		Quena								"0,1"	"0,1"	"0,1"	"0,1"				
ANTHERICACEAE		Arthropodium	minus		Small Vanilla Lily			"0,1"	"0,1"											
ANTHERICACEAE		Tricoryne	elatiar		Yellow Rush Lily			"0,1"												
COLCHICACEAE		Wurmbea	dioica		Early Nancy					"1,1"						"0,1"				
CYPERACEAE		Carex	inversa		Knob Sedge									"0,1"						
CYPERACEAE		Eleocharis	sp											"0,1"						
JUNCACEAE		Juncus	sp		Rush											"2,1"				
POACEAE		Agrostis	avenacea	var. avenacea	Blown Grass											"0,2"	"0,3"			
POACEAE		Aristida	behriana		Brush Wiregrass			"0,1"	"1,2"	"0,1"										
POACEAE		Aristida	jerichoensis	subsp. nullifera	No9 Wiregrass			"0,1"	"0,2"											
POACEAE	•	Bromus	hordeaceus		Soft Brome	"0,1"	"0,1"			"0,1"	"0,1"	"0,4"								
POACEAE	•	Bromus	molliformis		Silky Brome					"0,1"	"1,0"	"2,0"	"1,3"	"0,2"	"1,3"	"1,1"	"0,1"			"1,3"
POACEAE		Chloris	truncata		Windmill Grass					"0,1"			"0,1"		"0,1"					
POACEAE		Cynodon	dactylon		Couch Grass															"0,1"
POACEAE		Danthonia	sp		Wallaby Grass	"0,1"	"1,3"	"0,1"	"1,2"	"1,3"	"0,1"	"0,1"	"0,1"		"0,1"	"0,2"				"0,2"

[illegible]

Source: Charles Sturt University (1997) # Number of transects/quadrats that a species was recorded in for Transects T11-T93 and Quadrats Q1-Q47 • Introduced Species

Family	Intro	Genus	Species	Subspecies	Form/Var	Common Name	Q22	Q23	Q24	Q25	Q26	Q27	Q28	Q29	Q30	Q31	Q32	Q33	Q34
MARSILEACEAE		Marsilea	sp					"1,0"	"0,1"										
ASTERACEAE	•	Arctotheca	calendula			Capeweed	"1,2"	"3,4"	"5,4"							"5,4"	"2,0"	1	
ASTERACEAE		Bracteantha	bracteata			Sticky Everlasting										"0,1"		"3,0"	
ASTERACEAE		Brachycome	lineariloba			Hard-headed Daisy													
ASTERACEAE		Calocephalus	sonderi			Pale Beauty-heads	"0,3"										"0,1"	"0,1"	
ASTERACEAE		Calotis	hispidula			Bogan Flea											"1,1"		
ASTERACEAE	•	Cirsium	vulgare			Spear Thistle	"2,1"	"2,1"	"0,1"	"0,1"	"1,0"	"1,0"							
ASTERACEAE		Cotula	australis			Common Cotula											"3,1"	"3,3"	
ASTERACEAE		Gnaphalium	sphaericum			Japanese Cudweed	"1,1"											"0,1"	
ASTERACEAE		Hyalosperma	demissum			Dwarf Sunray												"3,0"	
ASTERACEAE		Hyalosperma	semisterile			Golden/Orange Sunray												"3,0"	
ASTERACEAE	•	Hypochoeris	glabra			Smooth Cat's Ears	"1,2"									"3,3"	"1,0"	3	
ASTERACEAE		Isoetopsis	graminifolia			Woolly Heads												3	
ASTERACEAE	•	Lactuca	serriola			Prickly Lettuce					"0,1"	"0,1"							
ASTERACEAE		Rhodanthe	corymbiflora			Grey Sunray											"0,1"		
ASTERACEAE		Rhodanthe	pygmaea			Pigmy Sunray												3	
ASTERACEAE	•	Soliva	sp				"2,0"										"0,1"		
ASTERACEAE	•	Sonchus	oleraceus			Common Sowthistle	"0,2"			"1,1"	"1,1"	"1,1"	"0,1"				"1,1"	"2,1"	
ASTERACEAE		Stuartina	muelleri			Spoon Cudweed										"1,0"		"0,1"	
ASTERACEAE		Triptilodiscus	pygmaeus			Common Sunray										"2,2"		3	
ASTERACEAE		Vittadinia	PINK/PUR FL				"0,1"	"1,0"											
BORAGINACEAE	•	Echium	plantagineum			Paterson's Curse	"0,2"	"3,4"	"3,5"							"2,3"	"1,1"		
BRASSIACEAE		Lepidium	africanum			Peppergrass	"1,0"	"3,2"	"1,0"					1					
BRASSIACEAE	•	Sisymbrium	irio			London Rocket											"3,3"	"4,4"	
BRASSIACEAE		Cuphonotus	humistratus			Mother-of-misery											"1,0"		
CARYOPHYLLACEAE	•	Spergularia	rubra			Sandspurry	"0,1"											2	
CASUARINACEAE		Casuarina	cristata			Black Oak/Belah												"2,2"	
CHENOPODIACEAE		Atriplex	?spinibractea			Spiny-fruit Saltbush			"0,2"										
CHENOPODIACEAE		Atriplex	sp						"1,0"										
CHENOPODIACEAE		Einada	nutans		limifolia	Climbing saltbush	"0,1"										"1,1"	"2,2"	
CHENOPODIACEAE		Maireana	?humillima			Bluebush											"0,1"	"0,1"	

[illegible]

Family	Intro	Genus	Species	Subspecies	Form/Var	Common Name	Q22	Q23	Q24	Q25	Q26	Q27	Q28	Q29	Q30	Q31	Q32	Q33	Q34
POACEAE		Agrostis	avenacea		var. avenacea	Blown Grass	"0,1"			"0,1"	"0,2"	"1,2"	"1,2"	"1,2"	"0,2"				
POACEAE		Aristida	behriana			Brush Wiregrass										"0,1"			
POACEAE	•	Bromus	molliformis			Silky Brome	"3,2"	"0,1"	"2,0"			"0,1"				"3,2"			
POACEAE		Chloris	truncata			Windmill Grass												"1,0"	
POACEAE		Cynodon	dactylon			Couch Grass	"0,1"	"0,2"	"0,3"										
POACEAE		Danthonia	sp			Wallaby Grass											"0,1"		
POACEAE		Elymus	scaber		scaber	Common Wheatgrass										"0,1"			
POACEAE		Enteropogon	acicularis			Curly Windmill Grass										"0,1"			
POACEAE		Eragrostis	australascia			Canegrass	"4,4"			"5,5"	"3,4"	"3,3"	"4,3"						
POACEAE	•	Hordeum	glaucum			Northern Barley Grass	"0,1"												
POACEAE	•	Hordeum	leporinum			Barley Grass	"4,4"	"3,3"	"2,3"	"1,0"	"1,1"	"1,1"	"0,1"	"1,2"	"0,1"	"2,1"	"3,6"	1	"3,5"
POACEAE	•	Hordeum	marinum			Sea Barley Grass	"0,2"		"0,1"										
POACEAE	•	Lamarckia	aurea			Golden Top											"3,3"		"2,3"
POACEAE	•	Lolium	perenne			Perennial/ Italian Ryegrass	"0,3"	"3,5"	"3,4"	"0,1"	"1,1"	"1,1"	"1,1"	"0,1"	"1,1"	"2,3"	"0,1"		"1,2"
POACEAE	•	Parapholis	incurva			Coast Barb Grass	"0,1"												
POACEAE	•	Phalaris	sp.				"0,3"				"0,1"								
POACEAE	•	Rostraria (Lophochloa)	cristata			Annual Cat's Tail	"0,1"								"0,1"				
POACEAE		Stipa	scabra		scabra	Rough Speargrass	"0,1"									"0,2"	"0,1"		
POACEAE	•	Vulpia	sp				"0,3"	"0,3"	"0,4"			"0,1"				"3,3"		1	
Total no. species							37	20	19	9	9	14	14	9	14	25	28	18	20
No. weed species							24	12	12	8	5	9	8	5	7	10	15	9	10
% Weed species							64.9	60.0	63.2	88.9	55.6	64.3	57.1	55.6	50.0	40.0	53.6	53.6	50.0
No. native species							13	8	7	1	4	5	6	4	7	15	13	9	10

Source: Charles Sturt University (1997) # Number of transects/quadrats that a species was recorded in for Transects T11-T93 and Quadrats Q1-Q47 • Introduced Species

Family	Intro	Genus	Species	Subspecies	Form/Var	Common Name	Q35	Q36	Q37	Q38	Q39	Q40	Q41	Q42	Q43	Q44	Q45	Q46	Q47	#
MARSILEACEAE		Marsilea	sp					"1,0"					"1,2"	"1,1"		"1,2"		"1,2"	"1,1"	8
SINOPTERIDACEAE		Cheilanthes	sieberi	sieberi		Mulga Fern		"1,0"												4
AMARANTHACEAE		Alternanthera	nana			Hairy Joyweed														2
AMARANTHACEAE		Ptilotus	semilanatus			Lamb's Tails														5
AMARANTHACEAE		Ptilotus	spathulatus			Pussy-tails										"0,1"	"1,1"	"1,1"	"1,1"	7
AMARANTHACEAE		Ptilotus	sp					"1,0"												1
APIACEAE		Daucus	glochidiatus		form D	Australian Carrot											"1,3"	"2,1"		10
ASTERACEAE	•	Arctotheca	calendula			Capeweed	"3,1"	"0,1"	"2,1"	"3,2"	"3,1"	"3,1"	"3,1"	"3,1"	"3,0"	"3,1"	"3,2"	"3,2"	"3,2"	30
ASTERACEAE		Bracteantha	bracteata			Sticky Everlasting														4
ASTERACEAE		Brachycome	lineariloba			Hard-headed Daisy	"1,0"								"2,0"		"3,0"			5
ASTERACEAE		Calocephalus	sonderi			Pale Beauty-heads	"0,3"						"0,1"	"4,5"		"0,1"	"3,3"	"0,2"	"0,2"	20
ASTERACEAE		Calotis	cuneifolia			Purple Burr Daisy														1
ASTERACEAE		Calotis	hispidula			Bogan Flea	"1,0"	"3,0"	"3,0"	"1,0"		"1,0"				"2,1"	"1,0"			16
ASTERACEAE		Calotis	lappulacea			Yellow Burr Daisy														1
ASTERACEAE	•	Carthamus	lanatus			Saffron Thistle												"1,1"		8
ASTERACEAE	•	Centaurea	melitensis			Maltese Cockspur			"1,1"										"0,1"	4
ASTERACEAE		Chryscephalum	apiculatum			Yellow Buttons							"2,0"							3
ASTERACEAE	•	Cirsium	vulgare			Spear Thistle				"1,0"										10
ASTERACEAE		Cotula	australis			Common Cotula														2
ASTERACEAE		Gnaphalium	sphaericum			Japanese Cudweed														3
ASTERACEAE	•	Hedypnois	rhagodiolooides			Cretan Weed				"2,3"						"3,2"	"2,3"			8
ASTERACEAE		Hyalosperma	demissum			Dwarf Sunray														1
ASTERACEAE		Hyalosperma	semisterrile			Golden/Orange Sunray		"3,3"	"4,4"									"3,3"		5
ASTERACEAE	•	Hypochoeris	glabra			Smooth Cat's Ears	"3,0"	"3,2"	"1,0"	"2,0"		"3,0"	"3,0"	"2,3"	"3,3"	"3,3"	"3,1"	"2,1"	"3,1"	28
ASTERACEAE		Isoetopsis	graminifolia			Woolly Heads	"2,0"	"3,1"	"3,0"				"2,0"		"2,0"	"2,2"	"2,1"	"1,0"	"1,0"	18
ASTERACEAE	•	Lactuca	serriola			Prickly Lettuce														2
ASTERACEAE	•	Podospermum	resedifolium			Scorzonera						"0,1"								1
ASTERACEAE		Rhodanthe	corymbiflora			Grey Sunray	"3,3"	"3,3"	"3,4"	"3,3"	"3,3"		"0,2"	"0,1"		"0,1"				18
ASTERACEAE		Rhodanthe	floribunda			Com. White Sunray												"3,3"		7
ASTERACEAE		Rhodanthe	pygmaea			Pigmy Sunray	"2,1"			"2,0"		"2,0"		"2,0"		"2,1"	"4,3"	"3,1"	"3,0"	17
ASTERACEAE	•	Soliva	sp				"3,0"	"3,1"	"3,0"	"2,0"	"3,0"		"1,0"	"1,0"	"3,0"	"1,0"	"1,0"	"2,1"	"3,0"	23

Family	Intro	Genus	Species	Subspecies	Form/Var	Common Name	Q35	Q36	Q37	Q38	Q39	Q40	Q41	Q42	Q43	Q44	Q45	Q46	Q47	#
ASTERACEAE	•	Sonchus	asper			Prickly Sow-thistle	"0,1"													4
ASTERACEAE	•	Sonchus	oleraceus			Common Sowthistle	"1,1"	"0,1"	"1,1"	"1,1"	"1,1"	"0,1"	"1,2"	"1,1"	"1,0"	"0,1"	"1,1"			30
ASTERACEAE		Stuartina	muelleri			Spoon Cudweed		"1,0"												9
ASTERACEAE		Triptlodiscus	pygmaeus			Common Sunray											"3,3"	"2,1"		12
ASTERACEAE		Vittadinia	PINK/PUR FL					"1,0"	"1,1"			"1,1"	"1,1"	"1,1"	"2,0"	"2,1"	"2,1"	"0,1"		20
BORAGINACEAE	•	Echium	plantagineum			Paterson's Curse	"0,1"		"1,1"	"1,1"	"2,1"	"2,1"	"1,1"	"2,2"	"1,0"	"2,3"	"2,1"	"2,0"	"1,1"	26
BORAGINACEAE		?Plagiobothrys	plurisepalus			White Forget-Me-Not		"1,0"												1
BRASSIACEAE		Lepidium	africanum			Peppergrass	"1,0"			"0,1"		"0,1"			"1,1"					10
BRASSIACEAE		Lepidium	psedohyssopifolium																	1
BRASSIACEAE	•	Sisymbrium	irio			London Rocket			"5,4"											3
BRASSIACEAE		Cuphonotus	humistratus			Mother-of-misery										"2,0"	"3,1"	"2,0"		9
CAMPANULACEAE		Wahlenbergia	gracilentia			Australian Bluebell										"1,1"	"2,1"			2
CARYOPHYLLACEAE	•	Petrorhagia	velutina			Velvet Pink											"2,1"			2
CARYOPHYLLACEAE	•	Spergularia	rubra			Sandspurrey	"2,3"													10
CASUARINACEAE		Casuarina	cristata			Black Oak/Belah														2
CHENOPODIACEAE		Atriplex	?semibaccata			Creeping Saltbush						"0,1"				"0,1"	"1,1"			3
CHENOPODIACEAE		Atriplex	?spini-bractea			Spiny-fruit Saltbush	"0,1"		"1,1"											8
CHENOPODIACEAE		Atriplex	sp																	2
CHENOPODIACEAE		Atriplex	BUSH																	1
CHENOPODIACEAE		Chenopodium	desertorum	microphyllum.		Desert Goosefoot														4
CHENOPODIACEAE		Einada	nutans	limifolia		Climbing saltbush	"1,1"			"1,2"							"0,1"			14
CHENOPODIACEAE		Enchylaena	?tomentosa			Ruby Saltbush														1
CHENOPODIACEAE		Maireana	?humilima			Bluebush	"0,1"	"0,1"	"1,3"	"0,1"	"2,1"		"0,1"	"1,1"		"0,1"	"0,1"	"0,1"		23
CHENOPODIACEAE		Maireana	microphylla			Eastern Cottonbush														1
CHENOPODIACEAE		Sclerolaena	birchii			Galvanised Burr				"1,3"		"1,1"		"0,1"		"0,1"	"0,1"	"1,0"	"1,1"	19
CHENOPODIACEAE			B. GREEN										"0,1"			"0,1"		"0,1"		5
CONVOLVULACEAE		Convolvulus	erubescens			Bindweed							"0,1"			"1,0"		"0,1"		6
CONVOLVULACEAE		Dichondria	repens			Kidneyweed														2
CRASSULACEAE		Crassula	decumbens	decumbens		Stonecrop	"1,0"				"1,0"				"3,0"	"2,1"	"2,0"	"1,0"	"0,1"	10
CRASSULACEAE		Crassula	sieberana			Australian Stoncrop	"1,0"	"3,0"	"3,0"	"3,0"	"3,0"				"1,0"	"1,0"	"2,0"	"2,0"		25
EUPHORBIACEAE		Chamaesyce	drummondii			Caustic Weed						"0,1"	"1,0"			"0,1"				4

FABACEAE	Glycine	sp	Glycine	2								
FABACEAE	• Medicago	minima	Small Woolly Burr Medic"0,1"	"1,0"	"1,0"	"3,0"	"3,0"	"2,3"	"2,0"	"2,0"	23	
FABACEAE	• Medicago	polymorpha	Burr Medic	"3,3"	"1,2"	"3,3"	"3,3"	"4,3"	"3,2"	"2,3"	"2,0"	38
FABACEAE	• Medicago	truncatula	Barrel Medic	"0,1"	"0,2"	"0,1"	"0,1"	"0,1"	"0,1"	"0,1"	"0,1"	20
FABACEAE	• Trifolium	angustifolium	Narrow-leaf Clover	"0,1"			"0,1"	"1,1"	"1,3"	"1,2"	"0,3"	17
FABACEAE	• Trifolium	arvense	Haresfoot Clover	"0,1"	"0,2"	"0,3"	"2,3"	"0,1"	"2,3"	"1,1"	"2,0"	24
FABACEAE	• Trifolium	campestre	Hop Clover				"0,1"		"0,3"			3
FABACEAE	• Trifolium	glomeratum	Clustered Clover	"0,1"	"0,1"	"0,3"	"0,3"	"0,2"	"0,1"	"0,3"	"0,3"	27
FABACEAE	• Trifolium	subterraneum	Subterranean Clover				"3,3"				"2,2"	10
FABACEAE	• Trifolium	tomentosum	Woolly Clover	"3,0"		"2,3"	"2,0"	"2,3"	"2,2"	"2,1"	"2,2"	31
FABACEAE	Trigonella	sp										1
FABACEAE	Acacia	pendula	Boree									4
GERANIACEAE	• Erodium	botrys	Long Storkbill					"1,0"	"3,1"			2
GERANIACEAE	• Erodium	cicutarium	Common Crowsfoot			"3,0"	"3,0"	"1,0"	"1,0"	"1,0"	"2,0"	15
GERANIACEAE	Erodium	crinitum	Blue Crowsfoot	"1,0"	"1,0"		"1,0"		"1,0"		"1,0"	19
GERANIACEAE	• Erodium	moschatum	Musky Crowsfoot			"3,0"			"3,2"		"1,0"	8
GOODENIACEAE	Goodenia	hederacea	Forest Goodenia									1
GOODENIACEAE	Goodenia	pinnatifida	Cut-leaf Goodenia			"3,0"	"1,1"	"2,0"	"1,1"	"1,2"		10
GOODENIACEAE	Goodenia	pusilliflora	Small-flower Goodenia	"1,0"						"2,0"	"2,0"	11
HALORAGACEAE	Myriophyllum	sp										2
LENTIBULARIACEAE	Utricularia	?dichotoma	Bladderwort							"2,3"		1
LOBELIACEAE	Pratia	concolor	Poison Pratia			"2,2"	"2,2"		"2,2"		"3,1"	4
MALVACEAE	• Malva	parviflora	Small-flowered Mallow			"0,1"						4
MALVACEAE	Sida	?corrugata		"0,1"	"0,1"		"1,0"		"1,1"	"2,1"	"0,1"	19
MALVACEAE	Sida	?trichopoda				"0,1"	"0,1"		"0,1"	"0,1"	"1,0"	11
NYCTAGINACEAE	Boerhavia	diffusa/dominii	Tar Vine			"0,1"						2
ONAGRACEAE	Epilobium	sp?										1
OXALIDACEAE	Oxalis	perennans	Wood-Sorrel			"2,1"	"1,1"	"2,1"	"0,1"	"2,1"	"1,1"	14
PLANTAGINACEAE	Plantago	turrifera	Small Sago-weed	"1,1"	"3,1"	"3,1"	"3,1"		"1,0"	"1,1"	"3,1"	23
POLYGONACEAE	Muehlenbeckia	florulenta	Lignum			"2,1"	"2,1"					2
POLYGONACEAE	• Polygonum	aviculare	Wireweed									3
POLYGONACEAE	Polygonum	plebeium	Small Knotweed									5

Family	Intro	Genus	Species	Subspecies Form/Var	Common Name	Q35	Q36	Q37	Q38	Q39	Q40	Q41	Q42	Q43	Q44	Q45	Q46	Q47	#
POLYGONACEAE		Rumex	brownii		Slender Dock														3
POLYGONACEAE		Rumex	SP NARR LEAF																9
POLYGONACEAE		Rumex	tenax		Shiny Dock										"0,1"				1
RANUNCULACEAE		Ranunculus	SP																1
ROSACEAE		Aphanes	australiana		Australian Piert														1
RUBIACEAE		Asperula	conferta		Common Woodruff						"1,0"								1
RUTACEAE		Geijera	parviflora		Wilga														1
SOLANACEAE		Solanum	esuriiale		Quena			"0,1"	"0,1"	"0,1"	"0,1"	"0,1"	"0,1"		"0,1"		"0,1"		10
URTICACEAE	•	Urtica	urens		Small Nettle														2
VERBENACEAE	•	Phyla	nodiflora		Carpet weed														1
AMARYLLIDACEAE		Calostemma	purpureum		Pink Garland Lily											"2,1"			1
ANTHERICACEAE		Arthropodium	minus		Small Vanilla Lily			"0,1"											4
ANTHERICACEAE		Tricoryne	elatior		Yellow Rush Lily														2
ASPHODELACEAE		Bulbine	bulbosa		Native Leek											"2,3"			1
COLCHICACEAE		Wurmbea	dioica		Early Nancy											2			2
CYPERACEAE		Carex	inversa		Knob Sedge				"0,1"	"0,2"	"2,0"	"2,2"	"0,1"		"0,1"		"2,2"	"0,1"	7
CYPERACEAE		Cyperus	?concinus		Trim Sedge												"0,1"		1
CYPERACEAE		Eleocharis	?pallens		Pale Spike Rush										"2,1"		"3,1"	"0,1"	3
CYPERACEAE		Eleocharis	sp																1
JUNCACEAE		Juncus	sp		Rush					"1,0"	"1,1"	"0,1"			"0,1"		"1,1"		5
LOMANDRACEAE		Lomandra	multiflora		Many Fl. Mat Rush														1
POACEAE		Agrostis	avenacea	var. avenacea	Blown Grass														9
POACEAE		Aristida	behriana		Brush Wiregrass														4
POACEAE		Aristida	jerichoensis	subspinulifera	No9 Wiregrass														2
POACEAE	•	Bromus	hordeaceus		Soft Brome														5
POACEAE	•	Bromus	molliformis		Silky Brome			"0,1"	"3,3"	"3,3"	"0,1"	"3,3"	"2,1"				"2,2"	"1,1"	21
POACEAE		Chloris	truncata		Windmill Grass			"0,1"						"0,1"			"2,2"	"0,1"	8
POACEAE		Cynodon	dactylon		Couch Grass					"2,0"	"2,0"	"2,3"					"2,0"	"2,0"	9
POACEAE		Danthonia	sp		Wallaby Grass		"0,1"	"0,3"	"0,1"		"0,1"	"0,1"	"0,1"	"0,1"	"0,2"	"2,3"	"1,1"	"0,3"	24
POACEAE		Digitaria	sp																3
POACEAE		Elymus	scaber	scaber	Common Wheatgrass												"0,1"		7

POACEAE	Enteropogon	acicularis	Curly Windmill Grass	"0,1"	"1,2"	"0,2"	"0,1"	"0,1"	"0,1"	"0,2"	21
POACEAE	Eragrostis	australascia	Canegrass								6
POACEAE	• Hordeum	glaucum	Northern Barley Grass								2
POACEAE	• Hordeum	leporinum	Barley Grass	"3,2"	"3,0"	"3,3"	"4,3"	"2,0"	"2,0"	"2,1"	34
POACEAE	• Hordeum	marinum	Sea Barley Grass				"3,4"	"3,3"	"3,4"	"2,1"	13
POACEAE	• Hordeum	MINI		"0,1"			"3,4"	"0,3"	"0,3"	"0,1"	6
POACEAE	• Lamarckia	aurea	Golden Top	"2,1"							8
POACEAE	• Lolium	perenne	Perennial/ Italian Ryegrass	"0,1"	"3,3"	"3,5"	"3,4"	"3,6"	"3,4"	"2,2"	37
POACEAE	Panicum	FINE							"0,1"		1
POACEAE	Paspalidium	constrictum	Knottbutt Grass								10
POACEAE	Paspalidium	jubiflorum	Warrego Grass								4
POACEAE	• Phalaris	sp.									3
POACEAE	• Rostraria (Lophochloa)	cristata	Annual Cat's Tail						"1,2"		8
POACEAE	Stipa	scabra	Rough Speargrass	"0,3"	"3,3"	"1,1"	"1,1"	"1,1"	"0,1"	"2,3"	26
POACEAE	Stipa	sp BIG				"0,3"	"0,3"			"0,1"	6
POACEAE	• Vulpia	sp		"3,0"	"3,4"	"3,3"	"3,0"	"0,1"	"3,0"	"3,3"	30
Total no. species				32	31	29	23	27	42	33	141
No. weed species				18	13	12	12	17	19	14	19
% Weed species				56.3	41.9	41.4	52.2	63.0	51.4	45.2	39.6
No. native species				14	18	17	11	10	18	24	29

Source: Charles Sturt University (1997) # Number of transects/quadrats that a species was recorded in for Transects T11-T193 and Quadrats Q1-Q47 • Introduced Species

Attachment A4

Fauna Species Recorded for Lake Cowal and Surrounds

Fauna Species Recorded for Lake Cowal and Surrounds*

Common Name	Scientific Name	Gunninah Consult. (1995)	Lane (1989-1991) EES (1992-1997)	Vestjens (1977)	Greg Richards & Assoc. (1997)	Lawler (1989)	Hatton (1991)	NSW Bird Atlasers (1995)	RAOU Records (1995)	CSIRO (1997)	NPWS NSW Wildlife Atlas Records (1997)	Illawarra Bird Observers Club
Birds												
Emu	<i>Dromaius novaehollandiae</i>	•		•			•	•	•	•	•	•
Malleefowl*	<i>Leipoa ocellata</i>									•	•	
Stubble Quail	<i>Coturnix pectoralis</i>	•		•				•		•	•	•
Brown Quail	<i>Coturnix ypsilophora</i>	•						•	•	•	•	•
Magpie Goose*	<i>Anseranas semipalmata</i>		•	•	•	•		•		•	•	
Plumed Whistling-Duck	<i>Dendrocygna eytoni</i>			•			•	•		•	•	
Wandering Whistling-Duck	<i>Dendrocygna arcuata</i>		•			•		•		•	•	
Blue-billed Duck*	<i>Oxyura australis</i>		•	•		•		•		•	•	•
Musk Duck	<i>Biziura lobata</i>		•	•			•	•		•	•	•
Freckled Duck*	<i>Stictonetta naevosa</i>		•	•		•	•	•		•	•	•
Black Swan	<i>Cygnus atratus</i>	•	•	•	•	•		•		•	•	•
Australian Shelduck	<i>Tadorna tadornoides</i>	•	•	•			•	•		•	•	•
Australian Wood Duck	<i>Chenonetta jubata</i>	•	•	•			•	•	•	•	•	•
Mallard*	<i>Anas platyrhynchos</i>									•		
Pacific Black Duck	<i>Anas superciliosa</i>	•	•	•		•	•	•		•	•	•
Australasian Shoveler	<i>Anas rhynchos</i>		•	•			•	•		•	•	•
Northern Shoveler ¹	<i>Anas clypeata</i>										•	
Grey Teal	<i>Anas gibberifrons</i>	•	•	•		•	•	•		•	•	•
Chestnut Teal	<i>Anas castanea</i>		•	•				•		•	•	•
Pink-eared Duck	<i>Malacorhynchus membranaceus</i>		•	•			•	•		•	•	•
Hardhead	<i>Aythya australis</i>		•	•		•	•	•		•	•	•
Australasian Grebe	<i>Tachybaptus novaehollandiae</i>	•	•	•		•	•	•	•	•	•	•
Hoary-headed Grebe	<i>Poliiocephalus poliocephalus</i>		•	•		•	•	•	•	•	•	•
Great Crested Grebe	<i>Podiceps cristatus</i>		•	•		•	•	•		•	•	
Darter	<i>Anhinga melanogaster</i>	•	•	•		•	•	•		•	•	

Fauna Species Recorded for Lake Cowal and Surrounds* Continued

Common Name	Scientific Name	Gunninah Consult. (1995)	Lane (1989-1991) EES (1992-1997)	Vestjens (1977)	Greg Richards & Assoc. (1997)	Lawler (1989)	Hatton (1991)	NSW Bird Atlassers (1995)	RAOU Records (1995)	CSIRO (1997)	NPWS NSW Wildlife Atlas Records (1997)	Illawarra Bird Observers Club
Little Pied Cormorant	<i>Phalacrocorax melanoleucos</i>	•	•	•	•	•	•	•	•	•	•	•
Pied Cormorant	<i>Phalacrocorax varius</i>	•	•	•				•	•	•	•	•
Little Black Cormorant	<i>Phalacrocorax sulcirostris</i>	•	•	•		•	•	•	•	•	•	•
Great Cormorant	<i>Phalacrocorax carbo</i>	•	•	•		•	•	•	•	•	•	•
Australian Pelican	<i>Pelecanus conspicillatus</i>	•	•	•		•	•	•	•	•	•	
White-faced Heron	<i>Ardea novaehollandiae</i>	•	•	•		•	•	•	•	•	•	•
Little Egret	<i>Egretta garzetta</i>	•	•	•			•	•		•	•	•
White-necked Heron	<i>Ardea pacifica</i>		•	•			•	•	•	•	•	•
Pied Heron	<i>Ardea picata</i>			•								
Great Egret ^{1,2}	<i>Egretta alba</i>	•	•	•		•	•	•		•	•	•
Intermediate Egret	<i>Egretta intermedia</i>	•	•	•			•	•		•	•	•
Cattle Egret ^{1,2}	<i>Ardeola ibis</i>	•	•	•						•	•	
Nankeen Night Heron	<i>Nycticorax caledonicus</i>	•	•	•		•	•	•		•	•	•
Little Bittern	<i>Ixobrychus minutus</i>			•						•		
Australasian Bittern*	<i>Botaurus poiciloptilus</i>			•						•	•	
Glossy Ibis ¹	<i>Plegadis falcinellus</i>		•	•		•	•	•		•	•	•
Australian White Ibis	<i>Threskiornis molucca</i>	•	•	•		•	•	•		•	•	•
Straw-necked Ibis	<i>Threskiornis spinicollis</i>	•	•	•		•	•	•		•	•	•
Royal Spoonbill	<i>Platalea regia</i>	•	•	•		•	•	•		•	•	•
Yellow-billed Spoonbill	<i>Platalea flavipes</i>	•	•	•			•	•	•	•	•	•
Black-necked Stork*	<i>Ephippiorhynchus asiaticus</i>										•	
Osprey*	<i>Pandion haliaetus</i>							•		•	•	•
Black-shouldered Kite	<i>Elanus notatus</i>	•		•				•		•	•	•
Letter-winged Kite	<i>Elanus scriptus</i>			•								
Square-tailed Kite*	<i>Lophoictinia isura</i>									•	•	
Black-breasted Buzzard*	<i>Hamirostra melanosternon</i>							•		•	•	•

Fauna Species Recorded for Lake Cowal and Surrounds⁷ Continued

Common Name	Scientific Name	Gunninah Consult. (1995)	Lane (1989-1991) EES (1992-1997)	Vestjens (1977)	Greg Richards & Assoc. (1997)	Lawler (1989)	Hatton (1991)	NSW Bird Atlasers (1995)	RAOU Records (1995)	CSIRO (1997)	NPWS NSW Wildlife Atlas Records (1997)	Illawarra Bird Observers Club
Black-tailed Godwit ^{*1,2}	<i>Limosa limosa</i>			•				•		•	•	
Bar-tailed Godwit ^{1,2}	<i>Limosa lapponica</i>			•						•		
Little Whimbrel ^{1,2}	<i>Numenius phaeopus</i>		•									
Marsh Sandpiper ^{1,2}	<i>Tringa stagnatilis</i>		•							•	•	
Common Greenshank ^{1,2}	<i>Tringa nebularia</i>									•	•	
Wood Sandpiper ^{1,2}	<i>Tringa glareola</i>									•	•	
Common Sandpiper	<i>Actitis hypoleucos</i>		•	•				•		•		
Red-necked Stint ^{1,2}	<i>Calidris ruficollis</i>		•	•						•		
Pectoral Sandpiper ²	<i>Calidris melanotos</i>		•							•		
Sharp-tailed Sandpiper ^{1,2}	<i>Calidris acuminata</i>		•	•				•		•	•	
Curlew Sandpiper ^{1,2}	<i>Calidris ferruginea</i>									•		
Painted Snipe ^{*1}	<i>Rostratula benghalensis</i>			•				•		•	•	
Bush Stone-curlew [*]	<i>Burhinus grallarius</i>									•	•	
Black-winged Stilt	<i>Himantopus himantopus</i>		•	•			•	•		•	•	
Red-necked Avocet	<i>Recurvirostra novaehollandiae</i>	•	•					•		•	•	•
Pacific Golden Plover	<i>Pluvialis fulva</i>		•	•								
Red-capped Plover	<i>Charadrius ruficapillus</i>		•	•				•		•	•	
Black-fronted Dotterel	<i>Elsyaornis melanops</i>		•	•			•	•		•	•	•
Red-kneed Dotterel	<i>Erythrogonyx cinctus</i>		•	•			•	•		•	•	•
Banded Lapwing	<i>Vanellus tricolor</i>		•	•				•		•	•	
Masked Lapwing	<i>Vanellus miles</i>		•	•			•	•		•	•	•
Australian Pratincole	<i>Stiltia isabella</i>		•	•						•	•	
Silver Gull	<i>Larus novaehollandiae</i>	•	•	•			•	•		•	•	•
Franklin's Gull	<i>Larus pipixcan</i>		•								•	
Gull-billed Tern	<i>Sterna nilotica</i>		•	•			•	•		•	•	
Caspian Tern ^{1,2}	<i>Sterna caspia</i>		•	•				•		•	•	

Fauna Species Recorded for Lake Cowal and Surrounds* Continued

Common Name	Scientific Name	Gunninah Consult. (1995)	Lane (1989-1991) EES (1992-1997)	Vestjens (1977)	Greg Richards & Assoc. (1997)	Lawler (1989)	Hatton (1991)	NSW Bird Atlassers (1995)	RAOU Records (1995)	CSIRO (1997)	NPWS NSW Wildlife Atlas Records (1997)	Illawarra Bird Observers Club
Horsfield's Bronze-Cuckoo	<i>Chrysococcyx basalidis</i>									•	•	•
Shining Bronze-Cuckoo	<i>Chrysococcyx lucidus</i>			•						•	•	•
Gould's Bronze-Cuckoo	<i>Chrysococcyx russatus</i>							•				
Barking Owl	<i>Ninox connivens</i>			•						•	•	
Southern Boobook	<i>Ninox novaezealandiae</i>	•	•	•				•		•	•	•
Masked Owl*	<i>Tyto novaehollandiae</i>										•	
Barn Owl	<i>Tyto alba</i>			•				•		•	•	•
Tawny Frogmouth	<i>Podargus strigoides</i>	•		•			•			•	•	
Spotted Nightjar	<i>Eurostoopodius argus</i>									•	•	
Australian Owllet-nightjar	<i>Aegotheles cristatus</i>	•		•						•	•	
White-throated Needle-tail ^{1,2}	<i>Hirundapus caudacutus</i>									•	•	
Fork-tailed Swift ^{1,2}	<i>Apus pacificus</i>			•						•	•	
Azure Kingfisher	<i>Alcedo azurea</i>										•	
Laughing Kookaburra	<i>Dacelo novaeguineae</i>	•		•			•	•	•	•	•	•
Red-backed Kingfisher	<i>Halcyon pyrrhopygia</i>							•		•		
Sacred Kingfisher	<i>Todiramphus sanctus</i>		•	•			•	•	•	•	•	•
Rainbow Bee-eater ²	<i>Merops ornatus</i>			•			•	•		•	•	•
Dollarbird	<i>Eurystomus orientalis</i>			•				•		•	•	
Noisy Pitta	<i>Pitta versicolor</i>										•	
White-throated Treecreeper	<i>Cormobates leucophaeus</i>							•		•	•	•
Brown Treecreeper	<i>Climacteris picumnus</i>	•		•				•	•	•	•	•
Superb Fairy-wren	<i>Malurus cyaneus</i>									•	•	
Splendid Fairy-wren	<i>Malurus splendens</i>										•	
Variegated Fairy-wren	<i>Malurus lamberti</i>	•		•			•	•	•	•	•	•
White-winged Fairy-wren	<i>Malurus leucopterus</i>			•						•	•	
Spotted Pardalote	<i>Pardalotus punctatus</i>									•	•	•

Fauna Species Recorded for Lake Cowal and Surrounds* Continued

Common Name	Scientific Name	Gunninah Consult. (1995)	Lane (1989-1991) EES (1992-1997)	Vestjens (1977)	Greg Richards & Assoc. (1997)	Lawler (1989)	Hatton (1991)	NSW Bird Atlassers (1995)	RAOU Records (1995)	CSIRO (1997)	NPWS NSW Wildlife Atlas Records (1997)	Illawarra Bird Observers Club
Fuscous Honeyeater	<i>Lichenostomus fuscus</i>									•	•	
White-plumed Honeyeater	<i>Lichenostomus penicillatus</i>	•	•	•			•	•	•	•	•	•
Black-chinned Honeyeater	<i>Melithreptus gularis</i>									•	•	
Brown-headed Honeyeater	<i>Melithreptus brevirostris</i>	•						•	•	•	•	•
White-naped Honeyeater	<i>Melithreptus lunatus</i>									•	•	
Painted Honeyeater*	<i>Grantiella picta</i>			•				•		•	•	•
Eastern Spinebill	<i>Acanthorhynchus tenuirostris</i>									•		
Black Honeyeater	<i>Certhionyx niger</i>									•	•	
Pied Honeyeater	<i>Certhionyx variegatus</i>										•	
Crimson Chat	<i>Epthianura tricolor</i>									•	•	
Orange Chat	<i>Epthianura aurifrons</i>							•		•		
White-fronted Chat	<i>Epthianura albifrons</i>			•			•	•		•	•	•
Jacky Winter	<i>Microeca fascians</i>	•						•	•	•	•	•
Scarlet Robin	<i>Petroica multicolor</i>									•	•	
Red-capped Robin	<i>Petroica goodenovii</i>	•		•			•	•	•	•	•	•
Flame Robin	<i>Petroica phoenicea</i>									•	•	
Rose Robin	<i>Petroica rosea</i>										•	
Hooded Robin	<i>Melanodryas cucullata</i>									•	•	
Eastern Yellow Robin	<i>Eopsaltria australis</i>	•						•	•	•	•	•
Southern Scrub-robin*	<i>Drymodes brunneopygia</i>									•	•	
Grey-crowned Babbler	<i>Pomatostomus temporalis</i>	•		•				•	•	•	•	•
White-browed Babbler	<i>Pomatostomus superciliosus</i>							•		•	•	•
Spotted Quail-thrush	<i>Cinclosoma punctatum</i>									•		
Chestnut Quail-thrush*	<i>Cinclosoma castanotus</i>									•	•	
Varied Sittella	<i>Daphoenositta chrysoptera</i>	•						•		•	•	•
Crested Shrike-tit	<i>Falcunculus frontatus</i>			•						•	•	

Fauna Species Recorded for Lake Cowal and Surrounds⁷ Continued

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White-winged Chough	<i>Corcorax melanorhamphos</i>	•		•			•	•	•	•	•	•
Apostlebird	<i>Struthidea cinerea</i>	•		•				•	•	•	•	•
Spotted Bowerbird	<i>Chlamydera maculata</i>									•		
Singing Bushlark	<i>Mirafrja javanica</i>			•				•		•	•	
Richard's Pipit	<i>Anthus novaeseelandiae</i>			•				•		•	•	•
Citrine Wagtail ¹	<i>Motacilla citreola</i>										•	
House Sparrow ⁺	<i>Passer domesticus</i>	•		•				•		•	•	•
Eurasian Tree Sparrow ⁺	<i>Passer montanus</i>										•	
Zebra Finch	<i>Taeniopygia guttata</i>	•		•			•	•	•	•	•	
Double-barred Finch	<i>Taeniopygia bichenovii</i>							•	•	•	•	•
Plum-headed Finch	<i>Neochmia modesta</i>									•	•	
Red-browed Finch	<i>Neochmia temporalis</i>									•	•	
Diamond Firetail	<i>Stagonopleura guttata</i>							•		•	•	•
European Goldfinch ⁺	<i>Carduelis carduelis</i>							•		•		
Mistletoebird	<i>Dicaeum hirundinaceum</i>	•		•				•	•	•	•	•
White-backed Swallow	<i>Cheramoeca leucosternus</i>									•	•	
Welcome Swallow	<i>Hirundo neoxena</i>	•		•				•		•	•	•
Tree Martin	<i>Hirundo nigricans</i>	•		•			•	•	•	•	•	•
Fairy Martin	<i>Hirundo ariel</i>			•				•		•	•	•
Clamorous Reed-warbler	<i>Accrocephalus stentoreus</i>			•			•	•		•	•	•
Little Grassbird	<i>Megalurus gramineus</i>			•			•	•		•	•	•
Rufous Songlark	<i>Cinclothrampus mathewsi</i>	•		•				•		•	•	•
Brown Songlark	<i>Cinclothrampus cruralis</i>			•				•	•	•	•	•
Golden-headed Cisticola	<i>Cisticola exilis</i>			•			•	•		•		•
Silvereye	<i>Zosterops lateralis</i>			•				•		•	•	
Common Blackbird ⁺	<i>Turdus merula</i>							•		•	•	

Fauna Species Recorded for Lake Cowal and Surrounds⁷ Continued

Common Name	Scientific Name	Gunninah Consult. (1995)	Lane (1989-1991) EES (1992-1997)	Vestjens (1977)	Greg Richards & Assoc. (1997)	Lawler (1989)	Hatton (1991)	NSW Bird Atlasers (1995)	RAOU Records (1995)	CSIRO (1997)	NPWS NSW Wildlife Atlas Records (1997)	Illawarra Bird Observers Club
White-striped Freetail-bat	<i>Myctinomys australis</i>	•		•	•					•	•	
Lesser Long-eared Bat	<i>Myctophilus geoffroyi</i>	•		•	•					•	•	
Greater Long-eared Bat*	<i>Nyctophilus timoriensis</i>									•	•	
Large-eared Pied Bat*	<i>Chalinolobus dwyeri</i>									•		
Gould's Wattled Bat	<i>Chalinolobus gouldii</i>	•		•	•					•	•	
Chocolate Wattled Bat	<i>Chalinolobus morio</i>				•					•		
Little Pied Bat*	<i>Chalinolobus picatus</i>	•									•	
Eastern False Pipistrelle*	<i>Falsistrellus tasmaniensis</i>									•		
Southern Myotis*	<i>Myotis macropus</i>									•		
Inland Broad-nosed Bat	<i>Scotorepens balstoni</i>	•								•	•	
Little Broad-nosed Bat	<i>Scotorepens greyii</i>	•			•						•	
Large Forest Bat	<i>Vespadelus darlingtoni</i>									•		
Southern Forest Bat	<i>Vespadelus regulus</i>	•			•					•		
Eastern Cave Bat*	<i>Vespadelus troughtoni</i>	•										
Little Forest Bat	<i>Vepadelus vulturinus</i>	•			•					•	•	
Unknown Forest Bat	<i>Vespadelus</i> sp.			•								
Water-rat	<i>Hydromys chrysogaster</i>			•						•	•	
House Mouse ⁺	<i>Mus musculus</i>	•		•						•	•	
Black Rat ⁺	<i>Rattus rattus</i>			•						•	•	
Dingo	<i>Canis lupus dingo</i>									•	•	
Dog ⁺	<i>Canis familiaris</i>										•	
Fox ⁺	<i>Vulpes vulpes</i>	•		•						•	•	
Cat ⁺	<i>Felis catus</i>	•		•						•	•	
Brown Hare ⁺	<i>Lepus capensis</i>	•								•	•	
Rabbit ⁺	<i>Oryctolagus cuniculus</i>	•		•						•	•	
Pig ⁺	<i>Sus scrofa</i>	•		•						•	•	

Cow ⁺	<i>Bos taurus</i>	•			•
Goat ⁺	<i>Capra hircus</i>			•	•
Sheep ⁺	<i>Ovis aries</i>	•			•
Reptiles					
Eastern Snake-necked Turtle	<i>Chelodina longicollis</i>		•		•
Murray Turtle	<i>Emydura macquarii</i>		•		
Marbled Gecko	<i>Christinus marmoratus</i>			•	
Eastern Spiny-tailed Gecko	<i>Diplodactylus intermedius</i>		•		
Box-patterned Gecko	<i>Diplodactylus steindachneri</i>			•	
Tessellated Gecko	<i>Diplodactylus tessellatus</i>			•	
Wood Gecko	<i>Diplodactylus vittatus</i>			•	•
Tree Drella	<i>Gehyra variegata</i>		•		•
Bynoe's Gecko	<i>Heteronotia binoei</i>			•	
Beaked Gecko	<i>Rhynchoedura ornata</i>			•	
Thick-tailed Gecko	<i>Underwoodisaurus miihi</i>	•		•	•
Pink-tailed Legless Lizard*	<i>Aprasia parapulchella</i>			•	•
Unbanded Delma	<i>Delma butleri</i>			•	
Patternless Delma	<i>Delma inornata</i>		•		•
Burton's Snake-lizard	<i>Lialis burtonis</i>			•	
Common Scaly-foot	<i>Pygopus lepidopodus</i>			•	
Hooded Scaly-foot	<i>Pygopus nigriceps</i>			•	•
Jacky Lizard	<i>Amphibolurus muricatus</i>			•	
Nobbi	<i>Amphibolurus nobbi</i>			•	•
Painted Dragon	<i>Ctenophorus pictus</i>			•	
Bearded Dragon	<i>Pogona barbata</i>	•		•	•
Lined Earless Dragon*	<i>Tympanocryptis lineata pinguicollis</i>			•	
Lined Earless Dragon	<i>Tympanocryptis lineata</i>		•		
Gould's Goanna	<i>Varanus gouldii</i>			•	
Lace Monitor	<i>Varanus varius</i>	•		•	•
Bold-striped Cool-skink	<i>Bassiana duperreyi</i>		•		•

Fauna Species Recorded for Lake Cowal and Surrounds⁷ Continued

Common Name	Scientific Name	Gunninah Consult. (1995)	Lane (1989-1991) EES (1992-1997)	Vestjens (1977)	Greg Richards & Assoc. (1997)	Lawler (1989)	Hatton (1991)	NSW Bird Atlassers (1995)	RAOU Records (1995)	CSIRO (1997)	NPWS NSW Wildlife Atlas Records (1997)	Illawarra Bird Observers Club
Southern Rainbow-skink	<i>Carlia tetradactyla</i>									•		
Spiny-palmed Shinning-skink	<i>Cryptoblepharus carnabyi</i>	•		•						•	•	
Brown-blazed Wedgesnout Ctenotus	<i>Ctenotus allatropis</i>									•	•	
Robust Ctenotus	<i>Ctenotus robustus</i>			•						•	•	
Eastern Barred Wedgesnout Ctenotus	<i>Ctenotus strauchii</i>										•	
Copper-tailed Skink	<i>Ctenotus taeniolatus</i>									•	•	
Spotted Ctenotus	<i>Ctenotus uber</i>									•		
Tree Skink	<i>Egernia striolata</i>									•	•	
Eastern Water-skink	<i>Eulamprus quoyii</i>									•		
Three-toed Earless Skink	<i>Hemiernis decresiensis</i>									•		
South-eastern Slider	<i>Lerista bougainvillii</i>									•		
Wood Mulch-slider	<i>Lerista muelleri</i>	•								•		
Eastern Robust Slider	<i>Lerista punctatovittata</i>			•						•		
Common Dwarf Skink	<i>Menetia greyii</i>			•						•		
Southeastern Morethia Skink	<i>Morethia boulengeri</i>	•		•						•	•	
Eastern Blue-tongued Lizard	<i>Tiliqua scincoides</i>			•						•	•	
Shingle-back	<i>Trachydosaurus rugosus</i>			•						•	•	
Southern Blind Snake	<i>Ramphotyphlops australis</i>									•		
Prong-snouted Blind Snake	<i>Ramphotyphlops bituberculatus</i>									•	•	
Blackish Blind Snake	<i>Ramphotyphlops nigrescens</i>									•		
Proximus Blind Snake	<i>Ramphotyphlops proximus</i>									•	•	
Claw-snouted Blind Snake	<i>Ramphotyphlops unguirostris</i>			•						•		
Brown-snouted Blind Snake	<i>Ramphotyphlops wiedii</i>									•		
Carpet & Diamond Python	<i>Morelia spilota</i>			•						•		
Common Death Adder	<i>Acanthophis antarcticus</i>									•		
Yellow-faced Whip Snake	<i>Demansia psammophis</i>			•						•		

White-lipped Snake	<i>Drysdalia coronoides</i>	•	•	•
Red-naped Snake	<i>Furina diadema</i>	•	•	•
Eastern Tiger Snake	<i>Notechis scutatus</i>	•	•	•
King Brown Snake	<i>Pseudechis australis</i>	•	•	•
Spotted Black Snake	<i>Pseudechis guttatus</i>	•	•	•
Red-bellied Black Snake	<i>Pseudechis porphyriacus</i>	•	•	•
Eastern Brown Snake	<i>Pseudonaja textilis</i>	•	•	•
Spectacled Hooded Snake	<i>Suta spectabilis</i>	•	•	•
Curl Snake	<i>Suta suta</i>	•	•	•
Bandy-bandy	<i>Vermicella annulata</i>	•	•	•
Amphibians				
Eastern Sign-bearing Froglet	<i>Crinia parinsignifera</i>	•	•	•
Common Eastern Froglet	<i>Crinia signifera</i>	•	•	•
Sloane's Froglet	<i>Crinia sloanei</i>	•	•	•
Eastern Banjo Frog	<i>Limnodynastes dumerilii</i>	•	•	•
Long-thumbed Frog	<i>Limnodynastes fletcheri</i>	•	•	•
Giant Banjo Frog	<i>Limnodynastes interioris</i>	•	•	•
Salmon-striped Frog	<i>Limnodynastes salmini</i>	•	•	•
Spotted Grass Frog	<i>Limnodynastes tasmaniensis</i>	•	•	•
Sudell's Frog	<i>Neobatrachus sudelli</i>	•	•	•
Crucifix Toad	<i>Notaden bennettii</i>	•	•	•
Brown Toadlet	<i>Pseudophryne bibronii</i>	•	•	•
Wrinkled Toadlet	<i>Uperoleia rugosa</i>	•	•	•
Water-holding Frog	<i>Cyclorana platycephala</i>	•	•	•
Green Tree-frog	<i>Litoria caerulea</i>	•	•	•
Peron's Tree-frog	<i>Litoria peronii</i>	•	•	•
Southern Bell Frog*	<i>Litoria raniformis</i>	•	•	•
Desert Tree Frog	<i>Litoria rubella</i>	•	•	•

* Listed on the NSW Threatened Species Act, 1995 + Introduced Species ▶ Note that the list contains species considered to be possible occurrences in the region and unrealistic vagrant species (eg. Grey Ternlet, listed by the NPWS NSW Wildlife Atlas Records, 1997).

1 Species listed on China – Australia Migratory Birds Agreement (CAMBA) 2 Species listed on Japan – Australia Migratory Birds Agreement (JAMBA)

Source:

Gunninah Consultants Pty Ltd (1995) Appendix A
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Australian Birds, 23(2):32-35.

Hatton, P.J. (1991). *Draft Water Management Plan for the*
Wilbertroy/Cowal Wetlands. Department of Water Resources.
In Gunninah Consultants as above.

NSW Bird Atlassers Records for 10 Minute Grids Centred
on 33°35" x 147°25' and 33°45" x 147°25'. In Gunninah
Consultants as above.

RAOU Records for 10 Minute Grids Bounded by 33°20'S to
33°50'S and 147°00' to 147°40'E. In Gunninah Consultants
as above.

CSIRO (1997). Expert assessments of species that occur, or
may occur, for the Lake Cowal area (33°15' to 34°00'S and
145°15' to 148°00'E).

NSW NPWS (1997). NSW Wildlife Atlas Records for the Lake
Cowal Area (33°00' to 34°00'S and 147°00' to 148°00'E).

Illawarra Bird Observers Club – Avifauna Species List for
the Lake Cowal Area. In Gunninah Consultants as above.

Attachment A5

Total Bird Counts for Waterbird Monitoring Survey

Total Bird Counts from Waterbird Monitoring Survey (1989-1997)

Species	Aug 89	Oct 89	Jan 89	Aug 90	Oct 90	Jan 91	Aug 91	Oct 91	Jan 92	Aug 92	Oct 92	Jan 93	Aug 93	Oct 93	Jan 94	Aug 94	Oct 94	Jan 95	Aug 95	Oct 95	Jan 96	Aug 96	Oct 96	Jan 97	Aug 97	Oct 97
Great Crested Grebe#	12	1	30								1															
Hoary-headed Grebe#	7	13	271	15	5								46			85	25		53	20		8	4		1	2
Australasian Grebe	16	9	61			24							9			1			5			3				
Australian Pelican#	8	236	518	11	88	989	269	285	241	136	53	67	155	242	1963	167	1184	528	45	254				233		68
Darter#	1	2	9	10	36	22	4	13	2	13	5	9	37	67	47	16	19	37	11	27				11		
Great Cormorant#	4	14	21	15	301	103	29	1	1	1	3	2	42	65	69	28	401	10	4	4				9		1
Pied Cormorant#	1	1	18	1	1	1	1	1	3							4	7		4	3		2	1			
Little Black Cormorant#	17	19	22	160	154	832	162	40	10	50	13	1	5	8	201	31	17	51	16	25				27		4
Little Pied Cormorant#	50	26	109	24	10	48	40	3			2			2	2	18	1	3	5	2				79		
White-necked Heron#	1	28	7		1				2		2	10	1	4		1	1									
White-faced Heron#	6	42	41	7	3	13	1	4	18		5	18	5	7	8	2	5	8	4					8	31	
Great Egret#	1	14	120	41	151	56	63	4	10	2	23	16	8	24	5	9	9	9	4	8				31		6
Little Egret#							3					1	3	1	1	1										
Intermediate Egret#	5			4						4				7	1			2	2					2		1
Cattle Egret	12																									
Nankeen Night Heron#				2						2	5	9		1				1						3		
Australasian Bittern											1															
Glossy Ibis				42	8			46						134	11	26	3	31						12	23	135
Australian White Ibis#	4	42	19	5	15	12	12		1	5		6	1	21	15		4	7	2	1				21	9	5
Straw-necked Ibis	16	24	6		32		65	14	20		3						10	163		34				4	25	
Royal Spoonbill#	23	5	8	10	7	5	14	1	8	1	70	5	4	31	4	18	5	6	17					24	14	18
Yellow-billed Spoonbill	4	17	8	13	26	31	58	22		7	20	9	28	19	6	22	16	12	9	33				43	10	
Black Swan	84	24	291	20	43	70	341	100	13	90	15	42	84	99	344	91	126	113	305	458				44	14	77
Freckled Duck	4	23													14				28							
Australian Shelduck	8	26	18	3	15	59	14	2	2	6		1	31	18	21	25	22	30	38	63				112	17	21
Pacific Black Duck	36	160	245	56	44	147	116	81	102	77	41	76	136	152	233	31	38	288	25	59				97	55	153
Grey Teal	472	1227	5056	111	68	1649	2301	687	444	293	98	217	600	543	1689	254	518	542	375	368				852	1687	2082
Chestnut Teal	15		25			5				2				2		11	4		2							
Australasian Shoveler	21	34	55	2	54	55	2	29	1	11	3	3	159	16	38	190	39	6	31	45						101
Pink-eared Duck		8	103		4	1	226		2	1	2	80	90	78	13	11			31					3		9
Hardhead	29	77	5		15			4	4	2		2	10	19	2				14							
Australian Wood Duck	15	223	332	122	67	119	24	11	8	21	197	116	103	93	38	107	110	9	11	18						18

Species	Aug 89	Oct 89	Jan 90	Aug 91	Oct 91	Jan 92	Aug 92	Oct 92	Jan 93	Aug 93	Oct 93	Jan 94	Aug 94	Oct 94	Jan 95	Aug 95	Oct 95	Jan 96	Aug 96	Oct 96	Jan 97	Aug 97	Oct 97
Musk Duck		2	13							4				2		5	2	1					
Blue-billed Duck			13																				
Black-tailed Native-hen			4	19						2		6	29	55									
Dusky Moorhen										1	2					2							
Purple Swanphen		1	49	17		2	2	9	10	408	18	28	562	338	116	278	119	22	80	107	43	175	619
Eurasian Coot		30	530	1105	331	133	213	393	331	754		195	576	825	683	1246	2629	586	2100		197		810
Brolga			3												2								
Masked Lapwing	25	88	109	6	11	73	6	24	23	6		12	5	19	97	12	32	77	12	35	43	63	79
Banded Lapwing			5																				
Pacific Golden Plover																							1
Red-kneed Dotterel			1			13							1	1		2					2		
Red-capped Plover						5	2	10											10	5		81	4
Double-banded Plover																						6	
Black-fronted Dotteral				2	5	30	4	2		1		2	5	9	1	2	2	3	22	6	9	83	2
Black-winged Stilt		34	332	13	2	325	48	4	28						320	5	28	11	28		335	68	1330
Red-necked Avocet			9			4									1				49	107			21
Little Whimbrel																							2
Greenshank						8	37	82	42						12			3	1		49		1
Marsh Sandpiper						39		41	3						3			1			2		19
Sharp-tailed Sandpiper						14	5	6												2	201		167
Pectoral Sandpiper								2															
Red-necked Stint						2																	
Latham's Snipe									5	2	4				4				14		6	1	
Australian Pranticole																							6
Silver Gull#	84	98	23	22	3	280	35	32	36	33	6	10	47	12	60	9	6	64	59		35	5	18
Franklin's Gull						1																	
Whiskered Tern#		65	239	46	4	21		112	93	14		41		19	200	1	123	2		119	699		871
Gull-billed Tern		2		3		2	7																
Caspian Tern#						1		1	1							1		1					
White-winged Black Tern																					4		
Number of Species	22	35	37	28	27	36	32	34	28	33	20	26	30	34	34	33	32	35	31	29	34	19	32
Total fish-eaters#	190	606	1303	450	405	2678	692	601	413	324	96	267	4046	502	1740	323	1811	735	164	469	1184	59	994
% fish-eaters	20.4	23.2	15.1	23.2	38.1	48.7	16.5	27.4	28.7	15.8	32.2	24.8	15.3	17.1	30.9	13.4	32.8	25.0	4.9	26.8	35.9	2.4	14.9
TOTAL	931	2608	8616	1943	1063	5499	4193	2194	1437	2046	298	1077	2646	2932	5640	2407	5524	2938	3346	1752	3296	2419	6668

Source: EES (1997c)

Attachment A6

The Record of Breeding Activity at Lake Cowal

The Record of Breeding Activity at Lake Cowal (1989–1997)

Species	Aug 89	Oct 89	Jan 90	Jan 91	Aug 91	Oct 91	Jan 92	Aug 92	Oct 92	Jan 93	Aug 93	Oct 93	Jan 94	Aug 94	Oct 94	Jan 95	Aug 95	Oct 95	Jan 96	Aug 96	Oct 96	Jan 97	Aug 97	Oct 97
Great Crested Grebe			*																					
Hoary-headed Grebe		*	*																					
Australasian Grebe			*																					
Darter	30		50	162		133	21			3			80		10	50		19	20			12		
Great Cormorant			*	40		1						6												
Pied Cormorant			*	15		8	1					10						10	30			10		
Little Black Cormorant	150		300	474		214	164			8		55	1000					60	30					
Little Pied Cormorant	100		350			3					6							10	20					
White-necked Heron	*		*	1							1													
White-faced Heron	*		*								1													
Great Egret			*	1																				
Intermediate Egret			7	1																				
Nankeen Night Heron			200	28														1						
Glossy Ibis			20+							100														
Australian White Ibis	120		120	24		5				500+		191	50					51	10			18		
Straw-necked Ibis	4000		*							1500+		3734	2500					350	4000			1500		
Royal Spoonbill	15		45	36		1				30		14	100						40			9		
Yellow-billed Spoonbill	*		*	12		1						20												
Black Swan	*	*	*					1	2	7		3	2				5		*		*			
Australian Shelduck	*														2						*			
Pacific Black Duck	*	*									1						1		1					
Grey Teal	*	*	*								2		5						1					
Pink-eared Duck	*	*	*																					
Hardhead	*	*	*																					
Australian Wood Duck	*						1					5						1			*			
Blue-billed Duck		*	*																					
Musk Duck			*																					
Eurasian Coot	*	*	*																					
Purple Swamphen													1											

Species	Aug 89	Oct 89	Jan 90	Jan 90	Aug 91	Oct 91	Jan 92	Aug 92	Oct 92	Jan 93	Aug 93	Oct 93	Jan 94	Aug 94	Oct 94	Jan 95	Aug 95	Oct 95	Jan 96	Aug 96	Oct 96	Jan 97	Aug 97	Oct 97
Masked Lapwing		*																						
Red-kneed Dotterel			*																					
Black-winged Stilt		*	*																					
Silver Gull					<10	9+				6								6						
Whiskered Tern		1000	500							15														
Gull-billed Tern			2/3																					
White-bellied Sea-eagle																				1				
TOTAL	*	5415	1594	912	<10	377	187	2	2	2148	0	4084	3794	0	12	50	6	508	4152	*	*	1549	0	*
Number of Species	9	19	29	11	1	9	3	2	1	7	0	11	13	0	2	1	2	9	9	2	2	5	0	1

* Denotes breeding record; numbers indicate the number of nests
Source: Lane, 1988-1991; Environmental and Educational Services, 1992-1997

Attachment A7

Results of a Bat Fauna Survey to Target Threatened Species

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November 1997

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Appendix 1	Location of Sampling Points
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DISCLAIMER¹

The following report is explicitly the opinion of the consultant, and is based upon data available and assessments conducted according to the methods described.

Greg Richards and Associates (GR&A) has had to rely on information from other sources in preparing this report (including the party for whom it is prepared) and is not in a position to, and has not, verified the accuracy or completeness of such information. Accordingly, GR&A takes no responsibility for and assumes no liability in respect of, any information provided to it by others for the purposes of preparing this report or the consequences of using such information.

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¹ *This is a requirement of the consultant's insurance company.*

EXECUTIVE SUMMARY

The bat fauna of the Lake Cowal area was inventoried by interrogating (before a field survey) a database of national distribution information, using a search block of 1.5 degrees of latitude by 3.0 degrees of longitude that was centred upon the project area. This showed that a potential fauna of 21 species could be expected in the region, and that 9 of these were listed in the NSW Threatened Species Conservation Act 1995.

Census points were stratified across all habitats and replication included all impact zones, such as the proposed open pit area, the waste rock emplacement site, the and tailings storage areas. A total of 16 sites were sampled. Habitats included woodland remnants comprising two vegetation communities, open pastureland, dams, and the shoreline of Lake Cowal. Census techniques were designed to target species that had been addressed in a previous Eight Part Test.

Bats were censused at each sampling point using harp traps with plastic netting wings attached to increase the catch area. Echolocation call detectors were also utilised to identify the bat fauna. Trip-lining was conducted at the dam near the exploration camp at the minesite. Disused mine areas were searched for potential subterranean roosts for bats, but most were unsuitable.

The survey was conducted between 20 and 25 October inclusive. A total of nine species were recorded, including the Yellow-bellied Sheathtail Bat (*Saccolaimus flaviventris*) that is listed in the NSW Threatened Species Conservation Act. This species was recorded electronically near the lake shore, to the east of the minesite.

INTRODUCTION

The consultant was commissioned by Resource Strategies Pty Ltd to conduct a bat fauna survey for a proposed mining operation to be conducted by North Ltd on the western shoreline of Lake Cowal. The location of the project area is shown as a red dot in Figure 1.

This survey was a logical expansion of the environmental assessment process for this development, and emanated from an assessment of the threatened species which was conducted using the requirements of Section 5A of the *Environmental Planning and Assessment Act 1979* (the "Eight Part Test") by Richards (1997a). This exercise identified a potential fauna of 21 species, 9 of which were listed in the *Threatened Species Conservation Act 1995*.

The bat fauna survey conducted at the minesite was therefore designed to target threatened species, primarily to verify their presence or to provide strong evidence of their absence.

BAT FAUNA EXPECTED

Reference to the consultant's database of approximately 16,000 bat location records (see Figure 2 for location of search block), and texts such as Hall and Richards (1979), Strahan (1983, 1995) and Parnaby (1992), generated the list of bat species shown in Table 1. A list of additional species to be addressed was provided to Resource Strategies Pty Ltd by the NSW National Parks and Wildlife Service.

METHODOLOGY

Bat survey

Several methods were used to collect data for the assessment of the bat fauna at the Cowal Gold minesite, and these are outlined as follows :

1. Using data from major surveys in eastern Australia, it has been shown that it is essential to use harp traps and electronic detectors together during bat surveys, because some species are impossible to capture, whilst others are infrequently detected. Each method cannot be used alone to obtain a full complement of data (Richards 1996). The basic field methodology used at the Cowal Gold minesite takes account of this point, and basically follows that described by Kunz *et al.* (1996 a & b).

Table 1 Bat species that may be expected in the Lake Cowal area, compiled from database records (D) with additions as also advised by NSW NPWS (N). Species listed as Vulnerable in the *Threatened Species Conservation Act 1995* are shown in bold.

<u>Pteropodidae</u>			
<i>Pteropus poliocephalus</i>		D	
<i>Pteropus scapulatus</i>		D	
<u>Emballonuridae</u>			
<i>Saccolaimus flaviventris</i>		N	
<u>Molossidae</u>			
<i>Mormopterus planiceps</i>		D	
<i>Nyctinomus australis</i>		D	
<u>Vespertilionidae</u>			
<i>Chalinolobus dwyeri</i>		N	
<i>Chalinolobus gouldii</i>		D	
	<i>Chalinolobus morio</i>		D
	<i>Chalinolobus picatus</i>		D
	<i>Falsistrellus tasmaniensis</i>		N
	<i>Miniopterus schreibersii</i>		D
	<i>Myotis macropus</i>		D
	<i>Nyctophilus geoffroyi</i>		D
	<i>Nyctophilus gouldi</i>		D
	<i>Nyctophilus timoriensis</i>		D
	<i>Scotorepens balstoni</i>		D
	<i>Scotorepens greyii</i>		D
	<i>Vespadelus baverstocki</i>		N
	<i>Vespadelus regulus</i>		D
	<i>Vespadelus vulturnus</i>		D
	<i>Vespadelus troughtoni</i>		N

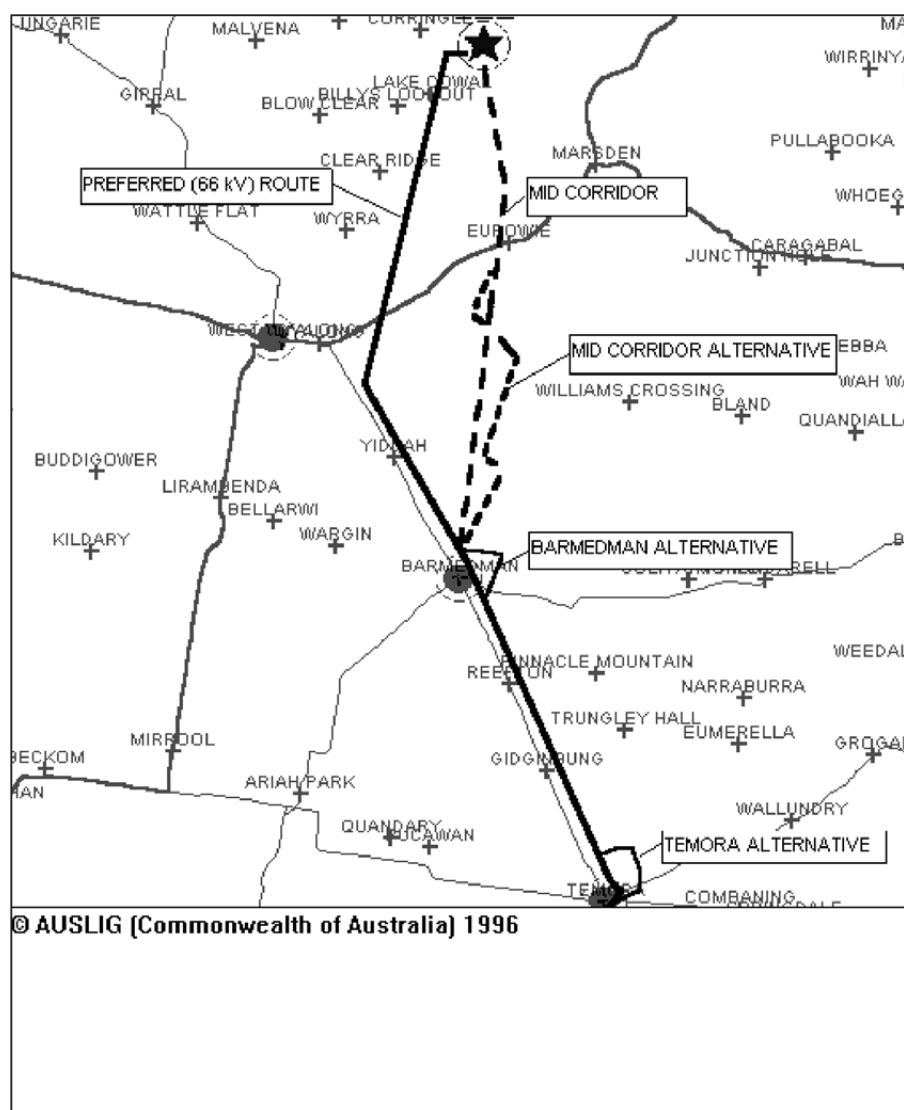


Figure 1

Location of the minesite project area on the western edge of Lake Cowal, NSW, shown as a red dot.

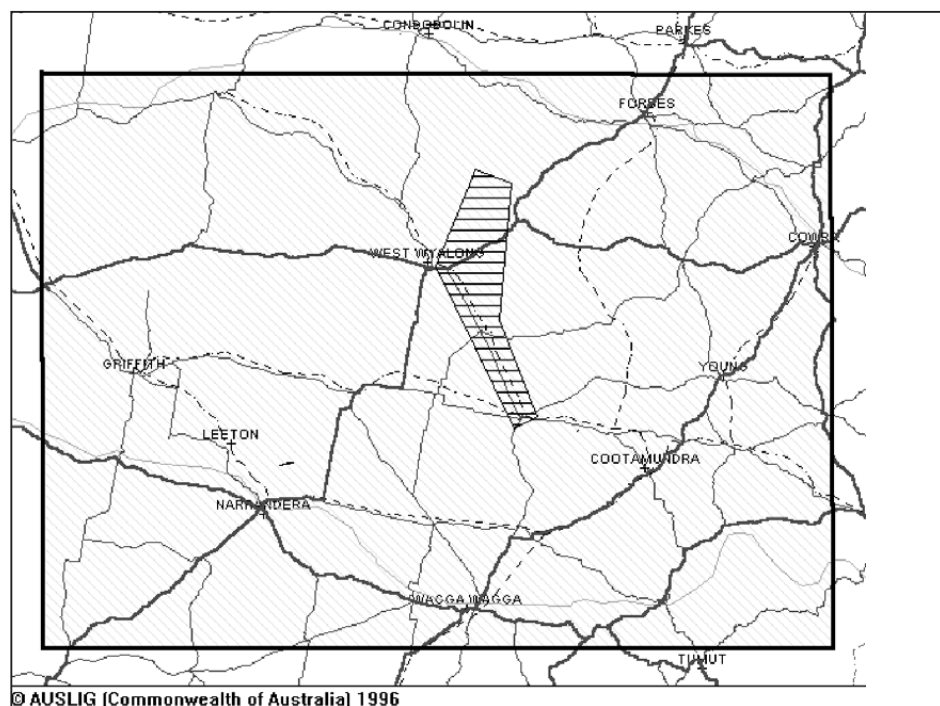


Figure 2

Search block for interrogation of consultant's database to obtain records for Vulnerable bat species listed in Table 2. The search area boundaries were 32°30' to 34°00' by 146°00' to 149°00'.

2. Anabat™ electronic detector systems were used to record bats throughout the night, using a voice-activated switching device. Systems were turned on automatically at dusk, and recorded throughout the night, each time that an echolocating bat passed through the microphone detecting space. This is an improvement on past surveys that usually record continuously after dusk on one side of a cassette tape, typically for only 45 minutes, whereas the voice-activated system can record for up to 12 hours. Sites were electronically monitored for one night each.

Species-specific echolocation calls were later analysed from digitised computer displays, and identifications of free-flying bats were then made. These identifications were made after each night, in the event that a threatened species had been recorded and may have required either specialised, intensive, and/or extended survey.

3. Harp traps were set for two nights in each wooded habitat to capture certain species that have low intensity echolocation calls, and may not have been recorded electronically unless in close proximity to the microphone. To improve the catch area of the harp traps, plastic net wings approximately 15 metres long were attached to the sides of the trap frame and set at a shallow angle. Years ago harp traps were designed to be used in flyways such as tracks in forest and have a standard width (catch area) of 2 metres. With the net wings the catch area is increased at least 10-20 fold, and adapts the trap to open habitats such as woodland. An example of such a trap site is shown in Figure 3, and trap sites are listed in Appendix 1.
4. Triplining was conducted from dusk for approximately three hours one evening during the survey at a stock dam near the exploration camp (site 2) to inventory species that could be expected in the area where the plant and open pit will be constructed. Triplining is a method where several monofilament fishing lines are criss-crossed and stretched tautly just above the water surface; bats that fly low to drink in the evening brush the line with their wing tips and hit the water, being captured before they fly off again when they have swum to the bank of the dam.
5. The influence of climatic conditions on bat activity has been documented for other regions (Richards 1989), and the survey was conducted in conditions that could be regarded as ideal. Moonlight was absent, night temperatures though cool near dawn were relatively mild for most of each night, and there was no rainfall during the study.
6. Although there are no limestone caves in the area (Matthews 1985), searches of other potential subterranean roost sites were conducted in old mining areas, using information from the data sheets that accompany the Forbes 1:250,000 metallogenic map (Bowman 1977). This latter publication shows old mining areas on maps, and for each disused mine

relevant data such as the type of shaft has been recorded. This gave a guide to potential roosts. Other roosts likely to be used by bats (especially threatened species) were also visually inspected, these included the ceilings of disused buildings and the mud nests of Fairy Martins.

7. The location of most of the sampling points was taken with a Magellan 2000 geographical positioning system having an accuracy of ± 25 metres. These coordinates are listed in Appendix 1.

The survey was conducted over 5 consecutive nights between 20 – 25 October 1997, using 5 harp trap sites that were operated for two consecutive nights each (= 10 trap nights), and also included 12 nights of electronic detecting of echolocation calls in the project area. A detector was operated for 3 nights at the lake shore to target species such as *Myotis macropus* that may have been foraging over water.

Sampling strategy

A total of 16 census points were stratified across all habitats, and replicated to include all impact zones identified, such as the open pit area, open pit site, and proposed tailings storage locations. The stratification and replication of sampling points is shown in Table 2. Overlap of habitats and impacts was, in broad terms, as follows:

- the mine open pit will remove a very small stand of red gum;
- the open pit will be located on a knoll that has eucalypt woodland; and
- the tailings storage area will remove a *Callitris* remnant.

RESULTS

Species recorded

The following 9 species were recorded on the site:

Yellow-bellied Sheath-tail Bat	(<i>Saccolaimus flaviventris</i>)
White-striped Freetail Bat	(<i>Nyctinomus australis</i>)
Little Freetail Bat	(<i>Mormopterus planiceps</i>)
Lesser Long-eared Bat	(<i>Nyctophilus geoffroyi</i>)
Gould's Wattled Bat	(<i>Chalinolobus gouldii</i>)
Chocolate Wattled Bat	(<i>Chalinolobus morio</i>)
Little Broad-nosed Bat	(<i>Scotorepens greyii</i>)
Southern Forest Bat	(<i>Vespadelus regulus</i>)
Little Forest Bat	(<i>Vespadelus vulturnus</i>)

No megachiropteran bats (listed in Table 1) were recorded during the survey either visually or by hearing social calls whilst feeding at night. No flying-fox camps were known in the area, nor were any eucalypt trees noted as flowering to the extent that they would be a food source for this group of bats.

The only one of these species that is listed in the NSW Threatened Species Conservation Act 1995 is the Yellow-bellied Sheath-tail Bat.

Table 3 shows the presence of species at each sampling point, tabulated by habitat and impact types.

Habitat utilisation

Table 4 shows that most of the community occupies the eucalypt woodland and *Callitris* remnants. *S. flaviventris* and *C. morio* appeared to be restricted to just one habitat, these being the lake shore and *Callitris* respectively. Other species, such as *N. australis*, *M. planiceps* and *C. gouldii* were wide-spread. The two former species have a high wing aspect ratio and can cover large areas when foraging, which is usually by aerial intercept mode (Richards 1994).

Abundance in each habitat can also be measured by analysing detector passes, with the exception of *N. geoffroyi* which is virtually undetectable (Richards 1996).

This is due to its low intensity (soft) echolocation calls, as well as its manner of sometimes not echolocating at all and instead listening for the noises made by insect prey on substrates (Hosken *et al.*, 1994).

Table 5 shows the abundance of the Cowal Gold Project bat community in each habitat as measured by the number of echolocation call passes at sites where detectors were used. *N. geoffroyi* has been excluded from this analysis (see text above). Table 6 shows the abundance of species caught in harp traps during the survey, and indicates the few species that were caught during the triplining session.

The use of detector passes as abundance data has been quite problematical. What do 20 passes indicate: 20 bats once or one bat 20 times, or combinations of both? For the purposes of this analysis, detector passes are used to indicate habitat quality for each species, where quality can be interpreted as either having higher levels of preferred prey, or having a structure that suits a particular species (Richards 1996).

Table 2 Stratification and replication of the 16 sampling points and the techniques used to survey the bat fauna at the Cowal Gold Project minesite. Values indicate the number of sites in each category, and one site was used for both detecting and trapping, hence the totals of 17 replicates. An "inventory" site is one that is not in an impact zone, but would have been attractive to bats and would provide extra data on the presence of local species.

Habitat	Number of:		Impact	Number of:	
	Trap sites	Detector stations		Trap sites	Detector stations
Lake edge	0	2	Pit	1	1
Red gum	1	1	Dump	2	3
Eucalypt Woodland	2	3	Tailings	2	6
<i>Callitris</i> Pine	2	3	Inventory sites	0	4
Stock dams	0	3			
Totals	5	12		5	12

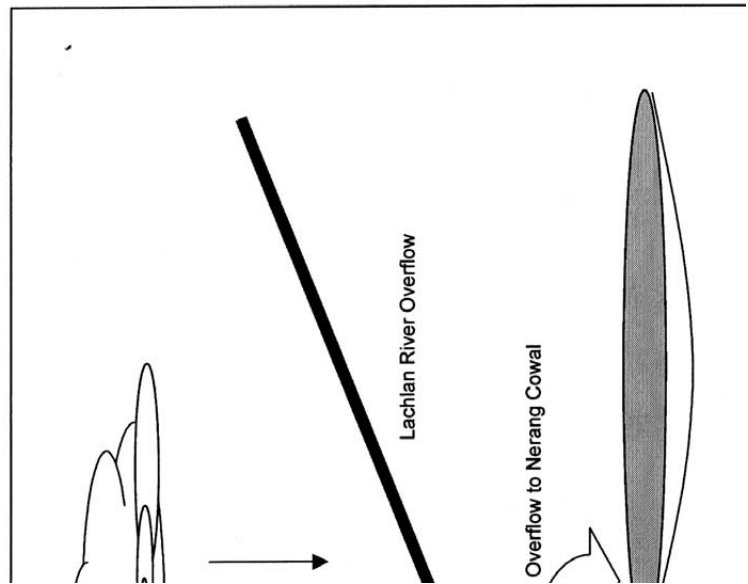
Table 3 Bat species present (indicated by an asterisk) at each site during the survey conducted in October 1997.

Habitats are: RG = Red Gum, Ew = Eucalypt woodland, CP = *Callitris* Pine, SD = Stock dam, LS = Lake shoreline. Impact zones are M= Minesite (open pit and plant area), D = dump for waste extracted from open pit (waste rock emplacement sites), T = proposed tailings storage area, and a dash indicates an inventory site that will not be impacted. Methods are indicated by H = harp trap, D = detector, T = triplining.

Site number	1	1	2	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Habitat	RG	RG	SD	SD	Ew	SD	LS	Ew	Ew	RG	CP	CP	CP	CP	CP	SD	Ew	Ew
Impact zone	M	M	M	M	D	-	-	D	D	M	T	T	T	T	T	-	D	D
Method	H	D	D	T	D	D	D	D	H	D	D	H	D	H	D	D	H	D
<i>S. flaviventris</i>	-	-	-	-	-	-	•	-	-	-	-	-	-	-	-	-	-	-
<i>N. australis</i>	-	•	•	-	•	•	•	•	-	•	•	-	•	-	-	-	-	-
<i>M. planiceps</i>	-	•	•	-	-	•	-	•	-	-	-	-	•	-	•	•	-	-
<i>N. geoffroyi</i>	•	-	-	-	-	-	-	-	•	-	-	•	-	•	-	-	•	-
<i>C. gouldii</i>	•	-	•	•	•	-	-	-	-	•	•	-	-	-	•	-	-	-
<i>C. morio</i>	-	-	-	-	-	-	-	-	-	-	-	•	•	-	-	-	-	-
<i>S. greyii</i>	-	-	•	•	•	-	-	-	•	-	-	-	-	•	-	-	-	-
<i>V. regulus</i>	-	-	-	-	-	-	-	•	-	-	-	-	-	•	-	-	-	-
<i>V. vulturnus</i>	-	-	•	•	•	-	-	-	-	•	-	-	-	-	-	•	-	•

Figure 3

A harp trap set in a woodland remnant to show a typical arrangement of the plastic netting wings used to increase the catch area. The netting is suspended from the top of the trap by yellow cord, and pink flagging tape has been attached to deter birds and livestock. Note that the trap has been situated to make use of branches and foliage overhead, to further block the flight path of bats.

**Figure 4**

Portion of the Forbes 1:250,000 metallogenic map (Bowman, 1977) scanned to show the location of the Billys Lookout Gold District that was inspected for potential bat roosts during the survey.

Apart from the species restricted to just one habitat, several species showed an apparent higher abundance in some habitats rather than others. Examples of this include the higher abundance of *S. greyii* in the eucalypt woodland, and *M. planiceps* over stock dams.

Even though they had plastic netting wings attached to increase their catch area, only 21 bats were captured in harp traps. It is doubtful that these data can be used to measure abundance and habitat utilisation, apart from the captures of the easily trappable *N. geoffroyi*. This species appears to be widespread across all three habitats (Table 4).

Table 4 Utilisation of Habitats by the Minesite Bat Community (detecting and trapping data inclusive)

	RG	EW	CP	SD	LS	Total habitats	Total sites	Species rank
<i>S. flaviventris</i>	0	0	0	0	1	1	1	6
<i>N. australis</i>	1	3	2	2	1	5	9	1
<i>M. planiceps</i>	1	1	2	3	0	4	7	2
<i>N. geoffroyi</i>	1	2	2	0	0	3	5	4
<i>C. gouldii</i>	1	2	2	2	0	4	7	2
<i>C. morio</i>	0	0	2	0	0	1	2	5
<i>S. greyii</i>	0	2	1	2	0	3	5	4
<i>V. regulus</i>	0	1	1	0	0	2	2	5
<i>V. vulturnus</i>	0	3	0	3	0	2	6	3
Number of species in each habitat	5	7	7	5	2			
Percentage of community in each habitat	56	78	78	56	22			
Number of replicates	2	6	5	3	1		17	

Table 5 The abundance of the Cowal Gold Project bat community in each habitat as measured by the number of echolocation call passes at sites where detectors were used. The habitat in which each species had the highest number of passes is shown in bold. *N. geoffroyi* has been excluded from this analysis (see text).

Habitat	RG	EW	CP	SD	LS	Total passes	Percentage in favoured habitat
<i>S. flaviventris</i>	0	0	0	0	2	2	100
<i>N. australis</i>	1	10	5	7	5	28	36
<i>M. planiceps</i>	8	2	5	21	0	36	58
<i>C. gouldii</i>	0	19	10	9	0	38	50
<i>C. morio</i>	0	0	4	0	0	4	100
<i>S. greyii</i>	0	14	0	4	0	18	78
<i>V. regulus</i>	0	2	0	0	0	2	100
<i>V. vulturnus</i>	0	15	0	13	0	28	54

The Bat Community in Impact Zones

Three impact zones are present in the project area: the mine open pit and associated plant structure, the waste rock emplacement site, and the tailings storage area. As mentioned above, these zones basically fall into separate habitat types, but nevertheless separate analyses were conducted to elucidate potential problems.

Table 7 shows that 6 species used the open pit/plant area, where the existing stock dam near the present exploration camp amenities certainly had an influence, particularly in the case of *M. planiceps* (see Table 5). This is also concluded on the basis that the species data for the red gum remnant in Table 5 is relatively low. However, when the mine is constructed, it would be expected that water points in this zone would be similarly attractive to the bat species listed in Table 7 in this impact category.

Abundance (that is, detector passes) was quite different when the open pit and tailings storage areas are compared, with the former being exactly double that of the latter. This is difficult to explain, as these habitats are ostensibly similar. Again though, it may be the influence of proximity to water, as the nearest stock dam to the *Callitris glaucophylla* community tailings storage area was almost one kilometre away, and was in an open crop field.

Trap data for *N. geoffroyi* was 1, 4 and 4 captures in the open pit/plant area, waste rock emplacement, and tailings storage areas respectively.

It is important to note the influence of water points in this study, as this has relevance as a potential issue with respect to the tailings storages. This survey was conducted during spring, when temperatures were relatively mild, with daily maxima around 28°C. With hotter summer weather, where daily maxima can exceed 40°C, the bat community will be more dependent upon water either for drinking from or as a higher source of prey than in drier areas.

Table 6 The abundance of the Cowal Gold Project bat community in each habitat in the project area as measured by the captures in harp traps. Species that were also caught by triplining are shown.

Species	Habitat			Total captures	Number caught by triplining
	RG	EW	CP		
<i>S. flaviventris</i>	0	0	0	0	0
<i>N. australis</i>	0	0	0	0	0
<i>M. planiceps</i>	0	0	0	0	0
<i>N. geoffroyi</i>	1	4	4	9	0
<i>C. gouldii</i>	4	0	0	4	2
<i>C. morio</i>	0	0	3	3	1
<i>S. greyii</i>	0	2	2	4	0
<i>V. regulus</i>	0	0	1	1	1
<i>V. vulturnus</i>	0	0	0	0	0
Totals	5	6	10	21	4

Impact of Tailings Dams and Cyanide

Apart from *S. flaviventris* (which was only recorded from the lake itself) none of the species assessed from the impact zones are listed in the *NSW Threatened Species Conservation Act 1995*. However, considering the bat community as a whole, the potential for deaths to occur when such small animals consume water from cyanide laden tailings dam water has been assessed as follows:

- Sturgess *et al.*, (1989), cited in the Mount Todd Gold Project Draft Environmental Impact Statement (NSR 1992) notes that "...studies have shown that waterbirds and bats can be attracted to residue dams and that they have been poisoned by cyanide". Cyanide levels in the dams in question at Mount Todd were apparently an order of magnitude higher than the levels predicted for the Cowal Gold Project, which are expected to comply with EPA criteria of less than 20 mg/L for 90% of the time and 30 mg/L for the remainder of the time (D. Lynes, Resources Strategies, pers. comm.).
- There is evidence that cyanides are neither mutagenic, teratogenic, nor carcinogenic (Ballantyne 1987), nor is there any biomagnification in living organisms, apparently due to its rapid detoxification. Detoxification occurs when absorbed cyanide metabolises through transulfuration in the presence of enzymes to produce thiocyanate which is excreted. This is generally a rapid process and animals can apparently ingest high sublethal doses of cyanide over an extended period without harm (Eisler, 1991). The detoxification process in a bat could be expected to be similar to the processes in other animals as described above. No accumulation of cyanide is therefore expected.
- Further to this point, the United States General Accounting Office (1991) note in their report "*Mineral Resources – Increased Attention Being Given to Cyanide Operations*", that when wildlife drink from cyanide ponds highly toxic hydrocyanic acid can form and react with iron in the blood to inhibit the blood's ability to carry oxygen to the body. Death can occur if the dose is strong enough, however, with regard to sub-lethal doses, the kidneys are able to purge cyanide from the blood and the body recovers (*ibid.*).
- In previous studies at a gold mine in north Queensland (Richards 1997b) showed that there were significant differences in bat species richness and abundance when tailings dams were compared with natural water sources, with both variables being higher at the latter. This was attributed to the lack of vegetation surrounding tailings cells. Richards (1994 and unpublished PhD studies) concluded that in temperate forests bat species richness was positively correlated with the diversity and density of understorey plants, which apparently dictates the level of insect prey. It is highly likely then that at the Cowal Gold minesite, where the amount of aquatic vegetation and aquatic insects would be lower than at natural water bodies, that the two tailings dams may not be sites that are attractive to bats.
- The number of species in the Cowal Gold Project Area that may drink over water is not known. From the data from the few hours of triplining at one stock dam, and the data from inventory sites at this and other stock dams, there is an indication that there may be just a portion of the community that actually consumes free water. It is of interest to note that only 3 species were actually caught at the water surface by triplines (Table 6), whereas 5 species were detected foraging over stock dams (Table 5). Furthermore, two species (*C. morio* and *V. regulus*) were triplined but not detected over dams, and both were only recorded in one habitat each. Does this indicate that upon leaving their roost they drank before foraging in preferred habitat? This is certainly a speculative analysis, especially considering the bias in time spent on the two methods (triplining was about 3 hours, detecting over dams totalled 3 full nights).
- From the current survey, it should be noted that the only species listed as threatened, the Yellow-bellied Sheathtail Bat (*S. flaviventris*) was not recorded foraging over small water points such as stock dams, and appeared to prefer the larger water body of Lake Cowal itself. Whether it requires free water in its diet, as opposed to obtaining it from insect prey, is unknown.
- In terms of sub-lethal effects, work by Pustos and Ma (1997) and Ma and Pustos (1997) identifies cellular effects of sub-lethal levels of cyanide on key organs of the Mallard Duck, however cellular activity did revert to control levels after a period of time. The detoxification process from sub-lethal cyanide doses to bats has not been assessed, although again, based on this evidence and known detoxification processes, long term sub-lethal effects are not considered likely.
- Because (a) the utilisation of tailings dams by bats in the project area is unknown but in all likelihood expected, and (b) that harmful effects of sub-lethal doses of cyanide from pond water are not expected but toxic levels of cyanide to bats are not accurately known, it is recommended that a monitoring program be incorporated into the project, as identified below:

Recommendation

That a bat fauna monitoring program be incorporated into the operation of the Cowal Gold Project to monitor:

- whether bats may be drinking pond water from the tailings dams, and
- whether this component of mining operations is detrimentally affecting bat populations.

Subterranean roost searches

The Forbes 1:250,000 metallogenic map from the then Department of Mineral Resources' geological survey of NSW (Bowman, 1977) provided information on areas discovered during past gold and tin mining activities. A portion of this map has been scanned to create Figure 4.

Table 7 Abundance of bats in each impact zone, based upon number of echolocation calls recorded by each detectable species. *N. geoffroyi* has been excluded from this analysis for reasons explained above.

	Open pit and plant area	Waste rock emplacement	Tailings storage	Total passes	Abundance rank
<i>S. flaviventris</i>	0	0	0	0	-
<i>N. australis</i>	9	8	5	22	3
<i>M. planiceps</i>	24	2	5	31	2
<i>N. geoffroyi</i>	0	0	0	0	-
<i>C. gouldii</i>	13	15	10	38	1
<i>C. morio</i>	0	0	4	4	6
<i>S. greyii</i>	11	7	0	18	5
<i>V. regulus</i>	0	2	0	2	7
<i>V. vulturnus</i>	5	14	0	19	4
Total passes	62	48	24	143	

Only the Billys Lookout Gold District was located during the bat survey. Bowman's data sheets for mines in this area indicated that they were all vertical shafts, and doubtfully suitable as bat roosts. All of these mineshafts had been filled in (Figure 5).

DISCUSSION

Validation of survey methods

An important question is to ascertain whether the methods used in fact targeted the threatened species that had the potential to be present. This section reviews the list in Table 1, as follows:

Chalinolobus dwyeri and *C. picatus* would have been captured in harp traps or detected, as they have the same capturability and detectability as sibling species *C. gouldii* and *C. morio*, both of which were recorded during the survey. *C. picatus* was tentatively recorded by electronic detectors in the Wamboyno Mountain area by Fanning (1995), though "identifications are not definite due to limited number of calls".

Falsistrellus tasmaniensis and *Miniopterus schreibersii* are species that are easily detected (Richards, 1996) as they have very loud echolocation calls and can even be recorded when flying over tall canopies in the temperate forests of the Great Dividing Range (Richards 1992 a & b).

Myotis macropus is also easily detectable and has a unique echolocation call structure. The detector that was operated at the lake shoreline near water was operated for 3 nights to target this species if it was utilising the habitat (open water) that this species favours (Dwyer, 1970a, Richards 1983a, Richards, 1995a). Other inventory sites with water present (the stock dams) did not record this species.

Nyctophilus timoriensis was targeted by trapping in the River Red Gum, which is suspected to be a favoured habitat (Richards, unpublished) as well as in other wooded habitats.

One *N. geoffroyi* was in fact captured at the River Red Gum site (Figure 6), as well as another two at a site in eucalypt woodland, so it can be assumed that the trap/net array was appropriate for capturing any representatives of this genus, including *N. gouldii* that is also listed in Table 1.

Vespadelus baverstocki and *V. troughtoni* would have been captured in harp traps or detected as they have the same capturability and detectability as sibling species *V. regulus* and *V. vulturnus*, both of which were recorded during the survey.

Scotorepens balstoni and *S. greyii* are similar species, and the absence of the former is considered to be realistic because the latter was recorded on several occasions.

Comparison with previous survey

The fauna survey reported by Fanning (1995) recorded 5 bat species in the minesite area, these being *N. australis*, *M. planiceps*, *C. gouldii*, *V. regulus* and *V. vulturnus*. The current survey increased the number of species known, and used additional survey methods such as harp trapping and triplining. The use of voice-activated switches with detectors increased the time spent per site on echolocation call recording from half an hour (Fanning, 1997) to the duration of the night (about 10 hours per site).

Threatened Species Not Recorded in Survey

Chalinolobus dwyeri

The little that is known of the biology of this species has been contributed by Dwyer (1966a), which was reviewed by Dwyer (1983b) and Hoyer and Dwyer (1995). It appears to require caves or their substitutes for breeding, but will utilise places such as the mud nests of Fairy Martins. It is considered to be quite rare, and as well as being listed as Vulnerable in the NSW TSC Act, it is also listed in the IUCN category Lower Risk – near threatened in the national Bat Action Plan (Richards and Hall, 1996).

The consultant's distribution database shows that the nearest locality for this species is Hill End, near Bathurst, which is approximately 300 kilometres to the north-north-east of Lake Cowal. During a search of potential roosts in the project area a disused water tank with Fairy Martin nests was located (Figure 7). This tank was found near the western edge of the project area, not far from the West Wyalong-Burcher railway line. The nests were probed with forceps but no bats were present.

Richards (1997a) considered that even though there is little known about the ecology of *C. dwyeri*, it was doubtful that it will be found anywhere in the project area.

Chalinolobus picatus

The little that is known of the biology of *C. picatus* has been contributed by Richards (1979), and the species has been reviewed by Richards (1983b, 1995a). It appeared to only require caves or their substitutes for roosting, but has also been found in buildings (Hall and Richards 1979). Richards (1979) reported on the largest known breeding colony of

Figure 5

The site assumed to be part of Billys Lookout Gold District located approximately 6 kilometres to the south of the proposed Cowal Gold Project minesite. This area was inspected as it may have had potential bat roosts.

**Figure 6**

A Lesser Long-eared Bat (*Nyctophilus geoffroyi*) captured in a harp trap set in a River Red Gum remnant (site 1a). The site was intended to target a sibling species, the rare and threatened Greater Long-eared Bat (*N. timoriensis*).

**Figure 7**

A disused water tank that contained mud nests of Fairy Martins that was found at the western end of the project area. The nests were inspected for roosting bats, however none were present.



about 40 individuals that roosted behind an open sliding door in an old building at Yathong Nature Reserve. This building was later destroyed in NPWS operations. A colony roosting in a disused mineshaft at Buddigower Nature Reserve was inspected during the survey trip, and echolocation calls of *C. picatus* were recorded at the entrance as bats exited one evening.

As well as being listed as Vulnerable in the NSW TSC Act, it is also listed in the national Bat Action Plan in the IUCN² category of Lower Risk-near threatened (Richards and Hall, 1996).

In New South Wales there are records of this species from the Willandra Lakes World Heritage Region, Mungo NP, Mallee Cliffs NP, Nocolèche NR, and Yathong NR, as well as the colony confirmed to be resident in Buddigower NR. The type locality is Depot Glen, near Milparinka, which is within Sturt NP.

Falsistrellus tasmaniensis

The little that is known of the biology of *Falsistrellus tasmaniensis* has been contributed by Parnaby (1976) and Phillips *et al.* (1985), and the species has been reviewed by Parnaby (1983a) and Phillips (1995). Although there is a single record from a cave, this species appears to roost primarily in tree hollows.

This species is listed as Vulnerable in the NSW TSC Act, but is not considered to be nationally endangered in the national Bat Action Plan (Richards and Hall, 1996).

Richards (1997a) considered that it would be unlikely that *F. tasmaniensis* would be found in the Cowal Gold Project area. Figure 8 shows the location of the author's database records, which support the hypothesis that this montane species is primarily restricted to the Great Dividing Range.

Miniopterus schreibersii

The Large Bentwing Bat was previously known as the Common Bentwing Bat, but the name was changed by a consensus of experts, based upon the case made by Parnaby (1996). The biology of *M. schreibersii*, which is an obligate cave dweller, is well known (compared with most other Australian bat species), particularly through studies such as those of Dwyer (1966b, 1969) and Hall (1982). The species has been reviewed by Dwyer (1983c, 1995), and its approximate distribution is shown in Figure 9. The nearest known colony is situated near Orange, which is 150 kilometres to the north-east.

Because it is susceptible to disturbance at its cave roost, particularly during breeding and hibernation periods, *Miniopterus schreibersii* has been listed as Vulnerable in the NSW TSC Act, it is also listed in the IUCN category Lower Risk – near threatened in the national Bat Action Plan (Richards and Hall, 1996).

Given that the ecology of *M. schreibersii* quite well known, it is surprising that if it was present in the Lake Cowal area

in the past then it should have been recorded before. Lake Cowal is at the margin of this species' distribution in NSW (Figure 9).

In NSW there are records of this species from Willi Willi, Bungonia, Wombeyan and Jenolan Caves reserves; New England, Mount Kaputar, Hill End, Wyrabalong, Bundjalung and Royal National Parks; Wee Jasper and Cockle Bay Nature Reserves; and the Big Scrub Flora Reserve. One would suspect, given the broad distribution of this species in eastern NSW, that it would also occur in the remainder of the reserve network in this region.

Myotis macropus

Prior to 1995, there was only one species considered to be present in this worldwide genus in Australia, *Myotis adversus*, which was distributed nationwide apart from arid and semi-arid regions. Kitchener *et al.*, (1995) revised the genus, devising a taxonomy that included *M. macropus* from southeastern Australia, *M. moluccarum richardsi* from Queensland, and *M. moluccarum moluccarum* from the Top End and the Kimberley. They also considered that *M. adversus* had a unusual disjunct distribution in only north-east NSW and south-east Asia.

Recent studies have shown that the Australian representatives of *M. adversus* are in fact genetically synonymous with *M. macropus*, and that *M. m. moluccarum* and *M. m. richardsi* are separable at species level (T.D. Reardon, pers. comm.).

What is known of the biology of this species has been contributed by Dwyer (1970 a & b) and Robson (1984), and the species has been reviewed by Richards (1983a, 1995b)³. It appears to be an obligate cave-dwelling species, although has also been found under bridges (especially concrete structures which can be considered as cave substitutes) and in drainage tunnels, as well as disused mines.

Apart from being very patchily distributed, *M. macropus* is also considered to be quite rare. As well as being listed as Vulnerable in the NSW TSC Act, it is also listed in the IUCN category Lower Risk-near threatened in the national Bat Action Plan (Richards and Hall, 1996).

Locations in the consultant's database for this species are shown in Figure 10, and the nearest known locality is Burrinjuck Reservoir, some 200 kilometres to the south-east of Lake Cowal (though this colony may now be absent due to disturbance by fishermen). This species appears to have a strict habitat requirements, which is related to the two essential components of its ecology: a cave (or substitute) roost near still or smooth-flowing water. There are no natural caves in the Cowal Gold Project area (Matthews, 1985), nor are there apparently any substitute subterranean roosts that would be suitable for this species.

² IUCN = International Union for the Conservation of Nature.

³ All of these publications have been under the name "*Myotis adversus*".

Figure 8

Known locality records in New South Wales for the Eastern False Pipistrelle, *Falsistrellus tasmaniensis*. The Lake Cowal area is shown by a star, and nearest localities are approximately 200 kilometres to the east.

**Figure 9**

Database records for the Large Bentwing Bat, *Miniopterus schreibersii*, that are nearest to the Cowal Gold site (shown by a star). The nearest location is Borenore, west of Orange, a distance of approximately 150 km to the north-east of the project area.





Figure 10

Known locality records in New South Wales for the Southern Myotis, *Myotis macropus*. The Lake Cowal area is shown by a star, and is approximately 200 kilometres to the north-east of the nearest locality (Burrinjuck Reservoir). The approximate boundary of this species distribution, along the Great Dividing Range, is shown by a dashed line.

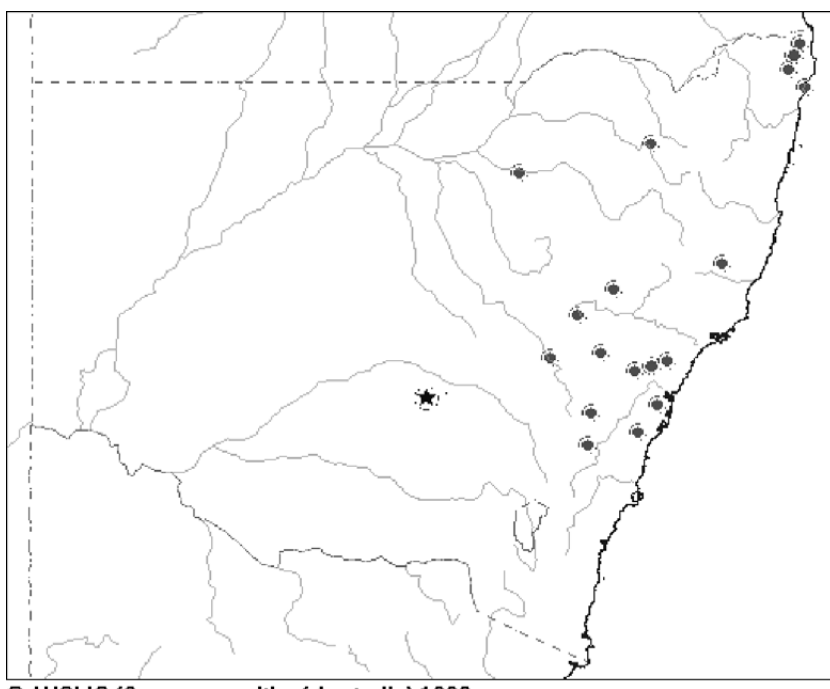


Figure 11

Known locality records in New South Wales for the Inland Forest Bat, *Vespadelus baverstocki*. The Lake Cowal area is shown by a star, and is 390 kilometres to the east of the nearest know record.

Nyctophilus timoriensis

The little that is known of the biology of this species has been reviewed by Richards (1983c) and Parnaby (1995a). The latter author has taxonomic evidence to show that, although in earlier publications it was considered to be distributed over southern Australia, this taxon is in fact a complex of three or four species. One of these taxa is basically restricted to the Murray-Darling Basin, and it has been listed as Vulnerable in the forthcoming national Bat Action Plan (Richards and Hall, 1996).

The Greater Long-eared Bat has been recorded from Lake Cowal itself, represented by a specimen collected in the 1960's and lodged in the Australian National Wildlife Collection at CSIRO, Canberra. The species is known to be quite rare, though this in part may be related to the difficulty of capture in the relatively open vegetation that it inhabits. However, during the intensive studies of Lumsden *et al.*, (1995), only one individual was recorded in a total of 1556 captures of bats in rural northern Victoria. Lumsden (1994) stated that only four records of this species are known from Victoria.

Although this species was targeted during the bat survey, no individuals were captured, even though a sibling species, *N. geoffroyi*, having similar trapability was caught at the minesite (see above).

In NSW there are records of this species from Mungo and Cocoparra National Parks, Buddigower, Yathong, and Pilliga Nature Reserves, and the Willandra Lakes World Heritage Region.

Vespadelus baverstocki

The little that is known of the biology of *V. baverstocki* has been reviewed by Richards (1995c). Prior to the mid-1980's this species was included in the species complex of *Eptesicus vulturnus*/*E. caurinus*, but the taxonomy was clarified by Kitchener *et al.*, (1987). Consequently, there has only been a decade in which this species could be studied without taxonomic confusion, so information is scant. *V. baverstocki* is common in the central arid zone of Australia, and there are just a few records for New South Wales (Figure 11).

In NSW there are records of this species from the Willandra Lakes World Heritage Region, Mungo National Parks and Nocolche Nature Reserve. It was not recorded at Yathong NR during the period 1979-1981 (Richards, unpublished), though given the taxonomic revision of Kitchener *et al.*, (1987) identifications from this site may need to be revised.

Vespadelus troughtoni

Most of what has been learnt about the biology of this species has come from the dry tropical areas of north Queensland, where this species is quite common and broadly distributed. In southern latitudes, populations appear to be patchy and localised (Parnaby, 1995b). The nearest known locality to the Cowal Gold Project area is at Hill End, near Bathurst, which is approximately 200 kilometres to the north-northeast. The Cowal Gold Project area does not

appear to offer suitable habitat, as in southern Australia it is only known from coastal forests. It is noteworthy that two sibling species were recorded in the Cowal Gold Project survey area, and it is assumed that *V. troughtoni* would have the same trapability and detectability (see above).

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Appendix 1

Location of Sampling Points

Location of sampling points taken with a Magellan 2000 geographical positioning system having an accuracy of ± 25 metres.

Site	Latitude	Longitude	Habitat		
1	33° 38' 26"	147° 24' 19"	Red gum patch	Harp trap and detector	Open pit/plant site
2	33° 38' 28"	147° 24' 12"	Stock dam near exploration camp	Detector, triplining	Open pit/plant site
3	33° 38' 17"	147° 23' 53"	Eucalypt woodland	Detector	Waste emplacement site
4	33° 37' 42"	147° 23' 41"	Stock dam in open pasture	Detector	Inventory site
5	33° 38' 24"	147° 25' 39"	Edge of Lake Cowal	Detector	Inventory site
6	33° 38' 01"	147° 23' 13"	Eucalypt woodland	Detector	Waste emplacement site
7	33° 38' 09"	147° 23' 13"	Eucalypt woodland	Harp trap	Waste emplacement site
8	33° 38' 04"	147° 24' 14"	Red gum patch	Detector	Open pit/plant site
9	33° 37' 58"	147° 21' 33"	<i>Callitris</i> woodland	Detector	Tailings storage site
10	33° 37' 56"	147° 21' 26"	<i>Callitris</i> woodland	Harp trap	Tailings storage site
11	33° 37' 58"	147° 21' 26"	<i>Callitris</i> woodland	Detector	Tailings storage site
12	33° 37' 56"	147° 21' 24"	<i>Callitris</i> woodland	Harp trap	Tailings storage site
13 ⁴	33° 37' 50"	147° 21' 40"	<i>Callitris</i> woodland	Detector	Tailings storage site
14 ⁴	33° 38' 00"	147° 22' 30"	Stock dam in open pasture	Detector	Inventory site
15 ⁴	33° 37' 50"	147° 23' 10"	Eucalypt woodland	Harp trap	Waste emplacement site
16 ⁴	33° 38' 30"	147° 23' 10"	Eucalypt woodland	Detector	Waste emplacement site

⁴ Coordinates not taken with GPS due to equipment malfunction, approximate locations determined from Wyalong 1:100,000 scale topographical mapsheet.

Appendix 2

Significance of Mining Operations on the Yellow-bellied Sheathtail Bat Eight Part Test of Significance

Significance of mining operations on the Yellow-bellied Sheath-tail Bat *Saccolaimus flaviventris*, as assessed by Eight Part Tests under section 5a, NSW Environmental Planning and Assessment Act 1995 (extracted from Richards 1997a).

INTRODUCTION

Very little is known about the biology of this species, though breeding has been analysed from museum specimens by Chimimba and Kitchener (1987). The general ecology has been reviewed by Richards (1983d, 1995d).

It has never been recorded in caves, and large colonies (around 40 individuals) have been found in some roosts (L.S. Hall, pers. comm.). It has been hypothesised, based on flight characteristics, that this species may be restricted to roosts in emergent trees because it needs a clear space below the roost to gain flight speed (Richards and Hall 1997).

S. flaviventris appears to be quite rare, especially in southern latitudes. Field surveys by the consultant in the Murwillumbah–Lismore area indicated that a large foraging range may be required, because detector passes were low and it appeared from these data that just a few individuals were making large circuits (Richards, unpublished). During an intensive survey in the Shoalwater Bay Military Training Area in central Queensland, that comprised 9 weeks of field work using 55 sites across two seasons, *S. flaviventris* was patchily distributed and restricted to denser habitats (Richards, 1992c, 1993).

This species is listed as Vulnerable in the NSW TSC Act, but is not listed in the national Bat Action Plan (Richards and Hall, 1996) because of its widespread distribution. Dickman (1994, Table 2) considers that the status of this species is "stable" in western NSW, as does Stephens (1992) for the Murray Mallee area. The distribution of this species in NSW is shown in Figure 11.

Section 5a Assessment (Eight Part Test)

(a) In the case of a threatened species, whether the life cycle of the species is likely to be disrupted such that a viable population of the species is likely to be placed at the risk of extinction.

In order to assess potential impacts on the life cycle of *S. flaviventris* it is necessary to address the primary components of its ecology, such as breeding, foraging, roosting and movement/migration.

Breeding

Females of this species have the typical pattern of breeding in summer, with a single young being weaned by the following early autumn (Chimimba and Kitchener, 1987).

Foraging

This species can be assumed to forage primarily upon insects that hunted by aerial intercept, which is typical of species with long tapered wings (high aspect ratio) and a high wing loading. This indicates (supported by field observations) that flight is fast, with little manoeuvrability, and given the loud,

long-range echolocation call, insects would be captured by interception rather than being pursued. It is highly likely that this species will be verified as present at Cowal Gold Project, and one would assume that it would utilise both woodland remnants and the open water of the lake itself.

Potential impact/s: The loss of woodland, if large tracts are involved, may affect foraging habitat for this species. However, given that this species apparently forages over a wide range (Richards, unpublished) the net effect of a loss of a small patch or patches may not be great. Whether such patches are in fact utilised should be verified during field survey, and if the lake is not also used then this hypothesis should be reviewed.

Suggested amelioration: If *S. flaviventris* is verified as present in the study area, and if shown to be foraging in vegetation that will be affected by the development, then ensure that replacement habitat is planted at a similar density.

Roosting

S. flaviventris roosts only in tree hollows, and as mentioned above, these are predicted to be large, located high in a tree, and situated such that there is enough clear space at the exit to allow an unencumbered drop until the bat attains normal flight speed. Because this bat is difficult to capture, and is usually recorded by echolocation call monitoring, it may be difficult to locate roosts by radio-tracking, as suggested for other species. It may be possible to pinpoint likely roost sites and observe them at dusk for exiting *S. flaviventris*.

Potential impact/s: If any potential roost sites are present in the impact zones, then these would be destroyed through mining operations, so a thorough search should be conducted and any that are located be suitably identified.

Suggested amelioration: If any roosts are present in the impact zones, and if *S. flaviventris* is present, then the following options should be considered:

- relocate the colony by removing the tree or a major branch, and monitor success (this has been done with an *S. flaviventris* colony in Brisbane (L.S. Hall pers. comm.)⁵
- construct a replacement roost well away from the impact zones, relocate the colony, monitor success before destruction of the original roost.

Movement/Migration

There is no information available in relation to movement or migration patterns that this species may exhibit. Richards (1983d, 1995d) concluded that because some *S. flaviventris* has been caught during the 1980's in situations where they appeared to be exhausted, and in open view of the public, that they may have been undertaking pre-winter migrations. Because several individuals of this species have been recorded over the last year to be afflicted with Lyssavirus

⁵ The consultant has been advised that when an *S. flaviventris* colony was discovered in a dead stag cut down for firewood on the outskirts of Brisbane, the branch containing the bats was capped and attached by a cable to another tree some distance away. The colony remained in this roost for several months, but has not been inspected since.

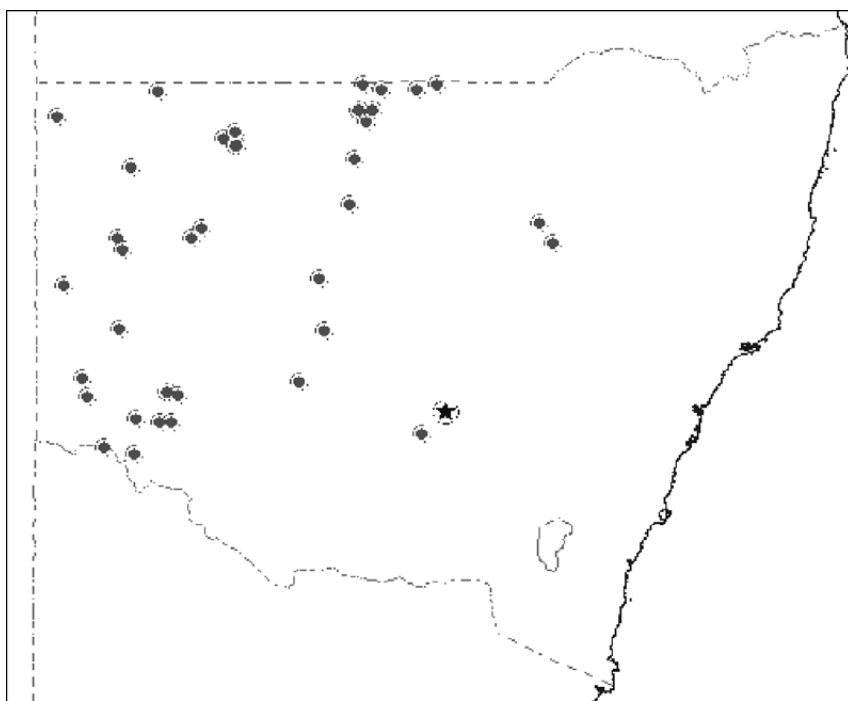


Figure 12

Known locality records in New South Wales for the Yellow-bellied Sheathtail Bat, *Saccoleimus flaviventris*. The Lake Cowal area is shown by a star.

(similar to rabies) the individuals observed may not have been exhausted but instead may have been diseased and unable to fly. The "migration" hypothesis therefore needs to be revised.

Potential impact/s: Unknown.

Suggested amelioration: Unknown.

Summary

Although there is little known about the distribution patterns of *S. flaviventris*, it can be expected to occur at Cowal Gold Project (Figure 11), and is likely that it will be found in the project area. It is likely that the development may have some effect (to an unknown extent) upon the viability of the **immediate** local population, particularly if roost sites were destroyed.

- (b) In the case of an endangered population, whether the life cycle of the species that constitutes the endangered population is likely to be disrupted such that the viability of the population is likely to be significantly compromised.**

See discussion above re threats to this species at a local level.

- (c) In relation to the regional distribution of the habitat of a threatened species, population or ecological community, whether a significant area of known habitat is to be modified or removed.**

Considering that this species requires an extensive foraging range (Richards, unpublished) the total extent of the project area may merely be a small proportion of the area required for a few individuals. It is highly likely that the area of the lake, which one would predict to have greater abundance of insects than woodland remnants or pasture-land, is the primary foraging area for local populations of this species. As the lake is to be unaffected by the development, then

"a significant area of habitat" is unlikely to be modified or removed.

- (d) Whether an area of known habitat is likely to become isolated from currently interconnecting or proximate areas of habitat for a threatened species, population, or ecological community.**

All of the wooded habitats in the project area and impact zones are already isolated from each other, and the lake is a discrete habitat unit.

- (e) Whether critical habitat will be affected.**

Not applicable, refer to section 2.2.1 of the Eight Part Test of Significance (Resource Strategies, CSIRO & Goldney, 1997).

- (f) Whether a threatened species, population or ecological community, or their habitats, are adequately represented in conservation reserves (or similar protected areas) in the region.**

In inland NSW, this species is known from Sturt, Kinchega and Nocolche National Parks, and is probably also present in the Willandra Lakes World Heritage Region, Mungo and Mallee Cliffs National Parks and Yathong Nature Reserve. One would suspect, given the broad distribution of this species in western NSW, that it would also occur in the remainder of the reserve network in this region, as well as those in coastal areas of the state.

- (g) Whether the development or activity proposed is of a class of development or activity that is recognised as a threatening process.**

While no threatening processes have been identified and gazetted by the NSW Scientific Committee at this point in time, it is considered that the proposed works could

potentially represent a process that may impact on this species, were it to occur, and in the manner outlined above.

(h) Whether any threatened species, population, or ecological community is at the limit of its known distribution.

As mentioned above, the Cowal Gold Project site is well within the widespread distribution of this species (Figure 11).

Appendix B

Cowal Gold Project Soils, Agricultural Suitability/Land Capability and Soil Resources

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Appendix B 1

Cowal Gold Project Soil Survey Consultancy Report to North Mining Limited

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Figures 4.2 – 4.4 include photographs of typical landscape and soil profiles. Copies of these figures can be obtained from North Limited Telephone (02) 6972 4500.

Figures 5.1 – 5.10 are not included in this report. They contain a large number of graphs generated by statistical analysis. Full data sets can be obtained from North Limited Telephone (02) 6972 4500.

LIST OF ATTACHMENTS

Attachment 7.1 Information Concerning Soil Test Results
Attachment 7.2 Physical, Chemical and Exchangeable Cation Test Result Rankings
Attachment 7.3 Physical Analyses Test Results
Attachment 7.4 Physical Analyses Interpretation
Attachment 7.5 Chemical Analyses Test Results
Attachment 7.6 Chemical Analyses Interpretation
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VOLUME TWO

Soil Data Cards (not included in this report – available from CaLM, South Wagga)

1.0 SUMMARY

The aim of this consultancy was to provide soils information for mining lease areas of the Lake Cowal Project to assist in the preparation of an Environmental Impact Statement.

Surface soil materials were described and sampled using test pits generally located on a grid pattern 500 m apart. A total of 62 soil profiles were described.

Soil materials from depths of 2 to 84 metres collected during Kalex core drilling at three sites were also described and sampled.

Selected samples were analysed for particle size analysis, dispersion, pH, electrical conductivity, organic carbon, cation exchange capacity and exchangeable cations.

Three major soil types were identified:

- hard pedal red duplex soils (Map Unit A)
- grey, brown and red cracking clays (Map Unit B)
- hill soils (Map Unit C)

The very thin (generally only 5 to 10 cm thick) A1 horizons of the hard pedal red duplex soils (Map Unit A) and the grey, brown and red cracking clays (Map Unit B) are rated as moderately suitable for revegetation. The main limitations are moderate structural problems. These soils generally have variable dispersion, very low to moderate salinity, variable pH and are sodic. These materials should be stripped as a 10 cm thick layer and each soil stockpiled separately; gypsum application would be required to ameliorate structural problems.

The upper subsoil between 10 and 35 cm depth in the hard, pedal red duplex soils (Map Unit A) is rated as a marginally suitable revegetation medium. The main limitations are significant structural problems and poor chemical fertility. These soils generally have high to very high dispersion, low salinity, widely variable pH, high erodibility, very low permeability and are sodic. If insufficient topdressing material is available these materials should be stripped as a layer 10-35 cm thick and each soil stockpiled separately; gypsum application would be required to ameliorate structural problems.

Subsoils below 35 to 50 cm depth in the hard red duplex soils (Map Unit A) and below 10 cm depth in the grey, brown and red cracking clays (Map Unit B) are rated as having low suitability for revegetation. The main limitations are severe structural and salinity problems and poor chemical fertility. These soil materials generally have high to very high dispersion, moderate to high salinity, widely variable pH, high erodibility, very low permeability and are strongly sodic. These materials should not be used for topdressing.

The materials represented by the Kalex core samples are similar to the lower subsoil materials described above, but have higher salinity and more severe sodicity. These materials should not be used for topdressing; if they are exposed at the surface application of gypsum would be required.

Coarse textured hill soils (Map Unit C) to depths of 50 cm are rated as marginally suitable for revegetation. The main limitations are low water holding capacity and acidity. Generally these soils have low dispersion, low salinity, strong to very strong acidity, very high gravel contents, very low clay contents, high permeability and are non sodic. Although rated as having low suitability as a revegetation medium these coarse textured materials may be required for revegetation of the proposed waste rock dump with native species; strip all as a 50 cm thick layer and stockpile separately.

Subsoils on mid to lower hill slopes (Map Unit C) between 50 and 80 cm depth are rated as having low suitability as a revegetation medium. The main limitations are severe structural problems and acidity. These materials should not be used for topdressing.

2.0 INTRODUCTION

2.1 Aim

The aim of this consultancy was to provide soils information for mining lease areas of the Lake Cowal Project to assist in the preparation of an Environmental Impact Statement.

2.2 Objectives

- Carry out a detailed survey of surface soils within mining lease areas of the Lake Cowal Project and characterise materials present.
- Characterise soil materials from depths of approximately 2 to 40 metres using core samples collected during exploration drilling operations.
- Assess suitability of soil materials for topdressing purposes.

2.3 Scope of the Consultants Commission

The scope of this consultancy included and was limited to the following tasks:

- Describe and sample soil materials to a depth of at least 2 metres or backhoe refusal using excavated pits located at an average density of approximately 1 testpit per 30 ha. Testpits proposed for geotechnical surveys and shown on Geopeko Drawing No. 4118 dated 3/11/93 were utilised where possible and other testpits installed as required.
- Carry out other soil observations as required using a hand auger to establish boundaries between soil map units.
- Describe and sample soil materials from depths of approximately 2 to 40 metres using cores collected by Peko-Wallsend during exploration drilling operations.
- Carry out laboratory tests on soil samples collected from surface pits and from cores of deeper materials.
- Store soil samples collected from excavated pits and from cores of deeper material for further laboratory testing and make samples available to other consultants as required.
- Mark the distribution of soil types on a 1:20 000 scale map provided by Peko-Wallsend.

- Assess the suitability of surface soil materials and soil materials from lower depths for topdressing purposes based on field descriptions and preliminary laboratory data.

3.0 METHODS

3.1 Field Soil Survey

Soil materials were described and sampled using test pits excavated by backhoe to a depth of 2 metres or backhoe refusal. Pits were generally located on a grid pattern 500 m apart at an average density of 1 testpit per 30 ha. A total of 62 soil profiles were described.

Profile descriptions were recorded on soil data system cards (Abraham and Abraham, 1992) and plain english reports for each profile are presented in Vol. 2 of this report.

Soil map unit boundaries were extrapolated from field observation sites using stereoscopic examination of colour 1:16,000 scale air photographs.

3.2 Kalex Core Samples

Soil materials from depths of 2-84 metres collected during Kalex core drilling at three sites were described and sampled.

Information complimentary to detailed geotechnical logs prepared by Coffey Partners International Pty Ltd during drilling operations (draft report G 255/12-AB) was recorded on soil data system cards as above and plain english reports are presented in Vol. 2.

3.3 Laboratory Soil Testing

Standard laboratory test methods and procedures detailed in Craze *et al.* (in press) were used for laboratory analysis. Laboratory tests undertaken are shown in Table B1-1.

Results for physical, chemical and cation exchange analysis are presented in Attachments 7.3, 7.5 and 7.7 respectively.

Graphs of selected laboratory data are presented in Figures 5.1 to 5.9.

4.0 DESCRIPTIONS OF SOIL MAP UNITS AND CORE SAMPLES

4.1 Introduction

Three soil map units were recognised in the study area. The location of soil map units and sample sites is shown in Figure B-1.

Each of the soil mapping units is described in the following sections. Detailed profile descriptions are presented in volume 2 of this report and may also be accessed through the computerised soil data system of the Department of Conservation and Land Management.

4.2 Map Unit A (Hard pedal red duplex soils)

These soils occur mainly on very gently inclined (about 1% slope) stagnant alluvial plains. Crabhole gilgai microrelief occurs with variable frequency, but is generally not as well developed as in Map Unit B. The soils in the gilgai depressions are usually cracking clays of Map Unit B. A typical landscape and soil profile is shown in Figure 4.2.

The vegetation has been extensively cleared and remaining tree species include Myall (*Acacia pendula*), Wilga (*Geijera parviflora*), Belah (*Casuarina cristata*) and Rosewood (*Heterodendrum oleifolium*).

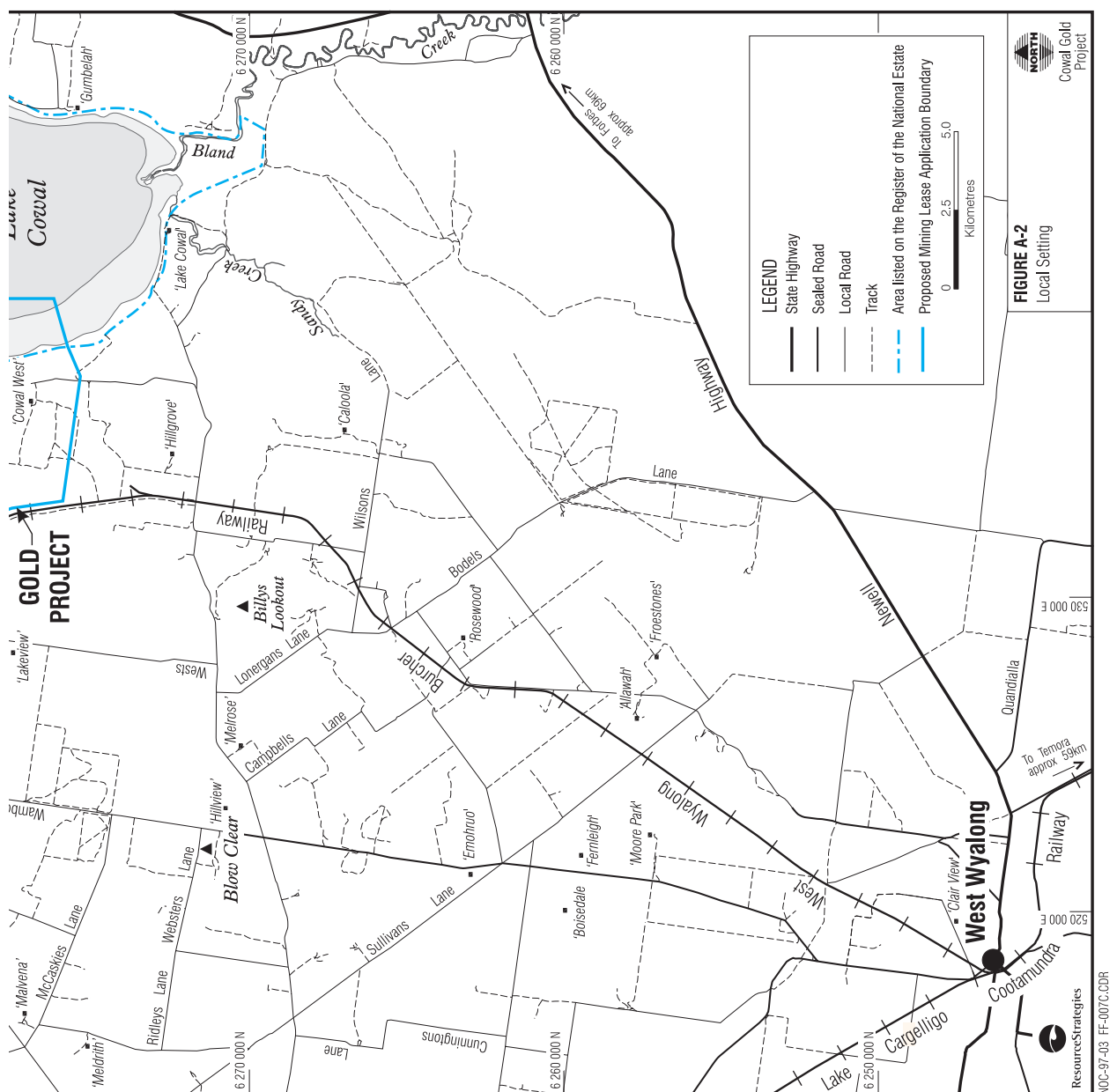
Landuse consists of cropping and voluntary native pastures. These soils have been more extensively cropped than those of Map Unit B.

These soils have distinct texture contrast between the topsoil and subsoil. Topsoils (A1 horizons) are thin, being less than or equal to 10 cm thick, dull reddish brown, and have fine sandy loam to clay loam (sandy) texture. They are hard-setting when dry and are usually massive.

Sometimes scattered cracks are evident at the soil surface, particularly where cultivation has mixed the thin topsoil with underlying clay subsoil. However, the occurrence of periodic cracking is much less than on Map Unit B.

Table B1-1 Soil Laboratory Tests

Test	Symbol	Units	SCS Lab. Code	References
Cation exchange capacity	CEC	cmol(+)/kg	C5A/3	Craze <i>et al.</i> (in press) Pleysier and Juo (1980)
Exchangeable cations		cmol(+)/kg	C5A/3	Craze <i>et al.</i> (in press) Pleysier and Juo (1980)
Dispersion percentage	DP	%	P8A/2	Craze <i>et al.</i> (in press)
Electrical conductivity (1:5 soil:water)	EC	dS/m	C2A/3	Craze <i>et al.</i> (in press) Abbott (1985)
Emerson Aggregate Test	EAT		P9B/2	Craze <i>et al.</i> (in press) Craze and Hamilton (1991)
Organic carbon	OC	%	C6A/2	Craze <i>et al.</i> (in press) Black (1965)
Particle size analysis	PSA	%	P7B/1	Craze <i>et al.</i> (in press)
pH (1:5 soil:water)	pH _w		C1A/2	Craze <i>et al.</i> (in press)
pH (1:5 soil:0.01M CaCl ₂)	pH _{ca}		C2B/2	Craze <i>et al.</i> (in press)



There is a clear change to the underlying subsoil (B horizon).

The upper subsoils are dark reddish brown to dull brown, medium clays with moderate to strong pedality. Segregations of soft and/or nodular carbonates usually occur below about 30 cm depth.

Below about 1 metre depth the soils are bright reddish brown to dull yellow orange, medium clays, extending to at least 2 metre depth.

Black manganiferous nodules and veins may occur in amounts ranging from very few to common below about 50 cm depth.

Permeability of the B horizon is very slow after the soil swells upon thorough wetting.

Surface soils are typically neutral to strongly acid (pH_w 7.3-5.1) while subsoils shallower than about 1 metre depth are generally neutral to very strongly alkaline (pH_w 6.8-9.5). Below about 1 metre depth the soil varies from very strongly acid to very strongly alkaline (pH_w 4.5-9.6). Examples of trends in pH with depth are shown in Figure 5.1.

Soils on the plain in the south-western corner of the study area and on the eastern slope of the hill in the north are similar to the above except that the topsoil is 15-40 cm deep. These soils are commonly called red-brown earths. They occupy only a very small proportion of the study area.

Soils similar to the common soils above also occur extensively throughout the riverine plains of south-eastern Australia and are often referred to as transitional red-brown earths (van Dijk and Talsma, 1964). They are so named because their properties are transitional between red-brown earths and grey, brown and red cracking clays typical of Map Unit B soils at this site. The most obvious difference between the soils of map units A and B is the texture contrast nature of Unit A compared to the uniform, fine-textured nature of Unit B soils.

4.3 Map Unit B (Grey, brown and red cracking clays)

These soils occur on very gently inclined (about 1% slope) stagnant alluvial plains. Crabhole gilgai micorelief is common. A typical landscape and soil profile is shown in Figure 4.3.

The vegetation has been extensively cleared and remaining tree species include Wilga (*Geijera parviflora*), Belah (*Casuarina cristata*) and Rosewood (*Heterodendrum oleifolium*).

Landuse consists of cropping and voluntary native pastures.

These soils have uniform fine-textured profiles that crack open periodically upon drying.

The surface soil is typically 5-10 cm deep, moderately to strongly structured and has medium clay texture. Colour varies from greyish olive to dark reddish brown. There is a clear to gradual change to the underlying strongly pedal, medium to heavy clay textured subsoil. The colour of the upper subsoil is typically greyish olive (grey clays), brown (brown clays) or dark reddish brown (red clays). These clays extend to at least 2 metres depth.

Segregations of soft and/or nodular carbonates occur in the subsoil and may sometimes occur within 2 cm of the soil surface.

Heavy rains penetrate deeply down cracks in the clay soil but once the surface wets and swells, the profile becomes very slowly permeable.

Surface soils are moderately acid to moderately alkaline (pH_w 5.8-8.3). Subsoils shallower than about 1 metre depth are neutral to very strongly alkaline (pH_w 6.9- 9.3). Below about 1 metre depth the soil varies from extremely acid to very strongly alkaline (pH_w 4.4-9.6). Examples of trends in pH with depth are shown in Figure 5.2.

4.4 Map Unit C (Hill soils)

These soils occur on the low hill in the north of the study area. A typical landscape and soil profile is shown in Figure 4.4.

The vegetation consists of woodland which has been cleared to a limited extent. The most common tree species is White Cypress Pine (*Callitris columellaris*). Landuse is voluntary native pasture.

Uniform coarse-textured soils occur on the gently inclined (5-6% slope) ridges and upper hill slopes. Rock outcrop on these areas is minor.

Soils are typically dark reddish brown to reddish brown with sandy loam to clayey sand texture and massive to weak pedality. High to very high amounts of coarse fragments up to 200 mm diameter occur throughout the profile.

The soils are shallow and backhoe refusal on rock commonly occurred at 50-75 cm depth.

Soils are slightly acid at the surface becoming moderately to strongly acid at depth.

Hard, apedal mottled yellow duplex soils occur on the gently inclined (7% slope) mid and lower hillslopes.

Topsoils are typically 50-60 cm deep, very dark to dark reddish brown with sandy loam texture and massive structure. Thin, bleached A2 horizons 10 cm thick occur. Moderate to high amounts of coarse fragments up to 20 mm diameter occur in the topsoils.

There is a clear change to the underlying dull orange to dull reddish brown, mottled subsoils which have medium clay texture and massive to weak pedality.

Subsoils extend to depths of 80 to 90 cms below which weathered substrate occurs. Backhoe refusal occurred at depths of 90 to 110 cm.

Topsoils are very strongly to slightly acid (field pH 4.5 to 6.5) while subsoils are strongly acid (field pH 5 to 5.5).

4.5 Kalex Core Samples

These cores were described in detail by Coffey Partners International Pty Ltd (draft report G 255\12-AB) during drilling and were further described using the SCS soil data system (profiles 43-46) to facilitate the collection of representative samples for laboratory analyses.

Soil textures vary widely with no relationship to material type except the occurrence of sand and gravel bands in the transported material. Field textures are commonly medium clays, silty light clays and silty clay loams.

The pH varies widely within layers of otherwise apparently similar material. A complete list of all field pH data is presented in the field notes section of the soil datacard plain english reports (Vol 2).

Soils materials are mostly neutral to slightly alkaline (pH_w 6.7-7.8), but moderately to strongly alkaline soils (pH_w 7.9-9.0) also occur.

5.0 SUITABILITY OF SOIL MATERIALS FOR REVEGETATION

5.1 Interpretation of Laboratory Test Results

Results for all physical, chemical and cation exchange analyses are presented in Attachments 7.3, 7.5 and 7.7 respectively, while graphs of selected laboratory data are presented in Figures 5.1 to 5.9.

The result of each laboratory test has been interpreted, or ranked, usually on a five class system. Details of the ranking categories used are presented in Attachment 7.2 while the actual rankings are shown in Attachments 7.4, 7.6 and 7.8.

Soil test result rankings have been collected from many references which have derived their data sets from international or regionally collected samples for a variety of purposes. Generally data sets for chemical and exchangeable cation analysis tend to be agronomic and therefore more regional and biased towards topsoil. Data sets for engineering interpretations tend to be derived from subsoil and more universal data sets.

Regardless of the considerations above, interpretations and individual ratings can generally be considered meaningful. The degree of cumulative inaccuracy involved with sampling, test selection and laboratory error can usually be expected to be much smaller than interpretive class widths. In other words, the ratings can be considered sufficiently accurate to indicate if a result is, for example, high or very high.

In the sections below, layers within each soil type have been classified in terms of their suitability as a revegetation medium and appropriate laboratory results have been summarised. The range of laboratory values given for each test indicates the range within which at least 80% of samples fall.

5.2 Hard Pedal Red Duplex Soils

(Map Unit A)

Selected laboratory data for these materials is presented in Figures 5.1 (pH), 5.3 (electrical conductivity), 5.4 (cation exchange capacity) and 5.5 (exchangeable sodium percentage).

5.2.1 A1 Horizon

The A1 horizon (generally only 10 cm thick) is generally nonsaline-sodic and is rated as a moderately suitable revegetation medium.

Relevant characteristics are:

- low to moderate dispersion (DP 33-40%)
- very low salinity (EC_e 0.3-1.89 dSm^{-1})
- low to moderate organic matter (1.76-2.90%)
- neutral to strong acidity (pH_w 7.3-5.1)
- generally sodic (ESP 4-10%)
- moderate erodibility
- hardsetting
- moderate permeability

The main limitations of this material as a revegetation medium are moderate structural problems.

The erosion hazard if used on sloping batters would be high.

Recommendation: this is the best material for plant growth at the site and should be stripped as a 10 cm thick layer and stockpiled separately; gypsum application would be required to ameliorate structural problems (see Section 5.6 for a discussion on the use of gypsum as a soil amendment); application of fertiliser may be required depending upon revegetation species.

5.2.2 Upper Subsoil

The upper subsoil between 10 and 35 cm depth (and sometimes 10 to 55 cm deep) is nonsaline-sodic and is rated as a marginally suitable revegetation medium.

Relevant characteristics are:

- high to very high dispersion (DP 63-85%)
- low to very low salinity (EC_e 0.4-4 dSm^{-1})
- low to extremely low organic matter (0.75-1.11%)
- pH widely variable from strong acidity to very strong alkalinity (pH_w 5.2-9.1)
- sodic, sometimes strongly sodic (ESP 8-26%)
- high erodibility
- extremely hard when dry and likely to form surface crusts
- very low permeability
- imbalance in the exchangeable Ca/Mg ratio with Ca being deficient; exchangeable K is also deficient

The main limitations of this material as a revegetation medium are significant structural problems and poor chemical fertility.

The erosion hazard if used on sloping batters would be very high.

Recommendation: if insufficient other topdressing material is available strip all as a layer 10-35 cm thick and stockpile separately; this material should be covered with a thin layer of A1 horizon material if possible; gypsum application would be required to ameliorate structural problems (see Section 5.6 for a discussion on the use of gypsum as a soil amendment); application of fertiliser may be required depending upon revegetation species.

5.2.3 Lower Subsoil

Subsoil materials below 35 to 50 cm depth are generally saline-sodic and are rated as having low suitability as a revegetation medium.

Relevant characteristics are:

- generally high to very high dispersion (DP 46-98%); some very low values are due to high salt content
- moderate to high salinity (EC_e 4-15 dSm⁻¹)
- extremely low organic matter (0.12-0.46%)
- pH widely variable from very strong acidity to very strong alkalinity (pH_w 4.5-9.6)
- strongly to very strongly sodic (ESP 18-46%)
- very high erodibility
- extremely hard when dry and likely to form surface crusts
- very low permeability
- imbalance in the exchangeable Ca/Mg ratio with Ca being deficient; exchangeable K is also deficient

The main limitations of this material as a revegetation medium are severe structural and salinity problems and poor chemical fertility.

The erosion hazard if used on sloping batters would be very high.

This layer is similar to the lower subsoil of Map Unit B. Recommendation: strip nil

5.3 Grey, Brown and Red Cracking Clays (Map Unit B)

Selected laboratory data for these materials is presented in Figures 5.2 (pH), 5.3 (electrical conductivity), 5.4 (cation exchange capacity) and 5.5 (exchangeable sodium percentage).

5.3.1 A1 Horizon

The A1 horizon (generally only 5 to 10 cm thick) is non saline-sodic to saline-sodic and is rated as a moderately suitable revegetation medium.

Relevant characteristics are:

- moderate to high dispersion (DP 29-58%)
- very low to moderate salinity (EC_e 0.6-8 dSm⁻¹)
- low to moderate organic matter (1.95-2.81%)
- moderate acidity to moderate alkalinity (pH_w 5.8-8.3)
- generally sodic (ESP 4-8%)
- high erodibility
- very low permeability

The main limitations of this material as a revegetation medium are moderate structural and salinity problems.

The erosion hazard if used on sloping batters would be high.

Recommendation: this is the second best material for plant growth at the site (after the A1 horizon of Map Unit A) and

should be stripped as a 10 cm thick layer and stockpiled separately; gypsum application would be required to ameliorate structural problems (see Section 5.6 for a discussion on the use of gypsum as a soil amendment); application of fertiliser may be required depending upon revegetation species.

5.3.2 Upper Subsoil

The upper subsoil between 10 and 50 cm depth (range is 10 to 90 cm) is nonsaline-sodic to saline-sodic and is rated as having low suitability as a revegetation medium.

Relevant characteristics are:

- moderate to very high dispersion (DP 40-72%)
- very low to high salinity (EC_e 0.3-11 dSm⁻¹)
- very low to low organic matter (0.28-1.35%)
- pH variable from neutral to very strong alkalinity (pH_w 6.9-9.3)
- sodic (ESP 8-11%)
- high erodibility
- very low permeability
- imbalance in the exchangeable Ca/Mg ratio with Ca being deficient; exchangeable K is also deficient

The main limitations of this material as a revegetation medium are significant structural and salinity problems and poor chemical fertility.

The erosion hazard if used on sloping batters would be high.

Recommendation: strip nil

5.3.3 Lower Subsoil

Lower subsoil materials (generally below 50 cm depth) are saline-sodic and are rated as having low suitability as a revegetation medium.

Relevant characteristics are:

- generally high to very high dispersion (DP 50-90%); some very low values are due to high salt content
- moderate to high salinity (EC_e 5-27 dSm⁻¹)
- extremely low organic matter (0.2-0.5%)
- pH widely variable from extreme acidity to very strong alkalinity (pH_w 4.4-9.6)
- strongly to very strongly sodic (ESP 16-40%)
- high erodibility
- extremely hard when dry and likely to form surface crusts
- very low permeability
- imbalance in the exchangeable Ca/Mg ratio with Ca being deficient; exchangeable K is also deficient

The main limitations of this material as a revegetation medium are severe structural and salinity problems and poor chemical fertility.

The erosion hazard if used on sloping batters would be very high.

This layer is similar to the lower subsoil of Map Unit A.

Recommendation: strip nil

5.4 Hill Soils (Map Unit C)

Selected laboratory data for these materials are presented in Figures 5.3 (electrical conductivity), 5.4 (cation exchange capacity), 5.5 (exchangeable sodium percentage) and 5.6 (pH).

5.4.1 Topsoils

Coarse textured soils on ridges and upper hill slopes to depths of approximately 50 cm and topsoils on mid and lower slopes to depths of approximately 50 cm are rated as having low suitability as a revegetation medium.

Relevant characteristics are:

- low to moderate dispersion (DP 21–40%)
- low to very low salinity (EC_e 0.6–3 dSm^{-1})
- low to very high organic matter (1.5–7.4%)
- very strong to strong acidity (pH_{ca} 3.7–4.3); field pH indicates very strong to slight acidity (pH 4.5–6.5)
- generally nonsodic (ESP 3–6%)
- very high gravel (particles > 2 mm diameter) content (21–78%)
- very low clay content (2–8%)
- high permeability
- imbalance in the exchangeable Ca/Mg ratio with Ca being low

The main limitations of this material as a revegetation medium are low water holding capacity and acidity.

Recommendation: although rated as having low suitability as a revegetation medium these coarse textured materials may be required for revegetation of the proposed waste rock dump with native species; strip all as a 50 cm thick layer and stockpile separately.

5.4.2 Subsoils

Subsoils on mid to lower hill slopes between 50 and 80 cm depth are rated as having low suitability as a revegetation medium.

Relevant characteristics are:

- low to high dispersion (DP 18–53%)
- very low salinity (EC_e 0.4–1 dSm^{-1})
- very low organic matter (0.47–0.77%)
- very strong acidity (pH_{ca} 3.8–4.2); field pH indicates strong acidity (pH 5–5.5)
- nonsodic to sodic (ESP 1–9%)
- low permeability
- imbalance in the exchangeable Ca/Mg ratio with Ca being deficient.

The main limitations of this material as a revegetation medium are severe structural problems and acidity.

This layer is thin and of limited extent.

Recommendation: strip nil

5.5 Kalex Core Samples

Selected laboratory data for these materials are presented in Figures 5.7 (pH), 5.8 (exchangeable sodium percentage and cation exchange capacity) and 5.9 (electrical conductivity).

The materials represented by these core samples are saline-sodic and are rated as having very low suitability as a revegetation medium.

Relevant characteristics are:

- very low to high dispersion (DP 3–92%) but is likely to be highly dispersible if excess salts are leached without ameliorants
- high to very high salinity (EC_e 12–57 dSm^{-1})
- extremely low organic matter (0.05–0.12%)
- pH variable from slight acidity to strong alkalinity (pH_w 6.4–9.0)
- very strongly sodic (ESP 28–63%)
- very high erodibility
- very low permeability
- imbalance in the exchangeable Ca/Mg ratio with Ca being deficient; exchangeable K is also deficient

The main limitations of this material as a revegetation medium are severe structural and salinity problems and poor chemical fertility.

Recommendation: this material should not be used for topdressing during rehabilitation; if this material is exposed at the surface application of gypsum will be required (see Section 5.6 for a discussion on the use of gypsum as a soil amendment).

5.6 Use of Gypsum on Sodic Soils

5.6.1 Clay Dispersion

Clay dispersion is defined as the formation of a stable suspension of particles in water. Dispersion is caused by the mutual repulsion between particles, which results from the presence of extensive negative electric fields surrounding them. Dispersion is enhanced by factors that increase the magnitude and extent of this field, such as the presence of highly hydrated monovalent cations (Na^+) and low electrolyte concentration in solution.

In sodic soils there is an excess of sodium cations adsorbed on the clay surface relative to other major cations (calcium and magnesium) and therefore clay dispersion is enhanced.

Sodic soils are defined as having an exchangeable sodium percentage (ESP) > 6%.

The effect of exchangeable sodium percentage and electrolyte concentration on clay dispersion is shown schematically in Figure 5.8.

Clay dispersion tends to increase with increasing ESP and decreasing electrolyte concentration.

Sodic soil materials at this site fall into two categories:

- nonsaline-sodic ($EC_e < 4$ dSm^{-1} , ESP > 6%)
- saline-sodic ($EC_e > 4$ dSm^{-1} , ESP > 6%)

In nonsaline sodic soils, soil particles disperse on wetting, the soil surface may seal over (crust) and restrictive layers may develop within the soil profile. These conditions impede air movement and water infiltration into and through the soil. Plants find it hard to survive and grow in these soils.

In saline-sodic soils, soil particles are generally flocculated due to the influence of high electrolyte concentration. As long as the EC_e remains $>4 \text{ dSm}^{-1}$ infiltration rates are generally not a problem. If excess soluble salts are leached downward the properties of these soils may change markedly and become similar to those of nonsaline-sodic soils (i.e. the destructive effects of sodicity are only evident after leaching has removed salts). Soil permeability declines significantly after initial leaching of excess salts.

One of the most serious problems in ameliorating sodic soils is getting water to move through the soil so that undesirable salts can be leached out and exchangeable sodium can be replaced with calcium.

5.6.2 Reclamation of Sodic Soils with Gypsum

Sodic soils may be treated with additions of lime, dolomite or gypsum, but gypsum is by far the most commonly used amendment for sodic soil reclamation because of its low cost, availability and ease of handling. The use of gypsum as an amendment for sodic soils has been comprehensively reviewed by Shainberg *et al.* (1989).

Gypsum dissolves to provide a level of electrolyte in the soil solution that maintains sufficient permeability to allow water entry into and through the soil profile and at the same time provides Ca for exchange with Na.

For example, gypsum is used extensively in the Hunter Valley of NSW during rehabilitation of coal mines when sodic soils ($ESP > 6\%$) are exposed on the surface. Rates of gypsum used are commonly 8–10 t/ha (Geoff Marsche, personal communication).

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Attachments

7.1 – 7.8

ATTACHMENT 7.1

Information Concerning Soil Test Results

7.1.1 General

Standard laboratory test methods and procedures detailed in Craze *et al.* (in press) were used and are outlined in Table 1. Brief outlines of test methods are included in this section.

Physical and chemical test results are presented separately for printing purposes. The information below applies to all results.

Soil Data System Site Number, Card Number and Layer Number

Soil Data System cards were used to describe soils during the course of the survey. Soil Data System site numbers, card numbers and layer numbers are included in all tables and are unique identifiers for all samples.

Grid Reference

Australian Map Grid is equivalent to Universal Transverse Mercator (UTM) projection. Map zones are not included but can be uniquely identified by 1:100 000 map sheet location. Sites were located by Geopeko surveyors using a GPS.

Easting Grid Reference

Easting grid reference is the Australian Map Grid reference which signifies position in an east-west direction. The fourth and fifth digits from the right indicate grid lines on the map. The last digit corresponds to 1 m accuracy.

Northings Grid Reference

Northings grid reference is the extended Australian Map Grid reference which signifies position in a north-south direction. The fourth and fifth digits from the right indicate grid lines on the map. The last digit corresponds to 1 m accuracy.

Depth Range

This is the range of depth, in metres, over which the soil horizon extends. It does not necessarily indicate the depth over which the sample was taken. It is measured downwards from the start of the mineral soil surface.

Sample Depth

This indicates the depth(s) at which layer samples were collected for sites 43-46.

Horizon Code

This is the shorthand code given to a soil layer to distinguish its describable properties (usually in the field) from other soil layers. See Abraham and Abraham (1992) and McDonald *et al.* (1990) for definitions of soil horizon nomenclature.

Material Type Code

For samples 43-46 the code for material type was taken from geotechnical logs prepared for Geopeko by Coffey Partners International Pty Ltd (draft report G255/12-AB).

T – transported
SO – soft oxide
HO – hard oxide

Not Detectable (nd) Code

Where levels are below the range of the measuring equipment/test used, nd (not detectable) is reported in the test results.

7.1.2 Physical Analysis tTests

This section explains the derivation of results given in the Physical Analyses Test Results Table (Attachment 7.3).

Soil Particle Analysis

Particle size analysis is the laboratory procedure for determining particle size distribution of a soil. The relative weights of gravel, coarse sand, fine sand, silt and clay are determined to the nearest percentage following crushing and end-to-end shaking with a chemical dispersant. The method used includes sieving and sedimentation measured by hydrometer (Craze *et al.* in press). Size ranges for fraction sizes are based on the international scale (cited in McDonald *et al.* 1990).

Clay	<0.002 mm
Silt	0.002 – 0.02 mm
Fine Sand	0.02 – 0.2 mm
Coarse Sand	0.2 – 2 mm
Gravel	2 – 60 mm

Emerson Aggregate Test

The Emerson aggregate test is an eight class classification of soil aggregate coherence (slaking and dispersion) in distilled water (Emerson 1967). Three aggregates from each sample are tested and results are based on the replicate with the lowest Emerson aggregate class.

Class	Result
1 Slakes	Complete Dispersion
2 Slakes	Some Dispersion
3 Slakes	Some Dispersion after remoulding
4 Slakes	No Dispersion (carbonate or gypsum Present)
5 Slakes	Dispersion in Shaken suspension
6 Slakes	Flocculates in shaken suspension
7 No Slaking	Swells in water
8 No Slaking	Does not swell

A modification has been developed by the Soil Conservation Service, with classes 2 and 3 being divided into subclasses:

Subclass	Dispersion
(1)	Slight milkiness immediately adjacent to the aggregate
(2)	Obvious milkiness, <50% of the aggregate affected
(3)	Obvious milkiness, >50% of the aggregate affected
(4)	Total dispersion, leaving only sand grains

Note: Class 2(4) is equivalent to Class 1.

The subclass is put in brackets. For example, a Class 3 aggregate which disperses completely on working leaving only sand grains is recorded as Class 3(4).

Dispersion Percentage

Dispersion is the ratio of dispersed soil particles <0.005 mm compared to the same size fraction of undispersed soil particles expressed as a percentage. The method is described in Crouch *et al.* (1991) and Craze *et al.* (in press).

Erodibility (USLE K factor)

The Unified Soil Loss Equation includes a soil erodibility factor known as K (Wischmeier and Smith 1978). K factor is a derived index of the susceptibility of a soil to sheet and rill erosion. The formula used to derive the K factor is USLE modified for Australian conditions and based on that used in SOILOSS (Rosewell and Edwards 1988) with profile permeability modified to follow that used by Soil and Water Conservation Society (1993).

Silt and fine sand percentages are derived from fine earth fraction particle size results.

Note: K factor of itself has a very limited value unless used in conjunction with all other factors in USLE.

7.1.3 Chemical Analysis Tests

This section explains the derivation of results given in the Chemical Analyses Test Results Table (Attachment 7.5). Some data is also presented graphically in Section 5.0.

pH

pH 1:5 soil:water (pH_w) is the activity of the negative log of hydrogen ions in a suspension of 1:5 soil:water, while pH 1:5 soil:0.01M $CaCl_2$ (pH_{ca}) is the activity of the negative log of hydrogen ions in a suspension of 1:5 soil:0.01M $CaCl_2$. It is considered that pH_{ca} approximately equates to average soil solution calcium and salinity levels (Russell 1973). Conyers and Davey (1988) have found that pH_{ca} is usually 0.5 to 1.0 units less than pH_w except in saline and some variable charge soils where the difference may be smaller (Russell 1973).

In this study pH_{ca} was determined on all samples. In addition, pH_w was determined on 65 samples from sites 47 to 66.

The following relationship was determined to convert pH_{ca} to pH_w for a given soil electrical conductivity:

$$\begin{aligned} pH_w &= 0.780768912 - 0.3073667331 EC_{1:5} \\ &\quad + 1.0511987792 pH_{ca} \\ R^2 &= 0.983, \quad N = 65 \end{aligned}$$

This relationship was used to determine pH_w for samples from soil map units A and B and for the Kalex core samples where pH_w was not measured in the laboratory.

The interpretation of pH_{ca} is uncertain where $pH_{ca} > 7.7$ or where $EC_{1:5} > 0.6$ dS/m (Mark Conyers, personal communication). The interpretation of pH_w is also uncertain where $EC_{1:5} > 0.6$ dS/m (Mark Conyers, personal communication). The interpretation of pH data is therefore complicated at this site by the high salinity of many samples.

To aid interpretation, pH data is also presented graphically in Figures 5.1, 5.2, 5.6 and 5.7.

Field pH

Field pH was measured using the method of Raupach and Tucker (1959) which usually corresponds to pH measured in a suspension of 1:5 soil:water +/- 0.5 pH unit.

Field pH measurements are presented in Attachment 7.5. The data is not directly comparable to laboratory pH measurements as the same samples were not used. Field pH may be up to 1.5 pH units higher than pH_{ca} .

Acidity

Acid soils are often leached of many soluble ions and are commonly deficient in major plant nutrients such as calcium, magnesium, nitrogen and phosphorus and possibly molybdenum. Phosphorus may be present in a form which is not available to plants. Metal ions may be soluble in toxic concentrations. Fungi rather than bacteria tend to dominate in acid soils (Russell 1973).

Alkalinity

Alkaline soils are often deficient in some plant nutrients such as iron, manganese, copper and zinc.

Organic Carbon

Organic carbon is tested using the Walkley-Black method outlined in Alison *et al.* (1965), Rayment and Higginson (1992) and Craze *et al.* (in press). Organic carbon is oxidised by dichromate, and the amount of dichromate reduced is determined by titration with ferrous sulphate using Ferroin indicator.

The method measures the amount of carbon in plant and animal remains including soil humus but not charcoal or coal.

Organic Matter

The conversion of organic carbon to organic matter is based on the assumption that soil organic matter = organic carbon * 1.755 (Rosewell and Edwards 1988).

Organic matter is a key component in assessing soil fertility, stability, hydrology and land condition.

Electrical Conductivity

Soil analysis methods for salinity are based on the electrical conductivity of a water extract of the soil.

The electrical conductivity of a 1:5 soil:water suspension ($EC_{1:5}$), which is prepared from the fine earth fraction of the sample (Abbott 1985), is a measure of the total quantity of soluble salts per unit weight of soil.

In order to assess the effects of salinity on plant growth an estimate of the electrical conductivity of a saturated paste extract (EC_e) is required. EC_e is estimated from the relationship $EC_e = f EC_{1:5}$ where the conversion factor (f) is after Taylor (1993).

Ranking of EC_e is based on Richards (1954). Critical levels of EC_e for plant growth are listed for many species in Richards (1954) and Taylor (1993).

7.1.4 Exchangeable Cation Analysis Tests

This section explains the derivation of results given in the Exchangeable Cation Analysis Test Results Table (Attachment 7)

Cation Exchange Capacity, CEC (cmol (+)/kg)

Cation exchange capacity is an indication of the number of exchange sites within a soil which may temporarily hold positively charged ions. It generally depends on the amount and type of clay and the amount of organic matter.

Cation exchange capacity is a general indicator of soil storage capacity for available, positively charged plant nutrients such as Ca, Mg, K and NH_4 .

Cation exchange capacity is normally determined by measuring residual silver in solution using atomic absorption spectrophotometry (AAS) after 4 h shaking of the sample in 0.01M silver-thiourea (AgTU)+. Displaced (exchangeable) cations are also measured by AAS. Samples are pretreated to remove salts by repeated washing in glycol-ethanol. The method is detailed as C5A/3 in Craze *et al.* (in press) and is related to methods outlined in Pleysier and Juo (1980) and Rayment and Higginson (1992).

Exchangeable Calcium (cmol(+)/kg)

Exchangeable calcium is the amount of cation exchange sites occupied by calcium ions in the cation exchange complex relative to the valency of calcium.

Exchangeable Calcium/CEC %

Exchangeable calcium is the percentage of calcium ions compared to cation exchange capacity.

Exchangeable Magnesium (cmol (+)/kg)

Exchangeable magnesium is the amount of cation exchange sites occupied by magnesium ions in the cation exchange complex relative to the valency of magnesium.

Exchangeable Magnesium/CEC %

Exchangeable magnesium is the percentage of magnesium ions compared to cation exchange capacity.

Exchangeable Potassium (cmol(+)/kg)

Exchangeable potassium is the amount of cation exchange sites occupied by potassium ions in the cation exchange complex relative to the valency of potassium.

Exchangeable Potassium/CEC %

Exchangeable potassium is the percentage of potassium ions compared to cation exchange capacity.

Exchangeable Sodium (cmol (+)/kg)

Exchangeable sodium is the amount of cation exchange sites occupied by sodium ions in the cation exchange complex relative to the valency of sodium.

Exchangeable Sodium Percentage

Exchangeable sodium is the percentage of exchangeable sodium ions compared to cation exchange capacity. Sodic soils are those with $\text{ESP} > 6\%$ (Northcote and Skene 1972, Isbell 1993).

Soils which contain very low to moderate amounts of exchangeable sodium (i.e., exchangeable sodium is $< 0.7 \text{ cmol}(+)/\text{kg}$) and have sufficiently low cation exchange capacities to qualify as being sodic often do not display sodic soil properties in the field. These soils are labelled as "sod1".

High percentages of exchangeable magnesium are thought to contribute to sodic soil symptoms (Tucker 1983).

Exchangeable Aluminium (cmol (+)/kg)

Exchangeable aluminium is the amount of cation exchange sites occupied by aluminium ions in the cation exchange complex relative to the valency of aluminium.

Exchangeable Calcium/Exchangeable Magnesium Ratio

This is the ratio of exchangeable calcium to exchangeable magnesium. Interpretations are provided a general guideline only. Tolerances and favourable conditions vary between plant species.

Exchangeable Magnesium/Exchangeable Potassium Ratio

Russell (1973) includes several examples of how magnesium and potassium may be antagonistic to plant growth. Tolerances and favourable conditions vary between plant species.

ATTACHMENT 7.2 Physical, Chemical and Exchangeable Cation Test Result Rankings

Test Name	Unit	V.Low (VL)	Low (L)	Mod. (M)	High (H)	V.High (VH)
Clay	%	<10	10-25	25-40	40-50	>50
Silt	%	<10	10-25	25-40	40-50	>50
Fine sand	%	<10	10-25	25-40	40-50	>50
Coarse sand	%	<10	10-25	25-40	40-50	>50
Gravel	%	<4	04-17	17-31	31-65	>65
DP	%	0-6	06-30	30-50	50-65	65-100
EAT	class	6,7,8	3(2),3(1), 5	2(1),3(4), 3(3)	2(2)	1,2(3)
USLE K Factor	t.ha.y/ ha.MJ.mm	<0.01	0.01-0.02	0.02-0.04	0.04-0.06	>0.06
Acidity (0.01M CaCl_2)	pH _{ca}	<3.7 (extreme)	3.7-4.2 (v. strong)	4.3-4.7 (strong)	4.8-5.2 (medium)	5.3-5.7 (slight)
Alkalinity (0.01M CaCl_2)	pH _{ca}			7.1-7.6 (medium)	6.6-7.0 (slight)	5.8-6.5 (neutral)
Acidity (pH in water)	pH _w	<4.5 (extreme)	4.5-5.0 (v. strong)	5.1-5.5 (strong)	5.6-6.0 (medium)	6.1-6.5 (slight)
Alkalinity (pH in water)	pH _w	>9.0 (v. strong)	8.5-9.0 (strong)	7.9-8.4 (medium)	7.4-7.8 (slight)	6.6-7.3 (neutral)
OM	%	0.5-1.0	1.0-2.0	2.0-3.0	3.0-5.0	>5.0
EC _e	dS/m	0-2	2-4	4-8	8-16	>16
CEC	cmol(+)/kg	<6	6-12	12-25	25-40	>40
Exch. Ca	cmol(+)/kg	<2	2-5	5-10	10-20	>20
Exch. Ca/CEC	%	<10	10-30	30-65	65-85	
Exch. Mg	cmol(+)/kg	<0.3	0.3-1	1-3	3-8	>8
Exch. Mg/CEC	%	<3	3-5	5-10	10-15	>15
Exch. K	cmol(+)/kg	<0.2	0.2-0.3	0.3-0.7	0.7-2	>2
Exch. K/CEC	%	<1	1-2	2-5	5-8	>8
Exch. Na	cmol(+)/kg	<0.1	0.1-0.3	0.3-0.7	0.7-2	>2
Exch. Na/CEC (ESP)	%		<6 (non-sodic)	6-15 (sod) ^a (Sod1) ^b	15-30 (SSod) ^a	>30 (VSSod) ^a
^a exch. Na > 0.7 cmol(+)/kg ^b exch. Na < 0.7 cmol(+)/kg						
Ca/Mg ratio		<1 (CaDef)	1-4 (CaLow)	4-6 (Balanced)	6-10 (MgLow)	>10 (MgDef)
Mg/K ratio	%	<1 (MgDef)	1-2.5 (MgLow)	2.5-5 (Balanced)	5-10 (KLow)	>10 (KDef)

ATTACHMENT 7.3 Physical Analyses Test Results

Soil map unit	Lab no.	Site no.	Data System Card no.	Layer no.	Aust. Grid Ref. m East	m North	Depth range (m)	Sample depth (m)	Horizon/ material type	clay (%)	silt (%)	f.sand (%)	c.sand (%)	gravel (%)	DP (%)	EAT	USLE K Factor
A	16	5	1	1	534750	6278250	0.00-0.07		A1	39	11	41	9	<1	33	2(1)	0.022
A	17	5	1	2	534750	6278250	0.07-0.35		B21	48	11	34	7	<1	69	2(3)	0.019
A	18	5	1	3	534750	6278250	0.35-1.00		B22	42	12	35	8	3	68	2(3)	0.023
A	19	5	1	4	534750	6278250	1.00-1.50			40	14	43	3	0	93	2(3)	0.029
A	20	5	1	5	534750	6278250	1.50-2.00			35	9	54	2	0	89	2(3)	0.034
A	26	7	1	1	536000	6278400	0.00-0.25		A1	18	10	44	20	8	36	2(1)	0.033
A	27	7	1	2	536000	6278400	0.25-0.42		A2	4	4	14	7	71	63	2(1)	0.043
A	28	7	1	3	536000	6278400	0.42-0.90		B21	56	13	20	8	3	23	2(1)	0.013
A	29	7	1	4	536000	6278400	0.90-1.40		B22	37	12	18	19	14	17	2(1)	0.018
A	30	7	1	5	536000	6278400	1.40-1.90			42	10	23	19	6	30	2(1)	0.017
B	53	12	1	1	535250	6277750	0.00-0.07		A1	36	13	42	7	2	29	2(3)	0.024
B	54	12	1	2	535250	6277750	0.07-0.50		B2	50	13	30	6	1	40	3(2)	0.018
B	55	12	1	3	535250	6277750	0.50-1.00		B2	47	12	31	6	4	6	2(3)	0.020
B	56	12	1	4	535250	6277750	1.00-1.50		B2	51	14	31	4	<1	18	2(3)	0.019
B	57	12	1	5	535250	6277750	1.50-2.00			56	15	26	3	0	50	2(3)	0.017
B	68	15	1	1	536790	6277690	0.00-0.06		A1	11	9	45	27	8	33	3(1)	0.034
B	69	15	1	2	536790	6277690	0.06-0.50		B11	31	9	18	11	31	67	1	0.018
B	70	15	1	3	536790	6277690	0.50-1.00		B22	30	9	17	12	32	66	2(3)	0.019
B	71	15	1	4	536790	6277690	1.00-1.50			37	11	25	18	9	5	3(1)	0.021
B	72	15	1	5	536790	6277690	1.50-2.00			41	14	29	15	1	58	2(1)	0.023
A	133	28	1	1	537250	6276750	0.00-0.10		A1	34	13	30	12	11	58	2(1)	0.023
A	134	28	1	2	537250	6276750	0.10-0.23		B21	42	11	26	13	8	72	2(3)	0.018
A	135	28	1	3	537250	6276750	0.23-0.80		B22	52	14	26	7	1	8	2(3)	0.017
A	136	28	1	4	537250	6276750	0.80-1.40			54	15	26	4	1	96	1	0.017
A	137	28	1	5	537250	6276750	1.40-2.00			57	19	22	2	0	89	1	0.017
A	147	31	1	1	535750	6276180	0.00-0.14		A1	26	16	47	10	1	33	8(3/2)	0.034

ATTACHMENT 7.3 Physical Analyses Test Results Continued

Soil map unit	Lab no.	Site no.	Data System Card no.	Layer no.	Aust. Grid Ref. m East	Aust. Grid Ref. m North	Depth range (m)	Sample depth (m)	Horizon/ material type	clay (%)	silt (%)	f.sand (%)	c.sand (%)	gravel (%)	DP (%)	EAT	USLE K Factor
A	148	31	1	2	535750	6276180	0.14-0.50		B21	49	17	28	6	<1	85	2(3)	0.020
A	149	31	1	3	535750	6276180	0.50-1.00		B22	45	18	25	8	4	76	2(1)	0.021
A	150	31	1	4	535750	6276180	1.00-1.50			46	15	23	11	5	81	2(2)	0.019
A	151	31	1	5	535750	6276180	1.50-1.80			42	13	30	12	3	95	2(3)	0.022
A	158	33	1	1	536750	6276250	0.00-0.08		A1	21	14	45	18	2	40	3(1)	0.036
A	159	33	1	2	536750	6276250	0.08-0.35		B21	45	13	29	12	1	78	2(2)	0.019
A	160	33	1	3	536750	6276250	0.35-0.55		B22	43	13	31	12	1	87	2(3)	0.021
A	161	33	1	4	536750	6276250	0.55-1.20		B23	45	15	26	12	2	46	3(1)	0.020
A	162	33	1	5	536750	6276250	1.20-1.50			49	16	23	11	1	75	2(3)	0.018
A	163	33	1	6	536750	6276250	1.50-1.80			39	13	28	16	4	98	2(3)	0.022
C	188	39	1	1+2	535820	6278240	0.00-0.20			2	4	9	11	74	40	NA	
C	189	39	1	3+4	535820	6278240	0.20-0.60			2	3	8	9	78	39	NA	
C	190	40	1	1	535780	6278320	0.00-0.10		A1	8	8	22	24	38	29	NA	
C	191	40	1	2	535780	6278320	0.10-0.45			2	4	9	8	77	22	NA	
C	192	40	1	3	535780	6278320	0.45-0.75			7	5	13	15	60	18	NA	
C	193	41	1	1	535730	6278300	0.00-0.18		A11	8	9	35	27	21	21	3(1)	
C	194	41	1	2	535730	6278300	0.18-0.50		A12	3	5	12	12	68	25	NA	
C	195	41	1	3	535730	6278300	0.50-0.60		A2	12	8	17	29	34	39	3(2)	
C	196	41	1	4	535730	6278300	0.60-0.90		B2	33	10	10	24	23	23	3(2)	
C	199	42	1	4	535690	6278280	0.50-0.80		B22	54	9	12	16	9	53	2(3)	
K	1	43	1	1	537852	6278049	1.00-5.00	2+4	C/T	62	12	15	8	3	81	2(3)	0.010
K	2	43	1	2	537852	6278049	5.00-10.00	6+9	C/T	48	13	26	13	<1	56	2(3)	0.018
K	3	43	1	3	537852	6278049	10.00-13.50	11+13	C/T	23	5	16	35	21	6	2(1)	0.017
K	4	43	1	4	537852	6278049	13.50-18.10	15.4+17.5	C/T	39	26	18	8	9	4	2(3)	0.027
K	5	43	1	5	537852	6278049	18.10-24.20	20+23	C/HO	28	39	26	7	0	4	6	0.047
K	6	43	1	6	537852	6278049	24.20-30.10	25+27	C/HO	22	35	32	11	0	5	6	0.051
K	8	43	2	2	537852	6278049	37.00-42.00	39+41	C/SO	28	39	27	6	<1	36	2(1)	0.047

K	10	43	2	4	537852	6278049	51.00-54.50	52+54	C/SO	16	26	24	9	25	56	2(1)	0.051
K	11	44	1	1	537900	6277650	2.00-7.00	3+4	C/T	46	10	31	6	7	88	1	0.019
K	13	44	1	3	537900	6277650	9.20-12.20	10+11	C/T	33	16	28	23	<1	5	2(1)	0.027
K	16	44	1	6	537900	6277650	16.40-22.80	17+18	C/T	17	1	12	45	25	9	2(1)	0.012
K	18	44	2	1	537900	6277650	22.80-27.40	24+26	C/T	34	28	15	14	9	5	6	0.030
K	20	44	2	3	537900	6277650	30.90-38.70	32+34	C/T	53	21	20	5	1	4	6	0.019
K	22	44	2	4	537900	6277650	38.70-42.80	40+42	C/T	33	29	25	13	0	5	6	0.035
K	23	44	2	6	537900	6277650	43.80-54.50	45+46	C/SO	55	13	8	10	14	3	6	0.010
K	25	44	2	6	537900	6277650	43.80-54.50	53+54	C/SO	35	27	14	19	5	4	6	0.027
K	29	45	1	3	537650	6277550	1.25-3.80	2+3	C/T	34	15	46	5	<1	92	1	0.035
K	30	45	1	5	537650	6277550	6.00-10.80	7+9.5	C/T	44	32	20	4	<1	64	2(3)	0.029
K	32	45	2	2	537650	6277550	14.50-22.40	15+17.5	C/T	21	3	1	45	30	14	2(1)	0.006
K	34	45	2	3	537650	6277550	22.40-25.80	23.5+25.5	C/T	28	33	35	4	<1	13	2(1)	0.047
K	35	45	2	4	537650	6277550	25.80-27.40	26+27	C/T	27	14	26	31	2	13	2(1)	0.027
K	36	45	3	2	537650	6277550	31.50-36.50	33+35.5	C/SO	46	24	9	12	9	7	6	0.019
K	38	45	3	4	537650	6277550	43.50-48.40	44.5+46.5	C/SO	43	19	12	24	2	8	6	0.018
K	40	45	3	6	537650	6277550	54.00-69.00	60+63	C/SO	28	38	12	15	7	8	6	0.039
K	42	46	1	1	537650	6277551	69.00-84.00	71+74+77	C/HO	13	19	30	38	<1	44	3(1)	0.039
B	1	47	1	1	532750	6278250	0.00-0.05		A1	29	9	36	10	16		3(1)	
B	2	47	1	2	532750	6278250	0.05-0.50		B21	36	5	26	12	21		2(1)	
B	3	47	1	3	532750	6278250	0.50-1.00		B22	31	6	32	12	19		2(1)	
B	4	47	1	4	532750	6278250	1.00-1.50			35	11	31	12	11		2(3)	
B	5	47	1	5	532750	6278250	1.50-2.00			28	10	42	13	7		2(3)	

ATTACHMENT 7.4 Physical Analyses Interpretation

Soil map unit	Lab no.	Site no.	Data System Card no.	Layer no.	Aust. Grid Ref. m East	Aust. Grid Ref. m North	Depth range (m)	Sample depth (m)	Horizon/ material type	clay (%)	Particle Size Analysis silt (%)	f.sand (%)	c.sand (%)	gravel (%)	DP (%)	EAT	USLE K Factor
A	16	5	1	1	534750	6278250	0.00-0.07		A1	M	L	H	VL	VL	M	H	M
A	17	5	1	2	534750	6278250	0.07-0.35		B21	H	L	M	VL	VL	VH	VH	L
A	18	5	1	3	534750	6278250	0.35-1.00		B22	H	L	M	VL	VL	VH	VH	M
A	19	5	1	4	534750	6278250	1.00-1.50			M	L	H	VL	VL	VH	VH	M
A	20	5	1	5	534750	6278250	1.50-2.00			M	VL	VH	VL	VL	VH	VH	M
A	26	7	1	1	536000	6278400	0.00-0.25		A1	L	L	H	L	L	M	H	M
A	27	7	1	2	536000	6278400	0.25-0.42		A2	VL	VL	L	VL	VH	H	H	H
A	28	7	1	3	536000	6278400	0.42-0.90		B21	VH	L	L	VL	VL	L	H	L
A	29	7	1	4	536000	6278400	0.90-1.40		B22	M	L	L	L	L	L	H	L
A	30	7	1	5	536000	6278400	1.40-1.90			H	L	L	L	L	L	H	L
B	53	12	1	1	535250	6277750	0.00-0.07		A1	M	L	H	VL	VL	L	VH	M
B	54	12	1	2	535250	6277750	0.07-0.50		B2	H	L	M	VL	VL	M	L	L
B	55	12	1	3	535250	6277750	0.50-1.00		B2	H	L	M	VL	L	L	VH	L
B	56	12	1	4	535250	6277750	1.00-1.50		B2	VH	L	M	VL	VL	L	VH	L
B	57	12	1	5	535250	6277750	1.50-2.00			VH	L	M	VL	VL	M	VH	L
B	68	15	1	1	536790	6277690	0.00-0.06		A1	L	VL	H	M	L	M	L	M
B	69	15	1	2	536790	6277690	0.06-0.50		B11	M	VL	L	L	H	VH	VH	L
B	70	15	1	3	536790	6277690	0.50-1.00		B22	M	VL	L	L	H	VH	VH	L
B	71	15	1	4	536790	6277690	1.00-1.50			M	L	L	L	L	VL	L	L
B	72	15	1	5	536790	6277690	1.50-2.00			H	L	M	L	VL	H	H	M
A	133	28	1	1	537250	6276750	0.00-0.10		A1	M	L	M	L	L	H	H	M
A	134	28	1	2	537250	6276750	0.10-0.23		B21	H	L	M	L	L	VH	VH	L
A	135	28	1	3	537250	6276750	0.23-0.80		B22	VH	L	M	VL	VL	L	VH	L
A	136	28	1	4	537250	6276750	0.80-1.40			VH	L	M	VL	VL	VH	VH	L
A	137	28	1	5	537250	6276750	1.40-2.00			VH	L	L	VL	VL	VH	VH	L
B	147	31	1	1	535750	6276180	0.00-0.14		A1	M	L	H	L	VL	M	VL	M
B	148	31	1	2	535750	6276180	0.14-0.50		B21	H	L	M	VL	VL	VH	VH	L

B	149	31	1	3	535750	6276180	0.50-1.00	B22	H	L	L	L	VL	L	VH	H	M
B	150	31	1	4	535750	6276180	1.00-1.50		H	L	L	L	L	L	VH	H	L
B	151	31	1	5	535750	6276180	1.50-1.80		H	L	L	M	L	VL	VH	VH	M
A	158	33	1	1	536750	6276250	0.00-0.08	A1	L	L	H	H	L	VL	M	L	M
A	159	33	1	2	536750	6276250	0.08-0.35	B21	H	L	M	M	L	VL	VH	H	L
A	160	33	1	3	536750	6276250	0.35-0.55	B22	H	L	M	M	L	VL	VH	VH	M
A	161	33	1	4	536750	6276250	0.55-1.20	B23	H	L	M	M	L	VL	M	L	L
A	162	33	1	5	536750	6276250	1.20-1.50		H	L	L	L	L	VL	VH	VH	L
A	163	33	1	6	536750	6276250	1.50-1.80		M	L	M	M	L	L	VH	VH	M
C	188	39	1	1+2	535820	6278240	0.00-0.20		VL	VL	VL	VL	L	VH	na	M	
C	189	39	1	3+4	535820	6278240	0.20-0.60		VL	VL	VL	VL	VL	VH	na	M	
C	190	40	1	1	535780	6278320	0.00-0.10	A1	VL	VL	L	L	L	H	L	na	
C	191	40	1	2	535780	6278320	0.10-0.45		VL	VL	VL	VL	VL	VH	L	na	
C	192	40	1	3	535780	6278320	0.45-0.75		VL	VL	VL	VL	L	L	L	na	
C	193	41	1	1	535730	6278300	0.00-0.18	A11	VL	VL	M	M	M	M	L	L	
C	194	41	1	2	535730	6278300	0.18-0.50	A12	VL	VL	L	L	L	VH	L	na	
C	195	41	1	3	535730	6278300	0.50-0.60	A2	L	VL	L	L	M	H	M	L	
C	196	41	1	4	535730	6278300	0.60-0.90	B2	M	L	L	L	L	M	L	L	
C	199	42	1	4	535690	6278280	0.50-0.80	B22	VH	VL	L	L	L	L	H	VH	
K	1	43	1	1	537852	6278049	1.00-5.00	2+4	C/T	VH	L	L	VL	VL	VH	VH	
K	2	43	1	2	537852	6278049	5.00-10.00	6+9	C/T	H	L	M	L	VL	H	VH	VL
K	3	43	1	3	537852	6278049	10.00-13.50	11+13	C/T	L	VL	L	M	M	L	H	L
K	4	43	1	4	537852	6278049	13.50-18.10	15.4+17.5	C/T	M	M	L	VL	L	VL	VH	L
K	5	43	1	5	537852	6278049	18.10-24.20	20+23	C/H0	M	M	M	VL	VL	VL	VL	M
K	6	43	1	6	537852	6278049	24.20-30.10	25+27	C/H0	L	M	M	L	VL	VL	VL	H
K	8	43	2	2	537852	6278049	37.00-42.00	39+41	C/S0	M	M	M	VL	VL	M	VL	H
K	10	43	2	4	537852	6278049	51.00-54.50	52+54	C/S0	L	M	L	VL	M	H	H	
K	11	44	1	1	537900	6277650	2.00-7.00	3+4	C/T	H	L	M	VL	L	VH	VH	L
K	13	44	1	3	537900	6277650	9.20-12.20	10+11	C/T	M	L	M	L	VL	H	H	M
K	16	44	1	6	537900	6277650	16.40-22.80	17+18	C/T	L	VL	L	H	M	H	H	L

ATTACHMENT 7.4 Physical Analyses Interpretation Continued

Soil map unit	Lab no.	Site no.	Data System Card no.	Layer no.	Aust. Grid Ref. m East	Aust. Grid Ref. m North	Depth range (m)	Sample depth (m)	Horizon/ material type	clay (%)	Particle Size Analysis silt (%)	f.sand (%)	c.sand (%)	gravel (%)	DP (%)	EAT	USLE K Factor
K	18	44	2	1	537900	6277650	22.80-27.40	24+26	C/T	M	M	L	L	L	VL	VL	M
K	20	44	2	3	537900	6277650	30.90-38.70	32+34	C/T	VH	L	L	VL	VL	VL	VL	L
K	22	44	2	4	537900	6277650	38.70-42.80	40+42	C/T	M	M	L	L	VL	VL	VL	M
K	23	44	2	6	537900	6277650	43.80-54.50	45+46	C/SO	VH	L	VL	L	L	VL	VL	VL
K	25	44	2	6	537900	6277650	43.80-54.50	53+54	C/SO	M	M	L	L	L	VL	VL	M
K	29	45	1	3	537650	6277550	1.25-3.80	2+3	C/T	M	L	H	VL	VL	VH	VH	M
K	30	45	1	5	537650	6277550	6.00-10.80	7+9.5	C/T	H	M	L	VL	VL	H	VH	M
K	32	45	2	2	537650	6277550	14.50-22.40	15+17.5	C/T	L	VL	VL	H	M	L	H	VL
K	34	45	2	3	537650	6277550	22.40-25.80	23.5+25.5	C/T	M	M	M	VL	VL	L	H	H
K	35	45	2	4	537650	6277550	25.80-27.40	26+27	C/T	M	L	M	M	VL	L	H	M
K	36	45	3	2	537650	6277550	31.50-36.50	33+35.5	C/SO	H	L	VL	L	L	L	VL	L
K	38	45	3	4	537650	6277550	43.50-48.40	44.5+46.5	C/SO	H	L	L	L	VL	L	VL	L
K	40	45	3	6	537650	6277550	54.00-69.00	60+63	C/SO	M	M	L	L	L	L	VL	M
K	42	46	1	1	537650	6277551	69.00-84.00	71+74+77	C/HO	L	L	M	M	VL	M	L	M
B	1	47	1	1	532750	6278250	0.00-0.05		A1	M	VL	M	L	L			
B	2	47	1	2	532750	6278250	0.05-0.50		B21	M	VL	M	L	M			
B	3	47	1	3	532750	6278250	0.50-1.00		B22	M	VL	M	L	M			
B	4	47	1	4	532750	6278250	1.00-1.50			M	L	M	L	L			
B	5	47	1	5	532750	6278250	1.50-2.00			M	L	H	L	L			

ATTACHMENT 7.5 Chemical Analyses Test Results

Soil map no.	Lab no.	Site no.	Soil Data System Card no.	Layer no.	Aust. Grid Ref. m East	Aust. Grid Ref. m North	Depth range (m)	Sample depth (m)	Horizon/ material type	pH in CaCl ₂	pH in water ¹	Field pH	EC _{1:5} dSm ⁻¹	EC _e dSm ⁻¹	Organic carbon (%)	Organic matter (%)
A	1	1	1	1	534750	6278750	0.00-0.08		A1	5.3	6.3		0.06	0.54		
A	2	1	1	2	534750	6278750	0.08-0.60		B21	6.1	7.2		0.05	0.35		
A	3	1	1	3	534750	6278750	0.60-1.30		B22	8.1	9.2		0.29	2.03		
A	4	1	1	4	534750	6278750	1.30-1.80			8.2	9.3		0.43	3.01		
A	5	1	1	5	534750	6278750	1.80-2.00			7.9	9.0		0.18	1.26		
A	6	3	1	1	536250	6278750	0.00-0.09		A1	5.6	6.6	6	0.06	0.42		
A	7	3	1	2	536250	6278750	0.09-0.50		B2	6.6	7.6	9	0.24	1.68		
A	8	3	1	3	536250	6278750	0.50-1.00		B2	8.0	8.6	9.5	1.86	13.02		
A	9	3	1	4	536250	6278750	1.00-1.50			6.1	6.6	6	2.01	14.07		
A	10	3	1	5	536250	6278750	1.50-2.00			4.5	4.9	5.5	1.86	13.02		
A	11	4	1	1	536750	6278750	0.00-0.04		A1	4.9	5.9		0.06	0.42		
A	12	4	1	2	536750	6278750	0.04-0.45		B2	6.0	7.0		0.14	0.98		
A	13	4	1	3	536750	6278750	0.45-0.90		B2	7.8	8.5		1.41	9.87		
A	14	4	1	4	536750	6278750	0.90-1.40			7.9	8.7		1.16	8.12		
A	15	4	1	5	536750	6278750	1.40-1.80			7.5	8.2		1.40	9.80		
A	16	5	1	1	534750	6278250	0.00-0.07		A1	5.5	6.5	7	0.14	1.26	1.40	2.46
A	17	5	1	2	534750	6278250	0.07-0.35		B21	7.2	8.3	9.5	0.23	1.61	0.50	0.88
A	18	5	1	3	534750	6278250	0.35-1.00		B22	8.3	9.2	9.5	1.10	7.70	0.25	0.44
A	19	5	1	4	534750	6278250	1.00-1.50			5.2	5.8	6	1.37	9.59	0.09	0.16
A	20	5	1	5	534750	6278250	1.50-2.00			4.3	5.0	6	1.11	7.77	0.07	0.12
A	21	6	1	1	535250	6278250	0.00-0.06		A1	5.4	6.4	6	0.12	1.08		
A	22	6	1	2	535250	6278250	0.06-0.40		B21	7.6	8.7	6	0.25	1.75		
A	23	6	1	3	535250	6278250	0.40-0.80		B22	8.2	9.2	9.5	0.81	5.67		
A	24	6	1	4	535250	6278250	0.80-1.25			8.1	8.9	9.5	1.21	8.47		
A	25	6	1	5	535250	6278250	1.25-1.60			4.7	5.4	7	0.89	6.23		
A	26	7	1	1	536000	6278400	0.00-0.25		A1	4.2	5.2	5.5	0.07	0.63	1.42	2.49
A	27	7	1	2	536000	6278400	0.25-0.42		A2	4.5	5.5	6	0.06	0.42	0.63	1.11
A	28	7	1	3	536000	6278400	0.42-0.90		B21	6.3	7.1	8.5	0.99	6.93	0.23	0.40
A	29	7	1	4	536000	6278400	0.90-1.40		B22	8.1	8.9	9.5	1.34	9.38	0.11	0.19
A	30	7	1	5	536000	6278400	1.40-1.90			8.3	9.1	9.5	1.17	8.19	0.09	0.16

ATTACHMENT 7.5 Chemical Analyses Test Results Continued

Soil map unit	Lab no.	Site no.	Soil Data System Card no.	Layer no.	Aust. Grid Ref. m East	Aust. Grid Ref. m North	Depth range (m)	Sample depth (m)	Horizon/ material type	pH in CaCl ₂	pH in water ¹	Field pH	EC _{1:5} dSm ⁻¹	EC _e dSm ⁻¹	Organic carbon (%)	Organic matter (%)
A	31	8	1	1	536250	6278250	0.00-0.10		A1	5.4	6.4	6	0.06	0.54		
A	32	8	1	2	536250	6278250	0.10-0.35		B21	6.1	7.1	8	0.16	1.12		
A	33	8	1	3	536250	6278250	0.35-0.45		B22	7.8	8.7	9.5	0.91	6.37		
A	34	8	1	4	536250	6278250	0.45-1.00		B2	8.3	9.1	9.5	1.37	9.59		
A	35	8	1	5	536250	6278250	1.00-1.50			7.1	7.7	8.5	1.72	12.04		
A	36	8	1	6	536250	6278250	1.50-1.80			5.2	5.8	6	1.61	11.27		
A	37	9	1	1	536750	6278250	0.00-0.06		A1	4.7	5.7		0.06	0.54		
A	38	9	1	2	536750	6278250	0.06-0.55		B2	6.8	7.8		0.42	2.94		
A	39	9	1	3	536750	6278250	0.55-1.00		B2	8.1	8.8		1.58	11.06		
A	40	9	1	4	536750	6278250	1.00-1.50		B2	8.3	9.1		1.24	8.68		
A	41	9	1	5	536750	6278250	1.50-2.00			8.3	9.1		1.26	8.82		
A	42	10	1	1	537250	6278350	0.00-0.06		A1	5.2	6.2	5.5	0.07	0.98		
A	43	10	1	2	537250	6278350	0.06-0.40		B21	6.2	7.2	8	0.16	1.12		
A	44	10	1	3	537250	6278350	0.40-1.20		B22	6.5	7.0	9.5	1.85	12.95		
A	46	10	1	4	537250	6278350	1.20-1.70			6.0	6.5	7.5	1.85	12.95		
A	47	10	1	5	537250	6278350	1.70-2.00			5.0	5.5	5.5	1.78	12.46		
B	48	11	1	1	534750	6277750	0.00-0.05		A1	6.1	7.1	8.5	0.16	1.12		
B	49	11	1	2	534750	6277750	0.05-0.50		B2	8.1	9.2	9.5	0.18	1.26		
B	50	11	1	3	534750	6277750	0.50-1.00		B2	8.6	9.6	9.5	0.74	5.18		
B	51	11	1	4	534750	6277750	1.00-1.50			7.7	8.4	9.5	1.69	11.83		
B	52	11	1	5	534750	6277750	1.50-2.00			5.4	5.9	6.5	1.76	12.32		
B	53	12	1	1	535250	6277750	0.00-0.07		A1	6.5	7.6	7	0.10	0.70	1.60	2.81
B	54	12	1	2	535250	6277750	0.07-0.50		B2	8.1	9.2	8.5	0.25	1.75	0.61	1.07
B	55	12	1	3	535250	6277750	0.50-1.00		B2	7.6	8.0	9.5	2.53	17.71	0.28	0.49
B	56	12	1	4	535250	6277750	1.00-1.50		B2	4.2	4.7	5.5	1.66	11.62	0.19	0.33
B	57	12	1	5	535250	6277750	1.50-2.00			4.0	4.6	5.5	1.40	9.80	0.12	0.21
B	58	13	1	1	535750	6277750	0.00-0.07		A1	7.2	8.3		0.15	1.05		
B	59	13	1	2	535750	6277750	0.07-0.50		B2	7.2	8.2		0.37	2.59		
B	60	13	1	3	535750	6277750	0.50-1.00		B2	8.4	9.1		1.53	10.71		
B	61	13	1	4	535750	6277750	1.00-1.50		B2	7.7	8.4		1.50	10.50		

B	62	13	1	5	535750	6277750	1.50-2.00	4.3	4.8	1.48	10.36	
A	63	14	1	1	536250	6277850	0.00-0.10	A1	4.7	5.7	6	0.63
A	64	14	1	2	536250	6277850	0.10-0.45	B21	5.8	6.9	7	0.49
A	65	14	1	3	536250	6277850	0.45-0.60	B22	7.9	9.0	9	2.52
A	66	14	1	4	536250	6277850	0.60-1.00	B2	8.3	9.5	9.5	0.77
A	67	14	1	5	536250	6277850	1.00-1.50		8.2	9.2	9.5	5.39
A	68	15	1	1	536790	6277690	0.00-0.06	A1	4.3	5.3	5	1.65
A	69	15	1	2	536790	6277690	0.06-0.50	B11	6.5	7.6	7.5	1.52
A	70	15	1	3	536790	6277690	0.50-1.00	B22	8.2	9.1	8.5	6.72
A	71	15	1	4	536790	6277690	1.00-1.50		8.2	8.8	8	14.00
A	72	15	1	5	536790	6277690	1.50-2.00		6.7	7.2	7	14.98
B	73	16	1	1	537250	6277750	0.00-0.10	A1	6.3	7.1	6.5	7.91
B	74	16	1	2	537250	6277750	0.10-0.30	B21	7.7	8.4	9	11.06
B	75	16	1	3	537250	6277750	0.30-0.90	B22	8.2	8.7	9	13.14
B	76	16	1	4	537250	6277750	0.90-1.50	B2	8.0	8.6	9.5	10.62
B	77	16	1	5	537250	6277750	1.50-2.00		8.2	8.8	9	17.28
A	78	17	1	1	534750	6277250	0.00-0.06	A1	5.5	6.5		0.12
A	79	17	1	2	534750	6277250	0.06-0.25	B2	6.8	7.9		1.75
A	80	17	1	3	534750	6277250	0.25-0.75	B2	8.2	9.1		7.49
A	81	17	1	4	534750	6277250	0.75-1.30	B2	6.2	6.9		1.40
A	82	17	1	5	534750	6277250	1.30-1.80		4.2	4.8		1.42
A	83	18	1	1	535250	6277250	0.00-0.05	A1	5.4	6.4		0.08
A	84	18	1	2	535250	6277250	0.05-0.35	B2	6.7	7.7		0.29
A	85	18	1	3	535250	6277250	0.35-0.80	B2	7.9	8.8		0.85
A	86	18	1	4	535250	6277250	0.80-1.50	B2	6.6	7.5		0.85
A	87	18	1	5	535250	6277250	1.50-2.00		4.6	5.3		1.02
A	88	19	1	1	535750	6277250	0.00-0.06	A1	4.5	5.5		0.07
A	89	19	1	2	535750	6277250	0.06-0.50	B21	6.3	7.4		0.13
A	90	19	1	3	535750	6277250	0.50-1.20	B22	7.5	8.3		1.03
A	91	19	1	4	535750	6277250	1.20-1.60		7.3	8.2		0.90
A	92	20	1	1	536250	6277250	0.00-0.09	A1	4.9	5.9		0.11
A	93	20	1	2	536250	6277250	0.09-0.45	B21	6.3	7.4		0.10
A	94	20	1	3	536250	6277250	0.45-0.90	B22	7.8	8.7		0.78

ATTACHMENT 7.5 Chemical Analyses Test Results Continued

Soil map unit	Lab no.	Site no.	Soil Data System Card no.	Layer no.	Aust. Grid Ref. m East	Aust. Grid Ref. m North	Depth range (m)	Sample depth (m)	Horizon/ material type	pH in CaCl ₂	pH in water ¹	Field pH	EC _{1:5} dSm ⁻¹	EC _e dSm ⁻¹	Organic carbon (%)	Organic matter (%)
A	95	20	1	4	536250	6277250	0.90-1.30		B2	8.1	8.9		1.13	7.91		
B	96	21	1	1	537250	6277400	0.00-0.10		A1	5.4	6.4	5.5	0.08	0.56		
B	97	21	1	2	537250	6277400	0.10-0.30		B21	5.8	6.9	8.5	0.04	0.28		
B	98	21	1	3	537250	6277400	0.30-0.90		B22	8.1	9.2	9.5	0.45	3.15		
B	99	21	1	4	537250	6277400	0.90-1.50		B2	8.0	8.7	9.5	1.45	10.15		
B	100	21	1	5	537250	6277400	1.50-2.00			6.3	6.9	6.5	1.71	11.97		
B	101	21	1	6	537250	6277400	2.00-2.30			5.0	5.5	6.5	1.87	11.22		
A	102	22	1	1	536750	6277100	0.00-0.15		A1	5.9	7.0	6.5	0.08	0.72		
A	103	22	1	2	536750	6277100	0.15-0.30		B21	7.3	8.4	8.5	0.20	1.40		
A	104	22	1	4	536750	6277100	0.40-0.80		B2	8.4	9.1	9.5	1.51	10.57		
A	105	22	1	5	536750	6277100	0.80-1.50			8.5	9.3	9.5	1.27	8.89		
A	106	22	1	6	536750	6277100	1.50-1.90			8.5	9.4	8	1.13	7.91		
A	107	23	1	1	534750	6276750	0.00-0.05		A1	4.8	5.8		0.09	0.81		
A	108	23	1	2	534750	6276750	0.05-0.40		B2	7.3	8.4		0.17	1.19		
A	109	23	1	3	534750	6276750	0.40-0.80		B2	8.5	9.4		0.90	6.30		
A	110	23	1	4	534750	6276750	0.80-1.30		B2	4.3	5.0		1.00	7.00		
A	111	23	1	5	534750	6276750	1.30-1.80			4.0	4.6		1.13	7.91		
A	112	24	1	1	535250	6276750	0.00-0.05		A1	4.9	5.9		0.09	0.81		
A	113	24	1	2	535250	6276750	0.05-0.40		B2	7.1	8.2		0.20	1.40		
A	114	24	1	3	535250	6276750	0.40-1.00		B2	8.5	9.4		0.91	6.37		
A	115	24	1	4	535250	6276750	1.00-1.50		B2	8.5	9.4		0.88	6.16		
A	116	24	1	5	535250	6276750	1.50-2.00			8.5	9.5		0.80	5.60		
A	117	25	1	1	535750	6276750	0.00-0.05		A1	4.8	5.8		0.09	0.81		
A	118	25	1	2	535750	6276750	0.05-0.40		B2	7.0	8.1		0.09	0.63		
A	119	25	1	3	535750	6276750	0.40-1.00		B2	8.5	9.3		1.22	8.54		
A	120	25	1	4	535750	6276750	1.00-1.50		B2	8.4	9.2		1.40	9.80		
A	121	26	1	1	536250	6276700	0.00-0.10		A1	4.5	5.5	6	0.14	1.26		
A	122	26	1	2	536250	6276700	0.10-0.30		B21	7.0	8.1	7	0.15	1.05		
A	123	26	1	3	536250	6276700	0.30-0.50		B22	8.2	9.2	8.5	0.49	3.43		
A	124	26	1	4	536250	6276700	0.50-1.00		B2	8.4	9.2	8.5	1.26	8.82		

A	125	26	1	5	536250	6276700	1.00-1.50		7.9	8.7	9	1.32	9.24
A	126	26	1	6	536250	6276700	1.50-1.80		6.1	6.9	6	1.04	7.28
A	127	27	1	1	536750	6276750	0.00-0.10	A1	5.6	6.6	6	0.12	0.84
A	128	27	1	2	536750	6276750	0.10-0.30	B21	8.0	9.1	8.5	0.22	1.54
A	129	27	1	3	536750	6276750	0.30-0.70	B22	8.6	9.5	8.5	1.15	8.05
A	130	27	1	4	536750	6276750	0.70-1.00		8.6	9.4	9	1.43	10.01
A	131	27	1	5	536750	6276750	1.00-1.50		5.5	6.2	6.5	1.21	8.47
A	132	27	1	6	536750	6276750	1.50-1.90		4.3	4.9	6.5	1.31	9.17
B	133	28	1	1	537250	6276750	0.00-0.10	A1	5.6	6.6	5.5	0.11	0.66
B	134	28	1	2	537250	6276750	0.10-0.23	B21	7.3	8.4	8.5	0.16	1.12
B	135	28	1	3	537250	6276750	0.23-0.80	B22	7.6	7.6	8.5	3.88	27.16
B	136	28	1	4	537250	6276750	0.80-1.40		4.6	5.2	5.5	1.26	8.82
B	137	28	1	5	537250	6276750	1.40-2.00		4.1	4.7	5	1.43	10.01
A	138	29	1	1	534750	6276250	0.00-0.16	A1	4.5	5.5	5.5	0.15	1.35
A	139	29	1	2	534750	6276250	0.16-0.47	B21	7.5	8.6	7	0.12	0.84
A	140	29	1	3	534750	6276250	0.47-1.00	B22	8.6	9.6	8.5	0.76	5.32
A	141	29	1	4	534750	6276250	1.00-1.40		7.8	8.7	8.5	0.76	5.32
A	142	30	1	1	535250	6276250	0.00-0.27	A1	5.2	6.2		0.05	0.40
A	143	30	1	2	535250	6276250	0.27-0.47	A2	5.9	7.0	6	0.03	0.27
A	144	30	1	3	535250	6276250	0.47-0.80	B21	6.7	7.8	6.5	0.03	0.21
A	145	30	1	4	535250	6276250	0.80-1.50		7.7	8.8	7.5	0.09	0.81
A	146	30	1	5	535250	6276250	1.50-2.00		8.4	9.5	8	0.26	2.34
A	147	31	1	1	535750	6276180	0.00-0.14	A1	5.5	6.5	5.5	0.18	1.62
A	148	31	1	2	535750	6276180	0.14-0.50	B21	7.6	8.7	7.5	0.22	1.54
A	149	31	1	3	535750	6276180	0.50-1.00		8.5	9.5	8.5	0.80	5.60
A	150	31	1	4	535750	6276180	1.00-1.50		8.5	9.4	9	0.96	6.72
A	151	31	1	5	536750	6276250	1.50-1.80	A1	8.5	9.5	9	0.86	6.02
A	152	32	1	1	536250	6276250	0.00-0.10	A1	5.3	6.3	5.5	0.06	0.54
A	153	32	1	2	536250	6276250	0.10-0.30	B21	6.7	7.8	6	0.18	1.26
A	154	32	1	3	536250	6276250	0.30-0.50	B22	7.9	8.9	7	0.62	4.34
A	155	32	1	4	536250	6276250	0.50-1.00		8.4	9.2	8.5	1.39	9.73
A	156	32	1	5	536250	6276250	1.00-1.50		8.0	8.8	8.5	1.37	9.59
A	157	32	1	6	536250	6276250	1.50-1.80		8.4	9.2	8.5	1.20	8.40

ATTACHMENT 7.5 Chemical Analyses Test Results Continued

Soil map unit	Lab no.	Site no.	Soil Data System Card no.	Layer no.	Aust. Grid Ref. m East	Aust. Grid Ref. m North	Depth range (m)	Sample depth (m)	Horizon/ material type	pH in CaCl ₂	pH in water ¹	Field pH	EC _{1:5} dSm ⁻¹	EC _e dSm ⁻¹	Organic carbon (%)	Organic matter (%)
A	158	33	1	1	536750	6276250	0.00-0.08		A1	5.0	6.0	5.5	0.08	0.72	1.00	1.76
A	159	33	1	2	536750	6276250	0.08-0.35		B21	6.4	7.5	7	0.13	0.91	0.60	1.05
A	160	33	1	3	536750	6276250	0.35-0.55		B22	8.4	9.5	9.5	0.50	3.50	0.43	0.75
A	161	33	1	4	536750	6276250	0.55-1.20		B23	8.5	9.3	9.5	1.33	9.31	0.18	0.32
A	162	33	1	5	536750	6276250	1.20-1.50			8.3	9.1	8.5	1.25	8.75	0.08	0.14
A	163	33	1	6	536750	6276250	1.50-1.80			5.3	5.6	6	0.95	6.65	0.10	0.18
A	164	34	1	1	537250	6276250	0.00-0.05		A1	6.2	7.3		0.11	0.99		
A	165	34	1	2	537250	6276250	0.05-0.30		B21	6.6	7.7		0.08	0.56		
A	166	34	1	3	537250	6276250	0.30-0.80		B22	8.5	9.3		1.34	9.38		
A	167	34	1	5	537250	6276250	1.20-1.80			5.8	6.5		1.30	9.10		
A	168	35	1	1	536250	6275750	0.00-0.04		A1	5.3	6.3		0.12	1.08		
A	169	35	1	2	536250	6275750	0.04-0.35		B2	7.5	8.6		0.35	2.45		
A	170	35	1	3	536250	6275750	0.35-0.80		B2	8.4	9.2		1.36	9.52		
A	171	35	1	4	536250	6275750	0.80-1.30			4.7	5.3		1.40	9.80		
A	172	35	1	5	536250	6275750	1.30-1.60			5.3	6.0		1.13	10.17		
A	173	36	1	1	536750	6275750	0.00-0.07		A1	4.5	5.5		0.04	0.28		
A	174	36	1	2	536750	6275750	0.07-0.23		B2	6.8	7.8		0.31	2.17		
A	175	36	1	3	536750	6275750	0.23-0.60		B2	8.4	9.3		1.03	7.21		
A	176	36	1	4	536750	6275750	0.60-1.20			8.4	9.1		1.63	11.41		
A	177	36	1	5	536750	6275750	1.20-1.30			7.0	7.7		1.49	10.43		
A	178	37	1	1	537250	6275750	0.00-0.05		A1	6.0	7.0		0.17	1.53		
A	179	37	1	2	537250	6275750	0.05-0.35		B21	8.3	9.3		0.64	4.48		
A	180	37	1	3	537250	6275750	0.35-0.70		B22	8.1	8.9		1.38	9.66		
A	181	37	1	4	537250	6275750	0.70-1.50			4.3	4.9		1.46	10.22		
A	182	37	1	5	537250	6275750	1.50-2.00			3.9	4.5		1.28	8.96		
A	183	38	1	1	537750	6275750	0.00-0.05		A1	5.4	6.4		0.12	1.08		
A	184	38	1	2	537750	6275750	0.05-0.30		B2	6.5	7.6		0.12	0.84		
A	185	38	1	3	537750	6275750	0.30-0.70		B2	8.4	9.3		0.93	6.51		
A	186	38	1	4	537750	6275750	0.70-1.50			5.3	5.9		1.53	10.71		
A	187	38	1	5	537750	6275750	1.50-2.30			3.9	4.5		1.40	9.80		

C	188	39	1	1+2	535820	6278240	0.00-0.20	A1	4.3	6.5	0.06	0.84	1.13	1.98
C	189	39	1	3+4	535820	6278240	0.20-0.60		4.3	5.5	0.04	0.56	0.86	1.51
C	190	40	1	1	535780	6278320	0.00-0.10	A1	4.3	6	0.22	3.08	4.23	7.42
C	191	40	1	2	535780	6278320	0.10-0.45		4.0	5	0.05	0.70	1.27	2.23
C	192	40	1	3	535780	6278320	0.45-0.75		3.9	5	0.05	0.70	0.44	0.77
C	193	41	1	1	535730	6278300	0.00-0.18	A11	3.9	5.5	0.17	2.38	2.97	5.21
C	194	41	1	2	535730	6278300	0.18-0.50	A12	3.7	5	0.07	0.98	1.29	2.26
C	195	41	1	3	535730	6278300	0.50-0.60	A2	3.9	5	0.04	0.56	0.16	0.28
C	196	41	1	4	535730	6278300	0.60-0.90	B2	3.8	5.5	0.06	0.42	0.27	0.47
C	197	42	1	1	535730	6278300	0.00-0.18	A11	4.3	4.5	0.08	1.12		
C	198	42	1	2	535730	6278300	0.18-0.50	A12	3.9	4.5	0.07	0.98		
C	199	42	1	4	535690	6278280	0.50-0.80	B22	4.2	5.5	0.14	0.98	0.26	0.46
K	1	43	1	1	537852	6278049	1.00-5.00	2+4	7.3	8.2	0.85	6.80	0.05	0.09
K	2	43	1	2	537852	6278049	5.00-10.00	6+9	5.9	6.4	1.77	12.39	0.04	0.07
K	3	43	1	3	537852	6278049	10.00-13.50	11+13	6.9	7.4	2.08	14.56	0.05	0.09
K	4	43	1	4	537852	6278049	13.50-18.10	15.4+17.5	6.7	6.8	3.95	27.65	0.06	0.11
K	5	43	1	5	537852	6278049	18.10-24.20	20+23	6.8	6.9	3.32	28.22	0.05	0.09
K	6	43	1	6	537852	6278049	24.20-30.10	25+27	7.0	7.0	3.69	25.83	0.05	0.09
K	7	43	2	1	537852	6278049	30.10-37.00	31+35	7.3	7.4	3.58	28.64		
K	8	43	2	2	537852	6278049	37.00-42.00	39+41	7.3	7.4	3.27	26.16	0.06	0.11
K	9	43	2	3	537852	6278049	42.00-51.00	43+47+50	7.4	7.8	2.49	19.92		
K	10	43	2	4	537852	6278049	51.00-54.50	52+54	7.4	7.7	2.91	20.37	0.04	0.07
K	11	44	1	1	537900	6277650	2.00-7.00	3+4	7.5	8.6	0.28	2.38	0.03	0.05
K	12	44	1	2	537900	6277650	7.00-9.20	7.5+9	6.4	6.9	2.03	17.26		
K	13	44	1	3	537900	6277650	9.20-12.20	10+11	6.6	7.0	2.26	15.82	0.04	0.07
K	14	44	1	4	537900	6277650	13.50-14.10	13.9	6.6	6.8	3.61	50.54		
K	15	44	1	5	537900	6277650	14.10-15.20	14.5	7.0	7.5	2.22	18.87		
K	16	44	1	6	537900	6277650	16.40-22.80	17+18	7.0	7.5	1.98	33.66	0.05	0.09
K	17	44	1	6	537900	6277650	16.40-22.80	20+22.5	6.9	7.3	2.50	17.50		
K	18	44	2	1	537900	6277650	22.80-27.40	24+26	6.7	7.0	2.64	18.48	0.07	0.12
K	19	44	2	2	537900	6277650	27.40-30.90	28+30	7.1	7.2	3.48	24.36		
K	20	44	2	3	537900	6277650	30.90-38.70	32+34	6.9	7.2	3.34	23.38	0.05	0.09
K	21	44	2	3	537900	6277650	30.90-38.70	36+38	6.4	6.7	2.79	19.53		

ATTACHMENT 7.5 Chemical Analyses Test Results Continued

Soil map unit	Lab no.	Site no.	Soil Data System Card no.	Layer no.	Aust. Grid Ref. m East	Aust. Grid Ref. m North	Depth range (m)	Sample depth (m)	Horizon/ material type	pH in CaCl ₂	pH in water ¹	Field pH	EC _{1:5} dSm ⁻¹	EC _e dSm ⁻¹	Organic carbon (%)	Organic matter (%)
K	22	44	2	4	537900	6277650	38.70-42.80	40+42	C/T	6.7	6.8	8.5	3.36	23.52	0.06	0.11
K	23	44	2	6	537900	6277650	43.80-54.50	45+46	C/SO	7.3	7.7		2.32	16.24	0.04	0.07
K	24	44	2	6	537900	6277650	43.80-54.50	48+49	C/SO	7.4	7.9	8	1.99	13.93		
K	25	44	2	6	537900	6277650	43.80-54.50	53+54	C/SO	7.2	7.7		2.16	15.12	0.03	0.05
K	26	44			537900	6277650	54.50-64.00	56+58	C/SO	7.6	8.0		2.64	18.48		
K	27	44			537900	6277650	54.50-64.00	60+61	C/SO	7.6	8.2		1.82	12.74		
K	28	44			537900	6277650	54.50-64.00	63+64	C/SO	7.2	7.8		1.83	12.81		
K	29	45	1	3	537650	6277550	1.25-3.80	2+3	C/T	8.0	9.0		0.64	5.44	0.03	0.05
K	30	45	1	5	537650	6277550	6.00-10.80	7+9.5	C/T	6.8	7.4		1.72	12.04	0.04	0.07
K	31	45	1	6	537650	6277550	10.80-13.00	12.5	C/T	6.6	6.8	6.5	2.37	20.15		
K	32	45	2	2	537650	6277550	14.50-22.40	15+17.5	C/T	6.4	6.7	8	2.47	41.99	0.06	0.11
K	33	45	2	2	537650	6277550	14.50-22.40	19+20	C/T	7.6	7.7		3.37	57.29		
K	34	45	2	3	537650	6277550	22.40-25.80	23.5+25.5	C/T	6.9	7.2	2.62		22.27	0.05	0.09
K	35	45	2	4	537650	6277550	25.80-27.40	26+27	C/T	7.6	7.9	7.5	2.81	19.67	0.04	0.07
K	36	45	3	2	537650	6277550	31.50-36.50	33+35.5	C/SO	7.2	7.5	8.5	2.83	19.81	0.07	0.12
K	37	45	3	3	537650	6277550	36.50-43.50	38+41	C/SO	7.2	7.2	8.5	3.89	27.23		
K	38	45	3	4	537650	6277550	43.50-48.40	91	C/SO	6.9	7.3		2.34	16.38	0.06	0.11
K	39	45	3	5	537650	6277550	48.40-54.00	50+52	C/SO	6.9	6.9		3.72	26.04		
K	40	45	3	6	537650	6277550	54.00-69.00	60+63	C/SO	7.3	7.1		4.50	31.50	0.07	0.12
K	41	45	3	6	537650	6277550	54.00-69.00	65+68	C/SO	8.4	8.5		3.63	30.86		
K	42	46	1	1	537650	6277551	69.00-84.00	71+74+77	C/HO	7.3	7.7		2.49	17.43	0.05	0.09
K	43	46	1	1	537650	6277551	69.00-84.00	79+80+81	C/HO	7.6	7.5		4.17	29.19		
B	1	47	1	1	532750	6278250	0.00-0.05		A1	6.8	8.1	8.5	0.18	1.62	1.39	2.44
B	2	47	1	2	532750	6278250	0.05-0.50		B21	8.3	9.3	9.0	1.22	8.54	0.29	0.51
B	3	47	1	3	532750	6278250	0.50-1.00		B22	8.2	8.6	9.0	2.76	19.32	0.18	0.32
B	4	47	1	4	532750	6278250	1.00-1.50			7.7	8.2	8.5	2.21	15.47	0.11	0.19
B	5	47	1	5	532750	6278250	1.50-2.00			5.4	5.3	6.0	1.62	11.34	0.08	0.14
A	6	49	1	1	533750	6278250	0.00-0.10		A1	4.8	5.9	5.5	0.08	0.72		
A	7	49	1	2	533750	6278250	0.10-0.40		B21	6.3	8.0	8.0	0.24	1.68		
A	8	49	1	3	533750	6278250	0.50-1.00		B22	8.1	9.0	9.0	1.41	9.87		

A	9	49	1	4	533750	6278250	1.00-1.50	8.1	8.8	8.5	1.23	8.61
A	10	49	1	5	533750	6278250	1.50-2.00	8.0	8.8	7.5	1.19	8.33
A	11	52	1	1	533250	6277750	0.00-0.06	A1	5.1	6.0	0.07	0.63
A	12	52	1	2	533250	6277750	0.06-0.50	B2	6.6	7.8	0.39	2.73
A	13	52	1	3	533250	6277750	0.50-1.00	B2	8.3	9.1	1.26	8.82
A	14	52	1	4	533250	6277750	1.00-1.50		8.4	9.2	1.06	7.42
A	15	52	1	5	533250	6277750	1.50-1.80		6.4	6.8	0.83	5.81
B	16	54	1	1	534250	6277700	0.00-0.10	A1	5.1	5.8	0.34	3.06
B	17	54	1	2	534250	6277700	0.10-0.50	B2	7.2	8.0	1.60	11.20
B	18	54	1	3	534250	6277700	0.50-1.00	B2	4.2	4.7	1.70	11.90
B	19	54	1	4	534250	6277700	1.00-1.50		3.9	4.4	1.82	12.74
B	20	54	1	5	534250	6277700	1.50-2.00		3.8	4.4	1.60	11.20
A	21	56	1	1	533250	6277250	0.00-0.07	A1	4.5	5.6	0.06	0.54
A	22	56	1	2	533250	6277250	0.50-1.00	B2	8.6	9.6	0.71	4.97
A	23	56	1	3	533250	6277250	0.50-1.00	B2	4.0	5.0	0.75	5.25
A	24	56	1	4	533250	6277250	1.50-2.00		3.8	4.7	0.77	5.39
A	25	57	1	1	533750	6277250	0.00-0.10	A1	4.9	6.0	0.08	0.72
A	26	57	1	2	533750	6277250	0.10-0.40	B21	7.5	8.8	0.35	2.45
A	27	57	1	3	533750	6277250	0.50-1.00	B22	8.4	9.2	1.12	7.84
A	28	57	1	4	533750	6277250	1.00-1.50		7.5	8.3	1.03	7.21
A	29	57	1	5	533750	6277250	1.50-2.00		4.2	4.9	1.00	7.00
A	30	59	1	1	532750	6276750	0.00-0.05	A1	4.5	5.4	0.21	1.89
A	31	59	1	2	532750	6276750	0.05-0.40	B21	8.2	8.8	1.19	8.33
A	32	59	1	3	532750	6276750	0.50-1.00	B22	8.5	9.1	1.46	10.22
A	33	59	1	4	532750	6276750	1.00-1.50		7.2	7.9	1.16	8.12
A	34	59	1	5	532750	6276750	1.50-2.00		4.5	4.9	1.43	10.01
A	35	61	1	1	533750	6276750	0.00-0.05	A1	4.7	5.4	0.11	0.99
A	36	61	1	2	533750	6276750	0.05-0.50	B21	8.2	9.1	0.63	4.41
A	37	61	1	3	533750	6276750	0.50-1.00	B22	7.5	8.6	0.84	5.88
A	37	61	1	4	533750	6276750	1.00-1.50	B22	4.1	4.7	0.98	6.86
A	39	61	1	5	533750	6276750	1.50-2.00		3.9	4.6	0.95	6.65
A	40	63	1	1	532750	6276250	0.00-0.05	A1	4.6	5.5	0.11	0.99
A	41	63	1	2	532750	6276250	0.05-0.15	A2	5.0	6.1	0.11	0.77

ATTACHMENT 7.5 Chemical Analyses Test Results Continued

Soil map unit	Lab no.	Site no.	Soil Data System Card no.	Layer no.	Aust. Grid Ref. m East	Aust. Grid Ref. m North	Depth range (m)	Sample depth (m)	Horizon/ material type	pH in CaCl ₂	pH in water ¹	Field pH	EC _{1:5} dSm ⁻¹	EC _e dSm ⁻¹	Organic carbon (%)	Organic matter (%)
A	42	63	1	3	532750	6276250	0.15-0.40		B21	4.8	6.2	6.0	0.13	0.91		
A	43	63	1	4	532750	6276250	0.50-1.00		B22	5.1	6.1	7.5	0.39	2.73		
A	44	63	1	5	532750	6276250	1.00-1.50			6.1	7.3	7.5	0.37	2.59		
A	45	63	1	6	532750	6276250	1.50-2.00			6.4	7.1	8.0	0.47	3.29		
A	46	64	1	1	533250	6276250	0.00-0.05		A1	4.5	5.1	6.5	0.20	1.80		
A	47	64	1	2	533250	6276250	0.05-0.35		B21	6.7	7.8	8.5	0.56	3.92		
A	48	64	1	3	533250	6276250	0.35-1.00		B22	7.2	8.3	9.5	1.17	8.19		
A	49	64	1	4	533250	6276250	1.00-1.50			4.2	4.8	5.0	1.09	7.63		
A	50	64	1	5	533250	6276250	1.50-2.00			4.0	4.7	5.0	1.06	7.42		
A	51	66	1	1	534250	6276250	0.03-0.20		A	4.7	5.7	6.0	0.19	1.33		
A	52	66	1	2	534250	6276250	0.20-0.55		B21	6.0	7.2	7.5	0.13	0.91		
A	53	66	1	3	534250	6276250	0.55-1.00		B22	8.3	8.9	9.0	1.22	8.54		
A	54	66	1	4	534250	6276250	1.00-1.50			6.0	6.3		1.50	10.50		
A	55	66	1	5	534250	6276250	1.50-2.00			4.1	4.8	6.5	1.07	7.49		

¹ pH(1:5 soil:water) data for sites 1-38 and 43-46 was derived by regression analysis (see Attachment 7.1.3 for details), while data for sites 47-66 was measured in the laboratory

ATTACHMENT 7.6 Chemical Analyses Interpretation

Soil map no.	Lab no.	Site no.	Soil Data System Card no.	Layer no.	Aust. Grid Ref. m East	Aust. Grid Ref. m North	Depth range (m)	Sample depth (m)	Horizon/material type	Acidity (CaCl ₂ pH)	Alkal. (CaCl ₂ pH)	Acidity (water pH)	Alkal. (water pH)	Salinity (EC _e)	Organic matter
A	1	1	1	1	534750	6278750	0.00-0.08		A1	SI	SI	SI		VL	
A	2	1	1	2	534750	6278750	0.08-0.60		B21		N		N	VL	
A	3	1	1	3	534750	6278750	0.60-1.30		B22				VSt	L	
A	4	1	1	4	534750	6278750	1.30-1.80						VSt	L	
A	5	1	1	5	534750	6278750	1.80-2.00						VSt	VL	
A	6	3	1	1	536250	6278750	0.00-0.09		A1	SI			N	VL	
A	7	3	1	2	536250	6278750	0.09-0.50		B2		SI		SI	VL	
A	8	3	1	3	536250	6278750	0.50-1.00		B2				St	H	
A	9	3	1	4	536250	6278750	1.00-1.50				N			H	
A	10	3	1	5	536250	6278750	1.50-2.00			St		VSt		H	
A	11	4	1	1	536750	6278750	0.00-0.04		A1	M		M		VL	
A	12	4	1	2	536750	6278750	0.04-0.45		B2		N		N	VL	
A	13	4	1	3	536750	6278750	0.45-0.90		B2				St	H	
A	14	4	1	4	536750	6278750	0.90-1.40						St	H	
A	15	4	1	5	536750	6278750	1.40-1.80						M	H	
A	16	5	1	1	534750	6278250	0.00-0.07		A1	SI				VL	M
A	17	5	1	2	534750	6278250	0.07-0.35		B21				M	VL	VL
A	18	5	1	3	534750	6278250	0.35-1.00		B22				VSt	M	EL
A	19	5	1	4	534750	6278250	1.00-1.50			M		M		H	EL
A	20	5	1	5	534750	6278250	1.50-2.00			St		VSt		M	EL
A	21	6	1	1	535250	6278250	0.00-0.06		A1	SI		SI		VL	
A	22	6	1	2	535250	6278250	0.06-0.40		B21				St	VL	
A	23	6	1	3	535250	6278250	0.40-0.80		B22				VSt	M	
A	24	6	1	4	535250	6278250	0.80-1.25						St	H	
A	25	6	1	5	535250	6278250	1.25-1.60			St		St		M	
A	26	7	1	1	536000	6278400	0.00-0.25		A1	VSt		St		VL	M
A	27	7	1	2	536000	6278400	0.25-0.42		A2	St		St		VL	L
A	28	7	1	3	536000	6278400	0.42-0.90		B21		N		N	M	EL
A	29	7	1	4	536000	6278400	0.90-1.40		B22				St	H	EL
A	30	7	1	5	536000	6278400	1.40-1.90						VSt	H	EL

ATTACHMENT 7.6 Chemical Analyses Interpretation Continued

Soil map no.	Lab no.	Site no.	Soil Data System Card no.	Layer no.	Aust. Grid Ref. m East	Aust. Grid Ref. m North	Depth range (m)	Sample depth (m)	Horizon/ material type	Acidity (CaCl ₂ pH)	Alkal. (CaCl ₂ pH)	Acidity (water pH)	Alkal. (water pH)	Salinity (EC _e)	Organic matter
A	31	8	1	1	536250	6278250	0.00-0.10		A1	SI		SI		VL	
A	32	8	1	2	536250	6278250	0.10-0.35		B21		N		N	VL	
A	33	8	1	3	536250	6278250	0.35-0.45		B22	St	M				
A	34	8	1	4	536250	6278250	0.45-1.00		B2				VSt	H	
A	35	8	1	5	536250	6278250	1.00-1.50				M	M	SI	H	
A	36	8	1	6	536250	6278250	1.50-1.80							H	
A	37	9	1	1	536750	6278250	0.00-0.06		A1	St		M		VL	
A	38	9	1	2	536750	6278250	0.06-0.55		B2		SI		SI	L	
A	39	9	1	3	536750	6278250	0.55-1.00		B2				St	H	
A	40	9	1	4	536750	6278250	1.00-1.50		B2				VSt	H	
A	41	9	1	5	536750	6278250	1.50-2.00						VSt	H	
A	42	10	1	1	537250	6278350	0.00-0.06		A1	M		SI		VL	
A	43	10	1	2	537250	6278350	0.06-0.40		B21		N		N	VL	
A	44	10	1	3	537250	6278350	0.40-1.20		B22		N		N	H	
A	46	10	1	4	537250	6278350	1.20-1.70				N			H	
A	47	10	1	5	537250	6278350	1.70-2.00			M		St		H	
B	48	11	1	1	534750	6277750	0.00-0.05		A1		N		N	VL	
B	49	11	1	2	534750	6277750	0.05-0.50		B2				VSt	VL	
B	50	11	1	3	534750	6277750	0.50-1.00		B2				VSt	M	
B	51	11	1	4	534750	6277750	1.00-1.50						M	H	
B	52	11	1	5	534750	6277750	1.50-2.00			SI		M		H	
B	53	12	1	1	535250	6277750	0.00-0.07		A1		N		SI	VL	M
B	54	12	1	2	535250	6277750	0.07-0.50		B2				VSt	VL	VL
B	55	12	1	3	535250	6277750	0.50-1.00		B2				M	VH	EL
B	56	12	1	4	535250	6277750	1.00-1.50		B2	VSt				H	EL
B	57	12	1	5	535250	6277750	1.50-2.00			VSt				H	EL
B	58	13	1	1	535750	6277750	0.00-0.07		A1				M	VL	
B	59	13	1	2	535750	6277750	0.07-0.50		B2				M	L	
B	60	13	1	3	535750	6277750	0.50-1.00		B2				VSt	H	
B	61	13	1	4	535750	6277750	1.00-1.50		B2				M	H	

B	62	13	1	5	535750	6277750	1.50-2.00	St	VSt	H
A	63	14	1	1	536250	6277850	0.00-0.10	A1	M	VL
A	64	14	1	2	536250	6277850	0.10-0.45	B21	N	VL
A	65	14	1	3	536250	6277850	0.45-0.60	B22	St	L
A	66	14	1	4	536250	6277850	0.60-1.00	B2	VSt	VL
A	67	14	1	5	536250	6277850	1.00-1.50		VSt	M
A	68	15	1	1	536790	6277690	0.00-0.06	A1	St	VL
A	69	15	1	2	536790	6277690	0.06-0.50	B11	N	VL
A	70	15	1	3	536790	6277690	0.50-1.00	B22	VSt	M
A	71	15	1	4	536790	6277690	1.00-1.50		St	H
A	72	15	1	5	536790	6277690	1.00-1.50	SI	N	H
B	73	16	1	1	537250	6277750	0.00-0.10	A1	N	M
B	74	16	1	2	537250	6277750	0.10-0.30	B21	M	H
B	75	16	1	3	537250	6277750	0.30-0.90	B22	St	H
B	76	16	1	4	537250	6277750	0.90-1.50	B2	St	H
B	77	16	1	5	537250	6277750	1.50-2.00		St	VH
A	78	17	1	1	534750	6277250	0.00-0.06	A1	SI	VL
A	79	17	1	2	534750	6277250	0.06-0.25	B2	SI	VL
A	80	17	1	3	534750	6277250	0.25-0.75	B2	VSt	M
A	81	17	1	4	534750	6277250	0.75-1.30	B2	N	H
A	82	17	1	5	534750	6277250	1.30-1.80		VSt	H
A	83	18	1	1	535250	6277250	0.00-0.05	A1	SI	VL
A	84	18	1	2	535250	6277250	0.05-0.35	B2	SI	L
A	85	18	1	3	535250	6277250	0.35-0.80	B2	St	M
A	86	18	1	4	535250	6277250	0.80-1.50	B2	SI	M
A	87	18	1	5	535250	6277250	1.50-2.00		St	M
A	88	19	1	1	535750	6277250	0.00-0.06	A1	St	VL
A	89	19	1	2	535750	6277250	0.06-0.50	B21	N	VL
A	90	19	1	3	535750	6277250	0.50-1.20	B22	M	M
A	91	19	1	4	535750	6277250	1.20-1.60		M	M
A	92	20	1	1	536250	6277250	0.00-0.09	A1	M	VL
A	93	20	1	2	536250	6277250	0.09-0.45	B21	N	VL
A	94	20	1	3	536250	6277250	0.45-0.90	B22	St	M

ATTACHMENT 7.6 Chemical Analyses Interpretation Continued

Soil map no.	Lab no.	Site no.	Card no.	Soil Data System Layer no.	Aust. Grid Ref. m East	Aust. Grid Ref. m North	Depth range (m)	Sample depth (m)	Horizon/ material type	Acidity (CaCl ₂ pH)	Alkal. (CaCl ₂ pH)	Acidity (water pH)	Alkal. (water pH)	Salinity (EC _e)	Organic matter
A	95	20	1	4	536250	6277250	0.90-1.30		B2				St	M	
B	96	21	1	1	537250	6277400	0.00-0.10		A1	SI		SI		VL	
B	97	21	1	2	537250	6277400	0.10-0.30		B21		N		N	VL	
B	98	21	1	3	537250	6277400	0.30-0.90		B22				VSt	L	
B	99	21	1	4	537250	6277400	0.90-1.50		B2				St	H	
B	100	21	1	5	537250	6277400	1.50-2.00				N		N	H	
B	101	21	1	6	537250	6277400	2.00-2.30				M		St	H	
A	102	22	1	1	536750	6277100	0.00-0.15		A1		N		N	VL	
A	103	22	1	2	536750	6277100	0.15-0.30		B21				M	VL	
A	104	22	1	4	536750	6277100	0.40-0.80		B2				VSt	H	
A	105	22	1	5	536750	6277100	0.80-1.50						VSt	H	
A	106	22	1	6	536750	6277100	1.50-1.90						VSt	M	
A	107	23	1	1	534750	6276750	0.00-0.05		A1	M		M		VL	
A	108	23	1	2	534750	6276750	0.05-0.40		B2				M	VL	
A	109	23	1	3	534750	6276750	0.40-0.80		B2				VSt	M	
A	110	23	1	4	534750	6276750	0.80-1.30		B2	St		VSt		M	
A	111	23	1	5	534750	6276750	1.30-1.80			VSt		VSt		M	
A	112	24	1	1	535250	6276750	0.00-0.05		A1	M		M		VL	
A	113	24	1	2	535250	6276750	0.05-0.40		B2		M		M	VL	
A	114	24	1	3	535250	6276750	0.40-1.00		B2				VSt	M	
A	115	24	1	4	535250	6276750	1.00-1.50		B2				VSt	M	
A	116	24	1	5	535250	6276750	1.50-2.00						VSt	M	
A	117	25	1	1	535750	6276750	0.00-0.05		A1	M		M		VL	
A	118	25	1	2	535750	6276750	0.05-0.40		B2		SI		M	VL	
A	119	25	1	3	535750	6276750	0.40-1.00		B2				VSt	H	
A	120	25	1	4	535750	6276750	1.00-1.50		B2				VSt	H	
A	121	26	1	1	536250	6276700	0.00-0.10		A1	St		St		VL	
A	122	26	1	2	536250	6276700	0.10-0.30		B21		SI		M	VL	
A	123	26	1	3	536250	6276700	0.30-0.50		B22				VSt	L	
A	124	26	1	4	536250	6276700	0.50-1.00		B2				VSt	H	
A	125	26	1	5	536250	6276700	1.00-1.50						St	H	

A	126	26	1	6	536250	6276700	1.50-1.80			N		N	M
A	127	27	1	1	536750	6276750	0.00-0.10	A1	SI			N	VL
A	128	27	1	2	536750	6276750	0.10-0.30	B21				VSt	VL
A	129	27	1	3	536750	6276750	0.30-0.70	B22				VSt	H
A	130	27	1	4	536750	6276750	0.70-1.00					VSt	H
A	131	27	1	5	536750	6276750	1.00-1.50		SI		SI		H
A	132	27	1	6	536750	6276750	1.50-1.90		St		VSt		H
B	133	28	1	1	537250	6276750	0.00-0.10	A1	SI			N	VL
B	134	28	1	2	537250	6276750	0.10-0.23	B21				M	VL
B	135	28	1	3	537250	6276750	0.23-0.80	B22				SI	VH
B	136	28	1	4	537250	6276750	0.80-1.40		St		St		H
B	137	28	1	5	537250	6276750	1.40-2.00		VSt		VSt		H
A	138	29	1	1	534750	6276250	0.00-0.16	A1	St		St		VL
A	139	29	1	2	534750	6276250	0.47-0.47	B21				St	VL
A	140	29	1	3	534750	6276250	1.00-1.00	B22				VSt	M
A	141	29	1	4	534750	6276250	1.40-1.40					St	M
A	142	30	1	1	535250	6276250	0.00-0.27	A1	M		SI		VL
A	143	30	1	2	535250	6276250	0.27-0.47	A2		N		N	VL
A	144	30	1	3	535250	6276250	0.47-0.80	B21		SI		SI	VL
A	145	30	1	4	535250	6276250	0.80-1.50					St	VL
A	146	30	1	5	535250	6276250	1.50-2.00					VSt	L
A	147	30	1	1	535750	6276180	0.00-0.14	A1	SI				VL
A	148	31	1	2	535750	6276180	0.14-0.50	B21				St	VL
A	149	31	1	3	535750	6276180	1.00-1.50					VSt	M
A	150	31	1	4	535750	6276180	1.50-1.80					VSt	M
A	151	31	1	5	536750	6276250	0.00-0.08	A1				VSt	M
A	152	32	1	1	536250	6276250	0.00-0.10	A1	SI		SI		VL
A	153	32	1	2	536250	6276250	0.10-0.30	B21		SI		SI	VL
A	154	32	1	3	536250	6276250	0.30-0.50	B22				St	M
A	155	32	1	4	536250	6276250	0.50-1.00					VSt	H
A	156	32	1	5	536250	6276250	1.00-1.50					St	H
A	157	32	1	6	536250	6276250	1.50-1.80					VSt	H
A	158	33	1	1	536750	6276250	0.00-0.08	A1	M		M		VL
													L

ATTACHMENT 7.6 Chemical Analyses Interpretation Continued

Soil map no.	Lab no.	Site no.	Soil Data System Card no.	Layer no.	Aust. Grid Ref. m East	Aust. Grid Ref. m North	Depth range (m)	Sample depth (m)	Horizon/ material type	Acidity (CaCl ₂ pH)	Alkal. (CaCl ₂ pH)	Acidity (water pH)	Alkal. (water pH)	Salinity (EC _e)	Organic matter
A	159	33	1	2	536750	6276250	0.08-0.35		B21		N		SI	VL	VL
A	160	33	1	3	536750	6276250	0.35-0.55		B22				VSt	L	VL
A	161	33	1	4	536750	6276250	0.55-1.20		B23				VSt	H	EL
A	162	33	1	5	536750	6276250	1.20-1.50						VSt	H	EL
A	163	33	1	6	536750	6276250	1.50-1.80			SI		M		M	EL
A	164	34	1	1	537250	6276250	0.00-0.05		A1		N		N	VL	
A	165	34	1	2	537250	6276250	0.05-0.30		B21		SI		SI	VL	
A	166	34	1	3	537250	6276250	0.30-0.80		B22				VSt	H	
A	167	34	1	5	537250	6276250	1.20-1.80				N		SI	H	
A	168	35	1	1	536250	6275750	0.00-0.04		A1	SI		SI		VL	
A	169	35	1	2	536250	6275750	0.04-0.35		B2				St	L	
A	170	35	1	3	536250	6275750	0.35-0.80		B2				VSt	H	
A	171	35	1	4	536250	6275750	0.80-1.30			St		St		H	
A	172	35	1	5	536250	6275750	1.30-1.60			SI		M		H	
A	173	36	1	1	536750	6275750	0.00-0.07		A1	St		St		VL	
A	174	36	1	2	536750	6275750	0.07-0.23		B2		SI		SI	L	
A	175	36	1	3	536750	6275750	0.23-0.60		B2				VSt	M	
A	176	36	1	4	536750	6275750	0.60-1.20						VSt	H	
A	177	36	1	5	536750	6275750	1.20-1.30				SI		SI	H	
A	178	37	1	1	537250	6275750	0.00-0.05		A1		N		N	VL	
A	179	37	1	2	537250	6275750	0.05-0.35		B21				VSt	M	
A	180	37	1	3	537250	6275750	0.35-0.70		B22				St	H	
A	181	37	1	4	537250	6275750	0.70-1.50			St		VSt		H	
A	182	37	1	5	537250	6275750	1.50-2.00			VSt		Ext		H	
A	183	38	1	1	537750	6275750	0.00-0.05		A1	SI		SI		VL	
A	184	38	1	2	537750	6275750	0.05-0.30		B2		N		SI	VL	
A	185	38	1	3	537750	6275750	0.30-0.70		B2				VSt	M	
A	186	38	1	4	537750	6275750	0.70-1.50			SI		M		H	
A	187	38	1	5	537750	6275750	1.50-2.30			VSt		Ext		H	
C	188	39	1	1+2	535820	6278240	0.00-0.20		A1	St				VL	L

C	189	39	1	3+4	535820	6278240	0.20-0.60		St		VL	L
C	190	40	1	1	535780	6278320	0.00-0.10	A1	St		L	VH
C	191	40	1	2	535780	6278320	1.10-0.45		V5t		VL	M
C	192	40	1	3	535780	6278320	0.45-0.75		V5t		VL	VL
C	193	41	1	1	535730	6278300	0.00-0.18	A11	V5t		L	VH
C	194	41	1	2	535730	6278300	0.18-0.50	A12	V5t		VL	M
C	195	41	1	3	535730	6278300	0.50-0.60	A2	V5t		VL	VL
C	196	41	1	4	535730	6278300	0.60-0.90	B2	V5t		VL	VL
C	197	42	1	1	535730	6278300	0.00-0.18	A11	St		VL	
C	198	42	1	2	535730	6278300	0.18-0.50	A12	V5t		VL	
C	199	42	1	4	535690	6278280	0.50-0.80	B22	V5t		VL	VL
K	1	43	1	1	537852	6278049	1.00-5.00	2+4	C/T	M	M	EL
K	2	43	1	2	537852	6278049	5.00-10.00	6+9	C/T	N	H	EL
K	3	43	1	3	537852	6278049	10.00-13.50	11+13	C/T	SI	H	EL
K	4	43	1	4	537852	6278049	13.50-18.10	15.4+17.5	C/T	SI	VH	EL
K	5	43	1	5	537852	6278049	18.10-24.20	20+23	C/H0	N	VH	EL
K	6	43	1	6	537852	6278049	24.20-30.10	25+27	C/H0	N	VH	EL
K	7	43	2	1	537852	6278049	30.10-37.00	31+35	C/H0	N	VH	
K	8	43	2	2	537852	6278049	37.00-42.00	39+41	C/S0	SI	VH	EL
K	9	43	2	3	537852	6278049	42.00-51.00	43+47+50	C/S0	SI	VH	
K	10	43	2	4	537852	6278049	51.00-54.50	52+54	C/S0	SI	VH	EL
K	11	44	1	1	537900	6277650	2.00-7.00	3+4	C/T	St	L	EL
K	12	44	1	2	537900	6277650	7.00-9.00	7.5+9	C/T	N	VH	
K	13	44	1	3	537900	6277650	9.20-12.20	10+11	C/T	SI	H	EL
K	14	44	1	4	537900	6277650	13.50-14.10	13.9	C/T	N	VH	
K	15	44	1	5	537900	6277650	14.10-15.20	14.5	C/T	SI	VH	
K	16	44	1	6	537900	6277650	16.40-22.80	17+18	C/T	SI	VH	EL
K	17	44	1	6	537900	6277650	16.40-22.80	20+22.5	C/T	SI	VH	
K	18	44	2	1	537900	6277650	22.80-27.40	24+26	C/T	SI	VH	EL
K	19	44	2	2	537900	6277650	27.40-30.90	28+30	C/T	M	VH	
K	20	44	2	3	537900	6277650	30.90-38.70	32+34	C/T	SI	VH	EL
K	21	44	2	3	537900	6277650	30.90-38.70	36+38	C/T	N	VH	
K	22	44	2	4	537900	6277650	38.70-42.80	40+42	C/T	SI	VH	EL

ATTACHMENT 7.6 Chemical Analyses Interpretation Continued

Soil map no.	Lab no.	Site no.	Soil Data System Card no.	Layer no.	Aust. Grid Ref. m East	Aust. Grid Ref. m North	Depth range (m)	Sample depth (m)	Horizon/ material type	Acidity (CaCl ₂ pH)	Alkal. (CaCl ₂ pH)	Acidity (water pH)	Alkal. (water pH)	Salinity (EC _e)	Organic matter
K	23	44	2	6	537900	6277650	43.80-54.50	45+46	C/S0				SI	VH	EL
K	24	44	2	6	537900	6277650	43.80-54.50	48+49	C/S0				M	H	
K	25	44	2	6	537900	6277650	43.80-54.50	53+54	C/S0				SI	H	EL
K	26	44			537900	6277650	54.50-64.00	56+58	C/S0				M	VH	
K	27	44			537900	6277650	54.50-64.00	60+61	C/S0				M	H	
K	28	44			537900	6277650	54.50-64.00	63+64	C/S0				SI	H	
K	29	45	1	3	537650	6277550	1.25-3.80	2+3	C/T				St	M	EL
K	30	45	1	5	537650	6277550	6.00-10.80	7+9.5	C/T		SI		SI	H	EL
K	31	45	1	6	537650	6277550	10.80-13.00	12.5	C/T		SI		N	VH	
K	32	45	2	2	537650	6277550	14.50-22.40	15+17.5	C/T		N		N	VH	EL
K	33	45	2	2	537650	6277550	14.50-22.40	19+20	C/T				SI	VH	
K	34	45	2	3	537650	6277550	22.40-25.80	23.5+25.5	C/T		SI		N	VH	EL
K	35	45	2	4	537650	6277550	25.80-27.40	26+27	C/T				M	VH	EL
K	36	45	3	2	537650	6277550	31.50-36.50	33+35.5	C/S0				SI	VH	EL
K	37	45	3	3	537650	6277550	36.50-43.50	38+41	C/S0				N	VH	
K	38	45	3	4	537650	6277550	43.50-48.40	91	C/S0		SI		N	VH	EL
K	39	45	3	5	537650	6277550	48.40-54.00	50+52	C/S0		SI		N	VH	
K	40	45	3	6	537650	6277550	54.00-69.00	60+63	C/S0				N	VH	EL
K	41	45	3	6	537650	6277550	54.00-69.00	65+68	C/S0				M	VH	
K	42	46	1	1	537650	6277551	69.00-84.00	71+74+77	C/H0				SI	VH	EL
K	43	46	1	1	537650	6277551	69.00-84.00	79+80+81	C/H0				SI	VH	
B	1	47	1	1	532750	6278250	0.00-0.05		A1		SI		M	VL	M
B	2	47	1	2	532750	6278250	0.05-0.50		B21				VSt	H	VL
B	3	47	1	3	532750	6278250	0.50-1.00		B22				St	VH	VL
B	4	47	1	4	532750	6278250	1.00-1.50						M	H	VL
B	5	47	1	5	532750	6278250	1.50-2.00			SI		St		H	VL
A	6	49	1	1	533750	6278250	0.00-0.10		A1	M		M		VL	
A	7	49	1	2	533750	6278250	0.10-0.40		B21		N		M	VL	
A	8	49	1	3	533750	6278250	0.50-1.00		B22				St	H	
A	9	49	1	4	533750	6278250	1.00-1.50						St	H	

ATTACHMENT 7.6 Chemical Analyses Interpretation Continued

Soil map no.	Lab no.	Site no.	Soil Data System Card no.	Layer no.	Aust. Grid Ref. m East	Aust. Grid Ref. m North	Depth range (m)	Sample depth (m)	Horizon/ material type	Acidity (CaCl ₂ pH)	Alkal. (CaCl ₂ pH)	Acidity (water pH)	Alkal. (water pH)	Salinity (EC _e)	Organic matter
A	43	63	1	4	532750	6276250	0.50-1.00		B22	M		SI		L	
A	44	63	1	5	532750	6276250	1.00-1.50				N		N	L	
A	45	63	1	6	532750	6276250	1.50-2.00				N		N	L	
A	46	64	1	1	533250	6276250	0.00-0.05		A1	St		St		VL	
A	47	64	1	2	533250	6276250	0.05-0.35		B21		SI		SI	L	
A	48	64	1	3	533250	6276250	0.35-1.00		B22				M	H	
A	49	64	1	4	533250	6276250	1.00-1.50			VSt		VSt		M	
A	50	64	1	5	533250	6276250	1.50-2.00			VSt		VSt		M	
A	51	66	1	1	534250	6276250	0.03-0.20		A	St		M		VL	
A	52	66	1	2	534250	6276250	0.20-0.55		B21		N		N	VL	
A	53	66	1	3	534250	6276250	0.55-1.00		B22				St	H	
A	54	66	1	4	534250	6276250	1.00-1.50				N	SI		H	
A	55	66	1	5	534250	6276250	1.50-2.00			VSt		VSt		M	

ATTACHMENT 7.7 Exchangeable Cation Analysis Test Results

Soil map	Lab no.	Site no.	Soil Data System	Card no.	Layer no.	Aust. Grid Ref.	Depth range (m)	Horizon/ material type	CEC	Ca	Ca/CEC %	Mg	Mg/CEC%	K	K/CEC%	Na	ESP %	Al	Ca/Mg	Mg/K
A	16	5	1	1	1	534750	6278250	0.00-0.07	A1	23.5	8.9	38	7.4	31	2.0	9	1.5	6	1.2	3.7
A	17	5	1	2	2	534750	6278250	0.07-0.35	B21	31.8	13.8	43	14.1	44	0.8	3	3.9	12	1.0	17.6
A	18	5	1	3	3	534750	6278250	0.35-1.00	B22	31.1	13.4	43	12.3	40	0.4	1	8.0	26	1.1	30.8
A	19	5	1	4	4	534750	6278250	1.00-1.50		22.8	4.9	21	9.1	40	0.4	2	7.4	32	0.5	22.8
A	20	5	1	5	5	534750	6278250	1.50-2.00		20.2	3.7	18	7.8	39	0.3	1	5.8	29	0.5	26
A	26	7	1	1	1	536000	6278400	0.00-0.25	A1	9.0	2.9	32	0.4	4	1.5	17	0.7	8	7.3	0.3
A	27	7	1	2	2	536000	6278400	0.25-0.42	A2	7.6	2.4	32	1.2	16	0.9	12	2.0	26	2.0	1.3
A	28	7	1	3	3	536000	6278400	0.42-0.90	B21	24.8	3.9	16	14.1	57	2.1	8	5.2	21	0.3	6.7
A	29	7	1	4	4	536000	6278400	0.90-1.40	B22	23.7	12.2	51	10.2	43	2.3	10	4.2	18	1.2	4.4
A	30	7	1	5	5	536000	6278400	1.40-1.90		25.5	9.8	38	11.4	45	2.4	9	5.4	21	0.9	4.8
B	53	12	1	1	1	535250	6277750	0.00-0.07	A1	24.1	13.0	54	6.5	27	2.8	12	1.0	4	2.0	2.3
B	54	12	1	2	2	535250	6277750	0.07-0.50	B2	37.1	19.7	53	12.6	34	1.6	4	3.1	8	1.6	7.9
B	55	12	1	3	3	535250	6277750	0.50-1.00	B2	36.4	15.4	42	12.8	35	0.6	2	8.7	24	1.2	21.3
B	56	12	1	4	4	535250	6277750	1.00-1.50	B2	30.7	5.5	18	11.3	37	0.4	1	8.4	27	1.1	0.5
B	57	12	1	5	5	535250	6277750	1.50-2.00		31.4	3.9	12	11.1	35	0.3	1	8.9	28	1.7	0.4
B	68	15	1	1	1	536790	6277690	0.00-0.06	A1	11.8	4.1	35	1.7	14	1.0	8	0.8	7	0.5	2.4
B	69	15	1	2	2	536790	6277690	0.06-0.50	B11	30.4	9.0	30	14.2	47	0.5	2	4.0	13	0.6	28.4
B	70	15	1	3	3	536790	6277690	0.50-1.00	B22	33.1	12.4	37	15.2	46	0.3	1	7.6	23	0.8	50.7
B	71	15	1	4	4	536790	6277690	1.00-1.50		33.0	13.2	40	15.5	47	0.3	1	7.0	21	0.9	51.7
B	72	15	1	5	5	536790	6277690	1.50-2.00		28.8	3.2	11	14.0	49	0.2	1	6.9	24	0.2	70
A	133	28	1	1	1	537250	6276750	0.00-0.10	A1	25.8	7.3	28	8.2	32	1.7	7	2.1	8	0.9	4.8
A	134	28	1	2	2	537250	6276750	0.10-0.23	B21	32.1	10.4	32	11.5	36	0.7	2	3.4	11	0.9	16.4
A	135	28	1	3	3	537250	6276750	0.23-0.80	B22	41.0	55.6	136	10.1	25	0.2	0	6.4	16	5.5	50.5
A	136	28	1	4	4	537250	6276750	0.80-1.40		31.8	6.2	19	9.2	29	0.3	1	7.4	23	0.7	30.7
A	137	28	1	5	5	537250	6276750	1.40-2.00		30.9	4.4	14	9.4	30	0.3	1	8.4	27	0.5	31.3
A	147	31	1	1	1	535750	6276180	0.00-0.14	A1	18.5	6.2	34	3.0	16	1.2	6	0.7	4	2.1	2.5
A	148	31	1	2	2	535750	6276180	0.14-0.50	B21	29.4	8.3	28	13.2	45	0.2	1	4.1	14	0.6	66.0
A	149	31	1	3	3	535750	6276180	0.50-1.00	B22	30.2	13.7	45	14.2	47	0.4	1	6.3	21	1.0	35.5
A	150	31	1	4	4	535750	6276180	1.00-1.50		27.8	10.9	39	12.6	45	0.5	2	7.0	25	0.9	25.2
A	151	31	1	5	5	535750	6276180	1.50-1.80		24.8	6.2	25	11.6	47	0.5	2	6.9	28	0.5	23.2

ATTACHMENT 7.7 Exchangeable Cation Analysis Test Results Continued

Soil map no.	Lab no.	Site no.	Soil Data System Card no.	Layer no.	Aust. Grid Ref. m East	m North	Depth range (m)	Horizon/material type	CEC	Ca	Ca/CEC %	Mg	Mg/CEC%	K	K/CEC%	Na	ESP %	Al	Ca/Mg	Mg/K
A	158	33	1	1	536750	6276250	0.00-0.08	A1	8.9	3.5	39	3.0	34	1.0	11	0.9	10		1.2	3.0
A	159	33	1	2	536750	6276250	0.08-0.35	B21	22.7	8.7	38	10.5	46	0.7	3	3.3	15		0.8	15.0
A	160	33	1	3	536750	6276250	0.35-0.55	B22	28.0	9.9	35	13.0	46	0.3	1	6.8	24		0.8	43.3
A	161	33	1	4	536750	6276250	0.55-1.20	B23	32.1	13.1	41	14.9	46	0.3	1	9.8	31		0.9	49.7
A	162	33	1	5	536750	6276250	1.20-1.50		29.0	8.6	30	13.6	47	0.4	1	9.6	33		0.6	34
A	163	33	1	6	536750	6276250	1.50-1.80		18.8	4.2	22	8.5	45	0.4	2	6.6	35		0.5	21.3
C	188	39	1	1+2	535820	6278240	0.00-0.20	A1	5.2	3.3	63	1.1	21	0.4	8	0.3	6	nd	3.0	2.8
C	189	39	1	3+4	535820	6278240	0.20-0.60		4.4	2.5	57	0.7	16	0.2	5	0.2	5	nd	3.6	3.5
C	190	40	1	1	535780	6278320	0.00-0.10	A1	9.0	5.4	60	1.6	18	1.3	14	0.4	4	nd	3.4	1.2
C	191	40	1	2	535780	6278320	0.10-0.45		5.4	1.5	28	0.4	7	0.9	17	0.2	4	nd	3.8	0.4
C	192	40	1	3	535780	6278320	0.45-0.75		5.3	0.9	17	0.5	9	0.4	8	0.5	9	nd	1.8	1.3
C	193	41	1	1	535730	6278300	0.00-0.18	A11	6.5	1.9	29	0.5	8	2.0	31	0.2	3	nd	3.8	0.3
C	194	41	1	2	535730	6278300	0.18-0.50	A12	5.7	1.0	18	0.5	9	0.4	7	0.8	14	nd	2.0	1.3
C	195	41	1	3	535730	6278300	0.50-0.60	A2	5.9	0.3	5	1.7	29	0.5	8	0.2	3	nd	0.2	3.4
C	196	41	1	4	535730	6278300	0.60-0.90	B2	13.9	0.1	1	8.6	62	1.0	7	0.2	1	nd	0.0	8.6
C	199	42	1	4	535690	6278280	0.50-0.80	B22	16.7	0.3	2	12.7	76	1.0	6	1.3	8	nd	0.0	12.7
K	1	43	1	1	537852	6278049	1.00-5.00	C/J	28.2	5.4	19	12.1	43	0.8	3	9.3	33		0.4	15.1
K	2	43	1	2	537852	6278049	5.00-10.00	C/J	18.0	3.1	17	8.3	46	0.5	3	6.3	35		0.4	16.6
K	3	43	1	3	537852	6278049	10.00-13.50	C/J	13.6	2.3	17	6.6	49	0.4	3	4.5	33		0.3	16.5
K	4	43	1	4	537852	6278049	13.50-18.10	C/J	14.8	2.7	18	8.1	55	0.3	2	5.1	34		0.3	27
K	5	43	1	5	537852	6278049	18.10-24.20	C/HO	8.8	3.1	35	4.8	55	0.2	2	3.7	42		0.6	24
K	6	43	1	6	537852	6278049	24.20-30.10	C/HO	8.7	1.8	21	4.9	56	0.2	2	3.9	45		0.4	24.1
K	8	43	2	2	537852	6278049	37.00-42.00	C/SO	27.2	3.1	11	9.9	36	0.4	1	14.8	54		0.3	24.8
K	10	43	2	4	537852	6278049	51.00-54.50	C/SO	36.6	3.6	10	10.6	29	0.4	1	23.1	63		0.3	26.5
K	11	44	1	1	537900	6277650	2.00-7.00	C/J	21.3	3.6	17	6.5	31	1.1	5	8.5	40		0.6	5.9
K	13	44	1	3	537900	6277650	9.20-12.20	C/J	17.5	3.1	18	7.1	41	0.8	5	5.5	31		0.4	8.9
K	16	44	1	6	537900	6277650	16.40-22.80	C/J	10.2	1.1	11	3.7	36	0.5	5	3.2	31		0.3	7.4
K	18	44	2	1	537900	6277650	22.80-27.40	C/J	13.3	1.9	14	5.3	40	1.2	9	4.2	32		0.4	4.4
K	20	44	2	3	537900	6277650	30.90-38.70	C/J	17.2	2.9	17	7.2	42	1.5	9	5.3	31		0.4	4.8
K	22	44	2	4	537900	6277650	38.70-42.80	C/J	12.2	1.7	14	5.0	41	0.6	5	4.0	33		0.3	8.3

K	23	44	2	6	537900	6277650	43.80-54.50	C/SO	16.4	2.0	12	6.4	39	0.5	3	5.6	34	0.3	12.8
K	25	44	2	6	537900	6277650	43.80-54.50	C/SO	11.8	1.5	13	3.9	33	0.4	3	4.0	34	0.4	9.8
K	29	45	1	3	537650	6277550	1.25-3.80	C/JT	17.8	2.0	11	6.6	37	0.7	4	6.3	35	0.3	9.4
K	30	45	1	5	537650	6277550	6.00-10.80	C/JT	17.2	2.4	14	7.7	45	0.7	4	5.8	34	0.3	11.0
K	32	45	2	2	537650	6277550	14.50-22.40	C/JT	10.8	1.5	14	5.3	49	0.4	4	3.0	28	0.3	13.3
K	34	45	2	3	537650	6277550	22.40-25.80	C/JT	14.8	2.9	20	6.9	47	0.7	5	5.1	34	0.4	9.9
K	35	45	2	4	537650	6277550	25.80-27.40	C/JT	10.8	2.0	19	5.2	48	0.5	5	3.2	30	0.4	10.4
K	36	45	3	2	537650	6277550	31.50-36.50	C/SO	21.8	3.3	15	9.6	44	1.5	7	6.8	31	0.3	6.4
K	38	45	3	4	537650	6277550	43.50-48.40	C/SO	12.3	2.5	20	5.4	44	0.4	3	4.0	33	0.5	13.5
K	40	45	3	6	537650	6277550	54.00-69.00	C/SO	11.5	3.4	30	5.6	48	0.3	3	3.8	33	0.6	18.5
K	42	46	1	1	537650	6277551	69.00-84.00	C/HO	31.3	5.0	16	7.9	25	0.4	1	18.7	60	0.6	19.8
B	1	47	1	1	532750	6278250	0.00-0.05	A1	29.0	21.2	73	5.2	18	8.1	28	0.5	2	4	1
B	2	47	1	2	532750	6278250	0.05-0.50	B21	34.3	15.6	45	13.9	41	0.3	1	9.8	29	1	46
B	3	47	1	3	532750	6278250	0.50-1.00	B22	29.7	14.9	50	12.6	42	0.3	1	8.5	29	1	42
B	4	47	1	4	532750	6278250	1.00-1.50		23.7	3.3	14	12.1	51	0.4	2	8.8	37	0	30
B	5	47	1	5	532750	6278250	1.50-2.00		18.9	2.4	13	8.7	46	0.2	1	7.6	40	1.9	0
A	25	57	1	1	533750	6277250	0.00-0.10	A1	12.0	4.2	35	2.6	22	1.2	10	0.9	8	2	2
A	26	57	1	2	533750	6277250	0.10-0.40	B21	22.9	7.7	34	9.6	42	0.3	1	5.0	22	1	32
A	27	57	1	3	533750	6277250	0.50-1.00	B22	28.7	9.1	32	13.0	45	0.4	1	7.8	27	1	33
A	28	57	1	4	533750	6277250	1.00-1.50		25.9	3.8	15	12.7	49	0.3	1	8.7	34	0	42
A	29	57	1	5	533750	6277250	1.50-2.00		23.2	2.0	9	10.8	47	0.2	1	7.7	33	2.9	0
A	30	59	1	1	532750	6276750	0.00-0.05	A1	9.8	2.6	27	1.6	16	1.7	17	0.5	5	1.8	2
A	31	59	1	2	532750	6276750	0.05-0.40	B21	32.5	9.1	28	17.3	53	0.4	1	7.8	24	1	43
A	32	59	1	3	532750	6276750	0.50-1.00	B22	27.9	4.4	16	14.7	53	0.3	1	8.6	31	0	49
A	33	59	1	4	532750	6276750	1.00-1.50		20.4	1.9	9	11.1	54	0.1	0	7.1	35	0	111
A	34	59	1	5	532750	6276750	1.50-2.00		14.3	3.0	21	7.5	52	0.1	1	4.8	34	0.9	0
A	51	66	1	1	534250	6276250	0.03-0.20		8.7	3.1	36	2.3	26	2.9	33	0.8	9	1	1
A	52	66	1	2	534250	6276250	0.20-0.55	A	18.4	5.0	27	7.2	39	5.2	28	1.5	8	1	1
A	53	66	1	3	534250	6276250	0.55-1.00	B21	35.8	11.0	31	19.7	55	1.4	4	8.7	24	1	14
A	54	66	1	4	534250	6276250	1.00-1.50	B22	25.3	3.4	13	13.1	52	0.4	2	10.0	40	0	33
A	55	66	1	5	534250	6276250	1.50-2.00		21.2	2.0	9	9.9	47	0.3	1	9.8	46	nd	0

ATTACHMENT 7.8 Exchangeable Cation Analyses Interpretation

Soil map no.	Lab no.	Site no.	Soil Data System Card no.	Layer no.	Aust. Grid Ref. m East	m North	Depth range (m)	CEC	Ca	Ca/CEC %	Mg	CEC and exchange. cations (cmol(+)/kg) Mg/CEC%	K	K/CEC%	Na	ESP %	Ca/Mg	Mg/K
A	16	5	1	1	534750	6278250	0.00-0.07	M	M	M	H	VH	H	VH	H	Sod	CaLow	Bal
A	17	5	1	2	534750	6278250	0.07-0.35	H	H	M	VH	VH	H	M	VH	Sod	CaDef	KDef
A	18	5	1	3	534750	6278250	0.35-1.00	H	H	M	VH	VH	M	L	VH	SSod	CaLow	KDef
A	19	5	1	4	534750	6278250	1.00-1.50	M	L	L	VH	VH	M	L	VH	VSSod	CaDef	KDef
A	20	5	1	5	534750	6278250	1.50-2.00	M	L	L	H	VH	L	L	VH	SSod	CaDef	KDef
A	26	7	1	1	536000	6278400	0.00-0.25	L	L	M	L	L	H	VH	M	Sod1	MgLow	MgDef
A	27	7	1	2	536000	6278400	0.25-0.42	L	L	M	M	VH	H	VH	H	SSod	CaLow	MgLow
A	28	7	1	3	536000	6278400	0.42-0.90	M	L	L	VH	VH	VH	VH	VH	SSod	CaDef	KLow
A	29	7	1	4	536000	6278400	0.90-1.40	M	H	M	VH	VH	VH	VH	VH	SSod	CaLow	Bal
A	30	7	1	5	536000	6278400	1.40-1.90	H	M	M	VH	VH	VH	VH	VH	SSod	CaDef	Bal
B	53	12	1	1	535250	6277750	0.00-0.07	M	H	M	H	VH	VH	VH	H	NSod	CaLow	MgLow
B	54	12	1	2	535250	6277750	0.07-0.50	H	H	M	VH	VH	H	M	VH	Sod	CaLow	KLow
B	55	12	1	3	535250	6277750	0.50-1.00	H	H	M	VH	VH	M	L	VH	SSod	CaLow	KDef
B	56	12	1	4	535250	6277750	1.00-1.50	H	M	L	VH	VH	M	L	VH	SSod	CaDef	KDef
B	57	12	1	5	535250	6277750	1.50-2.00	H	L	L	VH	VH	L	VL	VH	SSod	CaDef	KDef
B	68	15	1	1	536790	6277690	0.00-0.06	L	L	M	M	H	H	VH	H	Sod	CaLow	MgLow
B	69	15	1	2	536790	6277690	0.06-0.50	H	M	L	VH	VH	M	L	VH	Sod	CaDef	KDef
B	70	15	1	3	536790	6277690	0.50-1.00	H	H	M	VH	VH	L	VL	VH	SSod	CaDef	KDef
B	71	15	1	4	536790	6277690	1.00-1.50	H	H	M	VH	VH	L	VL	VH	SSod	CaDef	KDef
B	72	15	1	5	536790	6277690	1.00-1.50	H	L	L	VH	VH	VL	VL	VH	SSod	CaDef	KDef
A	133	28	1	1	537250	6276750	0.00-0.10	H	M	L	VH	VH	H	H	VH	Sod	CaDef	Bal
A	134	28	1	2	537250	6276750	0.10-0.23	H	H	M	VH	VH	M	M	VH	Sod	CaDef	KDef
A	135	28	1	3	537250	6276750	0.23-0.80	VH	VH	VH	VH	VH	VL	VL	VH	SSod	Bal	KDef
A	136	28	1	4	537250	6276750	0.80-1.40	H	M	L	VH	VH	L	VL	VH	SSod	CaDef	KDef
A	137	28	1	5	537250	6276750	1.40-2.00	H	L	L	VH	VH	L	VL	VH	SSod	CaDef	KDef
A	147	31	1	1	535750	6276180	0.00-0.14	M	M	M	M	VH	H	H	M	NSod	CaLow	MgLow
A	148	31	1	2	535750	6276180	0.14-0.50	H	M	L	VH	VH	VL	VL	VH	Sod	CaDef	KDef
A	149	31	1	3	535750	6276180	0.50-1.00	H	H	M	VH	VH	M	L	VH	SSod	CaDef	KDef
A	150	31	1	4	535750	6276180	1.00-1.50	H	H	M	VH	VH	M	L	VH	SSod	CaDef	KDef
A	151	31	1	5	535750	6276180	1.50-1.80	M	M	L	VH	VH	M	M	VH	SSod	CaDef	KDef

A	158	33	1	1	536750	6276250	0.00-0.08	L	L	M	M	VH	H	VH	H	Sod	CaLow	Bal
A	159	33	1	2	536750	6276250	0.08-0.35	M	M	M	VH	VH	M	M	VH	Sod	CaDef	KDef
A	160	33	1	3	536750	6276250	0.35-0.55	H	M	M	VH	VH	L	L	VH	SSod	CaDef	KDef
A	161	33	1	4	536750	6276250	0.55-1.20	H	H	M	VH	VH	L	VL	VH	VSSod	CaDef	KDef
A	162	33	1	5	536750	6276250	1.20-1.50	H	M	L	VH	VH	M	L	VH	VSSod	CaDef	KDef
A	163	33	1	6	536750	6276250	1.50-1.80	M	L	L	VH	VH	M	M	VH	VSSod	CaDef	KDef
C	188	39	1	1+2	535820	6278240	0.00-0.20	VL	L	M	M	VH	M	H	L	NSod	CaLow	Bal
C	189	39	1	3+4	535820	6278240	0.20-0.60	VL	L	M	L	VH	VL	M	L	NSod	CaLow	Bal
C	190	40	1	1	535780	6278320	0.00-0.10	L	M	M	M	VH	H	VH	M	NSod	CaLow	MgLow
C	191	40	1	2	535780	6278320	1.10-0.45	VL	VL	L	L	M	H	VH	L	NSod	CaLow	MgDef
C	192	40	1	3	535780	6278320	0.45-0.75	VL	VL	L	L	M	M	H	M	Sod1	CaLow	MgLow
C	193	41	1	1	535730	6278300	0.00-0.18	L	VL	L	L	M	H	VH	L	NSod	CaLow	MgDef
C	194	41	1	2	535730	6278300	0.18-0.50	VL	VL	L	L	M	M	H	H	Sod	CaLow	MgLow
C	195	41	1	3	535730	6278300	0.50-0.60	VL	VL	VL	M	VH	M	VH	L	NSod	CaDef	Bal
C	196	41	1	4	535730	6278300	0.60-0.90	M	VL	VL	VH	VH	H	H	L	NSod	CaDef	KLow
C	199	42	1	4	535690	6278280	0.50-0.80	M	VL	VL	VH	VH	H	H	H	Sod	CaDef	KDef
K	1	43	1	1	537852	6278049	1.00-5.00	H	M	L	VH	VH	H	M	M	VSSod	CaDef	KDef
K	2	43	1	2	537852	6278049	5.00-10.00	M	L	L	VH	VH	M	M	M	VSSod	CaDef	KDef
K	3	43	1	3	537852	6278049	10.00-13.50	M	L	L	H	VH	M	M	M	VSSod	CaDef	KDef
K	4	43	1	4	537852	6278049	13.50-18.10	M	L	L	VH	VH	L	M	M	VSSod	CaDef	KDef
K	5	43	1	5	537852	6278049	18.10-24.20	L	L	M	H	VH	VL	M	M	VSSod	CaDef	KDef
K	6	43	1	6	537852	6278049	24.20-30.10	L	VL	L	H	VH	VL	M	M	VSSod	CaDef	KDef
K	8	43	2	2	537852	6278049	37.00-42.00	H	L	L	VH	VH	M	L	L	VSSod	CaDef	KDef
K	10	43	2	4	537852	6278049	51.00-54.50	H	L	VL	VH	VH	M	L	L	VSSod	CaDef	KDef
K	11	44	1	1	537900	6277650	2.00-7.00	M	L	L	H	VH	H	H	VH	VSSod	CaDef	KLow
K	13	44	1	3	537900	6277650	9.20-12.20	M	L	L	H	VH	H	M	M	VSSod	CaDef	KLow
K	16	44	1	6	537900	6277650	16.40-22.80	L	VL	L	H	VH	M	M	M	VSSod	CaDef	KLow
K	18	44	2	1	537900	6277650	22.80-27.40	M	VL	L	H	VH	H	VH	VH	VSSod	CaDef	Bal
K	20	44	2	3	537900	6277650	30.90-38.70	M	L	L	H	VH	H	VH	VH	VSSod	CaDef	Bal
K	22	44	2	4	537900	6277650	38.70-42.80	M	VL	L	H	VH	M	M	M	VSSod	CaDef	KLow
K	23	44	2	6	537900	6277650	43.80-54.50	M	VL	L	H	VH	M	M	M	VSSod	CaDef	KDef
K	25	44	2	6	537900	6277650	43.80-54.50	L	VL	L	H	VH	M	M	M	VSSod	CaDef	KLow
K	29	45	1	3	537650	6277550	1.25-3.80	M	VL	L	H	VH	M	M	M	VSSod	CaDef	KLow

ATTACHMENT 7.8 Exchangeable Cation Analyses Interpretation Continued

Soil map	Lab no.	Soil Data System			Aust. Grid Ref.		Depth range (m)	CEC	Ca	Ca/CEC %	Mg	CEC and exchange. cations (cmol(+)/kg)					ESP %	Ca/Mg	Mg/K
		Site no.	Card no.	Layer no.	m East	m North						Mg/CEC%	K	K/CEC%	Na				
K	30	45	1	5	537650	6277550	6.00-10.80	M	L	L	H	VH	M	M	VH	VSSod	CaDef	KDef	
K	32	45	2	2	537650	6277550	14.50-22.40	L	VL	L	H	VH	M	M	VH	SSod	CaDef	KDef	
K	34	45	2	3	537650	6277550	22.40-25.80	M	L	L	H	VH	M	M	VH	VSSod	CaDef	KLow	
K	35	45	2	4	537650	6277550	25.80-27.40	L	VL	L	H	VH	M	M	VH	SSod	CaDef	KDef	
K	36	45	3	2	537650	6277550	31.50-36.50	M	L	L	VH	VH	H	H	VH	VSSod	CaDef	KLow	
K	38	45	3	4	537650	6277550	43.50-48.40	M	L	L	H	VH	M	M	VH	VSSod	CaDef	KDef	
K	40	45	3	6	537650	6277550	54.00-69.00	L	L	L	H	VH	L	M	VH	VSSod	CaDef	KDef	
K	42	46	1	1	537650	6277551	69.00-84.00	H	L	L	H	VH	M	L	VH	VSSod	CaDef	KDef	
B	1	47	1	1	532750	6278250	0.00-0.05	H	VH	H	H	VH	VH	VH	M	NSod	CaLow	MgLow	
B	2	47	1	2	532750	6278250	0.05-0.50	H	H	M	VH	VH	M	L	VH	SSod	CaLow	KDef	
B	3	47	1	3	532750	6278250	0.50-1.00	H	H	M	VH	VH	M	L	VH	SSod	CaLow	KDef	
B	4	47	1	4	532750	6278250	1.00-1.50	M	L	L	VH	VH	M	L	VH	VSSod	CaDef	KDef	
B	5	47	1	5	532750	6278250	1.50-2.00	M	L	L	VH	VH	L	L	VH	VSSod	CaDef	KDef	
A	25	57	1	1	533750	6277250	0.00-0.10	L	L	M	M	VH	H	VH	H	Sod	CaLow	MgLow	
A	26	57	1	2	533750	6277250	0.10-0.40	M	M	M	VH	VH	M	L	VH	SSod	CaLow	KDef	
A	27	57	1	3	533750	6277250	0.50-1.00	H	M	M	VH	VH	M	L	VH	SSod	CaLow	KDef	
A	28	57	1	4	533750	6277250	1.00-1.50	H	L	L	VH	VH	M	L	VH	VSSod	CaDef	KDef	
A	29	57	1	5	533750	6277250	1.50-2.00	M	L	VL	VH	VH	L	L	VH	VSSod	CaDef	KDef	
A	30	59	1	1	532750	6276750	0.00-0.05	L	L	L	M	VH	H	VH	M	NSod	CaLow	MgLow	
A	31	59	1	2	532750	6276750	0.05-0.40	H	M	L	VH	VH	M	L	VH	SSod	CaLow	KDef	
A	32	59	1	3	532750	6276750	0.50-1.00	H	L	L	VH	VH	M	L	VH	VSSod	CaDef	KDef	
A	33	59	1	4	532750	6276750	1.00-1.50	M	VL	VL	VH	VH	VL	VL	VH	VSSod	CaDef	KDef	
A	34	59	1	5	532750	6276750	1.50-2.00	M	L	L	H	VH	VL	L	VH	VSSod	CaDef	KDef	
A	51	66	1	1	534250	6276250	0.03-0.20	L	L	M	M	VH	VH	VH	H	Sod	CaLow	MgLow	
A	52	66	1	2	534250	6276250	0.20-0.55	M	L	L	H	VH	VH	VH	H	Sod	CaLow	MgLow	
A	53	66	1	3	534250	6276250	0.55-1.00	H	H	M	VH	VH	H	M	VH	SSod	CaLow	KDef	
A	54	66	1	4	534250	6276250	1.00-1.50	H	L	L	VH	VH	M	M	VH	VSSod	CaDef	KDef	
A	55	66	1	5	534250	6276250	1.50-2.00	M	L	VL	VH	VH	M	L	VH	VSSod	CaDef	KDef	

Appendix B 2

Agricultural Suitability/Rural Land Capability and Soil Resources

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October 1997

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1.0 INTRODUCTION

This Appendix provides additional agricultural suitability and rural land capability information which draws on information from the CaLM (1994) site soil survey and existing mapping. The intent of this attachment is to complement existing soils information to provide a complete land resource appraisal for the Project area.

2.0 AGRICULTURAL SUITABILITY AND LAND CAPABILITY

As a component of land resource assessment, agricultural suitability and land capability of the Project area is addressed in this Appendix.

The suitability and capability assessments draw on existing suitability and capability mapping information from the NSW Department of Agriculture (NSW Ag) (agricultural suitability assessment at a scale of 1:100,000 completed in 1990) and the DLWC (land capability assessment at a scale of 1:100,000 completed in 1983). Soils information for the Project area (CaLM, 1994) has also been drawn upon as supporting information for the suitability and capability assessments. This information has been used to evaluate potential limitations to agricultural production in terms of the agricultural land suitability and rural land capability classification systems. Due to the small scale of existing classification mapping (1:100,000) the Project area has been remapped at a scale of 1:16,000 (approx.) to allow meaningful assessment of the Project area. Larger scale mapping was conducted and agreed on site in consultation with NSW Ag. in September 1997.

2.1 Agricultural Suitability

The agricultural suitability assessment has been conducted in accordance with the five class system which allows for rapid assessment and identification of land worth retaining for agricultural purposes (Riddler, 1996). Agricultural suitability classes for the Project area are shown on Figure B-2 and consist of Classes 3, 4 and 5. Definitions of the various classes are presented below.

NSW Ag. mapping for the Project area classifies the area as predominantly Class 3 suitability.

Class 3 suitability is defined as:

Grazing land or land well suited to pasture improvement. It may well be cultivated or cropped in rotation with pasture. The overall level of production is moderate as a result of edaphic or environmental constraints. Erosion hazard or soil structural breakdown limit the frequency of ground disturbance, and conservation or drainage works may be required. (Cunningham *et al.* undated).

Class 4 land is restricted to the upper slopes of Cowal West Hill (approximately 45 hectares). Ground truthing indicates that the suitability of Cowal West Hill is limited by the increased slope, thin soils, rockiness and soil type, each of which require high levels of various inputs to ensure sustainability of the grazing activity. Class 4 land is defined as:

Land suitable for grazing but not cultivation. Agriculture is based on native pastures or improved pastures established using minimum tillage techniques. Production may be high seasonally but the overall level of production is low as a result of a number of major constraints, both environmental and edaphic. (Cunningham *et al.*, undated).

The area below Lake Cowal's high water line is mapped as Suitability Class 5. The suitability is limited by the seasonal change in the water level in the Lake and the incidence of inundation. The presence of gilgai microrelief which occurs with variable frequency along the foreshore, also demands active management of grazing practices to ensure sustainability. This land is, however, cultivated and grazed when water levels allow. Class 5 land is defined as:

Land unsuitable for agriculture or at best suited only to light grazing. Agricultural production is very low or zero as a result of severe constraints, including economic factors, which preclude improvement. (Cunningham *et al.*, undated).

2.2 Rural Land Capability

The rural land capability assessment has been conducted in accordance with the standard NSW eight class system. This system is based on the assessment of biophysical characteristics categorising land in terms of its general limitations such as erosion hazard, climate and slope. Land is classed based on the limitations to a particular type of land use (Emery, 1985). Rural land capability classes are shown on Figure B-3. Rural land capability classes II, IV and VI were recorded within the Project area. Definitions of those rural land capability classes identified within the Project area are presented below.

DLWC (formerly Soil Conservation Service) mapped the majority of the site as Class II land. This land is defined as:

Land which is capable of being regularly cultivated with soil conservation practices such as strip cropping, conservation tillage and adequate crop rotations. (Cunningham *et al.*, undated).

Usually gently sloping land suitable for a wide variety of agricultural uses. It has a high potential for production of crops on fertile soils, but increasing limitations to production due to site conditions. (Emery, 1985).

Limitations of this land class include soil erosion risks due to the length of slope on 1% to 2% sloping land with thin surface soils being about 10 cm thick. Field inspection indicated subsoils on Class II land in the study area, have a high degree of erodibility.

The small area at the top of Cowal West Hill is mapped as Class IV land. The main limitations for this area are moderate to high soil erodibility, rock outcrop and slope. Class IV land is defined as:

Land not capable of being regularly cultivated but suitable for grazing with occasional cultivation with soil conservation practices such as pasture improvement, stock control, application of fertiliser and minimal cultivation for the establishment or re-establishment of permanent pasture (Emery, 1985).

The area below Lake Cowal's high water line is defined as Class VI land due primarily to its susceptibility to periodic inundation. This land is, however, cultivated and grazed when lake levels allow. Class VI is defined as:

Land not capable of being cultivated but suitable for grazing with soil conservation practices including limitation of stock, broadcasting of seed and fertiliser, prevention of fire and destruction of vermin. This class may require some structural works (Emery 1985).

3.0 SOIL RESOURCE AND MANAGEMENT

The general strategy of soil resource management will be to strip soil resources from all proposed mine disturbance areas within the MLA and store these in dedicated stockpile areas for re-use during progressive rehabilitation works.

Soil resources to be stripped will include both topsoil and subsoil resources. Topsoil resources will be stripped and stored as distinct operations to subsoil stripping and storage. Recommendations included in the site soil survey report (CaLM, 1994) were specific to stripping soil material for use in rehabilitation operations as **topsoil** cover. This attachment combines these recommendations along with the additional aim to use soil material as **subsoil as well as topsoil** during rehabilitation operations.

Consequently, stripping depths of material intended for topsoil cover during rehabilitation are in accordance with CaLM (1994) recommendations. Additionally, stripping of subsoil material will occur along with gypsum amelioration during stockpile storage and/or re-application during rehabilitation.

3.1 Soil Resource

The soil resource of the Project area includes three major and one minor soil type (hard pedal red duplex soils; grey, brown and red cracking clays; hill soils; organic lake and non organic sediments). This section approximates the volume of soil resource (topsoil and subsoil) which will become available for rehabilitation purposes (i.e. topsoil and subsurface cover) when soil stripping operations are complete, as well as soil stripping management practices. The volume of resource has been calculated using the proposed areas of disturbance for each mine landform component (e.g. waste dump, tailings storages, etc.), and the existing CaLM (1994) soils mapping in concert with the top-dressing suitability assessment (CaLM, 1994) and

suitable subsoil criteria ($EC_e \leq 8$ dS/m and $EC_e > 8$ dS/m with gypsum treatment). Table B2-1 outlines the soil volume available for rehabilitation purposes.

3.2 Soil Management

In accordance with the general rehabilitation philosophy and objectives, the following strategy for the management of the site's topsoil and subsoil resources is proposed (Volume 1, Section 5):

- characterisation of the suitability of material for rehabilitation works is conducted prior to stripping;
- soil resources are stripped and stored selectively and managed according to their suitability for rehabilitation purposes;
- sufficient subsoil and stable topsoil resources are available for rehabilitation purposes;
- progressive soil stripping is undertaken on areas proposed for mine development;
- progressive rehabilitation of final landforms as soon as practical after completion of landforms or when areas are no longer required; and
- soil resources are stripped and stored in such a manner that their long term viability is maintained.

In accordance with these goals, four general soil stockpiles will be constructed:

- topsoil material suitable for top-dressing purposes;
- topsoil material from adjacent Cowal West Hill at western edge of the waste emplacement with native seed pool;
- low salinity (upper subsoil) material; and
- saline and dispersive (lower subsoil) material (to be gypsum treated).

The locations of stockpiles are shown on Figure 5-1, Volume 1.

All soil stockpiles will be subject to management practices which maintain the long term viability of stockpiled material. These management practices are to be finalised with DLWC and NSW Ag. soil conservation offices, and are likely to include:

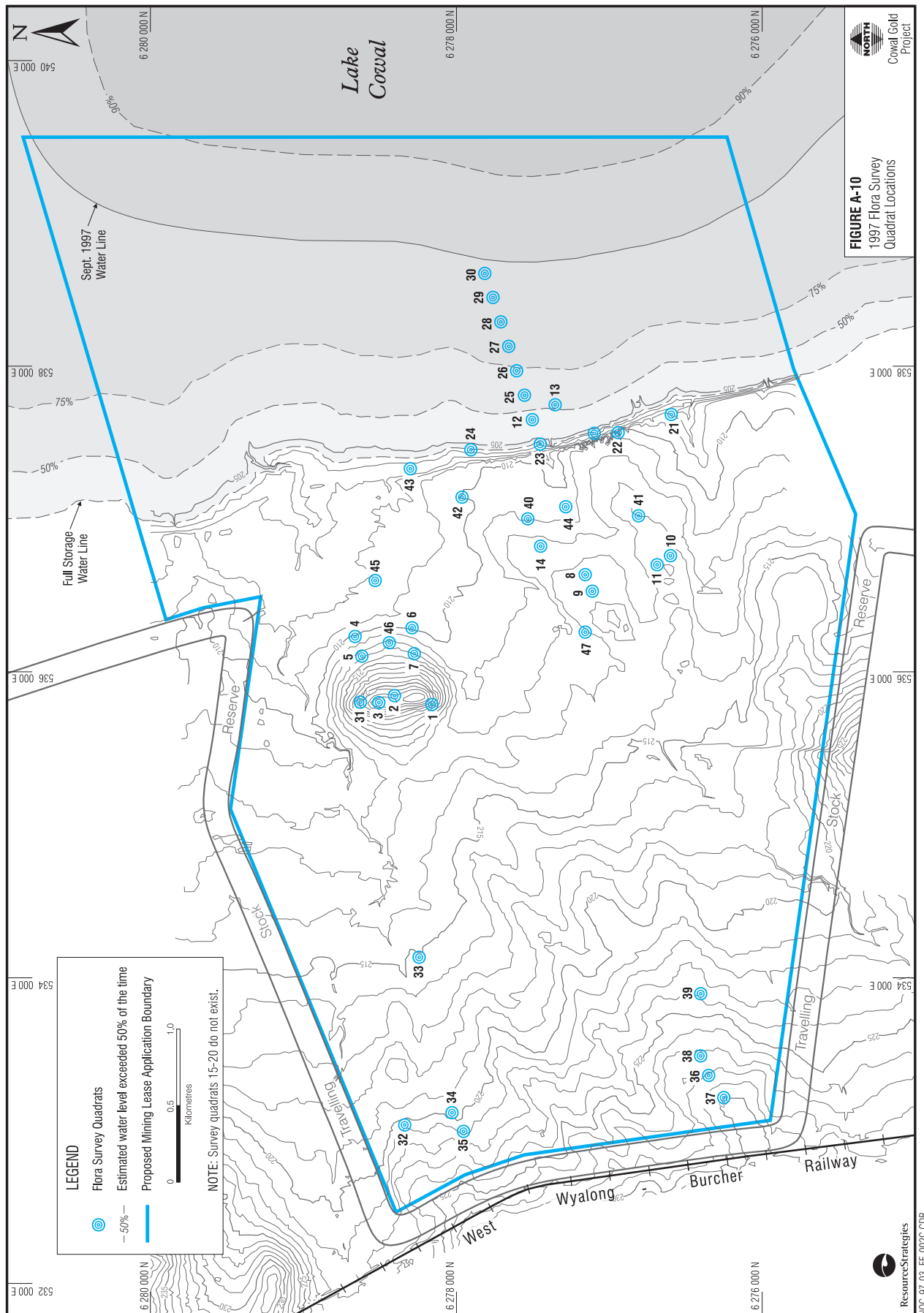
- stockpiles to be located on areas outside proposed mine development areas;

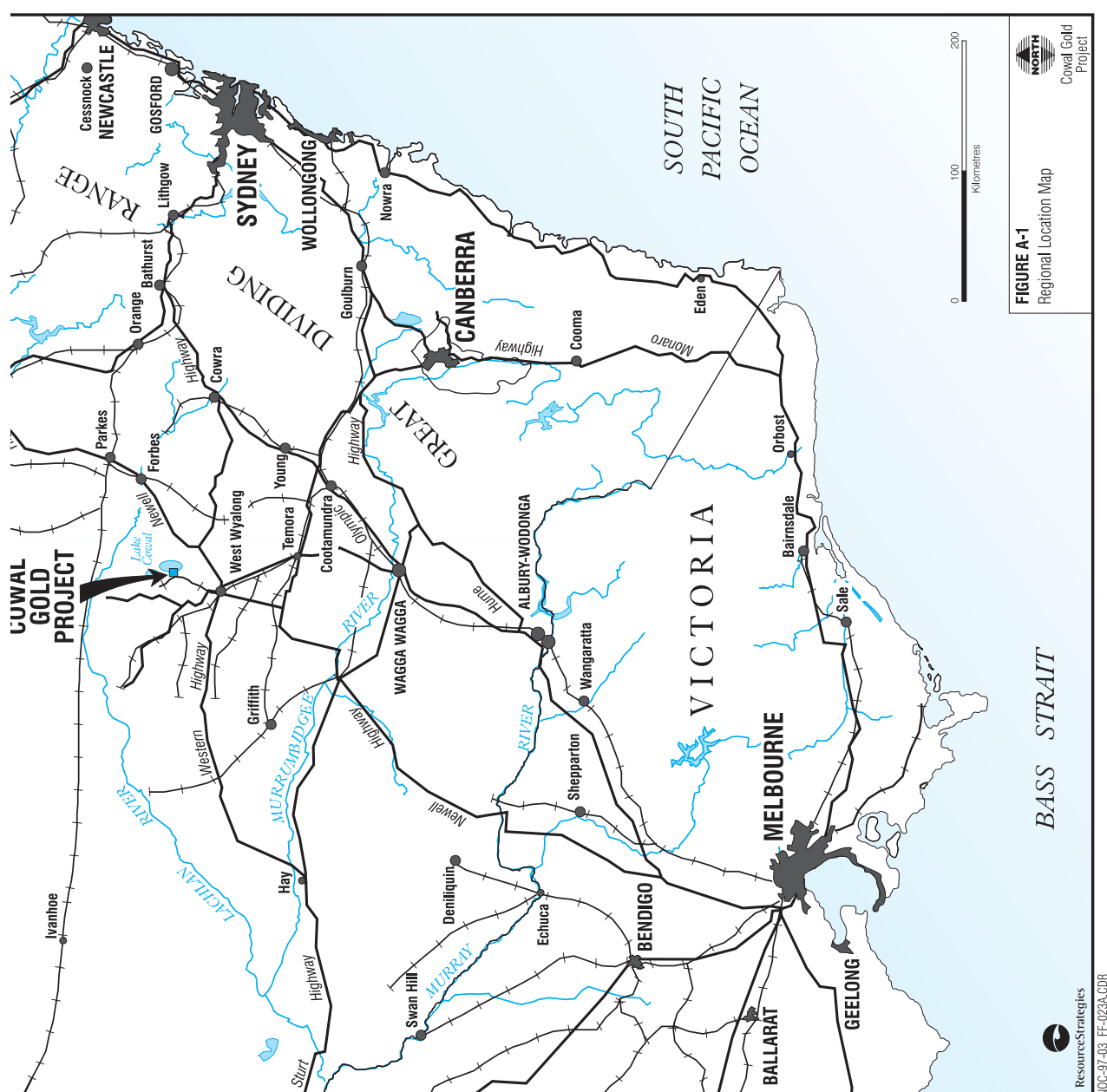
Table B2-1 Provisional Soil Volume Available for Rehabilitation Purposes¹

Soil Type	Suitable Topsoil m ³	Low Salinity Subsoil ($EC_e \leq 8$ dS/m) m ³	Gypsum Ameliorated Subsoil ² ($EC_e > 8$ dS/m) m ³
Hard pedal red duplex	2,090,000	3,284,000	7,763,000
Grey, brown and red cracking clays	35,000	139,000	1,397,000
Hill soils	25,000	15,000	0
Lake sediments	216,000	5,720,000	14,311,000
Total	2,366,000	9,158,300	23,471,000

¹ To be accurately quantified during pre-mining operations and stripping operations.

² Not to be used as surface 'soil' cover; sub surface use only





- topsoil and subsoil reserves to be stockpiled separately;
- topsoil stripping to be scheduled to occur at optimum soil moisture conditions to inhibit degradation of soil structural characteristics due to compaction or pulverisation during stripping operations;
- stockpiles to be constructed by dozers which will push windrows of material for collection by scrapers (thus minimising structural degradation due to scraper compaction);
- the surface of constructed stockpiles to be left in a "rough" condition to reduce erosion hazard, increase drainage and promote revegetation;
- stockpile material to be fertilised and seeded with native pasture and legume species to improve soil attributes (i.e. soil organic matter levels, promote soil structure and maintain soil microfauna and microbial activity); and
- application of gypsum to all stockpiled material to improve structural characteristics and to counter the general dispersive nature of the site's soil resources.

Gypsum and fertiliser application rates and seed species mix for soil stockpiles will be formulated in consultation with DLWC and NSW Ag.

Maximum soil stockpile heights will be in accordance with soil type management procedures and available space. Where required, to improve structural and fertility characteristics prior to application of material for rehabilitation purposes, stockpiles will be deep ripped, (to create aerobic conditions) and fertilised both 12 and six months prior to re-application.

Top-dressing Material

In accordance with CaLM (1994) recommendations, the A1 horizons of the hard pedal red duplex soils and grey, brown and red cracking clays would be stockpiled together. The upper organic lake sediments, which will be stripped from the proposed open pit and perimeter waste emplacement areas, and the upper subsoil from the hard pedal red duplex soils would be stored in the same stockpile type.

Native Seed Pool Top-dressing Material

These materials are to be used as subsurface cover during rehabilitation.

The A and upper subsoil (B₂₁) horizons of the hill soils from Cowal West Hill will be stockpiled separately in accordance with CaLM (1994) recommendations. The value of this soil resource is determined by its native seed pool. Accordingly this soil stockpile height will not exceed two metres.

Low Salinity (Upper Subsoil) Material

Subsoil material from all soil types with EC_e values ≤8 dS/m will be stockpiled together following gypsum treatment. Gypsum application will be determined in consultation with DLWC and NSW Ag. Typical depths of such material from the various soil types are detailed below:

- 0.35 to 0.90 m hard pedal red duplex soils;
- 0.5 to 0.8 m hill soils;
- 0.30 to 5.30 m lacustrine sediments; and
- 0.10 to 0.50 m grey, brown and red cracking clays.

Saline and Dispersive (Lower Subsoil) Material

These materials are to be used as subsurface cover during rehabilitation and will be treated with gypsum during stockpile construction to ameliorate structural problems. Material from all four soil types (except hill soils due to shallow soil profile) below the low salinity horizons to maximum profile depth will be stockpiled together. This depth is typically two metres for all soil types except lacustrine sediments where material may be stripped to the necessary depth required for rehabilitation volumes.

Appendix C

Waste Geochemistry

*Environmental Geochemistry Assessment
of Proposed Mining Activities for
Cowal Gold Project*

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September 1997

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Attachment B	Evaluation and Interpretation of Mine Waste Geochemical Data
Attachment C	Sequential Batch Test Methodology
Attachment D	Column Leach Test Methodology

3 November 1997

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Attention: Peter Ryan and Chris Joyce

Cowal Gold Project Implications of Saline Make Up Water on Tailings Geochemistry

Dear Peter and Chris,

I have reviewed the documentation you forwarded to me outlining the proposed use of saline groundwaters for gold processing. As you know, the test work we have performed and documented in our September 1997 report 'Environmental Geochemistry Assessment of Proposed Mining Activities - Cowal Gold Project' utilised tailings samples prepared with 'fresh' water rather than saline groundwater. However, saline groundwater was used for some of the test work conducted by EGi in 1994/95 for the previous project.

The result of this previous work suggest that cyanide decay from the saline liquor (TDS approximately 45,000 mg/L) was more rapid than decay from liquor generated from 'fresh' water (TDS approximately 1,500 mg/L). The transformation processes within the entrained liquor also appeared to be more effective with the saline sample. It was observed that the pH of the saline liquor decreased to about pH 7 more rapidly than the fresh water liquor. This is most likely the reason for the faster cyanide decay characteristic of the saline sample.

Although the tailings types are different for the current project, these earlier results suggest that the use of saline water for make-up will not adversely effect the cyanide chemistry and may enhance the decay and transformation processes.

I therefore expect that the cyanide chemistry predictions presented in our September 1997 report will also apply to tailings produced using saline groundwater. However, the predictions for TDS concentrations in the decant, reclaim water pond and leachates associated with the tailings facility during the operation will need to consider the higher TDS of the saline make up water. In the long term, after the soluble salts have been flushed, the geochemistry of the tailings solids will control the chemistry of the pore water and the results presented in the September 1997 report will be appropriate.

The saline process water therefore is unlikely to affect the operational or long term cyanide chemistry or long term leachate chemistry after the dissolved salts have been flushed from the tailings. However the TDS of the decant and reclaim water will be significantly higher and the pore water TDS will also be significantly higher during the operation and through the transition period while the tailings liquor is being displaced. The total potential load of soluble salts from the tailings facility will therefore be much higher (at least an order of magnitude higher) and this will need to be considered in the impact evaluation.

I recommend that when samples are available of tailings prepared using saline groundwater, these should be tested to confirm the cyanide predictions and to also determine the leaching requirement to flush the soluble salts.

Would you please include a copy of this letter with our report in the EIS documentation.

Yours sincerely,


Stuart Miller
Managing Director

EXECUTIVE SUMMARY

Environmental Geochemistry International (EGi) Pty Ltd have carried out environmental geochemical investigations on tailings, waste rock and local soils and sediments from the Cowal Gold Project for North Gold (WA) Limited. Previous work was carried out by EGi in 1995/96 and it was reported that the mine waste materials had the potential to present a salinity concern if not managed correctly and that arsenic occurred in environmentally significant concentrations in most materials, but was not found to be soluble under the existing geochemical conditions.

The overall objective of these investigations was to assess the potential for leachate and/or surface runoff of unacceptable quality entering nearby Lake Cowal and adversely effecting water quality. This included:

1. Determination of the capacity of basement soils underlying the tailings storages to attenuate cyanide and identified soluble elements, and prediction of the short and long-term leachate chemistry of the storage facility.
2. Estimation of salinity release rates and mechanisms of release from the tailings storage facility, waste rock dump and perimeter bund wall.
3. Prediction of the long-term leachate and runoff water quality from the waste rock dump and perimeter bund wall.
4. Provision of recommendations for operational and long-term mine waste management.

Tailings and the Tailings Storage Facility

Both the oxide and primary tailings are non-acid forming, but the primary tailings contain moderate amounts of reactive sulphur and relatively high concentrations of sulphate salts which are likely to be released when this material is exposed to oxidation processes. These materials also contain relatively high concentrations of Ag, As, B, Cd, Mo, Pb, S, Sb, and Zn. However, these elements are not likely to be significantly soluble under water leaching conditions and therefore are not likely to adversely effect water quality.

With respect to cyanide, EGi understands that North have committed the Cowal Gold project to meeting the following design specifications at the point of discharge to the enclosed tailings storage:

The tailings slurry discharge shall contain no greater than 30 mg/L CN_{WAD} for 100% of the time and no greater than 20 mg/L CN_{WAD} for 90% of the time.

On the basis of EGi's cyanide investigations, which indicate that about 75% of the cyanide in the process liquor is present as free CN, it is expected that ongoing decay in tailings storage should result in CN_{WAD} concentrations in the reclaim water dam from 5 to 10 mg/L when processing oxide ore and 10 to 15 mg/L when processing primary ore. Once discharge ceases it is expected that within 2 to 3 months the CN_{WAD} complexes in the ponded decant will decay to very low concentrations. Once entrained, the

Cu-CN complexes, which predominate in the tailings liquor, will transform to the more stable and non-toxic Fe-CN complexes.

Tailings leach columns currently under commission indicate that the dominant soluble salt in the oxide tailings is NaCl and the dominant soluble salt in the primary tailings is $CaSO_4$ and to a lesser degree NaCl. The column leachates indicate an initial flush of 'soluble' Cu and Zn from the oxide tailings and 'soluble' Cu from the primary tailings. However, this release is most likely associated with the residual cyanide in the tailings liquor and does not represent a long term concern.

The preliminary leach column results indicate that the sulphate release rate is either equivalent to or exceeds the carbonate consumption rate and that the oxide and primary tailings are most likely to be depleted of reactive sulphide before the available carbonates are consumed. Therefore it is highly unlikely that these materials will ever generate acid conditions. The column tests are continuing and will provide on-going results to refine and further evaluate these long term predictions.

Two sub-soil samples collected from beneath the proposed tailings storage facility were slightly acidic and sodic. These materials have a very low sulphur content and a low acid neutralising capacity (ANC), and are non-acid forming. Due to their high clay content these materials have a high cation exchange capacity. These materials contain no significantly enriched elements.

Sequential batch tests indicate that the sub-soil materials contain a high content of soluble salts, predominantly Na, Mg, Cl and SO_4 , and that the tailings pore water has a lower soluble salt concentration than natural waters passing through these underlying sub-soils. These tests also indicate that CN_{WAD} , Cu, Zn, As and Ca are likely to be attenuated from any tailings pore water passing through the underlying soils. Although CN attenuation will only be low, it is expected that Cu, Zn and As will be strongly attenuated.

Based on the findings of investigations carried out to date, the cyanide chemistry of water within the tailings storage facility during the operational phase is predicted as follows:

Parameter	Decant and Reclaim Water Dam OXIDE TAILINGS	Decant and Reclaim Water Dam PRIMARY TAILINGS	Tailings Entrained Liquor
CN_{WAD} (mg/L)	5 - 10	10 - 20	< 1 - 20
Cu (mg/L)	4 - 5	10 - 15	< 1 - 15
Zn (mg/L)	2 - 4	2 - 4	< 1 - 4

¹ The CN_{WAD} , Cu and Zn concentrations will initially be similar to those in the tailings liquor. However, as the depth of tailings increases over time the concentrations within the deposited tailings will trend towards the lower concentration estimates.

With respect to the likely impacts of leachate from the tailings storage facility on the underlying groundwater, reference should be made to the ground water investigations conducted by Kalf and Associates (May 1997).

Lake Protection Bund

It is proposed that nearby clay-pan material will be used to construct the lake protection bund. Samples of this material indicate that it is non-saline and non-sodic, slightly alkaline and classified as non-acid forming. This material also has a relatively high cation exchange capacity. Sequential batch tests indicate that the dominant soluble constituents in the clay-pan material are Na and Cl and that runoff from this material is likely to have a TDS concentration of between 100 and 200 mg/L.

Waste Rock Dumps

The oxide and primary waste rock are slightly alkaline and the oxide waste rock is likely to be highly saline, and the primary waste rock likely to be moderately saline. Both the oxide and the primary waste rock are non-acid forming. However, the primary waste rock contains reactive sulphides and has a high ANC, and therefore is likely to generate significant sulphate salts, such as gypsum, if left exposed to surficial oxidation processes.

Sequential batch tests indicate that the dominant soluble constituents in leachate and runoff from the waste rock dumps will be Na and Cl and to a lesser degree Ca, Mg and SO₄. Any infiltrating rainfall into the oxide waste is likely to have a TDS concentration of 2,000 to 2,500 mg/L and for primary waste a TDS of 1,500 to 2,000 mg/L. The long term steady state runoff from the waste rock dumps is likely to have a TDS of less than 100 mg/L. These tests also indicate that the high concentrations of As in the waste rock solids are not readily soluble and this element is not likely to be a water quality concern.

With respect to the likely impacts of leachate from the waste rock on the underlying groundwater, reference should be made to the ground water investigations conducted by Kalf and Associates (May 1997).

Pit Void

Exposed rock in the pit void walls and floor is unlikely to be acid forming. However, due to the presence of reactive sulphides, oxidation of the exposed primary rock is likely to generate moderate levels of sulphate salts. Regional groundwater that will be allowed to recharge the post-closure pit void has a TDS of approximately 40,000 to 45,000 mg/L and therefore, the contribution of sulphate salts from the exposed pit walls during flooding is expected to be negligible and will not adversely effect the pit water quality. Oxidation of the post-closure flooded mine wall rock will essentially be stopped.

1.0 INTRODUCTION

Environmental Geochemistry International (EGi) Pty Ltd have been commissioned by North Gold (WA) Limited to assist in an assessment of the long term compatibility of the Cowal Gold Project with the surrounding environment. EGi are conducting environmental geochemical investigations on tailings, waste rock and local soils and sediments to complement previous investigations carried out by EGi during 1995 (reported in June, 1995) and during 1996.

The previous investigations indicated that mine rock and tailings from the Cowal Gold Project were likely to be non-acid forming. However, the investigations also indicated that these materials were likely to present salinity concerns if not managed correctly. Additional to this, arsenic was found to be significantly enriched above average crustal rock concentrations in most materials, although it was not found to be soluble under the existing geochemical conditions.

North have advised that a number of changes have been made to the mine design and mine plan since the previous investigations were carried out by EGi in 1995/96. Most pertinent to the environmental geochemical issues raised during these investigations is the introduction of a flotation circuit during processing of the primary tailings. It is understood that the planned processing of primary ore will generate approximately 95% flotation tailings and 5% flotation concentrate. The flotation concentrate and oxide ore will be cyanide leached with the leach residue either being recombined with the flotation tailings or disposed of separately in the tailings storages. It was also advised that the residual cyanide in the leach residue will be treated prior to discharge to the tailings storages. The concentration of cyanide (CN_{wad}) in the tailings will be maintained at EPA specified concentrations (currently not to exceed 30 mg/L and maintained at below 20 mg/L 90 % of the time).

A long term geochemical issue for the Cowal Gold Project is the potential for leachate and/or surface runoff of unacceptable quality entering Lake Cowal and adversely effecting water quality. During the current investigations the geochemical characteristics of the flotation and cyanide leach tailings from the primary ore have been investigated, and the element solubility and salinity concerns in the tailings, waste rock and the proposed lake protection bund construction material have been further investigated. The capacity of the sub-soils beneath the proposed tailing storage facility to attenuate CN and previously identified elements of potential concern from tailings leachate were also investigated.

The specific objectives of these investigations have been to:

1. Confirm the non-acid forming nature of the oxide tailings.
2. Geochemically characterise flotation and concentrate residues from the primary tailings and identify any additional environmental issues. Determine the environmental benefits of disposing the residues separately or recombined.

3. Determine the elemental composition of the tailings, identify any elements of potential environmental concern and investigate the leaching behaviour of the tailings. Review previous cyanide decay test work results with respect to the proposed changes to processing of the primary ore.
4. Determine the capacity of basement soils underlying the tailings storages to attenuate cyanide and soluble elements, and predict the short and long-term leachate chemistry of the storage facility.
5. Investigate salinity concerns and estimate salinity release rates and mechanisms of release from the tailings storage facility, waste rock emplacement and lake protection bund.
6. Predict the long-term leachate and runoff quality from the waste rock emplacement and lake protection bund
7. Provide recommendations for operational and long-term mine waste management.

This report provides the results and findings from these investigations and predicts the leachate and runoff water quality from the different mine features under the current mine plan. Recommendations for long term environmental security are given. A summary of the findings from the previous investigations is also included.

2.0 PREVIOUS GEOCHEMICAL INVESTIGATIONS

Previous geochemical investigations were carried out by EGi on tailings, surface zone material and mine rock from Cowal in 1995 and reported in June 1995 (Environmental Geochemical Assessment of Process Tailings, Mine Rock and Surface Zone Materials). These investigations included an evaluation of the acid forming characteristics and assessment of element enrichments and solubilities of potential environmental concern. Additionally, the cyanide chemistry in the tailings was investigated and the capacity of the material underlying the proposed tailings storage facility to attenuate the cyanide species was investigated. During 1996 additional test work was carried by EGi on tailings geochemistry, and the cyanide speciation and decay characteristics in the tailings liquor. Following is a summary of the findings from these previous investigations.

2.1 Tailings

The oxide tailings had a low sulphur content and low acid neutralising capacity (ANC) and were classified as non-acid forming (NAF). The primary tailings had a relatively high total sulphur content (2 %S) and high ANC (80 kg H₂SO₄/t). The primary tailings were also classified as NAF. However, the presence of reactive sulphides in the primary tailings indicated that when left exposed to oxidation these tailings would generate sulphate salts. Due to the potential for sulphate salt generation it was suggested that a cover would be required to prevent salt-pan development as a component of tailings rehabilitation.

The only elements significantly enriched in the tailings of potential environmental concern were sulphur (S) and arsenic (As). However, S and As contents varied widely and it was suggested that final processing of low S, low As ore is one alternative that could provide suitable cover material for tailings closure.

Results from the cyanide (CN) speciation test work indicated that the dominant soluble metal-CN complexes in the tailings liquor were those associated with Cu and Zn. The CN decay test work indicated that CN_{wad} in the tailings liquor decayed rapidly and the free cyanide was volatilised from solution within a period of about one week. The results from the CN attenuation test work suggested limited adsorption of metal-CN species by the soils underlying the proposed tailings storage facility.

2.2 Surface Zone Material

The surface zone materials comprised soils and weathered materials ranging from 0 to around 50 m depth. These materials generally had low S contents with low to moderate ANC's and were classified as NAF. Surface zone materials situated above the ore body were found to contain relatively high concentrations of As, Zn and Cd compared to their average crustal abundance. However, testing revealed that these elements were not water soluble under the natural neutral to slightly alkaline pH conditions of these materials.

2.3 Mine Rock

Test work results indicated that oxidised mine rock had a low S content and low ANC and was shown to be NAF. The primary mine rock had a moderate S content (1.0 %S), but also contained a high ANC (mean of 106 kg H₂SO₄/t) and was also shown to be NAF. However the primary mine rock contained reactive sulphides, which are likely to oxidise slowly generating sulphate salts such as gypsum.

The mine rock also contained environmentally significant concentrations of As. The results suggested that the solubility of As would be low, however, additional test work was recommended to confirm this prediction. No other environmentally significant element concentrations were detected in the mine rock.

3.0 GEOCHEMICAL INVESTIGATION PROGRAM

3.1 Sample Acquisition, Description and Preparation

Samples of tailings, sub-soils, clay-pan materials and waste rock from Cowal were used during these investigations. Following is a description of the samples and how they were obtained and prepared prior to testing.

3.1.1 Tailings Samples

Simulated tailings samples for the Cowal Gold Project were provided by North Gold Ltd as slurries. These samples were prepared using simulated site surface water and include:

- Oxide tailings – generated from processing of oxide ore using cyanide leach.
- Primary flotation tailings – residue from flotation of primary tailings.
- Leached primary flotation concentrate – gold pyrite concentrate separated using flotation which is then intensely cyanide leached.
- Recombined primary tailings – the recombined flotation tailings and leached concentrate blended as a slurry at a ratio of 1:20 (1:20 w/w solids & 1:28 w/w liquors).

Preparation of the simulated oxide and recombined primary tailings involved treatment with Caro's Acid ($\text{H}_2\text{O}_2:\text{H}_2\text{SO}_4$) to reduce cyanide concentrations. Prior to testing, the tailings liquors were decanted and stored in air-tight containers out of direct sunlight to avoid decay of cyanide and the tailings solids were stored in a moist state.

3.1.2 Tailings Storage Sub-Soil Samples

Samples of sub-soil from beneath the proposed tailings storage facility were provided by Coffey Partners International Pty Ltd. The samples were collected as bulk representative samples from an auger drill hole positioned within the proposed tailings storage facility location. Two depth intervals were collected; 0 to 4 m and 4 to 8 m. All surface materials, likely to be excavated prior to tailings emplacement were removed prior to sampling. Both samples had a very high clay content and were classified as heavy clays with high plasticity. These samples were air dried prior to testing and a sub-sample was pulverised for the geochemical characterisation test work.

3.1.3 Clay-Pan Samples

Clay-pan samples were also provided by Coffey Partners International Pty Ltd from archive. Three samples were selected to represent the proposed material to be used for construction of the lake protection bund. The samples were collected from the east end of the lake, north of the proposed bund and south of the mine as defined by Coffey Partners International Pty Ltd. These samples were classified as silty clays with slight plasticity. They were thoroughly mixed and air dried prior to testing and sub-samples were pulverised for the geochemical characterisation test work.

3.1.4 Waste Rock Samples

Pulverised waste rock samples were retrieved from EGI archive. From these samples, composites were prepared for testing to represent oxide and primary waste rock. The samples selected to make up the composites are presented in Attachment A.

3.2 Geochemical Characterisation

The geochemical characterisation program utilised during these investigations included:

- determination of acid forming potential;
- evaluation of soil chemical properties;
- assessment of enriched elements in solid samples;

- determination of chemical composition of liquors; and
- assessment of constituent solubility, salinity and leaching behaviour.
- evaluation of attenuation characteristics.

These different aspects of the geochemical characterisation program are discussed below.

3.2.1 Determination of Acid Forming Potential

Determination of the acid forming potential of the tailings, sub-soils, clay-pan materials and waste rock from Cowal involved the acid-base account and NAG testing. The following analyses were used

- pH and electrical conductivity (on 1:2 sample/water suspension)
- total sulphur assay
- acid neutralising capacity (ANC)
- static net acid generation (NAG) testing

Further details on the testing program used for evaluating the acid forming potential of the materials are supplied in Attachment B.

3.2.2 Evaluation of Soil Chemical Properties

The soil chemical properties of the sub-soils and clay-pan materials were evaluated by determination of the soluble and exchangeable cations and calculation of the cation exchange capacity. These analyses were carried out by Sydney Environmental and Soil Laboratory Pty Ltd, Sydney.

3.2.3 Assessment of Enriched Elements in Solids

A common feature of mineralised terrains is enriched concentrations of particular metals depending on the style of mineralisation. Therefore, an assessment of enriched elements in the solid samples was carried out by comparing the multi-element composition of the solids to the average composition of the earth's crust. The extent of enrichment is reported as the Geochemical Abundance Index (GAI) which relates the actual concentration with the crustal abundance on a log 2 scale. Further details on the geochemical characterisation program for determining element enrichment is supplied in Attachment B.

3.2.4 Determination of Chemical Composition of Liquors

To determine the chemical composition of the tailings liquors the pH and electrical conductivity were determined and the total cyanide (CN_{Total}) and weak acid dissociable cyanide (CN_{WAD}), and multi-element composition were assayed.

3.2.5 Assessment of Constituent Solubility, Salinity and Leaching Behaviour

To assess constituent solubility, salinity and leaching behaviour of the tailings, waste rock and clay-pan material sequential batch and leach column tests were used.

Sequential Batch Test

The sequential batch test involved mixing a test solution with solid sample at a ratio of 1:2 (solid/solution) and extraction of the solution after a 24 hour period. The suspensions were agitated intermittently for the 24-hour period. The extracted solution was then re-introduced to fresh solid sample (Series A) and the solid sample was re-introduced to fresh test solution (Series B). This sequence was repeated four times and an aliquot of the test solutions was collected for analysis after each extraction. A flowchart showing the sequential batch test procedure is supplied in Attachment C.

Leach Column Test

Leach column tests are being performed under controlled laboratory conditions designed to simulate leaching and exposure conditions expected in the surficial environment. These tests are being carried out to confirm the predicted long-term leaching behaviour and pore water chemistry of the tailings. Two columns have been commissioned, one containing oxide tailings and the other containing recombined primary tailings. To provide information on sulphide oxidation the leach columns are designed and operated to ensure that oxygen diffusion into the column is not restricted. This is achieved by:

- using heat lamps to promote evaporative drying;
- a column design that prevents the development of water saturated conditions; and
- wetting the tailings weekly and flushing monthly.

Leachates are collected monthly and analysed for pH, EC, alkalinity/acidity and multi-element composition. The leach column design and operation procedures are provided in Attachment D.

3.2.6 Evaluation of Attenuation Characteristics

Sequential batch tests were used to determine the capacity of the sub-soils to attenuate soluble constituents from leachate. The procedure for the sequential batch test is

discussed above in Section 3.2.5 (Assessment of Constituent Solubility, Salinity and Leaching Behaviour) and a flowchart showing the sequential batch test procedure is supplied in Attachment C. The test solutions used for the attenuation test work included tailings liquor from the oxide tailings and the flotation and recombined primary tailings. Liquor from the oxide and re-combined primary tailings were used to investigate short to medium term leachate chemistry and liquor from the flotation tailings was used to investigate the longer term pore water chemistry.

3.3 Analytical Techniques

Total sulphur assays were performed with a Leco Automatic Sulphur Analyser by Enviroment Pty Ltd. Soil chemical property analyses were carried out by Sydney Environmental and Soil Laboratory Pty Ltd. ANC, pH and EC determinations, NAG tests and sequential batch tests were carried out by EGi Pty Ltd. The leach column tests are also being carried out by EGi Pty Ltd. Multi-element analyses of solids, sequential batch test solutions and leachates from the leach column tests were carried out by Genalysis Laboratory Services Pty Ltd using a combination of ICP-mass spectrometry, ICP-optical emission spectrometry, and atomic absorption spectrometry.

4.0 TAILINGS GEOCHEMISTRY

4.1 Acid Forming Characteristics

The acid forming characteristics of the tailings are presented on Table C-1.

The oxide tailings sample was alkaline with a pH₁₂ of 9.8 and had high salinity with an EC₁₂ of 4.86 dS/m. The total S content of the sample was low (0.03 %S) and, even though the acid neutralising capacity (ANC) was also low (9 kg H₂SO₄ kg/t), the sample had a negative net acid producing potential (NAPP) value (-8 kg H₂SO₄/t). The net acid generation (NAG) test confirms the NAPP value with a final NAGpH of 8.8, therefore, tailings represented by this sample are classified as non-acid forming (NAF).

Table C-1 Acid forming characteristics of tailings, tailings storage facility sub-soils, clay-pan material proposed for lake protection bund construction and waste rock, Cowal Gold Project

Material Type		pH	EC (ds/m)	Acid Base Analysis			NAG Test		Geochemical
				Tot.S (%)	ANC	NAPP	NAG	Final pH	Classification
Tailings	Oxide	9.8	4.86	0.03	9	-8	0	8.8	NAF
	Primary Flotation	8.5	0.621	0.02	62	-61	0	8.4	NAF
	Primary Concentrate	11.6	22.2	32.4	39	952	71	2.2	PAF
	Primary Recombined	9.5	0.882	2.40	71	2	0	8.3	NAF
Tailings Storage Facility Sub-Soils	Sub-Soil (0-4 m)	5.0	1.76	0.03	4	-3	-	-	NAF
	Sub-Soil (4-8 m)	4.9	1.88	0.02	3	-2	-	-	NAF
Clay-Pan Material - Perimeter Bund Construction	East of Lake	8.0	0.581	<0.01	5	-5	-	-	NAF
	North of Bund	7.9	0.418	<0.01	7	-7	-	-	NAF
	South of Mine	7.8	0.362	<0.01	6	-6	-	-	NAF
Waste Rock	Oxide Composite	8.5	2.29	0.03	14	-13	-	-	NAF
	Primary Composite	8.9	0.831	1.06	109	-73	-	-	NAF

The primary flotation and leached concentrate samples were alkaline with pH_{1:2} values of 8.5 and 11.5, respectively. The flotation sample had low salinity ($EC_{1:2} = 0.621$ dS/m) and the concentrate sample had very high salinity ($EC_{1:2} = 22.2$ dS/m). The flotation sample had a low S content (0.02 %S) and high ANC (62 kg H₂SO₄/t), and therefore was NAPP negative (-61 kg H₂SO₄/t) whereas the concentrate sample had a very high S content (22.2 %S) and moderate ANC (39 kg H₂SO₄/t) and correspondingly was strongly NAPP positive (952 kg H₂SO₄/t). The NAG results confirmed the NAPP values with the flotation sample having a NAGpH of 8.4 and being classified as NAF, and the concentrate sample having a NAGpH of 2.2 and being classified as potentially acid forming (PAF).

As expected the recombined primary tailings sample had an alkaline pH_{1:2} of 9.5 and a low salinity with an $EC_{1:2}$ of 0.882 dS/m. The S content was moderate at 2.4 %S and the ANC was relatively high at 71 kg H₂SO₄/tonne of tailings. The calculated NAPP value was slightly positive at 2 kg H₂SO₄/tonne and the NAG test, with a NAGpH of 8.3, classified the recombined tailings represented by this sample as NAF.

The NAG test provides a measure of the net amount of acid remaining in a sample after all acid generating and acid neutralising reactions have taken place and is used to determine the likely long-term acid forming potential of exposed materials. Results from NAG tests carried out on the oxide and recombined primary tailings therefore indicate that these materials are not likely to develop acid conditions after long-term exposure to oxidation processes. Leach column tests currently being carried out are expected to confirm the NAF nature of these tailings.

4.2 Multi-Element Composition and Element Enrichment

Tailings commonly contain enriched concentrations of a particular element suite as a result of mineralisation. Multi-element scans were performed and a geochemical abundance index (GAI) used to identify elements that occur in the solid tailings samples in significantly high concentrations compared to their average abundance in the earth's crust. Results from the scans along with the respective GAI values are presented on Table C-2. An explanation of the GAI methodology is contained in Attachment B.

The oxide sample was shown to have significantly high concentrations (GAI = 3) of arsenic (As), boron (B), lead (Pb) and antimony (Sb) compared to average concentrations in crustal rocks.

The sample of flotation residue from the primary tailings had significantly high concentrations of As, cadmium (Cd) and molybdenum (Mo). Whereas, the sample of leached concentrate residue from the primary tailings had significantly high concentrations of many elements

including; silver (Ag), As, bismuth (Bi), Cd, cobalt (Co), copper (Cu), mercury (Hg), Mo, nickel (Ni), Pb, S, Sb, selenium (Se) and zinc (Zn). Although, element enrichments in the concentrate residue were significantly reduced when recombined with the flotation residue, the recombined primary tailings sample still had significantly high concentrations of Ag, As, Cd, Mo, Pb, S, Sb, and Zn.

The high concentrations of As, B, Pb, and Sb in the oxide tailings and Ag, As, Cd, Mo, Pb, S, Sb, and Zn in the recombined primary tailings is consistent with findings from the previous geochemical test work carried out on the Cowal tailings. The solubility and leaching behaviour of these enriched elements is currently being assessed. Findings to-date are discussed in Sections 4.3 and 4.6.

4.3 Tailings Liquor Chemistry

The chemical composition of liquors from the oxide tailings and the flotation, leached concentrate and recombined primary tailings is presented on Table C-3. The liquors are alkaline with a pH range of 8.5 for the flotation liquor to 11.6 for the concentrate liquor. The oxide and recombined primary tailings liquors have a pH of around 9.5. As expected, the concentrate liquor has high EC ($EC = 22.2$ dS/m), however when re-combined with the flotation liquor the EC is significantly reduced ($EC = 0.882$ dS/m). The oxide tailings liquor has relatively high EC ($EC = 4.86$ dS/m) due to the presence of significant soluble salts in the oxide material.

Total cyanide (CN_{Total}) concentrations in the tailings liquors range from 29.4 mg/L in the oxide liquor to 4540 mg/L in the leached concentrate liquor. When the leached concentrate liquor is mixed with the flotation liquor, which contains no CN, the concentration of CN_{Total} is reduced to 64.5 mg/L. The predominant metal-cyanide (CN) species in these liquors are Fe, Cu and Zn. Copper and Zn species are only moderately to weakly stable and therefore they are detected, with free CN, using weak acid dissociable cyanide (CN_{WAD}) analysis. Iron-CN is highly stable and therefore not detected using CN_{WAD} analysis. These results indicate that approximately 75% of the CN_{WAD} is present as free CN.

The oxide tailings and recombined tailings were partially treated with Caro's acid to reduce the residual cyanide concentration. Although the samples were not prepared to the current design specifications for discharge (i.e. less than 30 mg/L 100% of the time and less than 20 mg/L 90% of the time), the cyanide decay principles discussed in the next section would apply.

The results given in Table C-3 also indicate that As concentrations in the oxide and primary flotation residue liquors are relatively low at 0.038 and 0.01 mg/L, respectively. The concentrate liquor has a As concentration of 6.4 mg/L which is lower than expected considering the high concentrations occurring in the concentrate solids. As a result of this the concentration of As in the recombined primary residue liquor is only 0.075 mg/L.

Table C-2 Multi-element composition and geochemical abundance indices for tailings and tailings storage facility sub-soils, Cowal Gold Project

Element	Element Concentration in Solids (mg/kg except where shown)					*Average Crustal Abundance	Geochemical Abundance Indices (GAI)#				
	Tailings				**TSF Sub-Soil 0-4 m		Tailings				**TSF Sub-Soil 0-4 m
	Oxide	Primary					Oxide	Primary			
		Recomb.	Conc.	Flot.				Recomb.	Conc.	Flot.	
Ag	0.2	1	9.4	<0.1	0.2	0.07	1	3	6	0	1
Al	12.50%	6.60%	3.40%	7.20%	5.60%	8.2%	0	0	0	0	0
As	104	195	2900	15	4	1.5	6	6	6	3	1
B	100	50	<50	<50	50	10	3	2	<2	<2	2
Ba	440	660	295	680	360	500	0	0	0	0	0
Be	1.2	0.9	0.5	0.8	1.3	2.6	0	0	0	0	0
Bi	0.1	0.1	1.5	<0.1	0.2	0.048	0	0	4	0	1
Ca	0.23%	2.00%	0.86%	1.55%	0.31%	4.1%	0	0	0	0	0
Cd	0.6	7.4	82	1.2	<0.1	0.11	2	5	6	3	0
Ce	62	56	43	56	49	68	0	0	0	0	0
Co	19	35	185	13	9	20	0	0	3	0	0
Cr	94	1160	340	680	54	100	0	3	1	2	0
Cu	130	185	1800	37	16	50	1	1	5	0	0
F	350	350	250	300	200	950	0	0	0	0	0
Fe	8.80%	5.80%	28.00%	3.90%	2.85%	4.10%	1	0	2	0	0
Hg	0.02	0.05	1.4	0.04	0.02	0.05	0	0	4	0	0
K	2.85%	3.30%	1.60%	3.70%	0.68%	2.10%	0	0	0	0	0
Mg	3400	9200	5800	9400	4800	23000	0	0	0	0	0
Mn	2150	2000	920	1750	215	950	1	0	0	0	0
Mo	8.5	96	24.5	44	0.5	1.5	2	5	3	4	0
Na	0.25%	2.00%	0.72%	2.15%	0.37%	2.30%	0	0	0	0	0
Ni	43	700	140	330	14	80	0	3	0	1	0
P	740	1550	740	1350	120	1000	0	0	0	0	0
Pb	165	130	1550	28	16	14	3	3	6	0	0
S	0.03%	2.30%	28.00%	0.04%	0.04%	0.03%	0	6	6	0	0
Sb	8.6	2	9.8	1	0.4	0.2	5	3	5	2	0
Se	0.22	0.35	4.9	0.03	0.24	0.05	2	2	6	0	2
Si	22.50%	28.50%	10.80%	29.00%	32.00%	27.7%	0	0	0	0	0
Sn	2	3	1	1	2	2.2	0	0	0	0	0
Sr	74	220	98	210	76	370	0	0	0	0	0
Tl	<0.2	<0.2	<0.2	<0.2	<0.2	1	0	0	0	0	0
V	230	54	50	56	88	160	0	0	0	0	0
W	3	9	3	5	2	1	1	3	1	2	0
Zn	275	960	10600	230	37	75	1	3	6	1	0

* Bowen H.J.M. (1979) Environmental Chemistry of the Elements

refer to text for explanation of GAI (0=not enriched ->6=highly enriched)

** TSF – Tailings Storage Facility

Table C-3 Chemical composition of liquors from the oxide tailings and the primary flotation, concentrate and recombined tailings sample, Cowal Gold Project

Parameter	Concentration in Solution (mg/L except pH & EC)				Detection Limit
	Oxide Tailings	Primary Tailings	Recombined Flotation Concentrate		
pH	9.8	9.5	8.5	11.6	0.1
EC (dS/m)	4.86	0.882	0.621	22.2	0.001
CN _{Total}	29.4	64.5	na	4540	0.005
CN _{WAD}	29.4	53.5	na	3040	0.005
Ag	0.0035	0.004	<	1.65	0.001
Al	0.22	0.26	0.1	2	0.01
As	0.038	0.075	0.01	6.4	0.002
B	0.03	0.06	0.06	-	0.01
Ba	0.017	0.036	0.07	0.11	0.001
Be	0.0003	<	<	0.001	0.0002
Bi	<	<	<	0.01	0.001
Ca	175	5	19	6.6	0.01
Cd	0.006	0.001	<	0.29	0.001
Ce	0.0001	<	0.0004	<	0.0001
Cl	1360	220	30	120	10
Co	0.045	0.018	<	0.46	0.002
Cr	<	0.01	<	0.05	0.01
Cu	4.32	10.8	0.01	408	0.01
F	2.5	1.1	1.1	2.0	0.1
Fe	0.03	10.3	0.03	379	0.01
Hg	0.0068	<	<	0.0620	0.0002
K	21	37	39	90	0.1
Mg	2.55	2.6	8.6	<	0.01
Mn	0.01	<	0.04	6.4	0.01
Mo	0.046	0.084	0.09	0.245	0.0005
Na	860	140	38	3900	0.1
Ni	0.04	0.13	<	0.4	0.01
P	0.3	0.2	0.1	1	0.1
Pb	<	<	<	0.04	0.005
Sb	0.0066	0.0115	0.003	0.500	0.0002
Se	<0.001	0.001	<	0.044	0.001
Si	2.5	3.5	3.2	-	0.1
Sn	0.001	<	<	0.01	0.001
SO ₄	380	68	50	1250	0.3
Sr	1.06	0.54	1.45	0.74	0.0001
Tl	<	<	<	0.002	0.0005
V	0.01	<	<	0.15	0.01
W	<	0.002	0.002	0.02	0.001
Zn	2.29	1.98	0.02	58.6	0.01

na - not analysed

Table C-4 Chemical composition of Collection 1 leachates from the tailing leach columns, Cowal Gold Project

Parameter	Concentration in Solution (mg/L except pH & EC)		
	Oxide Tailings	Primary Tailings	Detection Limit
pH	8.3	7.9	0.1
EC (dS/m)	2.15	1.81	0.001
Alkalinity/Acidity (mgCaCO ₃ /l)	45	66	1
Ag	<	<	0.001
Al	0.17	0.62	0.01
As	0.01	0.01	0.005
B	0.03	0.09	0.01
Ba	0.012	0.135	0.002
Be	<	0.0002	0.0002
Bi	<	<	0.001
Ca	18	120	0.01
Cd	<	<	0.001
Ce	0.0028	0.026	0.0002
Cl	220	65	5
Co	0.028	0.088	0.002
Cr	<	<	0.01
Cu	1.6	0.02	0.01
F	4.6	1.6	0.1
Fe	0.02	1.02	0.01
Hg	<	<	0.0002
K	4.3	74	0.1
Mg	3.8	62	0.1
Mn	0.03	0.62	0.01
Mo	0.014	0.104	0.001
Na	195	160	0.1
Ni	0.03	<	0.01
P	0.1	<	0.1
Pb	<	0.005	0.005
Sb	0.001	0.002	0.0005
Se	0.02	0.02	0.02
Si	3.9	3.7	0.05
Sn	<	<	0.002
SO ₄	106	1200	0.3
Sr	0.28	6.6	0.0002
Tl	<	<	0.0005
V	<	<	0.01
W	<	<	0.002
Zn	0.08	0.07	0.01

< signifies element at or below lower limit of detection

4.4 Nature and Fate of Cyanide in Tailings

Test work on the nature and fate of CN in the tailings has previously been carried out. This test work involved assessing the rate of CN decay in ponded decant liquor and in liquor entrained within the tailings.

Results from the decant liquor decay test work indicated that CN will decay rapidly in ponded decant liquor and in the reclaim water dam due primarily to the low metal content and high proportion of free CN. Therefore, it is expected that ongoing decay in tailings storage should result in CN_{WAD} concentrations in the reclaim water dam from 5 to 10 mg/L when processing oxide ore and 10 to 15 mg/L when processing primary ore. Once discharge ceases it is expected that within 2 to 3 months the CN_{WAD} complexes in the ponded decant will decay to very low concentrations.

Ongoing reactions will occur between the tailings solids and CN in the entrained liquor. The test work carried out indicated that these ongoing reactions result in cyanide transformation from Cu-CN complexes to the more stable, non-toxic Fe-CN complexes.

4.5 Leaching Behaviour of Tailings

Two leach columns have been commissioned to confirm the predicted long-term leaching behaviour and leachate chemistry of the oxide and recombined primary tailings. The leach columns have been operational for a period of 5 months, with leachates being collected and analysed monthly. The preliminary results for the first 5 months of leaching are provided on Tables C-4, C-5 and C-6. Multi-element scans performed on the first leachate collected from each column, shown on Table C-4, indicate that the dominant soluble salt in the oxide tailings is NaCl and the dominant soluble salt in the primary tailings is $CaSO_4$ and to a lesser degree NaCl.

Tables C-5 and C-6 show leachate chemistry for each monthly collection. The pH of leachates from both columns has remained above pH 7. The results show an initial flush of 'soluble' Cu and Zn from the oxide tailings and 'soluble' Cu from the primary tailings. These elements are most likely associated with the residual cyanide in the tailings liquor and, as discussed previously, this does not represent a long term concern.

A major purpose of the column leach test is to evaluate the long term geochemical security of the deposited tailings with respect to the prevention of acid generation. The results indicate that the leachates are undersaturated with respect to gypsum and hence the estimated sulphate release rate most likely reflects the sulphide oxidation rate within the sample.

Based on this assumption, the preliminary results indicate that the sulphate release rate is either equivalent to or exceeds the carbonate consumption rate and that carbonate is not being preferentially leached from the samples. Given that the ratio of the total available carbonate (ANC) to the maximum potential acid sulphate is about 10 to 1 in the oxide sample it is highly unlikely that this sample will ever generate acid conditions.

The inherent ratio of the total available carbonate (ANC) to the maximum potential acid sulphate in the primary tailings sample is about 1:1 and therefore it is also most likely that this sample will remain non-acid forming. At the current carbonate consumption rate it is estimated that more than 50 years of leaching would be required to deplete the sample of ANC. The data also suggest that the contained sulphides would be depleted within this time frame resulting in the formation of a barren tailings material which will be essentially devoid of reactive sulphide and carbonate.

The column tests are continuing and will provide on-going results to refine and further evaluate these long term predictions.

5.0 TAILINGS STORAGE SUB-SOIL GEOCHEMISTRY

5.1 Acid Forming Characteristics

The acid forming characteristics of the sub-soil samples from beneath the proposed tailings storage facility are presented on Table C-1. These results indicate that the soils are naturally slightly acidic with a $pH_{1:2}$ around 5.0 and saline with an $EC_{1:2}$ of around 1.8 dS/m. The S content of these materials is low (0.03 %S) as is the ANC (3 to 4 kg H_2SO_4 /t) and soils represented by these samples are classified as NAF.

5.2 Soil Chemical Properties

The soil chemical properties of the sub-soil samples are presented on Table C-7. These findings indicate that the sub-soils are sodic with high concentrations of exchangeable sodium (Na) magnesium (Mg) and aluminium (Al). Calcium (Ca) and potassium (K) are deficient. Due to the high clay content of these samples the cation exchange capacity (CEC) was high ranging from 9.51 to 19.62 meq%.

5.3 Multi-Element Composition and Element Enrichment

Results from multi-element scans performed on the sub-soil sample collected from 0 to 4 m depth and the respective GAI's are presented on Table C-2. These results indicate no significant element enrichments in this material.

5.4 Attenuation Characteristics

Sequential batch tests have been used to evaluate the capacity of the tailings storage sub-soils to attenuate CN and soluble elements. The procedure used for these tests is discussed in Section 3.2. (Evaluation of Attenuation Characteristics) and involved exposing tailings liquor from the oxide residues and the primary recombined and flotation residues to representative sub-soil material collected from the proposed tailings storage facility (see Attachment C for test methodology). Liquors from the oxide and re-combined primary residues were used to investigate short to medium term chemistry and liquor from the flotation tailings was used to investigate the longer term chemistry. Results from these tests are presented on Tables C-8, C-9 and C-10 for the oxide, and recombined flotation and primary residues, respectively.

Series A of the test involves the re-introduction of a sequential test solution to fresh sub-soil sample. Results from Series A of the test are used to observe trends in solution chemistry as the solution is in contact with an increasing amount of the solid sample. These trends are then used to predict the chemistry of liquor as it migrates through the underlying sub-soils. Series B of the test involves the re-introduction of fresh test solution to sequential sub-soil sample. The results from Series B of the test indicates the long-term liquor chemistry under quasi-equilibrium geochemical conditions.

Figure C-1 shows the change in pH as the test solution was introduced to fresh sub-soil material (Series A). The decreasing pH trend shown occurred due to the naturally low pH of the sub-soil material (pH = 4.9). Lower pH values in the oxide residue solutions indicate that the oxide liquor has relatively poor buffering capability, which is also indicated by lower alkalinity values in the solutions and low ANC in the oxide tailings solids.

Changes in EC values as the test solution was introduced to fresh sub-soil material are shown on Figure C-2. The increasing

trend in EC (1 to 2 dS/m) indicates a substantial contribution of soluble salts from the sub-soil material. The relatively high EC values for the oxide residue solutions are attributed to additional input of soluble salts from the oxide tailings.

Figures C-3, C-4 and C-5 show the changes in selected element and CN concentrations as the oxide, recombined and flotation residue test solutions, respectively, were introduced to fresh sub-soil material. These changes are shown as the ratio of the measured concentration in the equilibrated test solutions (C) to the concentration in the initial tailings liquors (C_0). The concentration trends indicate that CN_{WAD} , Cu, Zn, As and Ca in the oxide and recombined primary tailings liquors are attenuated by the sub-soil, and that Na, Mg, Cl and SO_4 are eluted from the sub-soil. The attenuated constituents ($C/C_0 < 1$) are indicated by the closed symbols on Figures C-3, C-4 and C-5 and the eluted constituents ($C/C_0 > 1$) are indicated by the open symbols. Figure C-5 shows that, without the presence of CN complexes in the flotation residue, Cu and Zn are eluted from the sub-soil indicating a greater contribution of these metals from the natural sub-soil material than from the flotation residue liquor.

Table C-5 Oxide Tailing leach column results to September 1997, Cowal Gold Project

Total S (%) = 0.03; ANC (kg H_2SO_4/t) = 9; NAPP (kg H_2SO_4/t) = -8; NAG (kg H_2SO_4/t) = 0; NAG pH = 8.8

Parameter	Concentration in Solution (mg/l except pH & EC)					
	0 Initial	4 1	8 2	12 3	16 4	20 5
Volume Leached (ml)	153	377	552	464	121	126
pH	8.8	8.3	8.2	8.1	7.5	8.3
EC (dS/m)	5.78	2.15	1.42	0.421	4.28	5.66
Alkalinity/Acidity (mg $CaCO_3/l$)	208	45	49	18	110	163
As	0.005	0.01	<0.005	<0.005	0.004	0.004
Ca	27.5	18	18.5	16.5	32	48
Cl	1600	220	65	15	1040	1250
Cu	11.2	1.6	0.01	0.01	0.02	0.05
Fe	0.07	0.02	<0.01	<0.01	0.34	0.41
Mg	2	3.8	4.3	5.2	20	26
Na	1040	195	68	21	680	900
SO_4	430	106	54	60	310	370
Zn	2.35	0.08	0.01	0.03	0.03	0.06
CALCULATED RESULTS						
Sulphate Release:						
Release Rate (mg $SO_4/kg/wk$)	33	5	4	3	5	6
Cum. Release (mg SO_4/kg)	33	38	42	45	55	66
Residual S (%S)	0.029	0.029	0.029	0.028	0.028	0.028
Carbonate Consumption:						
Empirical Consumption Rate (mg $CaCO_3/kg/wk$)	6	3	4	3	2	3
Theoretical Consumption Rate (mg $CaCO_3/kg/wk$)	34	5	4	4	5	6
Cum. Consumption Rate (mg $CaCO_3/kg$)	6	8	12	16	18	21
Residual ANC (kg H_2SO_4/t)	9.0	9.0	9.0	9.0	9.0	9.0
Sulphate Release Rate/Carbonate Consumption Rate	5.8	1.9	0.9	1.1	2.2	1.9

Table C-6 Recombined Primary Tailing leach column results to September 1997, Cowal Gold ProjectTotal S (%) = 2.4; ANC (kg H₂SO₄/t) = 71; NAPP (kg H₂SO₄/t) = 2; NAG (kg H₂SO₄/t) = 0; NAG pH = 8.3

Parameter	Concentration in Solution (mg/l except pH & EC)					
	0 Initial	4 1	8 2	12 3	16 4	20 5
Week Collection						
Volume Leached (ml)	310	281	283	268	294	292
pH	8.5	7.9	8.0	8.0	7.8	8.2
EC (dS/m)	0.542	1.81	1.67	1.72	1.86	1.23
Alkalinity/Acidity (mg CaCO ₃ /l)	118	66	52	53	81	87
As	0.01	0.01	<0.005	<0.005	0.002	0.004
Ca	12	120	144	150	102	76
Cl	40	65	50	60	45	100
Cu	1.5	0.02	0.01	0.02	0.11	0.05
Fe	0.22	1.02	0.11	0.17	0.23	0.15
Mg	4.9	62	68	68	47	39
Na	74	160	122	106	90	82
SO ₄	64	1200	820	760	540	320
Zn	0.08	0.07	0.49	0.04	0.1	0.05

CALCULATED RESULTS**Sulphate Release:**

Release Rate (mg SO ₄ /kg/wk)	10	42	29	25	20	12
Cum. Release (mg SO ₄ /kg)	10	52	81	107	146	170
Residual S (%S)	2.40	2.40	2.40	2.40	2.40	2.39

Carbonate Consumption:

Empirical Consumption Rate (mg CaCO ₃ /kg/wk)	7	17	20	19	14	11
Theoretical Consumption Rate (mg CaCO ₃ /kg/wk)	10	44	30	27	21	12
Cum. Consumption Rate (mg CaCO ₃ /kg)	7	24	43	63	77	88
Residual ANC (kg H ₂ SO ₄ /t)	9.0	9.0	9.0	8.9	8.9	8.9
Sulphate Release Rate/Carbonate Consumption Rate	1.4	2.5	1.5	1.3	1.4	1.1

Table C-7 Soil chemical properties of tailings storage facility sub-soils and clay-pan material proposed for lake protection bund construction, Cowal Gold Project

Soil Property	Cation	Unit	*TSF Sub-Soils		Clay-Pan Materials		
			Sub-Soil (0 to 4 m)	Sub-Soil (4 to 8 m)	East of Lake (L4)	North of Bund	South of Mine (L1-L3)
Soluble Cations	Na	meq %	3.76	2.82	0.68	0.65	0.50
	K	meq %	0.02	0.04	0.09	0.26	0.22
	Ca	meq %	0.11	<0.08	0.15	0.60	0.68
	Mg	meq %	0.29	0.16	0.16	0.54	0.62
	Al	meq %	-	-	-	-	-
Exchangeable Cation	Na	meq %	4.59	2.18	0.79	0.80	0.69
	K	meq %	0.35	0.34	1.11	1.18	1.11
	Ca	meq %	3.70	1.40	11.35	6.71	8.21
	Mg	meq %	9.61	4.70	6.04	5.01	5.50
	Al	meq %	1.37	0.89	-	-	-
Cation Exchange Capacity (CEC)	CEC meq %	meq %	19.62	9.51	19.29	13.70	15.51
Distribution of	Na	% of CEC	23.4	22.90	4.10	5.80	4.40
Exchangeable Cations	K	% of CEC	1.8	3.60	5.80	8.60	7.20
	Ca	% of CEC	18.9	14.70	58.80	49.00	52.90
	Mg	% of CEC	49.0	49.40	31.30	36.60	35.50
	Al	% of CEC	7.0	9.40	-	-	-

* TSF – Tailings Storage Facility

Table C-8 Chemical composition of solutions from a sequential batch attenuation test performed on tailing storage facility sub-soils using an oxide tailings liquor test solution, Cowal Gold Project

Element Solid/Soln. Ratio (g/mL)	Element Concentration in Solution (mg/l except pH & EC)										Detection Limit
	Test Solution	0.50	Series A 1.00	1.50	2.00	Test Solution	0.50	Series B 0.25	0.167	0.125	
pH	9.8	5.8	4.9	5.0	4.5	9.8	5.8	5.6	5.8	5.6	0.1
EC (dS/m)	4.86	6.06	7.67	7.65	6.71	4.86	6.06	6.28	5.12	6.14	0.001
Alkalinity (mg CaCO ₃ /L)	80	7	10	13	14	80	7	12	9	8	1.0
CN _{total}	29.4	29.7	27.9	25	13	29.4	29.7	31.6	29.8	31.3	0.005
CN _{WAB}	29.4	24.9	23.5	21.7	10.3	29.4	24.9	31.2	29.4	25.1	0.005
As	0.038	0.015	0.015	0.02	0.015	0.038	0.015	0.01	0.01	0.005	0.002
Bi	<	<	<	<	<	<	<	<	<	<	0.001
Ca	175	72	66	76	49	175	72	66	70	78	0.01
Cd	0.006	0.003	0.003	0.002	0.002	0.006	0.003	0.004	0.003	0.003	0.001
Cl	1360	1630	1980	2220	1710	1360	1630	1500	1390	1360	10
Cu	4.32	0.96	0.08	<	<	4.32	0.96	0.85	2.1	3.62	0.01
F	2.5	0.1	<	<	<	2.5	0.1	<	<	<	0.1
Fe	<	0.06	0.02	0.01	0.01	<	0.06	0.03	0.02	<	0.01
K	21	9	8.2	8.4	5.6	21	9	29.5	24.0	19.5	0.1
Mg	2.55	58	84	102	78	2.55	58	49	44	38.0	0.01
Na	860	1000	1180	1300	1060	860	1000	940	920	880	0.1
Ni	0.04	0.07	0.11	0.15	0.09	0.04	0.07	0.08	0.1	0.12	0.01
Pb	<	0.01	0.03	0.005	0.005	<	0.01	0.005	0.005	0.05	0.002
Sb	0.0066	0.0015	0.0005	0.0005	<	0.0066	0.0015	1	0.5	1.5	0.0002
Se	<	0.008	0.012	0.013	0.011	<	0.008	0.009	0.007	0.008	0.001
SO ₄	380	450	520	560	440	380	450	450	440	430	0.3
Zn	2.29	0.31	0.11	0.03	0.01	2.29	0.31	0.26	0.26	0.23	0.01

SERIES A: Re-introduction of sequential test solution to fresh solid sample. SERIES B: Re-introduction of fresh test solution to sequential solid sample.

Table C-9 Chemical composition of solutions from a sequential batch attenuation test performed on tailing storage facility sub-soils using a recombined primary tailings liquor test solution, Cowal Gold Project

Element Solid/Soln. Ratio (g/mL)	Element Concentration in Solution (mg/l except pH & EC)										Detection Limit
	Test Solution	0.50	Series A 1.00	1.50	2.00	Test Solution	0.50	Series B 0.25	0.167	0.125	
pH	9.5	6.6	6.6	6.9	6.3	9.5	6.6	6.7	7.5	7.3	0.1
EC (dS/m)	0.882	2.09	2.37	2.45	2.08	0.882	2.09	1.54	1.02	0.971	0.001
Alkalinity (mg CaCO ₃ /L)	186	63	–	–	–	186	63	–	209	–	1.0
CN _{total}	64.5	71.5	33.1	44.8	–	64.5	71.5	35.4	56.4	60.1	0.005
CN _{WAP}	53.5	32.7	16.8	19.6	–	53.5	32.7	16.5	34.6	26.3	0.005
As	0.075	–	0.006	0.006	0.007	0.075	–	0.07	0.07	0.072	0.002
Bi	<	<	<	<	<	<	<	<	<	<	0.001
Ca	5.0	7.2	5.6	4.9	5.2	5.0	7.2	5.2	5.0	5.0	0.01
Cd	0.001	0.001	0.001	0.001	0.002	0.001	0.001	0.002	0.002	0.002	0.001
Cl	220	490	240	240	175	220	490	170	195	185	10
Cu	10.8	9.16	7.90	6.54	8.31	10.8	9.16	7.59	16.8	16.9	0.01
F	1.1	0.1	1.4	0.4	1.8	1.1	0.1	1.8	1.8	1.8	0.1
Fe	10.3	9.1	2.9	8.5	4.3	10.3	9.1	–	–	–	0.01
K	37	6	30	6.8	35	37	6.0	37	36	34	0.1
Mg	2.6	11	4.3	7.2	3	2.6	11	2.8	3.1	2.9	0.01
Na	140	370	175	160	135	140	370	130	140	140	0.1
Ni	0.13	0.33	0.31	0.27	0.30	0.13	0.33	0.34	1.13	1.09	0.01
Pb	<	0.006	0.006	0.006	<	<	0.006	<	<	<	0.002
Sb	0.0115	0.0006	0.0084	0.0006	0.0100	0.0115	0.0006	0.0102	0.0102	0.0100	0.0002
Se	0.001	<	<	<	<	0.001	<	<	<	<	0.001
SO ₄	68	220	94	78	82	68	220	90	102	102	0.3
Zn	1.98	0.04	0.1	–	–	1.98	0.04	2.13	4.44	2.17	0.01

Table C-10 Chemical composition of solutions from a sequential batch attenuation test performed on tailing storage facility sub-soils using a primary flotation tailings liquor test solution, Cowal Gold Project

Element Solid/Soln. Ratio (g/mL)	Element Concentration in Solution (mg/l except pH & EC)										Detection Limit
	Test Solution	0.50	Series A 1.00	1.50	2.00	Test Solution	0.50	Series B 0.25	0.167	0.125	
pH	8.1	5.5	5.2	5.5	6.4	8.1	5.5	6.4	6.2	6.7	0.1
EC (dS/m)	0.621	1.95	3.71	3.52	1.99	0.621	1.95	1.13	0.924	0.532	0.001
Alkalinity (mg CaCO ₃ /L)	95	6	19	35	0	95	6	20	–	88	1.0
As	0.01	<	<	0.002	0.004	0.01	<	0.004	0.004	0.004	0.002
Bi	<	<	<	<	<	<	<	<	<	<	0.001
Ca	19	6.4	16.5	21.5	16.5	19	6.4	20	20	19.5	0.01
Cd	<	0.001	0.002	0.003	0.003	<	0.001	0.001	0.001	0.001	0.001
Cl	30	420	750	840	420	30	420	35	30	30	10
Cu	0.01	0.02	0.03	0.03	0.02	0.01	0.02	0.01	0.01	0.01	0.01
F	1.1	0.1	<	<	0.3	1.1	0.1	1.1	1.1	1.2	0.1
Fe	0.03	0.42	0.58	0.36	0.38	0.03	0.42	0.05	<	<	0.01
K	39	5.8	6.0	11	17	39	5.8	39	38	38	0.1
Mg	8.6	10.2	26.5	31	18.5	8.6	10.2	9.6	9.2	9.2	0.01
Na	38	340	560	620	340	38	340	44	39	37	0.1
Ni	<	0.01	0.01	0.01	0.01	<	0.01	<	0.01	0.01	0.01
Pb	<	<	0.002	0.02	0.002	<	<	0.01	<	0.006	0.002
Sb	0.003	0.0002	0.0002	0.0002	0.0012	0.003	0.0002	0.0026	0.0026	0.0024	0.0002
Se	<	<	<	<	<	<	<	<	<	<	0.001
SO ₄	50	210	295	300	165	50	210	50	47	47	0.3
Zn	0.02	0.04	0.03	0.04	0.05	0.02	0.04	0.02	0.03	0.02	0.01

SERIES A: Re-introduction of sequential test solution to fresh solid sample. SERIES B: Re-introduction of fresh test solution to sequential solid sample.

Figure C-1 Change in pH with increasing solid to solution ratio (Series A) for the sub-soil sequential batch tests.

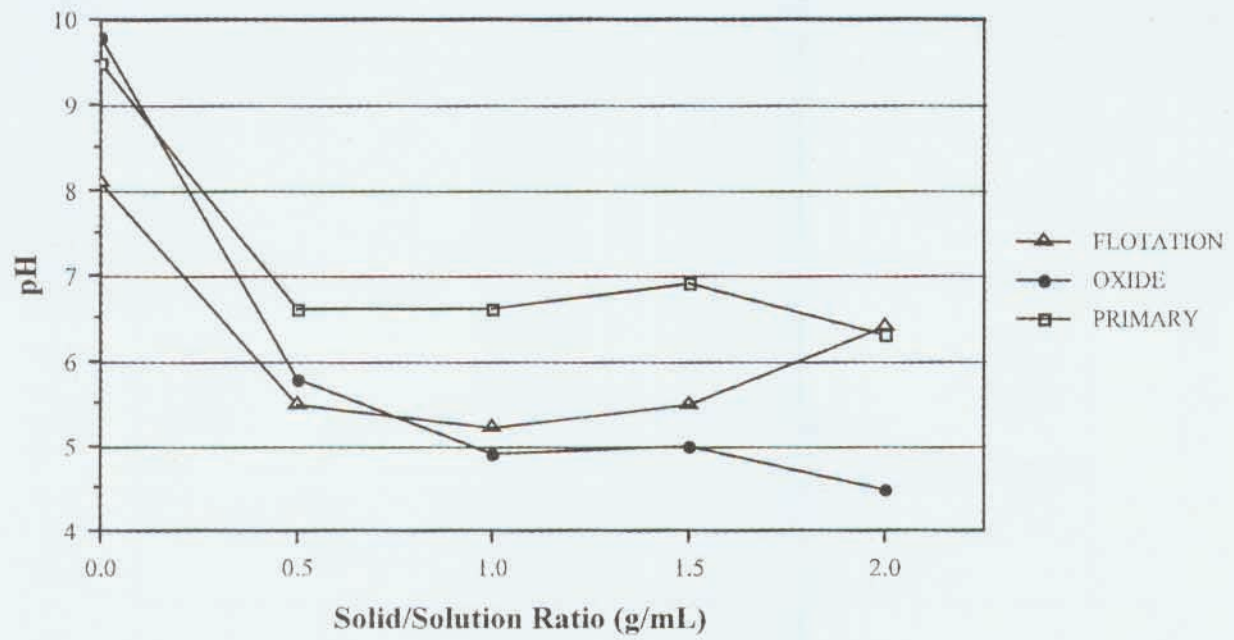


Figure C-2 Change in electrical conductivity with increasing solid to solution ratio (Series A) for the sub-soil sequential batch tests.

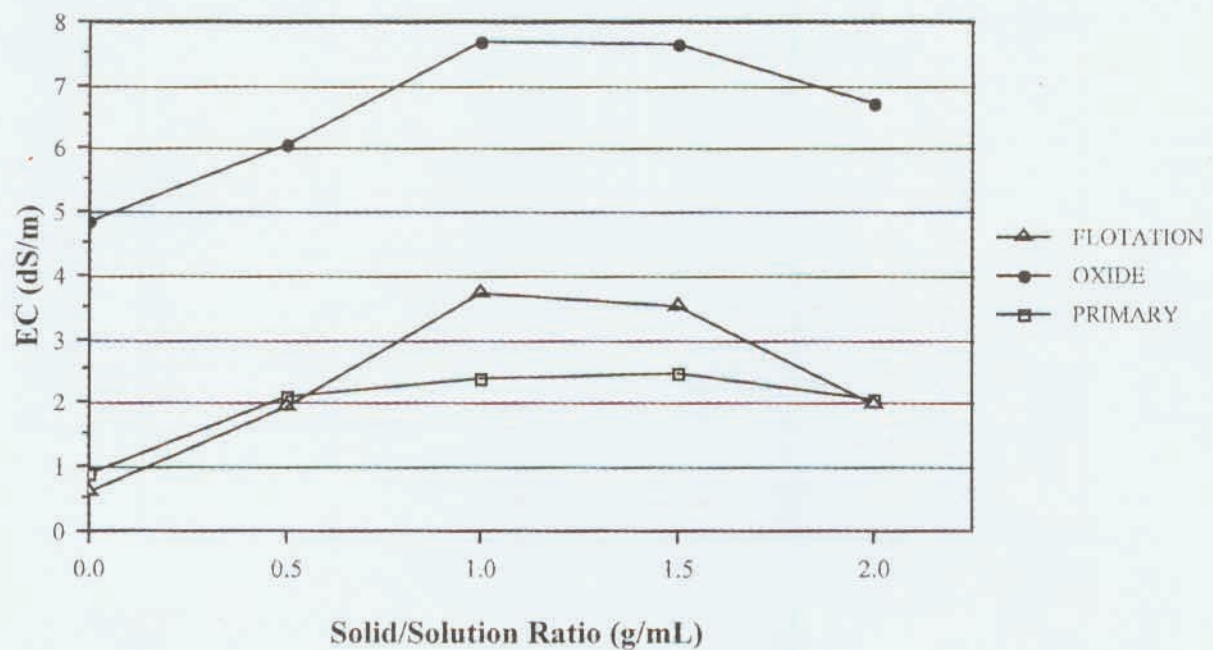


Figure C-3 Change in element and CN concentration in the oxide tailings liquor test solution with increasing solid to solution ratio during the sub-soil sequential batch test.

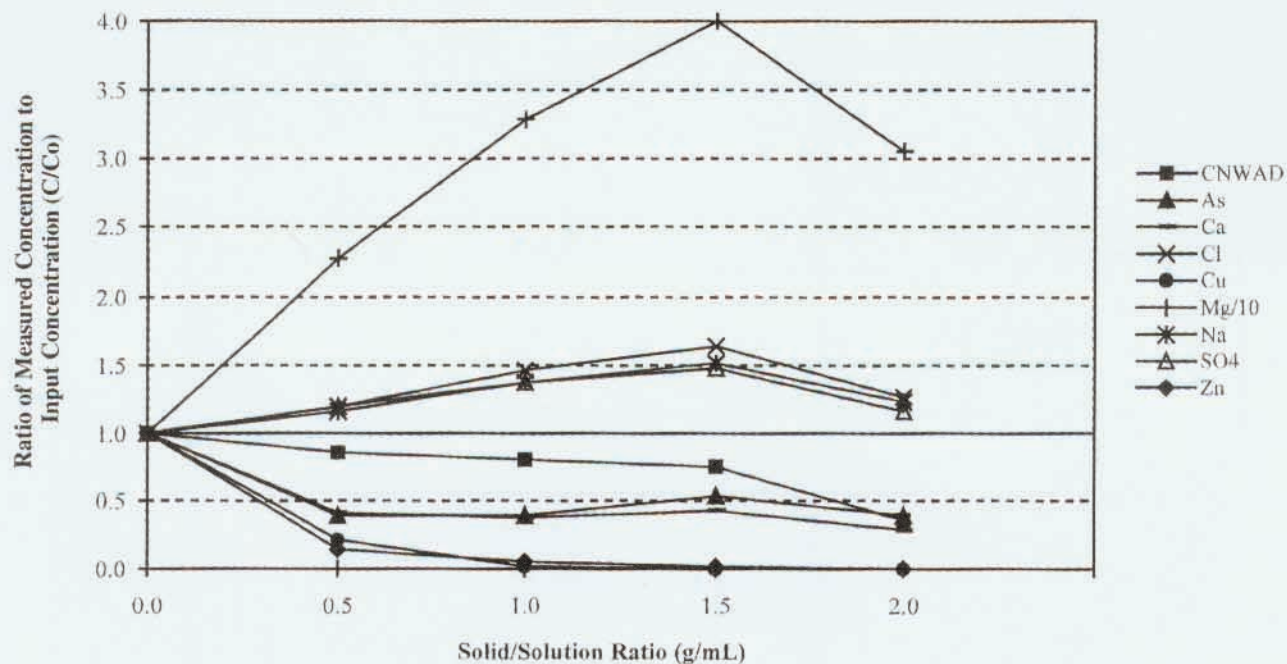


Figure C-4 Change in element and CN concentration in the recombined primary tailings liquor test solution with increasing solid to solution ratio during the sub-soil sequential batch test.

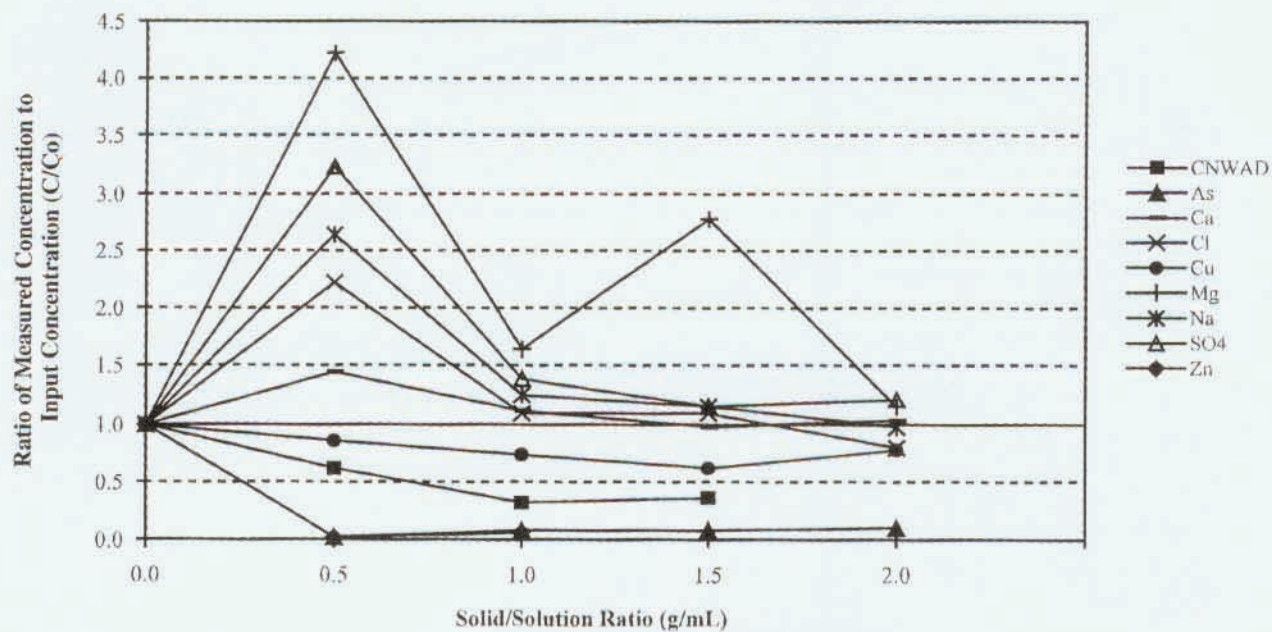
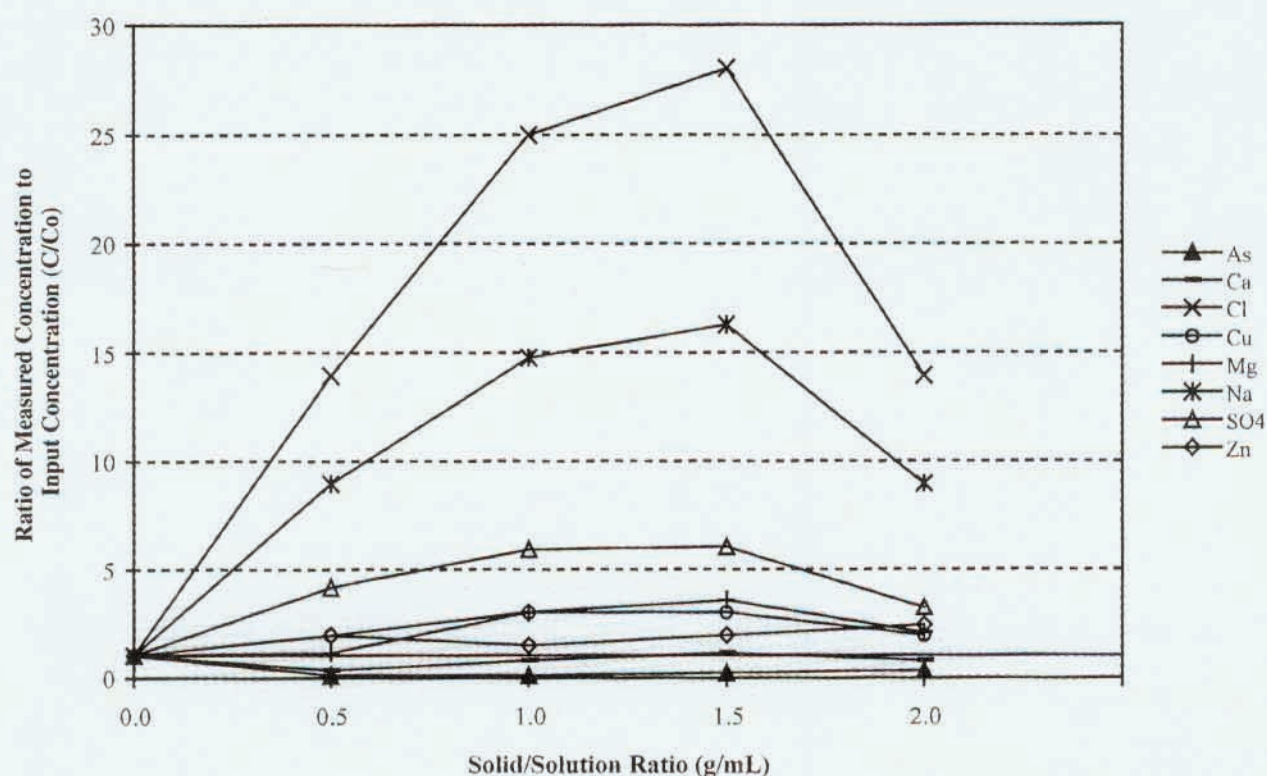


Figure C-5 Change in element concentration in the primary flotation tailings liquor test solution with increasing solid to solution ratio during the sub-soil sequential batch test.



The results indicate the following attenuation characteristics for the sub-soil material:

Constituent	Attenuation Capacity Characteristics of Sub-Soil		
	Oxide Tailings Liquor	Recombined Primary Tailings Liquor	Primary Flotation Residue Liquor
CN _{WAD}	Low	Low	–
Cu	High	Low	–
Zn	High	High	–
As	High	High	High

6.0 CLAY-PAN MATERIAL GEOCHEMISTRY

6.1 Acid Forming Characteristics

The acid forming characteristics of the clay-pan material samples (proposed to be used to construct the lake protection bund) are presented on Table C-1 and indicate that these materials are naturally slightly alkaline (pH_{1.2} of 7.8 to 8.0) and non-saline (EC_{1.2} of 0.362 to 0.581 dS/m). The S content is very low (<0.01 %S) and the ANC ranged from 5 to 7 kg H₂SO₄/t. These materials are classified as NAF.

6.2 Soil Chemical Properties

The soil chemical properties of the clay-pan material samples are presented on Table C-5. The results indicate that these materials are not sodic and that Ca concentrations are marginally low. These materials also have a relatively high cation exchange capacity (CEC = 13.7 to 19.29 meq%).

6.3 Solution Chemistry

To investigate the likely run-off chemistry from clay-pan material that will be used for the lake protection bund, a sequential batch test was carried out using deionised water. The sequential batch test procedure is discussed in Section 3.2.5 (Assessment of Constituent Solubility, Salinity and Leaching Behaviour) and results from the test are presented on Table C-11. The results indicate that runoff from the clay pan material is likely to be slightly alkaline pH (pH approx. 8.5) with a low salinity (EC approx. 0.10 to 0.15 dS/m). The dominant soluble constituents will be Na and Cl.

7.0 WASTE ROCK GEOCHEMISTRY

7.1 Acid Forming Characteristics

The acid forming characteristics of the composite oxide and primary waste rock samples are presented on Table C-1. A list of the samples used to produce the composites and their geochemical characteristics are supplied in Attachment A. These results indicate that the waste rock has a slightly alkaline pH (pH_{1.2} = 8.5 – 8.9) and that the oxide waste rock is likely to have high salinity (EC_{1.2} = 2.29 dS/m) while the primary waste rock is likely to have moderate salinity (EC_{1.2} = 0.831 dS/m). The oxide sample had a low S content (0.03 %S) and low ANC (14 kg H₂SO₄/t), and material represented by this sample is expected to be NAF. The primary waste rock sample had a moderate S (1.06 %S) and high ANC (109 kg H₂SO₄/t) and material represented by this sample is also expected to be NAF. However, the primary waste rock is likely to generate significant sulphate salts, such as gypsum, if left exposed to surficial oxidation processes.

Table C-11 Chemical composition of solutions from a sequential batch water extraction test performed on clay-pan sample (L4) collected from the proposed lake protection bund construction material source, Cowal Gold Project

Element Solid/Soln. Ratio (g/mL)	Element Concentration in Solution (mg/l except pH & EC)				Detection Limit
	0.50	0.25	Series B 0.167	0.125	
pH	8.2	8.3	8.6	8.6	0.1
EC (dS/m)	0.516	0.205	0.153	0.136	0.001
Alkalinity (mg CaCO ₃ /L)	74	62	62	46	1.0
Ca	1.95	1.00	0.68	2.00	0.01
Cl	15	10	15	30	10
Fe	0.18	0.33	0.33	0.30	0.01
K	4.6	2.8	2.6	2.9	0.1
Mg	1.4	1.2	1.1	1.6	0.01
Na	17.5	14.5	15.0	28.0	0.1
SO ₄	3.3	2.1	2.1	8.1	0.3

SERIES A: Re-introduction of sequential test solution to fresh solid sample.

Table C-12 Chemical composition of solutions from a sequential batch water extraction test performed on a composite oxide waste rock sample, Cowal Gold Project

Element Solid/Soln. Ratio (g/mL)	Element Concentration in Solution (mg/l except pH & EC)								Detection Limit
	0.50	Series A			0.50	Series B			
		1.00	1.50	2.00		0.25	0.167	0.125	
pH	7.6	8.4	8.2	7.9	7.6	8.5	8.6	8.6	0.1
EC (dS/m)	1.04	2.31	3.06	3.57	1.04	0.772	0.421	0.203	0.001
Alkalinity (mg CaCO ₃ /L)	26	48	56	58	26	43	33	30	1.0
As	<	<	<	<	<	<	<	<	0.005
Bi	<	<	<	<	<	<	<	<	0.001
Ca	9.4	23.5	29	33	9.4	6.2	2.55	2.7	0.01
Cd	<	<	<	<	<	<	0.001	<	0.001
Cl	200	530	740	820	200	140	45	15	10
Cu	0.01	<	<	<	0.01	<	0.01	<	0.01
F	0.9	1.6	1.6	1.5	0.9	1.3	0.9	0.5	0.1
Fe	<	<	<	<	<	<	<	0.07	0.01
K	8.2	8	8.2	8.6	8.2	2.6	1.5	1.5	0.1
Mg	7.8	23	30	36	7.8	5.4	2	2.2	0.01
Na	160	410	540	600	160	135	56	28	0.1
Ni	<	<	0.03	0.02	<	0.02	0.01	0.02	0.01
Pb	<	0.005	0.005	0.015	<	<	<	0.01	0.005
Sb	0.0005	<	<	<	0.0005	0.0005	0.0005	<	0.0005
Se	<	<	0.001	<	<	<	<	<	0.001
SO ₄	70	175	235	255	70	52	20.5	10.2	0.3
Zn	0.02	0.02	0.02	0.02	0.02	0.03	0.01	0.03	0.01

SERIES A: Re-introduction of sequential test solution to fresh solid sample. SERIES B: Re-introduction of fresh test solution to sequential solid sample.

Table C-13 Chemical composition of solutions from a sequential batch water extraction test performed on a composite primary waste rock sample, Cowal Gold Project

Element Solid/Soln. Ratio (g/mL)	Element Concentration in Solution (mg/l except pH & EC)								Detection Limit
	0.50	Series A			0.50	Series B			
		1.13	2.13	3.44		0.25	0.167	0.125	
pH	8.5	8.7	8.6	8.1	8.5	8.8	9.0	9.2	0.1
EC (dS/m)	0.742	1.46	1.92	2.15	0.742	0.562	0.209	0.132	0.001
Alkalinity (mg CaCO ₃ /L)	16	28	33	35	16	59	30	31	1.0
As	0.005	0.005	0.005	0.005	0.005	<	0.005	<	0.005
Bi	<	<	<	<	<	<	<	<	0.001
Ca	21	41	54	56	21	17	8.8	7.8	0.01
Cd	<	<	<	<	<	<	<	<	0.001
Cl	140	320	430	450	140	95	25	15	10
Cu	<	<	<	<	<	<	<	<	0.01
F	0.1	0.2	0.2	0.3	0.1	0.2	0.1	0.1	0.1
Fe	<	<	<	<	<	<	<	<	0.01
K	10	21.5	31	35	10	9.8	4.7	3.6	0.1
Mg	8	16.5	21.5	22	8	7.4	3	2.7	0.01
Na	100	205	280	295	100	82	31	21	0.1
Ni	<	<	0.01	0.01	<	0.01	0.01	0.02	0.01
Pb	<	0.005	0.005	<	<	0.005	<	<	0.005
Sb	0.0005	0.0005	0.001	0.001	0.0005	0.0005	0.0005	0.0005	0.0005
Se	<	<	<	<	<	<	<	<	0.001
SO ₄	70	145	195	215	70	72	29.5	23	0.3
Zn	0.01	0.02	0.02	0.02	0.01	0.02	0.01	0.02	0.01

SERIES A: Re-introduction of sequential test solution to fresh solid sample. SERIES B: Re-introduction of fresh test solution to sequential solid sample.

7.2 Salinity Release

Salinity release from the oxide and primary waste rock was investigated using a sequential batch test. Deionised water was used as the test solution to allow prediction of the leachate and run-off water quality from the waste dumps. Results from these tests are presented on Tables C-12 and C-13, respectively.

Series A of the test involved the re-introduction of a sequential deionised water test solution to fresh waste rock sample. This series simulates the reactions that take place as leachates migrate through a waste rock dump. Constituent concentrations in the test solutions indicate the likely upper concentration limits for soluble salts in dump leachate. Series B of the test involved the re-introduction of fresh deionised water test solution to sequential waste rock sample. Results from Series B are used to indicate likely run-off water chemistry under a more dilute system (e.g. run-off during storm events).

Test solution pH's for the sequential batch tests were relatively consistent and slightly alkaline ranging from 7.6 to 8.6 for the oxide waste rock and 8.1 to 9.2 for the primary waste rock.

Electrical conductivity values, presented on Tables C-12 and C-13, indicate an increase in soluble salt release as deionised water is sequentially mixed with fresh waste rock sample

(Series A). The dominant soluble constituents are Na and Cl and to a lesser degree Ca, Mg and SO₄. These soluble constituents exhibit similar concentration trends when the solid sample to solution ratio is increased and this trend is shown on Figures C-6 and C-7 for Ca and SO₄, respectively. These plots show that, with increased solid sample to solution ratio, soluble constituents within the waste rock exhibit a typical trend toward the upper concentration limits. As leachates migrate through the waste rock dump the upper concentration limits are likely to range from 2,000 to 2,500 mg TDS/L in the oxide waste rock and 1,500 to 2,000 mg TDS/L in the primary waste rock.

7.3 Metal Enrichment and Solubility

Previous test work carried out by EGi indicated a potential arsenic (As) concern. It was recommended that, because of high concentrations of As in the waste rock solids, that its indicated low solubility be further investigated. Results from the sequential batch tests performed during the current investigations confirm that As is not soluble under water leaching and is not likely to be a water quality concern.

8.0 PIT VOID WATER QUALITY

Final pit wall rocks will predominantly comprise coarse volcanics and intrusives (diorite/gabbro). Previous testing carried out on mine rock from the Cowal Project

Figure C-6 Change in Ca concentration with increasing solid to solution ratio (Series A) for the waste rock sequential batch tests.

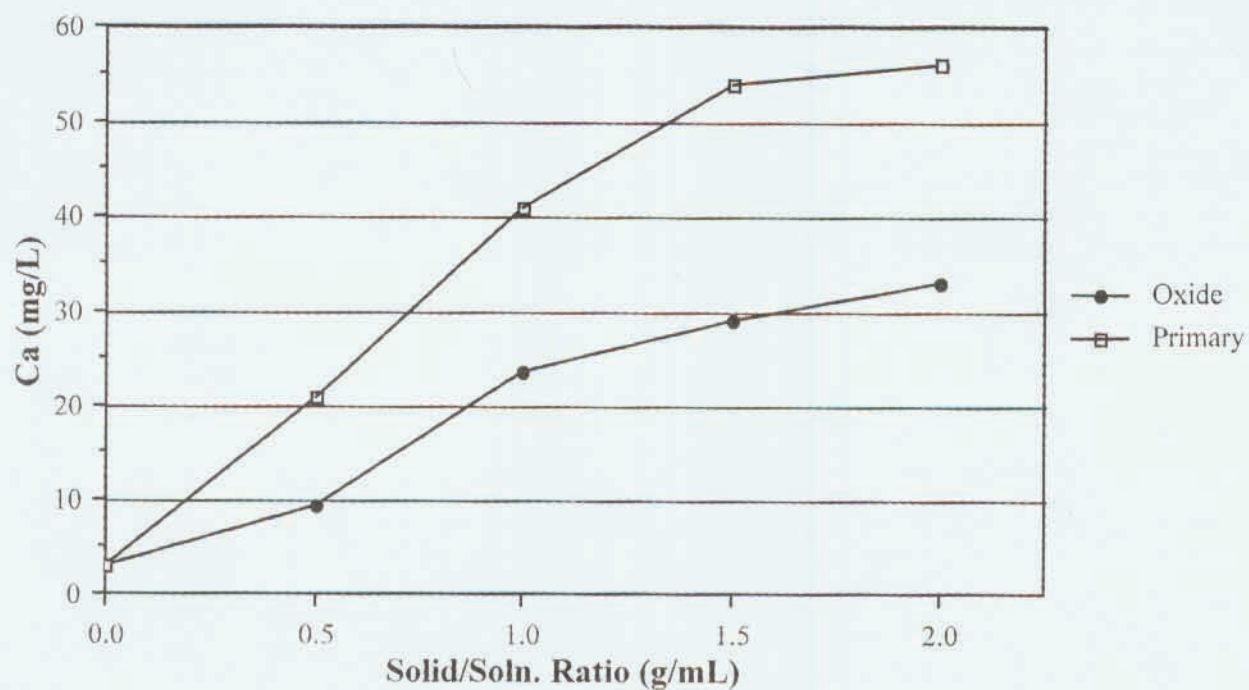
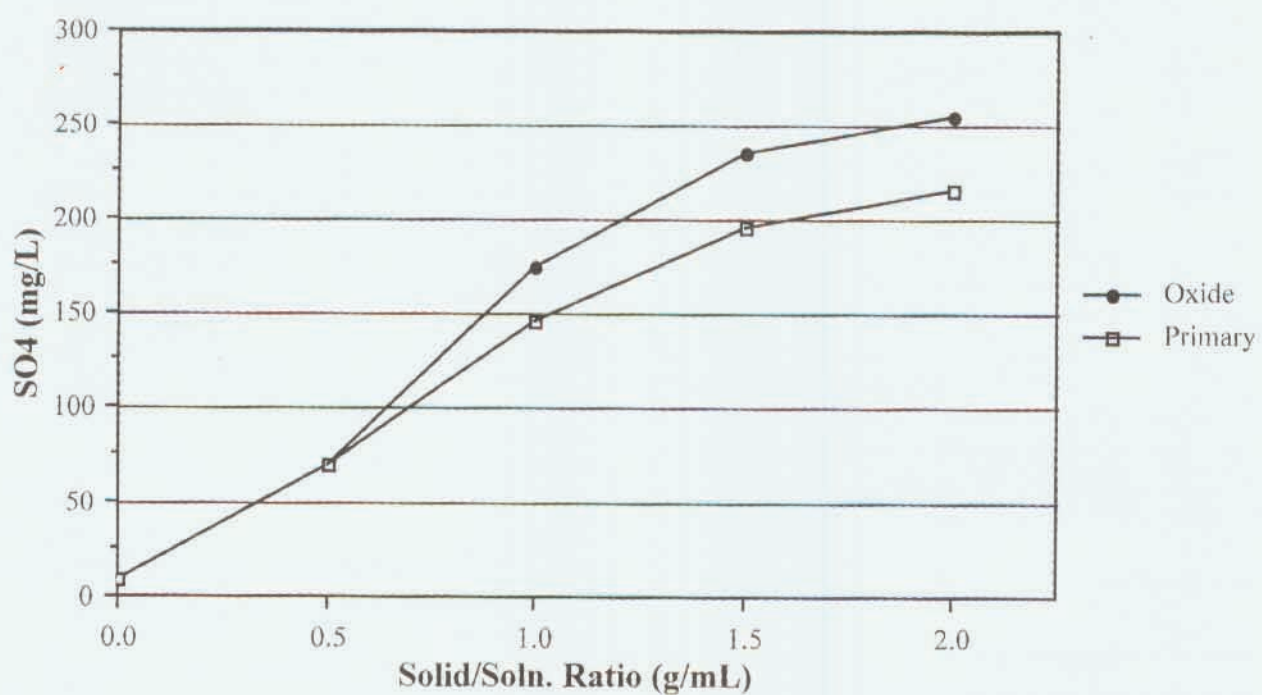


Figure C-7 Change in SO₄ concentration with increasing solid to solution ratio (Series A) for the waste rock sequential batch tests.



(EGi, 1995) indicates that these rock types are likely to be NAF (Attachment A). From a total 56 coarse volcanoclastics and intrusive samples tested only one was classified as PAF and this sample only had a low capacity to generate acid.

Even though the primary rock is expected to be non-acid forming, the rock contains, on average, about 1 %S and an ANC of about 100 kg H₂SO₄/t. Due to the presence of these reactive sulphides, oxidation of primary rock exposed along the pit walls is likely to generate a moderate load of sulphate salts. However, considering the regional groundwater has a TDS of around 40,000 to 45,000 mg/L, the contribution of sulphate salts from the pit walls to the overall TDS of pit water is expected to be negligible.

9.0 LEACHATE AND RUNOFF CHEMISTRY

9.1 Predicted Leachate Chemistry for the Tailings Storage Facility

Predicted leachate chemistry of the proposed tailings storage facility at the Cowal Project is presented on Table C-14.

During the operational phase leachate from the tailings storages is likely to have a pH from 4.5 to 7.0 and a total suspended solids (TDS) concentration of 1,500 to 2,500 mg/L. Concentrations of CN_{wad} between 20-40 mg/L are expected, however, this will be significantly reduced if the free CN component is removed prior to tailings liquor discharge. Copper concentrations are expected to be in the range below 1 up to 10 mg/L, Zn is expected to be below 1 mg/L and As below 0.05 mg/L.

For the purposes of predicting water chemistry resulting from mining activities at the Cowal Project, long term is defined as any point in time after mine closure. The long term tailings storage leachate chemistry is expected to have a pH range of 5.5 to 7.0 and a TDS of between 4,000 to 6,000 mg/L due the generation of sulphate salts through the process of sulphide oxidation. Concentrations of CN_{wad}, Cu and Zn are expected to be below 1 mg/L and As is expected to remain below 0.05 mg/L.

9.2 Estimated Salinity Release from Mining Activities

The long term steady state salinity release rates and total available soluble salt loads resulting from the proposed mining activities at the Cowal Project have been estimated and are presented on Table C-15. Under the current mine plan the potential sites of increased soluble salt loads include the following:

- tailings cover (surface zone material proposed);
- waste rock dumps; and
- lake protection bund (clay-pan material proposed).

The surface zone, waste rock and clay-pan materials are classified as non-acid forming and sulphide oxidation is not expected to contribute significantly to the total soluble salt load. The dominant soluble constituents in leachate and runoff will be Na and Cl. It is estimated that long term steady state leachate through the tailings cover material (sourced from the surface zone material) will have a TDS

Table C-14 Predicted chemistry of the leachate and underdrainage from the tailings storage facility, Cowal Gold Project.

Parameter	Oxide Tailings Leachate		Primary Tailings Leachate		Tailings Storage Underdrainage*	
	Operational Phase	Long Term	Operational Phase	Long Term	Operational Phase	Long Term
pH	10.0	7.5	9.5 – 10.0	7.5	4.5 – 7.0	5.5 – 7.0
Cl (mg/L)	1,000-1,500	<100	200-250	<50	400-800	<50
SO ₄ (mg/L)	300-400	<50	50-100	*2,000-2,500	300-400	*2,000-2,500
TDS (mg/L)	3,000-4,000	<300	400-600	3,000-5,000	1,500-2,500	4,000-6,000
CN _{wad} (mg/L)	<30	<1	<30	<1	<30	<1
Cu (mg/L)	4 – 5	<0.1	10 – 15	<0.1	<1 – 10	<1
Zn (mg/L)	2 – 4	<0.1	2 – 4	<0.1	<1	<1
As (mg/L)	0.05	0.05	0.1	0.1	<0.05	<0.05

* Tailings storage underdrainage includes leachate that migrates from the oxide and primary tailings through the underlying sub-soils.

* Sulphate concentrations in primary tailings leachate will be controlled by gypsum solubility at between 2,000 to 2,500 mg SO₄/L.

Table C-15 Estimated salinity release rates and soluble salt loads from mining activities at the Cowal Gold Project

Mine Component	Total Available Soluble Salts (mg/kg)	Long-Term Steady State TDS Concentration (mg/L)	
		Seepage	Runoff
Surface Zone Material (Tailings Cover)	*2,500 to 5,000	** 1,500 to 2,500	**<100
Waste Rock Dump: Oxide Waste Rock	*3,000	2,000 to 2,500	<100
Primary Waste Rock	*2,000	1,500 to 2,000	<100
Lake Protection Bund (Clay-Pan) Material	*1,500 to 2,000	–	100 to 200

* Assumes materials are non-acid forming and no significant sulphide oxidation.

** Estimated steady state concentrations.

of 1,500 to 2,500 mg/L. Drainage through the oxide waste rock is likely to have a TDS of 2,000 to 2,500 mg/L and through the primary waste rock, likely have a lower TDS of 1,500 to 2,000 mg/L. Long term steady state runoff from the tailings cover and waste rock dumps is likely to have a TDS of less than 100 mg/L and from the lake protection bund, is likely to have a TDS of between 100 and 200 mg/L.

10.0 CONCLUSIONS

10.1 Tailings Storage Facility

- The oxide and primary tailings are classified as non-acid forming. However, due to a moderate reactive S content (total S = 2.4 %S) and ANC (71 kg H₂SO₄/t) in the primary tailings, relatively high concentrations of sulphate salts are expected.
- High As concentrations in the tailings (~100 to 200 mg/kg) are a potential environmental concern for leachate water quality.
- With respect to cyanide, EGI understands that North have committed the Cowal Gold project to meeting the following design specifications at the point of discharge to the enclosed tailings storage:

The tailings slurry discharge shall contain no greater than 30 mg/L CN_{WAD} for 100% of the time and no greater than 20 mg/L CN_{WAD} for 90% of the time.

- On the basis of EGI's cyanide investigations using the samples supplied, which indicate that about 75% of the cyanide in the process liquor is present as free CN, it is expected that ongoing decay in tailings storage should result in CN_{WAD} concentrations in the reclaim water dam from 5 to 10 mg/L when processing oxide ore and 10 to 15 mg/L when processing primary ore. Once discharge ceases it is expected that within 2 to 3 months the CN_{WAD} complexes in the ponded decant will decay to very low concentrations. Once entrained, the Cu-CN complexes, which predominate in the tailings liquor, will transform to the more stable and non-toxic Fe-CN complexes.
- Leach columns of the tailings indicate an initial flush of 'soluble' Cu and Zn from the oxide tailings and 'soluble' Cu from the primary tailings. This release is most likely associated with the residual cyanide in the tailings liquor and does not represent a long term concern.
- The preliminary leach column results indicate that the sulphate release rate from the tailings is either equivalent to or exceeds the carbonate consumption rate and that contained sulphides in these materials will be depleted before the available carbonates (ANC). Therefore, it is highly unlikely that these materials will ever generate acid conditions.
- Cyanide is only poorly attenuated whereas Cu, Zn and As are generally strongly attenuated by the soils underlying the proposed tailings storages.

- The predicted chemistry of leachate under the tailings storage facility is summarised below:

Parameter	Operational Phase	Long Term
pH	4.5 - 7.0	5.5 - 7.0
TDS (mg/L)	1,500 - 2,500 ¹	4,000 - 6,000
CN _{WAD} (mg/L)	<30	< 1
Cu (mg/L)	< 1 - 10	< 1
Zn (mg/L)	<1	< 1
As (mg/L)	<0.05	< 0.05

¹ Assumes surface waters of low TDS used for processing.

10.2 Lake Protection Bund

- The clay-pan material proposed for the lake protection bund construction is classified as non-saline and has a high cation exchange capacity. The long term steady state runoff is expected to have a TDS concentration of 100 to 200 mg/L, and Na and Cl will be the dominant soluble constituents.

10.3 Waste Rock Dumps

- The oxide and primary waste rock are classified as non-acid forming, however, a salinity concern exists. The oxide waste rock has relatively high natural salinity and the primary waste rock has the potential to generate soluble salts through the oxidation of contained reactive sulphides.
- It is estimated that the long term steady state leachate through the waste rock dump will range in TDS from 1,500 to 2,500 mg/L depending on the oxide/primary waste rock dumping strategy. The oxide waste rock has a higher content of readily soluble salts than the primary waste.
- The long term steady state TDS concentration in runoff from the waste rock dump is not likely to exceed 100 mg/L.

10.4 Pit Void

- Pit walls and floor rock exposed during mine operation are expected to be non-acid forming. However, due to the presence of reactive sulphides in primary rock, oxidation is likely to generate a moderate load of sulphate salts. However, since groundwater with a TDS of around 40,000 to 45,000 mg/L will be the main water source in the pit, the contribution of sulphate salts from oxidising exposed rocks will be negligible.
- During the post-closure period the void will be allowed to fill with water (predominately groundwater). When flooded oxidation of the floor rock and pit wall (below the water level), will essentially stop.

Attachment A

Identification and Acid Forming Characteristics of Waste Rock Composite Materials

Table A1 Sample identification and acid forming characteristics of samples used to produce the oxide waste rock composite sample

Hole No.	Depth Interval (m)		pH	EC (dS/m)	Acid Base Analysis		
	From	To			Total S (%S)	ANC (kg H ₂ SO ₄ /t)	NAPP
PR/57	70	71	9.3	1.67	0.05	65	-63
	9	10	8.1	0.77	0.03	3	-2
DDH/73	70	71	8.4	0.11	0.01	1	-1
	87	88	7.2	0.61	0.01	2	-2
DDH/157	50	51	7.9	0.46	0.02	8	-7
RP/214	39	40	7.7	2.17	0.06	5	-3

Table A2 Sample identification and acid forming characteristics of samples used to produce the primary waste rock composite sample

Hole No.	Depth Interval (m)		pH	EC (dS/m)	Acid Base Analysis		
	From	To			Total S (%S)	ANC (kg H ₂ SO ₄ /t)	NAPP
DDH/42	70	71	8.4	2.62	0.18	81	-75
	90	91	9.4	0.20	0.60	139	-121
	110	111	9.4	0.22	0.43	185	-172
	129	130	9.4	0.25	1.69	125	-74
	150	151	9.6	0.19	0.15	187	-182
	170	171	9.3	0.20	1.15	88	-53
	190	191	9.4	0.17	0.11	88	-85
	210	211	9.3	0.15	0.68	68	-47
	230	231	9.3	0.16	0.63	90	-71
	250	251	9.4	0.17	0.75	73	-50
	273	274	8.3	0.21	2.45	99	-24
	291	292	9.3	0.15	0.35	83	-73
	310	311	9.3	0.17	0.59	75	-58
	330	331	9.1	0.17	1.41	52	-9
	347	348	8.9	0.24	1.68	74	-23
	370	371	9.0	0.16	1.49	123	-78
	390	391	9.0	0.13	0.04	143	-142
	410	411	9.4	0.19	0.46	174	-160
	430	431	9.6	0.16	0.30	164	-155
	450	451	9.0	0.13	0.07	235	-233
PR/57	470	471	9.2	0.16	1.23	131	-94
	90	91	9.0	0.20	0.93	122	-94
	110	111	8.9	0.16	0.66	195	-175
	130	131	9.2	0.18	1.02	124	-93
	150	151	9.0	0.15	0.62	42	-23
	170	171	9.3	0.22	0.27	117	-109
	190	191	9.4	0.15	0.36	74	-63
	210	211	9.3	0.15	0.26	7	1
	230	231	9.4	0.13	0.56	115	-98
	250	251	9.3	0.16	0.63	132	-113
DDH/73	111	112	9.6	0.27	1.13	110	-76
	131	132	9.7	0.23	0.86	80	-54
	150	151	9.6	0.21	0.88	165	-138
	170	171	9.7	0.20	4.58	131	8
	190	191	8.8	0.37	1.94	111	-52
	210	211	9.2	0.22	0.37	188	-177
	230	231	8.7	0.17	1.53	84	-38
	250	251	9.2	0.18	1.09	92	-59
	270	271	9.3	0.19	0.91	125	-97
	290	291	9.2	0.17	0.23	127	-120
RP/124	313	314	9.2	0.17	0.62	110	-91
	330	331	9.2	0.16	0.81	15	10
	349	350	9.2	0.15	3.28	101	-1
	130	131	8.4	2.72	0.74	78	-56
	146	147	9.3	0.67	0.09	247	-244
DDH/157	90	91	9.5	0.17	0.20	27	-21
	110	111	9.5	0.19	0.04	39	-38
	130	131	9.5	0.20	1.23	70	-33
	150	151	9.6	0.18	0.20	40	-34
	170	171	9.6	0.18	0.35	99	-88
	190	191	9.5	0.19	0.68	43	-23
	210	211	9.4	0.18	1.86	94	-38
	230	231	9.2	0.26	2.44	110	-36
	250	251	9.1	0.25	2.76	94	-10
	272	273	9.4	0.12	0.78	112	-89
RP/214	295	296	9.1	0.29	6.04	108	75
	150	151	8.4	1.93	4.77	170	-25
	170	171	8.7	1.20	0.08	134	-132
	190	191	8.6	1.24	0.55	97	-80

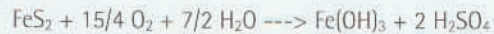
Attachment B

Evaluation and Interpretation of Mine Waste Geochemical Data

- Acid Generation and Prediction
- Element Enrichment and Solubility

ACID GENERATION AND PREDICTION

Acid generation is caused by the exposure of sulphide minerals, most commonly pyrite (FeS_2), to atmospheric oxygen and water. Sulphur assay results are used to calculate the maximum acid that could be generated by the sample by either directly determining the pyritic S content or assuming that all sulphur not present as sulphate occurs as pyrite. Pyrite reacts under oxidising conditions to generate acid according to the following overall reaction:



According to this reaction, the maximum potential acidity (MPA) of a sample containing 1 %S as pyrite would be 30.6 kg H_2SO_4 /t.

The chemical components of the acid generation process consist of the above sulphide oxidation reaction and acid neutralisation which is mainly provided by inherent carbonates and to a lesser extent silicate materials. The amount and rate of acid generation is determined by the interaction and overall balance of the acid generation and neutralisation components.

Net Acid Producing Potential

The net acid producing potential (NAPP) is used as an indicator of materials that may be of concern with respect to acid generation. The NAPP calculation represents the balance between the maximum potential acidity (MPA) of a sample, which is derived from the sulphide sulphur content, and the acid neutralising capacity (ANC) of the material, which is determined experimentally. By convention, the NAPP result is expressed in units of kg H_2SO_4 /t sample. If the capacity of the solids to neutralise acid (ANC) exceeds their capacity to generate acid (MPA), then the NAPP of the material is negative. Conversely, if the MPA exceeds the ANC, the NAPP of the material is positive. A NAPP assessment involves a series of analytical tests which include:

- **Determination of pH and EC**
pH and EC measured on 1:2 w/w water extract. This gives an indication of the inherent acidity and salinity of the waste material when initially exposed in a waste emplacement area.
- **Total sulfur content and Maximum Potential Acidity (MPA)**
Total sulphur content is determined by the Leco high temperature combustion method. The total content is then used to calculate the MPA, which is based on the assumption that all the sulphur occurs as reactive pyrite. A more accurate estimate of the MPA can be made by determining pyritic sulphur and other sulphur forms directly.

- **Acid neutralising capacity (ANC)**

By addition of acid to a known weight of sample, then titration with NaOH to determine the amount of residual acid. The ANC measures the capacity of a sample to react with and neutralise acid. The ANC can be further evaluated by slow acidimetric titration to a set end-point and then calculation of the amount of acid consumed and evaluation of the resultant titration curve.

- **Net acid producing potential (NAPP)**

Calculated from the MPA and ANC results. The NAPP represents the balance between a samples inherent capacities to generate and neutralise acid. If the MPA is greater than the ANC then the NAPP is positive. If the MPA is less than the ANC then the sample then the NAPP is negative.

Net Acid Generation

The net acid generation (NAG) test involves the addition of hydrogen peroxide to a sample of mine rock or process residue to oxidise reactive sulphide, then measurement of pH and titration of any net acidity produced by the acid generation and neutralisation reactions occurring in the sample. A significant NAG result (i.e. final NAGpH < 4) confirms that the sample is potentially acid forming and the test provides a direct measure of the net amount of acid remaining in the sample after all acid generating and acid neutralising reactions have taken place. A NAGpH = 4 indicates that the sample is non-acid generating.

The NAG test provides a direct assessment of the potential for a material to produce acid after a period of exposure and weathering and is used to refine the results of the theoretical NAPP predictions. The NAG test can be used as a stand alone test but is recommended that this only be considered after site specific calibration work is carried out.

The NAG test kinetics can also be monitored during the reaction and the acquired data can be used to provide an indication of the sulphide reactivity and likely reaction kinetics in the field. The two main NAG tests utilised by EGI are:

- **Static net acid generation (NAG) test**
By the hydrogen peroxide oxidation method. Standard NAG tests are usually carried out on all samples.
- **Kinetic net acid generation (NAG) test**
By the hydrogen peroxide oxidation method and including monitoring of changes in pH and temperature during oxidation. Monitored NAG tests provide information on sulphide reactivity and an indication of the lag phase that may proceed acid generation when waste rock is exposed in the field. EGI's experience and in-house data base is used to evaluate and interpret the monitored NAG test results.

ASSESSMENT OF ELEMENT ENRICHMENT AND SOLUBILITY

Multi-element scans are carried out to identify any elements that are present in a material at concentrations which may be of environmental concern with respect to surface water quality and revegetation. The samples are generally analysed for the following elements:

Major elements: Al, Ca, Fe, K, Mg, Na, Si, and S

Trace elements: Ag, As, B, Ba, Be, Bi, Cd, Ce, Co, Cr, Cu, F, Hg, Mn, Mo, Ni, P, Pb, Sb, Se, Sn, Sr, Ti, V, W, Zn

The assay result for each element is compared to the average crustal abundance for that element (Bowen, 1979)¹ to provide a measure of the extent of element enrichment.

The extent of enrichment is reported as the Geochemical Abundance Index (GAI) which relates the actual concentration with the crustal abundance on a log 2 scale. The GAI is expressed in 7 integer increments (i.e. 0 through to 6), where a GAI of 0 indicates the element is present at a concentration similar to, or less than, average crustal abundance; and a GAI of 6 indicates approximately a 100-fold, or greater, enrichment above average crustal abundance. As a general rule, a GAI of 3 or greater signifies enrichment that warrants further examination.

It should be noted that heavy metal enrichment of waste material is a common feature at mine sites and the GAI is simply a convenient measure with which to assess elements that may need further investigation or monitoring.

A significant GAI (i.e. GAI = 3), does not mean that an enriched element will necessarily be a concern for revegetation, drainage water quality, or public health. Similarly, because an element is not significantly enriched does not mean it will never be a concern, because under some conditions (e.g. low pH) the geochemical behaviour of common environmentally important elements such as Al and Fe increase significantly. Water extracts are used to determine the immediate element solubilities under the existing sample pH conditions of the sample.

For the assessment of element enrichment and solubility the following tests are carried out:

- **Multi-element composition of solids**

Multi-element composition of solid samples determined using a combination of ICP-mass spectroscopy (ICP-MS), ICP-optical emission spectroscopy (OES), and atomic absorption spectrometry (AAS).

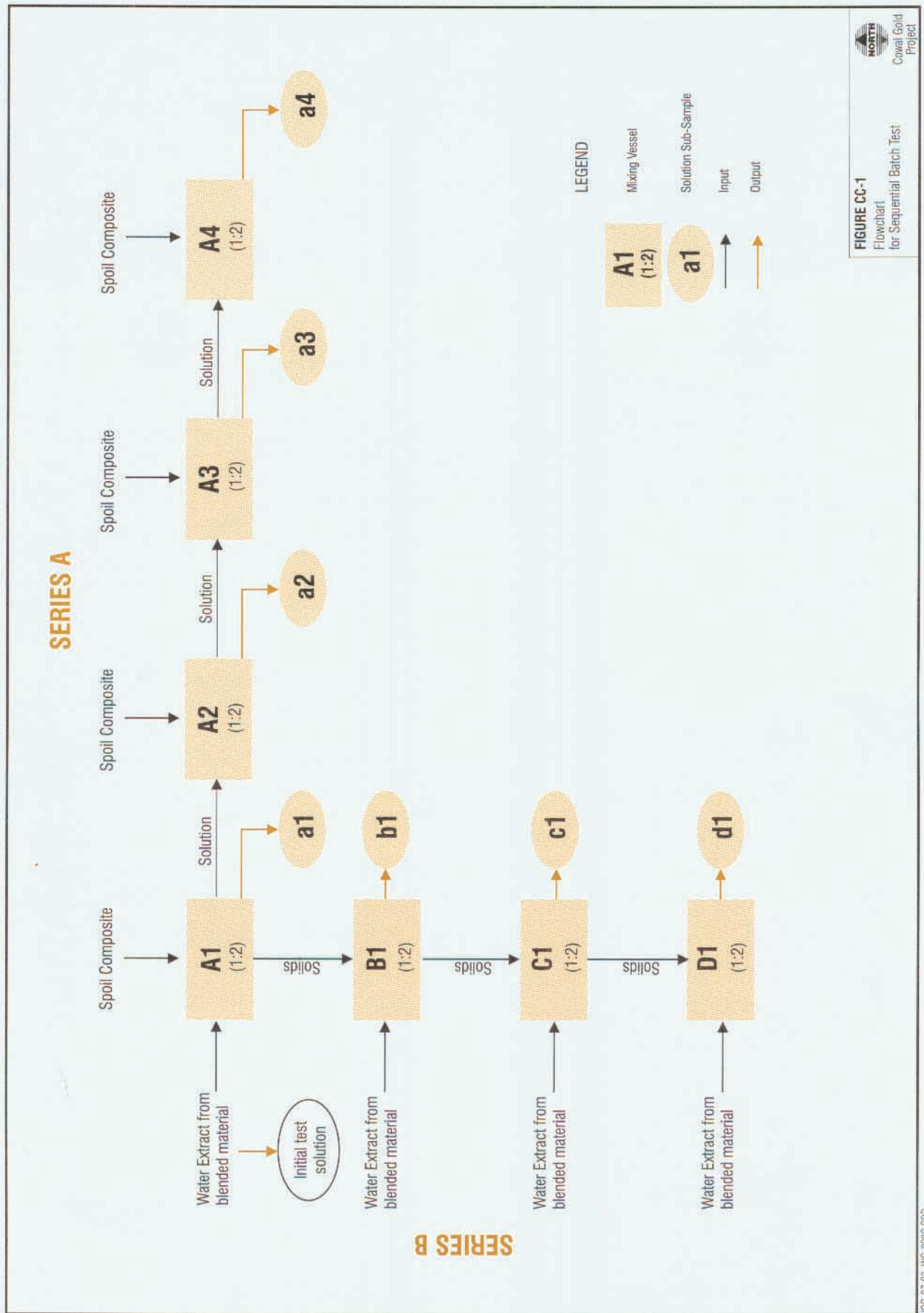
- **Multi-element composition of water extracts (1:2 sample:deionised water)**

Multi-element composition of water extracts from solid samples determined using a combination of ICP-mass spectroscopy (ICP-MS), ICP-optical emission spectroscopy (OES), and atomic absorption spectrometry (AAS).

¹ Bowen, H.J.M. (1979) *Environmental Chemistry of the Elements*. Academic Press, New York, p 36-37.

Attachment C

Sequential Batch Test Methodology



MOG-97-03 WC-0026 CDR

Attachment D

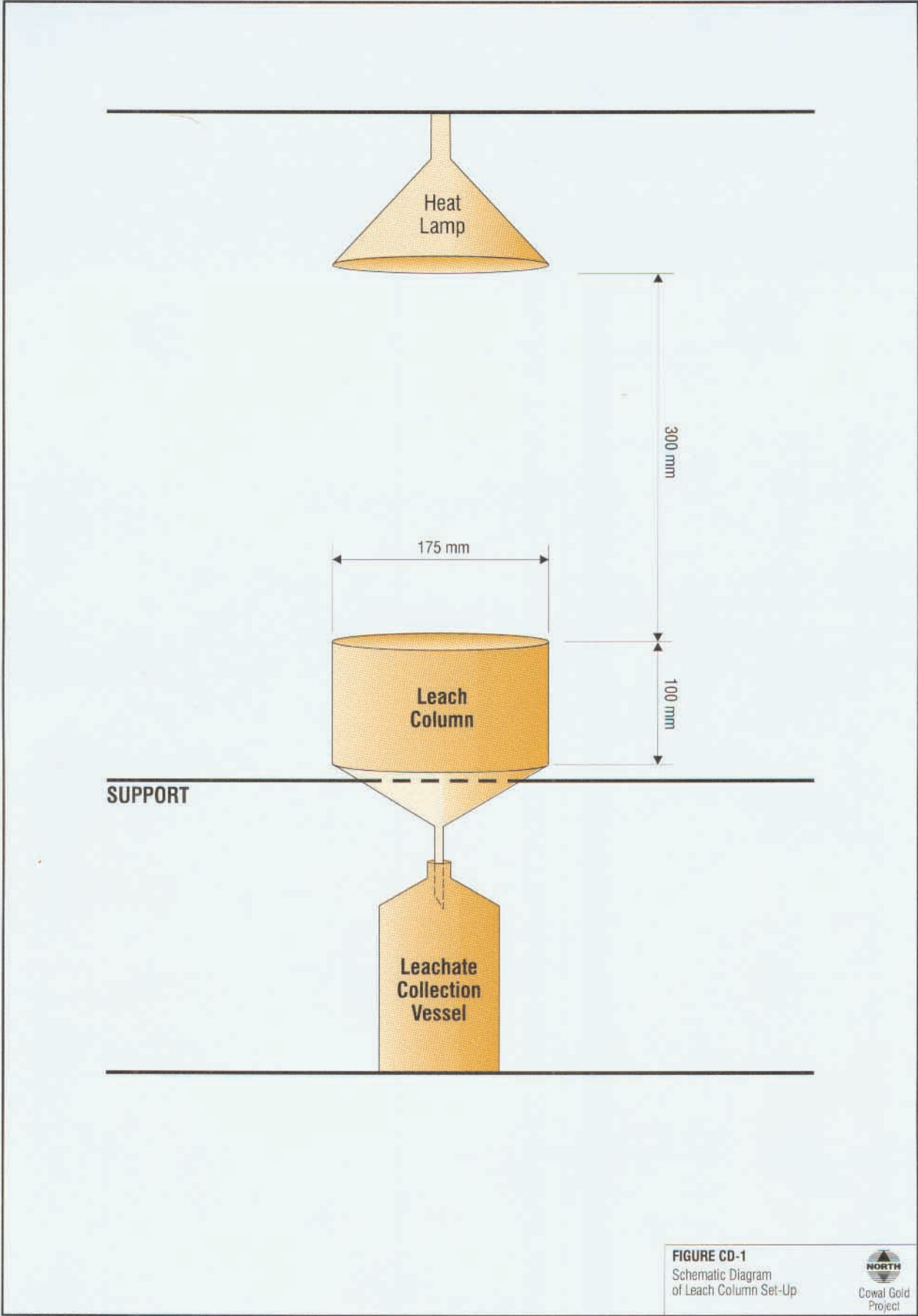
Column Leach Test Methodology

The design of the leach columns is shown schematically in Figure CD-1. Heat lamps are used between watering cycles to dry the sample sufficiently to ensure adequate air void conditions are achieved for optimal oxygen availability throughout the column.

The columns contain approximately 2 kg (dry wt.) of sample. They are wet weekly with deionised water at a rate of 100 ml/kg sample/week and flushed monthly at a rate of 400 ml/kg sample/month. The deionised water is added to the surface of the columns on the Friday of each week after heat lamp operation. Leachates are collected every fourth Monday following the flushing cycle. Following is an outline of the leaching program used:

Month	Week	Watering Volume (ml H ₂ O/kg sample) NB: for 2kg sample	Collection Number
1 to 6	1	200	1
	2	200	2
	3	200	3
	4	800	4

This program is designed to allow sufficient leachate to be collected for analyses each month. Once collected the leachate samples are analysed for pH, EC, acidity/alkalinity and selected elements.



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NOTES

